FISH, FISHING, AND CONSERVATION

DONALD J. ORTH

People, places, and approaches to fishing are as varied as the diverse fish fauna that exist on the planet. As conservation planners recognize the value of substantial engagement of stakeholders in decision making and ineffectiveness of rigid top-down management approaches, *Fish, Fishing, and Conservation* asserts that all peoples must play a role in conservation. Through case studies, engaging narrative and graphics, and exercises, the 413-page, undergraduate-level text explores major motivations for fishing and non-fishing related values, responsible fisheries practices, the rights of all people to decide how to manage and conserve fish, their habitats, and how they are utilized. For many fishes, overfishing remains a pressing global problem for which appropriate solutions are not easily found nor implemented.

Introductory chapters examine fish, fishing, and why fish matter and examine the role of values in driving conservation initiatives. Fish and their unique sensory capabilities are described along with a review of recent studies to examine issues of pain, sentience, and learning in fishes living in a foreign, underwater world. The text incorporates new findings in conservation and management leading readers to put ethical reasoning in practice to address welfare needs of wild and cultured fishes. Later chapters focus on the role of gender in fishing, conservation organizations, recreational fishing, and half of the chapters focus on specific fisheries that reveal the principles of conservation and management as they play out in major controversies.

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To Valerie, my much better half.

Contents

Introduction

When I was a kid growing up in Chicago, I learned about fish because fish were Friday dinner options for Catholics who abstained from meat. In my free time, my buddy and I would lash our cane poles to our bikes and ride to Marquette Park, where we fished the park lagoon. One summer day, we visited the local beach on Lake Michigan and encountered the awful stench from windrows of dead alewives. I wondered what happened and why. I asked many questions and got no answers. But I learned there were people who made their living by studying fish. Eureka! I had found my life's passion.

Each fish may teach us something, and each of us has a role to play in conservation. The message of the book is the principle that "Passionate and persistent people who understand the fish and the place will find a way to create partnerships to conserve valued fish in perpetuity."

—Don Orth

Goals for This Book

This book was written for a general audience interested in fish, fishing, and conservation. Other books have examined fish and fishing from many perspectives, beyond scientific understandings and traditional efforts to find the elusive maximum sustainable yield.

Fish matter. We struggle to live our lives in ways that respect the many values of fish and respect the perspectives of those with differing values. How we understand, value, and deal with fish depends on our culture and our personal reflections on fishy questions. I regularly question my own actions as a check against my hypocrisy. The place of fish in nature can be envisioned by each of us through our unique values, preferences, and disciplinary perspectives, whether it's law, philosophy, art, or natural science. Fish are exceedingly diverse and embedded in equally diverse, complex social-ecological systems. In this book, I focus on fish and fishing examples that provide diverse examples for interdisciplinary thinking. Whether we are interested in salmon, bass, cod, or tuna, we must also make connections among social and economic systems and ecological systems.

Scope

The book is not intended to be comprehensive. Rather, I selected topics that reflect contemporary understanding of the fish, differing types of fishing and fishers, and the current challenges that face conservationists. The many uses of fish reflect human needs and ingenuity in using fish to solve real human problems. Some island nations obtain most of their animal protein needs from fish. But fish provide so much more in unappreciated or unknown or unexplored benefits. Therefore, fishing may cause harms that are seldom considered. Too often, changes made by humans create unintended harms, reminding us that "They paved paradise and put up a parking lot." This is from a 1970 Joni Mitchell tune that became an iconic protest song for environmentalists that choose to fight the destruction of the Earth's ecosystems by human industrialization.

But conservation is more complex than protesting alone. From a broad range of conservation stories, we are learning about essential conditions that lead to successful conservation and sustainable fishing. These lessons must be learned by all thoughtful people.

About This Book

Few college courses focus on fish conservation, and this book fills this void. I wrote this book so that all types of college students could examine historical and contemporary influences on conservation of fish and engage in deliberative dialogue with others. Open educational resources are particularly well suited to inquiry-based pedagogical teaching. In this approach to teaching, students focus on answering a central question or solving a particular problem. The book provides students with their first thoughtful interaction with the problems and opportunities in fish conservation. Later phases involve clarification, questioning, and exploring actions from different parts of the world. Problem solving, argumentation, and critical thinking processes can be applied to each topic in the book.

Target Audience

The book was developed for college students in general education courses that critically examine dominant and emerging issues in the conservation of fish and management of fishing. In conversations on these topics, we need to develop not only a greater tolerance for each other but also a greater enthusiasm and competence for communicating and arguing. I make no assumptions about the reader's prior exposure to topics of fish, fishing, ecology, economics, ethics, evolution, and environmental planning. My hope is that the book will inspire some instructors to adapt and use all or parts of the book in their teaching.

Approach

We all share responsibilities to fish ethically, live ethically, and build a more ethical society. Ethical reasoning questions may be posed for each case study in this book while encouraging students to develop first-person ethical responsibilities. These cases provide us practice in examining ways of knowing what is true, who is responsible for what, and what should I do about issues about fish.

Parts of This Book

The book begins with two foundational chapters: *Fish, Fishing, and Why They Matter* and *Values Drive Fish Conservation*. The next three chapters summarize current understanding about the *Sensory Capabilities of Fish*, *Ethical Reasoning and Conservation Planning*, and *Pain, Sentience, and Animal Welfare*. Appreciation of fish and a little background in ethical reasoning may help us make better decisions when dealing with fish and fishing. After reading these first chapters, the students are prepared to examine issues that emerge in subsequent chapters. Learning more about fish and aquatic habitats is often enhanced by programs at public aquariums, a topic in *Public Aquariums and Their Role in Education, Science, and Conservation*. *Gender and Fishing* introduces gender and intersectionality concepts that can be directly applied to fishing and fish conservation.

The details about the fish, the people, and the places provide the context for implementing conservation, whether the fishing is for recreation, subsistence, or commercial purposes. Case histories are help students examine real stories in the management and conservation around the world. These chapters include:

- *Angling and Conservation of Living Fishy Dinosaurs*
- *Fly Fishing's Legacy for Conservation*
- *Recreational Fishing and Keep Fish Wet*
- *Integrating Fishers in the Management of Arapaima*
- *Conserving Tuna : The Most Commercially Valuable Fish on Earth*
- *Grouper and Spawning Aggregations*
- *Menhaden and Forage Fish Management*

The final chapter, *Takeaways for Successful Fish Conservation*, provides a synthesis of principles highlighted in the book.

Features of This Book

Key elements in each chapter assist with adopting this book for education. All chapters have learning objectives, key takeaways, profile of a fisheries professional, and extensive bibliographic references for those who wish to explore deeper. Frequent use of graphics illustrates and reinforces major concepts. Major terms are hyperlinked to definitions in a glossary. Questions to Ponder encourage the reader to stop and reflect on personal connections to concepts. The profiles in each chapter provide a brief introduction to fisheries specialists who are engage in fish conservation.

The book is provided online and in PDF, as well as in print at vendor cost of production. The book is an open education resource that is licensed with a Creative Commons license CC BY 4.0, the most open license. This license lets others remix, tweak, and build upon the work even for commercial purposes, as long as they credit the author and license their new creations under the identical terms.

Profiles in Fish Conservation

Each chapter in this book includes a Profile in Fish Conservation. The profiles describe the background, specialized expertise, and activities of scientists and leaders in fish conservation. Collectively the profiles in fish conservation reveal the highly diverse specialties engaged in fish conservation.

People make all the difference in fish conservation. Some cultivate knowledge while others are engaged in policy making. The work of conservation requires informed and engaged citizens, program managers, as well as many specialized scientists. Emerging studies in conservation reveal some key elements for successful conservation programs and practices. Fondness for fish is a common trait among fish biologists, recreational anglers, and aquarists who share a love of the species they pursue, study, or maintain.

But leadership activities in fish conservation may take many forms. Leaders may work with diverse groups, as exemplified by Solomon David, our profile for chapter eight. Or they can dialogue effectively as does our chapter six profile, Karen J. Murchie, in her work with public aquariums. Others build and maintain trust, as does Yvonne Sadovy de Mitcheson, among the many people whose livelihoods depend on grouper fishing. Still others can nurture relationships and partnerships, as demonstrated by chapter nine profile Dan Dauwalter, with numerous trout conservation groups. Finally, the work of chapter four profile, Mimi Lam, encourages communities to learn about alternative solutions for fishing conflicts. Examining fishing through the eyes of people like those profiled in this book, people who work daily to solve overfishing and other conservation problems, reveals a greater complexity than may be immediately apparent within the popular perception of fish in the world and those who study them.

The following Profiles in Fish Conservation showcase the persistence and dedication required to make positive advancements in fish conservation:

- Chapter 1: Holly K. Kindsvater
- Chapter 2: Larry Gigliotti
- Chapter 3: Andrij Z. Horodysky
- Chapter 4: Mimi E. Lam
- Chapter 5: Culum Brown
- Chapter 6: Karen J. Murchie
- Chapter 7: Danika L. Kleiber
- Chapter 8: Solomon David
- Chapter 9: Daniel C. Dauwalter
- Chapter 10: Sascha Clark Danylchuk and Andy Danylchuk
- Chapter 11: Leandro Castello
- Chapter 12: D.G. Webster
- Chapter 13: Yvonne Sadovy de Mitcheson
- Chapter 14: Kristen Anstead
- Chapter 15: Emmanuel A. Frimpong

Each profile is also offered as an audio recording at the end of each chapter. All fifteen profiles as a single episode that can be found here: https://doi.org/10.21061/fishandconservation.

To listen to these audio files on Spotify, visit https://open.spotify.com/show/06SnqAigflPXUgGNIHZxAX?si=Sljj3q9NRyOcclbmEE3npA or use the Spotify app to scan the image below.

History of This Book

The textbook reflects my long-standing teaching philosophy, which focuses on principles of respect, intentionality, optimism, and trust (R.I.O.T.). I model respect not only for each other but respect for oneself, one's path, and one's discipline. Respect of others encourages open dialogue and encourages trust. Intentionality involves the incorporation of a philosophical or ethical perspective to the hard sciences. I am a strategic optimist, that is someone who sets high expectations and actively avoids thinking about failure. I maintain optimism that we can find common ground as we seek answers to hard questions about the conservation of fish and their habitats. Solutions are elusive and it takes each of us to be persistent and optimistic that satisfactory (or at least better) solutions may be found. Human greed is an unstoppable force to overcome. Finally, I trust the reader to learn and ask questions. We won't act in conservation unless and until we trust in our own scientific and ethical thinking.

Expected Impact

This textbook will illuminate the world of fish, fishing, and conservation and allow students to engage in contemporary discussion over policy and regulations. True ethics teaching takes place only when the individual student realizes that personal change has taken place. We are all experts in different fields, but we should become at least a "competent amateur" in moral philosophy. Self-awareness is a common struggle for the college student but essential for work in civic society. I use storytelling, videos, and other social media in teaching. Interactive pedagogical approaches assist the student in developing self-authorship and building a new, more purposeful identity as a learner. The reader is asked to engage in self-reflection about the personal obligations to the fish, to the other fishers, and to a larger community via questions to ponder in each chapter.

About the Author

Donald J. Orth, PhD.

Donald J. Orth is the Thomas H. Jones Professor in the Department of Fish and Wildlife Conservation at Virginia Polytechnic Institute and State University. He has taught the following courses: Ichthyology, Stream Habitat Management, Fisheries Management, Fish Population Dynamics, Fish, Fishing, and Conservation, and First-Year Experience in Natural Resources. His principal interests are in population and community ecology, stream fish ecology, regulated rivers, instream flow and stream habitat assessment, fisheries management, and fish population dynamics. He has guided numerous undergraduate research projects and advised 33 graduate students during his career.

Don attended Eastern Illinois University (BS) and Oklahoma State University (MS and PhD). He is a Life Member of the American Fisheries Society and a Certified Fisheries Professional. He is also a Fellow of the American Fisheries Society, the American Institute of Fisheries Research Biologists, and the Virginia Natural Resources Leadership Institute. Don has published more than 150 primary papers and 50 technical reports on fish, fisheries, and riverine management. Much of his research was also communicated with a general audience in over 180 popular articles. He has received numerous awards for his teaching and contributions to conservation and public outreach. Most recently, the Virginia Chapter of the American Fisheries Society awarded him the Eugene W. Surber Award for years of significant contributions to the field of fisheries science.

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Ronald B. Meyers coauthored chapter 4: Ethical Reasoning and Conservation Planning. Thank you, Dr. Meyers!

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Additional Resources and Links

Fish

Eschmeyer's Catalog of Fishes

Global Database on Fishes FishBase

Virginia Tech Ichthyology Class Blog

Virginia Tech Ichthyology Public Facebook Group

Fishing and Fisheries

American Sportfishing Association

Marine Fish Conservation Network

National Fisherman

The Fisheries Podcast

The Fishing Professor Rod Cast

The State of World Fisheries and Aquaculture 2020

Take Me FishingTM

Recreational Boating and Fishing Foundation

NOAA Fisheries

US Fish and Wildlife Service Fish and Aquatic Conservation

Women in Fisheries

Fishing Has No Boundaries

Brown Folks Fishing

Special Report on Fishing in US (Recreational Boating and Fishing Foundation)

Sea Around Us

Conservation

Center for Biological Diversity

Future of Fish

International Union for Conservation of Nature

Monterey Bay Aquarium

Project Seahorse

Seafood Watch

U.S. Fish and Wildlife Service

Aquaculture

Best Aquaculture Practices

Fish Welfare Initiative

Global Seafood Alliance

Third Party Certifications in Aquaculture

Ethics and Argumentation

Ethics – International Encyclopedia of Philosophy

Ethical Reasoning and Analysis – Radford University Core Handbook

People for the Ethical Treatment of Animals

Principles of Argumentation

Stanford Encyclopedia of Philosophy

The Golden Rule as Interpreted by Different Religions

Religion and the Care, Treatment, and Rights of Animals

Resources for Combatting Religious Prejudice

Instructor Resources

How to Adopt This Book

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Instructors reviewing, adopting, or adapting this textbook are encouraged to register at https://bit.ly/fishandconservation_interest. This assists the Open Education Initiative at Virginia Tech in assessing the impact of the book and allows us to more easily alert instructors of additional resources, features, and opportunities.

Finding Additional Resources for Your Course

The main landing page for the book is https://doi.org/10.21061/fishandconservation.

This page includes:

- Links to multiple electronic versions of the textbook (PDF, ePub, HTML)
- Links to the instructor resource-sharing portal (https://www.oercommons.org/groups/fish-fishing-and-conservation-instructor-group/14049)
- Link to errata document (report errors at https://bit.ly/fishandconservation_error)

Sharing Resources You've Created

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1. Fish, Fishing, and Why They Matter

Learning Objectives

- Explain the multiple benefits of fish conservation.
- Define fish and describe multiple approaches used for classifying fish.
- Describe changes in history of fishing over time.
- Classify and compare major types of fishing practices.
- Compare and contrast the importance of commercial, recreational, and subsistence fishing.
- Describe why fish matter to humans.
- Describe the types of ecosystem services provided by fish.
- Construct a list of threats and trends in the uses of fish.

1.1 Introduction

Fish live on every continent and in all types of aquatic environments. Think about a fish that you are most familiar with. Its value to you depends on if, how, and where you interact with the fish. The essence of this fish depends on your perspectives. Your familiar fish may be valued as a living room pet, favorite food, trophy, or the source of your livelihood.

Imagine you are sitting in a meeting of the Alaska Board of Fisheries, which conserves and develops the state's fishery resources. Before the formal meeting you would hear commercial gillnetters speak of their concerns about season lengths and quotas. Outfitters and local tourism officials are concerned about crowding during sportfishing seasons and what locals call combat fishing because of anglers competing to find and protect fishing spots. Native American tribal fishers, like many others, would complain about declining quotas and gradual loss of culture and identities tied to salmon fishing. You thought you knew all about salmon, but the conversations are filled with unfamiliar terms, such as over-escapement, subsistence, hatchery strays, purse seiners, humpies, ocean warming, the salmon enhancement tax, drought, heat stress, damn seals, and Pebble Mine. More than once you hear someone say, "Fishing is in my blood." Fish and fishing may be central to everyone present, but everyone has different preferences.

It is a challenge to ensure that the benefits provided by fish and fishing continue long into the future. Fish of the world are becoming increasingly imperiled, and the search for simple, generally applicable solutions for fish conservation often elude us. Humans and ecosystems alike benefit from the very presence of fish in all aquatic habitats on earth, but it is this **ubiquitous** presence that also results in conflicts with other human activities.

Fish and **fishing** are complicated subjects. Conservation of fish is not easy. Fish represent over half the vertebrate animals on our planet, but receive little attention in major conservation initiatives compared to birds and mammals. Think of the Bald Eagle (*Haliaeetus leucocephalus*), Gray Wolf (*Canis lupus*), Giant Panda (*Ailuropoda melanoleuca*), Tiger (*Panthera tigris*), and African Elephant (*Loxodonta africana*). These are flagship species, or "popular, charismatic species that serve as symbols and rallying points to stimulate conservation awareness and action." (Caro 2010). Most of the fish lack such high levels of public awareness.

Ultimately, because fish inhabit diverse environments and serve many important ecological and anthropogenic services, fish conservation and management issues come down to our value systems. Goals for conservation are derived by asking "What should we care about?" Personally, I believe that fish conservation should be to ensure that fish persist so that future generations may decide on how they will interact with these fascinating animals. Values influence how we define sustainable fishing and how we reverse the tendency for overharvest and degradation of aquatic ecosystems. Planning for fish conservation requires ethical reasoning about fish and fishing. Answers to fundamental questions about conservation of fish may involve rethinking and adopting ethical principles in governance and giving people a bigger role in conservation. Thinking about fish as sophisticated and sentient creatures may change our perspective about how fishing should be conducted. Ethical issues such as social justice, corporate responsibility, and power sharing in democratic decision making should be central to fish conservation. From the case studies provided in later chapters, we learn that the keys to successful conservation of fish include persistence, passionate leadership, partnerships, trust, and optimism. I propose the following working principle that serves as an overarching guide: passionate and persistent people who understand the fish and the place will find a way to create partnerships to conserve valued fish in perpetuity.

In next sections, I characterize the types of fish and fishing, and how the way humans interact with fish can influence the way in which we classify and value fish. In doing so, we begin our exploration into why fish matter, and the challenges facing us we work to conserve fishing and fishing in the Anthropocene.

1.2 Types of Fish

What is a Fish? A biologist would define a fish as a "cold-blooded animal that lives in water, breathes with gills, and usually has fins and scales." (Berra 1981). But that definition, though accurate, does not fully describe the essence of a fish. That indispensable quality of a fish is given by humans. An evolutionary biologist might say that fish are the dominant vertebrate group, highly successful in their radiation, colonizing every conceivable habitat niche in almost every part of the world. After 400 million years of evolutionary innovations, fish comprise some of the most sophisticated and complex examples of evolution. For example, pupfish can live in geothermal springs at 94°F, icefish occur at temperatures below freezing, and wrasses change sex from female to male to ensure mating success.

Ichthyologists classify fish into five major classes. The most ancestral groups are the jawless lampreys and hagfish, which are in classes Petromyzontida and Myxini, respectively. All other fish have jaws; these include the sharks, skates, and rays (class Chondrichthyes), coelacanths and lungfish (Sarcopterygii), and the ray-finned fish (class Actinopterygii). The ray-finned fish represent the largest and most diverse group, containing 96% of the 36,345 valid fish species (Fricke et al. 2022). Given this diversity of fish, simple definitions seem uninspiring.

Major class of fish	Number of species
Hagfishes — Myxini	88 species
Lampreys — Petromyzontida	48 species
Cartilaginous fishes — Chondrichthyes	1,291 species
Lobe-fin fishes — Sarcopterygii	8 species
Rayfinned fishes — Actinopterygii	34,910 species

Table 1.1: Number of fish species for each of the five major classes of fish.

Beyond taxonomic classification, scientists can classify fish in other ways that describe their human uses or ecological characteristics. For example, fish can be described by their habitat requirements or preferences (freshwater and saltwater or stream fish), their behavior (highly migratory or sedentary), whether they are targeted by anglers (sport fish and nongame fish), and many others. Some use terms such as "rough," "coarse," or "trash" fish, pejoratives ascribing low-to-zero values. However, use of such terms say more about the person using the term than about the fish itself.

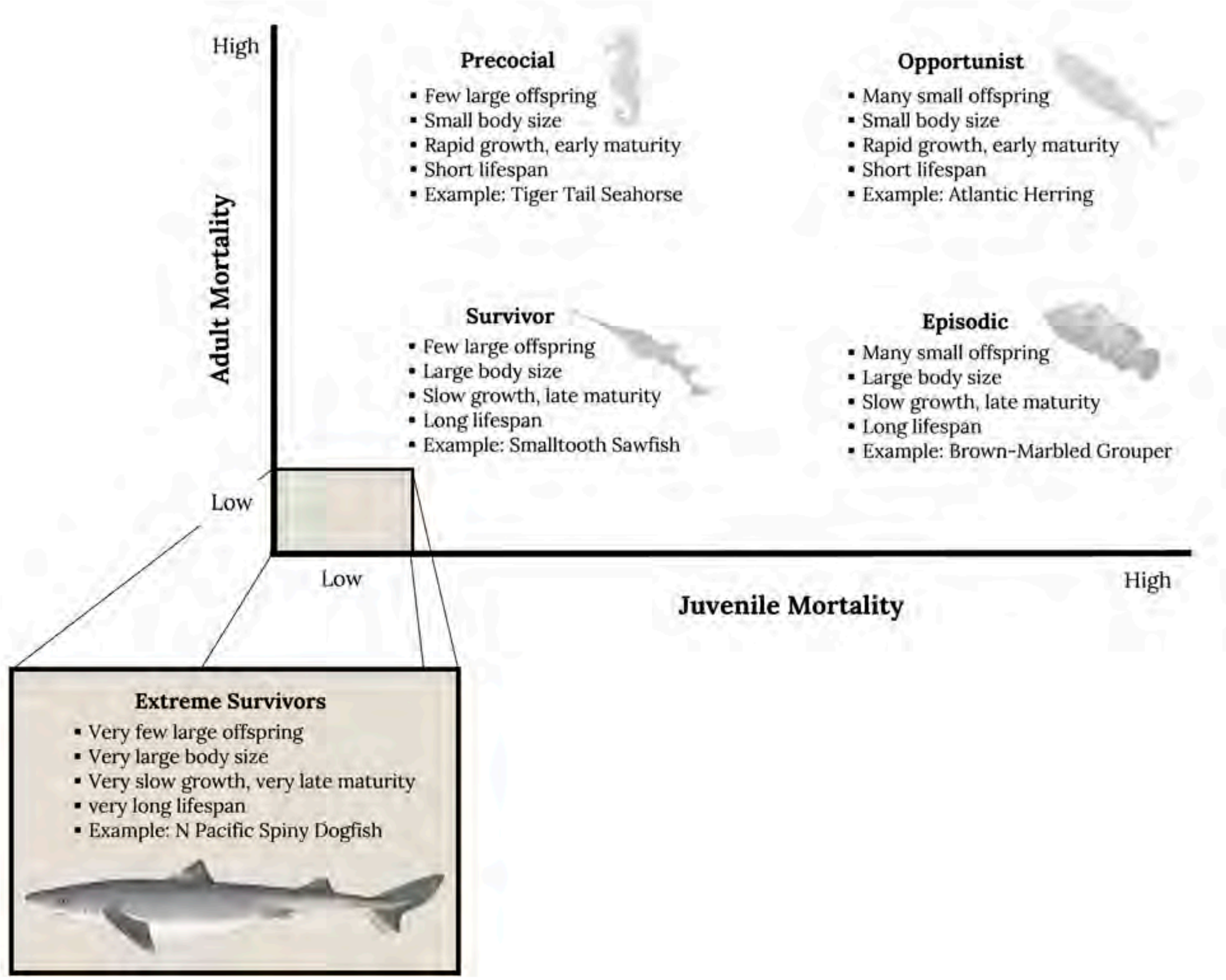

Figure 1.1: Classification of life history of fish. [Long description](#).

One way that scientists classify fish is based on the species' life-history traits, namely precocial, opportunist, survivor, extreme survivor, and episodic (Figure 1.1). Precocial fish, such as seahorses, have few large offspring, small body size, rapid growth, early maturity, and short lifespan. Opportunist fish, such as herring, have many small offspring, small body size, rapid growth, early maturity, and a short lifespan. Survivor fish, such as sharks, have few large offspring, large body size, slow growth, late maturity, and a long lifespan. Some sharks such as Greenland sharks live over 400 years and are extreme examples of survivors. Episodic fish, such as Brown-Marbled Grouper, have many small offspring, large body size, slow growth, late maturity, and a long lifespan (Kindsvater et al. 2016). Classifying fish by life-history traits often provides insights into species' unique conservation needs and challenges.

Yet, scientific classifications may mean little to the average person. When humans think of fish, we may connect more strongly to the water, the life-giving element of the world, than to scientific jargon. In some cultures, fish symbolize rebirth, good fortune, fertility, strength, or endurance. In 2017, ethologist Jonathan Balcombe in *What a Fish Knows* explored evidence of perception and cognition in fish, thereby changing our view of fish from simple to more complex. No longer were fish the dead-eye offerings at the fish market, the fish oil in a capsule, or processed flesh in cans. Thinking about fish as sentient, aware, intelligent, and social beings changes our relationship with fish. Fish may still be the target of your next fishing trip, but your actions are certainly influenced by what you know about the fish. The more you know about the target of your fishing, the more likely you are to be successful. More people are finding ways to view fish in their environment via mask, snorkel, and SCUBA, and even deepwater submersibles. For these reasons, how fish are classified often extends beyond strict scientific definitions and depends on how humans interact with fish. Some classifications may be based on methods to capture fish, while others may focus on how a fish is used for food or recreation.

***Questions to ponder*:**

Before reading the chapter, how would you normally classify fish or which dominant values would you place on fish? How does this reflect your personal cultural biases?

1.3 Types of Fishing

Humans have been capturing fish for tens of thousands of years. Stone Age burial heaps in Africa contained harpoons, spears, fish bones, and a wide range of terrestrial animals dated from 90,000 to 75,000 years BP (Sahrhage and Lundbeck 1992; Robbins et al. 1994; Henshilwood et al. 2001). It's only in the last 1,000 years that humans have developed a pervasive culture around fishing for profit (Pitcher and Lam 2015). Today, there are many types of fishing, and fish can be classified by how, where, and by whom they are caught.

To manage fishing, one must first understand the types of fishing, fishers, and communities, to impose the correct regulation from a diverse array of management actions. The term "fisheries" refers to the place or occupation or industry of catching fish. Fisheries are based on the capture of fish or shellfish, even if there is the possibility of their release after capture. Historically, humans have focused on highly valued food fish, such as tuna, bass, salmon, and cod, which continued to be intensively harvested for food (Figure 1.2; Greenberg 2011). Commercial fishing is the activity of catching fish or seafood for commercial profit, and is the last wild harvest of wild food. Given this, and perhaps not surprisingly, most valued fish are easily overfished. Meeting the future demands for fish will depend on domestication and fish culture to supply the increasing demand as consumption per capita increases (FAO 2018).

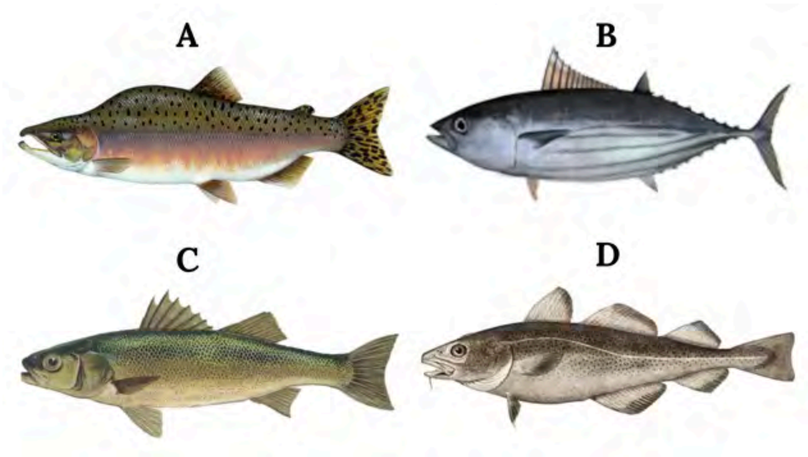

Figure 1.2: The four most consumed food fish are (A) Pink Salmon, (B) Skipjack Tuna, (C) European Sea Bass, and (D) Atlantic Cod. Long description.

There are many ways to commercially fish, and gear selection plays a role in determining cost, efficiency at catching the target species, and rate of bycatch of nontarget species. Seines (including purse seines), trawls, gill nets, and longline gears are responsible for over 90% of the commercial catch (Figure 1.3), and successive technological improvements to fishing gear and vessels have increased their effectiveness (Watson et al. 2006). Small fish, low on the food chain, are typically caught in seines and bottom trawls, either intentionally or unintentionally as part of bycatch. Large top predators are most often caught via longline gears. Industrial fisheries are a subset of commercial fishing that harvests fish with a high level of technology, investment, and impact, often with large purse seiners, trawlers, and factory boats.

Commercial fishing may target seafood for human consumption, or for nonfood purposes, such as fish oil and fish meal. Commercial fishing most frequently occurs in oceans where most of the landings consist of only 200 marine fish species, or roughly 1% of all species found in oceans (Palomares and Pauly 2019). Despite our substantial scientific knowledge of fish and fishing, we are faced with troubling headlines about the dismal state of the world's fisheries (Worm et al. 2009). Fishing occurs on more than 55% of ocean area and has a spatial extent more than four times that of agriculture (Kroodsma et al. 2018). Commercial fishing in the high seas is dominated by countries that subsidize fishing fleets, in particular China, Taiwan, Japan, South Korea, Spain, France, the United States, and Indonesia. Governments subsidized high-seas fishing with $4.2 billion in 2014, far exceeding the net economic benefit of fishing in the high seas (Sala et al. 2018). Drifting longliners and purse seiners, targeting mainly large, mobile, high-value fish such as tuna and sharks, are among the most profitable high-seas fisheries. Deep-sea bottom trawling catches everything, much of which is wasted. Despite our long history of commercial fishing, unresolved fisheries problems, such as widespread unreporting, unfair wages or forced labor, and shipment at sea, remain (Pew Charitable Trusts 2019).

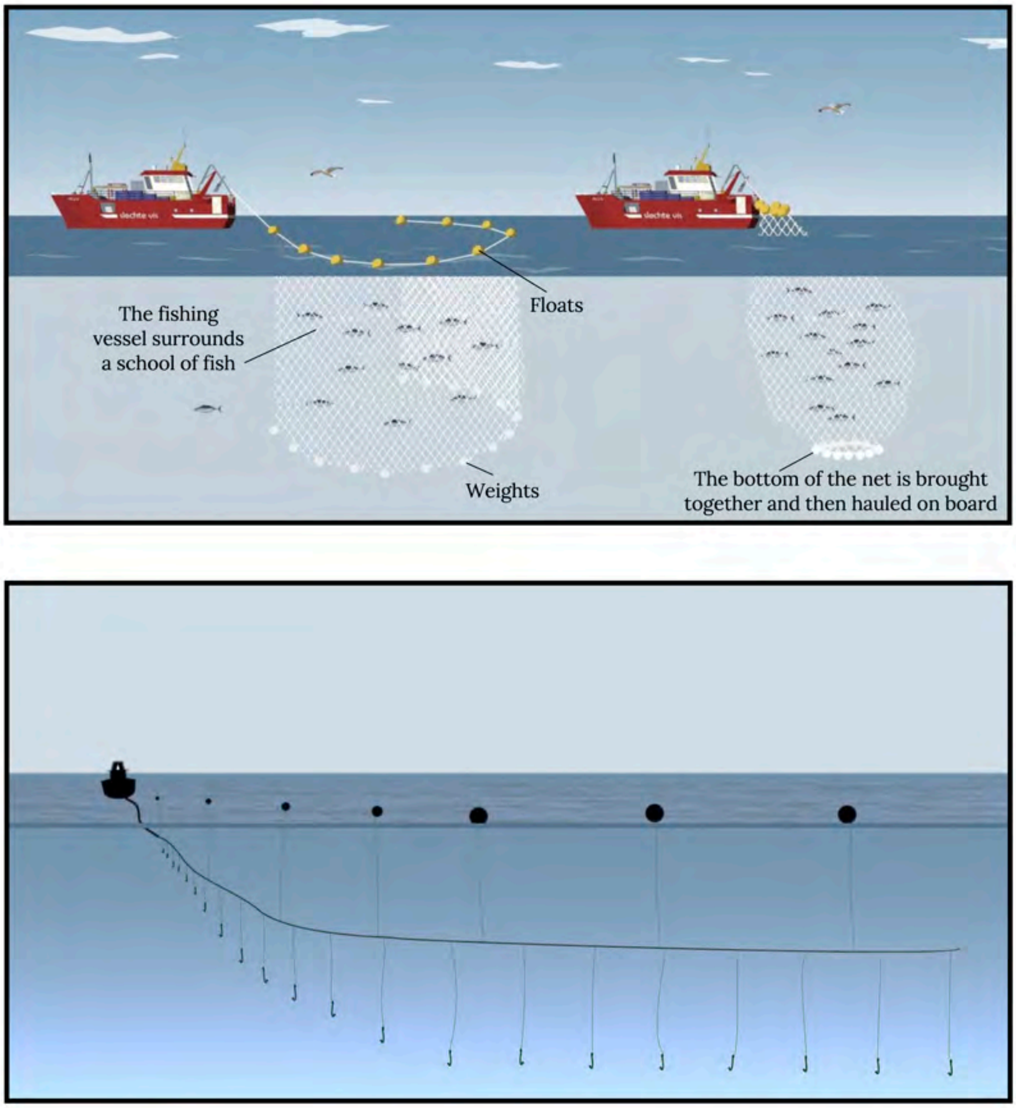

Figure 1.3: Purse seines (top) and longlines (bottom) are common techniques for commercial fishing. [Long description](#).

Fisheries employ 260 million people, and fish are the primary protein source for ~40% of the world's population. Over the past 50 years, annual global consumption of seafood products per person has more than doubled, from almost 10 kg in 1960 to over 20 kg (or approximately 200 servings) in 2014 (Figure 1.4). Overfishing is therefore common, which threatens the food security in countries dependent of fish for protein (Pauly and Zeller 2016).

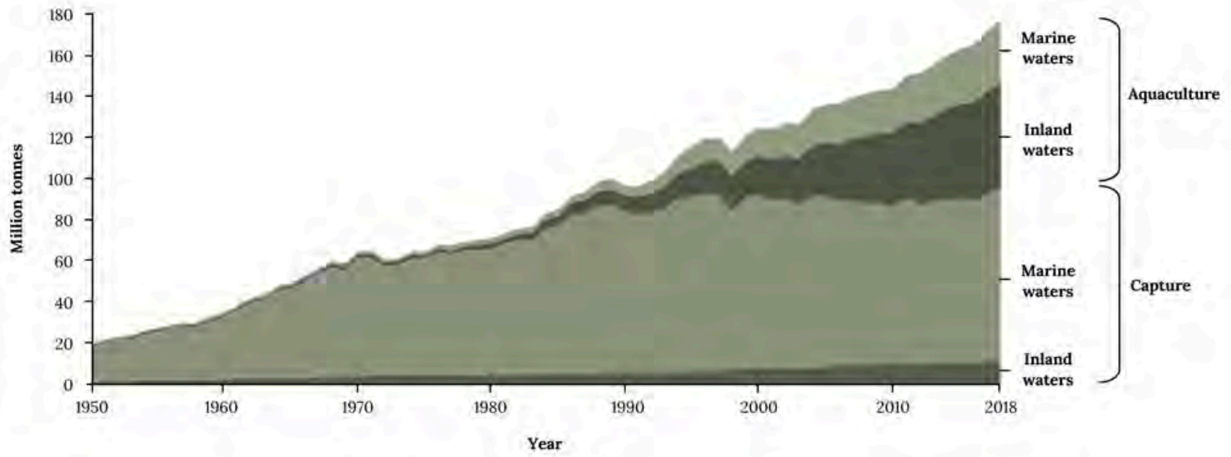

Figure 1.4: World capture fisheries and aquaculture production. [Long description](#).

Many nations rely on imports to meet national demands for seafood products, which complicates the management of commercial fishing at national level. As much as 60% of the fish harvested for fish meal or fish oil enters international trade markets rather than local markets (Guillen et al. 2018) Some of this is used in developing aquaculture feed, which is more efficiently converted to human food than livestock, poultry, or pork.

Inland fisheries are also important sources of nutritional, recreational, and economic value. While only 1.2% of the Earth's water is fresh and surface water, inland capture fisheries contributed 12.7% of the global fish catch in 2019 (FAO 2019). The actual inland fish harvest is likely substantially higher due to methodological or reporting issues (Cooke et al. 2016). While most marine fishing is commercial or subsistence, inland fisheries may be commercial, recreational, or subsistence. The biggest commercial inland fisheries are in Asia and Africa, whereas, recreational freshwater fisheries predominate in higher latitude and developed countries (Funge-Smith and Bennett 2019).

Questions to ponder:

What types of fish are most overfished and where? Do a quick search on Google News (or similar) for the term "overfishing." What about the term "fishing down the food web?" How many hits do you get? What species and places are in the current news?

Recreational fishing uses a variety of gear types, but the most common is rod and line to catch fish for fun and/or food. Recreational fishing is defined as the fishing of aquatic animals (mainly fish) using one or more of several possible techniques in which aquatic animals do not constitute the individual's primary resource to meet basic nutritional needs and are not sold or otherwise traded on export or domestic or black markets (Cooke et al. 2018). The objective of recreational fishing is the overall recreational experience, and catch is only one important component. The propensity to harvest or to engage in voluntary catch-and-release varies among cultures, locations, species, and fisheries. The role of recreational fishing in supporting nutrition (and thus food security) at regional, national, or global scales is underappreciated (Cooke et al. 2018).

In addition to being a valuable food source, recreational fishing can also contribute significantly to local economies. In the United States, there are over 49 million recreational anglers that are a potent economic force due to spending habits. Outdoor recreation in general and sportfishing in particular are growing enterprises that contribute greatly to the overall economy. Fishing licenses and boat registration, taxes on boat motor fuel, and fishing equipment provide the funding for recreational fisheries management programs. Recreational angler motivations change over time from catch any, to catch many, to catch big fish, and finally to catch no fish but pass on knowledge and passion for fishing (Table 1.2; McKenna 2013). At some point many successful anglers wish to help others catch fish or to help researchers better assure that the fish and fishing experiences enjoyed in the past will still be around well into the future (Oh and Ditton 2008).

Stage	Motivation
1	I just want to catch a fish!
2	I want to catch a lot of fish!
3	I want to catch big fish.
4	I'm just happy to be out fishing.
5	I want to give back. I want to pass on my knowledge and passion for fishing and help others or the fish themselves.

Table 1.2: Stages of development of the recreational angler.

1.4 Fish Harvest

Human perception of fish and fisheries depends not only on fishing method, but also on whether the fishery intends to harvest their catch. For indigenous peoples who live on islands or on the water, fish are a principal source of protein and nutrition. Because fish flesh spoils quickly, many methods have been developed to make fish last longer in different parts of the world. Therefore, we have canned, smoked, fermented, pickled, dried, pureed, and even lye-soaked fish (i.e., lutefisk) to increase their shelf life. Today, fish are important nutritional resources. Fish are a source of many micronutrients, and fish consumption can prevent nutrient-deficiency diseases, a leading cause of infant deaths worldwide (Hicks et al. 2019). Marine-derived oils in fish (omega-3 fatty acids) provide many human health benefits, reduce risk of coronary and neural disease, and enhance cognitive development (Morris et al. 2003, 2016; Hibbeln et al. 2019). In many instances, fish are more affordable animal-based food with a lower environmental impact (Willett et al. 2019). Because of the prevalence of fish in our diet, contamination of aquatic environments (e.g, mercury, polychlorinated biphenyls, or **PCBs**) is a global health concern.

Traditional small-scale fisheries are prominent in many parts of the world. These artisanal and subsistence fisheries generate about one-third to one-half of the global catch that is used for direct human consumption and employ more than 99% of the worlds 51 million fishers (Pauly and Zeller 2016; Jones et al. 2018). Small-scale fisheries may also be described as (1) subsistence, (2) aboriginal, or (3) artisanal fisheries. Subsistence fisheries are “local, noncommercial fisheries, oriented not primarily for recreation but for the procurement of fish for consumption of the fishers, their families and community” (Berkes 1988). Subsistence fishers may forever be the “forgotten stepchild” in fisheries management and are adversely affected by the attention lavished on the commercial and recreational sectors (Schumann and Macinko 2007). Aboriginal or indigenous fisheries harvest fish for sustenance and customary and traditional uses. One example would be Alaska Native tribes’ harvest of Pacific Halibut. Artisanal fisheries employ small vessels and short fishing trips to capture fish for local consumption and can be commercial or subsistence. These are traditional fishers who employ small vessels and short fishing trips to capture fish for local consumption.

In many cases, fish are killed by nonfishing activities. Legally, this is referred to as “take.” Section 3(18) of the Federal Endangered Species Act (16 U.S.C. § 1531 et seq.) defined “take” to mean “to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or to attempt to engage in any such conduct.” Bowhunting, minnow trapping, noodling, and all take fish and are typically regulated by inland fisheries agencies.

The diversity of fishing practices complicates conservation and management strategies. We don’t often appreciate the diversity of fishing practices and behaviors. While we know there is no such thing as the average angler or the average boat or typical fishing day, we often assume as much to simplify analyses. Regulations on fishing must be compatible with the type of fishing. For example, recreational anglers do not appreciate quotas because they may close fishing just when recreational anglers are vacationing to fish. If inappropriate regulations are imposed on some types of fishers, they will lose confidence in the management authority and the likelihood of noncompliance will increase. In the case of recreational angling, the angler may choose to quit participating, resulting in a loss of license revenues to support fish conservation. Effective management and conservation require that we know our fishers well because the diversity of perceptions and fishing styles influences how they will comply with fishing regulations (Boonstra and Hantati-Sundberg 2016).

Questions to ponder:

A healthy, balanced diet should include at least two 3-ounce portions of fish a week, including one of oily fish. Which of the following fish products do you think is most expensive? Bluefin Tuna, sardine, farmed Atlantic Salmon, or Haddock. How does the cost of the most expensive fish compare with cost of porterhouse steak (per pound)? Do a quick google search for "fresh seafood for sale" to find current prices for fresh fish. Why are salmon, tuna, bass, and cod so highly valued by humans?

1.5 Why Fish Matter

Valuation of fish populations for human societies has predominantly focused on fishing, yet fish can also be classified by the direct services they provide to humans and other organisms. For example, fish provide four types of ecosystem services, namely provisioning, regulating, supporting, and cultural (Figure 1.5; Cowx and Aya 2011). Fundamental services are essential for ecosystem function, such as nutrient cycling. These are ultimately a prerequisite for human existence. Demand-derived ecosystem services are formed by human values and demands, and not necessarily fundamental for the survival of human societies. These include recreational activities.

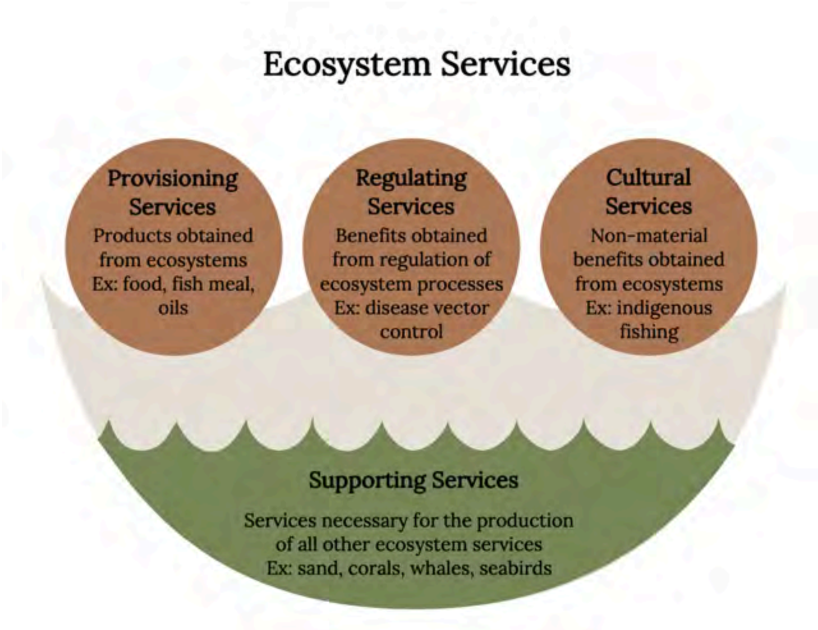

Figure 1.5: Four types of ecosystem services provided by fish with examples. [Long description](#).

Figure 1.6: A variety of ornamental koi (Cyprinus rubrofuscus).

Scuba diving is a fast-growing form of special interest tourism that attracts individuals interested in underwater recreation and fish watching. Scuba diving is now a multibillion-dollar industry and one of the world's fastest growing recreational sports (Ong and Musa 2011; Musa and Dimmock 2013). Although there is generally no harvest of fish, scuba diving can have negative effects on fish populations, as heavily dived sites experience habitat damage, and popular areas are managed to regulate diver carrying capacity. Similarly, fish watching with snorkeling is a low-cost entry into this recreational activity, and many localities are facilitating growth of this activity. Other new and growing fish-watching activities include Whale Sharks, stingrays, and cage diving to watch Great White Sharks.

Fish keeping has grown 14% per year since the 1970s, and the global aquarium fish trade is valued at between $15 and 30 billion and involves >5,300 freshwater and 1,802 marine fish species (Penning et al. 2009; Raghavan et al. 2013; and Evers et al. 2019). The Guppy (*Poecilia reticulata*) and Neon Tetra (*Paracheirodon innesi*) dominate by numbers but certainly not value. Aquarium keeping supports an extremely lucrative industry and sparks conservation efforts among the serious participants (Marchio 2018).

Among the ornamental fish, the Koi are special forms that originated in Japan in 1781 and is now a global commodity with as many as 120 different varieties produced by breeders (DeKock and Gomelsky 2015). Many varieties are judged at competitions based on their colors (Hi = red, Shiroji = white, and Sumi = black) along with their degrees of finish, body size, and steps in the patterns. These fish are swimming jewels, and their colors and elegant bodies create a feast for the eyes in many ornamental koi ponds (Figure 1.6).

Questions to ponder:

Imagine the variety of tropical fish that are kept by aquarium hobbyists. What do you think are the most expensive ornamental fish? Do a google shopping search for "tropical fish for sale" or "saltwater fish for sale" to find online stores that advertise price. What was the most expensive fish you found for sale?

Other examples of ecosystem services provided by fish include disease vector control. Some fish eat mosquito larvae, which could reduce local abundance of adult *Anopheles* mosquitoes that transmit the *Plasmodium* parasites that cause malaria (Walsche et al. 2017). Some cichlids feed on snails that serve as hosts for **Schistosomiasis**, a disease caused by parasites (Stauffer et al. 1997). After these snail-eating cichlids were overfished or lost due to changes in water quality in Lake Malawi, the prevalence of schistosomiasis increased dramatically from initial zero prevalence (Madsen et al. 2011).

Fish play ecological roles in life and in death. Think about the brown bears eating salmon as they migrate upstream. Bears transfer marine-derived nutrients from the salmon to the terrestrial ecosystems. Carcasses from anadromous fish have been shown to constitute a substantial transfer of carbon and nutrients from marine to freshwater and terrestrial ecosystems. These increased nutrients stimulate productivity of freshwater streams and fish growth rates (Wipfli et al. 2003; Collins et al. 2015; Twining et al. 2017). Many fish serve as bioturbation agents, meaning that their activity can rework sediments and modify the substrate. Salmon disturbance of the streambed during redd digging can have strong short-term and seasonal effects on stream microbes. Similarly, many other fish mix bottom sediments.

Some parrotfish species feed directly on live corals and produce large quantities of carbonate sediment (i.e., sand) as a by-product of grazing on reef surfaces (Perry et al. 2015). Parrotfish are building coral reef islands! Fish serve as nutrient sinks through their feeding behavior. Some fish, such as Gizzard Shad, via their feeding behavior, resuspend adsorbed nutrients from benthic substrates into the water column (Havens 1991; Vanni 2002). Coral reef fish, such as the Gray Snapper, slowly and steadily feed (via concentrated urine) the coral reef ecosystems that, in turn, provide food and shelter to the fish (Allgeier et al. 2016).

Fish feed us, fish inspire us, and fish are part of our living natural history. Louis Agassiz, a famous Swiss naturalist and zoologist, would exhort his students to "Take this fish and look at it." Professor Agassiz knew that a full appreciation of the specimen required the full examination of its internal and external anatomy. Why do fish matter? I urge you to take a look at the fish and look at it to provide your own answer. Let the fish inspire you and learn how and where they live.

Figure 1.7: "Goldfish in fish swimming amid falling flowers" by Liu Cai.

Figure 1.8: "Fish Market" by Frans Snyders. [Long description](#).

For thousands of years, humans have found inspiration in fish as they painted fish and fishing scenes (Jackson 2012). Living fish were painted depicting their natural habitats and flowing movements during the Song Dynasty (AD 960–1279; Figure 1.7). The Golden Age of painting included many sea fish paintings, depicting landed fish in the sixteenth and seventeenth centuries. The "Fish Market" painting by Frans Snyder depicts an endless variety of fish and other inhabitants of rivers, seas, and lakes (Figure 1.8). Whether depicted being caught or cooked, fish remain a constant source of fascination for artists and writers. Some classic literature on fish and fishing includes *A River Runs through It* (Norman Maclean), *The Old Man and the Sea* (Ernest Hemingway), *The Founding Fish* (John McPhee), *Cod: A Biography of the Fish That Changed the World* (Mark Kurlansky), *Your Inner Fish* (Neil Shubin), and *The Compleat Angler* (Izaak Walton).

1.6 Fish Conservation in the Anthropocene

Conservation is "securing populations of species in natural habitats for the long term" (Barongi et al. 2015). In the Anthropocene geological epoch, which began at the start of significant human impact on Earth's geology and ecosystems, conservation of fish will require substantial change in policy and human behavior (Steneck and Pauly 2019). Fish conservation and management professionals and citizens must deal with the long-standing and emerging threats from climate change, overfishing, deforestation of watersheds, widespread overfishing, dams and hydropower, irrigation, invasive species, eutrophication, plastics, dead zones, harmful algal blooms, and more (Reid et al. 2018). As demand for fish increases, fishers implement technological innovations, and use more efficient methods to harvest many species before management policies are in place.

In the next chapter, we explore a values framework for examining efforts to conserve and manage fisheries. An interdisciplinary approach is essential to successful conservation of fish. For example, the naturalistic fallacy is often suggested. This belief suggests that if we could just go back to the way things were, fisheries and ecosystems would be restored to their previous state. However, this view fails to recognize that there is no chance of going back to an earlier pristine world without the effects of humans. We can mourn the loss of the past, but your experiences with fish and fishing will not be the same as those of your parents or grandparents. For that reason, this book emphasizes effective, forward-looking conservation which relies on many elements, including: (1) public education and participation; (2) ecological research, management, and monitoring; and (3) a legal framework for enforcement (Jacobson 1995). Collectively, the chapters provide ample evidence that successful conservation depends on people who display persistence, passionate leadership, partnerships, trust, and strategic optimism. Therefore, in each chapter I profile at least one conservation professional in "profiles in fish conservation."

Question to ponder:

Select one of your favorite fish. Discuss three ways of classifying that fish. How do these different schemes influence how the fish is protected or conserved in the future?

Profile in Fish Conservation: Holly K. Kindsvater, PhD

Scan the QR code or visit https://doi.org/10.21061/fishandconservation to listen to this Profile in Fish Conservation.

Holly Kindsvater is an Assistant Professor in the Department of Fish and Wildlife Conservation at Virginia Tech. She received her undergraduate degree in marine biology from University of California, Santa Cruz, and a Ph.D. from Yale University in ecology and evolutionary biology. Her research group examines basic and applied questions in marine and freshwater systems, from high seas fisheries to Appalachian salamanders. From advancements in understanding the life-history theory, she connects unique fish biology to population models for fishes such as tuna, sharks, rays, and grouper, and estimates rates of population decline and species loss. Many of these fishes are at risk from overfishing and, without the advancements from her lab group, investigators would lack sufficient data for sophisticated analyses. The Shark Conservation Fund supports her lab's development of a large data base, SharkTraits https://www.sharktraits.org, to aid in the assessment of risks of overfishing and extinction.

Figure 1.9: Holly Kindsvater, PhD.

Previous investigations examined how social interactions and variation in mate quality affect reproduction in species with parental care, including swordtails, darters, and wrasses. Kindsvater and associates validated a novel approach for reconstructing mathematical models to understand the consequences of this variability for the life-history traits of numerous populations of tuna that sustain some of the world's largest and most valuable fisheries. Grouper and salmon are two valuable fish groups that display aggregation behaviors that increase catchability in fisheries. In the case of grouper, overfishing risk is further increased because "plate-sized" fish are highly preferred in the live reef food fish trade and sex changes from female to male as grouper grow. Kindsvater and associates analyzed the consequences of size-selective harvesting in grouper, thereby providing management rules in allow sustainable harvest.

Holly Kindsvater was raised in the Mojave Desert in southern California and was fascinated with fish from an early age. Early visits to Puget Sound and visits to the Monterey Aquarium stoked her curiosity about rockfish, a large, long-lived live bearer that lives in the kelp forest. She wanted a career that kept her in contact with the ocean and learned about the controversy related to overfishing rockfish in California by commercial fishing fleets. She worked during college as a field technician for the National Oceanic and Atmospheric Administration (NOAA) on surveys of salmon streams in California. These experiences led her to appreciate how the role of human modifications via barriers and water use influenced salmon viability. She also realized you can get paid to study fish.

Both field and analytical skills allowed her to investigate numerous fishes in a variety of habitats around the world. Clever wrasses quickly learned how to avoid capture, and in field studies Kindsvater improved her skill to collect fish with a small dip net underwater while using SCUBA or mask and snorkel. Kindsvater examines the effects of fishing because "Fishing gives us a window on the world of the ocean." Fishing is exploration and often the first sign of a change in ocean conditions. The notion that evolution happens on current time scales was first revealed in a landmark study on fishery-induced evolution (Conover and Munch 2002) that Holly Kindsvater read as a graduate student in 2002. She witnessed the scientists debating on the topic and realized that "this must be important." Through her persistence and many collaborations, she is making a difference today in examining the effects of fishing intensity and fishing selectivity and providing advice for sustainable fishing practices. In "Ten principles from evolutionary ecology essential for effective marine conservation" published in 2016, Kindsvater and her associates provide ensuring a sustainable relationship with our seafood.

For more information about her work, review the website https://kindsvater.fishwild.vt.edu/.

Key Takeaways

- Fish are cold-blooded animals that live in water, breathe with gills, and usually have fins and scales.
- Fish are highly successful in colonizing every conceivable aquatic habitat on the planet.
- Fish are classified by their taxonomic position, human uses, ecological characteristics, or life history.
- Commercial fishing is the last wild harvest of wild food, recreational fishing dominates fishing in inland waters, and subsistence fishing is the dominant type of fishing in much of the developing world.
- Not all types of fish are harvested for food, many are converted to fish oil and fish meal.
- Fish provide benefits to ecosystems in the form of provisioning resources, regulating, supporting ecosystem components, and contributing to human cultures.
- In addition to feeding us, fish inspire humans to create art and literature.
- Fish conservation and management are complicated issues, and the goals of those endeavors depend on our value systems.

This chapter was reviewed by Holly Kindsvater.

Long Descriptions

Figure 1.1: High adult mortality and low juvenile mortality include, Precocial: few large offspring, small body size, rapid growth, early maturity, short lifespan, example: Tiger Tail Seahorse; Opportunist: many small offspring, small body size, rapid growth, early maturity, short lifespan, example: Atlantic Herring; Low adult mortality and high juvenile mortality include, Survivor: few large offspring, large body size, slow growth, late maturity, long lifespan, example: Smalltooth Sawfish; Episodic: many small offspring, large body size, slow growth, late maturity, long lifespan, example: Brown-marbled; Extreme Survivors have an overall low mortality: very few large offspring, very large body size, very slow growth, very late maturity, very long lifespan, example: N Pacific Spiny Dogfish. Jump back to Figure 1.1.

Figure 1.2: Pink salmon (bright greenish-blue on top and silvery on its sides), skipjack tuna (streamlined body that is mostly without scales; their backs are dark purple-blue and their lower sides and bellies are silver with four to six dark bands), European sea bass (silvery gray to bluish on the back, silvery on the sides, and white on the belly; elongated body, larger scales, and a stripe down their sides), and Atlantic Cod (heavy-bodied with a large head, blunt snout, and a distinct barbel under the lower jaw). Jump back to Figure 1.2.

Figure 1.3: Top: The fishing vessel surrounds a school of fish with a large net that has floats to keep the top of net at sea level and weights holding the bottom of net below. The bottom of the net is brought together and then hauled on-board. Bottom: The fishing vessel drags a long line with baited hooks behind it. Jump back to Figure 1.3.

Figure 1.4: Steady increases in global aquaculture and capture fisheries starting in 1950 with 20 million tonnes leading to 2018; aquaculture = 180 million tonnes and inland waters =140 million tonnes; capture = 80 million tonnes and inland waters = 10 million tonnes. Jump back to Figure 1.4.

Figure 1.5: Ecosystem Services include: 1) provisioning, products obtained from ecosystems, ex. food, fish meal, oils; 2) regulating, benefits obtained from regulation of ecosystem processes, ex. disease vector control; 3) cultural, non-material benefits obtained from ecosystems, ex. indigenous fishing; 4) supporting, services necessary for the production of all other ecosystem services, ex. sand, corals, whales, seabirds. Jump back to Figure 1.5.

Figure 1.8: Painting of a scene at a fish market from the 1600's. Various general and exotic species of fish lay in piles on a table and a seller pours them from a basket into a large display area. Jump back to Figure 1.8.

Figure References

Figure 1.1: Classification of life history of fishes. Kindred Grey. 2022. CC BY 4.0. Adapted from https://doi.org/10.1002/ece3.2012 (CC BY). Includes Seahorse by Laymik, 2017 (Noun Project license, https://thenounproject.com/icon/seahorse-1078152/), Herring by Mallory Hawes, 2012 (Noun Project license, https://thenounproject.com/icon/herring-7089/), Smalltooth Sawfish by NOAA (public domain, https://www.fisheries.noaa.gov/species/smalltooth-sawfish), Pacific Spiny Dogfish by NOAA (public domain, https://www.fisheries.noaa.gov/species/pacific-spiny-dogfish), and Brown-Marbled Grouper by Rickard Zerpe, 2020 (CC BY 2.0, https://commons.wikimedia.org/wiki/File:Brown-marbled_grouper_(Epinephelus_fuscoguttatus).jpg).

Figure 1.2: The four most consumed food fish are: (A) Pink Salmon, (B) Skipjack Tuna, (C) European Sea Bass, and (D) Atlantic Cod. Kindred Grey. 2022. CC BY 4.0. Includes Pink Salmon FWS by Timothy Knepp, 2001 (public domain, https://commons.wikimedia.org/wiki/File:Pink_salmon_FWS.jpg), *Katsuwonus pelamis* by NOAA FishWatch, 2012 (public domain, https://commons.wikimedia.org/wiki/File:Katsuwonus_pelamis.png), FMIB 51236 Bass (*Labrax lupus*) by Reinhold Thiele, 1904 (public domain, https://commons.wikimedia.org/wiki/File:FMIB_51236_Bass_(Labrax_lupus).jpeg), and Atlantic cod by NOAA Photo Library, 2004 (public domain, https://commons.wikimedia.org/wiki/File:Atlantic_cod.jpg).

Figure 1.3: Purse seines (top) and long lines (bottom) are common techniques for commercial fishing. Kindred Grey. CC BY SA 4.0. Includes Purse-Seine by Lauren Packard, 2013 (CC BY 2.0, https://flic.kr/p/i2VTBd) and Ecomare – tekening visserijtechniek longline (longline) by Ecomare/Oscar Bos, 2016 (CC BY-SA 4.0, https://commons.wikimedia.org/wiki/File:Ecomare_-_tekening_visserijtechniek_longline_(longline).jpg).

Figure 1.4. World capture fisheries and aquaculture production. Kindred Grey. 2022. CC BY 4.0. Data from FAO, 2020 (page 20 of https://www.fao.org/3/ca9229en/ca9229en.pdf)

Figure 1.5: Four types of ecosystem services provided by fish with examples. Kindred Grey. 2022. CC BY 4.0.

Figure 1.6: A variety of ornamental koi (*Cyprinus rubrofuscus*). Bernard Spragg. NZ. 2009. Public domain. https://flic.kr/p/2o1rKG8

Figure 1.7: "Goldfish from fish swimming amid falling flowers," by Liu Cai. Liu Cai. c.1080–1120. Public domain. https://commons.wikimedia.org/wiki/File:Goldfish_in_Fish_Swimming_Amid_Falling_Flowers_by_Liu_Cai_(cropped).jpg

Figure 1.8: "Fish market" by Frans Snyders. Frans Snyders. 1620s. Public domain. https://commons.wikimedia.org/wiki/File:Frans_Snyders_-_Fish_Market_-_WGA21513.jpg

Figure 1.9: Holly Kindsvater, PhD. Used with permission from Holly Kindsvater. CC BY 4.0.

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2. Values Drive Fish Conservation

The land ethic simply enlarges the boundaries of the community to include soils, waters, plants, and animals, or collectively: the land. . . . In short, a land ethic changes the role of Homo sapiens from conqueror of the land-community to plain member and citizen of it.

—Leopold 1949

Learning Objectives

- Describe multiple value orientations of people.
- Apply the notions of values, rules, and knowledge as aspects of decision-making contexts that enable or constrain adaptation.
- Apply appropriate approaches for fish conservation and management that match values and knowledge in a particular place.
- Adopt and justify use of existing seafood certification initiatives.

2.1 Introduction

Values, the importance or usefulness of something, are important influences on how people will behave regarding uses of fish. Imagine that your favorite fish is a wild Cutthroat Trout. If so, it is likely that you value spending time in the wild places. Contrast that with a resident of a small Pacific Island where fish may be the only source of protein. This island resident values fish for providing essential nutrition. Whether you are inclined to engage in activities to protect nature depends on your experiences, values, and beliefs about natural environments.

The theory of emotional affinity explains that a person's ties to nature depend on the importance of spending time in nature, sharing positive experiences and feelings in nature (Kals et al. 1999). Another theory, the value-belief-norm (VBN) theory, postulates a causal relationship from values to beliefs, norms, or attitudes (Figure 2.1; Stern 2000). These complementary theories may be used to explain behaviors that involve nature (Fulton et al. 1996; Jacobs et al. 2012). People derive value from their relationship to fish or fishing, and these values are important to their well-being. In creating conservation plans it is critically important to consider the individual's internal value orientations, which are stable and central to their beliefs. It is also important that multiple value orientations are included so that many types of fishing are considered in management plans.

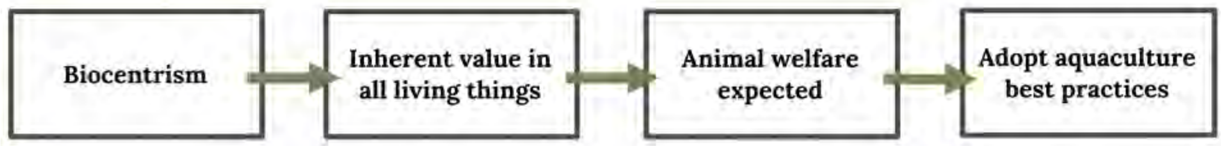

Figure 2.1: Causal chain of influence between biocentrism, inherent value in all living things, animal welfare expected, and adopt aquaculture best practices. Long description.

Conservation and management plans that are successful at achieving their measurable objectives over long periods of time require passionate leadership, persistence, partnerships, trust, and strategic optimism. While the first two characteristics are possessed by individuals, the other characteristics require participatory engagement to overcome uncertainty and other obstacles. It takes persistence, because finding ways to develop trusting partnerships and to compare values as different as personal well-being, cultural importance, and financial gains in policy formulation is complex. Social acceptance of management actions is a key element of contemporary management. Trust only develops through repeated collaborative interactions between parties aimed to avoid conflict and facilitate management (Stern and Coleman 2015).

Ultimately, questions of law and policy regarding fish conservation reflect deep value preferences. If you need to eat to survive, you will value fish as food. For others whose essential nutritional needs are met, they may desire the experience of fishing more than the nutrition it provides. Fishing fanatics may exhibit values that reflect more general philosophical tenets that may border on religious beliefs (Snyder 2007). Fly fishers often refer to rivers as their church and to nature as sacred, thereby justifying initiatives to preserve these places. Values are classified as intrinsic or instrumental. Intrinsic values are inherent and exist independent of their use to humans. Instrumental values include goods, services, and psychospiritual benefits and are, therefore, utilitarian or anthropocentric. An important difference between intrinsic and instrumental values relates to who must demonstrate harm in disputes. For example, the burden of proof lies with the conservationists if values are only instrumental. On the other hand, if values are intrinsic as well as instrumental, the burden of proof will be on the fishers (Callicott 2005).

The differing value orientations matter for inclusive decision making and policy development for fish conservation. We may also use the term "relational values." Relational values are all values that can arise out of a person's or society's relationship with nature (Chan et al. 2016; Skubel et al. 2019). Ecosystem services, first introduced in Chapter 1, are relational values that include relational, intrinsic, and instrumental values. Imagine that you are the owner and operator of a shark ecotourism company in The Bahamas. For you, the relational values important to you are financial. When we talk with others about fish, fishing, and conservation, we often encounter pufferfish moments. The pufferfish gulps water to increase its size when threatened. While the adaptation protects the pufferfish, it renders it unable to perform other functions. We frequently encounter people with differing value orientations who lack the ability to communicate or understand their perspectives or attitudes. We are like a pufferfish that instinctively avoids conflicts, and we are unable to relate. To deal with our pufferfish moments, we should seek first to understand the values and beliefs of others.

Values can be based on more than simple utilitarian reasons. For example, people in Hawaii and China both have historical preferences for eating sharks. Shark fins were a luxury food item as early as the Sung dynasty (AD 960–1279). In China, shark consumption has always been associated with a belief that the consumer would become strong like a shark, and the shark fin, consumed in soup, was associated with wealth and prestige. As the population of China expanded, more and more of the sharks consumed had to be imported. Currently, Hong Kong is a top global importer of sharks, creating a global shark conservation conflict with Hong Kong fish markets selling at-risk species (Fields et al. 2018). In Hawaii, on the other hand, the shark held mythical, cosmological, and spiritual significance. Today, laws in Hawaii make it illegal to capture, possess, entangle, or abuse any sharks and rays. The Hawaiian longline fishery uses monofilament leaders to prevent bycatch of sharks. The shark consumption story emphasizes how understanding the values and beliefs for human behavior may lead to successful conservation interventions.

Value orientations for wildlife are often classified along two dimensions, labeled as *domination* and *mutualism* (Manfredo et al. 2009). Domination values are tied to a belief that wildlife exists for human use, whereas mutualist values arose due to a modernized lifestyle wherein people were removed from direct contact with wildlife and, given the human tendency to anthropomorphize, began to view wildlife as deserving of certain rights or opportunities. Such differing views on values complicate conservation (Table 2.1).

Values	Beliefs	Actions
Livelihood	Manage fish for maximum profit	Commercial fishing
Leisure	Renewed by contact with wild fish	Recreational fishing
Local food	Environment sustains us	Subsistence fishing
Emotional bonds	Comfort from seeing wild fish	SCUBA diving

Table 2.1: Examples of values, beliefs, and actions for different uses of fish.

Conservation is complicated by divergent ethical frameworks. For example, ecocentrists will naturally focus on ecological attributes or processes; anthropocentrists do not worry about ecological impacts unless they drive economic or social damages; and **zoocentrists** accord equal moral consideration to every living being and oppose eradication plans (Epstein 2017). Successful conservation requires that we acknowledge and consider pluralistic values of a diverse society.

Globally, illegal and unreported fishing make sustainable fishing impossible and hinder recovery of overexploited fish populations (Agnew et al. 2009). In small island states, such as The Bahamas, illegal, unreported, and unregulated fishing coupled with inadequate regulations and enforcement, along with other anthropogenic impacts, are the main factors contributing to the decline of Bahamian fisheries (Sherman et al. 2018). Compliance with fishing regulations depends in part on underlying attitudes of the anglers. Are they oriented to catch-and-release angling, fishing for food, or are they tied to fishing in a particular place? Certain regulations may result in reduced participation rather than compliance with the regulation (Murphy et al. 2019). Participation of local stakeholders may lead to improved conservation management strategies that have the potential to improve economic and food security.

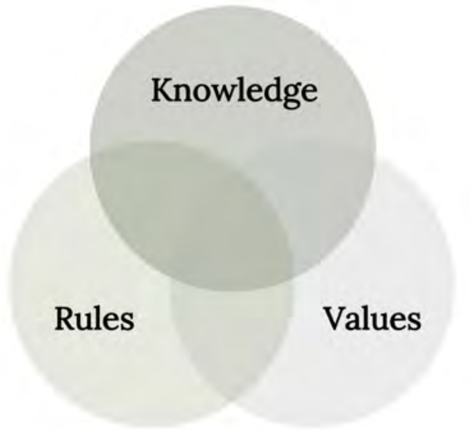

Figure 2.2: The values-rules-knowledge perspective (VRK) for identifying those aspects of societal decision-making contexts that enable or constrain adaptation.

A lack of a full understanding of the biological, legal, social, and economic factors hinders the success of fisheries management (Defeo et al. 2017). The decision context should consider the interconnected system of values, rules, and knowledge (Figure 2.2; Gorddard et al. 2016; Colloff et al. 2017). Consider your role in the process of making decisions about setting fishing regulations. Your values may influence the way people select actions and evaluate proposed changes. Rules are norms, practices, and habits that include regulations, legislation, treaties, and ordinances. Knowledge includes evidence and experiential meanings applied by experts and nonexperts in decision making. Your unique knowledge about a fish, the place, and how the fish are harvested should play a role in determining management rules. It is one of several factors in making decisions. The decision-making context involves iterative learning where the decision problem is defined, options are evaluated and implemented, and the outcomes monitored. A richer array of management actions via the values-rules-knowledge framework should enable more sensible and equitable decisions.

Questions to ponder:

What are your dominant uses of fish? What values and beliefs are most important in leading to these actions?

2.2 History of Values in Fisheries Conservation

Many simple solutions—fallacies in some cases—have been proposed to fix the complex problem of fisheries, primarily concerning commercial fisheries (Pitcher and Lam 2010). The essence of the overfishing problem is that human demands for fish and fish products often exceed the sustainable production, and harvesting methods often have negative consequences for the ecosystem. In 1918, Fedor Baranov wrote that "the exploitable stock of fish is a changeable quantity, which depends on the intensity of the fishery. The more fish we take from a body of water, the smaller is the basic stock remaining in it; and the less fish we take, the greater is the basic stock, approximating to the natural stock when the fishery approaches zero" (Gordon 1954).

Furthermore, how we depend on fish for livelihoods or lifestyles or both results in a bias toward our personal interests (Arlinghaus 2008; Cochrane 2008). Each of the following approaches may be of interest in the conservation and management of fish and represent what people value when conserving fish. Differing values, rules, and knowledge illustrate the wide variety of management and conservation ideas that guide people's actions. You may feel an affinity to some but not all of these approaches.

Privatization arose as a solution from economists extending the legal concept of property rights to public-trust fisheries resources. Fishers are given ownership rights or individual transferable quotas (ITQ) to harvest an allocation of the fishery resources. ITQ theory seeks to use market forces in which harvest rights can be traded, thereby giving harvesters incentives to manage the fishing wisely. ITQs are not property rights but rather dedicated access privileges. While ITQs may reduce the conflicts over scarce fish and end the "race for fish," in practice they do not always eliminate illegal fishing (Costello et al. 2008; Birkenbach et al. 2017). One well-publicized application has been the Pacific Halibut (*Hippoglossus stenolepsis*), in which the open season in 1990 lasted just six days, and 435 vessels fished subject to unknown weather (Fina 2011). With a short season, processing facilities were inadequate, and few vessels made money. Today, with the application of ITQs, fewer vessels fish over an eight-month season in a directed halibut fishery, and all halibut can be landed in local communities where they are sold fresh. The fallacy of ITQs relates to the belief that ownership promotes good stewardship and social justice is achieved via allocation of ITQs (Gibbs 2009). In other examples, the allocation of catch shares or ITQs has marginalized artisanal fisheries and communities all over the world (Bailey 2018).

Total economic valuation deals with capturing the total economic value of ecosystem services and future generations to sustain healthy and productive fish stocks into the future. Without explicit values, fish are often implicitly valued in policy decisions, and that reduces protections. However, using market-based instruments to place financial values on fishing and ecosystem services will not serve the interests of the poor in society. Economic valuation of saltwater marsh habitats provided a direct link to many marine saltwater fish that depend on marsh habitats during their life (Bell 1997). In this example, economic valuation provides justification for acquiring land for preservation to save it from development. Valuation of fish that are not harvested for commercial or recreational fisheries provides a value to justify preservation of rare or endangered fish (Bishop et al. 1987). Social equity and intergenerational equity concerns are not addressed by conventional discounting using market interests. Adding social and cultural values of fish may result in more **holistic** perspectives for management.

Laissez-faire strategies presume that if commercial fishers were allowed to manage their own fishing, they would efficiently allocate fishery resources. Laissez-faire strategies value freedom above all. However, many examples prove otherwise: fishers act from the perspective of private interest and will continue to fish even as fish stocks decline. Laissez-faire strategies for fisheries were devised in the seventeenth century and accepted up through the nineteenth century, leading to overfishing of stocks of cod and flatfish. Overcoming laissez-faire strategies continues to this day throughout the world. New England's commercial harvesters were slow to respond to technological change, as predicted by unrestrained laissez-faire strategies. Rather, they actively opposed fishing innovations (Gersuny and Poggie 1974). Famous fishery collapses attributed to relaxed regulations include the Atlantic Cod (*Gadus morhua*) in the northwest Atlantic Ocean (Myers et al. 1997) and the Nassau Grouper (*Epinephelus striatus*) in the Caribbean (Whitehouse et al. 2020).

Selective fishing technology is a solution often proposed by commercial fishing interests that imagine improvements in fishing gears to eliminate bycatch and discards and damage to habitat. This approach focuses on regulating fishing gear to achieve conservation goals. Restricting harvest to a limited range of ages (or sizes) can provide long-term sustainability even at high rates of fishing mortality (Reed 1980). Harvest slot length restrictions as applied in recreational angling and Maine lobster fisheries typically outperform minimum length limit rules (Comeau and Hanson 2018; Ahrens et al. 2020). However, improvements in fishing technology sometimes increase the numbers of species caught and result in serial depletions of fish stocks (Berkes et al. 2006).

Recreation fishing regulations are often imposed to fit the unique motivations of recreational anglers and often involve size restrictions or daily creel restrictions. Not all recreational anglers have the same fishing preferences. Participation in recreational fishing varies widely, from ~2% in South Africa to 30% in Norway, and averages 10.5% in industrialized countries. Typically, an angler selects gear and locations for a particular target fish. The continuum between fishing as a contemplative sport versus a competitive sport may lead to conflicts among angler groups. Consequently, the approaches to managing recreational fishing vary greatly and seek to maximize the participation and angler satisfaction rather than harvest.

Marine protected areas (MPA) are protected areas of the ocean where human activities are restricted to achieve conservation objectives, mainly supporting a goal of protecting biodiversity. "No-take" marine reserves are permanently closed to all fishing and other extractive uses, whereas zones of integrated ocean management are MPAs that regulate uses within zones. By protecting against risk and uncertainties from traditional stocks assessments, they serve as ecological insurance policies. Unfortunately, less than 1% of the oceans are in marine reserves and 94% of marine protected areas allow fishing (Costello and Ballantine 2015). Reserves and protected areas are very seldom applied to inland waters. Success of an MPA depends on size, implementation, and enforcement (Sala and Giakoumi 2018). Although the original intent of MPAs was to protect ecosystems within their boundaries, they have also been shown to enhance local fisheries and food security and to create jobs and new incomes through ecotourism (Cabral et al. 2020; Chen et al. 2020).

Maximum sustainable yield (MSY) is derived from classical fisheries science and deals narrowly with sustainability in a single-species fishery. MSY has been defined with reference to the maximum catch levels that can be maintained and is based on individual priorities toward catching fish. MSY seeks to find the exploitation rate that results in highest long-term harvest (Figure 2.3).

Consider the basic equation of how change in abundance (N) varies with abundance:

$$\frac{dN}{dt\ N} = r\left\{1 - \frac{N}{K}\right\}$$

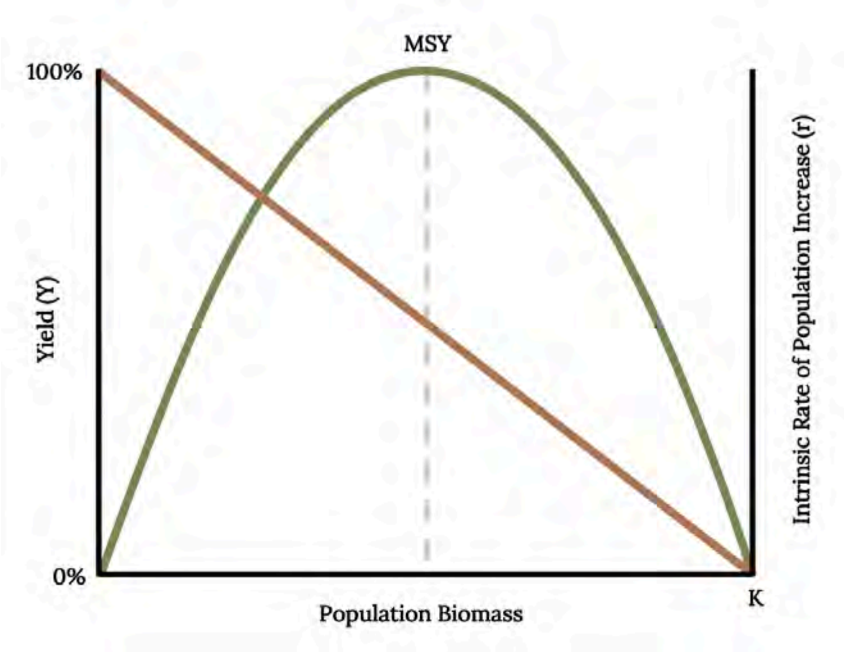

Figure 2.3: Equilibrium relation between yield (Y, green curve) and intrinsic rate of population increase (r, tan line) and population biomass. [Long description](#).

where N = abundance, K is carrying capacity, and r is the intrinsic rate of growth (Verhulst 1938). Given reasonably accurate estimates of parameters and fish biomass, this equation may allow determination of sustainable yields (Quinn and Colley 20005). Sophisticated single-species, density-dependent population dynamics models are data intensive and parameter rich, yet they may still miss important features in human and fish dynamics. However, most fisheries of the world are data poor. Furthermore, five major challenges with this approach are the facts that (1) many fisheries catch more than one species; (2) it is difficult to forecast recruitment accurately; (3) landing limits are often disregarded; (4) underreporting has biased the data; and (5) trust between fishers and scientists has been destroyed. An **epitaph** was written in 1977, but MSY is still alive and kicking (Larkin 1977).

Larkin's Epitaph for MSY

M.S.Y. 1930s–1970s

Here lies the concept, MSY.

It advocated yields too high,

And didn't spell out how to slice the pie.

We bury it with the best of wishes,

Especially on behalf of fishes.

We don't know yet what will take its place,

But hope it's as good for the human race.

R.I.P.

Maximum economic yield (MEY) represents the harvest level that maximizes profit, which is typically a commercial fishing goal. MEY seeks to gain economic wealth and is based on individual priority of profit (Figure 2.4). However, in open access fisheries, regulations often fail to control fishing mortality, so MEY is seldom attained. In other cases, subsidies for fishing permit development of fisheries that are only marginally profitable but maximize employment.

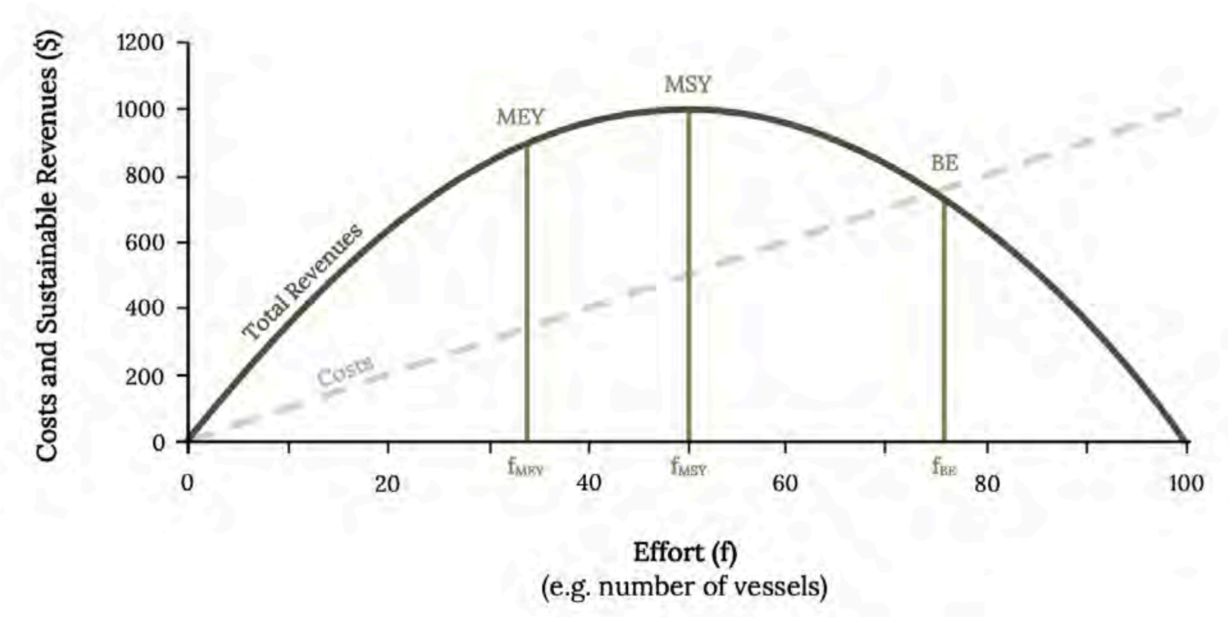

Figure 2.4: Gordon–Schaefer bioeconomic model of costs and sustainable revenues for a fishery as a function of fishing effort (f). MEY = maximum economic yield, MSY = maximum sustainable yield, and BE = bioeconomic equilibrium. Long description.

Pretty good yield (PGY) is defined as "sustainable yield at least 80% of the maximum sustainable yield. Such yields are generally obtained over a broad range of stock sizes (20–50% of unfished stock abundance), and this range is not sensitive to the population's basic life-history parameters, such as natural mortality rate, somatic growth rate, or age at maturity" (Worm et al. 2009). In the analysis of 166 global fish stocks, most stocks have fallen below the biomass that supports maximum yield (B < BMSY) but have the potential to recover if the low exploitation rates (*u* < *u*MSY) are maintained long enough (Worm et al. 2009; Hilborn 2010). PGY cares mostly about catch levels and is most appropriate in multispecies fisheries, for which single-species analysis is impractical.

Optimum sustainable yield (OSY) is a deliberate melding of biological, economic, social, and political values in determining management targets (Roedel 1975). OSY seeks to incorporate such considerations as the nonmonetary values of recreational fisheries, the conservational value of fish stocks, the sustainability of fishing communities, quality of the fish caught or the fishing experience, and ecosystem integrity. In many recreational fisheries, most anglers are seeking a quality fishing experience where size of fish caught is more important than the total biomass of fish harvested. The idea of OSY has expanded the need for human dimensions information to be collected and incorporated into management decisions (Arlinghaus et al. 2002). For example, there are four types of trout anglers: occasional anglers, generalists, technique specialists, and technique and setting specialists. Acceptable fishing regulations will vary among the four groups, and specialists are likely to oppose trout stocking. Increasing recreational fishing opportunities requires enhancing many nonfishing-related aspects, such as access, water quality, scenery, and other aspects of the fishing experience. In the United States, the Magnuson-Stevens Fishery Conservation and Management Act requires that "conservation and management measures shall prevent overfishing while producing, on a continuing basis, the optimum yield from each fishery for the United States fishing industry."

Community-based management (CBM) lets local stakeholders and coastal communities share authority in developing management rules. This type of comanagement seeks to empower the local fishers and encourage conservation of fish on which they depend for food and livelihood. Some examples exist in the Pacific islands, Alaska, and British Columbia and with Maine lobster and *Arapaima* in parts of the Amazon. In experimental management of the Pirarucu (*Arapaima* spp.) in the Amazon basin, the fishers play an active role in management process, such as collecting data and enforcing rules, and thereby increased monetary returns (Castello et al. 2009). While it can be successful, success requires financial investment, local infrastructure, targeted public education, and strong legal support.

Traditional ecological knowledge (TEK) attempts to incorporate local, cultural information and values in the governance of fishing. While this approach is appealing, in practice, the diversity of local stakeholders may have many ways of interpreting evidence and understanding of nature (Hind 2015). River herring (*Alosa* spp.) were culturally important to East Coast Native American tribes and First Nations in the United States and Canada. These men and women, by virtue of time spent on the water, had knowledge of the distribution, abundance, and migration behavior gained from firsthand observations. River herring were harvested for centuries and are an important part of the region's fishing heritage. Furthermore, the fishermen and women were able to detect changes in fish stocks before the changes were evident from data collected by fisheries scientists.

Managers and conservationists can engage in an equitable exchange of knowledge with local fishers to improve knowledge of fish taxonomy, ecological interactions, and seasonal movement and behavior so that TEK complements conventional scientific methods (Gaspare et al. 2015). View the video to learn more about the perspectives of river herring harvesters and other community members who know more than anyone else about the fish in their local rivers.

Precautionary approach involves the application of prudent foresight and considers the uncertainties in fisheries. The precautionary approach values risk avoidance and applies *primum non nocere* or "first, do no harm" fisheries management. It was first introduced in 1995 in the Food and Agriculture Organization's *Code of Conduct for Responsible Fisheries* (FAO 1995). There is little consensus on how the precautionary approach should be applied. Many marine fisheries have an overcapacity of fishing fleets, and some countries subsidize fishing fleets. Consequently, short-term economic pressures dominate. A precautionary approach reduces fishing to restore the population size to above the limit point if it has fallen or is about to fall below that level. The red-yellow-green typology (Figure 2.5) shows the use of both limit and precautionary reference points for spawning biomass and fishing mortality metrics. When a fishery is characterized by fishing-induced habitat damage, a stock rebuilding strategy that incorporates both harvest control rules and marine reserves (a precautionary approach) will outperform a strategy that uses the two control mechanisms individually (Nichols et al. 2018). Because of the gaps in our knowledge and the failure to acknowledge them, regulations often fall short of being precautionary (Abrams et al. 2016).

Ecosystem-based management (EBM) is the most comprehensive conceptual approach. It focuses on keeping the trophic web intact while calling for (1) taking account of environmental factors influencing growth, maturation, natural mortality, and recruitment; (2) creating accountability for the full footprint of fisheries; (3) making governance broadly inclusive with meaningful stakeholder participation; and (4) integrative management (Beard et al. 2011; Rice 2011). Each of these components is equally important and challenging to implement. For example, the footprint of fisheries includes gear impacts on habitats, mortality because of bycatch of other fish, invertebrates, seabirds, mammals, and turtles, and indirect trophic impacts because of the altered abundances of targeted and bycaught species. One-quarter of 200 fisheries assessments in the United States included at least one type of interaction between the assessed species and its ecosystem, especially physical drivers of habitat and climate, though assessments of diets were less common (Marshall et al. 2019).

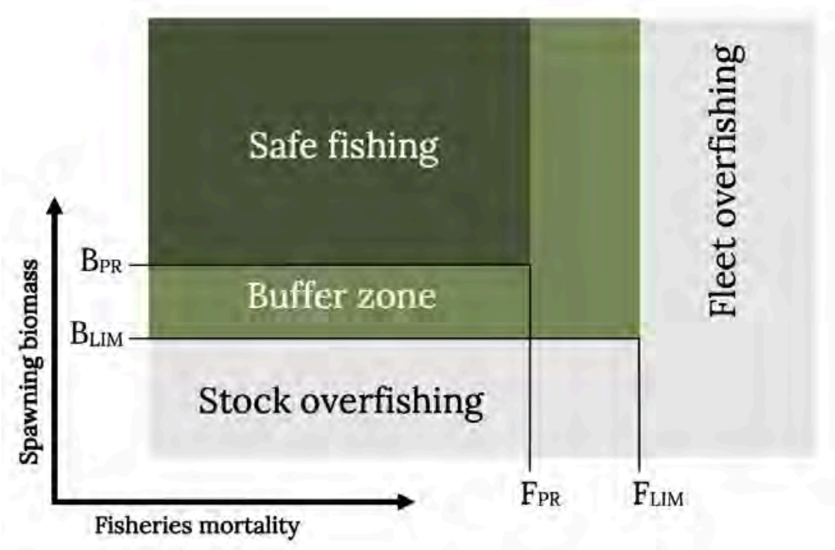

Figure 2.5: Visualization of a harvest control rule (HCR) specifying when a rebuilding plan is mandatory in terms of precautionary and limit reference points for spawning biomass and fishing mortality rate. Long description.

While EBM explicitly includes humans as part of an ecosystem, in practice, it often falls short from an ethical perspective that places humans at the apex, benefiting from goods and services provided by ecosystems, as well as controlling use. This is a fishy version of Leopold's A-B cleavage between utilitarian value versus a broader definition of value in nature (Leopold 1949). Many scholars propose a radical rethinking of the traditional approach to implement ecosystem-based management (Bundy et al. 2008; Berkes 2012; Patrick and Link 2015a, 2015b; Berkes and Nayak 2018). Humans are provided goods and services from the natural resources, and as a result, ecosystems are degraded. An alternative perspective considers ethics, including social justice arguments, and corporate responsibility in a form of governance that shares the power in decision making. We still have a long way to go to fully implement ecosystem-based management.

Ecosystem-services approach is based on the instrumental values provided by intact ecosystems, whereas conventional practices focus on single species or habitats. However, fisheries systems are characterized by complex interrelationships between society and the natural environment. Threats to freshwater fisheries originate mainly from outside the fishing sector; thus, sustainable conservation practices must be considered as integrated parts of a holistic management of (specific) aquatic ecosystems or watersheds. Unfortunately, in many scenarios these three domains (including scientific research) are disconnected, which constrains the application of the ecosystem-services approach (Cowx and Aya 2011).

Naturalistic fallacy is the belief that if we could just go back to the way things were, fisheries and ecosystems would be restored. This type of historically based restoration seeks to turn back the clock when there is no chance of going back. Many ecosystems have been fundamentally altered by overfishing for so long that they are unlikely to recover. A more practical restoration agenda based on achievable EBM could adopt the concept of an optimal restorable biomass (Pitcher and Pauly 1998). But there is no going back to a pristine, historic condition.

Questions to ponder:

Consider a fishery that is familiar to you. Which of the approaches to thinking are evident in the rules and regulations? Are there different types of fishers who may prefer markedly different fishing rules?

2.3 Seeking Sustainable Fisheries

None of the previous ways of thinking has proven consistently optimal for fisheries management. Traditional conceptions of exploitation (MSY, MEY, PGY) may promote an exploitative use of fish stocks with little focus on human or ecosystem well-being. Ways of thinking about fisheries decisions often ignore considerations for welfare, freedom, and justice that are discussed in Chapter 4. Fishery policy goals are visions of what a society desires for its future (Lam and Pitcher 2012). As such, goals are choices to be made before instituting regulations. Failures of fish conservation may result from the widespread failure to consider management of fisheries as a whole system or from inadequate communications between science and decision making. Many large industrialized commercial fisheries have favored economy of things (marketed goods and services) over relationships (embedded in communities and ecosystems). Despite differences in approaches, most practitioners agree to adopt a management-oriented **paradigm** that involves (1) formulating management objectives that are measurable, (2) specifying sets of rules for decision making, and (3) specifying the data and methods to be used, all in such a way that the properties of the resultant system can be evaluated in advance (Karjalainen and Marjomäki 2005). For a fishery to be sustainable, there must be a fishery management system that can serve to adjust fishing pressure to appropriate levels as needed (Hilborn et al. 2015). Where fisheries are intensively managed with such an approach, the fish stocks are above target levels or rebuilding (Hilborn et al. 2020).

Fisheries management is management of people, habitat, and fish. The interplay of diverse human interests, values, and preferences with respect to fishery resources is a global challenge that cannot be easily solved. Rather, conflicts and challenges are to be expected in all but the very simplest fishing situations. For example, the urgent need to feed people may override the desire for sustainable fisheries. Today's global fisheries operate at an average trophic level of about 3.3, meaning that we are harvesting mostly carnivores that eat herbivores. However, reducing this to 2.3 (eating mostly herbivores) would theoretically increase the world's food harvest tenfold (Pitcher and Lam 2010). Forage fish, that is, small and medium-sized pelagic fish eaten by larger fish, seabirds, and marine mammals—are caught for nonfood purposes, such as reduction to fishmeal, feed for poultry and carnivorous fish in aquaculture, and fish oil used in the food industry. Industrial uses of fish products compete with traditional human consumption of lower trophic–level fish. Evaluation of ethical fisheries and the use of multiple criteria for decision making will change how we manage fisheries (Aguado et al. 2016).

Seafood certification, or ecolabeling, provided by third parties such as the Marine Stewardship Council and Seafood Watch, attempts to certify ethical fisheries. Fishing practices changed dramatically in response to public outrage over harvest of dolphins in tuna purse seining, demonstrating that consumer demands can influence fishing practices. Fisheries that meet Marine Stewardship criteria are highly selective for the target species, limited access, well regulated, enforced, and often involve comanagement between government, scientists, and fishers. These third-party certifications of sustainability have not yet delivered on the promise of price premiums, improved governance, or improved environmental conditions (Roheim et al. 2018). Challenges remain in the implementation of seafood sustainability due to potential for confusion about the overlapping goals of a growing range of sustainability initiatives (Figure 2.6; McClenachan et al. 2016; Marine Stewardship Council 2019; Tlusty et al. 2019).

Figure 2.6: Three types of seafood sustainability initiatives and example goals of each. [Long description](#).

Do fishers have a right or a privilege to fish? What's the desired goal of fisheries management? These fundamental questions involve ethical reasoning about values as applied in the local context. In fisheries we are faced with challenges for fisheries management in inland and ocean waters. Inland fisheries contribute over 40% of the world's reported finfish fisheries and aquaculture production. Inland capture fisheries comprise less than 10% of this reported total, but the actual fish harvest is likely substantially higher (Cooke et al. 2016). The importance and plight of inland fisheries are poorly recognized by society (Youn et al. 2014). Yet, sportfishing is a potent economic industry in many industrialized countries (American Sportfishing Association 2018). To enhance inland fisheries, we need to (1) raise awareness of diverse values of inland fish, (2) balance the multiple use and conservation objectives, and (3) ensure productive inland fisheries given externalities (Lynch et al. 2017). Global marine fisheries can be enhanced via fewer subsidies and capital investments for fishing, precautionary management, and greater equity in distribution of benefits (McClenachan et al. 2016). The language of ethical analyses may assist in addressing these challenges via effective management so that there can still be "plenty more fish in the sea" and a continuous flow of benefits for our future (Watson et al. 2017).

In summary, it may at first appear that our communities have many overlapping core values. Some may feel that they have overlapping core values within themselves. The wisdom of embracing a pluralistic view of these overlapping core values is evident from taking a pragmatic view (Norton 2005), which opens value questions to community discussion and problem solving. Pragmatism is a philosophy that embraces multiple core values and relies on participatory processes to increase listening, build trust, and consciously cultivate a ground of mutual respect (Cooke et al. 2013; Clayton and Myers 2015; Young et al. 2016). Environmental pragmatists believe that the diversity of values should be respected to allow for deliberate, creative conflict mediation and social learning in contrast to some quest for ethical perfection. The use of social media is likely to play a more prominent role in the future (Giovos et al. 2018). No single management approach can be a **panacea**; instead, the answer lies in adopting a participatory governance style that works for the local and regional context (Ostrom 1990, 2007).

Questions to ponder:

What values are most relevant to you when you select a seafood product to buy? If you do not eat fish, what are the values and beliefs you hold that led to that decision?

A thing is right when it tends to preserve the integrity, stability and beauty of the biotic community. It is wrong when it tends otherwise.

—Leopold 1949

Profile in Fish Conservation: Larry Gigliotti

Scan the QR code or visit https://doi.org/10.21061/fishandconservation to listen to this Profile in Fish Conservation.

Figure 2.7: Larry Gigliotti.

Larry Gigliotti is Professor and Assistant Unit Leader at the South Dakota Cooperative Fish and Wildlife Research Unit, located on the campus of South Dakota State University. He has a BS in wildlife ecology from Pennsylvania State University and an MS and PhD in human dimensions from Michigan State University. Gigliotti maintains certifications as both a Certified Wildlife Biologist and a Certified Fisheries Scientist. His research examines attitudes, values, perceptions, beliefs, and expectations of hunters, anglers, and others related to recreation and resource use. As such, he provides novel information for resource management by understanding the social and psychological determinants of angler behavior and attitude formation and how to involve various publics in conflict resolution and planning.

His first job was as a wildlife biologist in New York and Michigan, and he entered graduate school with a goal of developing unique strengths in research in human dimensions of fish and wildlife. Consequently, he was the first human dimensions specialist hired by the South Dakota Game, Fish and Parks Department. In this position he piloted several innovations to guide the agency's efforts to be more responsive to citizens, especially hunters and anglers. In particular, he spearheaded many surveys of hunters, landowners, anglers, and residents. His research examined internet-based surveys and revealed important findings regarding response rates and age-related biases.

As an early researcher on the human dimensions of fish and wildlife, his contributions are unique and varied. His perspective as an agency professional and researcher over his career furthered the status of human dimensions as an essential specialization, which draws on sociology, psychology, communications, economics, recreation, education, anthropology, statistics, and other subjects with biology and ecology to make wise management decisions concerning renewable natural resources. One example of his unique influence is the development of a measurement scale to measure crowding among deer hunters, one of many determinants of a hunter's satisfaction with the hunting experience. He did one of the early investigations of the effects of illegal harvesting behavior among anglers on common sport fishes. He promoted an ecosystem approach to the Great Lakes Lake Trout rehabilitation and explicitly considered the beliefs and attitudes of multiple stakeholders. His investigations on angler use and satisfaction revealed that the opportunities provided to younger anglers by community fishing lakes enhanced their satisfaction with fishing trips. Most recently, he and his associates examined landowner trust in natural resource management agencies as related to competence and fairness, a rarely studied question.

Larry Gigliotti was an early adopter and developer in the human dimensions field and supported fisheries managers in managing for benefits, reflecting a wide range of social values and segmenting anglers based on attitudes and beliefs.

Key Takeaways

- People develop both strong positive and negative thoughts, feelings, and actions toward use of fish.
- Two frameworks, the value-belief-norm and emotional affinity, help to explain how personal values and experiences lead to behavioral norms.
- People will differ with respect to their values and beliefs.
- Commercial fisheries globally have relied on the concept of maximum sustainable yield as a management goal for many decades.
- In recreational fishing, angler satisfaction is more related to noncatch-related factors.
- An ecosystem approach to fisheries management will require additional research and development before it can be fully implemented.
- Seafood certification, or ecolabeling, provided by third parties represents the beginnings of evaluation of ethical fisheries.
- Developing communications and developing partnerships and trust are keys to conservation.

This chapter was reviewed by Larry Gigliotti.

URLs

Video: https://www.youtube.com/watch?v=olvAtex8mJo

Long Descriptions

Figure 2.1: Four boxes are connected with arrows showing that biocentrism influences inherent value in all living things, which influences animal welfare expected, which influences adopt aquaculture best practices. Jump back to Figure 2.1.

Figure 2.3: Line graph depicting dome-shaped relationship between yield and fish biomass and linear decline in intrinsic rate of increase. Jump back to Figure 2.3.

Figure 2.4: Line graph depicting dome-shaped relationship between revenues for a fishery as a function of fishing effort, linear increase in costs, and location on curve for maximum economic yield, maximum sustainable yield, and bioeconomic equilibrium. Jump back to Figure 2.4.

Figure 2.5: Regions of safe fishing, a precautionary buffer zone, and stock and fleet overfishing related to spawning biomass and fisheries mortality. Jump back to Figure 2.5.

Figure 2.6: Three overlapping circles: 1) Fair Trade, no forced or child labor; 2) Local, reduced carbon footprint; 3) Eco-label, reduced habitat destruction. Where fair trade and local overlap, socioeconomic development and diversification. Where Eco-Label and Local overlap, improved stock status and reduced bycatch. Where all overlap, traceability. Jump back to Figure 2.6.

Figure References

Figure 2.1: Causal chain of influence between biocentrism, inherent value in all living things, animal welfare expected, and adopt aquaculture best practices. Kindred Grey. 2022. CC BY 4.0.

Figure 2.2: The values-rules-knowledge perspective (VRK) for identifying those aspects of societal decision-making contexts that enable or constrain adaptation. Kindred Grey. 2022. CC BY 4.0.

Figure 2.3: Equilibrium relation between yield (Y, green curve) and intrinsic rate of population increase (r, tan line) and population biomass. Kindred Grey. 2022. Adapted under fair use from Maximum Sustainable Yield, by Athanassios C. Tsikliras and Rainer Froese, 2019 (https://doi.org/10.1016/B978-0-12-409548-9.10601-3).

Figure 2.4: Gordon–Schaefer bioeconomic model of costs and sustainable revenues for a fishery as a function of fishing effort (f). MEY = maximum economic yield, MSY = maximum sustainable yield, and BE = bioeconomic equilibrium. Kindred Grey. 2022. Adapted under fair use from *The Economic Theory of a Common-Property Resource: The Fishery*, by Gordon H. Scott, 1954 (doi:10.1086/257497) and *Some Considerations of Population Dynamics and Economics in Relation to the Management of the Commercial Marine Fisheries*, by M. B. Schaefer, 1957. doi:10.1139/f57-025.

Figure 2.5: Visualization of a harvest control rule (HCR) specifying when a rebuilding plan is mandatory in terms of precautionary and limit reference points for spawning biomass and fishing mortality rate. Kindred Grey. 2022. CC BY 4.0. Adapted from Harvest Control Rule graph by Arnejohs, 2006 (public domain, https://commons.wikimedia.org/wiki/File:Harvest_Control_Rule_graph.gif).

Figure 2.6: Three types of seafood sustainability initiatives and example goals of each. Kindred Grey. 2022. Adapted under fair use from *Fair Trade Fish: Consumer Support for Broader Seafood Sustainability*, by Loren Mcclenachan and Sahan T. M. Dissanayake, 2016 (DOI:10.1111/faf.12148).

Figure 2.7: Larry Gigliotti. USGS. 2016. Public domain. https://www.usgs.gov/media/images/larry-gigliotti

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3. Sensory Capabilities of Fish

Learning Objectives

- Recognize the adaptive significance of sensory capabilities of fish.
- Compare and contrast the sensory system of humans and fish.
- Relate the sensitivities of fish to the characteristics of the underwater world.
- Describe how sensory capabilities relate to the fish's ability to communicate and orient.
- Express how the sensory abilities lead to responses to environmental stimuli.
- Apply concepts of fish sensory capabilities to predict effects of humans on fish.

3.1 Introduction

Fish may seem alien to us because they evolved in water and their senses are more adapted to an aquatic environment. Yet, like humans, fish depend on many senses for survival. Vision is a dominant sense in fish, and we humans can appreciate the capability for depth perception and color discrimination. But what happens when you attempt to see underwater? Your vision is very blurry underwater. Somehow fish solved the problem of seeing underwater. Sensory capabilities of fish are adapted to accommodate the special characteristics of the aquatic environment.

Imagine, if you will, a day in the life of a fish. Without eyelids, their eyes are open all the time. Daily cycles of light intensity are sensed by **photoreceptors** in the eye and **pineal** organ in the brain, which contains light-sensitive nerve endings. Vision is a dominant sense of fish that we humans can appreciate. Whether the fish finds a meal or becomes prey depends on many senses, such as the abilities to see, hear, smell, taste, and to detect water movement and electrical fields. Fish have a special sense that humans do not have: the ability to detect vibrations moving through water. Because sound vibrations move easily through water, fish do not need external ear openings, and yet they also have sensitive hearing.

Together, fish use these senses to inspect the world around them. Imagine an angler tossing a lure nearby. The fish will feel the vibrations caused by the waves moving from the lure. With wide-angle vision, the fish moves toward the lure to inspect it. With an acute sense of smell, it detects no signal that suggests it's living. In some cases, the fish will grab a bait, taste it with sensitive taste buds, and reject it as nonfood. If captured, the fish has many sensory structures in the skin to detect touch and temperature changes.

But fish use sense for more than just finding food. Fish can rely on one or more sensory cues and different sensory mechanisms to gain information about their environment and guide their behavior. Senses are engaged whether the fish is moving toward a sound, away from a threat, or following a scent of food or **pheromones**. For example, young glass eels (*Anguilla* spp.) return to estuaries and detect currents using their magnetic compass to memorize magnetic direction of tidal flows (Cresci et al. 2019). As you learn more about the sensory capabilities of fish, you will be better able to understand their behavior.

3.2 Characteristics of the Water Shape Sensory Capabilities

Humans share some homologous organs and body parts with fish (Table 3.1). However, characteristics of water exert evolutionary pressures on fish to enhance their sensory capabilities in water. Water is dense, colorless, and odorless and can **refract** and reflect light waves in such a way that some colors are absorbed, particularly at deeper depths. Consequently, sound waves travel fast, scents are rapidly dissolved and detected in low concentrations, and vision is keen in fish that are active during the daytime. There is less oxygen dissolved in water than in the atmosphere. Therefore, gills are highly efficient at oxygen diffusion, and oxygen-sensing cells are sensitive at detecting changes in oxygen content of the water, sending signals to increase gill ventilation as oxygen declines. Similarly, terrestrial vertebrates have oxygen-sensing cells in the lungs to signal a change in breathing rate.

It's not just the presence but also the location of sensory organs that reflects these evolutionary pressures (Figure 3.1). Fish smell with nares, far forward on the head, in front of the eyes, so that new scents are detected as the fish swims forward. Taste buds in fish are not restricted to the mouth but are distributed throughout parts of the body to allow the fish to taste its environment. Eyes are typically above the midline and on either side of the head, allowing fish a wide field of vision in front and along the sides and above—locations of typical predator threat. Water flow patterns are detected along the entire length of the body via sensory hair cells in the lateral line and other locations. In this way, the fish detects the flow field as it swims forward and detects disturbances in the flow field made by prey and predators. For example, when a fish detects the accelerating flows of suction or ram actions of predators, it will instinctively make a turn or C-shaped body bend and move in an opposite direction (Mirjany et al. 2011). The reaction occurs within 10 milliseconds.

Some fish have evolved a reduced or negative capacity for some senses to match their environment. Fish in muddy water habitats often have very small eyes because vision is less important. Some fish that live in dark caves have totally lost the sense of vision. Blind cavefish use the flow-sensing capabilities of their lateral line system rather than vision to avoid swimming into obstacles.

Human	Fish
Lungs	Gills
Stomach	Stomach
Liver	Liver
Kidneys	Kidneys
Ears	Lateral line, otoliths, and inner ear
Skin	Scales and slime layer
Nose	Nares
Arms	Pectoral fins
Legs	Pelvic fins

Table 3.1: Homologous organs in humans and fish.

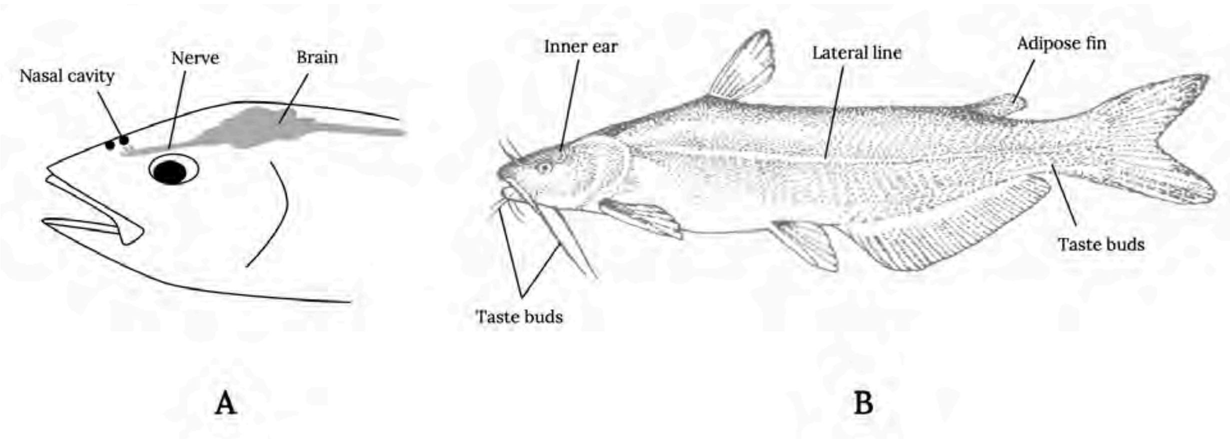

Figure 3.1: Locations of sensory structures on the body of a fish. (A) Nares, eye, pineal, and brain locations. (B) Inner ear, lateral line, adipose fin, and taste bud locations. [Long description](#).

Question to ponder:

You are assigned a task at work to create the perfect marketable fish bait. Draw (with color) and describe the most ideal bait for either a catfish or a tuna. Describe how this will move through the water when fished and other features that would make it more marketable to anglers. Modify your design and description after you complete your reading of this chapter.

3.3 How We Study Sensory Ecology

Sensory ecology focuses on the study of animal sensory systems to understand how environmental information is perceived, how this information is processed, and how this affects interactions between the animal and its environment (Dangles et al. 2009). The stimulus-response model (Figure 3.2) describes the basic reactions from the stimulus, through receptors to the central nervous system and brain, which are then transmitted to neurons and organs that respond due to detection of the stimulus. A stimulus is any change in the environment (either external or internal) that is detected by a receptor. It may be a predator threat, an easy prey item, or a potential mate. Receptors transform environmental stimuli into electrical nerve impulses. These impulses are then transmitted via neurons to the central nervous system and brain where decision making occurs. When a response is selected (consciously or unconsciously), the signal is transmitted via neurons to effectors. Effectors are organs (either muscles or glands) that produce a response to a stimulus. A response is a change in the organism resulting from the detection of a stimulus.

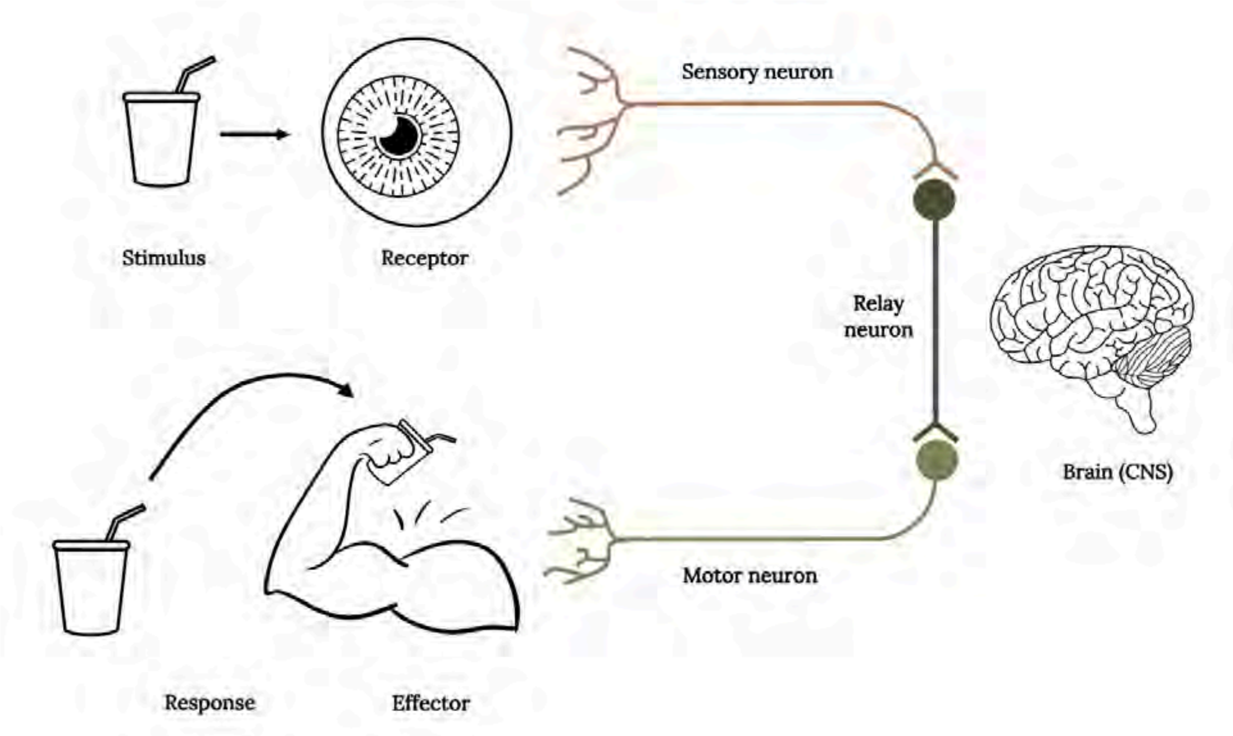

Figure 3.2: Diagram of the connections in the stimulus-response model in fish, which displays a stimulus, odor receptor (nares), sensory neuron, relay neuron, motor neuron, brain, effector, and response. Long description.

Three types of neurons are required to transmit information via the stimulus-response pathway: (1) sensory neurons transmit information from sensory receptors to the central nervous system (CNS); (2) relay neurons (interneurons) transmit information within the CNS as part of the decision-making process; and (3) motor neurons transmit information from the CNS to effectors (muscles or glands), to initiate a response.

The fascinating interplay between the different sensory abilities of the fish leads to their unique response to environmental stimuli that we observe. Consequently, biologists who study sensory ecology apply both behavioral and physiological approaches. The behavioral approach involves training or conditioning fish so that they respond to a stimulus. The fish is trained to do some tasks, such as move to one side of a tank, when it receives a stimulus such as a sound, a smell, or a visual cue. In this way, biologists can measure the reaction of fish to various stimuli.

The electrophysiological approach measures the responses to a stimulus by placing electrodes close to the nerve. The approach does not require any behavioral response by the fish; it only indicates that the stimulus was detected. The basic pathway for a nerve impulse is described by the stimulus-response model. The locations of sensory neurons of cutaneous taste buds of catfish were mapped in detail long ago (Herrick 1901), which allowed the first studies that exposed taste buds on the skin to various chemical stimuli and measured the responses in specific nerves via electrodes and amplifiers to display the electrical signal response (Hoagland 1933).

Catfish have a keen sense of taste and smell, and their taste buds are densely packed on the barbels, mouth, and skin. Barbels are particularly useful for catfish, as they literally "taste" the surrounding environment in the dark of night. As an example of the behavioral approach, a study of catfish in a large aquarium revealed that small catfish quickly responded to a small drop of pork juice and could locate the source with taste alone within 24 seconds (Bardach et al. 1967). The value of the behavioral approach is also revealed by a study that demonstrated the ability of sharks and rays to locate a flatfish buried in the sand by using their ability to detect weak electric fields generated by the hidden flatfish (Kalmijn 1971; King and Long 2020). Understanding the behavior of fish is of widespread interest, especially in the study of **anthropocentric** pollution that may obscure or interfere with detection of stimuli that fish use to make sense of their surroundings.

3.4 Distant Touch and Hearing

Humans hear sound when air molecules vibrate and move in a pattern called *waves* or *sound waves*. Fish have sensitive hearing that is adapted to the underwater environment, where sound waves move four times faster than in air because water particles are packed closer together. Because sound waves move faster in aquatic environments, the underwater world is filled with **myriad** sound sources that provide the fish with information from far greater distances than do other sensory stimuli. Fish use their hearing abilities to assess their surrounding soundscape and determine the availability of food, mates, or competitors, as well as the threat of predators (Putland et al. 2019). Fish may not hear the sounds of two anglers speaking in a boat because their sound waves are traveling through the air. However, fish will hear the propeller from an electric trolling motor from a good distance away.

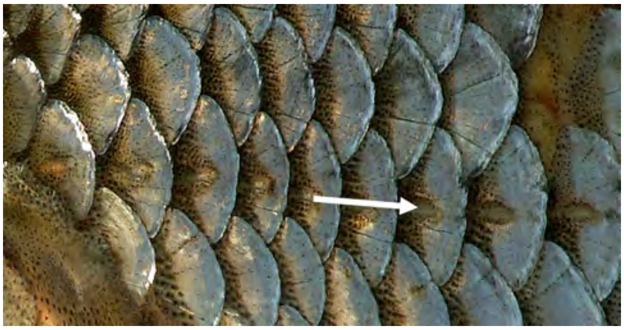

Figure 3.3: Scales along the lateral line (see arrow) of the Roach Rutilus rutilus.

Sound perception is so critical to survival of fish that the hearing anatomy is fully developed within two days of hatching, when fish are just developing swimming and other sensory capabilities. Unlike humans, which have external ears, fish have two organs for hearing that are not obvious to the casual observer. Fish have an internal ear and an external lateral line system. The lateral line is an organ of microscopic pores primarily used to sense vibrations and pressure in the water (Figure 3.3; Montgomery et al. 2014). The pores are lined with neuromasts, which contain sensory hair cells (Figure 3.4). Each hair cell has bundles of **cilia** embedded in a gelatinous structure, called the *cupula*. Water movements deflect the cupula and cilia bundles, creating a change in membrane potential that is transmitted to the sensory neuron.

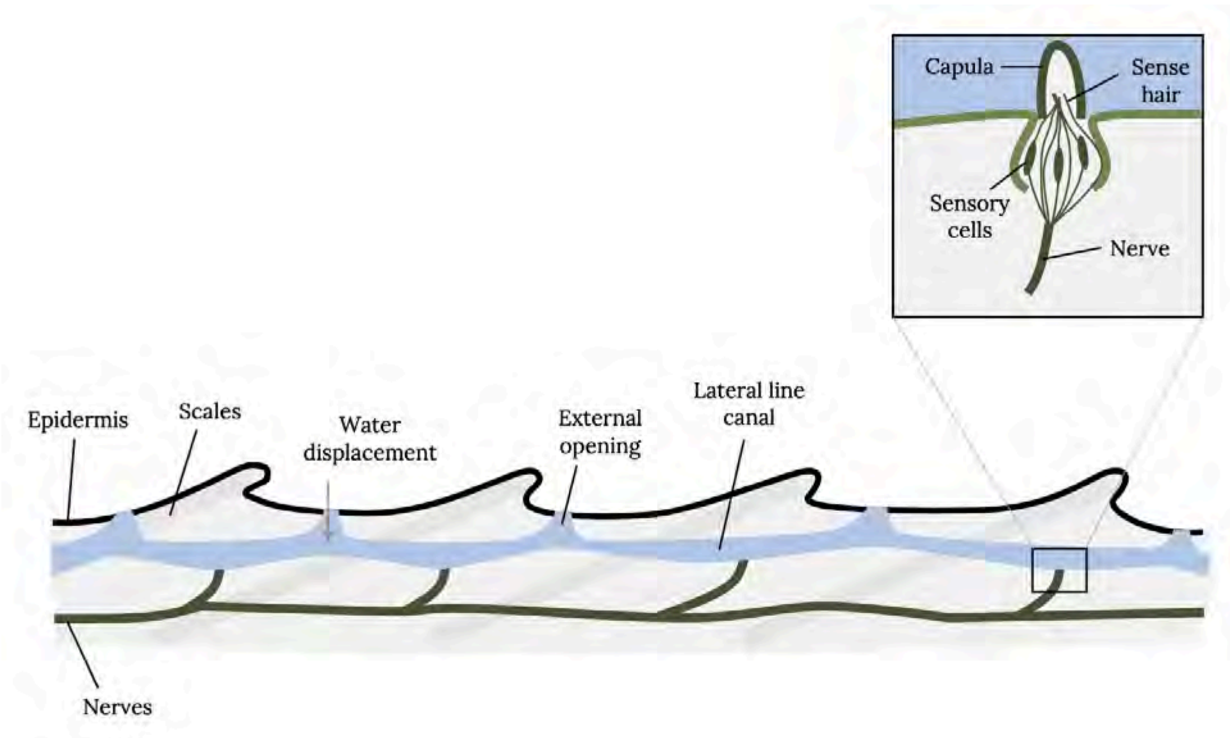

Figure 3.4: Schematic of the lateral line system of fish. Movements of water in the lateral line canal cause the cupula to move, thereby stimulating sensory hair cells connected to nerves. [Long description](#).

In addition to neuromasts found in the lateral line canal (see Figure 3.4), fish also have neuromasts in canals and on the surface of the skin in clusters on the head, trunk, and tail fin. The number and location of neuromasts influence the sensitivity. For example, the Goldfish has more superficial neuromasts and is more sensitive to water vibrations than the Rainbow Trout. Biologists have found that fish spend much of their time orienting their body, and the ability to sense local water movements is essential to the motion of the fish (Liao 2007; Coombs and Montgomery 2014). The small adipose fin, which is only present in some families of fish, detects water flow across the dorsal surface near the caudal region of the body and aids in swimming (Stewart and Hale 2013). Another unique specialization of neuromasts is the extended lateral line canal along the bottom jaw of the halfbeak fish, which allows it to detect, track, and intercept small but relatively fast-moving prey without using vision (Montgomery and Saunders 1985).

Fish utilize the lateral line to detect movements of prey, predators, currents, and objects in the water. If there is any difference between the relative movements of the body of the fish and the movements of the surrounding water, it will be sensed by the lateral line (Mogdans 2019). In this way, the fish knows if it is swimming in highly turbulent or still waters. The lateral line is also very sensitive to water vibrations from great distances underwater, so this sixth sense is sometimes called the *far-field hearing* (Figure 3.5).

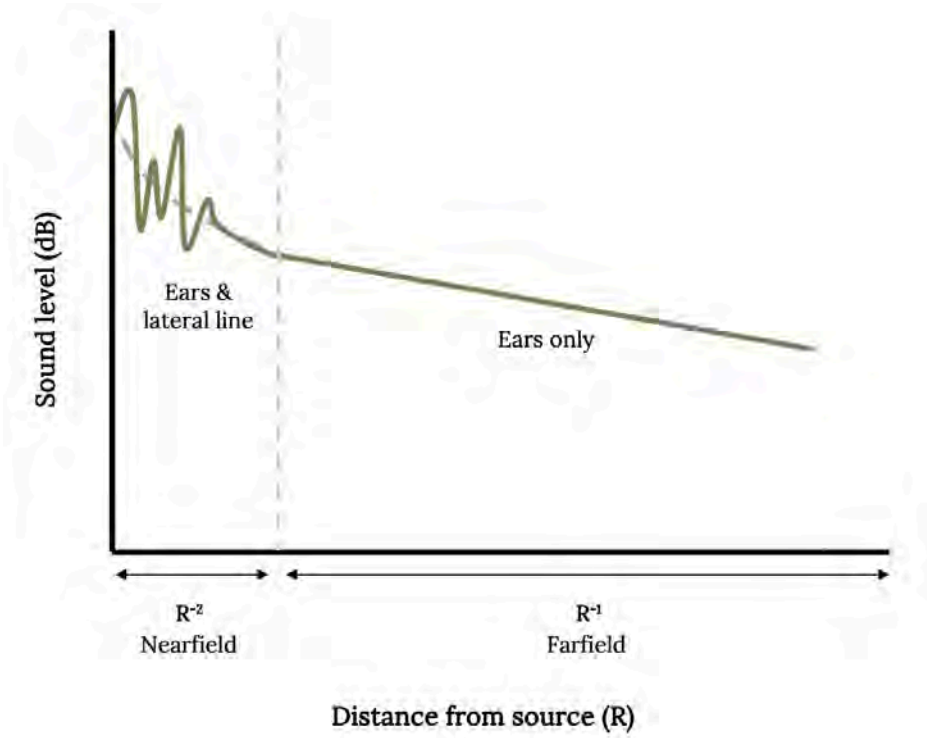

Figure 3.5: Sound level in decibels plotted as a function of distance from the source. [Long description](#).

The inner ear of bony fish consists of semicircular canals connected to organs with otoliths, or ear stones (Figure 3.6). It is similar to the cochlea in humans and other vertebrates. When sound waves go through a fish, the denser ear stone moves more slowly and the sensory hair cells and cilia are deflected, thereby sending signals to the brain. Some deflections are interpreted as sounds, and some signal acceleration of the fish (Tavolga et al. 1981; Popper and Schilt 2008; Popper et al. 2019). Swim bladders in bony fish vibrate as well, and direct connections to the inner ear enhance the hearing sensitivity in certain fish, such as Goldfish.

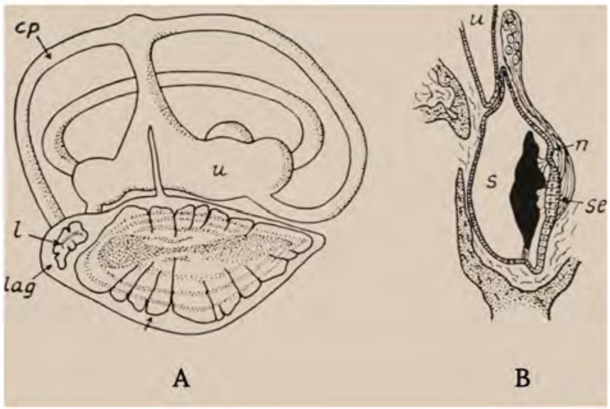

Figure 3.6: (A) Labyrinth of a flying fish (Exocoetus). (B) Section through the sacculus of the trout. Key structures illustrated: cp = posterior semicircular canal; s = statolith of lagena; lag = lagena; n = nerve; s = sacculus; se = sensory epithelium; and u = utriculus. [Long description](#).

Far-field and near-field hearing are adaptations for increased survival, feeding success, and breeding in fish. During the early development of many fish that occupy coral reefs, the planktonic larvae drift in the currents. Drifting larval fish use sounds produced by different underwater habitats to orient and locate suitable habitats to settle into. Furthermore, some fish use sound to discriminate between habitats when moving from sheltering to feeding habitats at night. Herring and shad have elongated gas ducts that extend from the swim bladder to the skull, which enhances hearing to ultrasound up to 100,000 Hz, overlapping the range of echolocation sounds of dolphins and porpoises. When American Shad hear ultrasonic clicks like those of dolphins, the fish either swim in the opposite direction of the sound source or move chaotically, making it harder for the dolphin to detect and capture the fish (Mann et al. 1997). Herring also escape approaching predators by detecting changes in water flow that the predator causes. In many sound-producing fish, the males produce sounds to attract a receptive female in initial courtship interactions. For example, females tend to choose males based on calling rate or effort, which is linked to body fat reserves and gonad size. Consequently, these and many other examples demonstrate how fish survival and breeding success are enhanced by specialized hearing.

3.5 Vision

Every experienced angler is aware of the keen vision of fish and uses this knowledge to catch more fish. The eyes of most fish are placed laterally on the head and tilted forward and upward. Vision is therefore nearly absent downward and to the rear, providing wide-angle monocular vision and a narrow zone of binocular vision. Consequently, for most sport fish, the angler's best line of attack is directly behind in the blind zone (Figure 3.7A). The angler also knows that light waves are reflected, refracted, or absorbed, depending on the angle. Therefore, fish have a cone-shaped range of vision that is approximately two times the depth of the fish. Outside this cone, the fish sees nothing and the angler's approach is hidden. The water surface around the window is either black or a mirror, depending on the angle at which light rays are reflected (Figure 3.7B).

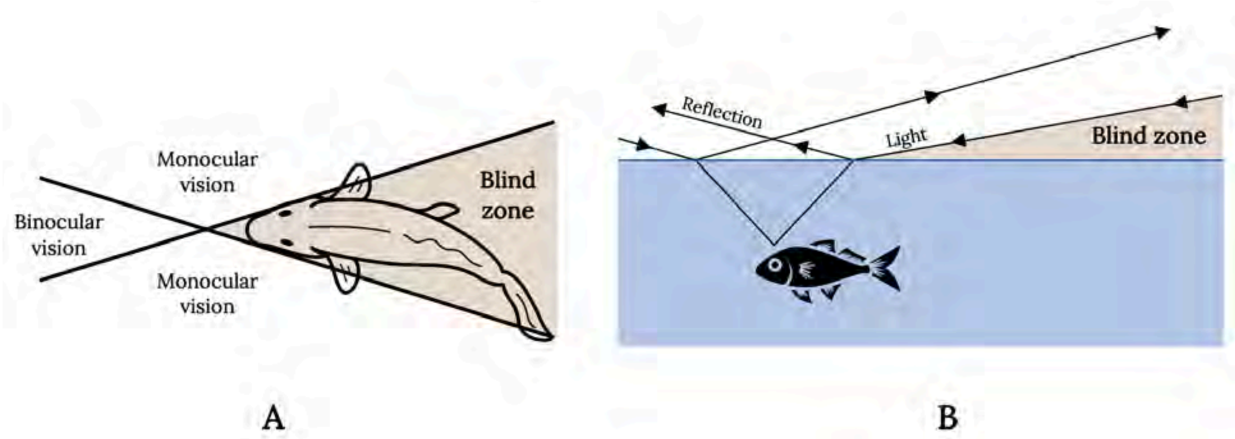

Figure 3.7: Diagram shows the refraction of light at the interface of air and water and the cone-shaped range of vision in the fish. (A) Top view. (B) Side view. [Long description](#).

Tips for stalking fish based on fish vision (Mayer 2019):

- Bottom brim of your hat should be a dark color.
- Wear dark or camouflage clothing and avoid wearing shiny objects.
- Wear polarized sunglasses that cover the sides of your eyes thoroughly.
- Block unwanted reflected rays by placing your arm beneath your chin.
- Keep the sun at your back and watch your shadow.
- Approach from downstream and keep a low profile.
- Place your fly upstream and within the binocular zone (a 30–36° angle) of a position-holding trout.
- Remember that the fish is holding position deeper and closer than it looks.

The eye of a fish has a similar anatomy to humans and consists of a cornea, iris, lens, sclera, choroid, and retina and is filled with a gel (or vitreous humor) between the lens and the retina (Figure 3.8). However, a fish's eye operates differently than that of a human to accommodate underwater sight. The lens of a fish's eye is purely spherical, unlike ours, and it has a refractive index (light-bending ability) of 1.65, which is higher than that of any other group of vertebrates. The lens focuses light waves on the retina, which influences the sensitivity of fish vision (Li and Maaswinkel 2006). Furthermore, the lens is fixed in its shape, meaning its shape cannot be adjusted to facilitate focusing on nearer or more distant objects. Therefore, unlike humans, most fish adjust focus by moving the lens closer or further from the retina. Bony fish do so by contracting a muscle.

Also like humans, the retina of the fish's eye is made up of photosensitive rods and cones. The rods detect only the presence or absence of light, and the cones detect color (Douglas and Djamgoz 1990). Most bony fish can detect color (Marshall et al. 2017). Most sharks, however, have only rods, and therefore they distinguish contrast, not color. In most bony fish, rods for low-light vision are much more common than cones, which are better for bright-light vision. As a general rule, the deeper a fish lives the fewer cones it has.

Color vision in fish is a hotly debated topic for some anglers. This is because fish do not see colors as humans do, and color sensing is highly variable among different fish. Walleye, for example, are adapted to low-light conditions, and their eyes have more rods than cones, whereas Rainbow Trout color vision is more like human color vision. Furthermore, different color wavelengths travel through water differently. Longer wavelengths disappear more quickly than shorter waves. Therefore, the depth of fish will influence light penetration and color availability. The vivid reds and yellows on your fishing lure will lose that brightness as long wavelengths are absorbed in deeper water. In turbid water, light waves disappear even quicker. Commercial gill-net fishers dye nets blue or green so they blend into the background color in very deep water. The subject of color selection for trout angling is fully explored in many books, such as *The New Scientific Angling: Trout and Ultraviolet Vision*; *What Fish See: Understanding Optics and Color Shifts for Designing Lures and Flies*; and *Trout Sense: A Fly Fisher's Guide to What Trout See, Hear, & Smell*. For the angler, it is often more about the contrast that the lure provides than the colors.

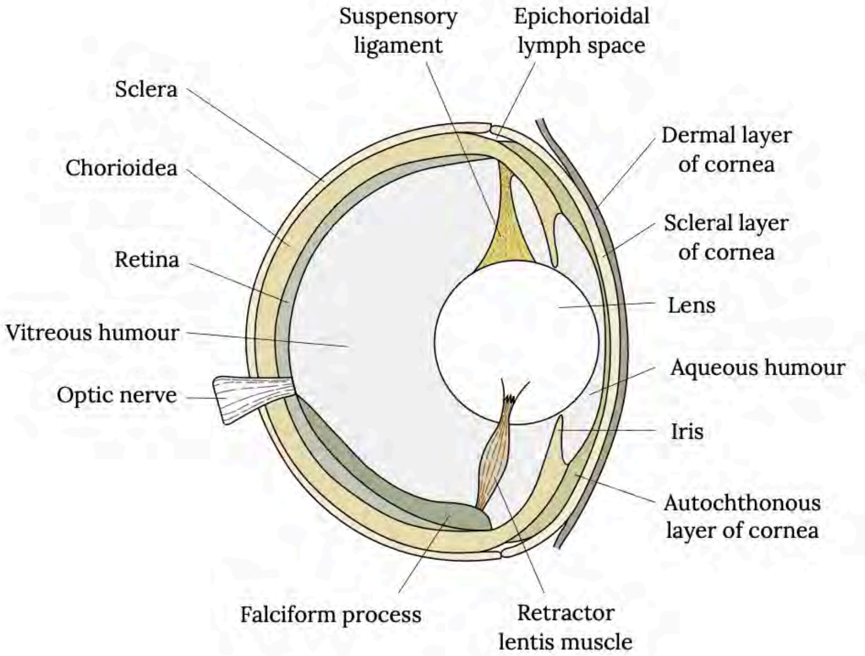

Figure 3.8: Diagrammatic vertical section through the eye of a teleost fish after Walls (1942). Long description.

Two visual capabilities of some bony fish include polarization and ultraviolet (UV) vision. It is at dusk and dawn when the maximum amount of polarized light is refracted in water, and much of it is in the UV wavelengths. Humans perceive polarized light as glare. However, certain fish can discriminate polarized light. Damselfish, clownfish, trout, minnows, and anchovy may use this ability to enhance detection of small prey within the fish's field of vision (Kamermans and Hawryshyn 2011). Many shallow-dwelling fish are capable of detecting UV radiation. Because humans cannot see UV light, the significance of this capability was initially a mystery. Scientists hypothesized that the ability of some fish to see UV reflections could represent a secret communication channel, hidden from predators. In coral reef fish, visual communication is a key mechanism for recognizing members of the same species. Experiments with damselfish demonstrated that they use their UV capabilities to discriminate between UV facial patterns of closely related species and their own (Siebek et al. 2010). These same facial patterns are invisible to humans and other fish but provide a hidden communication signal in damselfish.

Question to ponder:

Consider your favorite fishing target and their preferred habitat. How do you expect that the ability to hear (near and far) and vision influence your preferred choice of fishing lure or bait?

If you do not have a favorite fishing target, consider the Walleye and review this website.

3.6 Taste and Smell

Fish have an especially sensitive system for taste and smell, which have been well studied (Zielinski and Hara 2006; Kasumyan 2019). Smell occurs in the sensory folds with the nares on the head of a fish. However, fish are unique among vertebrates because they have taste buds that occur in many locations, which means a fish can literally taste its environment or food without putting it in its mouth. Taste buds can be seen on fish with a magnifying lens and appear as small pores with sensory cells connected to nerves (Figure 3.9). Fish have the highest number of taste buds recorded for vertebrate animals, and the amount of neural tissue devoted to sensing taste approaches 20% of the entire brain mass in some fish (Kotrschal and Palzenberger 1992). Fish are unique among vertebrates because they have external taste buds on their body in addition to taste buds on the lips and mouth. As early as 1827, taste buds of Common Carp were first described, and subsequently distribution of taste buds was studied in many other freshwater and marine fish. The location of taste buds on the body, barbels, or fin tips means that the fish can taste its environment as it moves and adapt or orient to potential food (Bardach and Atema 1971; Burton and Burton 2017). Studies frequently noted that the fish excelled humans in tasting tested substances and surprisingly showed a strong response to human saliva (Konishi and Zotterman 1961)—so there's no evidence to support the idea that spitting on your bait brings good luck.

In some bony fish, taste and smell are dominant sensory modalities. In fact, some substances are both tasted and smelled. Taste sensors detect the presence and location of distant food sources. However, taste and smell are not just for feeding: they can also play a role in the protection of the young and in courtship.

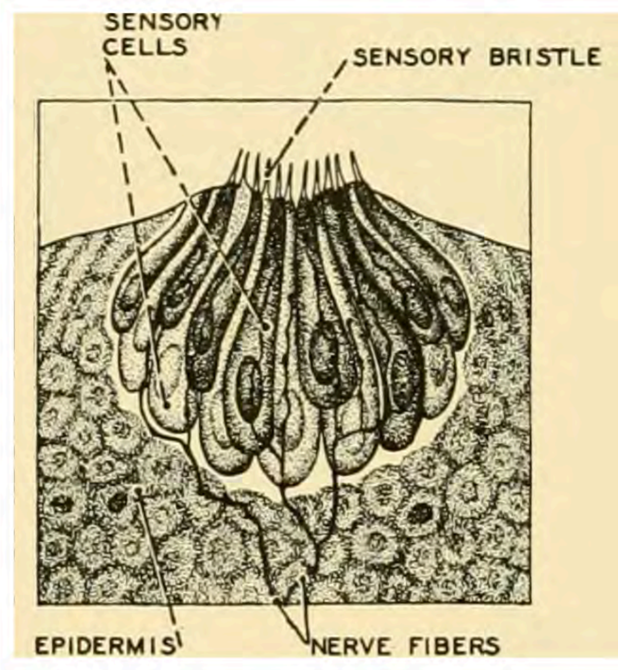

Figure 3.9: Diagram of the taste buds in fish.

The key drivers for feeding are hunger and **satiety**. What is chosen to eat, however, is not determined solely by physiological or nutritional needs but by other factors such as the sensory properties of food. An encounter with food odor evokes feeding agitation and searching activity in fish and in most cases precedes grasping of the detected food item. The odor of familiar or habitual food makes fish grasp and test many previously indifferent dietary items, even those that in size, shape, or coloration only distantly remind the fish of real food.

The fact that odors attract certain fish has been used by recreational and commercial fishers for a long time. Worms are often kept in damp coffee grounds because the coffee smell attracts fish. Many baits and smelly fish are used in hoop nets and traps to attract catfish, lobsters, and crabs. Trout anglers have used garlic-scented marshmallows and corn for years because they work. Numerous scents are infused in formulated baits, such as Powerbait® and Gulp®. Many oils, such as menhaden milk, herring oil, shrimp oil, and squid oil, are used as fish attractants.

Serious catfish anglers have their favorite, secret recipe for stink baits made from liver, shad guts, old cheese, peanut butter, garlic, and many other aromatic foods.

The taste buds within the mouth allow fish to demonstrate strong and stable preferences for some foods. Fish quickly spit out a nonfood or nonpreferred food item. For example, common amino acids (L-alanine, L-cysteine, L-aspartic acid, glycine), sugars, and citric acid are preferred substances, and formulated diets for captive fish often use this information to formulate palatable artificial feed (Konishi and Zotterman 1961).

In addition to finding food, bullhead catfish use their sense of smell not only to identify but also to remember individuals in a group. This sense helps us to explain the development of dominance hierarchies in the bullheads. In dominance hierarchies, catfish will know one another; there will be one dominant catfish and others known as subordinates. The behaviors and recognition depend on the chemical cues, because even blinded individuals are capable of social recognition (Todd 1971).

Question to ponder:

Why might it be a good thing that fish have a keen sense of taste and do not consume everything that enters their mouth?

3.7 Electrosensory and Magnetosensory Capabilities

Figure 3.10: Pores with ampullae of Lorenzini in snout of Tiger Shark.

Some fish can receive signals from weak sensitive fields. Imagine swimming along the ocean bottom and sensing a live, hidden fish that you cannot see nor smell. Sharks are more sensitive to electric fields than any other animal, responding to charges from weak electrical potentials generated by muscle contractions of marine fish (Newton et al. 2019). Sharks, skates, and rays have hundreds or more small pores, known as ampullae of Lorenzini, that detect electric fields in the water (Figure 3.10). The pores are filled with a conductive gel that allows the potential to be transmitted to the nerve. This stimulus may be interpreted as a prey nearby, and the shark can orient toward the prey that is generating electric fields. Pores are primarily located around the mouth and body in sharks, skates, and rays to allow the fish to orient toward the prey (Collin et al. 2016). A secondary function of electroreception is detection of predators in less mobile juveniles.

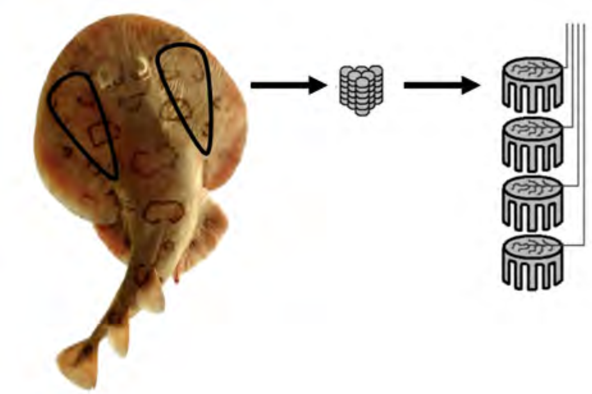

Figure 3.11: An electric ray (Torpediniformes) showing locations of electric organs and electrocytes stacked within them. [Long description](#).

Certain electrosensitive fish also have an electric organ that generates a very weak electric field (Figure 3.11). The electric field generated helps the fish to navigate, communicate, incapacitate prey, and defend the fish from predators. Common examples include the electric ray, African elephantnose fish, and South American knifefish. Elephantnose fish can switch between relying on visual and electric sense, just as humans switch between sight and touch sensors. Processing electrical senses requires a very large brain and, therefore, electric fish use more oxygen for brain functions compared with humans. Interestingly, the brain size in Peters's Elephantnose Fish is 3% of body mass, which is higher than the brain/body mass ratio of 2% in humans (Nilsson 1996).

Because of their electrosensitivity, sharks avoid certain rare-earth elements, such as lanthanide, which have magnetic properties. Experiments are ongoing to test whether certain metals or strong magnets can induce sufficient avoidance that they may be used for reducing bycatch in certain fishing gears (Richards et al. 2018).

Many fish possess the ability to detect and respond to the direction and intensity of magnetic fields (Formicki et al. 2019). Discovered relatively recently, the magnetic sense helps to explain the predictability of long-distance migration patterns observed in eels, sharks, tuna, and salmon. Salmon respond to the magnetic field with magnetoreceptor cells located in the nose of the fish.

Question to ponder:

How are the senses different from a shark (an open-water predator) and a flounder (benthic predator)?

3.8 Nociception

Nociception is the detection of harmful or unpleasant stimuli. When exposed to any harmful substance, fish make a reflex reaction and quickly withdraw. Stimuli that could cause tissue damage include high mechanical pressure, extremes of temperature, acids, venoms, and prostaglandins. While nociception is underexplored in fish, the free nerve endings (nociceptors) exist in the skin of Rainbow Trout, Zebrafish, Common Carp, and Goldfish and act as an alarm system to alert the fish to potential harm (Sneddon 2007). In the next chapter, the issues of pain and welfare are introduced.

3.9 Sensory Orientations

Variation in sensory capabilities is extremely high among groups of fish. This variation reflects the fact dominant habitats and habits are exhibited by different fish along with their evolutionary history. The jawless hagfish and lampreys are the oldest lineages of fish and have well-developed olfactory bulbs and a prominent brain stem, yet other senses (including sight) as measured by the size of brain parts are less developed. Cartilaginous fish (sharks, skates, and rays) have a highly developed sense of odors, as well as electric fields. In the bony fish, those that colonized and occupy a bottom-dwelling or benthic lifestyle, often have enhanced senses of taste, smell, and touch, which are more important than vision. Fish of clear water lakes and streams have excellent vision (Kotrschal and Palzenberger 1992; Kotrschal et al. 1998). Fish adapted to large, turbid rivers and estuaries have enhanced senses of taste and smell. Open-water fish rely more heavily on the lateral line sense. The cichlids and butterfly fish rely on integrating multiple sensory capabilities to allow life in complex spatial and social relationships. Therefore, we should never conclude that all types of fish have the same sensory specializations. Rather, sensory capabilities reflect the dominant habitats and way of life.

3.10 Sensory Disruptions and Human Presence

When we think of pollution to aquatic environments, we often picture images of trash and dirty water. However, human activities also add sensory pollutants that alter aquatic environments in ways that decrease the ability of fish to sense their underwater world. Imagine a world in which one or more of your senses was eliminated or greatly impaired by interference of some kind. In coastal embayments that surround ports and harbors, the ambient sound level is estimated to double in intensity every decade (Merchant et al. 2012). Further, pollution, toxicants, anthropogenic noise, and dams are human modifications that may influence sensory functions, depending on degree and type of change. Fish, in habitats greatly altered by humans, experience what biologists are calling *sensory smog* from many artificial stimuli (Preston 2019). Motorboats, pile driving, seismic airguns, and other activities produce sounds that may drown out other sounds. Ocean acidification influences the sense of smell in sea bass, decreasing their chances of detecting food or predators (Porteus et al. 2018). Ocean acidification and reductions in dissolved oxygen alters otoliths, which may affect sensory development (Simpson et al. 2011; Hamilton et al. 2019). Water pollution decreases underwater visibility and interferes with feeding and communication in fish (Fisher et al. 2006). Toxicants may influence the sensitive organs involved in taste and smell. Mitigation measures may protect animals from impacts of human activities. For example, activities that produce sound may be undertaken in ways that will reduce not just the levels and characteristics of the sound but also their effects on aquatic animals (Popper et al. 2020). Artificial light levels at night alter the biorhythms of fish, raising concerns that fish in urban waters may have impaired sleep (Kupprate et al. 2020). The future global changes will likely influence sensory behavior in fish, and many gaps in our understanding remain (Draper and Weissburg 2019; Dominoni et al. 2020).

Profile in Fish Conservation: Andrij Z. Horodysky, PhD

Scan the QR code or visit https://doi.org/10.21061/fishandconservation to listen to this Profile in Fish Conservation.

Andrij Z. Horodysky is a Research Fish Biologist at NOAA's Northeast Fisheries Science Center. He is a broadly trained organismal fisheries ecologist with research interests centered on the ecophysiology, behavior, and conservation biology of commercially and recreationally important estuarine, coastal, and pelagic marine fish. His research investigations use comparative interdisciplinary approaches that integrate field, laboratory, and specimen-based techniques with tools ranging in scale from microscopes to satellites.

Figure 3.12: Andrij Z. Horodysky, PhD.

Findings from Horodysky's research have led to a number of direct applications to recreational billfish management. Most of the U.S. billfish effort is from recreational tournament and charter fisheries. Consequently, Horodysky studied White Marlin caught and released by recreational angling with an innovative tag technology called pop-up satellite archival tag. Instead of having to retrieve the animal carrying the tag to get the data, these devices send the data to the researcher via satellite. Once the pin dissolves, the slightly buoyant tag floats to the surface and starts transmitting the continuous record of temperature, light, and pressure (depth) to satellites. In this way, Horodysky was able to determine hook trauma and survival of White Marlin caught on circle and straight-shank hooks in the recreational fishery and released. White Marlin that survived catch and release moved into areas of varying depths and temperature, whereas White Marlin that died quickly sank to the seafloor and to constant temperatures. White Marlin caught on circle hooks were much more likely to survive release from recreational fisheries than those caught on straight-shank or "J" hooks. J hooks are more likely to cause bleeding, deep hooking, and tissue damage. Regulations requiring the use of circle hooks in natural baits for all U.S. Atlantic billfish tournaments took effect on the first of January 2008.

Horodysky is one of very few experts on the visual world of game fish. In an innovative study of visual function in a variety of fish including sharks and drums, Horodysky's lab used electroretinographic techniques to describe light sensitivities and the color wavelengths that these fish respond to. The five fish studied occupy turbid coastal and estuarine habitats throughout their range, and their visual systems are well adapted to prevailing light conditions. Environmental changes may alter the behavior of these fish.

Most recent investigations have applied physiological approaches to uncover the mechanisms through which climate change and habitat alterations may affect fish. These avenues of research have great potential to improve stock assessments, describe essential fish habitat, predict rates of postrelease mortality, develop effective bycatch reduction strategies, and forecast the population effects of increases in global temperatures and ocean acidification.

When not engaged in teaching and research, Horodysky is an accomplished recreational angler and fly tyer and designer. For more background, refer to his website.

Key Takeaways

- Understanding and appreciating the diversity of fish requires that we know some basics of sensory capabilities and the ability to learn.
- The stimulus-response model for understanding sensory systems in fish is the same model used for all vertebrate organisms.
- Fish have excellent systems for hearing as well as a lateral line for detection of far-field water movements.
- Senses of smell and taste are well developed in fish, and there are many applications of that information in formulating artificial feeds and baits for fishing.
- Fish that live in shallow, clear waters often see well in color, while other fish may see contrasts in low-light conditions.
- Electrosensory perception evolved in a number of unrelated groups of fish and permits enhanced prey detection and capture.
- Some fish can generate an electric field, which is used for communication, defense, and foraging.
- Fish senses differ among fish based on their preferred environment.
- Human activities may interfere with some sensory systems of fish, and many gaps in our understanding limit our ability to predict the influence of global changes.

This chapter was reviewed by Andrij Z. Horodysky.

URLs

Walleye: https://ladiesofangling.com/nicole-stones-walleye-fishing-setup/

Horodysky: https://home.hamptonu.edu/science/

Long Descriptions

Figure 3.1: Left: Simple drawing of fish showing location of nasal cavity in front of eye, a nerve above eye, and brain behind eye at back of head. Right: A more complex drawing of a fish shows location of taste buds in protruding appendages from chin, inner ear above and behind eye, lateral line at the center of main body, adipose fin before back fin, and taste buds on underside close to back fin. Jump back to Figure 3.1.

Figure 3.2: Drinking cup is a stimulus, arrow points to eyeball as receptor, nerves attached to a line is sensory neuron leading to a circle and line representing relay neuron, (brain to the right of line), leads to motor neuron, with nerves leading to a muscled arm lifting the drinking cup as effector, the drinking cup being brought up by the arm is the response. Jump back to Figure 3.2.

Figure 3.4: Drawing of close-up lateral line of fish, including epidermis, nerves, scales, water displacement, external opening, and lateral line canal. Movements of water in canal cause capula to move, to stimulate sensory hair cells. Jump back to Figure 3.4.

Figure 3.5: Line graph depicts the sound levels detected by fish by inner ear and lateral line when sound source is near, which are higher than sound levels detected by inner ear alone when sound source is distant. Jump back to Figure 3.5.

Figure 3.6: Two line drawings, one depicting inner ear and the other depicts close up of sacculus with labels for posterior semicircular canal, statolith of lagena, lagena, nerve;sacculus, sensory epithelium and utriculus. Jump back to Figure 3.6.

Figure 3.7: Two diagrams that show top and side views of how light waves are refracted and resulting field of vision and blind spots for fish. Blind spot is behind the fish. Jump back to Figure 3.7.

Figure 3.8: Drawing of vertical cross section of fish eye, including dermal layer of cornea, scleral layer of cornea, lens, aqueous humour, iris, autochthonous layer of cornea, retractor lentis muscle, falciform process, optic nerve, vitreous humour, retina, choroidea, sclera suspensory ligament, and epichorioidal lymph space. Jump back to Figure 3.8.

Figure 3.11: Photograph of an electric ray with two upside down triangles drawn on either side of the eyes, an arrow leads to a drawing of stacked coin shapes to represent electrocytes, and an arrow to four drawings of stacked electric organs. Jump back to Figure 3.11.

Figure References

Figure 3.1: Locations of sensory structures on the body of a fish. (A) Nares, eye, pineal, and brain locations. (B) Inner ear, lateral line, adipose fin, and taste bud locations. Kindred Grey. 2022. Adapted under fair use from "Ocean Fish Are under Threat if We Don't Curb Carbon Dioxide Emissions," by Cosima Porteus, 2018 (https://theconversation.com/ocean-fish-are-under-threat-if-we-dont-curb-carbon-dioxide-emissions-107312). Includes Blue Catfish by Louisiana Sea Grant College Program Louisiana State University, 2007 (https://flic.kr/p/2A7sP1).

Figure 3.2: Diagram of the connections in the stimulus-response model in fish, which displays a stimulus, odor receptor (nares), sensory neuron, relay neuron, motor neuron, brain, effector, and response. Kindred Grey. 2022. CC BY 4.0. Includes drinking glass by sumhi_icon, 2017 (Noun Project license, https://thenounproject.com/icon/drinking-glass-1274096/), bicep muscle by Vectors Point, 2020 (Noun Project license, https://thenounproject.com/icon/bicep-muscle-3149162/), eyeball by ME, 2017 (Noun Project license, https://thenounproject.com/icon/eyeball-931632/), brain by Mahmure Alp, 2019 (Noun Project license, https://thenounproject.com/icon/brain-2300842/).

Figure 3.3: Scales along the lateral line (see arrow) of the Roach *Rutilus rutilus*. Piet Spaans. 2006. CC BY-SA 2.5. https://commons.wikimedia.org/wiki/File:RutilusRutilusScalesLateralLine.JPG.

Figure 3.4: Schematic of the lateral line system of fish. Movements of water in the lateral line canal cause the cupula to move, thereby stimulating sensory hair cells connected to nerves. Kindred Grey. 2022. CC BY SA 3.0. Adapted from LateralLine Organ by Thomas.haslwanter, 2012 (CC BY-SA 3.0, https://commons.wikimedia.org/wiki/File:LateralLine_Organ.jpg).

Figure 3.5: Sound level in decibels plotted as a function of distance from the source. Kindred Grey. 2022. Adapted under fair use from "The Potential Overlapping Roles of the Ear and Lateral Line in Driving 'Acoustic' Responses," by Dennis M. Higgs and Craig A. Radford, 2016 (https://doi.org/10.1007/978-3-319-21059-9_12).

Figure 3.6: (A) Labyrinth of a flying fish (Exocoetus). (B) Section through the sacculus of the trout. Key structures. Nicol, J. A. Colin. c. 1960s. Public domain. https://flic.kr/p/wLFLig.

Figure 3.7: Diagram shows the refraction of light at the interface of air and water and the cone-shaped range of vision in the fish. (A) Top view. (B) Side view. Kindred Grey. 2022. Adapted under fair use from "Some Important and Interesting Aspects about Yellowfish" (https://www.fishingowl.co.za/flyfishyel2.html) and "The Science of Stalking Fish," by Alan Bulmer, 2017 (https://activeanglingnz.com/2017/02/01/the-science-of-stalking-fish/). Includes Goldfish top view by Oleksandr Panasovskyi, 2020 (Noun Project license, https://thenounproject.com/icon/goldfish-top-view-3635952/) and "Fish," by Kangrif, 2017 (Noun Project license, https://thenounproject.com/icon/fish-1186818/).

Figure 3.8: Diagrammatic vertical section through the eye of a teleost fish, after Walls (1942). Kindred Grey. 2022. CC BY-SA 4.0. Adapted from "Bony Fish Eye Multilang," by Gretarsson, 2019 (CC BY-SA 4.0, https://commons.wikimedia.org/wiki/File:Bony_fish_eye_multilang.svg).

Figure 3.9: Diagram of the taste buds in fish. Herbert Vincent and Herbert Wilbur. 1939. Public domain. https://flic.kr/p/wsuopv.

Figure 3.10: Pores with ampullae of Lorenzini in snout of Tiger Shark. Albert kok. 2009. CC BY-SA 3.0. https://commons.wikimedia.org/wiki/File:Lorenzini_pores_on_snout_of_tiger_shark.jpg.

Figure 3.11: An electric ray (Torpediniformes) showing locations of electric organs and electrocytes stacked within them. Kindred Grey. 2022. CC BY-SA 3.0. Includes Fish4345 – Flickr – NOAA Photo Library by NOAA, 2007 (public domain, https://commons.wikimedia.org/wiki/File:Fish4345_-_Flickr_-_NOAA_Photo_Library.jpg) and "Elektroplax Rochen," by Alexander Graetz, 2006 (CC BY-SA 3.0, https://commons.wikimedia.org/wiki/File:Elektroplax_Rochen.png).

Figure 3.12: Andrij Z. Horodysky, PhD. Used with permission from Andrij Horodysky. Photo by Stjani Ben (May 2015; Thingvallavatn, Iceland). CC BY 4.0.

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4. Ethical Reasoning and Conservation Planning

I have purposely presented the land ethic as a product of social evolution because nothing so important as an ethic is ever "written." . . . It evolves in the minds of a thinking community.

—Aldo Leopold, *The Land Ethic, A Sand County Almanac*

Learning Objectives

- Identify ethical dilemmas, intrinsic and extrinsic values, and value chains.
- Distinguish between normative and factual statements in an ethical argument.
- Compare and contrast common ethical theories and advantages and disadvantages.
- Recognize ethical dilemmas common to managing different types of fisheries and conserving rare and endangered species.
- Examine our personal values and how they influence our ethical norms.
- Identify the ethical principles involved in co-management and collaborative planning.
- Examine different ethical codes of conduct.
- Apply ethical reasoning steps in issues involving uses of fish.

4.1 Ethical Questions and Practical Ethics

Ethics involves deliberating about the moral principles that inform (or should inform) our actions. The human and natural worlds are too complex to expect easy-to-identify rules and absolute truths to guide our actions. In our modern world, people follow many different ethical theories to help them identify what actions are right. Ethical thinkers are needed today more than ever to help us understand our own and each other's ethics and work together to develop policies for humans to coexist with each other and fish in natural and human-altered ecosystems.

In policy making, just as in our personal lives, we are often faced with a difficult choice between two possible moral imperatives, neither of which is clearly acceptable nor preferable. For example, regulating the take from a fish population to conserve options for future generations conflicts with the moral imperative of freedom to pursue fishing without restriction. The complexity arises because following one moral imperative (freedom) would result in **transgressing** another (conservation). For example, is it ever acceptable to kill one animal in order to save another (e.g., kill sea lamprey to protect more valuable fish)? Is it acceptable to displace people from their local community to create a protected area to save an endangered species? Should we kill all nonnative trout to restore a unique population of Cutthroat Trout? How do you restrict access to fishing to maintain productivity of fish and provide livelihood opportunities for future generations? Should we compensate for salmon losses at hydroelectric projects with mass release of hatchery-reared salmon from large-scale artificial production facilities? Should you eat farmed fish raised in cages or wild-caught fish?

Depending on your needs, preferences, and interests, you may differ in how you answer these questions. Our conscience is that inner feeling or voice that guides us to a morally right behavior, yet when two actions with morally **laudable** goals conflict, we have an ethical dilemma. In these cases, explicit consideration of values at stake should be part of careful debate about human involvement and what constitutes good or bad interventions. The explicit application of ethical principles while considering the opportunities, constraints, and interests is what we refer to as *practical ethics*.

***Questions to ponder*:**

Can you characterize your prevailing use of fish? Do you consider fish to be primarily valuable to you as a source of food, sport, livelihood, cultural or spiritual connections, or are there other ways that you value fish?

4.2 Values

Philosophers provide us with many useful tools to help us think through these questions. Though they often disagree on their theories and answers to very difficult questions, there is surprising agreement on what we need to do morally in our everyday life. An essential tool we use to explore moral choices and dilemmas is to distinguish different types of values.

Intrinsic values lie at the very heart of ethics. When we speak of the value a fish has in and of itself, we are speaking of its *intrinsic* value. Many philosophers maintain that all animals have some type of intrinsic value in themselves, irrespective of their usefulness to other animals (human or otherwise), such as the beauty of a sailfish. The opposite of intrinsic value is **extrinsic** value (also called use or instrumental values), such as the value we place on a highly palatable food fish because it is useful for eating. Fish, lobsters, crabs, and oysters all have extrinsic value to various people because they eat them, enjoy delicious flavors, and are provided with valuable livelihoods and economic benefits.

It is common for fish to hold both intrinsic and instrumental values. For example, marlin have very high extrinsic value when used in sashimi and in big game fishing. They also have a high intrinsic value because of their unique size, power, and rareness among offshore fish. Table 4.1 shows many different types of values, categorized into instrumental and intrinsic values.

Value	Examples
Instrumental	
Food	Prevents hunger with lean protein, low in saturated fat
Nutrition	Lowers risk of heart disease and hypertension and source of calcium, phosphorus, niacin, vitamin B-12, and omega-3 fatty acids
Products	Fish oils, fish meal, glue, biofuels, candles, gelatin, isinglass, biopolymers, bio-piezoelectric nanogenerator, cosmetics, biomedicine, tools, apparel, jewelry, musical instruments, souvenirs (Olden et al. 2020)
Livelihood	Employing workers in capture fisheries, aquaculture, recreational tourism, and boats and fishing tackle
Recreation	Pleasure, competition, sport, pets, aquarium and pond displays
Culture	Music, cooking, and products that are related to local fish and fishing traditions
Art	Depictions of fish from ancient Egypt to the present, reflecting importance of fish
Ecological	Regulating nutrient cycles and disease vectors, biological control
Educational	Examples of vertebrate evolutionary change, specimens for laboratory dissection
Scientific	Medaka and zebra fish are research models for laboratory studies of genetics and developmental biology
Intrinsic	
Spiritual	Fish offerings to gods, symbols (Ichthys, Figure 4.2) of the faithful not driven by passions
Art	Beauty of fish
Existence	Their existence has value in and of itself

Table 4.1: Diverse values of fish. Isinglass refers to a kind of gelatin obtained from fish, especially sturgeon, and used in making jellies, glue, or clarifying ale. Bio-piezoelectric generator refers to a type of generator that converts one form of energy to another form.

A problem arises when fish are viewed only as resources that provide benefits to humans—we are holding exclusively extrinsic or instrumental values. When fish are viewed only as resources for humans, we tend to overexploit fisheries and not conserve them for future human uses. When people overexploit a fishery, this is more of a problem of short-term thinking, or immediate needs, since they are destroying the fishery they presumably want to continue to use. The conservation movement arose to help ensure that we could maintain the use value of natural resources, including fisheries, for the long run for human uses.[1] A potential problem with viewing fish as having only use value is that management of fish for the long run can still have cascading ecological impacts that cause harm to the environment (e.g., salmon farms that spread disease to wild salmon populations and alter ecosystems from excess nutrients). Conservationists who recognize that these adverse impacts to the environment harm the use value of the environment have proposed actions to reduce those impacts.

1. Much research has been done on why people act for the short term, finding a range of explanations. Hardin (1968) argued that the Tragedy of the Commons drives people to do this because the lack of a management system encourages individuals to overexploit the resource. Hardin also explained that people in poverty need to prioritize short-term survival over long-term planning, so they overexploit resources.

Some argue that we must believe that fish and ecosystems have only intrinsic value so we do everything we can to protect them. Generally, a belief that something has only intrinsic value leads to the conclusion that we are not allowed to use it at all. For fish, then, if someone believes that they have only intrinsic value, the logical conclusion is that the use of fish for fishing and food should be banned because these are uses of fish. Some accept this conclusion, but it is unlikely that many people would accept this conclusion as reasonable. Fortunately, philosophers reasoned long ago that things with intrinsic value, such as our fellow humans, also have use value to each other through the work we do for each other. The problem is when a person's intrinsic value—and our obligation to respect them—is violated by abusing how we use their work, through stealing their labor through wage theft or slavery, for example.

The Latin phrase *abusus non tollit usum* ("abuse does not cancel use") in this case means that there is no justifiable reason to condemn all uses of fish because some individuals may overexploit them. Norton (2005) argued that people logically can and do believe that fish have only use value and still accept their obligation to protect fisheries and ecosystems, while others logically can and do believe that fish have both intrinsic and use value and support the same policies.

4.3 Ethical Obligations and Actions

Our understanding of ethics and fishing needs to recognize four categories of actions. These are (1) morally forbidden, (2) permissible, (3) obligatory, and (4) supererogatory. The first three consider the actions that are easily understood as right or wrong or good or bad. **Supererogatory** actions are acts that are morally praiseworthy but not morally obligatory or beyond the call of duty. Most ethical dilemmas involve distinguishing two very different types of moral obligations: direct obligations and indirect obligations. Disagreements over beliefs in intrinsic versus extrinsic values can become quite vehement, and they can prevent us from finding agreement that we both want to protect fish. Likewise, disagreements over whether we have direct moral obligations to fish to protect them, or whether we have indirect moral obligations to protect them, too often get in the way of realizing that we both believe we have moral obligations to protect fish. Let's examine these definitions so we can figure out how to find agreements when possible.

Direct obligations are defined as those we have directly to a fish, usually because we believe that a fish has some type of intrinsic value that gives it direct moral considerability. People have widely differing views about the intrinsic value of fish, as a result of having different views about the facts concerning whether or not fish can feel pain similar to people and can make plans and suffer if they don't get to fulfill those plans.

For example, if we believe that a fish has the capacity to feel pain similarly to humans, then we would generally conclude that fish require our moral consideration regarding pain. They are in our moral circle for feeling pain. The moral consideration can be said to be a direct moral obligation to avoid causing it pain similar to human pain. Likewise, if we think that fish create long-term plans like humans and that fish feel some kind of mental loss and suffering from not executing those plans, then we can logically conclude that we have a direct moral obligation to fish to allow them to fulfill their plans. In this situation, it is logical that fish can both feel pain similarly to humans and suffer from not fulfilling their plans, so we have stronger direct moral obligations to fish. These obligations depend on the capacity of fish to feel pain similarly to humans or to have aims like humans and feel mental loss like humans. This relationship of facts and intrinsic value and moral obligations is important to understand, since people have very different beliefs about the facts, and science is making new discoveries. What if we disagree that fish can feel pain similarly enough to humans to require our moral consideration? If they can't feel pain like that, but they are under stress due to an aquatic habitat that is so polluted by heat, nutrients, or lack of food that they die, do we have some type of obligation to them? This is where the concept of an indirect moral obligation is helpful.

Indirect moral obligations are those that we must fish because we have direct obligations to something else (usually humans) to protect the fish. For example, most people believe we have a moral obligation to sustainably protect fisheries so other humans have access to fisheries for economic and food benefits they provide. It is a direct obligation to other people to protect the fisheries. It is an indirect obligation to the fishery to protect it so we can fulfill our direct obligations to other people. This is a rather complex way to talk about our obligations, so why do it? It makes it easier to identify if we have agreement on whether or not we have any type of obligation to fish.

For example, if we believe we have a moral obligation (be it indirect or direct) to protect the many individual fish that comprise a fishery from dying from adverse environmental conditions, then we can agree that we need to eliminate those environmental conditions by passing policies to do so. Policies to reduce heat pollution or nonpoint source pollution can be supported by those who have different beliefs about intrinsic versus use values and direct versus indirect moral obligations. Similarly, we may disagree over whether or not any catching of fish that causes pain similarly to humans could be allowed, but progress would be made to reduce waste and bycatch. The effort, and habit, of finding commonalities in support for protection of fish is critical to passing policies that can be passed now, while laying groundwork for discussions on more sophisticated policies. As scientific research discovers facts about fish and other animals' capacities to feel pain and make plans similarly to humans, we can identify how we can (or ought not to) fish in ways to meet our direct or indirect obligations to reduce suffering of fish.

An important concept in ethics concerns our moral obligations to act. We all likely have wondered if we are really obligated to perform an action that would help another person but would cost us greatly in terms of money, physical or mental or social harm, or our life. In ethics, an act is supererogatory if it is good but not morally required to be done. For example, let's imagine that you conclude that the destruction of a fishery through overfishing is morally wrong and that you are obligated to help protect the fishery. Different ethical systems might conclude that you have slightly different moral obligations, but none would say that you needed to starve yourself to death rather that eat fish from such a fishery if that were your only way to survive. Neither would an ethical system require you to put your life in danger to stop a commercial fishing boat from fishing. Rather, they might require you to make sure that you purchase only from sustainable fisheries or to educate others and make efforts to change policies to stop overexploitation of fisheries. These latter obligations would meet the obligation to act without being supererogatory.

4.4 Burden of Proof in Value Systems

Now we turn to consideration of how beliefs in intrinsic or use value affect discussions about policies. An important difference between intrinsic and instrumental values that is relevant to fish conservation relates to who must demonstrate harm in disputes (Figure 4.1). For example, the burden of proof lies with the conservationists if values are only instrumental. On the other hand, if values are intrinsic as well as instrumental, the burden of proof will be on the fishers or others who are harming fish or their environment (Callicott 1995).

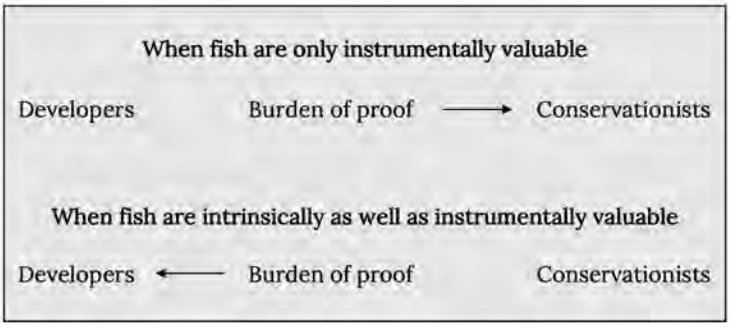


Figure 4.1: Burden of proof as it relates to instrumental and intrinsic value systems. [Long description](#).

The diversity of values associated with fish and fishing complicates conservation. Two main approaches to conservation include (1) the wise use of nature and (2) the preservation of nature. These two approaches both reject the unthinking marginalization or destruction of nature. But when it comes to the actual management of fish, the two approaches differ. The wise-use approach aims to accommodate humanity's continuous use of wild nature as a resource for food, oils, and other raw materials, as well as for recreation. The idea of wise use appeals to the best interests of humans, or to the interests of humans over time, including future people (this approach is often called "sustainable use"). The goal of management is to enhance and maintain nature's yield as a valuable resource for human beings.

For the preservationist, on the other hand, the goal is to protect pristine nature, not to use it, carefully or otherwise. If human intervention has damaged wild nature (e.g., by pollution), then it is important to restore nature to something like its former state. From a preservationist perspective, wild places should be allowed to develop on their own with as little interference from humans as possible. The "otherness" or "naturalness" of the non-human world is what is most valued here. The only use allowed by humans in protected areas is for recreation, and this is only if recreation leaves no trace behind. Values beside resource values and the value of "untouched" nature have become increasingly important. These include the value of untouched nature, whole ecological systems, the value of species, and, in particular, the importance of animal welfare.

Preservationists tend to recognize that humans need to use natural resources to survive and thrive. So how do they reconcile the fact that humans need to use natural resources to survive while they are against using natural resources? Generally, it is by supporting the idea that humans should only use what is necessary for our welfare and to use natural resources in ways that protect nature.

4.5 Ethical Norms

When communicating about fishing and conservation issues, we should distinguish between normative and descriptive language. Descriptive language in ethics refers to observable facts about the world. Science can explain facts and descriptive patterns. For example, we know much about the behavior and competitive displacement of trout species and the effects of fishing on survival of fish. When we describe, not evaluate, the ethical beliefs of the public through interviews and surveys, our findings are descriptive ethics.

Normative language is used in ethics to make claims about how things should be, which actions are right or wrong, and so on. Ethical norms are patterns of behavior generally acceptable for a society, company, or organization. Norms reflect the way the group believes the world should be. The statement "Do not harvest juvenile fish" is a normative claim of fish conservationists. Norms may be formalized in policies, regulations, or standards of conduct. For example, when recreational anglers treat the fish they catch in a humane manner or avoid disturbing another angler's fishing spot, they are following fishing norms.

However, deciding what is right or wrong involves consideration of values. David Hume (1711–1776) articulated the "is-ought" problems or the fact-value gap. His philosophical law maintains that one cannot make statements about what ought to be based on descriptive statements about what is. The NOFI (No-Ought-From-Is) idea that one cannot deduce an "ought" from an "is" means that we can make no logically valid arguments from the nonmoral (descriptive) to the moral (normative) without clearly introducing a normative argument. A much-needed skill in working with others is the ability to identify the facts and the values being used in discussions about conservation policy. When faced with a normative question, after the values that are sought are identified, then it is usually important to identify the facts of the situation.

***Questions to ponder*:**

Think about a favorite fish or a fish that you know well. Describe examples of the different ways in which the fish has value to you or others. Review Table 4.1 for types of values. Can you write a normative statement and a descriptive statement about this fish? Can you write a descriptive statement about the value of fish to someone other than yourself?

4.6 Where Do Ethics Come From?

Metaethics is a branch of philosophy that explores the foundations and existence of moral values. There are many different philosophical arguments for morality and ethics, some based on religious beliefs and some not. In this section, we explore various religious traditions and their environmental ethics toward fish. Those raised in the same religious tradition tend to hold common beliefs and follow common norms. In some religions, there are specific beliefs about values of fish and wildlife, and in other religions values are ambiguous. From the first book of Genesis, one gets a clear view of the prevailing Christian view of our relationship with fish and fowl until about the latter half of the 20th century (i.e., 1960s to 1990s).

> *And God said, Let us make man in our image, after our likeness: and let them have dominion*[2] *over the fish of the sea, and over the fowl of the air, and over the cattle, and over all the earth, and over every creeping thing that creepeth upon the earth.*
>
> *So God created man in his own image, in the image of God created he him; male and female created he them.*
>
> *And God blessed them, and God said unto them, Be fruitful, and multiply, and replenish the earth, and subdue it: and have dominion over the fish of the sea, and over the fowl of the air, and over every living thing that moveth upon the earth.*
>
> Genesis 1:26–28

During the latter half of the 20th century, coinciding with the rise of the environmental movement, the "greening" of Christianity led to a new mainstream view that did not focus on human domination of nature but rather on human stewardship of nature. It was based on the second book of Genesis.

> *Yahweh God took the man and settled him in the garden of Eden to cultivate and take care of it.*
>
> Genesis 2:15

In the Buddhist view, however, "One should not kill a living being, nor cause it to be killed, nor should one incite another to kill" (Nalaka Sutta, Sutta Nipāta III:11, 26–27). The fact that Buddhist teachings considered animals to have moral significance is evident in his condemnation of occupations that involve slaughtering animals (Saṃyutta Nikāya 19), instruction for monks to avoid wearing animal skins, and prohibition of behavior that intentionally causes harm to animals. A Buddhist-based tradition maintains that it is compassionate not to kill or harm animals. One should be compassionate. So, one should not kill or harm animals (Chengzhong 2014).

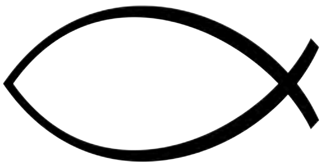
2. Correct translation from Hebrew means "to take responsibility for meaning that humans were created by God . . . to exercise responsibility for the well-being of the garden Earth".

Buddhism believes in reincarnation and teaches us that all living beings around you can be or may have been your mother in a previous or next incarnation or life. The very animal you shoot may have been your friend in a previous life. Whether you believe in reincarnation or not, it is true that every being's fate can once become your fate as well. There are no or very few hunters or fishers in Buddhist traditions. The only exception is killing in self-defense or in order to end its physical suffering when an animal is severely wounded.

Any well-functioning social group depends on ethical norms for behavior. These norms often reflect society and the collective beliefs and values of its citizens, and they may or may not reflect religion (Crabtree 2014; Guglielmo 2015). Major religions influence our perspectives about biodiversity conservation and hunting and fishing. Christianity, Islam, Hinduism, Daoism (also known as Taoism), Buddhism, Jainism, Judaism, and Shinto are some religions practiced globally. Zoroastrianism, one of the world's oldest, continuously practiced religions, shaped Judaism, Christianity, and Islam with concepts of a single god, heaven, hell, and a day of judgment.

One of the oldest conservation tools for biodiversity conservation of ancient people practiced was to declare certain natural areas as sacred or taboo. Today, conservationists engage religious and other spiritually motivated communities for their support of and advocacy for marine protected areas (Schaefer 2017; Murray and Agyare 2018). Beliefs about what wild foods are permissible were derived by ancient religions. For example, Jews did not eat catfish because it was considered "unclean," as it did not have fins and scales (Leviticus 11:19). According to the Shafi'i, Maliki, and Hanbali branches of Islam (Quran 2:173), "all fish and shellfish would be halal" (permissible to eat). Off the coast of Tanzania, fishers used dynamite, a very damaging technique, to harvest fish. Local Muslim **sheikhs** used passages from the Koran that promote pro-environmental behavior to convince the fishers that dynamite fishing was against Muslim teaching (Bauman et al. 2017).

Religions provide a long history of symbols associated with use and values of fish and fishing (Figure 4.2; Lynch 2014). Ichthys is a Christian symbol of a fish and signifies the person who uses it is a Christian. In Islam, according to the Quran, the fish is a symbol of eternal life and also of knowledge. In Hinduism, in the sect of Vaishnavism's Supreme God (Vishnu) first appeared as Matsya, a fish that helped the first man survive the great flood.



Christianity

Ichthys is an important identification symbol in Christianity.

Judaism

In Judaism, fish is a symbol of fertility and luck, and gefilte fish is a traditional dish.

Hinduism

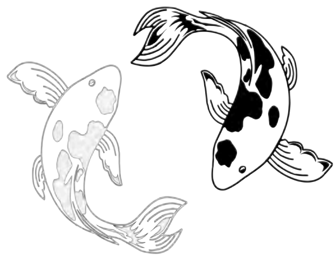
In Hinduism, Matsya, a fish is the first supreme god.

Islam

In Islam, fish is a symbol of eternal life and of knowledge. The mythical Al-Khidr is depicted here standing on the fish and using it to travel.

Buddhism

In Buddhism, the golden fish are one of eight auspicious symbols.



Daoism

In Daoism, the yin and yang is often illustrated with two koi fish.

Figure 4.2: Religious symbols associated with fish and fishing. [Long description](#).

Questions to ponder:

What religious or cultural tradition(s) most influenced you during your childhood? How does your upbringing and early learning through your early social interactions influence your perspectives on fishing or conservation?

4.7 Ethical Theories: Schools of Thought

The ethical systems and conclusions that societies believe and act upon change over time for many reasons. The disadvantages of ethical systems lead philosophers to develop new ethical theories. Changing needs and scientific understandings lead to new conclusions about how to achieve the moral goals of each system. Because there are few clear ethical judgments, each of us needs to take ownership of our ethical beliefs—sometimes referred to as *first-person ethics* (Elliott 2006).

In Western philosophy, three traditions dominate ethical reasoning: virtue theory, **deontological** or duty-based theories, and **teleological** or **consequentialism**. Here I summarize these, in addition to ethical pragmatism and ethics of caring. The three schools are virtue ethics, consequentialist ethics, and deontological or duty-based ethics. Virtue ethics can be traced to Aristotle (384–322 BCE) and involves aspiring to a set of virtues, avoiding vices, and finding the right balance among values.

Duty-based ethics (deontological) asks "What are my duties and obligations regarding the treatment of others?" Kant's (1787, 1998) categorical imperative held that the rightness or wrongness of actions does not depend on their consequences but on whether they fulfill our duty. Duties are obligatory. Common duties include "respect for humanity," because persons have intrinsic value and should not be treated as things merely to be used for the benefit of others.

Consequentialist ethics can be traced to David Hume, Jeremy Bentham (1789), and John Stuart Mill (1863). There are two types of consequentialist schools of thought: ethical **egoism**, which treats self-interest as the foundation, and utilitarianism. Utilitarianism aims to bring about the greatest good for the greatest number of people or the greatest balance of good over evil. Actions are right if they tend to promote happiness (more formally, well-being), wrong if they tend to produce the reverse of happiness. Unfortunately, much critique of Mill did not recognize that his utilitarianism also profoundly advocated that individual liberty and strong government to promote education and culture were the foundation to promoting well-being, and that he was a strong abolitionist and suffragist (Mill 1859, 1975; Eggleston and Miller. 2014).

> The only purpose for which power can be rightfully exercised over any member of a civilized community, against his will, is to prevent harm to others. His own good, either physical or moral, is not a sufficient warrant. (Mill 1859, 10)
>
> The needs of the many outweigh the needs of the few. (Spock, *Star Trek: The Wrath of Khan*)

Moral relativism is the view that judgments are true or false only relative to some standpoint (for instance, that of a culture or a historical period) and that no standpoint is uniquely privileged over all others. Although the public may understand the concept, moral relativism is discredited among philosophers.

Pragmatic ethics was developed by William James and John Dewey at the turn of the 20th century to synthesize the best of prior ethical theories and to approach ethics more scientifically. From virtue theory, it recognized that character was very important; from duty-based theory it drew the importance of gradually changing society by keeping the best of the old and improving with new understandings. From utilitarianism, it focuses on the actual consequences of our actions. It emphasized the use of emotion, evidence, and reason when individuals were confronted with an actual situation that required a moral choice. Pragmatism focused on guiding people to consider the real choices that were possible to them and the impacts those choices would have on other people (Dewey 1932). The moral rule can be summed up as making sure you take the time to gather evidence, reflect, and take actions that improve the good in a specific situation, including consideration of the long-term impacts of that action.

Each school of ethics has advantages and disadvantages. We must consider these when choosing the school of ethics we will use to help us make ethical decisions (Table 4.2).

***Questions to ponder*:**

Which ethical system (Table 4.2) do you prefer? Why?

Type of theory	Advantages	Disadvantages
Consequence-based (Utilitarian)	Stresses promotion of happiness and utility	Permits "tyranny of the majority," Mill (1859, 1975; p. 6) which ignores concerns of justice for the minority population
Duty-based (Deontology)	Stresses the role of duty and respect for persons	Underestimates the importance of happiness and social utility between different people
Feminist ethics of caring	Stresses caring in personal relationships, for animals and the environment	Unequal moral consideration of others (friends and family cared for more than others)
Pragmatism	Simple moral rule—improve individual and social well-being, use science to achieve	Requires individuals to take responsibility for moral reasoning
Contract-based (rights)	Provides a motivation for morality	Emphasized individualism, offers only a minimal morality
Character-based (virtue)	Stresses moral development and moral education	Depends on homogeneous community standards for morality
Ethics of caring	Highlights the differences between men's and women's situations in life	Differs from most Western traditions and many may not relate to orientation of caring

Table 4.2: Advantages and disadvantages of six types of ethical theories.

4.8 Comparing Ethical Theories and Their Use

The ethical theories developed and modified over time have been used and abused in many ways. As noted above, their abuse does not prohibit their proper use. Like the physical and biological sciences, doing ethics well requires study and practice. In this section I briefly address which ethical theories are in common use in the last one hundred years and how they have been used or abused.

Figure 4.3 provides another way to understand the relationship of ethical theories. It makes no judgment as to which is better or worse.

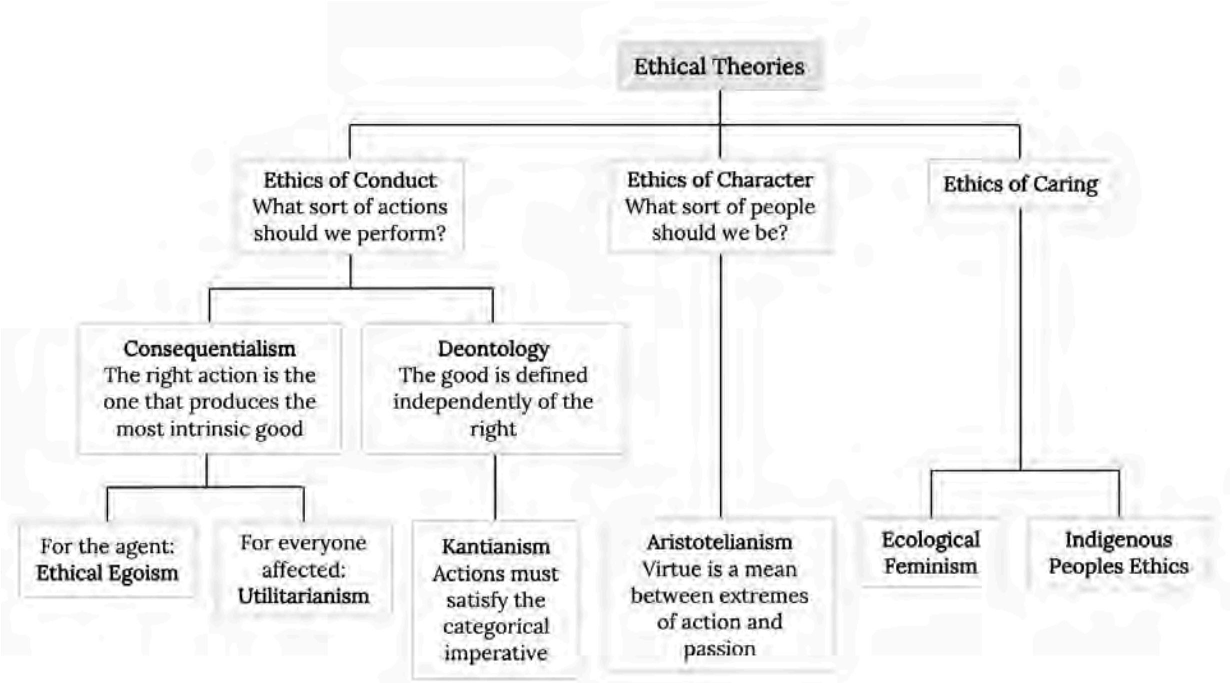


Figure 4.3: Hierarchical relationships among traditional Western ethical theories and ethics of caring. Long description.

On the left side of the figure is ethical egoism, a form of consequentialism. Ethical egoism is widely regarded as a very weak ethical theory, antithetical to ethics, since it does not guide action to consider others. In short, any ethical theory that argues that it is good to be inconsiderate of others doesn't seem to be very ethical.

Utilitarianism is applied frequently in fish conservation and dominates the public policy arena. Utilitarianism is the basis of contemporary economic theories, which commonly hold or assume that individuals are best served when they are able to pursue and satisfy their preferences within a free market. Utilitarianism is often justified because (1) happiness does matter, (2) flexibility is important, (3) it appeals to our commonsense intuitions, and (4) it ensures equal consideration of all interests. Utilitarianism, like most ethical theories, is not a practical approach when individuals differ in how they measure utility or happiness, in identifying duties in a specific situation, or on what is virtuous (pluralism). As an example of how consequentialism is often misinterpreted, John Rawls, one of the most famous and influential political philosophers in the 20th century, did not recognize utilitarianism's founding principle of the need to respect individual liberties. Rawls (1971) and Cochrane (2000) criticized utilitarianism for not considering how in many fisheries, justice, fairness, and rights may be more important than consequences.

Utilitarians may recognize human rights of those who fish (Ratner et al. 2014) and private ownership of fishing rights. Conservationist Roderick Haig-Brown (1939, 135) recognized that "When angling rights are privately owned, the owners spend a great deal of money on the preservation of value and restrict themselves and their friends to catches and practices that will ensure preservation." In practice, in regulating harvest of fish, it is difficult to predict future responses to reduced harvest, and harvesters often adopt the "if-I-don't-get-'em-somebody-else-will" philosophy.

Duty-, rights-, and responsibility-based ethics tend to ignore crucial ethical questions, such as: "What is the best life for me?" "How do I go about living?" or "What actions will make a better society?" These questions are the focus of ethics of character, or virtue ethics. Proponents of virtue ethics focus on actions and character (Taylor 2002; Sandler and Cafaro 2005; Westra 2005). A virtue ethics approach can and often does inform best practices for welfare in aquariums and fish farms and in codes of angler ethics. It does so by guiding us to ask what a virtuous person would do in various situations. In ordinary situations, like whether or not we should treat animals and fish well, it and most other ethical theories agree that yes, we should treat them well.

In contrast to the Western philosophies of moral reasoning, ethics of indigenous peoples and ecological feminism focus on ethics of caring. Many indigenous peoples follow an ethic of care for all kinds of others, as well as the complex value of ecological interdependencies (Figure 4.3; Gilligan 1982; Whyte 2015; Whyte and Cuomo 2016). Ecological feminism often focuses on the ethics of care and links their analysis to beliefs about gender roles in patriarchy (Gilligan 1988). Gilligan argues that many commercial and subsistence fisheries are based on male-dominated decision making, and the role and contributions of females in the fisheries is undervalued (Thompson 1985; Frangoudes and Gerrard 2018). Care ethics maintains that ethical living depends on mutually beneficial caring relationships that do not exploit the caregivers and value animals and dependencies (Gaard and Gruen 1993).

4.9 Ethics and the Expanding Moral Circle

Figure 4.4: A moral circle encompasses those we consider worthy of moral consideration. [*Long description*](#).

Over the course of human history, more and more beings in the world have been deemed to be worthy of serious moral consideration (Singer 2011a). The boundary drawn around those entities in the world deemed worthy of moral consideration, referred to as the *moral circle*, has expanded (Figure 4.4). Many people think that sentience, the ability to feel sensations like pain and pleasure, determines membership in our moral circle. If that's the case, we need to ask what degree of sentience is required to make the cut?

Your personal beliefs about membership in the moral circle are likely a product of your culture. Use your reasoning to think beyond your inherited biases. For example, those raised in the Jain religion have always included all animals and all of nature in the circle. Extending the moral circle led to concerns for animal welfare and a code of conduct in use of animals to reduce suffering of people and animals. Singer's notion of the expanding circle proposes that our moral sense, though shaped by evolutionary forces to overvalue self, kin, and clan, can propel us on a path of moral progress, as ethical reasoning will force us to include larger circles of sentient beings in our ethical deliberations.

Question to ponder:

Consider who is part of your moral circle of consideration. Yourself, your family, and your siblings are at the center of the circle. Draw multiple circles around the center and describe considerations you use to consider whether humanity, members of your group, your neighborhood, the nation, mammals, birds, fish, insects, plants, ecosystems, and future human generations should be included. What ethical theories do you find to be most applicable in defining your moral circle of consideration?

4.10 Model of Ethical Reasoning

Moral education involves improving the ability to identify ethical issues and then make a justified choice of how to act. There are many ways to organize our ethical reasoning. Sternberg (2012) identified eight sequential steps that are involved in ethical reasoning:

1. Recognize that there is an event to which to react,
2. define the event as having an ethical dimension,
3. decide that the ethical dimension is of sufficient significance to merit an ethics-guided response,
4. take responsibility for generating an ethical solution to the problem,
5. figure out what abstract ethical rule(s) might apply to the problem,
6. decide how these abstract ethical rules apply to the problem so as to suggest a concrete solution,
7. prepare for possible repercussions of having acted in what one considers an ethical manner, and
8. act.

This model will be adopted in discussion of case studies described in subsequent chapters.

Your moral argument uses both normative and descriptive language and is organized as (1) premises, (2) general moral principle, and (3) conclusion. The premises on which you base your argument will be descriptive, factual statements, whereas the other parts of the moral argument are normative statements. Ethical reasoning assists us in participating in debates and policy deliberations as an individual or as members of a group. Adopting the ethical reasoning model in a formal way helps us prevent ethical drift—that is, the gradual erosion of standards when there is competition for time and resources or an organizational culture that tolerates ethical lapses.

Questions to ponder:

Consider the many decisions related to fish and wildlife that are made by the Board of Game and Inland Fisheries in Virginia (see Virginia Code, Title 29.1 – Game, Inland Fisheries and Boating). Can you imagine any regulations regarding one of these articles having a significant ethical dimension? If so, what?

4.11 Ethical Perspectives Relevant to Fish and Fishing

Six perspectives consider common notions underlying ethical approaches to wild animals:

1. **A contractarian perspective.** In this view, wild animals fall outside the moral circle and are viewed as a resource for human use.
2. **A utilitarian perspective.** This view is a form of consequentialism taking into account everyone affected by decisions. Fish and wildlife can suffer, so they are inside the moral circle. Consequently, their welfare is taken into account in management decisions.
3. **An animal rights perspective.** This view maintains that certain animals share similarities with humans that underpin moral rights, such as the ability to suffer, or for some, the fact that they are alive. Consequently, there are some things we may never do to them. We should not kill, confine, or otherwise interfere in the lives of wild animals unless necessary. It is neither our right nor our duty to cull or in other ways to manage wild animals. These are very complex theories with many variations.
4. **Respect for nature perspectives.** This is an overlapping group of views on protecting values of naturalness itself, including whole species, ecosystems, and biodiversity. It was popularized by writings of Aldo Leopold (1949). The moral importance of individual animals depends on whether they promote or threaten environmental values. Keystone species are to be protected, while invasive species should be removed or killed. A popular quote from this perspective is, "Examine each question in terms of what is ethically and esthetically right, as well as what is economically expedient. A thing is right when it tends to preserve the integrity, stability, and beauty of the biotic community. It is wrong when it tends otherwise" (Leopold 1949).
5. **A contextual (or relational) view.** This view emphasizes the nature of the human-animal relationships. For example, there are different relations, and therefore different moral obligations, to wild animals than there are to domestic animals (Palmer 2010).
6. **Hybrid or pluralist view.** This view argues for creating a pragmatic and pluralistic ethical framework from which scientists and conservation managers can draw when complex moral questions arise. This pluralistic ethical framework incorporates different approaches to environmental and animal ethics (Minteer and Collins 2005; Norton 2005). In a pluralistic society, we can't expect to persuade others on fundamental questions of the good and the right. We can, however, attempt to persuade them to adopt our views on policy by offering arguments that appeal to their fundamental values, even if we don't share them.

The hybrid view may be considered *practical ethics*, which is ethics developed in the religious, legal, and medical arenas and focuses on the full range of moral values that inform our lives, such as what is right, good, just, and caring. Practical ethics looks to these and other moral concepts, as well as the empirical reality of individual cases, for guidance in making ethical decisions. By honoring the insights of many moral ideas and not a single ethical theory, practical ethics has a deep reservoir of concepts available to **triangulate** on the best understanding of a moral problem. These cases were described in three editions of Peter Singer's *Practical Ethics* (2011b).

***Questions to ponder*:**

Among the six ethical perspectives described above, which are you most likely to agree with and which ones do you disagree with? Why?

Moral pluralism is the view that acknowledges the existence of multiple values (Marrietta 1993). There are different ways to think about and judge what is moral, especially including other voices that are often marginalized, (e.g., indigenous peoples and women [Warren 1982]). Callicott (1990) argues that personal worldviews must be challenged and, if needed, abandoned. In this way, we make moral progress and are not guilty of moral relativism. Recognition of moral pluralism is one of the founding principles in the United States, particularly Virginia, where the individual's right to have their own religious and moral systems is part of the Constitution. Respecting other's views provides the start to respectful discussion between people about what actions and policies we agree are right. Then we can either try to make those agreements in moral norms, or pass programs or laws to help enact them.

Clearly, some cultural practices may be wrong. The ancient ritual in which Buddhists free captive animals to generate positive karma through an act of kindness (i.e., compassionate release of prayer fish) has been changed over time to become a commercial enterprise in which people buy animals specifically to release them. For example, the practice of compassionate release of captive animals may not serve the needs of the animals released nor the receiving ecosystem (Actman 2017). This well-intended practice may, in fact, be a threat to many species (Everard et al. 2019).

Ethical reasoning is helpful as we identify our values, others' values, and what ethical system is preferred. Many ethical systems have very similar recommendations for what to do in common situations. The public and professionals in fish and wildlife management and other professions can increase the good when they help themselves and others find agreement on what actions to take. Recognizing that the ethical theories that other people hold have useful views can help unravel moral questions and bring people into agreement by recognizing their contributions to solving ethical questions.

Relying on a utilitarian principle for managing a fish or wildlife population to maximize human welfare is unworkable without also considering the principle of justice or other theories of ethics that require us to ensure rights of others. For yourself, I suggest that what you think, say, and do are in sync so that your values and actions are consistent. In addition, we should seek ways to respect the views of others and improve our ability to find agreement on how to protect people and fisheries.

4.12 Codes of Ethics

Ethical codes are specific codes of ethics adopted by or on behalf of professions (e.g., psychologists, doctors, wildlife professionals) or other practitioners to guide the behavior of members, interactions among members, and interactions between members and the public. In the context of a code adopted by a profession or by a governmental or **quasi-governmental organization** to regulate that profession, an ethical code may be styled as a code of professional responsibility, which informs about difficult issues of what behavior is "ethical."

There are many forms of fishing practiced worldwide and, consequently, many ethical codes. Similarly, ethical codes exist for recreational anglers (http://www.ethicalangler.com/the-code-of-ethical-angling.html), fly fishers (https://flyfishersinternational.org/Resources/Educational-Resources/Code-of-Angling-Ethics), and commercial fisheries (FAO 2010–2020). The Association of Zoos and Aquariums (AZA) adopted a Code of Professional Ethics that includes mandatory standards and an Ethics Board that reviews complaints (AZA 2017). Aquarium and pond keepers in Australia abide by a code of conduct.

Questions to ponder:

What ethical codes have you learned or are expected to follow in your professional discipline or avocations? What difficulties do you anticipate regarding following these codes? What ethical theories provide the basis for the code of conduct for your discipline? You may wish to review ethical theories in Table 4.2 or online.

NOAA's Fisheries Service (NMFS) adopted the following "Code of Angling Ethics" in cooperation with marine recreational fishing groups to implement the public education strategy (NOAA 1999).

The Ethical Angler:

- Promotes, through education and practice, ethical behavior in the use of aquatic resources.
- Values and respects the aquatic environment and all living things in it.
- Avoids spilling, and never dumps, any pollutants, such as gasoline and oil, into the aquatic environment.
- Disposes of all trash, including worn-out lines, leaders, and hooks, in appropriate containers, and helps to keep fishing sites litter-free.
- Takes all precautionary measures necessary to prevent the spread of exotic plants and animals, including live baitfish, into non-native habitats.
- Learns and obeys angling and boating regulations, and treats other anglers, boaters, and property owners with courtesy and respect.
- Respects property rights, and never trespasses on private lands or waters.
- Keeps no more fish than needed for consumption, and never wastefully discards fish that are retained.
- Practices conservation by carefully handling and releasing alive all fish that are unwanted or prohibited by regulation, as well as other animals that may become hooked or entangled accidentally.
- Uses tackle and techniques which minimize harm to fish when engaging in "catch-and-release" angling.

4.13 Management of Invasive Fishes

Often because of human modifications of waterways or intentional and accidental releases, many fish species develop large populations and cause excessive damage to ecosystems of native fish communities. These species are referred to by many terms, including *invasive*, *introduced*, *translocated*, *exotic*, *alien*, or *pest*. Debates persist on the need and approach to manage invasive fish. Invasive species cause harm as defined by human interests and/or ecosystems, and these harms must overwhelm rights of individual animals for control measures to be initiated. In two of three examples, the harm was high enough to result in large-scale destruction programs. Many species of carp of China were introduced to North America and expanded in population size and range, competing with native fish (Reeves 2019). Harvesting to reduce populations and electric and physical barriers to limit migration are two strategies employed to reduce populations of carp. When the Sea Lamprey entered the upper Great Lakes, the added mortality caused native lake trout populations to drop 98% in a few decades (Brant 2019). Large-scale poisoning of streams occupied by juveniles was initiated and continues annually to depress populations of the Sea Lamprey in order for native fish to recover. Recent research on pheromones revealed an approach to attract spawning Sea Lampreys so they could be trapped and removed, rather than using poisons. The Northern Snakehead, which was established in many waterways by intentional releases followed by population expansion, has been both reviled and targeted by recreational anglers. Researchers have failed to document significant harm that the Northern Snakehead causes to native fishes or economies. Rather, local recreational anglers found it to be another sportfishing target, despite regulations in Virginia and Maryland calling for anglers to kill any Northern Snakehead caught (Orth 2019). In October 2019, one Snakehead was found in Georgia. “Kill it immediately” was the initial advice to anglers, even those who practice catch and release and never kill their catch.

The Northern Snakehead case raised the ethical question of whether a state agency can require an angler to kill a fish. In the present day, a reconceptualization of the relationships between humans, translocated species, and ecosystems is warranted. In a reversal of past practice, the National Park Service has a program of killing for conservation in Yellowstone National Park. In this case, Lake Trout were introduced to Yellowstone Lake and threaten populations of native fish, including Yellowstone Cutthroat Trout (Koel 2017). We will see more cases in which humans must manage novel combinations of fish in ecosystems.

4.14 Ethical Fisheries

Fish are the last wild animals harvested commercially, and the importance of fish for providing essential protein for people around the world is substantial. Fisheries employ 260 million people, and fish are the primary protein source for ~ 40% of the world’s population (FAO 2018). Fisheries are managed by actions and interactions of government bodies, the market, and civil society (Lam and Pauly 2010). Government policies and the market seldom consider ethical issues unless they come up within public involvement processes in civil society and nongovernmental organizations. Consequently, many large fisheries are managed with the belief in the right of individuals to maximize their profits through their own initiative with minimum government interference. However, in an open fishery there are never enough fish for everyone to have all they can catch, and if fishers act independently in their own self-interest, the fishery will collapse.

The Code of Conduct for Responsible Fisheries sets out principles and international standards of behavior for responsible practices with a view to ensuring the effective conservation, management, and development of living aquatic resources, with due respect for the ecosystem and biodiversity (FAO 2010–2020, Pitcher et. al. 2009). The code recognizes the nutritional, economic, social, environmental, and cultural importance of fisheries and the interests of all stakeholders of the fishing and aquaculture industries. It considers the biological characteristics of the resources and their environment and the interests of consumers and other users.

For example, the management of many fisheries around the world is complicated by a complex global supply chain and, in some nations, weak governance. Government subsidies, bycatch, and employment vary greatly between commercial or large-scale fisheries and subsistence or small-scale management (Table 4.3; Lam 2016). Fisheries are sometimes managed by providing harvesters with individual transferable quotas or shares of the allotted catch. While this strategy provides for more efficient fisheries, the quotas are often unfairly distributed based on historical catches, which disadvantages small, subsistence coastal fishers. Yet small-scale, artisanal and subsistence fisheries generate about one-third to one-half of the global catch that is used for direct human consumption, and they employ more than 99% of the world's 51 million fishers (Pauly and Zeller 2016; Jones et al. 2018).

Fisheries Benefits	Large-scale	Small-scale
Annual landings for human consumption	~ 60 million tonnes	~ 27 million tonnes
Annual catch discarded at sea	9 million tonnes	Almost none
Annual catch for industrial reduction to fishmeal & fish oil	26 million tonnes	Almost none
Fuel used per tonne of fish for human consumption	10–20 million tonnes	2–5 million tonnes
Number of fishers employed	0.5 million	~ 12 million
Government subsidies	25–30 billion US $	5–7 billion US $

Table 4.3: Comparison of benefits for large- and small-scale fisheries. From Pauly and Zeller (2016).

Canned tuna may be a cheap, nutritious, and healthy protein, but the activities along the global supply chain are often hidden from consumers. Some harvest methods are unsustainable and include government subsidies, high levels of illegal, unreported, and unregulated fishing, and in some cases forced labor aboard fishing vessels (Couper et al. 2015; Urbina 2019). These hidden costs of canned tuna or other seafood products are not considered unless the product contains appropriate labeling (Fishwise 2015). Seafood certification, or ecolabeling, provided by third parties, such as the Marine Stewardship Council and Seafood Watch, attempt to certify ethical fisheries based on a variety of goals, including fair trade, worker welfare, habitat, and bycatch (Kittinger et al. 2017; Lam 2019).

Figure 4.5: Goals used for three types of certifications for fisheries. [Long description](#).

Intensive and participatory management of fisheries dominates in many developed nations, which have the resources to invest in scientific data collection and stock assessment. Many previously overfished fish stocks subjected to low fishing pressure are now rebuilding in regions where fisheries are intensively managed (Hilborn et al. 2020). However, fisheries in developing countries are under intense pressure from increasing human populations, overharvest, and conflicts over access. Typically, there are too many small-scale fisheries, weak governments, and poor fisheries management.

Comanagement involves a shared management responsibility among government, fishing communities, and other stakeholders to develop a shared knowledge base and democratic decision making (Berkes et al. 2000; Viswanathan et al. 2003; Defeo and Castilla 2005; Gelcich et al. 2005; Armitage et al. 2009; Lam and Pauly 2010; Villanueva-Poot et al. 2017). When fishers facing common dilemmas form cooperative communication ties with direct resource competitors, they may achieve positive gains (Barnes et al. 2019). Comanagement is still in its infancy in the United States, although the Magnuson-Steven Act includes few barriers to it in developing fishery management plans (Emmett Environmental Law & Policy Clinic and Environmental Defense Fund 2016.). Organized opposition from agencies and special interests and difficulties in consensus building must be overcome to implement comanagement (Ayers et al. 2017). Comanagement is a gradual process that relies on voluntary involvement of diverse stakeholders, but the sharing of responsibilities can make fisheries more sustainable if benefits are greater than the costs to change (Arlinghaus et al. 2019; Hoefnagel et al. 2006).

Collaborative governance is becoming more politically feasible as emerging social norms consider a broader range of values (Lam and Pauly 2010). Creating a social network of fishers with authority to comanage fisheries may lead to solutions to many problems, including the following:

- Tyranny of scale, which means that too many small fisheries spread over a wide geographic area and cannot be monitored at these small scales by a single management entity (Prince 2010).
- The integration of fishers' knowledge and practices inform fishery management plans and research.
- Coordination and negotiation of agreements with wealthy nations and nations that subsidize fishing have more fleet capacity and dominate the fisheries.
- Reduction in unreported and illegal fish harvests occurs from efforts at self-enforcement.
- Fishing income is more equitably distributed among participants in the fishery.
- Reduce marginalization of subsistence fishers, thereby enhancing livelihoods and reducing behaviors that degrade the local environment (Robbins 2012).
- Fishing boats from wealthy nations are kept out of the country's exclusive economic zone (EEZ), reducing the stealing of fish from the poor (McCauley et al. 2018).
- People of small island states are most vulnerable to sea level rise and storm surges and depend entirely on fish for their protein. Yet, the USA and European Union contribute disproportionately to greenhouse gas emissions.
- Managing recreational fishing is tailored to specific anglers who have both catch- and noncatch-related motivations.

Effective public participation requires deliberation on issues by all those affected by a decision (Dewey 1927; Barber 2003), yet most fisheries' management deliberations are done by governing boards. Board members are often appointed rather than elected and serve out of duty rather than interest. When the governing board is not forced to decide what is best for the whole, individuals may lapse into self-interest. In participatory comanagement, all stakeholders, not only harvesters, are present for discussing ethical issues of public trust, intergenerational **equity**, fishing rights, human welfare, social justice (exclusion), and freedoms (Lam and Pauly 2010; Lam and Pitcher 2012). This deliberative, democratic approach ensures that ethical issues along with economic factors, social policies, and political decisions are considered, as well as the condition of relevant ecosystems. In this way, environmental values and basic human interests (welfare, freedom, and justice) are considered (Lam 2016, 2019). Therefore, the ethical management of fisheries must address five moral imperatives:

- Avoid overexploitation and ensure long-term conservation in a just manner that enhances all people's well-being;
- Allocate allowable harvest in a fair and equitable manner;
- Minimize restricted access to fishing areas;
- Enforce regulations with reasonable consequences; and
- Minimize or avoid fish welfare impacts of fishing practices and behaviors.

Requirements for ethical fisheries are summarized in Table 4.4 by components of the fishery and major ethical principles. Social justice is justice in terms of transparent decision making regarding the distribution of wealth and opportunities and privileges for fishers, other stakeholders, and consumers. Ecological justice requires putting the economy in its place as a subsystem within society and the wider natural world. Consideration of ecological justice recognizes that there are many more indicators of well-being beyond gross national product (Smith et al. 2013). The term *distributive justice* refers to fairness in the distributing benefits from a fishery and ecosystem.

Subject	Objectives related to welfare (well-being)	Objectives related to freedom (autonomy)	Objectives related to justice
The ecosystem	Ecosystem integrity; habitat and biodiversity protection	Maintenance of capacity to change; resilience	Stewardship and interests represented by human institutions
Fish stocks	Stock and genetic conservation; animal welfare	No barriers to migration	Fair conditions for reproduction
Fisheries	Economic viability; sustainable development; safety on board	Conditional freedom to act	Cross-sectoral equity (in taxes and law); access to tribunals
Fishers and their communities	Adequate income and working conditions; poverty eradication; cultural diversity	Freedom to change or not; empowerment; cultural identity	Fair treatment in trade and law; equitable access to resources; compensation
Other stakeholders	No or reduced externalities from fishing	Freedom to compete	Equitable share of resources; dispute resolution
Consumers	Safe, nutritious, affordable food; societal efficiency	Availability of choice (e.g. labelling)	Equitable access to food; no barriers to trade; cross-sectoral equity
Politicians	Availability of alternative policy choices	Capacity to decide; free participation in public deliberation	Transparency; accountability; liability; public oversight

Table 4.4: Ethical matrix for the ethical analysis of fisheries. Source: FAO.

Examination of the ethical matrix forces a fuller dialogue of the ethical principles important for different stakeholders (Lam and Pitcher 2012, Lam 2016, 2019). For example, government proposals to designate no-take marine reserves are intended to protect ecosystem integrity and the well-being or recovery of fish stocks. These benefits must be considered in the context of freedom and justice for fishers and fishing communities that are most affected by the designation (Jones 2009). Fishers will respond to such proposal with statements such as “Fishing is our way of life and our way of earning a living—it’s not just about money,” or “It’s not just the loss of an individual business if a fisherman leaves the industry, it’s the loss of the fishing culture, on which whole villages are dependent.” Another example includes proposals to grant property rights to fish stocks or fishing grounds. In these proposals, the consumer may benefit from a more efficient fishery and more affordable seafood. However, the freedom of certain fishers to fish will be lost, and equitable distribution of a quota must be considered. In developing countries, commonly needed fisheries reforms include justice issues, such as the evictions for coastal development, child labor, forced labor, unsafe working conditions, gender-based violence, and loss of fishing rights (Ratner et al. 2014). In small-scale, subsistence fisheries, governance systems that give fishers access rights provide strong incentives to engage in processes of data collection, assessment, and management (Prince 2010). Furthermore, the difficult tradeoffs can be made more easily in a collaborative, comanagement governance where stakeholders share knowledge and develop trusting relationships (Armitage et al. 2009).

***Questions to ponder*:**

The justice ethical principle states that decision makers should focus on actions that are fair to those involved. In most developed countries, about 1 in 10 people are recreational anglers. Should those individuals who are not recreational anglers be involved in policies related to fishing? License fees and excise taxes on equipment and motorboat fuels fund sportfishing programs. Faced with declining revenues, how should state agencies fund fish conservation?

4.15 Concluding Thoughts

To ensure that fish practitioners are aware of ethical principles that guide their actions, ethical reasoning should be incorporated into all curricula, major meetings, and conferences, and state and federal agencies should establish ethics components in agency operations and procedures (Hadidian et al. 2006). Teaching should focus on *being ethical* and not simply knowing ethical principles (Kretz 2015). Ethics of caring has yet to gain widespread acceptance for fish conservation. Other concepts, such as social justice, distributive justice, and ecosystem justice, rarely enter into the policy-making process. The capacity to make genuine moral judgments is grounded in emotional attachments (Andreou 2007) that are engaged by making deliberations with others who have opposing sentiments. Recognizing the role that emotions play permits us to involve both hearts and minds in deciding right actions.

Young students in particular are prone to be pessimistic and despair over the daunting challenges in fish conservation. We need to avoid both pessimism and idealistic optimism. Being optimistic about the strategies used will allow us to persist in difficult circumstances. As Clayton and Myers (2005, 206) put it, “Sometimes the fear that we can never make enough of a difference—ecosystems will perish anyway—prevents us from making the attempt.” If we continue to ignore discussing ethical concerns with all interested stakeholders, we risk alienating a large segment of the populace. Not all members of the public value fish or fishing in the same way as you might. Ignoring ethical issues will further erode the credibility and efficacy of management agencies, forcing citizens to adopt the public ballot initiative process to be heard (Loring 2017; Manfredo et al. 2017). Emerging global threats to biodiversity and shifts in distributions of many marine fish will necessitate new, more responsive models of governance (Holling and Meffe 1996; Knight and Meffe 1997; Free et al. 2020).

Profile in Fish Conservation: Mimi E. Lam, PhD

Scan the QR code or visit https://doi.org/10.21061/fishandconservation to listen to this Profile in Fish Conservation.

Figure 4.6: Mimi E. Lam, PhD.

Mimi E. Lam is a researcher and Marie Skłodowska-Curie Alumna at the University of Bergen.

Mimi E. Lam (https://www.uib.no/en/persons/Mimi.E..Lam) studied theoretical chemistry and physics in university, earning a BSc honors degree at the University of British Columbia and a PhD from Dalhousie University. This academic background gives her unique analytical insights and methods to examine the complex interactions and underlying mechanisms governing both physical and human-natural systems. She tackles "wicked" societal problems in fisheries and marine governance, where a plurality of values prevents a unique problem definition or solution, with collaborative teams drawn from the academic and non-academic sectors. She examines how human values, beliefs, attitudes, perceptions, and behaviors influence our interactions with nature. Consequently, her investigations at the science-policy-society interface inform the decision-making of individuals, communities, and society in "post-normal" situations, where facts are uncertain, values are in dispute, stakes are high, and decisions are urgent. Mimi Lam's innovation is designing deliberation and decision-support tools that promote both scientific and ethical reflection, evaluation, and analysis to inform robust policy decisions.

In her transdisciplinary approach to fisheries, Mimi Lam works across disciplines, sectors, and cultures, routinely engaging scholars from fisheries ecology, psychology, and philosophy, as well as stakeholders and citizens from local and indigenous communities, fishing industries, nongovernmental agencies, and governments. Past research papers have established Mimi as a leader in the transdisciplinary study of the ethics of seafood, value chains, and fisheries governance. She co-led an interdisciplinary team elucidating the diverse values and ecology of herring to help reconcile the Pacific herring fishery conflict in Haida Gwaii, British Columbia, Canada. At conflict were herring's cultural value as traditional food for coastal indigenous peoples, socio-economic value in the commercial roe fishery, and ecological value as forage fish for predatory fish, marine mammals, and seabirds. Stakes were high and facts were contested when the federal government decided whether or not to reopen the herring fishery. Her team's novel value- and ecosystem-based management approach combined practical ethics to elicit values with ecological modeling to evaluate impacts and risks to open conflicting stakeholders to dialogue and to inform a compromise on a feasible management strategy.

Currently Dr. Lam is leading a project in Norway called Managing Ethical Norwegian Seascape Activities (https://mensa.w.uib.no/), which focuses on how to reconcile the inherent value trade-offs and ethical dilemmas involved in managing seascape activities that encompass not only fisheries, but also aquaculture, oil and renewable energy production, shipping, transportation, tourism, and recreation. Seascape activities are diverse, complex, and dynamic human enterprises that may intersect spatially and/or temporally in the coasts and oceans. Different ways of knowing and valuing coexist, which can lead to management and policy conflicts that must be understood from numerous perspectives in order to effectively govern the marine resources and activities. Dr. Lam's approach in managing fisheries and other seascape activities fosters the extremely difficult consideration of values and deliberations for improved understanding and trust among different participants (for example, among disciplinary experts, fisher and non-fisher, policy-maker and activist, male and female, and wealthy and poor). Her transdisciplinary approach recognizes and offers ethical deliberation and decision-support tools to reconcile the plurality of values and worldviews that exists in modern society and among individuals and cultural groups.

In summary, Mimi Lam champions scientific and ethical approaches to complex environmental and societal challenges that bring diverse parties and perspectives together to develop dialogue and trust, by accepting differences and embracing tolerance for other values and ways of knowing. She received the Conservation Beacon Award from the Society for Conservation Biology for "pioneering an ethical approach to the conservation of marine resources, both natural and cultural, through interdisciplinary research and community engagement at the science-policy interface." The legacy of her influence will be to promote a more sustainable and ethical future by informing policies that support diverse voices and sustain the ways of life of indigenous peoples and local communities, productive fisheries, and resilient ecosystems.

Key Takeaways

- Ethical reasoning deals with values and whether actions are right or wrong.
- Ethical arguments consist of premises, moral principles, and conclusions.
- Success or failure in environmental problem solving is often determined by the way a problem is formulated and discussed in public discourse.
- Five approaches for ethical thinking that may guide decision making include (1) virtue theory, (2) deontological or duty-based theories, (3) teleological or consequentialism, (4) ethical pragmatism, and (5) ethics of caring.
- Ethical reasoning assists us in participating in debates and policy deliberations as an individual, member of a group, and as a member of society.
- Codes of ethics for fishing have been developed to encourage ethical behavior.
- Ethical fisheries can evolve only with dialogue and consideration of principles of freedom, equity, fairness, and justice.
- Collaborative governance is necessary for developing trust among stakeholders.
- When fishers facing common dilemmas form cooperative communication networks with direct resource competitors, they may achieve positive gains.

This chapter was reviewed by Mimi E. Lam and Dennis Scarnecchia.

URLs

Virginia Code, Title 29.1 – Game, Inland Fisheries and Boating: https://law.justia.com/codes/virginia/2014/title-29.1

Ethical theories: https://www.youtube.com/watch?v=Uw7W1PpnbZQ

Long Descriptions

Figure 4.1: Arrow diagram showing that burden of proof is on conservationists when fish are instrumentally valuable and on developers when fish are intrinsically valuable. Jump back to Figure 4.1.

Figure 4.2: 1) Christianity, simple 2 line drawing of outline of a fish; Ichthys is an important identification symbol in Christianity; 2) Judaism, a painting of fish with other cooking ingredients; in Judaism, fish is a symbol of fertility and luck, and gefilte fish is a traditional dish; 3) Hinduism, a giant gray fish is larger than the boat it swims alongside filled with people; in Hinduism, Matsya, a fish is the first supreme god; 4) Islam, an older man stands atop a large fish, holding his hands in prayer; In Islam, fish is a symbol of eternal life and of knowledge. The mythical Al-Khidr is depicted here standing on the fish and using it to travel; 5) Buddhism, painting of 2 golden fish; in Buddhism, the golden fish are one of eight auspicious symbols; Daoism, drawing of 2 koi fish; in Daoism, the yin and yang is often illustrated with two koi fish. Jump back to Figure 4.2.

Figure 4.3: Ethical theories organizational chart; 1) Center line: Ethics of character; what sort of people should we be? leads to Aristotelianism, virtue is a mean between extremes of action and passion; 2) Left line: Ethics of conduct; what sort of actions should we perform? branches out to Consequentialism; the right action is the one that produces the most intrinsic good; Deontology; the good is defined independently of the right. Consequentialism branches out to for the agent: ethical egoism and for everyone affected: utilitarianism. Deontology leads to Kantianism; actions must satisfy the categorical imperative. 3) Right line: Ethics of caring branches out to ecological feminism and Indigenous peoples ethics. Jump back to Figure 4.3.

Figure 4.4: A circle made up of dashes encompasses human icons within it (adult male, adult female, male child and female child). on top of the dashes and outside the circle are a pig, an ant, a fish, and a tree. Jump back to Figure 4.4.

Figure 4.5: Three overlapping circles: 1) Fair Trade, no forced or child labor; 2) Local, reduced carbon footprint; 3) Eco-label, reduced habitat destruction. Where fair trade and local overlap, socioeconomic development and diversification. Where Eco-Label and Local overlap, improved stock status and reduced bycatch. Where all overlap, traceability. Jump back to Figure 4.5.

Figure References

Figure 4.1: Burden of proof as it relates to instrumental and intrinsic value systems. Kindred Grey. 2022. CC BY 4.0.

Figure 4.2: Religious symbols associated with fish and fishing. Kindred Grey. 2022. CC BY 4.0. Includes "Ichthus," by Fibonacci, 2006 (public domain, https://commons.wikimedia.org/wiki/File:Ichthus.svg), Still life "Tor Marancia Vatican," by Sconosciuto, 1506 (public domain, https://it.wikipedia.org/wiki/File:Still_life_Tor_Marancia_Vatican.jpg), "The fish avatara of Vishnu saves Manu during the great deluge," by unknown author, acquired in 1965 (public domain, https://commons.wikimedia.org/wiki/File:The_fish_avatara_of_Vishnu_saves_Manu_during_the_great_deluge.jpg), "Khizr," by unknown author, mid-17th century (public domain, https://commons.wikimedia.org/wiki/File:Khizr.JPG), "Eight Auspicious Symbols," wall mural, Tibetan Buddhist symbols; vase, flower, infinity knot, wheel, fish, banner, umbrella, shell, hotel, Boudha, Kathmandu, Nepal, by Wonderlane, 2007 (CC BY 2.0, https://flic.kr/p/8kaZV9), and koi, by kareemov, 2022 (Noun Project license, https://thenounproject.com/icon/koi-4630545/).

Figure 4.3: Hierarchical relationships among traditional Western ethical theories and ethics of caring. Kindred Grey. 2022. Adapted under fair use from *Ethics: A Pluralistic Approach to Moral Theory*, 2nd ed., by L. M. Hinman, 1998 (https://www.brainkart.com/article/Ethical-Theories_11639/).

Figure 4.4: A moral circle encompasses those we consider worthy of moral consideration. Kindred Grey. 2022. CC BY 4.0. Includes Pig by Adindar, 2020 (Noun Project license, https://thenounproject.com/icon/pig-3362726/), Family by Gan Khoon Lay, 2017 (Noun Project license, https://thenounproject.com/icon/family-1245000/), Ant by Cédric Stéphane Touati, 2015 (Noun Project license, https://thenounproject.com/icon/ant-93320/), Fish by Sari, 2018 (Noun Project license, https://thenounproject.com/icon/fish-2099999/), and Tree by Misru, 2019 (Noun Project license, https://thenounproject.com/icon/tree-3369293/).

Figure 4.5: Goals used for three types of certification for fisheries. Kindred Grey. 2022. Adapted under fair use from *Fair Trade Fish: Consumer Support for Broader Seafood Sustainability*, by Loren Mcclenachan and Sahan T. M. Dissanayake, 2016 (DOI:10.1111/faf.12148).

Figure 4.6: Mimi E. Lam, PhD. Used with permission from Mimi E. Lam. Photo by Tony J. Pitcher. CC BY-ND 4.0.

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5. Pain, Sentience, and Animal Welfare

Learning Objectives

- Describe the nervous system components involved in the perception of pain in fish.
- Apply criteria for pain to assess whether an animal perceives pain.
- Describe different criteria used to judge sentience.
- Create and critique ethical arguments for the treatment of fish.
- Judge conditions that are most likely to cause fish pain and suffering and actions to alleviate pain and suffering.
- Distinguish between three alternative views on animal welfare.
- Describe specific actions that can be taken to improve welfare of fish.

5.1 Relevant Questions

Fish are not stupid creatures. In fact, fish are socially complex, with highly developed learning abilities (Brown 2015). Fish feel pain and suffer as a consequence, and we must carefully examine welfare, use, and fishing practices. Scientists have questioned the outdated perspective that fish cannot have consciousness as their brain morphology is too simple and lacks the cerebral cortex present in humans. Yet, denial of fish pain perception prevails despite many recent, fascinating discoveries that demonstrate that fish do experience and remember exposures to **noxious** stimuli in a fashion that is far more complex than mere reflex. Consequently, there are many lively discussions on how we should treat fish.

Think of all the ways that you use fish in your life. Perhaps you enjoy sportfishing or keep tropical fish in aquariums. Maybe you harvest live fish for bait fishing. You may prefer to purchase fresh fish from the local seafood market. You may enjoy watching fish in public aquariums or by SCUBA diving. Or perhaps you identify with Santiago, the aging fisherman in *The Old Man and the Sea*, who struggles to reel in a giant marlin. Humans use fish for sport, food, pets, business, education, scientific research, and many other purposes (Olden et al. 2020). Whenever we use fish for any reason, we need to ask certain questions: How might our actions influence fish? Do fish feel pain? Do fish suffer? Are fish aware of their actions? Do fish in captivity have what they want? Is the fish healthy? How can we balance fish welfare with the benefits humans get from fish?

Although anglers and others have long pondered these questions, scientists began systematic investigations of these questions only within the last 50 years (Vettese et al. 2020). According to the International Association for the Study of Pain, pain is “An unpleasant sensory and emotional experience associated with, or resembling that associated with, actual or potential tissue damage” (Raja et al. 2020). What causes “unpleasant” and “emotional” responses in fish is a difficult scientific question to answer, long neglected by researchers. Early laws that regulated how animals are used in experiments excluded cold-blooded animals. The Health Research Extension Act of 1985 (PL 99-158, 1985) and the Animals (Scientific Procedures) Act (1986) gave protections to fish and further stimulated the science of animal suffering to include fish (Dawkins 2008; Braithwaite 2010). After the first study investigating whether fish feel pain was published (Sneddon 2002; Sneddon et al. 2003a), many strong feelings and debates emerged (Figure 5.1). This chapter presents the factual evidence and philosophical views and practices related to minimizing pain and suffering in fish.

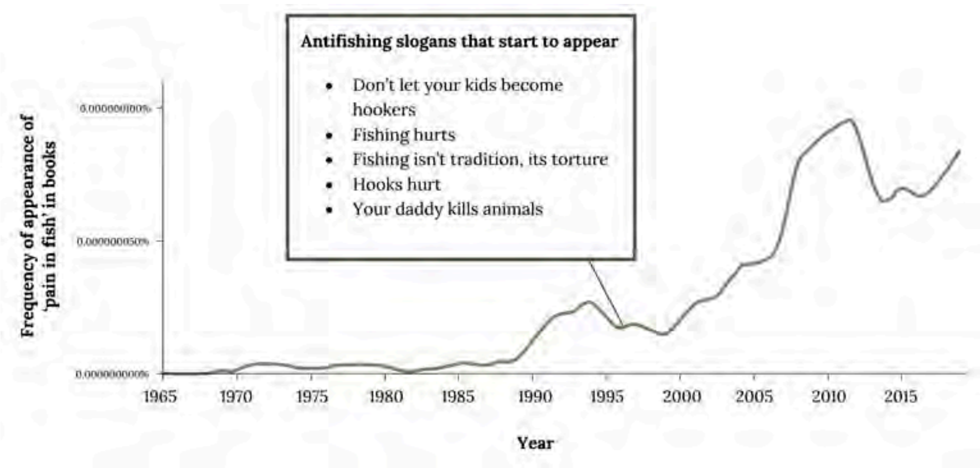

Figure 5.1: Frequency of appearance of “pain in fish” in books since 1965 coincides with appearance of antifishing slogans after 1996. [Long description](#).

Our personal decision making about how to treat fish involves reflecting on facts, intuitions, and moral principles about pain and suffering in fish. As such, we judge the relevance of both factual or descriptive statements as well as relevant moral principles. In practice, these reflections are difficult and demand that we participate in dialogue and debate with others who may disagree with our views. Disagreements may be over acceptability of moral principles or over the facts about consequences of different welfare measures on fish consciousness and suffering. Ethical considerations of fish involve application of existing **normative** theories (Meijboom and Bovenkerk 2013; Michel 2019; Veit and Huebner 2020), resulting in alternative perspectives (List 1997; Allen 2013; Rose et al. 2014; Key 2015, 2016a, b). If this was easy, someone would have done it already.

Who hears the fishes when they cry?

—*Henry David Thoreau, A Week on the Concord and Merrimack Rivers, 1849*

5.2 Pleasure and Pain Perception

Jeremy Bentham was one of the great thinkers in moral philosophy. He developed the theory of utilitarianism as the basis for law in 18th century England. In Bentham's view, laws should serve to maximize the interests and preferences of all individuals. The foundation of utilitarianism held that pleasure is the only good, and pain, without exception, is the only evil. In response to creating a penal code regarding cruelty to animals, Bentham wrote, "The question is not, Can they *reason*? nor, Can they *talk*? but, Can they *suffer*?" This proposition formed the beginnings of utilitarian arguments for the ethical treatment of animals (Singer 1975).

Until recently, few scientists asked the question, "Do fish feel pain?" Here I highlight some key findings from studies on fish pain that asked three questions: (1) Do fish have the necessary receptors and nerve fibers to detect painful events? (2) Did a potentially painful stimulus trigger activity in the nervous system? (3) How did the experience of a potentially painful event affect the behavior of fish and decisions made? (Sneddon et al. 2003a; Braithwaite 2010).

Do fish have receptors to detect painful events? **Nociceptors**, the sensory receptors to detect noxious stimuli, are present in mammals, birds, reptiles, amphibians, lampreys, and bony fish. Even far distant animal groups, such as leaches, sea slugs, and fruit flies, have nociceptors (Whitear 1971; Matthews and Wickkelgren 1978; Sneddon 2002; Smith and Lewin 2009). Strangely, a few studies suggest that sharks and rays seem ill equipped to detect noxious stimuli, although more studies are needed (Snow 2003). The first descriptions of pain receptors in bony fish revealed that they were similar in size and structure to those observed in birds and mammals (Schnitzler and Ploner 2000; Sneddon 2002; Sneddon et al. 2003a, 2003b, 2018; Sneddon 2019). Nociceptors mapped on the head of Rainbow Trout indicate where pressure and chemical stimuli are detected (Figure 5.2).

Does the painful stimulus trigger activity of the nervous system? Scientists measure the electrical signals in nerves to determine if they respond to stimuli. They also use a technique called electroencephalography (EEG) to record electrical activity of the brain. For example, EEG was used to determine loss of and return of consciousness following stunning in studies designed to discover the quickest methods for killing fish (Robb et al. 2000). When the pain receptors in trout were stimulated by mechanical means, heat, or acid, activity in nerve fibers was recorded (Ashley et al. 2007). The painful stimulus triggered a quick reflex reaction. The second response to the painful stimulus requires processing in the brain and leads to the third question.

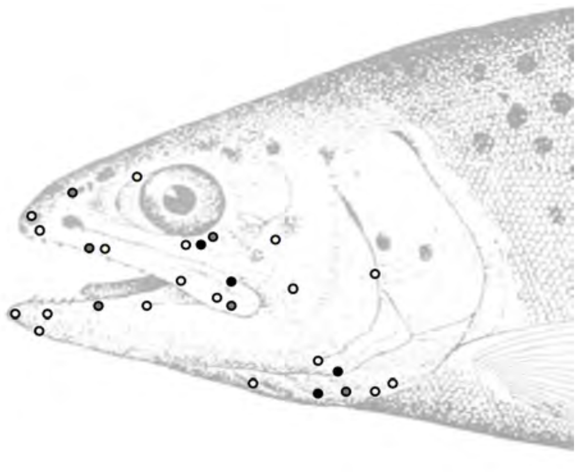

Figure 5.2: Sketch of Rainbow Trout with locations of nociceptors. Pale yellow circles: polymodal nociceptors. Black circles: mechanothermal nociceptors. Green circles: mechanochemical receptors. Long description.

How did the experience of a potentially painful event affect the behavior of fish and decisions made? Think about pain that you have experienced. Minor pain may be tolerated without much affect. However, chronic or intense pain will be a priority concern and cause you to change your behavior. Therefore, the third question asks whether behavior or decision making changes after a potentially painful event. Trout responded to acid or bee venom applied to the lips by rubbing their lips against the gravel at the bottom of the holding tank (Sneddon et al. 2003a, 2003b). In other experiments in which Rainbow Trout were exposed to noxious stimuli, they stopped feeding and showed lower antipredator behaviors and lowered aggression with other Rainbow Trout (Ashley et al. 2009). The adverse effects were relieved by painkillers, such as aspirin, morphine, and lidocaine (Lopez-Luna et al. 2017; Sneddon 2015, 2019; Sneddon et al. 2018a).

Questions to ponder:

What is the principal evidence for concluding that fish can experience pain? Explain the questions and methods for the scientific studies. Would you expect all types of fish to have the same types, locations, and number of pain receptors? Why?

5.3 Are Fish Sentient?

In judging whether an animal deserves respect or protection, what matters morally is whether an animal is sentient and can be benefited or harmed by our actions (Singer 1975, 2010, 2011; Horta 2018). A sentient being can detect and sense external stimuli and is aware of how this perception alters its mental status. The concept of sentience provides the foundation for the animal welfare and animal rights movements (Regan 1983). The moral reasoning follows the argument: (1) If a being is sentient, then it deserves serious moral consideration; (2) fish are likely to be sentient; (3) therefore, fish deserve serious moral consideration (Lund et al. 2017). Whether an animal is sentient is based on the following five capabilities (Figure 5.3; Broom 2014).

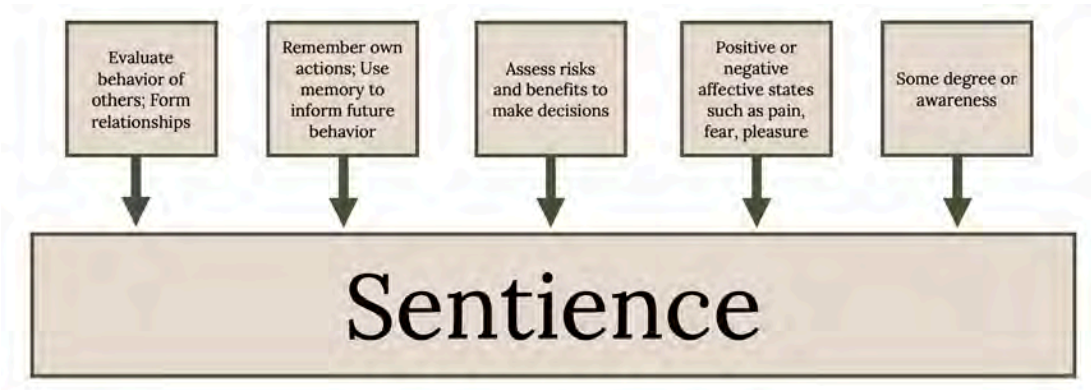

Figure 5.3: Diagrammatic representation of the five capabilities that make an animal sentient. [Long description](#).

Evaluate the actions of others in relation to itself and third parties (i.e., form relationships within and between species).

Anyone who has ever kept fish in aquariums knows that fish will quickly remember who feeds them and gradually **habituate** to the presence of the person doing the feeding. Fish develop relationships with their aquarium feeder. Fish develop relationships with other fish. We see behavioral displays and dominance in a small group of fish, especially when fish are in captivity. Cooperative relationships are observed in breeding cichlid fish, which care for their young offspring. Even different species, such as moray eels and grouper, may form cooperative hunting behaviors to enhance feeding success (Bshary et al. 2006). They can evaluate hierarchies from a third-part perspective through transitive inference.

Remember some of its own actions (the cognitive ability to learn and recall those memories that should influence future behavior).

In captivity, fish will quickly learn where the food is coming from; if the location changes, fish will learn a new location. In fish farms, fish learn to operate demand feeders. Fish also learn by watching each other (social learning) and avoid fighting with larger, stronger individuals. Many species of fish will return to their home after being experimentally displaced. They learn spatial arrangements in the environment and can remember the whereabouts of different locations and learn migration routes from watching other more experienced fish. Fish learn to avoid nets and hooks and retain that memory for almost a year. They also learn the location of dangerous places and avoid them. More studies on fish learning are highlighted in section 5.6.

Assess risks and benefits (make decisions based on the information available externally and its own subjective state).

Fish in the wild are always at risk of being eaten by a larger predator. If all behaviors were instinctive, the amount of risk-taking behavior would be constant, but that is not the case. In a controlled experiment, juvenile sea bass with higher metabolic demands were more likely to take risks after being deprived of food (Killen et al. 2011). Their behavior changed because the motivation (and benefits) of feeding when very hungry outweighed the potential risk of predation (i.e., they prioritized food over predation risk). Therefore, the risk taking depended on the relative benefits and was not a simple stimulus-response reflex. Fish behavior is often guided by the risk sensitivity: they are constantly attempting to balance the risk of certain behaviors (such as exposure to predators while feeding) with the expected benefits (increased feeding leads to growth and reproduction).

Have some feelings (positive or negative affective states such as pain, fear, and pleasure).

We understand and regularly speak of human emotions, such as fear, anxiety, grief, love, happiness, and pain. We can see these emotions in the faces of other humans. The idea that fish have feelings is often met with a response of disbelief. Whether fish have feelings or emotions was not studied because most behaviorists believed responses to stimuli, such as presence of a predator, was instinctive and not related to the emotion of fear. Discerning whether a fish has feelings is challenging, in part because fish live in environments that make it difficult to observe. Yet, fish need to experience pain, fear, and other feelings in order to respond effectively to their environment and survive (Darwin 1872; Millot et al. 2014; Cerqueira et al. 2017).

Fear is a feeling that protects animals from danger. The flight or fright physiological response is a conservative trait in vertebrates. Brains of fish and mammals have **homologous** structures that process fear stimuli and cause consistent responses. Fish such as Siamese Fighting Fish and zebra fish respond to antidepressant drugs by reducing aggression (Dzieweczynski and Hebert 2012; Theodoridi et al. 2017). These studies demonstrate that fish exhibit responses similar to those observed in humans and that these responses are controlled by the same neurotransmitters.

In addition to fear, fish are capable of positive and negative moods. Recently, ethologists tested whether Convict Cichlid fish, a monogamous fish, showed a negative mood (pessimistic) when partnered with a nonpreferred mate (Laubu et al. 2019). These findings demonstrated that fish experience similar emotions to humans. Serotonin plays a role in emotions in all vertebrates; zebra fish are extensively used to test new medications for anxiety and depression (Pittman and Lott 2014). Play behavior was long deemed to be a trait only exhibited in mammals. To study play in fishes, play was defined as "repeated, seemingly non-functional behavior differing from more adaptive versions structurally, contextually, or developmentally, and initiated when the animal is in a relaxed, unstimulating, or low stress setting." Behaviors of fish that fit the definition of play include leapfrogging, balancing twigs, batting around balls, jumping into the air, and striking a self-righting thermometer (Burghardt et al. 2015).

Have some degree of awareness (often termed *consciousness*).

The ability to recognize oneself in a mirror is a rare capacity, once believed to be restricted to great apes, elephants, dolphins, and magpies (Gallup 1970; Plotnick et al. 2006; Prior et al. 2008; Reiss 2012). If an animal recognizes that the image in the mirror is its own, it will cease to respond to the reflection socially and will recognize changes over time. The mirror test is a long-standing test of self-awareness (Gallup 1970), and until recently, few studies tested self-recognition in fish. When manta rays were exposed to the mirror test, they spent more time when a mirror was present in their holding tank, especially in the first ten minutes of the experiment. While visually oriented to the mirror, manta rays made unusual or repetitive behavior, including bubble blowing and atypical social behaviors (Ari and de Agostino 2016). When exposed to a mirror, the Cleaner Wrasse (*Labroides dimidiatus*) first interacted aggressively as if seeing a rival, but aggressive reactions decreased over time. Instead, it showed atypical behaviors. After individuals were given a visible mark, they would posture in front of the mirror in order to view the location of the mark. Compared to controls with marks that were not visible, marked Cleaner Wrasse spent significantly longer in postures that would allow them to observe color-marked sites in the mirror reflection (Kohda et al. 2019). These findings that fish "passed" the mirror test were surprising to most scientists. It is still unclear whether scientists will accept the findings or question the mirror test and seek alternative tests for cognitive abilities of fish (de Waal 2019; Vonk 2020).

It is difficult to characterize what nonhuman animals are thinking about in relation to others, feelings, or awareness because they do not use a language that humans understand. Therefore, the evidence of sentient abilities in fish often comes from studies of fish behavior (Brown 2015; Sneddon and Brown 2020). In the study of fish behavior, scientists attempt to understand the thoughts of fish from manipulative studies that provide fish with choices and rewards. It's a neat way of allowing fish behavior to tell scientists what the fish is thinking. From many recent studies of fish cognition, patterns are emerging to support the five criteria for sentience in fish (Sneddon and Brown 2020).

Questions to ponder:

Think about a fish species for which you have some familiarity. Does this fish exhibit some or all of the five capabilities that are criteria for sentience? If you are uncertain, how might you test the fish for one or more of these capabilities? Link to https://scholar.google.comand search for "fish_name" AND "pain" to see if any scientific studies have been published.

5.4 Skeptics and the Pursuit of Empathy

Since the first studies of fish pain, many skeptics have questioned the finding that fish feel pain and suffer and have opposed the need for regulations governing the welfare of fish (Rose 2002; Rose et al. 2014; Key 2015; Diggles and Browman 2017; Browman et al. 2019). Unlike certain mammals, fish lack a familiar face and voice that reveals emotional cues, and they lack nonhuman charisma that motivates advocates (Lorimer 2007). In response to the arguments of skeptics, Sneddon et al. (2018b) note that (1) "Skeptics still deny anything beyond reflex responses in fishes and state that they are incapable of complex cognitive abilities"; (2) "Processing is not restricted to hindbrain and spinal reflexes as skeptics have suggested"; and (3) "Widespread calls for use of the precautionary principle have been called into question by skeptics"—for example, "We should abandon the precautionary principle because the costs to industry would be too high."

The "no cortex, no cry" argument, the dominant argument of the skeptics (Smith 1968; Rose 2002; Key 2016a; Dinets 2016), maintains that (1) If x feels pain, then x has a neocortex; (2) Fish do not have a neocortex; (3) Therefore, fish do not feel pain.

The counterargument **postulates** that fish depend on different neural pathways for pain processing that closely parallel those of the amygdala and hippocampus in mammals (Agetsuma et al. 2010; Michel 2019). Basic features of the forebrain (i.e., basal ganglia) involved in decision making, behavior, and rewards are similar in mammals and lampreys, a vertebrate lineage that diverged 560 million years ago (Grillner and Robertson 2016). While the brain of fish is smaller and less structured than the brain of mammals, there is high variation in brain structure among different fish species. Brain functions and neural circuits in fish, though not homologous to the mammalian brain, are complex enough to support phenomenal reasoning and consciousness (Brown et al. 2011; Woodruff 2017).

Charles Darwin first explored the notion of evolutionary continuity and emotions and believed that if humans feel emotions and can suffer, then so too can other animals, but their feelings are not necessarily identical (Darwin 1872). Although scientists have accumulated much evidence that fish fulfill Brown's criteria for sentience, denial of sentience in fish persists. At the risk of oversimplifying the many writings by those denying sentience in fish, I offer two views often presented. First, many criticize the experiments and argue that scientists have yet to falsify the null hypothesis that "fish do not feel pain" or claim that pain is fundamentally different in nonhuman animals (Key 2016b; Browman et al. 2019). The other common argument is often a "slippery slope" **fallacy** that asserts that relatively small steps in protecting animals will culminate in significant restriction or bans in certain fishing sectors.

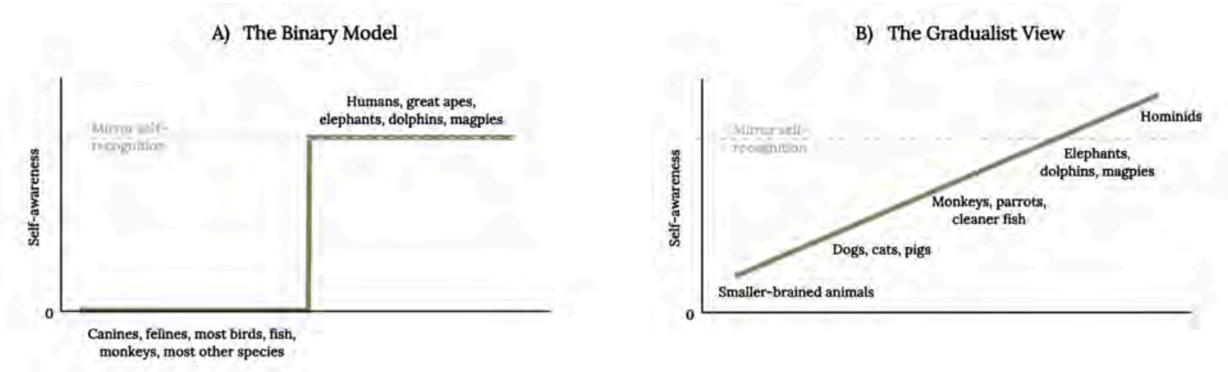

Figure 5.4: Two different perspectives on the evolution of self-awareness. The binary model (A) maintains that species that show mirror self-recognition possess a self-concept, and all others do not. The gradualist view (B) assigns highest self-awareness to hominids, who explore and play with their reflection and care about their appearance, and assigns intermediate or lower levels to others. [Long description](#).

With the emergence of studies on fish consciousness, scientists have questioned whether there is a distinctive line between sentient and nonsentient animals (de Waal 2019; Vonk 2020). Studies of behavior and cognition in fish point to the need for more valid tests for cognitive abilities of fish. Sentience is typically treated as a property that organisms either have or do not have. Alternatively, organisms may possess varying degrees of sentience (Figure 5.4) that influence moral considerability (Veit and Huebner 2020). The controversy over sentience opens a new challenge of understanding the basis for empathy across different species. As a human society, we are struggling to understand what knowledge may lead to actions of care for others (Adriaense et al. 2020).

Questions to ponder:

Regarding pain and sentience in fish, do you feel empathy for fish? Does your need for seafood to eat eclipse sentience? How do you reconcile findings about fish sentience and your sense of moral obligation to making a difference in lives of fish?

5.5 Learning in Fish

Numerous studies support the hypothesis that fish are intelligent, highly social animals. As expected, fish show variation in learning abilities. Fish are capable of learning because they have high-order capabilities, including awareness, reasoning, and consciousness. Yet, popular media are not kind to fish. Dory, the regal Blue Tang in the movie *Finding Nemo*, is a caricature of the forgetful fish with a short-term memory. In contrast, recent studies tell us that certain fish have long-term memories comparable to other vertebrates (Brown 2001; Brown and Laland 2003, 2011). Fish can recognize one another, learn from dominance relations, use tools, cooperate with other fish, develop cultural traditions, and even have distinctive personality traits. Examples from a few significant experiments reveal impressive memory and abilities to learn.

Behaviors observed in fish reveal their memory and learning. Transitive inference is the ability to infer a relationship between items that have not been previously directly compared. In humans, children around the age of five can infer that if *John is taller than Mary, and Mary is taller than Sue, then John is taller than Sue*. In one experiment, a male cichlid fish, which is aggressive with other males, was able to observe fights between pairs of male cichlids. Let's assume the individual cichlid watches as combatant A beats combatant B, B beats C, and C beats D. If the cichlid is now placed in a chamber with A and D, would it avoid either cichlid? If the cichlid avoided A more than D, it has deduced the dominance relationship, even though it never observed the two fish together. This is an example of **transitive inference**, which requires conscious awareness of the relationships (Grosenick et al. 2007).

In another experiment, rainbow fish learned to escape from a net trawled through an experimental tank and remembered the information for 11 months (Brown and Warburton 1999; Brown 2001). This length of memory was similar to that observed by Common Carp. After capture by hook and line, Common Carp learned to avoid baits presented on hooks and remembered this experience for many months. When foraging in food patches where previous hooking events took place, carp change behavior and spit out baited hooks without being hooked (Klefoth et al. 2013). Common Carp do not have to be captured in order to learn this lesson. Individuals that observed the hooking, struggle, and release of other carp, avoided baits on hooks seven days after the experience (Wallerius et al. 2020).

Tool use was long considered a defining feature separating humans from all other species. Our human perception of "tools" creates difficulty for fish, which have no grasping appendages. Furthermore, the watery environment is more viscous and buoyant, which restricts the mechanical forces involved in operating a "tool." Studies on cognition in nonhumans necessitated a new definition of tool use that required that the animal "must directly handle an agent to achieve a goal." Suddenly, many behaviors indicated that some fish were tool users (Keenleyside and Prince 1976; Keenleyside 1979; Coyer 1995; Bshary et al. 2002; Paśko 2010; Jones 2011; Bernardi 2012; Brown 2012). Brown Hoplo Catfish (*Hoplosternum thoracatum*) glues its eggs to a leaf and carries it like a tray (tool) to the safety of a foam nest. South American cichlids also lay eggs on leaves and will move the eggs on leaves to protected locations. The Sixbar Wrasse, when presented with food pellets too large to swallow, used a rock held in its mouth as a tool to batter the food pellet. Archerfish learn to shoot a stream of water at terrestrial insects above the water. Damselfish clean a vertical rock face by gathering sand in their mouth and sandblasting (Keenleyside 1979). Damselfish also maintain desirable algal patches by weeding out other algal species.

Fish recognize each other, which allows for cooperative behavior, social learning, and signaling (Griffiths and Ward 2011). Fish can recognize familiar individuals by their unique odor or visual cues. They can also identify close kin. Recognition provides fish with the ability to form large shoals of similar fish, thereby creating safety in numbers. Migrating Steelhead Trout, for example, form associations that persist during their long-distance migrations. Constant associations may lead to formation of social networks among individuals (Krause et al. 2017) and enhance social learning pathways. Social learning was previously thought to be restricted to birds and mammals. However, experiments with fish demonstrate numerous situations where individual fish learn from others (Brown and Laland 2011). For example, fish can learn about risky habitats from their own experience or from the reactions of other fish. Human fishing activities may influence fish learning. Removal of more knowledgeable individuals may disrupt social transmission of information, such as location and routes to feeding or spawning grounds. Furthermore, the improved effectiveness of fishing gears may at some point overcome the ability of fish to learn (Ferno et al. 2011), which means fish can no longer adapt their behavior to avoid being caught. Understanding how fish learn has important and unexplored applications, such as training of fish before conservation restocking.

***Questions to ponder*:**

International Association for the Study of Pain (IASP) states that "activity induced in the nociceptor and nociceptive pathways by a noxious stimulus is not pain, which is always a psychological state." Pain requires a state of consciousness, which is processed in the cortex in humans. Do we know where fish consciousness resides? How do we know fish are aware? Are you convinced that fish can and do experience pain?

5.6 Welfare and Well-Being

The emerging picture informs our understanding of the intelligence, learning, and memory of fish. Evidence that fish are sensitive to pain and are self-aware is sufficient to lead many to conclude that fish exhibit relevant, morally significant capacity to suffer. Animals that are intelligent have greater capacity to suffer, and people are more likely to show empathy toward fish that they believe are intelligent (Bekoff 12014; Brown 2015). Fish are popular pets—only cats and dogs are more popular (Iwama 2007). Fish caught by global fisheries number in the trillions, and fish farming kills billions each year, more than the number of chickens killed for human consumption. Yet, wild fish are hardly as visible to us and do not share a common environment. This separation creates a challenge for questions of animal welfare (Meijboom and Bovenkerk 2013).

The term “welfare” addresses the physical and mental health and well-being of a fish or group of fish. Scientists and ethicists differ on how to approach animal welfare. For example, the animal welfare views held by individuals may be based on

- Function, that is, indicative of growth or fecundity;
- Nature, which relates to the ability to lead a natural life in the wild; or
- Feelings, which focuses on mental states rather than physical health and emphasizes not only the avoidance of stress or fear, but also the opportunity to experience positive feelings (Fraser 1995).

The function-based approach is advocated by recreational angling interests (Arlinghaus et al. 2007). The third view is advocated by animal welfare advocates. Good animal welfare practices mean fish “are healthy and have what they want” (Dawkins 2008). This statement obliges us to determine animals’ wants and presupposes that we can determine positive states of emotion. However, the scientific findings regarding pain and consciousness are now being filtered through ethical disputes between anglers, fishing and fish farming industries, and animal-rights advocates to develop norms and legal protections for fish. As expected, the animal rights advocates stress that the lives of fish are valuable in and of themselves (intrinsic value) and not because of their utility to humans. The views of others who value fish for human uses are in conflict. Therefore, they may question whether it is relevant that fish feel pain and suffer or can feel pleasure and enjoyment.

The views of stakeholders and society at large about mental capacities of fish and their moral status have not been systematically examined, but welfare decisions will have to consider a plurality of moral views. Attempts to provide objective measures of welfare in captivity or during and after capture may not be easily determined from existing models of domestic livestock (McGreevy et al. 2018; Barrell 2019; Browning 2020). While some scientists reject the empirical evidence on fish sentience, animal welfare practices are costly, debatable, and engage numerous social values and novel questions (Jacquet 2018). Only in the context of different fishing practices does it make sense to engage in the debates over animal welfare. Behavioral and physiological assessment of fish can be conducted to determine if fish are relaxed, agitated, anxious, or distressed. For example, levels of cortisol in the blood are universally used to indicate stress, a negative welfare status.

Questions to ponder:

In the future, do you believe that fish will continue to be treated as commodities—that is, caught, farmed, and eaten without moral consideration? What moral status will fish occupy in the future? Which of the three views (feelings, nature, functions) would you adopt to decide how to address welfare of fish?

5.7 Fish as Research Subjects

Fish are used in a wide variety of research studies, and this use may cause suffering or death. Therefore, suffering or death of research animals must be justified by scientific or medical advances that could not be achieved in any other way. Any scientist planning to use animals in their research must first show why there is no alternative, and consider the three Rs in order to minimize numbers of fish suffering:

- **Replace** the use of animals with alternative techniques or avoid the use of animals altogether.
- **Reduce** the number of animals used to a minimum, to obtain information from fewer animals or more information from the same number of animals.
- **Refine** the way experiments are carried out, to make sure animals suffer as little as possible. This includes better housing and improvements to procedures that minimize pain and suffering and/or improve animal welfare.

From a risk-management perspective, the ethical costs of making an error in this judgment are huge given the massive number of fish that are involved in fisheries and scientific research (Brown 2015). Guidelines for the use of fish in research are most often informed by empirical evidence with regard to the capacity of animals to experience pain (Sneddon 2015; Message and Greenhough 2019). Scientific associations have developed ethical justifications for allowable use of fish in research (Metcalfe and Craig, 2011; AFS 2014; Elsevier 2012).

5.8 Fish as Pets

Although welfare of fish as pets has been historically ignored, recent findings on fish pain, aesthetic concerns, and higher costs among serious hobbyists have raised concerns. Fish, such as Goldfish, have feelings and perceive pain and are capable of learning. Pet fish owners who provide adequate environments will see healthy fish that display a broader array of behaviors in fish tanks. Some estimates suggest that the aquarium-keeping industry is worth between 15 and 40 billion U.S. dollars globally, with approximately 10% of the U.S. and U.K. populations already invested in aquarium keeping (Marchio 2018; Sneddon and Wolfenden 2019). Growing numbers of veterinarians are gaining clinical experience with pet fish (Hartman et al. 2006). Common welfare issues include purchasing fish that grow too large for aquariums, overstocking an aquarium, water quality, inadequate water filtration, poor diets, and mixing incompatible species. Many aquarium keepers have misconceptions regarding the lifespans of fish and the required level of care. Further, when individual fish are affordable, their perceived value and concern for welfare are very low. Many unique varieties of Goldfish are prone to medical conditions that affect their welfare in captivity (Brown et al. 2019). Other welfare issues relate to the conditions in the supply chain, which often includes harvesting from wild populations and little concern for welfare during transport. Because fish are often one of the first pets that children obtain and care for, there is great opportunity for education in welfare concerns and conservation via the aquarium-keeping industry (Marchio 2018). In the future, better education, veterinary care, and creating codes of practice should improve the welfare of ornamental fish in captivity (Walster et al. 2015).

5.9 The Angler's Dilemma

Justification for other uses of fish often considers the type of benefits that humans derive and whether harm is intentional (Figure 5.5). When viewing fish, humans are not consuming or removing individuals and do not intend to harm them. Consequently, little attention is paid to welfare issues associated with viewing wild fish. However, recreational fish may be pursued for food, competition, trophies, or leisure (catch and release). Most recreational anglers practice a mix of these pursuits, which complicates the ethical considerations. Subsistence and commercial fishing and fish farming are responsible for the highest numbers of fish killed worldwide.

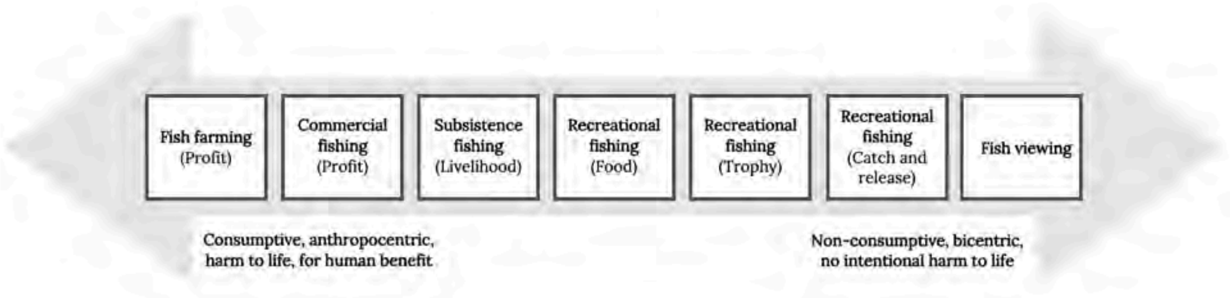

Figure 5.5: Human motivations for types of fish and fish viewing. [Long description](#).

The angler's dilemma about treatment and welfare of the fish captured has a long history. The utilitarian argument maintains that the only morally justifiable reason for catching fish is to kill and eat them. When assessing the consequences of our actions, it is necessary to take the interests of animals seriously and to weigh any adverse effects on those interests from human actions as part of the consequences of those actions (Singer 1975). Consequently, some anglers feel strongly that catching fish for mere sport, not for food, is objectional. British poet and fly angler John Gay (1685–1732) argued in favor of the moral superiority of fly-fishing over other forms of angling on the grounds that fly anglers did not mistreat worms, insects, small fish, and frogs as did bait fishers (Schullery 2008). The first fishing code of ethics that advised anglers on how to minimize cruelty to fish was published in 1876 (Raymond 1876). Despite the long history of concerns, the welfare concerns about recreational fishing are still hotly debated today.

"If a fish could scream, a lot of things would be different"—this statement was attributed to fly-fishing writer Charles Brooks (Schullery 2008). It is easier for us to discount the suffering of fish because they do not make the intensity of their suffering known to us in a way that evokes our emotional response. As such, we would never permit fly-fishing for songbirds. Roderick Haig-Brown, in "The People's Right to Go Fishing" (1939, 162) wrote, "There can be no doubt that animals, birds and fish feel pain. . . . They feel pain; and they know fear—not fear of death or future suffering—but immediate fear of an immediate, visible threat to themselves, fear of present pain or present restraint, and ever fear of something directly associated with pain or restraint." Apparently, Haig-Brown was decades ahead in refuting the long-held notion that fish lack the neurological mechanisms to feel pain or experience awareness.

Among the three perspectives on welfare with respect to recreational fishing, most angling interests have argued for the functions-based or feelings-based approaches, and not the nature-based approach. Feelings-based approaches sometimes critique fishing terms, such as "fighting" or "playing" the fish. Writer John McPhee (2002) considered "playing" a euphemism for "at best torturing and at worst killing a creature you may or may not eat." And de Leeuw (1996) maintained that sportfishing involves (a) killing fish and (b) purposefully inflicting pain and suffering in them in order for anglers to have "sport" with them. This is sometimes referred to as the "**sadistic**" argument against sportfishing. If one holds true to the principle of avoiding all suffering in animals, then they must reject all sportfishing. Sport anglers value sport with fish more than they respect the lives of animals pursued (de Leeuw 1996). Participation in sportfishing requires justification for inflicting avoidable pain and suffering.

Participants will claim that the utilitarian benefits of sportfishing outweigh any harm to fish. If conservation does not arise from angling, then clearly one cannot justify angling (de Leeuw 1996). Anglers support conservation via license fees, excise taxes, support for conservation organizations, and participation in creel surveys and volunteer work. Do these efforts justify the avoidable pain and suffering? One must consider the activities supported and whether they create more fish in the future. Do these activities outweigh harm to fish? Answering that question is a very substantial task. The argument proposed by de Leeuw (1996) did precipitate other counterarguments (Chipaniuk 1997; List 1997). As outlined by Olsen (2003), the sadistic argument is as follows (note: I replaced "sport fisherman" with the gender-neutral term "angler"):

- Premise: if the angler deliberately inflicts pain on fish and the infliction of pain on fish is the source of enjoyment, then sportfishing is an activity that involves deliberate and excessive cruelty morbidly enjoyed;
- Premise: the angler deliberately inflicts pain on fish;
- Premise: the infliction of pain on fish is the source of enjoyment for anglers;
- Premise: all activities that involve deliberate and excessive cruelty morbidly enjoyed are sadistic;
- Premise: all sadistic activities are unethical activities;
- Conclusion: sportfishing is an unethical activity.

Indigenous people advocate for banning the practice of catch-and-release fishing. In Switzerland and Germany, catch-and-release fishing is considered inhumane and is now banned. In some cases, the acceptance of the pain and suffering argument has led to bans on competitive fishing, put-and-take fishing, and use of live baitfish. The sadistic argument has not persisted because in the mind of the angler, there is a disconnect between fish behavior and fish pain. It is not the infliction of pain in fish that the angler enjoys but the experience of enticing the fish to bite and retrieving the struggling fish. If the fish did not struggle on the line, it is unlikely that sport anglers would pursue fishing. To argue that all who participate in sportfishing are sadists is an attack on the person more than the argument. *Argumentum ad hominem*, which refers to an attack on the person and not the argument, is a weak form of argumentation. Sportfishing may be wrong, but those who participate in the activity need not be sadists.

Those who argue for welfare considerations for fish from a functions-based view recognize that angling induces stress and may cause injuries (Arlinghaus et al. 2007, 2009; Arlinghaus and Schwab 2011). For example, angling often causes injuries that may depress the ability of the fish to feed and survive after release (Thompson et al. 2018). The pragmatic argument maintains that recreational fishing is a legitimate leisure activity that also contributes to overall food security and personal nutrition (Cooke et al. 2018). Furthermore, fishing may serve as a therapeutic coping mechanism for distressed individuals (Craig et al. 2020). The pragmatic argument may or may not accept the existence of pain, suffering, and consciousness in fish. However, rather than applying a rigid egalitarian perspective that fish morally deserve equal status, the pragmatist adapts to the complexity of real-life tradeoffs (Crittendon 2003; Dawkins 2017). Hence, the focus is on the welfare of fish from measures of health and fitness of individuals and attempt to balance the interests of anglers with the interests of fish. Anglers and fisheries managers may implement regulations or recommendations for gear choice, landing nets, catch-and-release fishing, and other practices that minimize fish welfare impairments (Ferter et al. 2020).

In practice, the weighing of concerns of fish and humans has not been a routine activity (Sandøe et al. 2009), but it is obvious in some fishing codes of ethics. Cooke and Suski (2005) and Cooke and Sneddon (2007) suggested that there are specific actions that anglers could take to minimize negative consequences on fish.

- Minimize angling duration.
- Minimize air exposure and improve handling.
- Terminal tackle choices can affect fish.
- Avoid angling in extreme environmental conditions or habitats.
- Avoid angling during the reproductive period.
- Avoid tethering of live fish on stringers.
- All fish bleeding from hooked gills should be killed.
- Dispatching a caught fish should be undertaken quickly and humanely by a blow to the head or spiking through the brain just behind the eye.

Questions to ponder:

Consider the last time you went fishing for recreation. How did you handle your catch? Was it released? If you kept it, did you kill it in a humane way? Watch this video, "The Right Way to Kill a Fish." The video demonstrates the use of ikejime for humane killing of recreationally caught tuna. Do you know how the fish you purchase to eat are caught and killed?

5.10 Commercial and Subsistence Fishing

Most discussions around commercial and subsistence fishing focus on conservation and maintenance of traditional fishing-based livelihoods and not on the emerging evidence of pain and suffering of fish. Suffering is caused to wild-caught fish throughout the process of capture until death. Yet, discussion of capture, landing, and killing practices in commercial fisheries is uncommon. However, advocates for animal welfare for commercially caught wild fish highlight the trillions of slow deaths (Mood 2010). Globally, 84 million tonnes of fish were harvested in 2019. In terms of numbers, between 0.8 and 2.3 trillion fish were killed each year by commercial fishing operations between 2007 and 2017 (based on registered landings only, not including all bycatch and discards; fishcount.org.uk). Observations of fishing at sea are difficult; but a few studies report that most fish were alive and conscious when landed and left to die of asphyxia or gutted alive. Death may typically take one hour (trawls), from one to four hours (seines), and from four to six hours (hooks), depending on the species, while nets may take up to 24 hours (Håstein et al, 2005). Moreover, the practice of placing live fish on ice merely prolongs the suffering.

Commercial and subsistence fishing provides food necessary for human sustenance, which would qualify as a reason for certain infringements on the interests of fish. However, the compromises that are morally acceptable depend on the philosophy being applied (Sandøe et al. 2003). If one argues that it is morally impermissible to harvest fish from the wild, and if it were to be prohibited, the lifestyle of many traditional and modern communities would be lost. Perhaps the moral benefit of preserving these communities and lifestyles outweighs the harm of at least certain kinds of fishing. The principle of cultural preservation would claim that fishing is a long-standing cultural practice that is central to a community's way of life. The cultural preservation arguments would support claims for preserving fishing as a moral consideration to be weighed against other moral considerations. These arguments are especially relevant for small-scale **artisanal** or subsistence fishing.

Welfare of commercially caught and farmed fish from the wild is the last frontier for animal food production (Cook et al. 2018; Browman et al. 2019). These types of debates are inevitable, and guidelines for responsible fisheries were outlined in the Food and Agricultural Organization Code of Responsible Fisheries (FAO 1995). The FAO has no legislative authority, so the code is voluntary and depends on the willingness of the fishing industry, fishery managers, fishing communities, and peer pressure for adoption. Stakeholders in the commercial and subsistence fishing sectors must participate and raise concerns about the human interests to be balanced against interests of fish (Lam and Pitcher 2012; Lam 2019).

Question to ponder:

The largest fishery in the USA targets Alaska Pollock via midwater trawls. Vessels harvest, process, package, and freeze catch within hours of harvest to produce frozen fillets, fish sticks, and to supply McDonald's Filet-O-Fish®. Learn more about this large commercial fishery by watching this video. How might you address fish welfare issues in this fishery?

5.11 Welfare Considerations in Fish Farming

Fishing farming is the fastest-growing animal producing sector in the world and plays an important role in global food security. Since the 1990s, most growth in fish production has come from aquaculture, which currently accounts for 49% of total fish production (FAO 2020). Many challenges face the fish farming sector as it grows (Klinger and Naylor 2012), and fish welfare has not been a priority concern. Between 48 and 160 billion farmed fishes were slaughtered in 2015 (fishcount.org.uk). Fish farmers understand the many benefits to improving animal welfare and know that improvements to food production systems that allow fish to thrive, grow, and stay healthy will result in higher-quality fish products. Although there are currently no laws providing protection of farm-raised fish in the United States or in the European Union, the emergence of animal welfare concerns led to criteria for feeding, housing, health, and emotional states for all captive animals, including farmed-fish criteria (Botreau et al. 2007; Levenda 2013). For example, Norway is the world's leading exporter of salmon and trout, and the Norwegian Animal Welfare Act (passed in 2010, Olesen et al. 2011) protects all vertebrates raised for food. Salmon farming has grown in size and intensity, from net-pen culture to land-based salmon farms, some of which are capable of harvesting over 1,000 tonnes per year (https://salmonbusiness.com/these-are-the-leading-land-based-salmon-farms-in-the-world-right-now/).

Fish farming adopts welfare indicators to judge the state of the welfare of farmed fish. Prominent welfare standards exist for Atlantic Salmon and Rainbow Trout (Noble 2020). Welfare indicators include disease, parasites, wounds, anomalies, and behavior, which are each scored from good to bad. High-intensity, high-output fish farms have the greatest welfare concerns due to overcrowding, handling, transport, starvation, and slaughter (Ashley 2007; Santurtun et al. 2018). A global assessment of welfare of 41 farmed fish indicated that the majority of fish farms have poor welfare conditions (Saraiva et al. 2019).

Indicators of the welfare of fish may be used by fish farms to draw attention to early signs of problems related to captivity conditions and allow intervention before harmful states are reached (Arechavala-Lopez and Saraiva 2019). For example, the social environment for Nile Tilapia had negative effects on stress levels, growth, and aggression, all of which can be resolved with changes in lighting, environment color, and enrichment structures (Gonçalves-de-Freitas et al. 2019). The more intelligent an animal, the more cognitive stimulation it requires to avoid boredom and experience positive states such as pleasure and excitement. Changes in the design of fish farms that recognize the unique behavioral needs of the fish being raised may yield important benefits to fish welfare and farm yields (Fife-Cook and Franks 2019). Furthermore, Norwegian consumers are willing to pay more for improved welfare in farmed salmon (Grimsrud et al. 2013).

Question to ponder:

Watch "Rethink Fish" here. What questions or concerns do you have about how your farmed fish are raised?

5.12 Killing Fish

Fish slaughter is the process of killing fish, typically after harvesting at sea or from fish farms. Despite the trillions of fish slaughtered annually, they are excluded from the U.S. Humane Slaughter Act (P.L. 85-765; 7 U.S.C. 1901 et seq.). This means that fish are killed without regard to the suffering they endure before death.

In 2004, the European Food Safety Authority observed that "Many existing commercial killing methods expose fish to substantial suffering over a prolonged period of time." The Aquatic Animal Health Code of the World Organisation for Animal Health considers the following slaughter methods inhumane: air asphyxiation, ice bath, salt or ammonia bath, and **exsanguination** without stunning. More humane killing methods include stunning, pithing, and electrical stunning, and inventors have filed dozens of patents for stunning devices (Lines et al. 2003). Percussive and electric stunning causes loss of consciousness, based on EEG correlations (Robb et al. 2000). While some ethicists have argued that there are no available humane slaughter methods for fish (Browning and Veit 2020), improvements in killing techniques are being adopted by some fisheries (Goldfarb 2019).

Recent discoveries demonstrate that the more humanely a fish is killed, the better it tastes (Bane 2015; Lefevre et al. 2016; Goes et al. 2019). The combination of stress and intense physical activity can increase the degree of protein denaturation, leading to faster muscle softening (Hultmann et al 2012). This discovery provides a utilitarian argument for humane killing. Humane slaughter has been adopted in some fish farms. Are consumers willing to pay? Some high-end restaurants purchase "Humane Harvest" cod for their menus, providing direct value for welfare of sentient animals (Carlier and Treich 2020).

Question to ponder:

Socrates, in Plato's Republic, said, "Would this habit of eating animals not require that we slaughter animals that we knew as individuals, and in whose eyes we could gaze and see ourselves reflected, only a few hours before our meal?" (360 BC). How often have you looked into the eyes of an animal you were about to slaughter for a meal? Do you agree with Marc Bekoff (2018) that "It's time to stop pretending that fish don't feel pain."

Watch "How to Kill a Fish" here.

If you had to kill an animal in order to eat it, would you eat less meat?

5.13 Closing Thoughts

The debates over pain in fish have illustrated the difficulty that people have in changing long-held views and behaviors. Scientists need to do more than provide evidence in scientific articles that test whether fish are sentient and emotional beings who feel pain. Dialogue about the issue has more frequently been presented at one-way arguments that were certain to be countered with alternative interpretations. Simply giving people more information does not necessarily change how people feel about an issue. This is referred to as the information deficit model, which attributes skepticism or hostility to a lack of understanding and a lack of information. Scientists who study the public understanding of science have concluded the information deficit model is an insufficient strategy for communication and changing people's views. One alternative strategy for communicating in contentious situations involves making personal connections in ways that permit the participants to listen, share, and connect with others in order to understand the mental model(s) used by others (Crandall et al. 2020). The process of dialogue can build understanding of personal values, interests, ideology, worldviews, moral foundations, group identity, and religious background that contribute to disputes. Although disagreements will continue, the process permits all stakeholders in fish welfare issues to contribute to solutions.

Profile in Fish Conservation: Culum Brown, PhD

Scan the QR code or visit https://doi.org/10.21061/fishandconservation to listen to this Profile in Fish Conservation.

Culum Brown is Professor of Fish Behavioral Ecology at Macquarie University, where he directs research in the Behaviour, Ecology and Evolution Laboratory. His lab studies social learning and memory in a variety of fish. Some journalists refer to him as Dr. Fish Feelings in recognition of his expertise in fish feeling.

Figure 5.6: Culum Brown, PhD.

His research has revealed that many fish are sophisticated learners that can retain memories for months. His findings related to social learning in fish have direct implications for conservation and restoration of exploited fish. For example, if older, more experienced fish are preferentially harvested, the collective information on feeding and breeding grounds and migration routes may be lost, thereby reducing growth and survival. Also, widespread use of hatchery-reared fish is inefficient because of the high mortality they experience immediately after release. He developed protocols for life-skills training to improve performance of salmonids after release in the wild. Expanding our knowledge of the role of learning in fish behavior has direct applications to welfare of fish raised in captivity for release or human food. Understanding the behavioral preferences provides fish farmers with specific ways to enrich the environment.

Dr. Brown's research asks basic questions about learning and memory in the natural environment. Fish have a richer visual and acoustic environment than humans can appreciate. Fish have advanced sensory capabilities for vision, hearing, and smell, that directly influence their abilities to learn about their environments and communicate with other fish. For example, most fish have four types of cones in their eyes, and therefore they see more colors and see them more vividly than humans can. The ability of some fish to detect polarized and ultraviolet light waves permits them to distinguish more from their environment than humans can see. In addition to vision, fish hear an amazing chorus from animals underwater and communicate with other fish by making all sorts of fishy sounds. Vision, smell, and hearing enable fish to orient in familiar locations and remember locations of food patches, shelter, and breeding sites.

Another character trait explored by Culum Brown's lab is the notion of personality in fish. His lab has found that personality, laterality, and stress reactivity are all linked. Most humans are right-handed, and other vertebrates show lateral preferences in the brain that translate into sidedness. This question of left-right dominance was seldom studied in fish, until Culum Brown's lab investigated whether native rainbow fish used one eye or both eyes while looking out for potential dangers. The rainbow fish showed differences in boldness, a personality trait, and their personality was linked to whether one eye or both eyes were dominant.

One of Dr. Brown's popular research subjects is the Port Jackson Shark, which he calls the "puppies of the sea." His research discovered the complex social structure and intelligence in the Port Jackson Shark, disputing the notion that sharks are robot-like, antisocial killers. Recent research reveals that Port Jackson Sharks show individual preferences for either left-eye or right-eye dominance, have personalities, and vary in how they respond to handling (docility). Following highly mobile sharks and rays, his research has demonstrated group formation and affiliation among social networks. The abilities to learn, remember, communicate, form relationships, and use tools are all characteristics of sentience.

Brown's collective works in behavior and cognition have contributed to the formation of a new field of neuroethics of nonhuman animals. He released a collection of works in two books, entitled *Fish Cognition and Behaviour*, published in 2006 and 2011, and he has published more than 150 scientific articles on fish behavior. He is also Editor of the *Journal of Fish Biology*. His work on fish cognition is increasingly used as a basis for the justification of positive welfare for fish.

For more information, see https://www.thefishlab.com/PI.html.

Key Takeaways

- Humans use fish in a variety of ways, which may influence how they perceive the value of a fish's life.
- Fish feel pain and suffer as a consequence, and we must carefully examine welfare, use, and fishing practices.
- Studies of pain in fish examined pain receptors, nerve activity, and behavior change.
- Whether an animal is sentient is based on five capabilities that have been studied scientifically.
- Scientists apply the three Rs—Replacement, Reduction, and Refinement—for consideration when minimizing pain and suffering in experiments.
- Actions to improve welfare in recreational and commercial fisheries and fish farms are part of lively debates.

This chapter was reviewed by Culum Brown.

URLs

Video 1: https://www.youtube.com/watch?v=TS4AM9mPX-8

Video 2: https://www.youtube.com/watch?v=WXCzpamTvcc

Video 3: https://www.ciwf.org.uk/our-campaigns/rethink-fish/

Humane Harvest: https://www.hsa.org.uk/

Video 4: https://www.youtube.com/watch?v=TS4AM9mPX-8

Long Descriptions

Figure 5.1: Anti-fishing slogans "don't let your kids become hookers," "fishing hurts," "Your daddy kills animals" rose in late 1980s and again from 2000-2010 and 2018 and on. Jump back to Figure 5.1.

Figure 5.2: Position of polymodal mechanoreceptors (or nociceptors), mechanothermal receptors, and mechanochemical receptors on the head and face of the rainbow trout. Pale yellow circles: polymodal nociceptor. Black circles: mechanothermal nociceptor. Green circles: mechanochemical receptor. Jump back to Figure 5.2.

Figure 5.3: These are the 5 factors that contribute to sentience in fish: 1. Evaluation behavior of others; form relationships, 2. Remember own actions' use memory to inform future behavior, 3 . Assess risks and benefits to make decisions, 4. Positive or negative affective states such as pain, fear, pleasure, 5. Some degree or awareness. Jump back to Figure 5.3.

Figure 5.4: Line graph A) The binary model shows that canines, felines, most birds, fish, monkeys, and most other species have no self-awareness. Line graph B) The gradualist view shows a linear climb of self-awareness starting with smaller-brained animals, dogs, cats, pigs, monkeys, parrots, cleaner fish, elephants, dolphins, magpies, and doesn't reach mirror self-recognition until Hominids. Jump back to Figure 5.4.

Figure 5.5: An arrow displays two categories with (left) consumptive, anthropocentric, harm to life, for human benefit and (right) non-consumptive, bicentric, no intentional harm to life. From left, motivations listed include, 1) fish farming (profit); 2) commercial fishing (profit); 3) subsistence fishing (livelihood); 4) recreational fishing (food); 5) recreational fishing (trophy); 6) recreational fishing (catch and release); 7) fish viewing. Jump back to Figure 5.5.

Figure References

Figure 5.1: Frequency of appearance of "pain in fish" in books since 1965 coincides with appearance of antifishing slogans after 1996. Kindred Grey. 2022. CC BY 4.0. Data from Google ngram viewer.

Figure 5.2: Sketch of Rainbow Trout with locations of nociceptors. Kindred Grey. 2022. Adapted under fair use from *Do Fishes Have Nociceptors? Evidence for the Evolution of a Vertebrate Sensory System*, by Lynne U Sneddon, Victoria A Braithwaite, and Michael J Gentle, 2003 (doi: 10.1098/rspb.2003.2349). Includes PSM V47 D194 Rainbow Trout Adult Salmo Mykiss Walbaum, by unknown author, 1895 (public domain, https://commons.wikimedia.org/wiki/File:PSM_V47_D194_Rainbow_trout_adult_salmo_mykiss_walbaum.jpg).

Figure 5.3: Diagrammatic representation of the five capabilities that make an animal sentient. Kindred Grey. 2022. Adapted under fair use from "Mental Capacities of Fishes," by Lynne U. Sneddon and Culum Brown, 2020 (https://doi.org/10.1007/978-3-030-31011-0_4).

Figure 5.4: Two different perspectives on the evolution of self-awareness. Kindred Grey. 2022. CC BY 4.0. Adapted from "Fish, Mirrors, and a Gradualist Perspective on Self-Awareness," by Frans B. M. de Waal, 2019 (CC BY 4.0, DOI:10.1371/journal.pbio.3000112).

Figure 5.5: Human motivations for types of fish and fish viewing. Kindred Grey. 2022. Adapted under fair use from *Tourism and Animal Ethics*, by David A. Fennell, 2012, 182 (ISBN 9781138081345).

Figure 5.6: Culum Brown, PhD. Used with permission from Culum Brown. CC BY 4.0.

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6. Public Aquariums and Their Role in Education, Science, and Conservation

Learning Objectives

- Explain the conservation mandate of public aquariums for research, conservation outreach, policy, and education.
- Summarize the motivational factors of visitors to public aquariums.
- Articulate the potential affects that visitation to public aquariums has on visitors.
- Describe new initiatives to propagate rare and endangered fish in partnerships with public aquariums.
- Examine the future challenges for public aquarium management.

6.1 Role of Public Aquariums

Public aquariums[1] are special places for people to learn about aquatic life. The number of public aquariums has grown since the opening of the first in Regent's Park, London, in 1853 (Hillard 1995). Early aquariums were devoted to game fish and were auxiliary locations for hatchery-reared fish. Public aquariums have four aims today—aesthetic, educational, entertainment, and scientific—while introducing many people to fish, their adaptations, habitats, values, and human uses. Expansion of aquariums in many large urban centers was intended to enhance tourism and promote an "Age of Aquariums" (Murr 1988). Broad-based community support and high visitation rates make public aquariums among some of the most important places for public engagement in fish conservation to begin. More than 700 million people visited zoos and aquariums worldwide in 2008 (Gusset and Dick 2010). In the United States alone, over 183 million people visit zoos and aquariums annually—this is three times the number of recreational anglers in the country.

1. I use the term *public aquarium* to include institutions, such as aquariums and marine parks, open to the public that may be supported by private or public funds.

The World Association of Zoos and Aquariums defines conservation as "securing populations of species in natural habitats for the long term" (Barongi et al. 2015). As you read more about the roles and challenges of public aquariums, you should envision the future potential for public aquariums to become even more influential in fish conservation programs. Public aquariums strive to communicate the issues, raise awareness, change behaviors, and gain widespread public and political support for conservation actions (Reid et al. 2013). Aquariums are often the first place where aspiring young conservation champions are first exposed to aquatic animals. For example, pioneering ichthyologist Dr. Eugenie Clark first visited the New York Aquarium at age nine (Clark 1951).

Large public aquariums are accredited by the Association of Zoos and Aquariums. Accreditation is a process by which the aquarium is evaluated by experienced and trained experts in operations, animal welfare and husbandry, and veterinary medicine and is measured against the established standards and best practices of aquarium management. In accredited aquariums, the behavioral and physical needs of animals are being met by providing opportunities for species-appropriate behaviors and choices. Consequently, a reliable way to choose an aquarium for visitation is to look for the notice, "Accredited by the Association of Zoos and Aquariums."

6.2 Education and Interpretation

Education and interpretation are both on-site and off-site programs for targeted audiences, such as school groups, teachers, and families. Educational programs are proven methods for increasing awareness and participation in aquatic conservation. Conservation education programs are designed to fulfill specific goals of each institution. Many types of interpretive methods may be employed, but they typically involve graphic and video displays, exhibits of live animals, ambassador animals, and talks by animal care and conservation specialists.

At a time when fish conservation needs are acute in marine and freshwaters, the tensions and tradeoffs are apparent for aquarium conservation programs. Animal welfare concerns must be balanced against educational values of displays (Maynard 2018). **Built aquatic habitats** vary greatly in their suitability for fish. Consequently, the displays offer the potential to explain unique requirements of the displayed animals. Increasingly, video displays have emerged for education that can be delivered at aquariums as well as online. For example, Shark Cams (explore.org) installed around the world provide a view of sharks in their underwater world.

While shark displays are very popular in public aquariums, they may invoke controversies. Some aquarium goers prefer sharks with a predatory appearance, with streamlined bodies that display strong swimming ability. These include Blacktip Shark, Grey Reef Shark, and Sandbar Shark. Such shark displays require enormous tanks and skilled and experienced caretakers who use feeding tongs to ensure proper nutrition, thereby minimizing sharks eating their tank mates. Large sharks are difficult to capture and transport from the wild to aquariums. Sharks have declined in many parts of the world (Dulvy et al. 2014), and displays must convey a strong conservation message to justify their captivity. Other sharks, such as the Zebra Sharks, nurse sharks, carpet sharks, and other skates and rays more readily adapt to life in captivity.

Ambassador animals provide a powerful catalyst for learning. These are select animals whose role includes handling and/or training by staff or volunteers for interaction with the public and in support of institutional education and conservation goals. They allow the public to observe and interact with an animal that they may never see otherwise (Spooner et al. 2021). Ambassadors are important advocates for the protection of habitats and animals in nature.

In the 1930s, the John G. Shedd Aquarium in Chicago displayed a Smalltooth Sawfish (*Pristis pectinata*, Figure 6.1) for the first time. Since that time, other public aquariums have connected visitors with these unique and endangered fish. Millions of visitors have enjoyed the experience of seeing a sawfish up close and wondering about their existence in the wild. Worldwide, the sawfish and rays are among the most endangered fish. The educational displays of sawfish create a common understanding of their plight as the first step in a multifaceted approach needed to conserve populations of sawfish.

Figure 6.1: Smalltooth Sawfish from public aquarium display.

In an age where children lack nature experiences, public aquariums, by providing access to live animals in natural-like settings, enable human-fish relationships to be developed (Miller 2004; Louv 2008; Bekoff 2014; Brown 2015). Visitation at public aquariums allows thoughtful people to build a common definition of the conservation problem and understanding of the essential planning process.

The education and interpretation missions are undoubtedly the most important. They connect people to animals that they may never see otherwise, and that connection is important in developing advocacy for protection of habitats and animals in nature. To expand their education impact, public aquarium staff often collaborate with community groups, school districts, local colleges, and universities to expand the reach of education and interpretation programs.

6.3 Connecting Aquarium Visitors to Biodiversity Conservation

How do we motivate people who do not fish to care about aquatic life? Millennials, people born between 1981 and 1997, are more likely to be concerned with animal welfare issues than environmental protection (Palmer et al. 2018). Millennials are also more likely to believe in individuals as the source of solutions and trust less in the effectiveness of governments or nongovernmental organizations (Dropkin et al. 2015). Public support for conservation depends on committed and engaged conservationists who work for or with public aquariums. Their actions flow from acceptance of wildlife values, beliefs that fish are under threat, and beliefs that personal actions can help alleviate the threat and restore values. Self-interest, altruism toward other humans, and altruism toward other species and the biosphere are value orientations linked to pro-environmental behavior (Stern et al. 1999). People can be subtly influenced to change their behavior (i.e., nudged) by using seemingly innocuous persuasion (Thaler and Sunstein 2008). Committed individuals move conservation forward via pro-environmental behavior, often in the face of **inertial** and active resistance (Ballantyne and Packer 2016).

All members of the World Association of Zoos and Aquariums have a goal of creating a strong connection between their resident animals and their counterparts in nature and **integrated species conservation plans** (Barongi et al. 2015). The educated public expects a strong conservation message from public aquariums. Some of the best public aquariums have dynamic educational programs as well as collaborative **in situ** conservation programs (Knapp 2018). Public aquariums train and support staff in accurately evaluating educational benefits of visitation via questionnaires and interviews (Falk et al. 2007; Marino et al. 2010; Mellish et al. 2019). Understanding and knowledge of biodiversity loss significantly increased after visits relative to previsit levels (Moss et al. 2015).

But do aquariums influence conservation actions? Empathy for the plight of animals is an emotional capacity that develops over time and is reinforced through interactions (Fennel 2012). Empathy relies on the ability to perceive, understand, and care about the experiences or perspectives of another person or animal. Empathy, an internal motivator toward acting, is elicited more by exposure to primates, elephants, and canines than to fish. Fish lack facial expressions and other cues for human empathy (Myers 2007; Webber et al. 2017). Motivating visitors to take action is a complex interplay among barriers, incentives, affective outcomes, and internal motivators (Young et al. 2018). Research studies support the idea that people who establish personal connections with nature are likely to value and protect elements of natural environments. Public aquariums play an essential role in providing opportunities for people to connect to fish and aquatic life and learn to care about conservation. Positive messaging, rather warnings about a coming apocalypse, are more likely to result in support for conservation actions (Jacobson et al. 2019).

Questions to ponder:

The following quote by Baba Dioum is often used in communications about conservation:

"In the end we will conserve only what we love, we will love only what we understand, and we will understand only what we are taught." Baba Dioum (1986, cited in Valenti et al. 2005)

Do you agree or disagree with this sentiment? What type of information is most relevant to you in supporting conservation practices?

6.4 Restorative Nature of Public Aquariums

Public aquariums are popular tourist attractions and are interested in the guests' motivations and experiences. Many are interested in whether an aquarium visit provides humans benefits in terms of psychological well-being or relaxation. Humans benefit from interactions with companion animals, primarily cats and dogs. If you ever had a pet dog, you know dogs can relieve a sense of loneliness. Dogs seem to know when you are feeling down and provide emotional support. Studies show that interactions with nonhuman animals lowered blood pressure and reduced risk of heart disease (Levine et al. 2013; Stanley et al. 2014; Mubanga et al. 2017; Brooks et al. 2018). Is it possible our interactions with pets can lead to longer life spans? A review paper published by the American Heart Association concluded that (1) pet ownership, particularly dog ownership, may be reasonable for reduction in risk of cardiovascular disease; and (2) pet adoption, rescue, or purchase should not be done for the primary purpose of reducing risk of cardiovascular disease (Levine et al. 2013). The association of pet ownership and regular aerobic activity is likely related to the effects. Although the "pet effect" on physical and mental health remains a hypothesis that is routinely debated, therapeutic interventions with animals continue to be practiced.

Few systematic studies have measured the benefits of fish viewing. Those who keep fish as pets find that it provides purpose and enjoyment in life (Langfield and James 2009). Early observations in medical facilities suggested a link between viewing fish in aquariums and benefits such as reduced blood pressure and increased relaxation (Riddick 1985). In controlled, experimental settings, fish viewing improved mood and reduced anxiety (Wells 2005; Gee et al. 2019). In some cases, fish viewing reduced stress and anxiety in patients (Cracknell et al. 2018; Clements et al. 2019). It is difficult to design a study of the psychological or physiological responses of visitors to public aquariums because of the difficulty of isolating causal factors, such as what exhibits were viewed or the effects of social interactions during the aquarium visit. However, there are enough indications that aquarium visiting has a calming effect (Cracknell et al. 2018; Clements et al. 2019) to support the argument that biodiversity in aquariums may influence well-being outcomes for the visitors.

***Questions to ponder*:**

Can you remember a visit to a public aquarium? In what ways were you affected by the visit? Can you describe the type of exhibit or experience that was most memorable? Does it matter to the visitors that the displays at public aquariums are built and not natural?

6.5 Conservation and Public Aquariums

The larger and more progressive public aquariums are expanding their missions and conservation portfolios to align with the World Zoo and Aquarium (WZ Conservation Strategy (Barongi et al. (2015), which calls for a more action-driven, field-based conservation. Many responsibilities are outlined here:

- Provide the highest-quality care and management of wildlife within and across institutions.
- Develop and adapt intensive wildlife-management techniques for use in protecting and preserving species in nature.
- Support conservation-directed social and biological research.
- Lead, support, and collaborate with education programs that target changes in community behavior toward better outcomes for conservation.
- Use zoological facilities to provide for populations of species most in need of genetic and demographic support for their continued existence in the wild.
- Promote and exemplify sustainable practices in the management of animal populations, our facilities, and the environment.
- Provide a public arena to discuss and debate the challenges facing society as extinction accelerates and ecosystem services are degraded.
- Act as rescue-and-release centers for threatened animals in need of immediate help, with the best knowledge and facilities to care for them until they are fit to go back to the wild.
- Be major contributors of intellectual and financial resources to field conservation.
- Provide ethical and moral leadership.

In 2014, the Association of Zoos and Aquariums developed a common approach for expanding the scope of field conservation called Saving Animals from Extinction (SAFE). The mission of SAFE is to "combine the power of zoo and aquarium visitors with the resources and collective expertise of AZA members and partners to save animals from extinction." This mission is achievable because accredited zoos and aquariums are uniquely positioned to become a force for global conservation, with more scientists, more animals, and more ability to activate the public than any other nongovernmental institution. SAFE is built on aquarium and zoo's 100-year track record of success in saving endangered species from extinction. SAFE uses the One Plan Approach, where management strategies and conservation actions are developed by those with responsibilities for all populations (Grow et al. 2018). Priorities for selecting conservation projects depend on location, expertise, collection composition, institutional culture, financial restrictions, and collaboration with stakeholders (Knapp 2018). Sharks and rays—which are decreasing at alarming rates along with many critically endangered species and lack sustainable captive populations—were the first group of fish to be selected for applying the AZA SAFE approach. Seattle Aquarium, Shark Trust, Point Defiance Zoo & Aquarium, North Carolina Aquariums, the Wildlife Conservation Society, and many others collaborate to leverage the large audiences of public aquariums to increase awareness.

In some cases, public aquariums have dedicated research institutes to lead research efforts. For example, the Monterey Bay Aquarium Research Institute is a world leader in deep-ocean science and technology and uses novel tools to monitor ocean change, carbon emissions, and harmful algal blooms. Public aquariums with a long history of focusing on discoveries have been instrumental in supporting explorers and scientists. Consider the inspirational story of Eugenie Clark, who became a world authority on sharks and fish and founded the Mote Marine Lab (Rutger 2015), which later added a public aquarium. Eugenie Clark's first exposures to marine life, as noted earlier, were at the New York Aquarium at age nine. She made the first groundbreaking discovery that sharks could be trained to learn visual tasks as fast as some mammals, and she left a long legacy of shark research.

Large public aquariums are engaged in numerous partnerships for conservation. These partnerships require trust, a key driver for effective collaborations, conflict resolution, and performance in implementing conservation (Ostrom 2003; Fulmer and Gelfand 2012). Nonscientists form public opinions about conservation policy issues and rely on many sources. Scientific knowledge is only one source, but it enables citizens to engage in political decisions. Public aquariums, through their combined mission of conservation science and education, are a trusted source of science information and work on fish conservation through many partnerships (Rank 2018; Huber et al. 2019).

Many public aquariums also work to restore degraded local habitats and support ecosystem health. In these actions, they must partner with local volunteers in nearby waters, parks, forests, and preserves. Public aquariums in large urban centers work to install treatments that help reverse effects of polluted stormwater runoff for impervious surfaces, storm drains, cracked pipes, and more. The National Aquarium in Baltimore, Maryland, and the Shedd Aquarium in Chicago, Illinois, are installing floating wetlands to treat excess nitrogen and create fish habitat in the local waters. The plants on the wetlands grow **hydroponically** and take up nutrients directly from the water before they cause harmful algal blooms. In these highly modified, urban waters, the floating wetlands are planted with native plants and attract a variety of native species. The floating wetland prototype designed by the National Aquarium was recognized by the American Society of Landscape Architects.

Figure 6.2: Floating wetland at Inner Harbor, Baltimore.

Larger public aquariums, including the New England Aquarium, Monterey Bay Aquarium, and Shedd Aquarium, are global leaders in outreach and use a portion of their budgets to fund larger programs. Shedd Aquarium has focused on charismatic flagship species, such as seahorses, sharks, and Nassau Grouper in The Bahamas, *Arapaima* in Guyana, as well as less well-known species, such as Queen Conch in the Caribbean and suckers in the Great Lakes. These outreach programs follow naturally from a vibrant research program focused on marine species (corals, Queen Conch, Nassau Grouper, sharks, and rays) and freshwater species (amphibians, freshwater mussels, and a diverse array of Great Lakes fish).

The public aquariums have scientific expertise on their staffs that give these conservation initiatives strong scientific grounding. A recent decline in favorability toward zoos and aquariums (Bergl 2017) may suggest a **concomitant** decline in trust; however, there are numerous examples of productive fish conservation programs emanating from public aquariums. Some public aquariums have research in their mission statements and support their staff to do research with direct conservation benefits (Knapp 2018; Loh et al. 2018). Consequently, you will find public aquariums playing an essential role as a trusted resource on fish conservation partnerships throughout the world. Collaborative programs include numerous partnerships. For example, the World Fish Migration Day raises global awareness about free-flowing rivers and migratory fish. Global FinPrint unites collaborators around the world to study sharks, rays, and other marine life with baited remote underwater video.

***Question to ponder*:**

Can you imagine ways in which aquarium visitation leads to the appreciation and conservation of the natural environments and life therein?

6.6 Partnerships to Propagate and Restore Rare Fish and Habitats

On any visit to a large public aquarium, you will learn about efforts to propagate and restore rare fish. You may even be able to view rare or extinct in the wild fish. Currently, aquariums hold four of the six fish species listed by the IUCN Red List as "Extinct in the Wild." (Table 6.1; da Silva et al. 2019). Public aquariums often keep and breed threatened species in captivity until such time as suitable conditions exist for reintroduction to the wild. Many other species with conservation value are held and, in some cases, propagated by public aquariums. In fact, 9.3% of ray-finned fish species, 10.7% of sharks, skates, and rays, and 62.5% of all lobe-finned fish species are displayed in public aquariums (da Silva et al. 2019).

Conservation cannot be done in a vacuum. For example, the Tennessee Aquarium was part of a team that discovered the few remaining populations of the Barrens Topminnow (*Fundulus julisia*), an endangered fish that occurs only in isolated springs of Tennessee (George et al. 2013). The Barrens Topminnow is endangered because many spring ponds and runs were converted to livestock pastures or plant nurseries, and the introduced Western Mosquitofish (*Gambusia affinis*) eat their young. These findings naturally led to proposing actions in concert with other conservation partners. Aquariums are ideally placed to influence public opinion and policy makers so that more species threatened by international trade are included on the list in the multilateral treaty, Convention on International Trade in Endangered Species (CITES 1973).

Fish species on IUCN Red List	
Potosi Pupfish	*Cyprinodon alvarezi*
La Palma Pupfish	*Cyprinodon longidorsalis*
Butterfly Splitfin	*Ameca splendens*
Golden Skiffia	*Skiffia francesae*

Table 6.1: Four fish species on IUCN Red List "Extinct in the Wild" held in public aquariums.

Public aquariums, because of their in-house expertise, can act quickly to collect and breed rare fish. Actions to prevent the extinction of the Barrens Topminnow include monitoring populations and propagating and stocking juveniles into existing or newly created spring habitats. The Tennessee Aquarium assisted with propagations and developed a program called "Keeper Kids," where students on spring break help feed the Barrens Topminnows in a behind-the-scenes experience.

Figure 6.3: Photo of the critically endangered Butterfly Splitfin (Ameca spendens).

The breeding colonies of the Butterfly Splitfin (Figure 6.3) at the London Zoo and elsewhere serve as ark populations essential to the survival of this species. Butterfly Splitfins are endemic to the Río Ameca in western Mexico and almost extinct in the wild. Actions such as nonnative fish removal, stream restoration, and sanctuary designation may take decades before eventual introduction and survival in the wild. The Tennessee Aquarium is part of a large partnership to guide hatchery augmentation and recovery of the rarest darter in North America (U.S. Fish and Wildlife Service 2019). The Conasauga Logperch (*Percina jenkinsi*), a federally endangered darter (Percidae), is found only in a 30-mile (48 km) stretch of the Conasauga River in Georgia and Tennessee (Moyer et al. 2015).

Figure 6.4: Lake Sturgeon (Acipenser fulvescens).

The Banggai Cardinalfish (*Pterapogon kauderni*), a small, endangered tropical cardinalfish in the family Apogonidae, is now bred and displayed in numerous public aquariums after overharvest in the wild drove wild populations to near extinction. Consequently, most Banggai Cardinalfish sold to hobbyists in the United States and European Union today are captive bred.

Finally, the expertise in husbandry has led to high standards for care of fish in captivity and numerous published husbandry manuals (Grassman et al. 2017).

The Saving the Sturgeon program is a collaborative effort to reintroduce Lake Sturgeon (*Acipenser fulvescens*, Figure 6.4) into the Tennessee River and surrounding waters (George et al. 2013). Lake Sturgeon, an important commercial species, was once abundant throughout the Great Lakes and Mississippi River drainages. It was overfished, and spawning migrations were blocked by construction of dams. By the 1970s it was extirpated from the Tennessee River. This collaborative program is a formal partnership of the Tennessee Aquarium, Tennessee Aquarium Conservation Institute, Tennessee Tech University, University of Tennessee, Tennessee Valley Authority, U.S. Geological Survey, U.S. Fish and Wildlife Service, World Wildlife Fund, Conservation Fisheries Inc., Tennessee Clean Water Network, and Wisconsin Department of Natural Resources. The working group raises Lake Sturgeon for release as juveniles and collaborates with commercial and recreational anglers to monitor their health. The Tennessee Aquarium raises awareness and money for the conservation initiative. It also maintains a sturgeon touch-tank display and teaches elementary schoolchildren about sturgeon rearing, life history, and conservation. Touch displays for sturgeon are popular, as visitors can feel the unique leathery texture of the sturgeon's skin and the hard bony plates.

6.7 Seahorse Conservation

Public aquariums are places where people first encounter the fascinating seahorses. The family Syngnathidae includes seahorses, sea dragons, sea moths, and pipefish. Because these are not targets of commercial or recreational fisheries, public aquariums first introduced them to the public. The World Aquariums and Zoo Association and Project Seahorse have worked collaboratively to improve husbandry of seahorses in order to decrease pressure on wild populations (Lunn et al. 1999; Koldeway et al. 2015; Muka 2018). Currently, rearing techniques are available for a dozen seahorse species. Aquariums were integral to studying biology and behavior (discover), distributing captive-bred specimens (act), and educating about their conservation status (share; Figure 6.3). The Association of Zoos and Aquariums organizes experts regarding the husbandry, veterinary care, conservation needs/challenges, research priorities, ethical considerations, and other issues of seahorse conservation (AZA 2014). The attention we give to seahorses in captivity is a necessary condition for conservation since many seahorse species are classified as vulnerable or worse (IUCN 2020). Trade in seahorses is highly regulated, and seahorses in public aquariums must be legally sourced.

The ethics of caring is illustrated by many stories about the fish in captivity, and in particular stories about the seahorses. Part of caring about a being is to be (1) curious about it, (2) willing to learn about it, and (3) responsible for its well-being (Schmitt 2017). A thoughtful person, in learning about the breeding and care for seahorses, is impressed and fascinated by the story of the male seahorse providing parental care in a protective pouch and nutrients and ionic balance to ensure normal embryonic development (Figure 6.5). The normal function of a female's uterus is provided by the male seahorse. In addition, the appearance of seahorses swimming upright with curved neck, long snout, and tail that curls around a blade of seagrass or coral makes them unique in the world of fish.

Figure 6.5: Two pregnant Potbelly Seahorses at the Tennessee Aquarium, USA.

Seahorses may be one of the very few fish to possess nonhuman charisma and operate as flagship species for conservation (Lorimer 2007). Flagship species are popular, charismatic symbols, and they serve as rallying points to stimulate conservation awareness and action (Leader-Williams and Dublin 2000). Seahorses live in some of the world's most threatened habitats, and their plight has led to creation of marine protected areas and restoration projects. Recently, the rare Weedy Seadragon (*Phyllopteryx taeniolatus*) was raised at the Birch Aquarium, California. Saving seahorses means saving our seas.

Question to ponder:

In what ways do public aquariums educate the public? View this one-minute videodeveloped by the Birch Aquarium to see how effective a short video can be for public education.

6.8 Efforts to Influence Seafood Choices

Marine environments are inaccessible to many due to simple facts of inland geographic locations or the lack of boats or equipment. Consequently, viewing displays at public aquariums is as close as most people come to experiencing marine life. One personal connection that even the inland residents have is our consumption of seafood. Consequently, public aquariums may educate visitors about challenges of providing sustainable seafood to consumers. In making personal choices about our seafood, we should ask: (1) Where did it come from? (2) Is it farmed or wild caught? And (3) If it's wild, how was it caught? In 1999, in response to global overfishing, the Monterey Bay Aquarium began working to solve the most critical barriers to transitioning to sustainable seafood. Today, the aquarium staff reaches an online audience of over 3 million followers who regularly seek reliable, up-to-date information on sustainable seafood at the Seafood Watch® website, https://www.seafoodwatch.org/.

Seafood Watch summarizes information for seafood businesses, restaurants, and consumers by categorizing seafood choices as best choice, certified, good alternative, or avoid. Most fish on restaurant menus or in grocery stores do not mention source, so consumers are not able to make wise choices. Seafood Watch develops recommendations based on environmental protection, social responsibility, and economic viability. Best choice seafood would be grown or harvested in ways that protect the environment and maintain fish for the future. Three aquariums in France, Italy, and Spain launched a similar campaign, called Mr. Goodfish, www.mrgoodfish.com, to promote consumer awareness of sustainable seafood purchases.

Consumers in the United States import 90% of the seafood consumed, and a willingness to pay a premium to buy sustainable seafood has a global impact.

6.9 Ethical Considerations for Public Aquariums

Zoos and aquariums grapple with many conservation and welfare questions, such as, "What constitutes our conservation obligations? What is the moral and scientific basis of aquariums? And, Should aquariums exist at all?" (Mazur and Clark, 2001, 185). Where can we obtain live fish for displays? In captivity animals may be deprived of needed interaction. Some people may believe that deriving entertainment from sentient animals is wrong. Increasingly, aquariums are dealing with such questions about their ethical obligations to aquatic animals through AZA standards (Bekoff 2014).

Most public aquariums are not-for-profit organizations and seek grants and donations to maintain conservation and science programs and exhibits. Monterey Bay Aquarium was built and fully funded with a gift from David and Lucile Packard. Georgia Aquarium, the largest aquarium in the United States, was built in 2000 at a cost of $290 million, most from donations. Promoters for new aquarium construction sell them as both conservation initiatives and as enterprises that bring jobs and revenues to revitalize distressed downtowns. Tax breaks and bonds often subside public aquarium construction. Most also charge a daily entrance fee and annual memberships. Aquarium professionals have seen great variation in attendance, with high attendance numbers in the first years followed by dramatic declines if new exhibits are not developed and promoted (Lindquist 2018). Funding to support research and conservation efforts must compete with funds for maintenance and operations. Georgia Aquarium's international Whale Shark research and conservation program is funded in part by proceeds from sales of a Whale Shark IPA launched by the Atlanta Brewing Company. Other innovative funding solutions exist in many public aquariums.

Many have begun to question moral acceptability of keeping animals in captivity. Do the benefits of keeping fish in captivity accrue to the institutions more than to conservation in the wild? How can we justify our captive animal programs based on attention and protection of species in the wild? Animal rights advocates stress that fish are valuable in and of themselves (they have inherent value) and that their lives are not just valuable because of what they can do for humans (their utility). In their view, the right actions are not found by invoking utilitarianism, in which the general rule of thumb is that the right actions are those that maximize utility summed over all those who are affected by the actions. No matter what you believe, animal welfare concerns must be a priority for public aquariums that exhibit fish.

Principles of ethics, compassion, humility, respect, coexistence, and sustainability should guide us in our interactions with aquarium animals. As we learn more about inner workings of the mind of fish, societal forces will increasingly ask about the level of respect and moral consideration given to fish (Bekoff 2014). These are not new questions, and we don't yet have satisfactory answers, but we should expect to engage in dialogue.

Public aquariums believe there should be no boundaries to visitation. Therefore, exhibits, restrooms, and parking are fully accessible, and public transportation is available. In addition, some visitors with sensory processing disorders or photosensitive considerations are accommodated by scheduling low-sensory presentations with reduced volume and dimmed lighting. Assisted-listening devices and American Sign Language interpreters are often available for the hearing-impaired visitors. Audio-described presentations and tactile models are provided for the vision-impaired visitors.

Public aquariums maintain large and diverse collections of live animals for display and are committed to sustainability of aquatic animal trade (Tlusty et al. 2013, 2017). Some collect their own specimens but also share and engage in ornamental trade. The accreditation of Association of Zoos and Aquariums (AZA) requires that suppliers do not cause environmental damage when collecting specimens and that they have all required legal permits. Consequently, they are interested in supporting sustainable trade by educating consumers and retail chains about best options for purchasing ornamental fish.

In addition, public aquariums encourage and communicate the examples of sustainable ornamental fish trade, such as the Rio Negro cardinal tetra fishery (Chao and Prang 1997). Nearly 20 million live fish are exported from the region annually, generating more than U.S. $2 million annually for the local economy. In some cases, such as sharks and rays, captive populations are challenging to sustain. Therefore, public aquariums engage in comprehensive assessments of the sustainability of future harvests so they can protect wild populations and permit some harvest for live displays (Buckley et al. 2018). In other cases, aquariums may have enough captive-bred fish to permit sharing among other aquariums. Zebra Sharks (*Stegostoma tigrinum*)—commonly known as Leopard Sharks throughout the Indo-Pacific—have declined in the wild. Public aquariums are assisting in recovery via introduction of juveniles bred in managed care and hatched from eggs supplied by participating AZA-accredited facilities.

Displays are increasingly designed for immersive experience for public education. Not all species are suited or captivity and display. If an animal suffers from being on display, it will never be a good specimen (Leddy 2012; Semczyszyn 2013). If the visitor finds the display is undignified, then it will not be a good display for aesthetic, education, or scientific purposes. Public aquariums are getting larger; the Atlanta Aquarium's largest tank is 23,850,000 liters (that's 6.3 million gallons) (Lindquist 2018). Keeping some fish, such as Whale Sharks and Great White Sharks in captivity, is controversial due to their feeding and extensive movements (Bruce et al. 2019; Roy 2019).

While public aquariums are places where visitors go to appreciate aquatic environments, for many of us, they remain the only glimpse of the underwater world. Yet, aquarium displays are human-created artifacts and not natural. The rapidly changing ethical and social perspective means that issues of animal welfare, animal rights, climate change, captive breeding, and commercialization may create tensions. Built displays will always be different from appreciation of nature and the natural environment (Semczyszyn 2013). Therefore, in addition to meeting the life requirements of live specimens, the aquarium displays must pay attention to the aesthetic experience. One alternative display option is to create smaller, more interactive models (Lindquist 2018, 343), such as touch displays for stingrays and sturgeon. In other aquarium displays, the display tanks are designed as invisible to focus attention on the living specimens. Choices made about displays recognize that not all species are equally suited to life on display.

Energy demands of large aquariums are substantial, with vast quantities of water and air that must be heated or cooled and treated. Electricity production generates waste as carbon dioxide (CO2). Shedd Aquarium's CO2 emissions were once compared with "an endless 2,200 car traffic jam" (Wernau 2013), before a major initiative to reduce energy consumption, reduce and reuse water, and reduce waste (Shedd Aquarium 2020). The Aquarium Conservation Partnership is a new initiative that shares best practices in conservation actions designed to make conservation a core business strategy of public aquariums.

Profile in Fish Conservation: Karen J. Murchie, PhD

Scan the QR code or visit https://doi.org/10.21061/fishandconservation to listen to this Profile in Fish Conservation.

Figure 6.6: Karen J. Murchie, PhD.

Karen J. Murchie is the Director of Freshwater Research at Shedd Aquarium, where she oversees a team of biologists focused on freshwater biodiversity conservation in the Great Lakes region. Her early experiences spending much time outside, from exploring a local conservation area near her home to a summer experience in a ranger program, led to an appreciation for nature. The first time she donned a mask and snorkel in Jamaica, a small purple and yellow Fairy Basslet entered her view and hooked her on a career in fisheries. Her experiences allowed her to learn about fish and explore aquatic habitats in the Caribbean, the Arctic, the Amazon, and many other places. Her first fisheries jobs included some environmental consulting gigs examining stream crossings and also working with American Eels on the St. Lawrence River, and then longer-term positions with the Department of Fisheries and Oceans in the Great Lakes region, followed by an environmental consulting job in the Northwest Territories of Canada. After completing her PhD at Carleton University, she worked as an Assistant Professor at the College of The Bahamas (now University of The Bahamas), where she taught biology courses and did research on bonefish through engagement with local guides and fishing lodge owners.

In 2016, she joined Shedd Aquarium as research biologist and instructor, which exposed her to the important roles that public aquariums play in education and conservation. In addition to maintaining a rigorous research program focused on migratory fish in collaboration with other researchers and fisheries **practitioners**, she also instructed a yearly fall semester course in Freshwater Ecology to college students at Shedd, through the Associated Colleges of the Chicago

Area. In this course, students are connected with many hands-on opportunities related to local conservation work in the greater Chicago area.

In 2019, Karen became the Director of Freshwater Research at Shedd and began to oversee a team of freshwater biologists, in addition to running the migratory fish conservation research program. Education and outreach, whether through collaborative programs with the Learning and Community Department at Shedd, engagement of the public in community science, or sharing knowledge through seminars, activities in the aquarium and via social media are all aspects of the position. Dr. Murchie enjoys highlighting the value of the often-overlooked freshwater fish through her fieldwork and various public engagement activities.

Key Takeaways

- Public aquariums have an important role in communicating the issues, raising awareness, changing behaviors, and gaining widespread public and political support for conservation actions.
- Conservation education and inspiration for their visitors are common missions of public aquariums.
- As people learn more about the things they care about, then they may act to protect and conserve the species and ecosystems that they are aware of and value.
- The restorative nature of visiting public aquariums is difficult to study, but an interest in therapeutic intervention with aquatic animals continues.
- Public aquariums are expanding conservation efforts via the SAFE program, for Saving Animals from Extinction and other outreach programs.
- Despite the broad base of support and interests, public aquariums continue to face challenges by welfare advocates, climate activists, and conservationists.
- Public perceptions of aquariums range widely, and some people are concerned about the benefits and morality of keeping animals in captivity.
- Aquariums engage with the ornamental fish trade by promoting market-based initiatives that link retailers to captive-bred rather than wild-caught fish.
- Immersive exhibits provide more opportunities for aquarium visitors to interact with displayed animals.

This chapter was reviewed by Anna L. George and Karen J. Murchie.

URLs

Accredited by the Association of Zoos and Aquariums: https://www.aza.org/inst-status

Video: https://www.youtube.com/watch?v=pCDSzAsG3DY

Figure References

Figure 6.1: Smalltooth Sawfish from public aquarium display. Simon Fraser University, Communications & Marketing. 2007. CC BY 2.0. https://flic.kr/p/nRQ4G5.

Figure 6.2: Floating wetland at Inner Harbor, Baltimore. Ron Cogswell. 2015. CC BY 2.0. https://flic.kr/p/vRqNqx.

Figure 6.3: Photo of the critically endangered Butterfly Splitfin (*Ameca spendens*). Przemysław Malkowski. 2008. CC BY-SA 3.0. https://commons.wikimedia.org/wiki/File:Ameca_splendens.jpg.

Figure 6.4: Lake Sturgeon (*Acipenser fulvescens*). George Brown Goode. 1884. Public domain. https://commons.wikimedia.org/wiki/File:FMIB_51148_Lake_Sturgeon.jpeg.

Figure 6.5: Two pregnant Potbelly Seahorses at the Tennessee Aquarium, USA. Joanne Merriam. Unknown date. CC BY-SA 3.0. https://www.academia.edu/31808923/Interspecies_Care_in_a_Hybrid_Institution.

Figure 6.6: Karen J. Murchie, PhD. Used with permission from Karen J. Murchie. Photo by Shedd Aquarium/Brenna Hernandez. Use of the contribution is permitted at no cost in perpetuity in this and all future versions of this work.

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7. Gender and Fishing

Learning Objectives

- Describe the roles that women play in fishing, fisheries, and aquaculture.
- Recognize the contributions of women to the science of managing fish and fishing.
- Explain the activities of governance where women's issues are not recognized.
- Explore intersectionality as a starting point for discussions of human rights and social justice related to fish conservation.

7.1 Why Gender Is Relevant to Sustainable Fishing

The old axiom goes "Give a man a fish and he eats for a day. Teach a man to fish and he eats for a lifetime." A feminist version of this would be, "Teach a woman to fish, and everyone eats for a lifetime" (Sharma 2014). Contributions of women in fishing and fisheries science have been historically invisible because someone else got credit for them. Furthermore, in scientific fields dominated by white males, harassment and other behaviors discourage participation by women. Women's contributions to fishing communities may be direct or indirect, such as: (1) direct contribution of women's labor in catching or processing operations; (2) creating the next generation by bearing and raising children; and (3) special responsibilities because of the absence of men away while fishing (Thompson 1985). In some fisheries, the catching of fish for sale is dominated by males, while the catching of fish for feeding the family is dominated by females (Bennett 2005; Santos et al. 2015; Ameyaw et al. 2020; Tilley et al. 2020).

Women hold knowledge, skills, and traditions relevant for fisheries management. However, despite the seemingly valuable contributions, women are often not paid for their work and, consequently, women's fishing activities are not included in official statistics. Because of both diminished appreciation and differing roles, women in the fishing industry are likely to have a smaller role in governance and suffer disproportionately during difficult times. For example, the COVID-19 pandemic affected women fishers differently due to gender-based norms or restrictions (Lopez-Ercilla et al. 2021; Woskie and Wenham 2021). More inclusive consideration of gender in fishing should result in more sustainable fisheries, yet important obstacles remain.

Gender refers to a social construct based on how women and men relate. Thus, gender is expressed in behaviors, roles, social status, and rights of women and men as organized and justified by society on the basis of biological differences between the sexes. However, gender analysis in fisheries is impossible without observations and data by gender or sex. Categorization of gender and sex as binary (i.e., male or female) is not a full or accurate portrayal of the diversity of human behavior or biology. American adults identifying as lesbian, gay, bisexual, transgender, queer, intersexual, or asexual (LGBTQIA) rose to 5.6 percent in a 2021 Gallup poll (Jones 2021). LGBTQIA adults are unlikely to see themselves represented in fishing and fish conservation arenas and other groups.

Increasingly, we are examining gender differences in participation in different types of fishing. Much of this work has focused on small-scale subsistence fishing, where fisheries support the economy of local communities (Campbell et al. 2021). Contributions of women in all types of fisheries, as well as in fisheries science and management, are overlooked by society, industry, and policy makers. However, the premise and promise of sustainability is rooted in the belief that no effort to restore ecological balance and integrity will succeed if it does not also address the social inequities and human suffering in our communities.

In this chapter, I examine implicit biases related to gender and fishing and encourage you to consciously and explicitly consider gender and diversity of those engaged in fishing. A modern view of fisheries should begin with the assumption that women do fish, rather the inverse. When we take a gender perspective, we identify where there are differences that generate inequalities, vulnerabilities, fears, and exclusion. Transforming harmful social ideas and practices requires everyone's collaboration, regardless of their gender. This more inclusive view will bring women and historically underrepresented groups into the management process and will provide the base for better governance and policy reform.

Questions to ponder:

What is gender? What gender-related information would you want to have in order to manage a fishery or conserve a threatened fish population?

7.2 Harmful Fishing Stereotypes

A stereotype is any overgeneralized, widely accepted opinion, image, or idea about a person, place, or thing. We use stereotypes to simplify our world and reduce the amount of thinking we have to do. You may have heard someone remark that "women are bad luck on boats," "girls are bad drivers," "women are too emotional," "the humanities are useless," or "males are better at math." At a boat ramp or fishing pier, one might hear that "you did really well for a woman," which leads to anger and hostility. Stereotypes are harmful because we don't work to see or understand the person and their identity. Instead, we substitute the stereotype. Such stereotypes may serve as self-fulfilling prophecies and affected individuals are at risk of being marginalized. Stereotypes may also lead to hostility between groups. Imagine that you are being judged and labeled without sharing anything about your creativity and uniqueness.

Our language continues to support the stereotype that those who catch fish are males. The term "fishermen" dominated the scientific literature in fisheries during most of the 20th century. Attempts to use gender-neutral terms, such as fisher or fisherfolk, have been increasing to the point that *fishers* and *fishermen* occurred equally in the most recent literature (Branch and Kleiber 2015). According to Welch (2019), women do not consistently take offense from the term "fishermen." Two quotes from females are instructive:

> *I enjoy the term fishermen. I'd much rather be called a fisherman than a fisher woman. I feel like it would separate me as crew. I don't want to be treated like a woman on the boat. I want to be treated like a crew member.*
>
> *As a woman I have always considered myself a fisherman. My dad taught me how to fish, and I feel like it is something that is important to many families. Especially father daughter relationships and I think it should stay the way that it is.*

The way we govern fisheries is influenced by gender stereotypes. Holding a stereotypic view that only males do the fishing means that access to fishing grounds, ownership of fishing boats, and the rights to fish are considered the domain of males (Figure 7.1). Therefore, males often have greater support from governing bodies in controlling harvest and influencing decisions than do females. Unfortunately, this leads to poor management decisions and marginalizing the role of women in fishing communities.

Questions to ponder:

What familiar stereotypes have you encountered? Are they positive or negative? What gender-neutral term do you typically use to describe one who harvests fish? Why would you prefer to use a gender-neutral term?

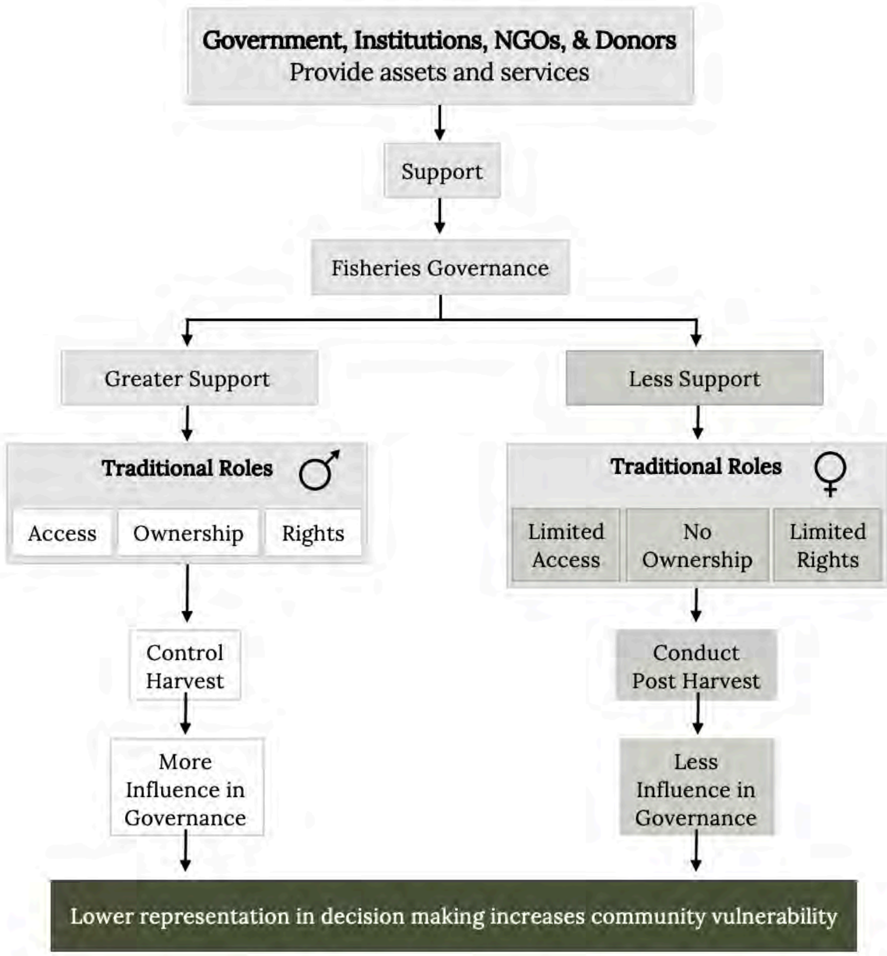

Figure 7.1: Conventional fisheries governance gives greater support for traditional roles of males, leading to lower representation of females in decision making. Long description.

7.3 Gender Issues That Prevent Gender Equality

Women are a minority in many male-dominated sectors of fishing value chains, fisheries management, and fisheries science. Gender equality is not only a basic human right, but its achievement has enormous socioeconomic ramifications. Creating a world without gender-based discrimination is a global priority. Therefore, the United Nations Food and Agriculture Organization (FAO) and others have encouraged the use of a gender lens to examine and promote fisheries sustainability (FAO 2015, 2017; Kleiber et al. 2017). Only by applying a gender lens can we identify and eliminate barriers that exclude women from equal access to fisheries jobs, markets, and fishing resources. Avoidance of gender discrimination requires each of us to speak up and oppose inappropriate sexist behaviors and policies.

Sexism refers to any prejudicial attitudes or discrimination against women on the basis of their sex alone. Sexism is evident in our (a) beliefs, (b) behaviors, (c) use of language, and (d) policies reflecting and conveying a pervasive view that women are inferior (Herbst 2001). Nine issues are so engrained in society that most people experience one of these at some point but may fail to identify or call it out:

- Gender stereotypes
- Unrealistic body standards
- Unequal pay
- Negative female portrayals
- Sexist jokes
- Shaming language
- Gender roles
- Sexual harassment
- Toxic masculinity

Gender stereotypes. Many cultures around the world adopt a patriarchy—that is, a hierarchical system of social organization in which cultural, political, and economic structures are controlled by men. Male **hegemony** refers to the political and ideological domination of women in society.

Among those who fish for sport, only 27% of U.S. anglers are female, and females appear on 10% of covers, in 9% of fishing images, and in 6% of hero images in sportfishing magazines. Only 1% of feature articles are authored by females (Carini and Weber 2017; Burkett and Carter 2020).

Unrealistic body standards. These unrealistic standards of beauty have psychological effects that lead to women fixating negatively on their weight and appearance. From an early age, girls are subjected to unrealistic body images. Fishing is an activity that should emphasize safety as a priority, not body image. Another unrealistic assumption is that females prefer pink and will buy pink-colored fishing attire (Merwin 2010).

Unequal pay. Globally, women represent about 50% of all seafood workers. Yet, female workers are consistently overrepresented in low-skilled, low-paid, low-valued positions, remaining mostly absent at the other end of the value chain (Briceño-Lagos and Monfort 2018). Women's labor is likely to be viewed as being part of the household duties assisting their husbands, while the high-paid positions in fisheries are mostly occupied by men.

Negative female portrayals. While many women are experts in fishing, ecology, and conservation, this expertise is not reflected in media portrayals. Rather, media portrayals too often focus on the rarity of "females who fish," rather than on the expertise these individuals possess. Males who fish are not judged by their appearance and neither should females.

Objectification. There are many examples of fishing cultures that sexually objectify women and seek and to share photos of scantily clad women showing off the fish they catch. Among the detrimental effects of sexual objectification (Miles-McLean et al. 2019; Sáez et al. 2019), we can expect that objectification is a barrier to participation.

Sexist comments and jokes. The purpose of sexist jokes or comments is to disparage women. For example, the sexist joke — "What do you call a woman with half a brain? Gifted"—conveys the notion that women as a group are not very smart. The use of humor decreases the perception that the speaker is sexist and ultimately decreases the probability that the listener will confront the perpetrator (Mallett et al. 2016). In male-dominated fields, such as fishing or fisheries science, the frequency of sexist jokes is likely higher. Sexist jokes result in stress and anxiety over how or whether to respond or confront. Furthermore, sexual jokes may increase tolerance of sexual harassment. Clearly, men view sexist humor as more humorous and less offensive than do women. In the workplace, women who experience sexual humor are less likely to be satisfied with their jobs and more likely to withdraw from the workplace. This inappropriate behavior continues until men are confronted about the unwelcome jokes. People often hesitate to confront sexism for fear of social repercussions. Women, in particular, may be accused of being overly sensitive when they confront the perpetrator.

Failing to call out the sexist joke teller is a tacit endorsement of inappropriate behavior and damages group culture. Confronting sexism means quickly expressing disapproval when a sexist comment or situation arises (Monteith et al. 2019; Woodzicka et al. 2020; Woodzicka and Good 2021). Direct responses to sexist jokes and comments using the following statements are most effective.

- That made me uncomfortable.
- That's against our code of conduct.
- That wasn't funny at all.
- I don't get it, can you explain.
- Disrespectful words are not tolerated here.

Shaming language. Shaming or patronizing language toward women—for example, explaining unnecessary things (e.g., mansplaining)—can make it more difficult to build productive working relationships in a male-dominated field. "Mansplaining" refers to the tendency of men to explain things to women, whether they need them explained or not. In many cases, a man may assume that a female is unaware of tips for winterizing a boat motor, finer points of baitcasting, or when to drift a nymph versus a dry fly. Adding further insult, the man may interrupt or speak over women, a behavior sometimes referred to as "manterrupting." Often, men may compliment women at the expense of other women. For example, if one says "Most women are terrible when it comes to navigating with maps," they are implying that there is a rule that women are inferior or incompetent in some way. Also, men may use gendered language to imply what is right or good. For example, a male may refer to another male as a "pussy" or may urge him to "man up," which perpetuates a myth that females are weak.

Gender roles. Many fishing communities and organizations reflect the culture of society, and males typically have greater access to power. Commonly the division of labor in fishing communities is based on gender, which leads to unequal access to benefits of fishing. Gender roles are a source of prejudice and place limits on individuals and their behavior. Rural women face obstacles emanating from a strong patriarchal culture, prejudice, and tyranny rooted in religious traditions, as well as limited control over economic resources and the decision-making process (Deb et al. 2015). In some fishing communities, women fish close to home with little costly equipment in places where fishing may be done in the company of children. In Ghana, women called "Big Mammies" play major roles financing the tuna trade (Drury O'Neill et al. 2018). Gender roles can and do change over time (Gustavsson 2020). For example, in North America, the latter half of the 20th century saw an increase in working wives and mothers and their struggle to balance work and family life.

Sexual harassment. Harassment includes unwanted sexual advances, requests for sexual favors, or other verbal or physical conduct of a sexual nature. The growing sexual harassment problem hinders women's participation in male-dominated parts of the fisheries value chain as well as the management and science sectors. Many women have been the target of some form of harassment, especially those with less power in the workplace. In a 2013 global survey across scientific disciplines, 64% of respondents reported being subjected to sexual harassment during fieldwork and 20% to sexual assault (Clancy et al. 2014). Among female observers on Alaskan commercial fishing boats, roughly half said they had experienced sexual harassment aboard vessels (Gross 2019). Such inappropriate and sexist behavior and its aftermath can derail a career and close off opportunities for women (Nelson et al. 2017).

Toxic masculinity. The term "toxic masculinity" was coined in the 1980s by Shepherd Bliss to characterize his father's authoritarian masculinity. Toxic masculinity, sometimes called harmful masculinity, involves cultural pressures for men to behave in a way that corresponds to an old idea of "manliness" that perpetuates dangerous societal standards, such as male domination, homophobia, and aggression. In conversation, a male might respond with "I'm a guy, what do you expect?" Toxic masculinity teaches men that aggression and violence are acceptable solutions to problems. Toxic masculinity is expressed in some connections between environmental degradation and sexual power (Voyles 2021).

Recognizing that these gender issues exist is the first step in examining fishing with a gender lens. It is unacceptable to assume that if I don't see it, it must not exist. Codes of conduct and rules for enforcement are essential to equal opportunity for all participants. The pervasive nature of these gender issues means that many allies will be needed to support gender equity in fishing and fisheries. These allies recognize that "If I were to remain silent, I'd be guilty of complicity." Therefore, the message to all is to "See it. Name it. Stop it."

7.4 Foundational Gender Concepts Apply to Fishing

Figure 7.2: The progression of gender influences begins with difference and illustrates a common pattern by which power is accrued by individuals who embody certain characteristics.

Many differences exist among individuals and how they fish or do not fish. The problems arise when individual differences translate to differing preferences, privilege, and power (Figure 7.2). Differences mean that individuals display preferences that lead to certain unearned privileges. These privileges of males in fishing and fisheries are often a result of patriarchy where men are dominant figures who hold power. In fishing communities, males have much greater power in the catching and management of fish and occupy positions of power. In these male-dominated situations, males have ready access to resources and maintain differential power, and females are oppressed or their roles discounted. Over time, the oppression is internalized in ways that members of marginalized groups may see themselves as less or inferior. Men—especially middle-aged, middle-class white ones—are lacking in self-awareness of unearned privilege because they have gone through life taking their privileged position for granted (Perry 2017).

In addition to gender, multiple forms of oppression and identity interact to create one's experience and access to influence and power (Figure 7.3). Therefore, the term "intersectionality" is a useful construct here as it acknowledges that everyone has their own unique experience of discrimination and privilege. Intersectionality is a crucial starting point in discussions and is grounded in social justice (Crenshaw 1989, 1991). Fishing controversies are seldom single-issue struggles. For example, fishing access may be constrained by race, class, language, or disability. Numerous factors, including gendered stereotypes, **pedagogy**, and science curricula, all conspire against a young woman's ability to develop a science identity. In small-scale fisheries, gender intersects with issues such as human rights, well-being, food security, and climate change.

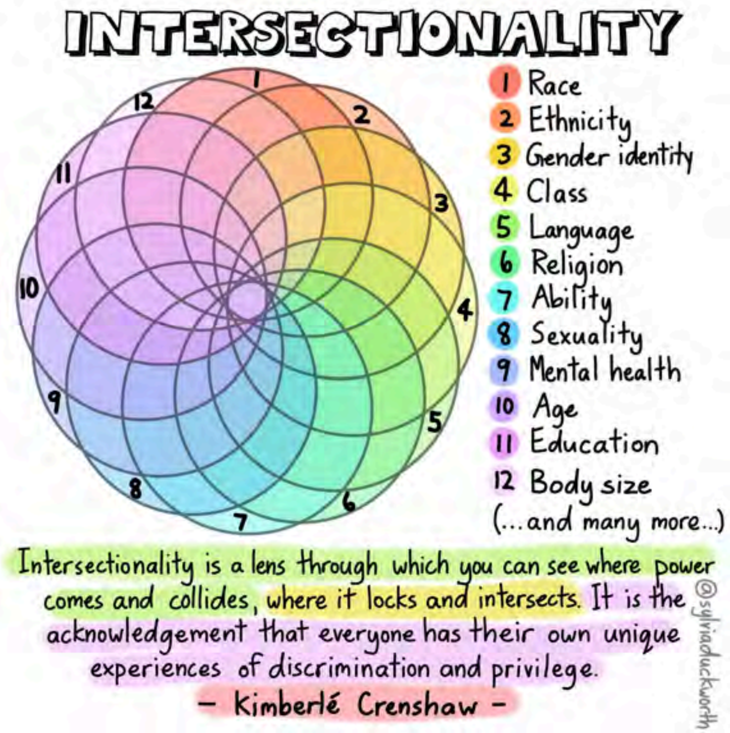

Figure 7.3: Intersectionality is a powerful framework that acknowledges that everyone has unique experiences of discrimination and privilege. [Long description](#).

Society traditionally regards women as dissimilar to men in most fishing contexts. The difference often leads to societal preferences for men in fishing and may limit participation by women. Women are a minority in many male-dominated sectors of fishing value chains, fisheries management, and fisheries science. Participation by females in sportfishing depends on local culture and its ideas about a woman's place (Toth and Brown 1997).

Gender socialization refers to the learning of behavior and attitudes considered appropriate for a particular gender. The group's beliefs, behaviors, language, and policies will influence an individual's initial involvement, attachment, and commitment. Females in fishing groups were seeking social aspects of fishing, while males were more interested in sport-related aspects (Kuehn et al. 2006).

***Question to ponder*:**

Individuals reveal their sexist attitudes in their beliefs, behavior, and language, whereas institutions reveal sexist biases in established policies. Can you think of sexist beliefs, behaviors, language, or policies related to fishing?

Ecological feminism considers several foundational beliefs to guide our viewing of fishing through a gender lens (Gilligan 1988; Gaard 1993; Gaard and Gruen 1993). Foundational beliefs of feminism include the following:

- Women are oppressed and mistreated.
- The oppression and mistreatment of women is wrong.
- The analysis and reduction of the oppression and mistreatment of women are necessary (but not sufficient) for the creation and maintenance of the kind of individual and communal lives that should be promoted within good societies.
- Because different forms of oppression are intermeshed, the analysis and reduction of any form of oppression, mistreatment, or unjustified domination is necessary for the creation and maintenance of the kind of individual and communal lives that should be promoted within good societies (Cuomo 1998).

Language, practices, and values that lead to oppression of women are similar to those leading to exploitation or degradation of nature. For example, consider the passage from Warren (1994, 37):

> *Women are described in animal terms as pets, cows, sows, foxes, chicks, serpents, bitches, beavers, old bats, old hens, mother hens, pussycats, cats, cheetahs, bird-brains, and hare-brains. . . . "Mother Nature" is raped, mastered, conquered, mined; her secrets are "penetrated," her "womb" is to be put into the service of the "man of science." Virgin timber is felled, cut down; fertile soil is tilled, and land that lies "fallow" is "barren," useless. The exploitation of nature and animals is justified by feminizing them; the exploitation of women is justified by naturalizing them.*

Systematic analysis of gender differences in fishing is lacking, leading to persistence of implicit biases. "Implicit bias" describes when we have attitudes toward people or associate stereotypes with them without our conscious knowledge. Further analysis may help us understand differences in behavior and reveal biases that persist. We must remember that just as all men are not alike, all women are not alike. Yet, the studies done thus far support the conclusion that women experience more constraints to their participation.

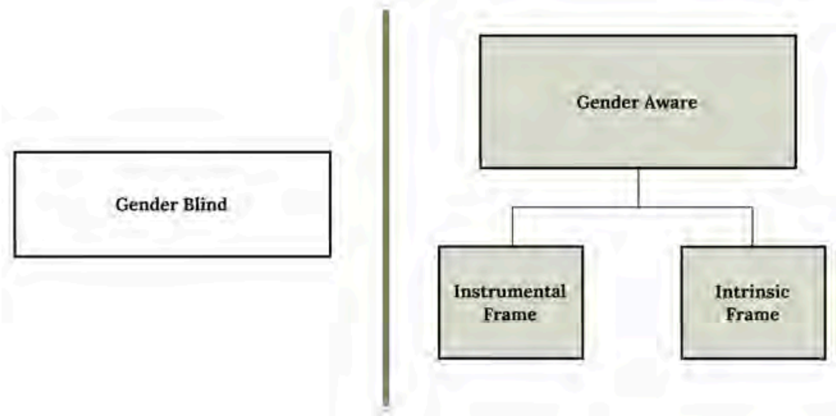

Figure 7.4: Policies may be gender blind or gender aware, and gender-aware policies may be instrumental or intrinsic.

Author Ernest Hemingway wrote about the quintessentially masculine image in this story of big game fishing in *The Old Man and the Sea*. Santiago, the main character, says, "I'll kill him and all his greatness and his glory. I will show him what a man can do and what a man endures." This is clearly a male author using masculine language to communicate this—the struggle between him and the fish. Ernest Hemingway and other writers always promoted the idea when they're fighting these big trophy fish, that they were males and they were referred to as males—an implicit bias. This male bias misinforms us about the biology of fish. Females are more likely to be the larger individuals in many big game species, such as swordfish.

Fishers are a socially and culturally diverse group of people. However, the privilege and power differentials often lead to poor representation of marginalized groups in decision making. Therefore, fishing policies are often inappropriate when viewed with a gender lens (Williams 2008). Fishing and aquaculture policies currently do not collect gender-**disaggregated** data and do not value all the forms of labor. This leads to gender-blind policies, which may be inappropriate because they do not recognize the difference in motivations or roles (Figure 7.4). Gender-aware policies that take into consideration the gender differences so that better outcomes are achieved use instrumental frames to promote gender equality, whereas other gender-aware policies rely on **intrinsic** frames of fairness and justice as primary outcomes.

7.5 Towards the Goal of Gender Equality

Dialogues on gender equality in the seafood and fishing industries should be stimulated to create consciousness, to bring information, to share good practices, and to stimulate progressive initiatives. When we take a gender perspective, we look at relationships between women and men to identify where there are differences that generate inequalities, vulnerabilities, fears, and exclusion. Transforming harmful social ideas and practices requires everyone's collaboration, regardless of their gender.

What prevents women from entering sportfishing? It only takes a single barrier to prevent females from becoming regular participants in fishing. The list below, shared by Betty Bauman of Ladies, Let's Go Fishing!®, is only a partial list.

Sample Barriers to Participation by Females in Recreational Fishing:

- Husband/boyfriend says fishing is for guys only, won't take them
- Can't learn from others on the boat—no time to instruct
- Want to take their kids fishing but nobody knows how
- They have to stay home with kids while husband fishes
- Too early in the morning
- No one else to fish with
- Don't like touching slimy fish
- Seasickness
- Feeling like "the alien" when entering a tackle shop
- Lack of knowledge and confidence regarding fishing skills (being on the team when you don't know the game)
- Unable to launch or drive a boat
- Yelling / condescending comments / afraid to ask stupid questions

To encourage participation by females in sportfishing, we need to understand that certain motivations are unique to females. In a survey of licensed anglers in Minnesota in 2000–2001,

1. Men reported higher involvement in fishing than women did.
2. Women rated motivations related to catching fish for food higher than men did.
3. Men rated developing skills and catching trophy fish higher than women did.
4. Men agreed more with ethics related to catch-and-release fishing (Schroeder et al. 2006).

Questions to ponder:

In your lifetime, who has had the greatest influence on your behavior and personality? Take the implicit assumption test https://implicit.harvard.edu/implicit/ , which is a free test designed to allow an individual to identify their own unconscious biases related to gender, race, ethnicity, and obesity. What privileges do you possess due solely to your individual characteristics?

7.6 Examples of Women's Impact

Sportfishing. Among those who fish for sport, only 27% of U.S. anglers are female (Burkett and Carter 2020). Underrepresentation of females in sportfishing is ironic, as the first publication on fly-fishing, dating from the 15th century, was written by Dame Juliana Berners, entitled *Treatyse of Fysshynge with an Angle*, a publication that heavily influenced novelty of the sport for European enthusiasts. Though sometimes invisible, women are slowly changing the world of sportfishing by breaking stereotypes. Future growth of sportfishing will rely on female anglers, instructors, and guides. Here I share a few examples on women making a substantial impact through their passion toward fishing. These examples demonstrate women who loved and valued what they did. If the paucity of female role models discourages females from seeing the relevance of fishing to them, these examples should inspire.

Figure 7.5: Georgina Ballantine holds the British record for a 64-pound rod-caught salmon from River Tay, Scotland in 1922.

Frederick Buller (2013) chronicled the very long list of large Atlantic Salmon caught by female anglers, which are outnumbered 200 to 1 by male salmon anglers. Georgina Ballantine holds the British record for a 64-pound rod-caught Atlantic Salmon from River Tay, Scotland, in 1922 (Figure 7.5). Joan Wulff was introduced to fly-fishing by her father when she was ten and won several fly-fishing accuracy championships before winning the 1951 Fishermen's Distance competition against all-male competitors. She became the first female spokesperson for Garcia Corporation in 1959 and advocated for women anglers in her writings for *Outdoor Life* and *Rod & Reel*. Today, females make up 30% of participants in the sport of fly-fishing (Recreational Fishing and Boating Foundation 2021). Joan Wulff participated in many distance casting events and did trick casting. She snapped a cigarette from the mouth of Johnny Carson on the TV show "Who Do You Trust?" (Fogt 2017). Starting in 1978, Wulff opened a fly-casting school on the Upper Beaverkill River in New York. Her *Fly-Casting Techniques*, published in 1987, and *New Fly-Casting Techniques*, published in 2012, are classic guides to learning her techniques. When asked about her favorite fish, she would respond, "Whatever I'm fishing for," and her favorite place to fish was "Wherever I am."

Most avid bass anglers can identify Roland Martin, Bill Dance, and Jimmy Houston, who dominated competitive bass fishing in the first decade of Bass Anglers Sportsman Society (B.A.S.S.) and have had TV fishing shows for decades. Kim Bain-Moore began competing in bass tournaments at age 19 and in 2009 became the first woman to compete in the Bassmaster Classic tournament. Only three females have been inducted into the Bass Fishing Hall of Fame. The first was Christine Houston, who organized the first-ever all women's bass club, the "Tulsa Bass Belles." But female participation in competitive bass fishing never took off as expected. Fewer that one in five readers of *Field & Stream*, *Outdoor Life*, and *Bassmaster* magazines are female (Carini and Weber 2017).

There are signs of change since Betty Bauman, the founder and CEO of Ladies, Let's Go Fishing!® created "The No-Yelling School of Fishing." Baumann realized that women preferred a nonintimidating atmosphere where they could learn fishing techniques (Crowder 2002). Since the first program in 1997, over 8,000 participants have graduated from the Ladies, Let's Go Fishing! Training. In 2018, the Lady Bass Anglers Association was formed to promote the Women's Pro Bass Tour. Wild River Press released *Fifty Women Who Fish*, by Steve Kantner. Many female fishing guides are emerging, as well as fishing resources for female anglers. One indigenous fly-fishing guide, Erica Nelson, became an avid fly fisher, guide, and advocate for inclusive fishing (Aiken 2022).

Subsistence Fishing. Women make up a significant, yet hidden, portion of the subsistence fishing workforce (Ogden 2017). Many times the catches are taken along the shoreline, on foot, or from small nonmotorized boats (Figure 7.6). Yet recent estimates suggest that the catch by women is a substantial contribution, especially to local communities (Harper et al. 2020). According to the Food and Agriculture Organization (FAO), 47% of the 120 million people who earn money directly from fishing and processing are women, while women make up some 70% of those engaged in aquaculture (Montfort 2015).

Figure 7.6: Rana Tharu women go fishing in southwest Nepal.

Catches by women are partially for home consumption or sold to support the household and child-rearing expenses, they are not part of the measured economic output. The work of women in subsistence fishing helps improve their living conditions, educate children, and gain economic independence. In Asia and Africa, many small-scale fisheries also produce dried fish (Figure 7.7). Over 50% of the workforce in fish drying yards of Bangladesh are women from marginalized groups, such as lower castes and refugees (Belton et al. 2018). Women working to process and market dried fish are constrained by gender restrictions that influence their ability to purchase fresh fish (Manyungwa et al 2019). Policy makers and development practitioners throughout the world often overlook the women's burdens that are not shared by her brothers (Sharma 2014). The hegemony of dominant male fishermen is slowly beginning to crack as contributions of women are demonstrated (Weeratunge et al. 2010; Harper et al. 2012, 2017; Branch and Kleiber, 2017; Frangoudes and Gerrard 2018; Smith and Basorto 2019). Yet, many changes are needed for gender equity in fishing.

Commercial Fishing. Earliest commercial fisheries in North America recruited migrants to work in seasonal fisheries. Only white men engaged in these fisheries, and violence was common as men sought their place or power in commercial fishing industries. In the salmon fisheries that developed on the Columbia River, the fishing culture shifted from a rough, violent masculinity of seasonal labor to one dominated by ethnic patriarchy that emphasized fishing as the principal work for family breadwinners. Women played important if unrecognized roles as bookkeepers, parts runners, and general hands. By the 1970s, technological advancements provided a few openings for women on the boats, but by that time the commercial fisheries had dramatically declined in scope (Friday 2006).

Figure 7.7: Woman selling dried fish at fish market in Cambodia.

Today, commercial fishing fleets are overwhelmingly male dominated, with fewer than 4% of commercial fishing licenses issued to women in Oregon and Washington states. Yet women contribute to resilient communities by caring for family and maritime households, and increasingly women play a significant role in science, fisheries management, policy, and decision making (Calhoun et al. 2016). The following quote is from a participant in an oral history project:

> *I used to go to groundfish management team meetings 25 years ago, and if there was one woman scientist in the groundfish management team it was a big deal. And now you see women are the chairs of the groundfish management team. So seeing changes, growth of women in both management and in science. Although I know those areas are still a challenge too. And then the rise of women participating in the decision-making process.* (Calhoun et al. 2016)

Fisheries Science. In the early 20th century, research universities were seldom willing to offer women academic positions and a lab of their own. However, some women prevailed despite the discrimination (Brown 1994). I describe experiences and influences of Eugenie Clark and Emmeline Moore, recognizing that there were many other female scientists who were inspirational figures.

Eugenie Clark (1922–2015) was a zoologist at a time when the field was male dominated. Her illustrious career accomplishments are even more impressive when one considers the blatant sexism early in her career. In her first book, *Lady with a Spear*, she wrote of her expeditions to the West Indies, Hawaii, Guam, Palau, and the Red Sea, as well as early research trials on vision and behavior in gobies, puffers, triggerfishes, and sharks. In an interview, she said, "We had to work extra hard, especially on field trips, to prove we could keep up with males." Eugenie Clark became a self-taught expert in the art of throwing a cast net and catching fish with both wooden-handled harpoons and spearguns. She pioneered research on behavior of sharks, conducted numerous submersible dives around the world, and founded the Mote Marine Lab before becoming a professor at the University of Maryland. Clark was a productive researcher who made 71 research dives with submersibles, and her many awards and accolades include the Legend of the Sea Award (Staff 2015).

Emmeline Moore (1872–1963) was a pioneering researcher investigating lakes from an ecosystem and landscape perspective (Zatkos 2020). Moore was the first woman scientist employed by the New York Conservation Department (1920–1925) and later led the New York Biological Survey, the most comprehensive watershed study of aquatic resources at the time. She was Chief Aquatic Biologist for New York State from 1932 to her retirement in 1944. Moore was an active member and leader in the American Fisheries Society, being elected as first female president of the organization in 1927. Her research on pond plants, food web dynamics, pollution, and fish parasites helped change the way fish were managed.

7.7 Toward More Inclusive Public Participation in Fisheries

Conventional wisdom for managing fisheries has focused on employment and products that contribute to value of all goods and services. However, mainstream economists (mostly male) tend to focus only on those things measured in monetary terms. Yet, feminist economists argue that many measures of human well-being from fisheries are ignored by prevailing governance systems (Cohen et al. 2019). Furthermore, the "tragedy of the commons" maintained that in trying to serve their own self-interests, individuals end up hurting themselves—and the public good—in the long run. Consequently, government intervention was needed to prevent the collapse.

The pioneering work of Elinor Ostrom demonstrated that human cooperation, self-governance, and sharing allow people to overcome the tragedy of the commons (Ostrom 1990). She argued that there was "no reason to believe that bureaucrats and politicians, no matter how well meaning, are better at solving problems than the people on the spot, who have the strongest incentive to get the solution right." Her research has led to management of natural resources via comanagement. FAO's *Voluntary Guidelines for Securing Sustainable Small-Scale Fisheries in the Context of Food Security and Poverty Eradication* (FAO 2015, 2017) is one of the few policy guidelines that addresses the role of gender in fisheries. These guidelines call for equal participation of women and men in organizations and in decision-making processes. Consider the following argument claim for comanagement of fisheries:

Premise: *Historically, fisheries decision-making literature focused primarily on stakeholder groups who were mostly comprised of men.*

Premise: *Environmental knowledge is gendered.*

Premise: *Who has a voice in community conservation influences how well a group functions and who gains and loses from or is affected by interventions.*

Premise: *Omitting stakeholders may also obscure the difference between those who have a stake in fish conservation and those who have the ability to act on it.*

Premise: *Participatory approaches often aim to overcome stakeholder neglect by purposefully including diverse stakeholders.*

Normative Claim: *Solutions to problems should be built on shared negotiation processes with all stakeholders.*

Comanagement of fisheries represents a wide spectrum of user participation. Consider the range of opportunities for participation illustrated (Figure 7.8). Management approaches that consciously and explicitly consider gender and diversity of actors may provide the basis for better fisheries governance (de la Torre-Castro 2019). In simpler cases, participation by fishers is limited and governments are able to effectively manage fisheries with minimal exchange of information. This is sometimes called Decide-Announce-Defend, or DAD for short. The DAD method is not suited for fisheries, where a wide range of technical, social, cultural, and economic factors are influencing the current situation and the various possible alternatives to it, and successful implementation involves a lot of people, and these people are not in an obvious command structure. Governments may provide opportunities for participants to provide input (consultative). Most believe comanagement requires at least a cooperative arrangement where participants are equal participants. In fisheries where staffs of small governments are overwhelmed by the number of fishers who are mobile and can select from many fishing opportunities within a region, governments may choose to allow groups to advise or make management decisions collectively. One example demonstrated that comanagement provided a new source of female income from fisheries and an unprecedented recognition of female participation in fishing activities (Freitas et al. 2020).

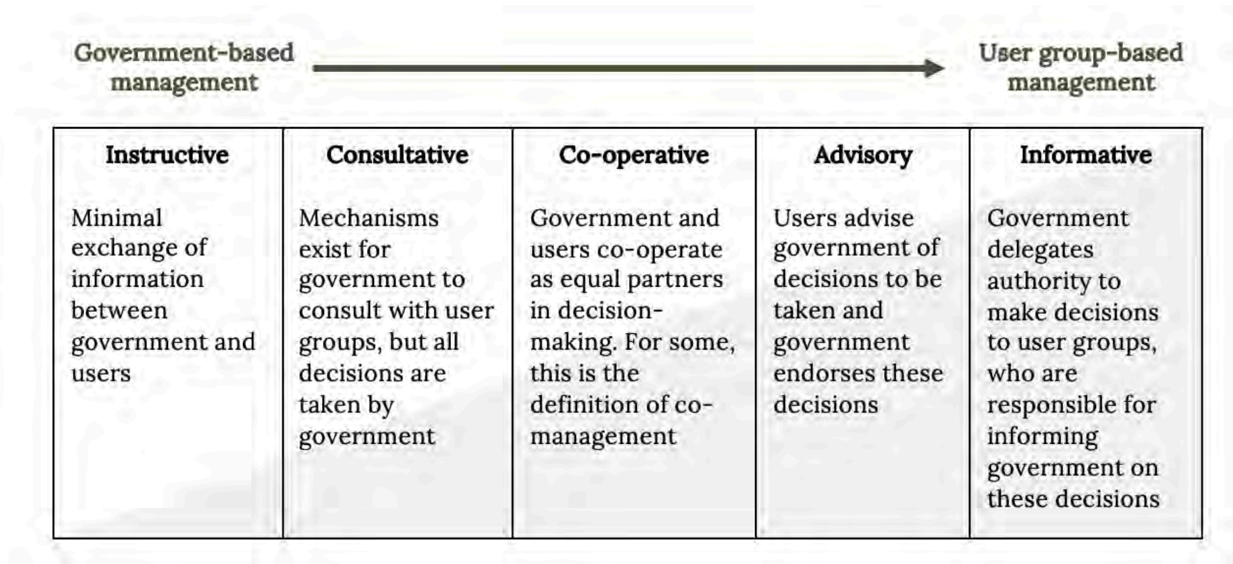

Figure 7.8: Spectrum of comanagement showing increasing participation of users from government-based to user group–based management. [Long description](#).

Today, there are organizations throughout the world to support equitable participation in fishing. A few examples are listed here:

1. **Commercial and Subsistence Fishing**
    - Strength of the Tides: Community organization aiming to support, celebrate, and empower all women, trans, and gender queer people on the water.
    - Dried Fish Matters: Goal is to identify the overall contribution of dried fish to the food and nutrition security and livelihoods of the poor and examine how production, exchange, and consumption of dried fish may be improved to enhance the well-being of marginalized groups and actors in the dried fish economy.
    - Minorities in Aquaculture: Goal is to educate women of color on the environmental benefits of aquaculture and support them as they launch and sustain their careers in the field, growing the seafood industry and creating an empowering space for women along the way.
    - Women in Fisheries Network and other initiatives support women fishing.
    - Gender in Aquaculture and Fisheries: Addresses the data gaps and issues faced by women in fisheries.
2. **Recreational Fishing**
    - Ladies Let's Go Fishing: Dedicated to attracting women to fishing and to promoting conservation and responsible angling.
    - Angling For All: Encourages fishing companies to sign the Angling for All Pledge that establishes a commitment to addressing racism and inequality throughout a pledgee's internal culture, consumer-

facing behaviors, and broader community.

- Brown Folks Fishing: Cultivates the visibility, representation, and inclusion of people of color in fishing and its industry.
- United Women on the Fly: Committed to building an inclusive community that educates, provides resources, encourages, and connects anglers from all backgrounds into the sport of fly-fishing.

Today we are regendering many types of work and leisure activities, including fishing. The significant challenges that we face in fish conservation at home and abroad will require input from all. Rather than propagating stereotypes of fishing activities, we need to explore the participation across gender and other differences so we can do a better job evaluating outcomes of conservation for the well-being of all humans.

Women and men have significantly different approaches and views on public policy issues, which means that women's voices and those of minorities need to be heard.

—Janet Yellen

Profile in Fish Conservation: Danika L. Kleiber, PhD

Scan the QR code or visit https://doi.org/10.21061/fishandconservation to listen to this Profile in Fish Conservation.

Figure 7.9: Danika L. Kleiber, PhD.

Danika Kleiber is a fisheries social scientist for the National Oceanic and Atmospheric Administration (NOAA) based in Hawaiʻi. She was always interested in blending her interests in fisheries biology and feminism and earned a degree in biology and women studies at Tufts University.

Today, her research specialty focuses on issues of equity and the intersection of gender and natural resources, in particular socioecological research approaches to small-scale fisheries management. Her research has uncovered some hidden relations between gender, food security, and participatory governance.

In a study for her dissertation, Kleiber characterized the participation of women in small-scale fisheries from 106 case studies from around the world. This landmark study revealed reasons why women are seldom adequately studied in fisheries. In some cases, it is considered culturally unacceptable for women to fish. In other cases, analysts used very limited definitions of what counts as fishing. In fact, in some languages, such as Greek and Greelandic, there is no female equivalent for the term "fishermen." These and other gender biases reinforced the clear need for fisheries scientists to embrace gender approaches and appreciate women in fishing as parts of an interdisciplinary ecosystem approach.

Kleiber's studies of small-scale fisheries demonstrated the scope and economic impact of women in a variety of roles. Gleaning was often overlooked by previous studies. But this hand collection of invertebrates from shallow intertidal water is the main livelihood for many rural women. To advance fisheries management, Kleiber is pioneering studies of social impacts of proposed fisheries management measures on fishing communities. Social impact assessment tracks many indicators beyond catch and revenues and recognizes that fishing also contributes to culture and social cohesion of island communities.

Key Takeaways

- Women are involved in all aspects of the fishing industry, including skinning, drying, curing, salting, processing, and marketing seafood.
- Rights, equity, and justice are mainstream principles of good fisheries governance.
- Women's role in fishing or fisheries is often overlooked in decision making for cultural reasons.
- Foundational concepts of ecofeminism and intersectionality are useful constructs for analyzing fisheries gender issues.
- Fisheries management policies are set by governance bodies that exclude women.
- Intersectionality is a crucial starting point in all discussions and is grounded in social justice.

This chapter was reviewed by Kafayat Fakoya.

Long Descriptions

Figure 7.1: Government, Institutions, NGOs, & Donors, provide assets and services give support to fisheries governance. Chart splits showing, left: fisheries governance gives greater support in traditional roles to (male symbol) in access, ownership, rights; leads to control harvest, more influence in governance; right: fisheries governance gives less support in traditional roles (female symbol) with limited access, no ownership, limited rights; leads to conduct post harvest, less influence in governance. Both lines lead to lower representation in decision making increases community vulnerability. Jump back to Figure 7.1.

Figure 7.3: Intersectionality displays how social identities intersect with one another and are wrapped in systems of power with overlapping circles of a spirograph, including 1) race, 2) ethnicity, 3) gender identity, 4) class, 5) language, 6) religion, 7) ability, 8) sexuality, 9) mental health, 10) age, 11) education, 12) body size, and many more. Quote by Kimberle Crenshaw reads, "intersectionality is a lens through which you can see where power comes and collides, where it locks and intersects. It is the acknowledgement that everyone has their own unique experiences of discrimination and privilege." Jump back to Figure 7.3.

Figure 7.8: Range of co-management arrangements from government-based management to user group-based management. From left, 1) instructive, minimal exchange of information between government and users; 2) consultative, mechanisms exist for government to consult with user groups, but all decisions are taken by government; 3) co-operative, government and users co-operate as equal partners in decision-making. For some this is the definition of co-management; 4) advisory, users advise government of decisions to be taken and government endorses these decisions; 5) informative, government delegates authority to make decisions to user groups, who are responsible for informing government on these decisions. Jump back to Figure 7.8.

Figure References

Figure 7.1: Conventional fisheries governance gives greater support for traditional roles of males leading to lower representation of females in decision making. Adapted under fair use from *A Review of Women's Access to Fish in Small-Scale Fisheries*, by Angela Lentisco and Robert Ulric Lee, 2015 (https://www.fao.org/3/i4884e/i4884e.pdf). Includes "Male," by Heri Sugianto, 2018 (Noun Project license, https://thenounproject.com/icon/male-1745485/), and "Female." by Maurizio Fusillo, 2012 (Noun Project license, https://thenounproject.com/icon/female-3446/).

Figure 7.2: The progression of gender influences begins with difference and illustrates a common pattern by which power is accrued by individuals who embody certain characteristics. Kindred Grey. 2022. CC BY 4.0.

Figure 7.3: Intersectionality is a powerful framework that acknowledges that everyone has unique experiences of discrimination and privilege. Sylvia Duckworth. 2020. Used with permission from Sylvia Duckworth. CC BY 4.0.

Figure 7.4: Policies may be gender blind or gender aware, and gender-aware policies may be instrumental or intrinsic. Kindred Grey. 2022. CC BY 4.0.

Figure 7.5: Georgina Ballantine holds the British record for a 64-pound rod-caught salmon from River Tay, Scotland in 1922. Photo by Raeburn Studio. Illustrated London News, "A woman breaks the record for tay salmon: A 64-pounder." 2022. Public Domain.

Figure 7.6: Rana Tharu women go fishing in southwest Nepal. Yves Picq. 2004. CC BY-SA 3.0. https://commons.wikimedia.org/wiki/File:N%C3%A9pal_rana_tharu1818a_Crop.jpg.

Figure 7.7: Woman selling dried fish at fish market in Cambodia. McKay Savage. 2008. CC BY 2.0. https://commons.wikimedia.org/wiki/File:Cambodia_08_-_036_-_markets_-_dried_fish_for_sale_(3198824843).jpg.

Figure 7.8: Spectrum of comanagement showing increasing participation of users from government-based to user group–based management. Kindred Grey. 2022. Adapted under fair use from "Fisheries co-management: a comparative analysis," by Sevaly Sen and Jesper Raakjaer Nielsen, 1996 (https://doi.org/10.1016/0308-597X(96)00028-0).

Figure 7.9: Danika L. Kleiber, PhD. Used with permission from Danika L. Kleiber. CC BY 4.0.

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8. Angling and Conservation of Living Fishy Dinosaurs

Learning Objectives

- Explain the ancestral origins of primitive bony fishes of North America.
- Describe the major threats to Alligator Gar populations.
- Apply life history theory to explain the vulnerability of Alligator Gar to human activities.
- Describe habitat changes that strongly influence recruitment in Alligator Gar.
- Apply the concept of the values-beliefs-norms-actions causal chain to changes in human perceptions of gars.

8.1 The Primitive Bony Fish of North America

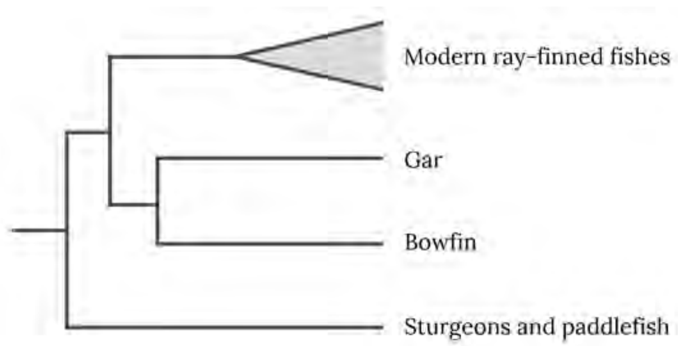

Figure 8.1: Phylogenetic tree depicting the accepted relationships between sturgeons and paddlefish, gars, bowfins, and bony fish. Bowfin and gars are sister groups to all bony fish.

When the first flowering plants appeared on Earth and dinosaurs were the dominant large land animals, the ancestors of gars, bowfins, sturgeons, and paddlefish swam the waters of the ancient Tethys Sea. Hence, these primitive bony fish are often referred to as fishy dinosaurs. Paddlefish and sturgeon appeared in the fossil record 245 to 208 million years ago (Mya) near the end of the Triassic, making them among the most ancient of still-living ray-finned (actinopterygian) fish (Figure 8.1). These primitive fish groups survived the last major extinction on Earth (66 million years ago) and persisted throughout the second age of radiation of bony fish. With such a long history on Earth, one would assume that these fish are extinction proof. However, most populations of sturgeons and paddlefish are at risk of extinction (Boreman 1997; Pikitch et al. 2005), and the Chinese Paddlefish was recently declared extinct (Zhang et al. 2020). Overharvest and habitat change have influenced these primitive bony fish, and the success of conservation efforts depends, in part, on changes in human attitudes that will stimulate conservation actions.

Sturgeon and paddlefish are vulnerable to impacts from human activities, in particular fisheries. Paddlefish and sturgeons display strong spawning site fidelity, and large shoals of adults gather over clean gravel-cobble stream substrates for spawning. Females have late maturity and do not breed each year. Even though a large female may produce a million or more eggs, these big, old, fat, fecund, female fish (BOFFFF) are very rare in exploited populations. The North American Sturgeon and Paddlefish Society (NASPS), the North American affiliate of the World Sturgeon Conservation Society, is dedicated to promoting the conservation and restoration of sturgeon species in North America by developing and advancing research pertaining to their biology, management, and utilization (Bruch et al. 2016). Efforts to restore Lake Sturgeon in the Winnebago System has resulted in opening of a well-regulated winter spearing season (Bruch et al. 2007). Similarly, recreational harvest is permitted for the American Paddlefish (*Polyodon spathula*) in certain Oklahoma waters (Cha and Melstrom 2018) and White Sturgeon in the Columbia River (Beamesderfer et al. 1995).

Figure 8.2: Alligator Gar (Atractosteus spatula).

Unlike the sturgeons and paddlefish, gars and Bowfins are among North America's most disliked fish, largely because of concerns that they eat game fish. The gar (family Lepisosteidae) have been around since the Jurassic and Cretaceous Periods (~150 to 160 million years ago), long before game fish of today emerged. Gars and Bowfins are the sister group (i.e., the closest relatives) to other teleost fish (Figure 8.1) and, therefore, of interest to evolutionary biologists. The largest gars are in the genus *Atractosteus* — the three extant species are Alligator Gar (*A. spatula* or Catan in Mexico), the Cuban Gar (*A. tristoechus*) or Manjuari from western Cuba, and the Tropical Gar (*A. tropicus*) or Pejelagarto from southern Mexico and Central America. Among these three, the largest is the Alligator Gar, which is most imperiled (Figure 8.2).

***Questions to ponder*:**

What types of fish were living on planet Earth in the age of dinosaurs (345 to 66 million years ago)? How did these fish survive and dinosaurs went extinct?

8.2 Life History of Gars

Gars have a long, flexible cylindrical body with a hard bony covering and pointed snout with many sharp teeth. This body form is extremely well adapted for a sit-and-wait, ambush predator and not for fast, sustained swimming. The hard bony protection provided by ganoid scales emerged at a time when very large toothy aquatic reptiles, the large **pliosaurs** and their relatives, were still around. This bony covering is extremely difficult to pierce, even with a sharp filet knife. Each ganoid scale is rhomboid in shape and has a dorsal peg that articulates with a ventral socket joint on the adjacent, dorsally placed scale. Ganoid scales have a bony basal layer, a layer of dentine, and an outer layer of ganoine (an inorganic bone salt). Ganoid scales in gars are tightly overlapping on all parts of the body, creating the diamond-shaped pattern and the rather inflexible body form. Ganoid scales can resist powerful bite forces of self-predation and attack by alligators (Sherman et al. 2017). This chapter focuses mostly on the largest of the seven species of gars, the Alligator Gar (Figure 8.2).

Populations of the gars in the genus *Lepisosteus* (Longnose Gar *L. osseus*, Shortnose Gar *L. platostomus*, Spotted Gar *L. oculatus*, and Florida Gar *L. platyrhincus*) remain stable throughout much of their North American ranges. Longnose Gar, Spotted Gar, and Shortnose Gar are easily distinguishable from other gars by snout length and pigment patterns (Orth 2015; David 2016). For example, the spots on the body of the Longnose Gar are smaller and generally less well developed than on Spotted Gar. The snout length of Longnose Gar is more than 13 times its narrowest width in specimens 50 mm long or larger (Figure 8.3). Juveniles have a shorter snout, which grows proportionally faster than the body.

The Alligator Gar is rare, endangered, and has been extirpated from many outer areas of its range. Historically, the Alligator Gar's home range included the Mississippi River and its tributaries from the lower reaches of the Ohio and the Missouri rivers southward to the Gulf of Mexico. Today, Alligator Gars are primarily restricted to coastal rivers, with inland populations persisting not only in Oklahoma but also in Florida, Georgia, Alabama, Tennessee, Arkansas, and Texas.

Figure 8.3: Longnose Gar.

The unique life history of the Alligator Gar makes it very susceptible to overharvest and habitat change. Alligator Gars and other gar species have been commercially fished in southern states, and in recent years it has become a target of recreational hook-and-line anglers as well as bowfishers. The large size of the Alligator Gar and its numerous sharp teeth mean that it can produce a serious bite wound to those who attempt to handle it. There are no verified reports of attacks on humans. Eggs of all gars are poisonous to humans and other mammals, birds, and crayfish (Ostrand et al. 1996).

Figure 8.4: Largest Alligator Gar captured in 2011 weighed 327 pounds.

How large can they get? That's hard to know because large specimens are no longer present in exploited populations. A commercial fisherman, while fishing for buffalo fish, caught a large Alligator Gar from Lake Chotard, Mississippi, on February 14, 2011. He had never seen an Alligator Gar that big—over twice his weight. The fish was barely alive after being tangled in the fisherman's gill net. The fisherman barely had any freeboard after loading the big gar into his 16-foot boat. After calling a game warden, he found metal yard that had a big enough scale. The fish proved to be the largest Alligator Gar that's ever been officially measured. It was 8.5 feet long, 47 inches in girth, and weighed 327 pounds (Figure 8.4). According to the International Game Fish Association (IGFA), the world record Alligator Gar captured by hook and line weighed 279 pounds. Larger Alligator Gar may be swimming in the wild, but the official measurements confirm that the Alligator Gar is the second-largest freshwater fish in North America (second only to the White Sturgeon).

The Alligator Gar is a very long lived fish, although previous estimates of longevity have been underestimates. To accurately age an Alligator Gar, scientists must remove the inner ear bone (otolith), because other structures such as fin rays and scales provide underestimates of true age (Daugherty et al. 2020). The record 327-pound Alligator Gar was aged by scientists, who verified that the individual was 95 years old (Figure 8.5).

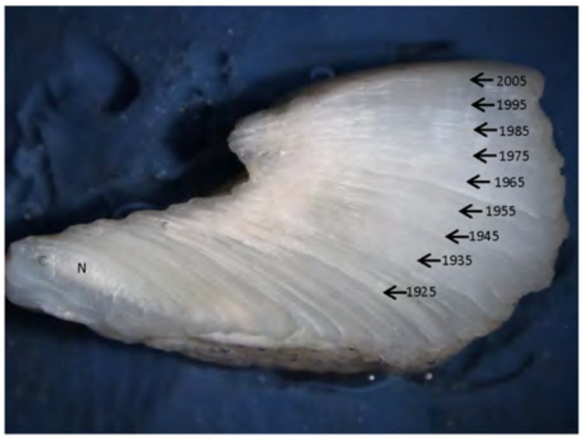

Figure 8.5: Processed otolith (sagittae magnified 12.5X) from the current world record Alligator Gar caught from the Mississippi River Basin in Mississippi on February 14, 2011. The individual was estimated to be 95 years of age using methods of Buckmeier et al. (2012), indicating that it hatched in 1915. Arrows mark the approximate location of every tenth annulus and the "N" notes the location of the nucleus.

The Alligator Gar is typically a solitary fish that appears passive and barely moving while watching for potential prey. Gars may feed during the day or night and spend their time in a "lie-and-wait" position before ambushing. They are not fast swimmers, but prey capture involves a flex of their tail with mouth open to impale their target on the double row of super-sharp teeth. As adults they mostly feed on other fish but can consume waterfowl, turtles, mammals, and whatever's most abundant.

What's unique about the growth of Alligator Gars is their fast growth in the first years of life followed by slower growth (Figure 8.6; Figure 8.7). Juvenile Alligator Gars quickly transition to fish-eating habits (Butler et al. 2018). A fish diet means the juveniles grow at 4-5 mm per day in the first three months of life, so that by the end of the first growing season they may reach 1.5 to 2 feet in length (~40–70 cm) and 8–10 pounds in weight (Sakaris et al. 2019). Despite their fast growth, young Alligator Gars are preyed upon by many larger fish.

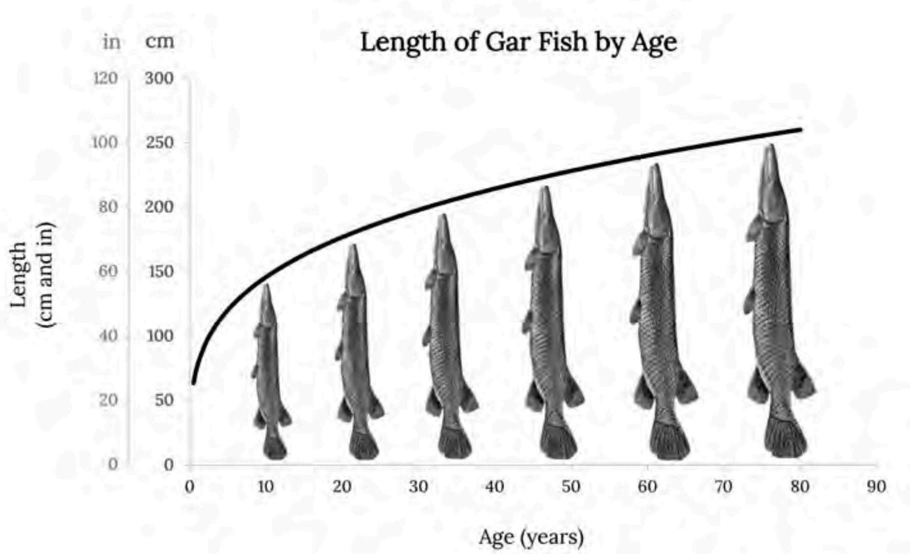

Figure 8.6: Growth in length of Alligator Gar in Texas. Figure 8.7: Growth in weight of Alligator Gar in Texas. Long description.

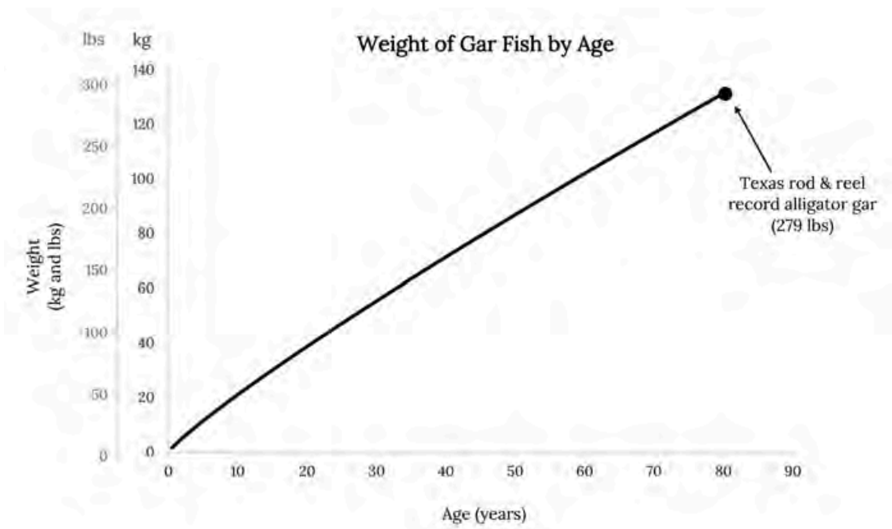

Figure 8.7: Growth in weight of Alligator Gar in Texas.

Addition of new individuals to a population depends on fish surviving to maturity, finding mates, and surviving and growing through many challenges in egg, larval, and juvenile stages. Although many eggs may be produced, survival to maturity is very low. In fact, recruitment failure is typical in Alligator Gar populations, with successful recruitment observed in only 3 of 10 years (Figure 8.8).

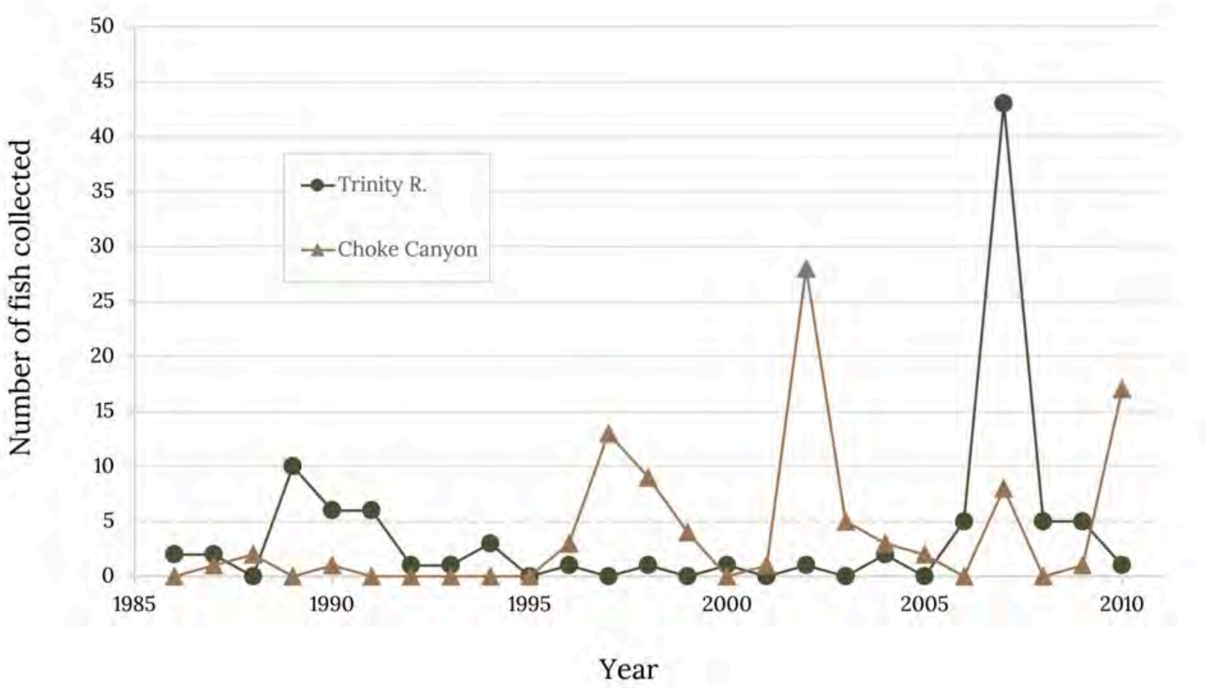

Figure 8.8: Recruitment of two populations of Alligator Gar in Texas demonstrates variable recruitment.

After the first year, very few predators threaten Alligator Gars. The only known predator is the American Alligator, and annual survival for adults may be as high as 91.5%. This means that only a few individuals in a population will survive to be trophy catch or BOFFFF, especially in populations that are heavily fished (Figure 8.9). BOFFFFs typically produce more and more viable eggs, are able to outlive unfavorable periods, and survive to spawn multiple times (Hixon et al. 2014). Unfortunately, in the case of Alligator Gars, the benefits are not fully realized because the large fish in the lower Trinity River, Texas, had high concentrations of mercury, polychlorinated biphenyls (PCBs), and **organochlorine** pesticides (Harried et al. 2020).

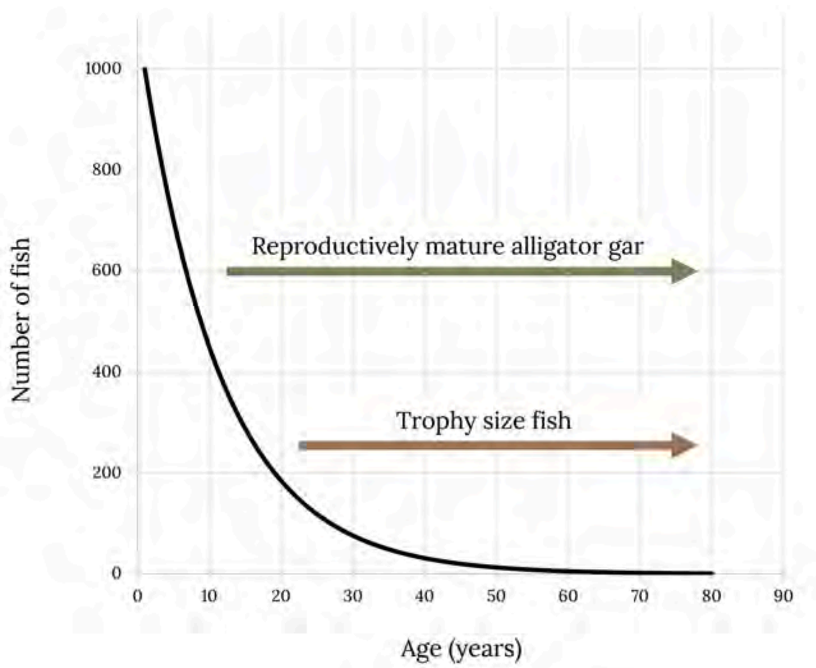

Figure 8.9: Hypothetical decline in numbers of Alligator Gar with age, beginning with 1,000 individuals at the age of one year. Long description.

Long life, variable recruitment, and low juvenile survival lead to vulnerability to overfishing in Alligator Gars. Female Alligator Gars produce many small offspring, and tiny little eggs. Male Alligator Gars remain in shallow spawning areas longer, making them vulnerable to sight-fishing. And all those traits mean that these fish are vulnerable to overfishing without restrictions on daily harvest. Every loss of a mature Alligator Gar influences the total number of eggs that may be produced. The biggest gars are almost always female fish. The spawning potential ratio (SPR) measures the total output of eggs relative to that in an unfished population. SPR drops rapidly as the exploitation rate increases (Smith et al. 2018; Figure 8.10). Alligator Gar populations may be able to sustain annual harvests of only 5%. Thus, regulations in some trophy waters are set at only one fish per day bag limit (Binion et al. 2015; Buckmeier et al. 2016).

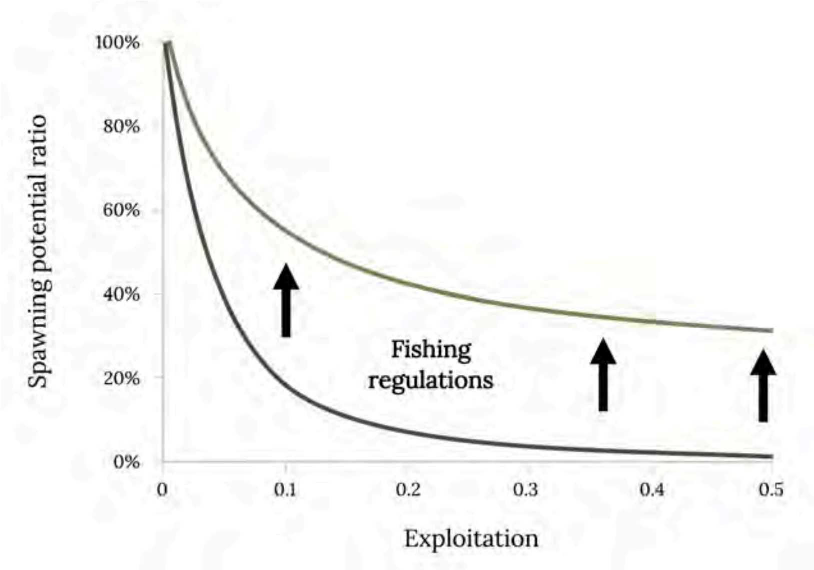

Figure 8.10: Expected effects of fishing regulations on spawning potential ratio (SPR), with the percentage of spawning fish relative to the unfished state (SPR = 100).

Question to ponder:

Describe aspects of the life history of Alligator Gar that makes them vulnerable to overfishing.

8.3 Mistreatment of Gars

Before European colonists came to North America, the gars were held in high status by indigenous peoples. Gars are still a popular food fish in various parts of Mexico and Cuba. In the southeast United States, indigenous people ate a variety of fish and mollusks, but gars were captured for food (Reitz et al. 2021). Native peoples did eat gar, and the scales were used to make arrow points, and the skins were used as breastplates. There is also evidence that ritual dances of Native American tribes were inspired by the gar.

European colonists did not give gars respect as a food fish or game fish. Instead, they were considered voracious pests based on misinformation. They were believed to be "responsible for the destruction of great numbers of useful and valuable fishes," and that's where the story of gar persecution begins (Caldwell 1913). The following quotes from so-called authorities at the time would eventually be proven incorrect:

- "Fishermen everywhere destroy it [the Longnose Gar] without mercy. Its flesh is rank and tough and unfit even for dogs" (Jordan 1905, page 30).
- "Certainly if our commercial fisheries are to be properly conserved, stringent measures will have to be taken against these 'weeds' and 'wolves among fishes" (Richardson 1913, 407).
- Gars "are responsible for the destruction of great numbers of useful and valuable fishes" (Gowanloch 1933).
- "The time will doubtless come where thorough going measures will be taken to keep down to the lowest practicable limit the dogfish [bowfin] and the gars—as useless and destructive in our productive waters as wolves and foxes were in our pastures and poultry yards" (Forbes and Richardson 1920, 41).
- "First time I saw an alligator gar I damn near threw up. They ain't natural anything get that big. It's ten feet long and three feet at the girth. Not one of God's creations like you and me. Some say they ain't afraid of alligator gar fish. Bullshit. You look at that thing. It's big and mean. Swallow both of us. Them people say they ain't afraid tellin' lies" (Bukka White, blues singer and guitarist).
- "Gars are highly predaceous animals, stealthy and persistent destroyers of a vast quantity of aquatic life" (Gowanloch 1940, 292).

The following poem was written by Missouri Assistant Attorney General Lovan, interpreting the state's right to kill gars:

Mr. Deputy in charge of fish,

You are informed it is my wish,

That you take some dynamite in your flivver

And proceed to Jack's Fork river,

And, standing on the gravelly bar

Cast in the shots to kill the gar.

But when you execute this command

Don't forget the law will demand

That while killing a gar, you must not harass

A single sucker, catfish, or bass.

You must obey instructions without fail

Or run the risk of going to jail.

—State v. Freeland 1927, 627 (from Scarnecchia 1992)

Missouri Game and Fish and other agencies would target and kill large numbers of gars. In the April 1926 issue of *Missouri Game and Fish News* (Figure 8.11), we learn about law enforcement people in Missouri going out and destroying 5,000 gars because of the damage that they were believed to be causing. Many times, agencies directed efforts to exterminate gars, including the use of the Electrical Gar Destroyer deployed by the Texas Game Fish and Oyster Commission (Burr 1931). Up until recently, most states had no limits on harvesting gars.

6 MISSOURI GAME AND FISH NEWS

Raids Waged by Deputies Resulted in Destruction of Over 5,000 Gar

Large Schools Dynamited by Department—All Former Records Shattered—Officials Received Excellent Co-operation From Sportsmen.

An effective war against the destructive gar has been waged this year under direction of the State Game and Fish Department. The results have been very pleasing and all former records for the destruction of these fish-preying monsters were broken. More than 5,000 gar were killed during the raids made by department deputies. This is considered one of the feature accomplishments of the year.

Much of the success of the gar drive is attributed to co-operation afforded by sportsmen of the state. An appeal was issued to the sportsmen to notify the department of all gar found schooling. As a result of this co-operation much was accomplished.

The most significant individual record was made during January in the Gasconade river near Stolpe Basin in Gasconade county. Deputy George A. Jordan was notified of a large school of gar and immediate action was taken. The school was located and dynamited with the result that approximately 4,000 were killed. The gar were so thick following the discharge of the dynamite that it was possible to bring up five or six on a single thrust of a gig.

Between 500 and 1,000 gar were killed on the Gasconade river near Richland by members of the department. Several schools of gar were located on the Gasconade and prompt action was taken by deputies. Approximately 600 gar were killed in the Meramec river about eight miles northeast of Steelville under direction of Deputy N. E. Morrison. This school of gar were dynamited in what is known in that district as the blue-hole area.

The gar killed ranged from five to 30 pounds each and from one to four feet in length. Other fish will not stay in the water where the gar are schooling. As a result very few game fish were killed during the dynamiting, according to reports received by the department.

Activities of the department in the destruction of gar was not only noted throughout the state, but much interest was taken by the Arkansas Game and Fish department. Mr. Guy Amsler, of Little Rock, secretary of the Arkansas department seeing publicity given to the activity wrote Deputy N. E. Morrison, of St. James, asking for details concerning the methods used by the Missouri department. Mr. Morrison gladly furnished the desired data.

The gar should be eradicated as it destroys game fish in large numbers. Authorities claim a single gar can kill many game fish in a day and it is further stated that a gar can daily eat its weight in game fish. With this distressing information in mind the department has taken a keen interest in freeing Missouri streams of this predatory species.

UNIQUE AQUARIUM ON EXHIBIT AT SPRINGFIELD HOTEL

In Charles Sansone, proprietor of the Colonial hotel, located at Springfield, Mo., the State Game and Fish department has an enthusiastic booster. Mr. Sansone has become so attached to the work being done by the hatchery division of the department that he has inaugurated a novel manner of advertising the department at his hotel.

In the coffee shop of the Colonial Mr. Sansone has caused to be constructed a large fish aquarium. In this aquarium there has been placed fish of many varieties including the black bass, lineside bass, rock perch, sun perch, catfish, goldfish, crappie, trout and goggle-eye.

Fresh water is constantly flowing through the aquarium which has been one of the features that has made the exhibit such a success. The display is located in a front window and it is viewed by several thousand persons daily.

In constructing the aquarium Mr. Sansone received full co operation from J. W. Scott, superintendent of Sequiota State hatchery, located near Springfield.

Figure 8.11: Page from Missouri Game and Fish News article published in April 1926. Long description.

During most of the twentieth century, gars were viewed as harmful by most anglers and even fisheries managers. Yet, the Richardson (1913, 407) warning of the need for stringent measures against these "weeds" and "wolves" was based only on visual observations of adult Shortnose Gar (*Lepisosteus platostomus*) and not on any scientific evidence of harm.

Scarnecchia (1992) reported that even by the late 1980s, it was not legal to release gar alive in Iowa. Section 109.114 stated, "It shall be unlawful for any person to place any gar pike in any waters of the state, and such fish when taken shall be destroyed." Tarzwell (1945) explored the possibility of commercial fishing for rough fish in Tennessee Valley Authority reservoirs. Too often the gars were simply thought of as a rough fish problem to be solved and not a resource to protect and conserve. Ironically, today fish markets of Arkansas cannot supply the demand for gar meat, which fetches a price higher than catfish fillets. Researchers investigating feeding habits of gar support the view that consumption of game fish is minimal.

Catching an Alligator Gar (often referred to as "gator gar") is not so easy. They are not abundant today and occur in large floodplain rivers of the delta region of Louisiana, Arkansas, Mississippi, and Texas. It is very hard to impale the toothy jaws with a barbed hook. Most gars are caught by accident by commercial fisheries or targeted by bowfishers. Unfortunately, those who learn to catch gator gar with bowfishing, trot lines, and heavy-duty equipment often leave them dumped by the truckload or turned into fertilizer. Today, some anglers are "hooked" on targeting the monster gator gar, or *le poisson armé* (the armored fish), as the French explorers referred to it. When author Mark Spitzer (2010, 2015) hooked his second monster gar, it was just as Jack Harper described in *Outdoor Life* (1950): "They call him gar. His mother is a hurricane and his father is a ring-tailed tornado, and when he's mad he's one fish wave of destruction."

***Question to ponder*:**

Describe the causal chain of influence from values, beliefs, norms, and actions as it applies to early actions of European colonists toward gars. Contrast that with values, beliefs, norms, and actions of modern conservationists.

8.4 Bowfishing Controversies over Ethics and Waste

Bow anglers are a growing and dedicated constituency with specialized boats and equipment. Bowfishers in Texas represented only 3% of Texas freshwater anglers, were primarily male (97%), and fished 46 days per year, reporting a success rate of 57% (Bennett et al. 2015). Bowfishing may account for the majority of recreational harvest of Alligator Gar in Texas (Buckmeier 2008).

Bowfishing has grown in popularity, despite controversies over ethics and waste. Unlike hook-and-line fishing, bowfishing means that Alligator Gar are captured and killed. There is no such thing as catch and release. Wanton waste laws can be applied to all fish caught, requiring anglers to either release them or eat them. For example, Virginia's Wanton Waste Law holds that "No person shall kill or cripple and knowingly allow any nonmigratory game bird or game animal to be wasted without making a reasonable effort to retrieve the animal and retain it in their possession" (4 VAC15-40-250 Wanton Waste Virginia Law).

Also, because many bowfishers stalk fish at night in order to get close, the notion of fair chase has been questioned. Fair chase is the ethical, sportsmanlike, and lawful pursuit and taking of any free-ranging wild, native North American big game animal in a manner that does not give the hunter an improper advantage over such animals. Many dislike the idea of bowfishing because modern equipment and practices do not permit fair chase.

In response to criticisms, the Colorado Bowfishing Association (COBF) developed a member code of ethics (see below).

It is our responsibility, as sportsmen and members of the COBF, to act in a responsible, professional, and ethical manner when engaging in the sport of bowfishing. Our individual actions, both good & bad, can have an enormous impact on the sport of bowfishing for current and future generations of sportsmen.

This code provides a clear standard of conduct for a bowfisher and gives the public a clear indication of what to expect from a COBF member.

- As a member of COBF, I will subscribe to a higher standard of ethical and sportsmanlike conduct.
- I will not breach, encourage or condone any violation of the Colorado Division of Wildlife's fishing regulations or local lake regulations. I will always be in possession of a valid fishing license when engaging in the sport of bowfishing and will only pursue and harvest those species deemed legal by the Colorado Division of Wildlife for take with archery equipment.
- I will always engage with a safety first policy when bowfishing which includes inspecting my equipment—bowstring, arrows, nocks, tips, reel and line—for unsafe wear or damage; keeping my bow pointed in a safe direction and being sure of my target—what is in front of it, to the side of it and behind it.
- I will be aware of others around me. If other fishermen are nearby I will keep a safe, courteous distance and will share the waters with my fellow sportsmen.
- I will take the time to answer questions about the sport of bowfishing and always represent the COBF in a professional and courteous manner.
- I will make good use of the fish I harvest and will never leave my fish on the public shoreline or within communal trash receptacles. Doing so is not only unethical but tarnishes the sport of bowfishing for all. If I do not have a plan to make good use of the fish I am about to harvest, I should not be bowfishing.
- I will make my best attempt to rotate where I bowfish so to not over fish a body of water. I will do this to help manage Colorado's fisheries and hopefully ensure the preservation of the sport of bowfishing for current and future generations.

Scarnecchia and Schooley (2020) reported that only nine states surveyed had bowfishing education programs and none had articulated bowfishing management goals. Management agencies can examine how many native fish are currently being managed or not managed. Native fish advocates maintain that certain fish—including Alligator Gar, Bigmouth Buffalo, and paddlefish—should not be permitted targets of bowfishing, just as bowfishers may not shoot trout, bass, and other "game" species. With growing interest in bowfishing, the controversies will continue.

***Question to ponder*:**

In your opinion, what are some key characteristics of responsible, ethical fishing for Alligator Gar?

8.5 Habitat Connection

Gars are fascinating and misunderstood creatures, and unfortunately, the influence of habitat restoration for them has not yet been fully explored. Can we save one of the largest fish in North America with floodwaters? Rivers in the range of Alligator Gar are highly altered due to dams, dikes, dredging, and other forms of habitat and flow alteration. Managers need to understand what drives populations of Alligator Gar if the species has any chance to be restored throughout its range (Buckmeier et al. 2017). Recently, investigators confirmed suspicions that Alligator Gars are dependent on seasonal flooding in large floodplain rivers (Robertson et al. 2018).

Efforts are now underway to restore these magnificent creatures via supplemental stocking. It will take up to 50 years for stocked Alligator Gar to reach the potential maximum sizes. Stocking is an expensive short-term strategy, which may be necessary until natural spawning and rearing habitats can be restored. Although the effects of hydrologic modification of rivers is well documented, the prevailing questions related to reestablishing ecologically sustainable flows, such as "How much?" and "How often?" remain unanswered. Fully mature Alligator Gars may produce 200,000 or more large eggs (2–4 mm in diameter). These BOFFFF need to be protected from harvest, and we also need to provide habitat so that they will spawn naturally.

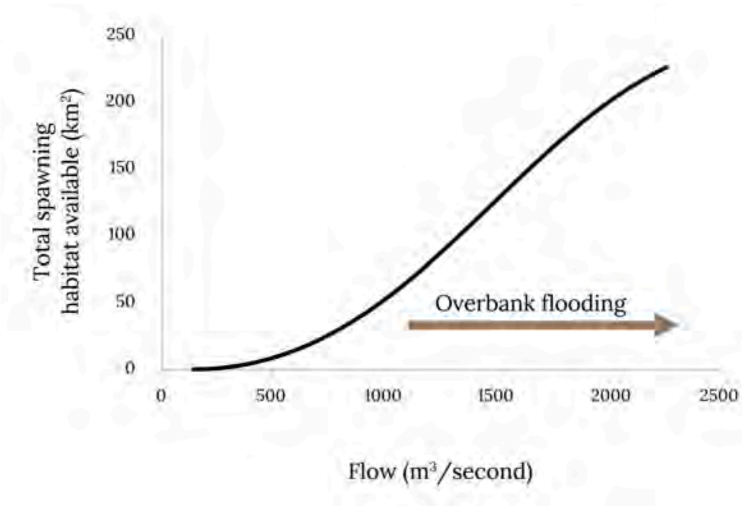

Figure 8.12: Spawning habitat suitable for Alligator Gar in the middle Trinity River, Texas, as related to river flow.

What is suitable habitat for spawning? The life history of Alligator Gar is tuned to life in large floodplain rivers where spawning is synchronized with the high flow-pulse events (Buckmeier et al. 2017). Alligator Gar spawning habitat includes floodwaters between 0.2 and 2 meters deep over woody vegetation and open-canopy vegetation types. Spawning habitat increases as the river flow increases enough to spill onto the floodplains (Figure 8.12; Robertson et al. 2018). However, Alligator Gars must be able to access these newly flooded habitats. Dams can block migrations of these fish as they seek spawning habitats (Lochmann et al. 2021).

Alligator Gar congregate in newly flooded backwaters (Kimmel et al. 2014) when water temperatures exceed 20°C (68°F). Fertilized eggs are deposited on woody debris and vegetation and will hatch in two to four days. The larvae of all species of gars have an attachment organ on the head (Figure 8.13) to allow larvae to attach to vegetation, as the yolk sac is used for energy. Eggs of gars are toxic to birds, mammals, and crustaceans, thereby reducing some predation. Rapid growth of larvae and juveniles will permit large numbers to survive if floodwaters occur at the right time and persist during this vulnerable period for young gars (Allen et al. 2020; Schumann et al. 2020).

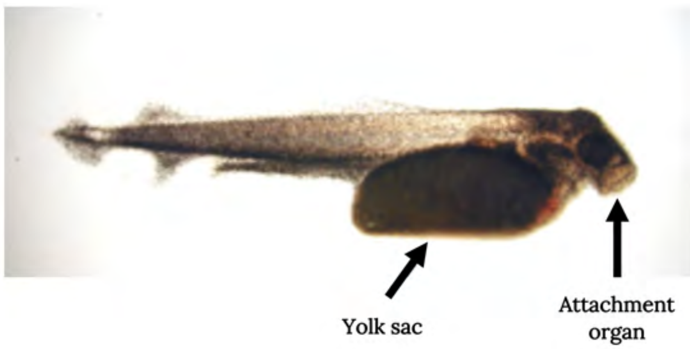

Figure 8.13: Shortnose Gar larva with yolk sac and adhesive organ.

The lessons from the Trinity River study give us optimism for population restoration here and elsewhere. The demand for water from the Trinity River is growing from population centers of Dallas-Fort Worth and Houston, and flood-pulse management may provide for periodic strong Alligator Gar recruitment. While many are experimenting with spawning and stocking of Alligator Gar (Mendoza et al. 2008; Schmidt 2015; Frenette and Snow 2016; Snow et al. 2018; Porta et al. 2019; Long et al. 2020), the restoration of natural habitat when and where it is needed has the best likelihood for long-term sustainable populations. Therefore, we must maintain the periodicity of flood pulses that connect river channel habitats to backwater areas to ensure Alligator Gar recruitment. Maintenance of river flows will also be critical to the preservation of estuarine habitats used.

Alligator Gar habitat restoration is a "Field of Dreams" plan—If you build it, they will come. If we create large expanses of spawning habitat, breeding Alligator Gar may receive the cue to initiate the courtship and spawning behavior. However, if dam operations cut off the flood pulse after spawning, recruitment will be reduced. The longer duration of the flood pulse enhances nursery habitats for young Alligator Gar.

8.6 From Pest to the Target of Conservation

The history of fish management depicts eras of abundance and discovery, followed by exploitation, then protection and management, and eventually holistic environmental management. The changes in human attitudes are evident, as people shifted from viewing gars as pests to be destroyed to targets for ecosystem conservation. The values-beliefs-norms-actions causal chain explains human perceptions and actions relative to the gars. European colonists in North America had value orientations associated with dominion over living things. Many early fish biologists were misinformed about the role of gars and viewed them as indiscriminate predators who decimate the highly valued game fish. These early beliefs made the lack of control programs and fishing regulations for gar as norms and encouraged people to remove them (Scarnecchia 1992). Gars were considered undesirable "rough fish."

"Rough fish" (or the slang, "trash fish") is a term used in the United States to describe fish that are less desirable to sport anglers. Harriet Carlander, in *History of Fish and Fishing*, explained that the term "rough" was a term used for lower-valued fish that had only been partly processed during a busy day of fishing. These fish could not be sold for full price. In northern Europe, the term is "coarse fish." Today, the term persists, but many types of rough fish (roughfish.com) are pursued by anglers interested in capturing the wide variety of species that exist in U.S. waters. The negative connotations of the term are unfortunate, and should be abandoned. Putting buffalo fish, carp, and gar in the same category for management makes no sense.

"What's in a name? That which we call a rose, By any other name would smell as sweet." Rough fish have value, and the terms we use should reflect that value. For example, the Common Carp and the four Asian carps all have demonstrated a high probability of causing ecological and economic effects where populations become established (Conover et al. 2007). Regulations on bowfishing should be liberal to encourage the take of these species so that they are turned into food or fertilizer. Bowfishing tournaments have partnered with organic fertilizer companies to utilize the harvest. Carpbusters Inc., a nonprofit, created the EcoCarp® project, which takes carp and makes nutritious, affordable food for zoos, sanctuaries, and other applications.

When recreational anglers did begin to target gars, they organized tournaments with bowfishing to remove undesirable fish. However, fish management agencies were slow to institute protective fishing regulations for gars. Alligator Gars were listed by experts as "vulnerable" (Jelks et al. 2008), prompting agencies to form the Alligator Gar Technical Committee and promote research and conservation for the species. Simultaneously, many recreational anglers got hooked on gar fishing. Television shows, such as National Geographic's *Monster Fish* with Zeb Hogan and *River Monsters* with Jeremy Wade, demonstrated catch-and-release fishing for Alligator Gar. Today more fishing guides have converted to strict catch-and-release advocates. Captain Kirk, featured on *River Monsters*, is an Alligator Gar catch-and-release guide (he hates stupid bow hunters who dump their kill).

Those who value Alligator Gars for their role in the ecosystem believe in ethical, well-regulated fishing practices (Miller 2017; Blok 2021; Rypel et al. 2021). The status of the Alligator Gar is still vulnerable, but progress is evident (Smith et al. 2020):

- Five states classify the Alligator Gar as a "commercial/rough fish," whereas Florida and Louisiana consider the species a "nongame fish."
- Four states identify the species as a "sport fish/game fish."
- Over half of the states (N = 7) in the species' range classify Alligator Gar as a "Species of Greatest Conservation Need" or similar under State Wildlife Action Plans. This classification frequently allows for funding conservation efforts and research for nongame species through the U.S. Fish and Wildlife Service's State Wildlife Grants program.
- Growing popularity of hook-and-line angling and bowfishing for Alligator Gar has prompted agencies to actively manage existing populations.
- Alligator Gar is now officially the State Primitive Fish of Arkansas.
- Illinois passed a resolution to protect gars in Illinois, justified based on the ecological importance of gars as apex predators.
- New regulations for the Trinity River, Texas, restrict taking Alligator Gar longer than 48 inches, bans nighttime bowfishing, and requires reporting Alligator Gar harvest in other Texas waters (Tompkins 2019).
- Minnesota has redesignated Shortnose and Longnose Gar as game fish and established bag limits for them.

The solutions suggested here are conceptually simple: manage gar and other "rough fish" the same as freshwater game fish and use science-based limits and regulations. Outdated notions that some fish are more valued and worthy of protection have been questioned (Rypel et al. 2021). The lack of bag limits on many "rough fish" encourages excessive kills and waste. A renewed focus on common fish is needed to understand the ecological role of species we take for granted (Frimpong 2018). We may find that the common species sustain the rare ones and even prevent more species from becoming vulnerable to extinction.

Question to ponder:

Why is the term "rough fish" not appropriate as a categorization for conservation purposes?

8.7 Concluding Thoughts

I argue that changes in human attitudes are happening and allowing changes in mortality on these long-lived creatures. The case studies of gar, sturgeon, and paddlefish further support the notion that ethical pragmatism[1] can play an important role in development of effective conservation programs. In the case of gars, anglers, bowfishers, and conservationists have examined the issues surrounding gars and have realized changes in norms and practices about gars and gar fishing.

Profile in Fish Conservation: Solomon David, PhD

Scan the QR code or visit https://doi.org/10.21061/fishandconservation to listen to this Profile in Fish Conservation.

Figure 8.14: Solomon David, PhD, with the skull of an Alligator Gar.

Solomon David is currently an Assistant Professor at Nicholls State University in Thibodaux, Louisiana, where he runs the GarLab and teaches biology, evolution and ecology, and biology of fish. His origin story begins with as a kid reading *Ranger Rick* magazine. Like many young children, he was fascinated with dinosaurs. When he first read about an Alligator Gar, which coexisted when dinosaurs lived on Earth, he was hooked on gar for life. He claims that "My career, dedicated to prehistoric fish, began with *Ranger Rick*," and he is still chasing his childhood fish fascination.

He earned a BS in biology from Ohio Northern University and an MS and PhD from the University of Michigan, where he studied the life history and genetic diversity of Spotted Gar across its range. David also worked as a research associate at Michigan State University on genomics of gar, before

1. View that we can and should carry on our practice of moral deliberation without reference to moral truths

he began a joint position as research scientist with the USGS Great Lakes Science Center, and Research Associate at John G. Shedd Aquarium and the University of Wisconsin. At the Shedd Aquarium he had ready access to primitive bony fish on display and contributed to many educational efforts on gars and other primitive bony fish.

Dr. Solomon has published more than thirty publications on a variety of freshwater fish, from gars and Bowfins to bloaters, Lake Whitefish, Northern Pike, and Lake Trout. He is active in international networks for gar research and other freshwater fish and has organized special symposiums dedicated to biology and conservation of gars. In addition, he has written numerous articles targeted at a nonscience audience and has offered training for professionals interested in science communications.

Since reading an article about gars in *Ranger Rick* magazine as a kid, he has become one of the fish's most vocal defenders and is quick to oppose any angler's or bowhunter's persecution of "trash" fish. Matt Miller's book, *Fishing through the apocalypse*, describes how Miller and David fished with drones and large carp heads for gargantuan Alligator Gar in Texas (Miller 2019b). They adopted a strict catch-and-release practice.

Solomon David is a popular teacher. From *Rate My Professors*, a student writes, "Very passionate about his subject material, which makes classes very interesting! He was always very understanding when I had issues arise." In what may be the first-ever gar-inspired romance, he met his future wife at the Shedd Aquarium. At the time, she thought the most charismatic and interesting creatures at the aquarium were the belugas, sharks, and penguins. But she was soon swept away by his enthusiasm for the African Lungfish, sturgeon, *Arapaima*, and, of course, the gars.

Solomon David is a charter member and former president of the Science Communication Section of the American Fisheries Society. He has a large following on Twitter (@SolomonRDavid), where he routinely builds enthusiasm and appreciation for primitive fish and debunks myths surrounding gar and other native fish. His work has influenced many new audiences to take another look at gar as a model for scientific studies or a target for recreational fishing. I must confess that he inspired me to write song lyrics for the parody The Accidental Gar. He is not one to avoid controversies. Those who follow him on social media will learn that he believes fish are better than birds, penguins are overhyped, and fish puns are fintastic.

Key Takeaways

- Sturgeons, paddlefish, gars, and Bowfins are old lineages whose ancestors were present on Earth over 150 million years ago.
- Sturgeons, Alligator Gars, and paddlefish were overexploited and extirpated from parts of their range due to habitat change.
- The gar family (Lepisosteidae) has been around since the Cretaceous Period (~100 million years ago).
- Success of gar recovery depends, in part, on changes in human beliefs, norms, and actions.
- Problems have been overharvest, persecution, and waste.
- Propensity for overfishing due to life history traits, including long life and delayed age of maturity.
- Habitats essential for spawning and early life were highly modified by dams, diversions, and floodplain draining.
- Shift in human values related to treating gars as game fish was a slow process.

This chapter was reviewed by Solomon David.

URLs

The Accidental Gar: https://vimeo.com/229492355

Long Descriptions

Figure 8.6: 1) 10 years, approx 60 in; 2) 25 years, approx 70 in; 3) 35 years, approx 80 in; 4) 50 years, approx 85 in, 5) 65 years, approx 90 in; 6) 80 years, approx 100 in. Jump back to Figure 8.6.

Figure 8.9: Decline in numbers of fish with age with 1,000 at age 1 and 0 at age 80; Fish are reproductively mature at age 12 and trophy size at age 23. Jump back to Figure 8.9.

Figure 8.11: Page from old Missouri Fish and Game News. Article titled, “Raids Waged by Deputies Resulted in Destruction of over 5,000 Gar: large schools dynamited by department- all former records shattered- officials received excellent co-operation from sportsmen”. Jump back to Figure 8.11.

Figure References

Figure 8.1: Phylogenetic tree depicting the accepted relationships between sturgeons and paddlefish, gars, Bowfins, and bony fish. Bowfins and gars are sister groups to all bony fish. Kindred Grey. 2022. CC BY 4.0.

Figure 8.2: Alligator Gar (*Atractosteus spatula*). Duane Raver. 2012. Public domain. http://www.publicdomainfiles.com/show_file.php?id=13483708812923.

Figure 8.3: Longnose Gar. USFWS Mountain-Prairie. 2019. CC BY 2.0. https://flic.kr/p/2fmqruA.

Figure 8.4: Largest Alligator Gar captured in 2011 weighed 327 pounds. Ricky Flynt—MS DWFP. 2011. Used with permission from Ricky Flynt. CC BY 4.0.

Figure 8.5: Processed otolith (sagittae magnified 12.5X) from the current world record Alligator Gar caught from the Mississippi River Basin in Mississippi on February 14, 2011. Otoliths were obtained by Mississippi Wildlife, Fisheries, and Parks, with age assessment and imaging by Texas Parks and Wildlife Department. Nathan G. Smith, Texas Parks and Wildlife Department. Used with permission from Nathan G. Smith. CC BY 4.0.

Figure 8.6: Growth in length of Alligator Gar in Texas. Kindred Grey. 2022. CC BY 4.0. Data from "Characteristics and Conservation of a Trophy Alligator Gar Population in the Middle Trinity River, Texas," by Buckmeier et al., 2016. https://seafwa.org/journal/2016/characteristics-and-conservation-trophy-alligator-gar-population-middle-trinity-river.

Figure 8.7: Growth in weight of Alligator Gar in Texas. Kindred Grey. 2022. CC BY 4.0. Data from "Characteristics and Conservation of a Trophy Alligator Gar Population in the Middle Trinity River, Texas," by Buckmeier et al., 2016. https://seafwa.org/journal/2016/characteristics-and-conservation-trophy-alligator-gar-population-middle-trinity-river.

Figure 8.8: Recruitment of two populations of Alligator Gar in Texas demonstrates variable recruitment. Kindred Grey. 2022. CC BY 4.0. Data from "Reproductive Ecology of Alligator Gar: Identification of Environmental Drivers of Recruitment Success," by Buckmeier et al., 2017. https://seafwa.org/journal/2017/reproductive-ecology-alligator-gar-identification-environmental-drivers-recruitment.

Figure 8.9: Hypothetical decline in numbers of Alligator Gar with age, beginning with 1,000 individuals at the age of one year. Kindred Grey. 2022. CC BY 4.0.

Figure 8.10: Expected effects of fishing regulations on spawning potential ratio (SPR), with the percentage of spawning fish relative to the unfished state (SPR=100). Kindred Grey. 2022. CC BY 4.0. Data from "Modeling the Responses of Alligator Gar Populations to Harvest under Various Length-Based Regulations: Implications for Conservation and Management," by Nathan Smith et al., 2018. https://doi.org/10.1002/tafs.10040.

Figure 8.11: Page from *Missouri Game and Fish News* article published in April 1926. Missouri Game and Fish Dept., *Missouri Game and Fish News*, 1926. Public domain. https://catalog.hathitrust.org/Record/100804086.

Figure 8.12: Spawning habitat suitable for Alligator Gar in the middle Trinity River, Texas, as related to river flow. Kindred Grey. 2022. CC BY 4.0. Data from "Development of a Flow-Specific Floodplain Inundation Model to Assess Alligator Gar Recruitment Success," by Robertson et. al., 2018. https://doi.org/10.1002/tafs.10045.

Figure 8.13: Shortnose Gar larva with yolk sac and adhesive organ. Kindred Grey. 2022. CC BY 4.0. Includes a picture used with permission from Konrad Schmidt.

Figure 8.14: Solomon David, PhD, with the head of an Alligator Gar. Used with permission from Solomon David. Photo by Derek Sallman. CC BY 4.0.

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9. Fly-Fishing's Legacy for Conservation

God never did make a more calm, quiet, innocent recreation than angling.

—Izaak Walton (1808)

Learning Objectives

- Examine the history of fly-fishing and early influencers on conservation on cold-water fishes, with emphasis on the Rocky Mountain west.
- Identify the four past eras of fly-fishing and describe their unique characteristics, and analyze change in fly-fishing over time.
- Recognize fly-fishing as a specialized fishing endeavor that led to early development of an angling code of ethics.
- Evaluate the historical significance of fly-fishing and cold-water conservation organizations in the development of conservation programs.
- Identify issues and conflicts of stocking nonnative trout and preserving wild trout.
- Understand future challenges for preserving cold-water fish in response to global change.

9.1 Introduction

Imagine the frustration of being surrounded by fish and casting to them, only to have them ignore or be spooked by all your offerings. Anglers learned long ago to imitate the same food that fish were eating and place the imitation fly without spooking the fish. While fishing can use a wide range of gears and baits, fly-fishing refers specifically to the sport of fishing using a long rod and an artificial fly. This form of fishing has been around for at least 1,800 years, based on writings from Eastern Europe, and may have been practiced earlier (Hoffman 2016). Fly-fishing initially focused on trout and salmon, but now it is widely used to catch other fresh- and saltwater fish.

Fly fishers targeting trout had an important influence in developing and sustaining conservation programs, although they were sometimes criticized for exclusive or single-interest advocacy. Here I review the history of trout fishing and fly-fishing with special focus on the Rocky Mountain West, where fly fishers first exerted their influence on conservation ethics and sportfishing policy. Although many individuals and organizations played roles, I concentrate on only two: Fly Fishers International (FFI) and Trout Unlimited (TU). These two organizations had similar interests in conservation, but important differences prevented them from working together on a unified goal of conservation. The legacy of fly-fishing demonstrates the importance of passion, persistence, and partnerships in fish conservation.

Trout and salmon are the only sport fish native to the Western states, and fly-fishing here became more than a leisure activity. Norman Maclean's novel, *A River Runs through It* (1976), begins, "In our family there was no clear line between religion and fly fishing." Later Maclean writes that "Something within fishermen[1] tries to make fishing into a world perfect and apart." The iconography of Western fly-fishing that Maclean and others wrote about was created by anglers, fisheries managers, tourists, guides, businesses, and region promoters. The history of Rocky Mountain fly-fishing parallels the history of the expansion of our Western frontier as well as fisheries management (Brown 2015). Although Henry David Thoreau (1862) maintained that "In wildness is the preservation of the world," humans are part of the trout fishing system and helped create, destroy, maintain, and restore the trout fishing we have today.

The first trout fishers were Native Americans. Native Americans used a variety of fishing methods, including weirs, spears, nets, traps, baskets, hook-and-line methods, and baits. They also caught fish by hand via tickling. Tickling for trout involves rubbing the underbelly of a trout with fingers to get the trout to go into a trance, after which they can then easily be thrown onto the bank (Martindale 1901). Native Americans were more patient than others. This method is different from noodling for catfish, where the noodler uses fingers as bait and grabs the catfish by its mouth. Native Americans also caught fish by fly-fishing with deer-hair flies, according to the writings of early American naturalist William Bartram (1739–1823) (Monahan, no date).

The story of Rocky Mountain trout fishing begins with displacement of Native Americans from their historical fishing and hunting grounds. Uninhabited wilderness had to be created through the dispossession of Native people before it could be preserved (Spence 1999). Explorers, trappers, pioneers, soldiers, and homesteaders brought fishing gear to frontier outposts. The Lewis and Clark Expedition (1804–1806) included a designated angler named Silas Goodrich. The expedition first described several new species of fish, including the Yellowstone Cutthroat Trout and Westslope Cutthroat Trout, caught by Goodrich. Later military expeditions spent time trout fishing in addition to fighting Native Americans. Custer's Last Stand at Little Bighorn might have been avoided if he'd joined a column of reinforcements under General George Crook. Crook's soldiers were comfortably camped close by on Goose Creek near the Tongue River—fishing, not fighting (Monnett 1993; Owens 2002a; Lessner 2010).

1. Although Maclean and other writers use the term fishermen, women are active anglers and contribute significantly to the sport.

The history of fly-fishing's legacy in the American West is organized in four overlapping historical eras. The history highlights changing values as well as the changing scientific understanding of complex topics, such as phylogeny and competitive displacement of trout species. Deciding what are right or wrong actions involves consideration of values as well as scientific findings. We use "ought" to reflect ethical norms, whereas "is" refers descriptive statements. David Hume (1711–1776) articulated the "is-ought" fact-value gap, which maintains that one cannot make statements about what ought to be based on statements about what is. The NOFI (No-Ought-From-Is) idea that one cannot deduce an "ought" from an "is" means that we can make no logically valid arguments from the nonmoral to the moral.

These eras (with approximate dates) are reflective of the shifting value systems of fishers and fish managers (Snyder 2016):

1. Era of Rugged Individualism 1730–1880
2. Era of Hubris and Hatcheries 1880–1970
3. Era of Wild Trout 1970–2000
4. Era of Restoration of Native Trout 2000–present

Values shifted from resource exploitation for food to concerns for overharvest, followed by attempts to fix trout overharvest with hatchery production. While the legacy of fishing for stocked trout remains today, values shifted toward appreciation of native trout and recognition of the need for restoration. The era of restoration of native trout arose as important influencers began to engage in these value arguments as the world changed and scientific understanding expanded.

9.2 Era of Rugged Individualism

A rugged individual is someone totally self-reliant and independent from outside assistance, including from government entities. "Rugged individualism" is a term closely associated with the Western expansion. Frontier settlers were disproportionately male, prime age, illiterate, and foreign born (Buzzi et al. 2017). A sense of Manifest Destiny, or the idea that settlers were destined by God to expand throughout the continent, led to widespread fishing for subsistence during westward expansion. Westward expansion was furthered by the Homestead Act of 1862, which provided adult citizens who had never borne arms against the U.S. government with 160 acres of surveyed government land.

Settlers did not want government interference with their freedom to follow the frontier road to riches. By the 1890s, loggers were removing timber, trappers were removing beavers, farmers were irrigating arid lands for agriculture, and some were buying land for fishing in remote areas of the Rocky Mountains. Miners and railroad workers introduced fishing with dynamite. The early settlers had little time for leisure activities nor the patience of tickling for trout.

When did rugged individualists become elitist fly fishers? The first fly fishers who visited the West wrote for outdoor magazines and popularized the notion of the Rocky Mountains as a paradise for fly-fishing. One of these was Thaddeus Norris, “Uncle Thad” (1811–1877), who published *The American Angler’s Book* in 1864 (Figure 9.1). *The American Angler’s Book* was the first comprehensive account of sportfishing at the time. Norris was racist and criticized indigenous fishing methods: “For the red man . . . was a destructive fisher; his weirs and traps at the time of their autumnal descent, the spear on the spawning beds, and his snare or loop, were murderous implements” (Norris 1864). Settlers also used nets, traps, seines, weirs, and dynamite to catch fish. Fly-fishing at the time was a luxury and a leisure pursuit of only the wealthy in the United States, whereas most other people fished for subsistence purposes. There was a social class, and “fly fishing in the USA retained a sense of masculine individualism . . .where the angling tourist exercised power over local land and people” (Mordue 2009).

Tourism led to a second wave of Western expansion by those who argued that fly-fishing was more ethical than either the spearfishing methods used by Native Americans or fishing with hook and line to feed the homesteader’s family. Whether real or imagined, fly-fishing in America developed a distinctive imagery, ethos, and subculture (Schullery 1987, 246). Boston physician and author of “The Fishes of Massachusetts” Jerome V. C. Smith described fly-fishing in 1833 as the “perfection of fishing” (Washabaugh and Washabaugh 2000, 56). However, I see a paradox of simplicity and complexity. Angling writer John Gierach wrote, “I love the simplicity and the surroundings. Fly fishing is a breath of fresh air amid your busy lives.” Yet, the zealous fly fisher seems to defy this simplicity. Cold-water streams are loaded with a variety of trout foods, such as different stages of insects, and fly fishers attempt to imitate natural insects with hand-tied artificial flies in order to fool fish. The technique of “matching the hatch” in different seasons and waters demands a mix of special knowledge on aquatic entomology, fish behavior, and fluid dynamics. It is much easier to fish with live bait. The use of artificial flies instead of mistreating worms or other live baits is one reason why fly fishers have perceived themselves as more ethical and, therefore, better people.

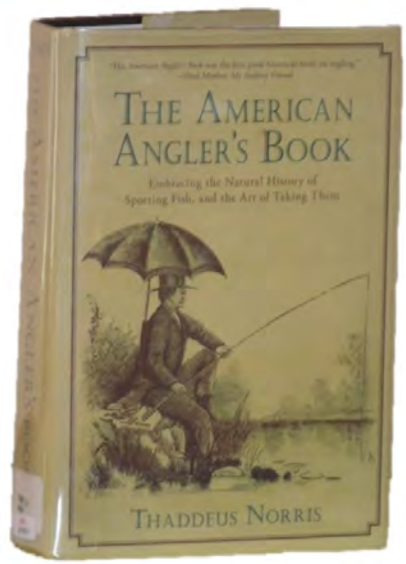

Figure 9.1: The American Angler’s Book: Embracing the Natural History of Sporting Fish, and the Art of Taking Them, by Thaddeus Norris.

This second wave included many writers who waxed poetic when it came to fly-fishing. Some writers—who were also fly fishers—claimed that “fly fishers are better people all around” (Soos 1999). After the Civil War, fly-fishing grew in popularity, spurred by the writings of popular authors like Thaddeus Norris and others. Fly-fishing became distinctly American with creation of fishing retreats, fishing clubs, lodges, specialty magazines, and fly-fishing organizations (Washabaugh and Washabaugh 2000). And Western fly-fishing was “a shiny badge of regional authenticity—of a person’s westernness” (Schullery 2006). Fly fishers toward the end of this era were tied to particular places and environments that they would eventually protect. Fly-fishing, and by extension fishing tourism, enlisted and promoted certain codes of practice and being that connected fly-fishing tourists to places.

At some point, the frontier trout anglers began to notice widespread declines in the rich abundance of trout. Methods other than hook and line for catching trout were outlawed in most states and territories by late 19th century. Early ichthyologists Barton Evermann (1891, 1894) and David Starr Jordan (1890) surveyed fish in the Rocky Mountain streams. In his 1889 surveys, Jordan commented on the many trout entrained in irrigation ditches and "left to perish in the fields." He also commented on the many surveyed waters where eastern Brook Trout were introduced and doing well. Declines in numbers of trout were inevitable and had many causes, including fishing, mining, overgrazing, water diversion, dams, logging, and removal of woody cover. The ironic move of rugged individuals asking for government assistance in building federal and state trout hatcheries led to the next era.

***Question to ponder*:**

The 19th-century movement of settlers into the American West began with the Louisiana Purchase and was fueled by the Gold Rush, the Oregon Trail, and a belief in "Manifest Destiny." In what ways was manifest destiny apparent among fly fishers during this period?

9.3 Era of Hubris and Hatcheries

Trout populations were declining, while a new scientific technology was developing that might reverse the decline. Seth Green, the father of fish culture, developed the first private fish hatchery in North America in Caledonia, New York, primarily to provide Atlantic Salmon and Brook Trout for food fish markets (Figure 9.2). Green's comprehensive work, *Trout Culture* (1870), was used by hatchery managers throughout the continent. Soon Green's hatchery was also producing American Shad, Brown Trout, and Rainbow Trout for stocking. More than any other individual, he is credited with introducing Rainbow Trout east of the Continental Divide, Brook Trout to Western states, and Brown Trout from Eurasia throughout the United States (Karas 2002; Halverson 2010; Newton 2013).

Figure 9.2: The father of fish culture, Seth Green, from Trout Culture (1870).

Before scientists understood the evolutionary history of the native trout and char of North America (Fausch et al. 2019; Trotter et al. 2018), hatcheries were built, eggs were taken, and millions of fish were stocked to provide trout fishing. Before the end of the 19th century, Rainbow Trout were propagated and widely introduced outside their range by the Ornithological and Piscatorial Acclimatizing Society of California. Seth Green was shipping eggs and fry of salmon and Rainbow Trout across the continent (Halverson 2010). Fish culturists and the New York Fish Commission promoted the superiority of the Rainbow Trout for their hardiness, ease of hatching, game qualities, ease of capture, and fighting qualities. Soon U.S. Fisheries Commissioner Spencer Fullerton Baird instructed Livingston Stone to build another hatchery devoted to Rainbow Trout on the McCloud River, California. The eastern Brook Trout, no longer thriving in their native range due to logging, sedimentation, and warming, were deemed superior for streams of Colorado and were widely planted on top of native Cutthroat Trout. Since that time, the National Fish Strain Register has described 64 strains and even more broodstocks of Rainbow Trout (Kincaid et al. 2001). Despite lessons learned from unrestrained carp plantings as a food-fish-turned-pest species (Bartlett 1910), all reports on nonnative trout were positive, until many decades later.

Trout hatcheries were a distinctly American invention that led to the formation of the American Fish Culturists' Association in 1870 (now recognized as the American Fisheries Society). The first federal fish hatchery, known as the Baird Hatchery, was established in 1872 on the McCloud River in California (Figure 9.3). Soon it was shipping eggs of trout and salmon throughout the United States and the world (Stone 1897). Other federal hatcheries were soon built in Leadville, Colorado (1889), Bozeman, Montana (1892), and Spearfish, South Dakota (1896), to stock Cutthroat Trout, Brook Trout, Rainbow Trout, and Brown Trout.

Many millions of trout were produced and stocked each year to meet the demand for trout fishing. Stocking catchable-sized trout provided higher returns and angler satisfaction than fry stocking (Wiley et al. 1993). But it is an expensive undertaking, and biosecurity and fish health concerns require substantial infrastructure improvements as well as feed and personnel costs. While fly fishers brought notions of fishing for sport, not subsistence, and concern for angler ethics, they also lobbied for regulation changes that set aside more waters for fly-fishing only.

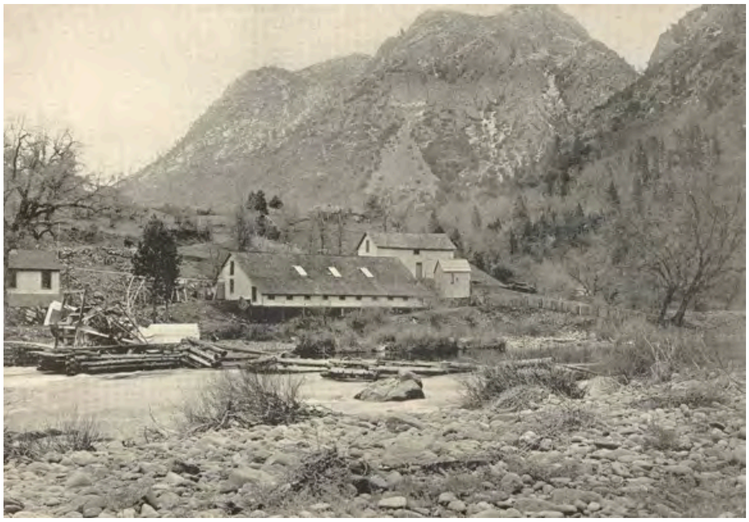

Figure 9.3: Baird Hatchery Station on McCloud River, California, with Mount Persephone in background (1897).

Scientists investigating trout waters soon revealed the fallacy of hatchery solutions over a long period of reckoning with hatchery plantings and their effect on aquatic ecosystems and fishing culture. I call it the "reckoning" because indirect effects of hatchery plantings (Table 9.1) and narrow emphasis on game species ignored needed efforts at ecosystem protection. The actions of the hatchery era are irreversible, eliminating options and choice for future generations.

Indirect effects of stocking nonnative trout
Hatchery effluents
Competition with native fish
Predation on native fish
Hybridization with native trout

Table 9.1: Indirect effects of stocking nonnative trout. Hatchery effluents refers to waste discharged from fish hatchery.

Since the beginnings of hatchery plantings of trout and salmon, scientists and anglers have debated both the harms and triumphs of planted trout and salmon. Native trout that were replaced with nonnative trout and any fish that was not a trout were automatically viewed as trash fish (Hoffman 2016). This derogatory term was unfortunate, as it influenced the actions of many anglers toward "trash fish."

During the postwar era, most states developed wide-scale fisheries by planting catchable-size Rainbow Trout, which were quickly removed by anglers. Rainbow Trout were selected because at the time they were considered to be easier to raise in hatcheries, they fought and jumped better, and they were well known by anglers. Spinning fishing gear began to be mass-produced at this time and made trout fishing with spinners and bait widely available. The postwar era also saw the emergence of fishing tackle manufacturers, such as Garcia Mitchell, Zebco, and others. And trout stamps—an actual stamp sold by fish and wildlife agencies in addition to a fishing license—contributed to commodifying trout fishing, as all revenues went to raising trout for stocking. In response to intense and widespread angler demand, nonnative stocked trout overpowered any concern for wild trout, or any other wild fish, at the time.

Fish and game laws defined fish as game fish or coarse fish. One by one, the coarse fish species were labeled as enemies because of presumed deleterious effects on game fish, in this case trout and salmon. Numerous species of chub, minnows, sculpins, suckers, and whitefish were labeled as "trash fish" and killed when inadvertently captured. Sculpins are often abundant in riffles where salmon and trout are spawning and in areas where salmonid fry are abundant. Early fisheries managers expressed concern that sculpins might decimate trout and salmon populations via predation on the eggs and fry and through competition for benthic invertebrates. Research suggests that only under exceptional or artificial conditions can sculpins severely limit salmonid populations (Moyle 1977).

Similarly, suckers were thought to be harmful to trout because of predation on eggs and fry and from competition for food. This influenced fisheries management programs in many states. Wisconsin passed a state law in 1973 requiring that "All rough fish taken in nets or on set lines shall be brought to shore and buried, sold, or otherwise lawfully disposed of, but no rough fish shall be returned to any waters." While evidence exists demonstrating that many species of suckers do prey on eggs when they have an opportunity, the evidence does not support the notion that sucker removals benefit trout population (Holey et al. 1979).

Mountain Whitefish (Figure 9.4) represent one of the most abundant native salmonid species in the Rocky Mountain West, yet they remain an "afterthought for most fisheries research and management programs in western North America" (Meyer et al. 2009). Mountain Whitefish were harvested by indigenous people and the non-elite during the 19th and 20th centuries. They survived the long period of mistreatment by anglers who considered them trash fish. Yet, Mountain Whitefish also declined, as did trout, salmon, and char in response to dams, excessive irrigation withdrawals, and other insults. Mountain Whitefish provided fishing opportunities in the past and will in the future without investment in hatcheries. The prejudice against any fish that was not trout or salmon influenced investments in hatcheries and fishing regulations. Consequently, conflicts still remain on the values of coarse or rough fish. The primacy of trout in the minds of fly fishers led to trout fisheries in unusual places and unjustified removals of native fish (Brown and Moyle 1981) and planting of nonnative trout.

Figure 9.4: Mountain Whitefish (Prosopium williamsi) (16 inches) was caught and released in the McKenzie River near the town of Blue River, Oregon.

The hatchery era also coincided with the development of major dams built by the Bureau of Reclamation, U.S. Army Corps of Engineers, and the Tennessee Valley Authority, which created additional opportunities for planting nonnative trout in tailwaters below dams. Deepwater releases of cold, oxygenated, nutrient-rich, and sediment-free water from dams displaced native fish and created opportunities for supporting "large numbers of trout that generally grow far faster, bigger, and fatter than trout in western freestone rivers without high dams" (Owens 2002b). The Bighorn River and Beaverhead River in Montana, Green River in Wyoming and Utah, Fryingpan River in Colorado, and South Platte River in Colorado are just a few of these unique tailwaters that produce exceptional growth rates for trout (Gebhards 1971;Wiley and Mullan 1975). Many new trout fisheries were established in cold tailwaters via stocking fingerling trout (Pfitzer 1975). Wild trout were often limited in tailwaters from lack of spawning habitat, high fishing pressure, fluctuating water levels due to hydropower generation, presumed competition with native species, and in some cases water temperature. Fly fishers adapted to fishing these special waters by mimicking the unique fauna. Simple, tiny black midges and amber scuds mimicked the dominant prey and resulted in catches of lunker trout by many fly fishers.

The hubris of the hatcheries era coincided with massive ecosystem change, dam construction with hatchery supplementation, environmental degradation, haphazard transplanting of nonnative trout, and lack of regard for any fish that was not a trout. The legacies of the hatchery era remain, and a broader ecosystem perspective would be needed for successful cold-water fish conservation.

Questions to ponder:

Can you recall your parents or grandparents talking about trout fishing in the past? How did they view trout fishing at the time?

9.4 Era of Wild Trout

The fundamental salvation of trout fishing in the west, or anywhere, lies in the maintenance of environment.

—Arthur Carhart (1950)

Hatchery stocking masked a long legacy of detrimental effects of mining, dewatering, overgrazing, and other forms of stream degradation on wild trout populations. Yet, it took many years to convince fisheries managers to quit heavy stocking in Western rivers. Roderick Haig-Brown preached earlier to "just protect the habitat, the rest will take care of itself" (Sloan and Prosek 2003). Two organizations, Trout Unlimited and Federation of Fly Fishers (Brown 2015), played key roles in advocating policies emphasizing wild trout, ethical fishing, and healthy habitat. Although its members included many fly fishers, Trout Unlimited did not consistently advocate for policies that favored fly-fishing–only regulations.

Trout Unlimited is the largest and certainly most prominent cold-water fishery conservation association in the United States. This nonprofit organization has 300,000 members and supporters dedicated to conserving, *protecting*, and restoring North America's cold-water fisheries and their watersheds. The philosophy of Trout Unlimited includes the following beliefs:

- Trout Unlimited believes that trout fishing isn't just fishing for trout.
- It's fishing for sport rather than food, where the true enjoyment of the sport lies in the challenge, the love and the battle of wits, not necessarily the full creel.
- It's the feeling of satisfaction that comes from limiting your kill instead of killing your limit.
- It's communing with nature where the chief reward is a refreshed body and a contented soul, where a license is a permit to use—not abuse, to enjoy—not destroy our trout waters.
- It's subscribing to the proposition that what's good for trout is good for trout fishermen and that managing trout for the trout rather than for the fisherman is fundamental to the solution of our trout problems.
- It's appreciating our trout, respecting fellow anglers, and giving serious thought to tomorrow.

Trout Unlimited (TU) was started in 1959 by 16 fly fishermen who met on the banks of the famous AuSable River in Michigan. The organization was the brainchild of George Mason, president of American Motors, and George A. Griffith, a commissioner with the Michigan Department of Natural Resources (Griffith 1993; Ross 2016). Trout Unlimited did not claim to be a flies-only club, though they advocated flies-only regulations in Michigan the year before they incorporated. Trout Unlimited members had two common interests: the love of trout and a desire to improve trout stream habitat. They saw weaknesses of bureaucratic systems in most fisheries departments and failures to consult with fisheries scientists. Trout Unlimited was guided by the principle that if we "take care of the fish, then the fishing will take care of itself." TU's first president, Dr. Casey E. Westell Jr., said, "In all matters of trout management, we want to know that we are substantially correct, both morally and biologically." TU relied on the best available science and included scientists on its Board of Directors. Membership grew from a local organization into many local chapters, state councils, and a national presence. Through the efforts of local chapters, TU focused on sustaining rural quality of life in watersheds, promoted economic activities compatible with local watersheds, protected and advocated for water rights or instream flows for trout, and promoted habitat restoration (Munday 2002; Owens 2002b). Today, the National Conservation Strategy of Trout Unlimited is set by its leadership council, a body of volunteers and grassroots leaders (Trout Unlimited 2016).

Fly Fishers International (formerly Federation of Fly Fishers) was founded in 1965 with a dual mission to educate fly fishers and promote conservation through advocacy. Its founding was motivated by concern for a decline in fishing quality in many well-known trout and salmon rivers. Founding members, Bill Nelson and Gene Anderegg, were driving forces behind recruiting members and developing a national meeting. Fly Fishers International (FFI) was organized as a federation of local fly-fishing clubs, loosely tied to a national office. FFI has over 11,000 members in 37 countries organized into over 200 clubs. The vision of FFI was to develop in fly fishers a conservation conscience and promote activism (Williams 2016). Early leaders included Ted Trueblood, editor of *Field and Stream*, and Lee Wulff. Lee Wulff and Roderick Haig-Brown were early advocates for the concept of catch and release in North American fisheries. Wulff wrote the aphorism, "gamefish are too valuable to be caught only once" (Wulff 1939). Catch-and-release regulations, first implemented in 1970, have become widespread in managing game fish. TU and FFI played key advocacy and advisory roles in supporting national conservation legislation, including the Clean Water Act (1972), the Endangered Species Act (1970), and the Wild and Scenic River Act (1968), as well as policies restoring native fish (Williams et al. 2011).

The first code of fly-fishing ethics was written in 1939 by Roderick Haig-Brown (1939), in "Limits and ethics" in *The Western Angler*. Haig-Brown and other FFI members were instrumental in educating and promoting fly-fishing ethics and ethical codes. The Fly Fishers International Code of Angling Ethics (Fly Fishers International 2002) asserts the following:

- Fly anglers understand and obey laws and regulations associated with the fishery.
- Fly anglers believe fly-fishing is a privilege and a responsibility.
- Fly anglers conserve fisheries by limiting their catch.
- Fly anglers do not judge fellow anglers and treat them as they would expect to be treated.
- Fly anglers respect the waters occupied by other anglers so that fish are not disturbed.
- When fishing from a watercraft, fly anglers do not crowd other anglers or craft or unnecessarily disturb the water.
- Fly anglers respect other angling methods and promote this Code of Angling Ethics to all anglers.

Beginning in 1974, Trout Unlimited and others sponsored a series of symposia on Wild Trout to exchange technical information on wild trout management. Held every three years, the Wild Trout Symposium brings together anglers, writers, students, and professionals from every trout region in the United States and Canada. The issue of stocking trout on top of wild trout populations was the hot topic at the first symposium. Willis King proposed that "wild trout are members of a naturally produced and maintained population, in a natural setting" (King 1975, 99). Based on studies by Dick Vincent, the Montana Fish and Game Department stopped stocking trout in streams and rivers that supported wild trout populations (Zachheim 2006). The new strategy was based on a concept of self-propagating fisheries, catch and release, fly only, barbless hooks, fly-fishing only, special regulations, and limited hatchery supplementation.

TU's National Leadership Council (NLC) passed a resolution in 2011 that states, "Resolved, that the NLC is opposed to Chapters or Councils stocking of non-native hatchery trout on top of native trout populations" (Trout Unlimited 2011). Other states began to debate the meaning of "wild" and to initiate restoration projects to focus on habitat protection and restoration to restore wild trout. Numerous restoration methods are needed for trout stream restoration, including enhancing instream flows in trout-rearing areas, preventing fish loss in irrigation canals, reconstructing altered streams to naturalize channel form and function, and fencing livestock from riparian areas (Pierce et al. 2019). To avoid the polarizing native-nonnative debates, TU often emphasized that "We just focus on the habitat."

Figure 9.5: Westslope Cutthroat Trout (Onchorhynchus clarkii lewisi).

The future of wild trout and wild trout fishing is threatened by a legacy of nonnative fish introductions, beaver extirpation, logging, wood removal, dams, irrigation withdrawals, and climate change. Popular game fish, such as Walleye and Northern Pike (McMahon and Bennett 1996) and nonnative trout (Dunham et al. 2002; Dunham et al. 2004; Quist and Hubert 2004; Budy and Gaeta 2018) displace native trout in the Rocky Mountain region. Whirling disease introduced from infected trout has the potential to reduce wild trout populations. But the threat of climate change on wild trout, especially Bull Trout and Cutthroat Trout, may be most difficult to mitigate because these species are already constrained to high elevations and latitudes, limiting their ability to adapt (Figure 9.5; Isaak et al. 2015; Hansen et al. 2019). The management with wild trout restoration and nonnative trout suppression will dominate the actions of fisheries and land managers for the next generation.

***Questions to ponder*:**

Why do you suppose there are still two large conservation organizations, Fly Fishers International and Trout Unlimited? Would it make more sense for the two organizations to merge into one larger, influential organization? What were the most significant influences these organizations had on conservation?

9.5 Era of Restoration of Native Trout

I know that neither hatcheries, nor biologists, nor all the thought and ingenuity of man can put them back when once they've gone.

—Roderick Haig-Brown, *Fisherman's Spring* (1951)

Many thought they were doing the right thing for the world at the time of indiscriminate and inconsiderate stocking of nonnative trout. Stockings supported a subsistence fishery, diversified fishing opportunities, and engaged more anglers. Yet, these decisions were irreversible, eliminating choice and options for future generations. Stocking nonnative fish outside their native range is passing through a door that goes in one direction—there's no going back. Once introduced, the consequences are uncertain and cannot be reversed except in the most special circumstances.

We understand values of fish for fishing and food. Trout provided for the well-being of trout anglers were of cultural importance to settlers of the frontier and provided direct financial gains for trout guides and private hatcheries. All of these were instrumental values, but other values of trout may be intrinsic or relational. The more we study trout in a variety of settings, the more diverse the set of values held will be. Conflicts over values affect decision making, and the stocking of nonnative trout only considered a narrow set of instrumental values. Nature's gifts (or nature's contributions) to well-being broaden the values perspectives (Pascual et al. 2017). Is stocking nonnatives right or wrong? What values are harmed with stocking? The answers to such questions depend on the value argument (Zablocki 2019). Consider the intrinsic values of protecting unique and irreplaceable evolutionary lineages of native trout. Instrumental values arguments would focus on the value of encouraging a vibrant economy based on abundant, catchable trout. Relational values arguments would focus on a unique way of life harmed by introduction of nonnatives.

Three voices—Aldo Leopold, James A. Henshall, and Edwin "Phil" Pister—were influential in early critiques of indiscriminate trout stocking. They advocated for recognizing values of native fish at a time when state and U.S. governments were investing heavily in trout hatcheries. It's taken a century of scientific investigations into indiscriminate, inconsiderate, and often planned trout plantings to develop a scientific basis for conservation actions to restore native fish.

Figure 9.6: *Leopold's trips to the Rio Gavilan region of the northern Sierra Madre in 1936 and 1937 helped to shape his thinking about land health.*

Aldo Leopold, after completing a master of forestry at Yale University, worked at the Apache National Forest in the Arizona Territory, Carson National Forest in New Mexico, and regional headquarters in Albuquerque, New Mexico (Figure 9.6). In this region, Leopold would be familiar with the endemic Apache Trout (*Oncorhyncus gilae apache*), Gila Trout (*Oncorhynchus gilae gilae*), and Rio Grande Cutthroat Trout (*Oncorhynchus clarkia virginalis*). Based on his observations on trout in these waters, Leopold presented a paper on "Mixing Trout" (Leopold 1918; Warren 2010). He wrote that "Nature, in stocking trout waters, sticks to one species." And Leopold recommended that to "Restock with the best adapted species, the native species [is] always preferred" (Leopold 1918, 102). Furthermore, in restocking empty waters, "ordinarily native and indigenous species are preferable." It would be years later that he reconstituted these ideas in these famous words:

The last word in ignorance is the man who says of an animal or plant: "What good is it?" If the land mechanism as a whole is good, then every part is good, whether we understand it or not. If the biota, in the course of eons, has built something we like but do not understand, then who but a fool would discard seemingly useless parts? To keep every cog and wheel is the first precaution of intelligent tinkering. (Leopold 1993, 145–146)

James A. Henshall, while best known for his *Book of the Black Bass*, was the first superintendent of the Bozeman National Fish Hatchery from 1897 until 1909 (Figure 9.7). The Bozeman Hatchery produced Brook Trout and Rainbow Trout for Colorado and Montana. Henshall described the accidental release of Brook Trout and Rainbow Trout into Bridger Creek. Noting pristine conditions prior to this, he wrote, "If depleted waters had been stocked with native fish, this happy and natural condition of affairs might have continued for many years to come" (Henshall 1919).

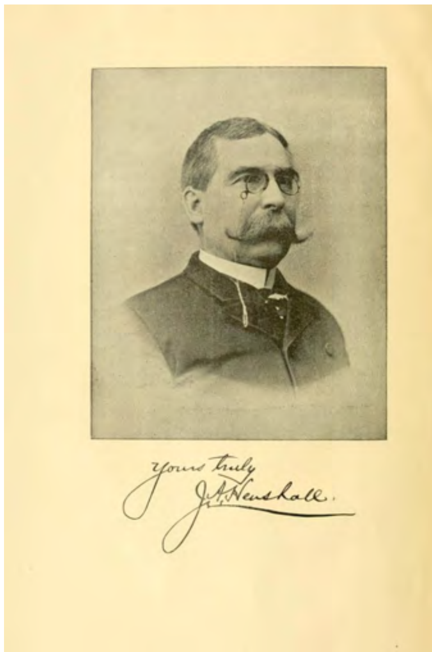

Figure 9.7: *Illustration of James A. Henshall, author of Book of the Black Bass (1881).*

Edwin "Phil" Pister read the works of Aldo Leopold while in graduate school. He worked as fisheries biologist with the California Department of Fish and Game during the height of the hatchery era. Hatchery trout and trophy fishing fueled a tourist economy in the High Sierra mountains of California. License buyers who funded most agency programs also overwhelmingly viewed trout as a commodity. Only one game species managed for fishing was native and that was the California Golden Trout (*Onchorhynchus mykiss aguabonita*), which is the State Freshwater Fish of California. Other species that were not managed were on the verge of extinction. In fact, one of the desert fish, the Ash Meadows Poolfish (*Empetrichthys merriami*), went extinct before the Ash Meadows Wildlife Refuge was established. On a visit to speak to Virginia Tech students after his retirement in 1991, Pister told the story of how in 1969 he scooped rare Owens Pupfish (*Cyprinodon radiosus*) out of a shoe-deep slough sure to dry (Figure 9.8). That day he literally saved the last population of Owens Pupfish—moving 800 fish in two buckets—away from certain destruction. The Owens Pupfish persists today and is classified as an endangered species.

Figure 9.8: Owens Pupfish (Cyprinodon radiosus), Fish Slough Ecological Reserve.

Pister worked tirelessly to establish and maintain the Desert Fishes Council. This group's mission is to "preserve the biological integrity of desert aquatic ecosystems and their associated life forms, to hold symposia to report related research and management endeavors, and to effect rapid dissemination of information concerning activities of the Council and its members." His work on Golden Trout began in 1959 when it was apparent the state fish was at risk of extinction (Figure 9.9). In the 1970s, he sided with the National Park Service against his agency directive. Park Service policy directed that since "Trout are not indigenous to the lakes of the High Sierra, they would no longer be planted in park waters." Nonnative trout stocking in fishless lakes led to near extinction of the Sierra Nevada Yellow-Legged Frog (*Rana sierrae*). Since the practice was eliminated in 1991, frog abundances have increased to levels similar to those in never-stocked lakes (Knapp et al. 2016).

Phil Pister also worked to reduce threats to the rare and threatened subspecies of Golden Trout in high-elevation streams of California. Pister liked to quote Stephen Jay Gould: "We are trapped in the ignorance of our own generation." The move from wild trout to native trout has been underway for nearly 100 years. Paul Schullery, in *Cowboy Trout*, explained it as follows:

Figure 9.9: California Golden Trout.

Most recently, it wasn't all that big a step from preferring wild fish to preferring wild native fish, which are now seen by many as providing a more authentic angling experience in nature. A fish that actually evolved over many millennia in the water has certain aesthetic advantages over a fish that only arrived a few decades ago (Schullery 2006).

Today, many Western states have a "native trout challenge" that encourages anglers to seek out various species/subspecies of (mostly native) trout and the places they inhabit as a way to get the public to appreciate the value of natives.

My role as a scientist is not to make a choice for all people about which trout to stock where. We all have many differences in attitude and outlook regarding restoration of trout. These are mostly cultural, not scientific differences. As a scientist, I can advocate for application of best science available, while recognizing that value arguments about nonnative trout stocking matter. The "No Ought From Is" idea should remind us to take time and slow down decision making so that the public develops trust and feels engaged in the process of fish conservation and management. Hatcheries have adapted over time because of public input, and today many hatcheries raise rare fish for introduction into their native habitats.

Conservationists are notorious for their dissensions. . . . In each field one group (A) *regards the land as soil. And its function as commodity-production; another group* (B) *regards the land as a biota, and its function as something broader.*

—Aldo Leopold (1947)

Questions to ponder:

In the 21st century, do you consider stocking nonnative trout as right or wrong? What values are harmed with stocking? When you think about fishing in cold-water streams, do you value wild more than native fish? Can you distinguish between native and naturalized fish?

9.6 Closing

The legacy of fly-fishing is important and has multiple dimensions. The popularity of fly-fishing for trout led to extensive planting of nonnative trout outside their range, including the continents of South Africa, Australia, New Zealand, and South America. Consequently, throughout the world managers deal with native trout restoration and nonnative trout suppression. The first code of fly-fishing ethics was traced to early writings of "Limits and Ethics" (*The Western Angler*), and fly-fishing organizations educate their members in the code of fly-fishing ethics (Ross 2008). Fly fishers were responsible for many of the first efforts at habitat restoration and protection, including the proposals of Native Fish Conservation Areas designed to protect entire watersheds and aquatic communities. Special fishing regulations, such as flies only and catch and release, were advocated by fly fishers, which led to declines in fishing by bait anglers who were displaced from local trout fisheries (Traver 2017). Importantly, fly fishers were some of the first anglers to support evidence-based fishery management programs. The fly-fishing literature is rich with stories as well as evidence to support the notion of sense of place influenced by trout and trout fishing. Robert Traver, in *Trout Magic*, wrote, "I fish because I love to. Because I love the environs in which trout are found, which are invariably beautiful, and hate the environs where crowds of people are found, which are invariably ugly" (Traver 1974). And David Quammen wrote, in *Wild Thoughts from Wild Places*, that "Trout were the indicator species for a place and a life I was seeking" (Quammen 1998). Strong conservation initiatives often start from grassroots action that taps into people's sense of place (Brown et al. 2019).

Exceptional (perhaps oversold) trout fisheries of the Western United States are neither totally wild nor natural; instead, they exist because of drastic and complicated environmental and social changes. The history of fly-fishing reveals the change in anglers' values from utilitarian self-interest toward biocentric, ecosystem-based conservation (Hoffman 2016). None of these changes were without conflict, and the political battles among anglers with differing values and different notions of how trout should be managed continue today. Having strong grassroots support from users, as well as a strong organizational structure, allows Trout Unlimited and the International Federation of Fly Fishers to lead conservation efforts. Climate change is the greatest threat to the viability of fisheries, and cold-water fish in streams are particularly at risk (Kunkel et al. 2013; Isaak et al. 2015). Restoration efforts can work toward mitigating expected effects of climate change (Williams et al. 2015).

> *Perhaps fishing is, for me, only an excuse to be near rivers. If so, I'm glad I thought of it.*
>
> —Roderick Haig-Brown (1974)

Profile in Fish Conservation: Daniel C. Dauwalter, PhD

Scan the QR code or visit https://doi.org/10.21061/fishandconservation to listen to this Profile in Fish Conservation.

Figure 9.10: Daniel C. Dauwalter, PhD.

Daniel C. Dauwalter is the Fisheries Research Director for Trout Unlimited in Boise, Idaho, and a Certified Fisheries Professional. He was born in Minnesota and earned a BA in biology and environmental studies from Gustavus Adolphus College (St. Peter, Minnesota), an MS in fisheries and aquaculture from the University of Pine Bluff, Arkansas, and a PhD in fisheries and wildlife ecology from Oklahoma State University.

After investigating aquatic monitoring protocols during his postdoctoral research at the University of Wyoming, he began his current position. His current work is focused mostly on aquatic conservation planning at the scale of large landscapes. In addition, he studies stream restoration science, effectiveness monitoring, habitat selection, and population viability of rare fish. His work directly benefits many species of trout and char, which are some of the more culturally, economically, and ecologically important taxa of freshwater fish worldwide. Nearly half of the world's trout and char are imperiled or at risk of global extinction, and conservation of native trout depends on progressive solutions focused on the root causes of imperilment. For Trout Unlimited, he helps identify where conservation programs may have the greatest influence on persistence of at-risk species of trout and supports management of trout fisheries.

Dauwalter has researched fish conservation and management across the country, ranging from broad-scale, spatial conservation assessments for native aquatic species to inform conservation programs, understanding the impacts of land management on and habitat requirements of fish at multiple spatial scales, and implementation of angler-based water quality programs using mobile applications in the Midwest. His wide-ranging work on fish communities and habitat selection has demonstrated that many recognizable stream features have direct ties to active and passive instream habitat restoration techniques. Consequently, restoration efforts that enhance habitat complexity may benefit many more species beyond trout.

He provides leadership in advocating for improved long-term monitoring programs for trout. In addition, he supports the profession as President of the Western Division of the American Fisheries Society and as Associate Editor of the *North American Journal of Fisheries Management*.

Dauwalter believes that trout are sentinels that depend on healthy watersheds that support clean and cold-water lakes and streams. Consequently, they are useful indicators of effects of global climate change, and the long-term prognosis for cold-water specialists is not good. Further, trout attract a large number of vocal advocates for new regulations that may squeeze out non–fly fishers. These advocates may also support large-scale efforts to build climate resilience. Many people are familiar with trout in artificial hatchery environments where they become domesticated and associate people with food. However, in the wild, trout quickly adapt to changes and human conditions and learn to avoid what anglers repeatedly throw at them. Through long time periods, unique locally adapted trout develop, and new species evolved over many millennia. Many unique trout species teach us important lessons of persistence and local adaptation to harsh environments. These include the Redband Trout, Lahontan Cutthroat Trout, Apache Trout, Gila Trout, Mexican Golden Trout, and several undescribed species of trout in Mexico. These species will become even more valuable under changing climate conditions.

Key Takeaways

- Fly-fishing is a highly specialized form of fishing.
- Nonnative trout were transplanted throughout North America in the 19th century, often threatening viability of native trout.
- Fly fishers played an important role in the 19th and 20th centuries in introducing trout on other continents, advocating for catch and release, and promoting a fly-fishing code of ethics.
- The history of fly-fishing reveals the change in anglers' values from utilitarian self-interest toward biocentric, ecosystem-based conservation.
- Fly Fishers International and Trout Unlimited are two organizations committed to conserving favored species and habitats.
- The folly of transplanting trout has shifted to "just protect the habitat, the rest will take care of itself."
- Furthermore, the legacy of exceptional (perhaps oversold) trout fisheries of the Western United States is neither wild nor natural, but rather they exist because of drastic and complicated environmental and social changes.

This chapter was reviewed by Daniel C. Dauwalter and Shannon L. White.

URLs

Trout Unlimited: https://www.tu.org/about/

Figure References

Figure 9.1: *The American Angler's Book: Embracing the Natural History of Sporting Fish, and the Art of Taking Them*, by Thaddeus Norris. Valerie F. Orth. Unknown date. CC BY 4.0.

Figure 9.2: The father of fish culture, Seth Green, from *Trout Culture* (1870). Seth Green, 1870. Public domain. https://commons.wikimedia.org/wiki/File:Seth_Green_from_Trout_Culture_(1870).JPG.

Figure 9.3: Baird Hatchery Station on McCloud River, California, with Mount Persephone in background (1897). Livingston Stone, 1897. Public domain. https://commons.wikimedia.org/wiki/File:FMIB_39938_Baird_Station_The_McCloud_River_in_the_foreground;_in_the_background_the_limestone_rocks_of_Mount_Persephone_Engine_house_and.jpeg.

Figure 9.4: Mountain Whitefish (*Prosopium williamsi*) (16 inches) was caught and released in the McKenzie River near the town of Blue River, Oregon. Woostermike, 2007. Public domain. https://commons.wikimedia.org/wiki/File:Prosopium_williamsoni.jpg.

Figure 9.5: Westslope Cutthroat Trout (*Onchorhynchus clarkii lewisi*). USFWS Mountain-Prairie, 2011. CC BY 2.0. https://flic.kr/p/9Mfg9G.

Figure 9.6: Leopold's trips to the Rio Gavilan region of the northern Sierra Madre in 1936 and 1937 helped to shape his thinking about land health. Pacific Southwest Forest Service, USDA, 2010. CC BY 2.0. https://flic.kr/p/9hS1XD.

Figure 9.7: Illustration of James A. Henshall, author of *Book of the Black Bass* (1881). J. A. Henshall, 1881. Public domain. https://commons.wikimedia.org/wiki/File:Book_of_the_black_bass_(Frontispiece-_J._A._Henshall)_BHL8568061.jpg.

Figure 9.8: Owens Pupfish (*Cyprinodon radiosus*), Fish Slough Ecological Reserve. California Department of Fish and Wildlife, 2011. CC BY 2.0. https://commons.wikimedia.org/wiki/File:Owens_pupfish_(Cyprinodon_radiosus).jpg.

Figure 9.9: California Golden Trout. Jordan, David Starr, 1907. Public domain. https://jenikirbyhistory.getarchive.net/amp/media/fmib-51959-golden-trout-of-soda-creek-f7d177.

Figure 9.10: Daniel C. Dauwalter, PhD. Used with permission from Daniel Dauwalter. .

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10. Recreational Fishing and Keep Fish Wet

Learning Objectives

- Describe the types of benefits provided by recreational fishing to the economy.
- Classify individual motivations for recreational fishing.
- Review options for maintaining satisfactory recreational fishing.
- Explain the basis for therapeutic value from recreational fishing.
- Understand the types of impacts that recreational fishing may have on fish, populations, and ecosystems.
- Explain how science can inform responsible fishing practices.
- Apply the Keep Fish Wet principles to minimize postrelease stress or mortality of released fish.
- Apply principles of behavior change to nudge recreational anglers to adopt responsible fishing practices.

10.1 Recreational Fishing and Its Importance

Recreational fishing is fishing for fun or sport, or fishing that "does not constitute the individual's primary resource to meet essential physiological needs" (Arlinghaus and Cooke 2009). While subsistence fishing has a longer history, the first recreational fishing began at different times in different regions of the world. *A Treatyse of Fysshynge with an Angle*, by Dame Juliana Berners (1496), was the first book written about recreational fishing. Today, recreational fishers dominate many freshwater and marine fisheries. At least 220 million recreational fishers use a variety of gear, including rod and line, handlines, spears, bow and arrow, traps, and nets, to catch fish while engaged in a leisure activity (Arlinghaus et al. 2015; Cooke et al. 2018). In this chapter, I refer to recreational fishers as anglers. The term "angler" has been used since the mid-15th century to refer to those who "fish with a hook."

Although commercial fishers have taken the brunt of the blame for fisheries depletions in the ocean, restrictive fishing regulations are often implemented for recreational fishing to prevent decline in catch rates (Lewin et al. 2006). In some freshwater lakes and streams, recreational fishing may be the only source of fishing mortality and may lead to collapse of important freshwater fisheries (Post et al. 2002). A major constraint in preventing overexploitation in recreational fisheries is the diffuse and open-access nature of the activity, making it very difficult to monitor the status of all fished populations (Arlinghaus and Cooke 2009). Privatization of recreational fisheries exists in only limited situations (Olausen and Block 2014), while many commercial fisheries have adopted individual transferable quotas.

The economic impact of recreational fishing is substantial, valued at U.S. $190 billion globally (World Bank 2012). However, the economic value of recreational fishing is often underappreciated, as is the secondary value of recreational catch as a source of food. In Wisconsin alone, recreational harvest from lakes amounts to ~4,200 metric tons and an estimated annual angler consumption rate of ~1.1 kg, nearly equal to the total estimated U.S. per capita freshwater fish consumption (Embke et al. 2020). The annual economic impact of trout fishing in Georgia alone is U.S. $130.3 million, which amounts to between $60 to $165 per trout angler (TenHarmsel et al. 2021). Although recreational fisheries have a greater importance in developed countries, as incomes rise in developing countries more opportunities arise to develop recreational fisheries and their links to tourism.

Figure 10.1: Two young recreational anglers using familiar spinning fishing gear.

Approximately 11% of individuals fish for recreation in industrialized countries, although participation decreases in industrialized and urbanized regions where fishing has a reduced cultural importance (Arlinghaus et al. 2015). In the United States, 54.7 million Americans fished at least once during 2020, with a participation rate of 18%. Freshwater fishing attracts more participants than saltwater fishing, largely due to access constraints. Time spent inside and more hours watching television, playing digital games, and following social media compete with nature-based activities in young people (Larson et al. 2019). In larger cities, fishing is one of the last remaining ways in which people connect with nature. In order for future fishing participation to increase or even remain the same, it is important to introduce children to fishing at a young age. Many (88%) of the current fishing participants first fished before the age of 12 (Figure 10.1).

In addition to the concern that recreational fishing can deplete fish populations, many of today's anglers are concerned about the welfare of fish that they catch, as well as noncompliance with fishing regulations by others. From the second a fish is hooked, they experience stress, and playing the fish has physiological effects. Fortunately, studies have revealed the following three key principles for releasing captured fish with minimal harm (Danylchuk et al. 2018): (1) eliminate air exposure; (2) eliminate contact with dry surfaces; and (3) reduce handling time. Numerous programs have developed to educate and promote a catch-and-release ethic that limits the effects on the captured fish. Many fishing groups have formulated and promoted the development of an angler's ethic for conservation of many marine and freshwater fish populations. Education about good angling practices may provide the best approach for improving the welfare of recreational fish.

10.2 Motivations for Recreational Fishing

We fish to be outdoors, to relax, and to experience the thrill of the catch. When we look more closely, these motivations vary among anglers. The five most common types of motivations include the following:

1. Enhancing psychological and physiological well-being,
2. Experiencing the natural environment,
3. Experiencing social connections,
4. Connecting to the fisheries resource, and
5. Improving fishing skills and equipment. (Fedler and Ditton 1994)

Catching fish is only one of many components of the angling experience. Some anglers may rank eating fish high, while others rate catching fish to eat lower, emphasizing the experience of nature. Making a connection to the environment was the most common motivation for recreational fishers (Figure 10.2; Young et al. 2016). Thirty-four percent of fishing participants said that getting away from the usual demands of life was one of the best things about fishing. Motivations are highly complex and changeable over time (Schramm and Gerard 2004; Young et al. 2016). Both catch-related factors (i.e., catch rate, size of caught fish, fish harvest) as well as non-catch-related components, such as sociability and crowding, influence angler satisfaction (Birdsong et al. 2021). Some degree of aggregation of anglers may be important, perhaps for social reasons, though further increase in crowding reduces satisfaction (Schuhmann and Schwabe 2004; Olaussen 2010). Not all anglers share similar interests in catching fish, as it depends on the value individuals place on these factors:

1. Catching something,
2. Retaining fish,
3. Catching large-sized fish, or
4. Catching large amounts of fish. (Anderson et al., 2007)

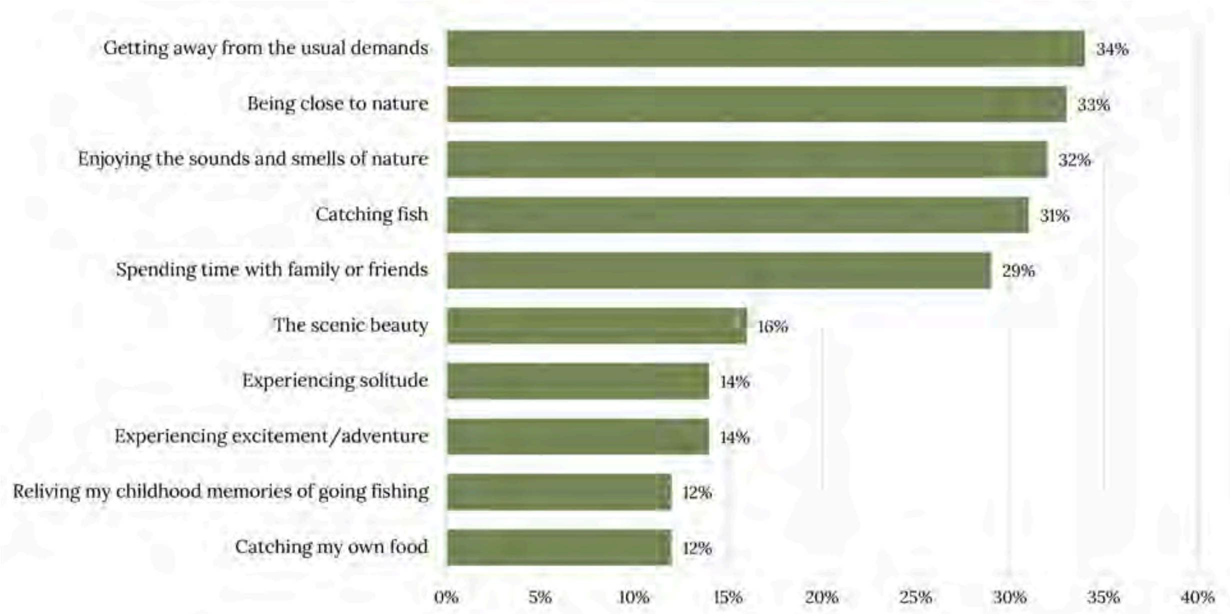

Figure 10.2: Positive attributes reported by recreational anglers in the United States. [Long description](#).

Over time, an angler's motivation may change from a catch orientation to emphasize noncatch motivations, such as being outdoors or passing on their passion for fishing (McKenna 2013). The progression often follows these stages:

- Stage 1: I just want to catch a fish!
- Stage 2: I want to catch a lot of fish!
- Stage 3: I want to catch big fish.
- Stage 4: I'm just happy to be out fishing.
- Stage 5: I want to pass on my knowledge and passion for fishing.

Studies of angler characteristics confirm that there is no such thing as an "average" angler. Rather, anglers are a **heterogeneous** and changing group. Therefore, we can segment anglers in distinct categories for analysis (Bryan 1977; Kyle et al. 2007; Beardmore et al. 2013; TenHarmsel et al. 2019). For example, Magee (2018) categorized recreational anglers into five distinct fisher classes with differing motivations (Table 10.1).

Type of angler	Motivation	Illustrative quote
Social fishers	Motivated by noncatch-related aspects of fishing, particularly socialization and escapism.	“We'll keep them live in a big tank, but if we don't catch many then I'll say let's put them back because there's no point. If we're not going to feed the whole family, then forget it.”
Trophy fishers	Motivated primarily by challenge and mastery aspects of fishing, including catching large fish.	“It's purely… for catching the fish, the fight of the fish and yeah, obviously at the top our mind, is the personal best I guess… It's the size of the fish that's most important.”
Outdoor enthusiasts	Tend to fish primarily for the opportunity for escapism and being outdoors.	“I always fish primarily by myself; it's the challenge of looking at the conditions, working out what's my best chance, where I should go, what lure I should use… and just the satisfaction of actually getting the fish.”
Generalists	A mix of fishing motivations. Individuals in this class rated escapism as an important aspect of fishing.	“The relaxing part of it is a big motivator, especially with the stresses of work… If the tide is right the anticipation of nailing a couple of big fish is pretty cool. That can be with friends or on my own.”
Hunter gatherers	A mix of different motivations, and a comparatively large percentage of individuals who gave neutral responses to each item.	“I'm part of a fishing club and there are a lot of guys in that I think are artists, whereas I'd probably use dynamite if I was allowed….I'm certainly more of a skull dragger than a finesse fisherperson.”

Table 10.1: Five distinct classes of recreational anglers.

Why do we need to know so much about angler motivations? If we ignore angler motivations, we risk providing the wrong mix of angling opportunities that fully meet public needs. This is a fundamental principle of fisheries management. With the many distinct types of anglers, the fisheries manager has many opportunities to improve fishing opportunities through stocking, regulations, access improvements, or habitat enhancements. The wrong choices will reduce angler satisfaction and the likelihood of returning. For example, more restrictive fishing regulations allowed Bull Trout numbers and average catch rates to increase dramatically, yet resulted in dramatic declines in participation by traditional anglers who did not favor the new regulation (Johnston et al. 2011). In addition to considering motivations of anglers, managers must also examine motivations and interests of the nonparticipating anglers and consider lost opportunities, or what economists call “opportunity costs.” Only 18% of the U.S. population fishes in any given year, leaving one to ask what we can do to allow the other 82% to fish.

Declining participation, stakeholder conflicts, regulations on harvest, and angler behavior and compliance are common concerns that can dramatically influence how satisfied an angler is with a fishing trip (Arlinghaus and Cooke 2009). Declining participation is associated with demographic shifts to urban living. Anglers choose fishing locations based on expected catch, but environmental and facility quality are also important determinants (Hasler et al. 2011; Hunt et al. 2019; Birdsong et al. 2021). How quickly a new fishing hole gets fished out depends on suitable regulations to avoid the phenomenon of an invisible collapse by highly mobile and successful anglers (Post et al. 2002; Post 2013).

As anglers become progressively diverse, fisheries managers need ways to satisfy users with different preferences while concurrently conserving a limited resource (TenHarmsel et al. 2019). Each angler group has differing views on the importance of fishing attributes, such as catch rate, fish size, or the environment. From the field of marketing, we can apply a framework that analyzes both the importance and satisfaction with each attribute of fishing. The framework reveals guidance for needed actions and recognizes that a "one size fits all" management approach is not optimal for large, complex fisheries with a heterogeneous mix of anglers (Ward et al. 2013).

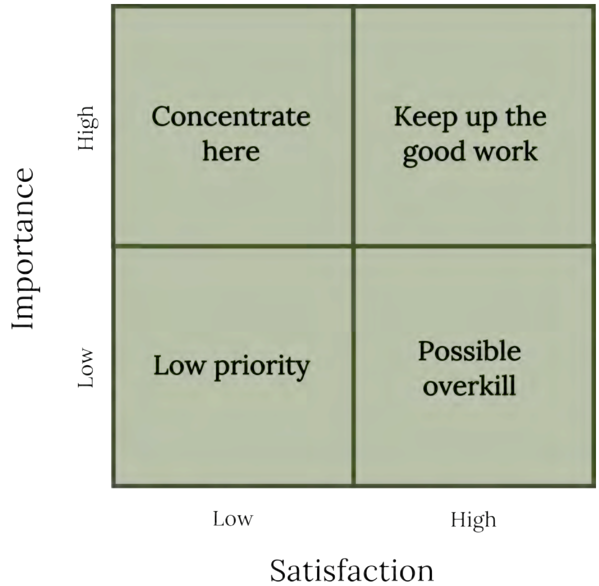

Figure 10.3: Four quadrants of management priorities based on importance to anglers and angler satisfaction with fishing experience. Long description.

The importance and satisfaction ratings for anglers can be displayed in a two-dimensional graph that shows importance versus satisfaction (Figure 10.3). The x-axis represents attribute satisfaction and the y-axis represents attribute importance, both ranging from low to high. Each of the four quadrants corresponds with management priorities. For example, trophy anglers who rate size of catch as most important would be dissatisfied with many small fish in their daily **creel**. This combination fits the upper-left quadrant, which indicates that fisheries managers should concentrate on improving the size of fish caught. High importance and low satisfaction means "concentrate here." The ideal combination is high importance and high satisfaction, which means fisheries managers should "keep up the good work." The case of low importance and high satisfaction means "possible overkill." Finally, the lower-left quadrant of both low importance and low satisfaction means "low priority."

Questions to ponder:

Many people love to fish, and perhaps you are one of these people. What are your primary motivations for fishing? Do you know any anglers who fit one of the categories defined in Table 10.1? If you do not fish, what alternative leisure time activities are you engaged in?

10.3 Therapeutic Benefits of Recreational Fishing

Recreational fishing reflects both cultural and emotional aspects of our relationships with places, fish species, and individual fish. Experienced anglers have memories of important places to fish, fishing partners, types of fish caught, and even individuals captured even if not landed. The positive influences of fishing create positive feedback, so that good fishing encourages more fishing. By making connections with nature via fishing, people feel better (McManus et al. 2011). In fact, Australia's national recreational fishing policy maintains that "Recreational fishing is a legitimate activity that contributes to Australians' health and well-being at individual, family and community levels" (Griffiths et al. 2017). In the United States, fly-fishing has been adopted as a therapy for treating combat-related post-traumatic stress disorder and improving the quality of life for women with breast cancer (Hildreth et al. 2019).

Casting for Recovery (2022) was formed in 1996 to introduce the benefits of fly-fishing to women with breast cancer. Approximately 200,000 new cases of breast cancer are diagnosed each year, and more than 2.9 million breast cancer survivors are living in the United States. Retreats organized by Casting for Recovery provide opportunities for breast cancer patients to escape to a safe space in nature while learning to fly-fish (Weston 2016). Participants in weekend retreats report a high degree of satisfaction, healing, and learning (Henry 2017).

Post-traumatic stress disorder (PTSD) is a mental disorder originating from experiencing a traumatic event (e.g., witnessing a violent act, sustaining a debilitating physical injury, combat). PTSD symptoms make it difficult for individuals to relax, enjoy, and participate in activities with others due to the fear of triggering symptoms. Approximately one in five of the 2.4 million troops who served in Iraq and Afghanistan meet the diagnostic criteria for PTSD or depression. Since 2005, Project Healing Waters Fly Fishing (PHWFF) began treating wounded military service members returning from combat in Iraq and Afghanistan. Participants learn fly-fishing through outings, insect identification, flytying, and rod-building classes. Project Healing Waters accommodates fly-fishing for clients with physical limitations or mobility issues.

Does fly-fishing work as a therapy? Few randomized controlled experiments by licensed mental health professionals have been done to answer this question. However, much has been learned from efforts by trained therapists to use fly-fishing to resolve trauma even when there is no control group used for comparison. Participants learn that it is not about the fish but the activities that assist in forming new memories while decreasing the intensity of traumatic memories (Parmenter 2022).

Fly-fishing can create a healing environment that can promote a return to healthy activity and personal transformation for veterans and military personnel with PTSD, and it facilitates a positive mood in individuals suffering from PTSD (Bennett et al. 2017; Hildreth et al 2019; Craig et al. 2020). The calming effect of sharing natural environments with other like-minded companions in pursuit of elusive wild fish was also alluded to in earlier writings about fishing. Author and ecologist Carl Safina (2011) likened fishing to meditation when he wrote, "Fishing in a place is a meditation on the rhythm of a tide, a season, an arc of a year, and the seasons of life."

Therapeutic fly-fishing programs can improve quality of life for veterans with combat-related disabilities. Participants demonstrated reduced symptoms of PTSD, depression, stress, and functional impairment in the immediate response to the program and increased leisure satisfaction even after three months (Bennett et al. 2017; Parmenter 2022). Interviews with participants in the Project Healing Waters Fly Fishing program demonstrated that the program facilitates positive mood, generates motivation for coping, provides hope for the future, and contributes to post-traumatic growth (Craig et al. 2020). However, the fact that fishing and other recreation therapy provides health and well-being benefits is underappreciated (Kemeny et al. 2020).

Benefits of fly fishing	Representative quotes
Positive mood	- "It helps you relax, to unwind…it puts you in a better frame of mind…it's just tranquil." - "It's hard to explain to people the tranquility of just being on a stream. It doesn't matter if I'm fishing, or just trying to see what kind of bugs are on the water; it's just that feeling of peace and quiet." - "It definitely helps me with my anxiety; just casting, alone in itself. And, just knowing, I've got to get better, I've got to go further … it's a soothing thing, it helps you just calm down within because you don't have to rush it."
Motivation for coping	- "When I first got back from Iraq, I didn't have any patience at all, my concentration wasn't there…I couldn't tie a fly. Now, with fly-fishing, I'm probably more patient than I have been in a long time." - "Because of PHWFF, I get out of bed."
Hope for the future	- "Fly-fishing breaks down a lot of barriers, and makes you feel like you're not alone…it's a big network, and a mentorship. For me, it's not about the fishing at all. I love to catch fish, but I don't go to fish at all, I go to see everybody." - "Everything about it is so—I'm not going to say divine—but it's just natural, just being around the water and the trees. And it helps you cope even when you're stuck. I was so stuck." - "I may have a bad week or two, but tell myself Friday is a casting session which helps me get through the day. I can deal with a few bad days because there is going to be one day I can go fishing."
Post-traumatic growth	- "I feel like I do love myself. I love fishing and I just feel happy and relaxed and peaceful. I got one thought in my head, not a million." - "With flyfishing, you have something you take on forever, you can take it with you. They don't come and feed you but teach you how to fish and feed yourself." - "It ain't about the fishing. It's about where it takes you and how it can reform you and make you over and help you get out of a rut, and just try. It'll transform you. It helped me to be more complete."

Table 10.2: Benefits of fly-fishing and representative quotes by participants (from Craig et al. 2020).

10.4 Conservation Issues Facing Recreational Fishing

In North America and other areas, fisheries are a public resource, and open access may lead to overfishing. Recreational fishing often **truncates** the natural age and size structure, resulting in fewer older larger fish (Figure 10.4). Recent studies also reveal that high fishing pressure may reduce genetic variability or influence evolutionary pressures (Sutter et al. 2012). Fishing may also alter aquatic food webs. A third effect relates to loss of fishing gear and lures that result in unintended ecosystem consequences. Habitat modifications to improve access for boats may make habitats less hospitable for fish (Lewin et al. 2006). The loss of bigger and older individuals in a population is a common influence of unrestricted recreational fishing. Even at a modest rate, fishing can greatly reduce the number of older fish in a population, resulting in catch dominated by small fish (Figure 10.4). Recreational fishing is facing a number of conservation challenges, including high exploitation, selective harvest, fishing and boating during spawning, pollution and contaminated fish, stocking, sublethal effects, fish welfare and antifishing sentiments, and community and ecosystem influences (Cooke and Cowx 2006; Lewin et al. 2006; Arlinghaus and Cooke 2009).

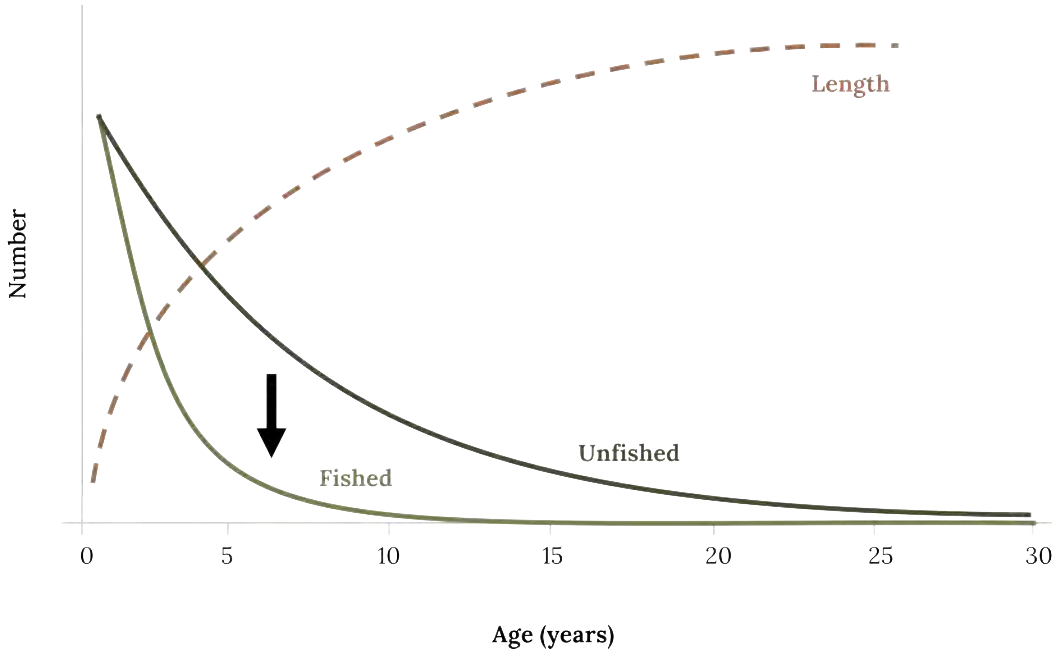

Figure 10.4: Theoretical comparison of number of fish in an unfished and fished age group through time. Long description.

High exploitation is a prominent conservation issue in recreational fishing, particularly in highly valued species. For example, recent studies show that approximately 40% of recreational Walleye fisheries of Wisconsin were overharvested (Embke et al. 2019). Other assessments indicated that a collapse of recreational fisheries may be more widespread than previously assumed (Simonson and Hewett 1999; Post et al. 2013; Rypel et al. 2016). Numerous technological innovations, such as social media, fish finders, drones, and underwater cameras, have greatly increased anglers' ability to locate and catch fish (Cooke et al. 2021). Such developments in fishing technologies have so greatly influenced success in finding and catching fish that we need to revisit questions of what constitutes "fair play" in recreational angling and what limitations, if any, should be imposed. Because these new technologies are cost prohibitive for some participants, an uneven playing field exists.

Recreational fishing is highly selective. Anglers have favorite species to target, and regulations are often needed to protect spawning or trophy-sized fish. Targeting rare trophy individuals of fish species that are late maturing or with variable recruitment may have effects on population viability. The International Game Fish Association continues to certify the world record size fish, even for species that are at risk of extinction (Shiffman et al. 2014; Cooke et al. 2016). If we continue to certify records for endangered fish species, we must ensure that the role of anglers in conservation exceeds the risk of population collapse. Some sportfishing-based conservation projects focus on at-risk fish species, including the mahseers, Taiman, Murray Cod, White Sturgeon, Atlantic Bluefin Tuna, *Arapaima* spp., and coastal sharks (Cooke et al. 2016; Gallagher et al. 2017). In these and other cases, anglers can promote conservation in a number of ways by raising funds, monitoring catch, and implementing guidelines for responsible angling practices (Schratwieser 2015).

Question to ponder:

Should we permit recreational fishing on fish that are at risk of extinction?

Recreational anglers learn the patterns of the fish they target and adopt fishing practices to increase the odds of success. For example, bass anglers soon learn that fishing during spawning season when males are creating and defending nest sites can be highly effective. In particular, parental males of black bass (*Micropterus* spp.) are highly vulnerable to angling while guarding nests in shallow water. Even temporary removal of guarding males may lead to predation on offspring or even male abandonment of the nest (Suski and Philipp 2004). Fishing may also influence fish populations indirectly via habitat disturbance. Boat noise near nesting bass may also reduce nest success (Mueller 1980; MacLean et al. 2020), and wading by anglers can kill developing trout eggs (Roberts and White 1992). Construction of moorings for recreational boating reduces aquatic vegetation, important habitat for juvenile fish (Hansen et al. 2019). Planning for quality recreational fishing requires that we minimize the indirect effects of recreational fishing.

Water pollution has reduced availability of fishable waters as well as eliminated the aesthetic quality of fishing experiences. Although water pollution laws have benefited recreational fishing tremendously (Vaughan and Russell 2015), consumption advisories for contaminated fish are commonplace, often eliminating the benefits of fishing for food (Cole et al 2004; Westphal et al. 2008). Pregnant women and young children are the most at risk fish consumers. Some anglers are not aware of the fact that contaminants bioaccumulate up the food chain from sediments to plants to fish. Fishing also generates litter from discarded fishing line, hooks, and lures that may result in injury to wildlife. The **deposition** of lead from fishing sinkers can lead to poisoning and death when ingested by waterfowl.

Stocking is an important tool for recreational fisheries management. It may supplement heavily fished populations, and in certain cases, nonnative fish stocking may cause problems for native populations. Stocking on top of native trout populations has been discontinued in many states, as noted earlier in Chapter 9 *Fly Fishing's Legacy for Conservation*. Introduction of species from outside their range may cause unintended consequences or may be beneficial. Throughout much of the industrialized world, novel ecosystems are increasingly widespread; there are no pristine environments and no species assemblages unaltered by human activity. For example, the unintentional introduction of the Sea Lamprey into the Great Lakes had profound consequences to all large-bodied fishes, such as Lake Trout, Burbot, and Lake Whitefish (Brant 2019). This introduction plus others so greatly changed the Great Lakes that an intentional creation of put-grow-take salmon and steelhead fisheries resulted in a world-renowned biologically and economically valuable fishery in the Great Lakes (Tanner 2019). These introductions are well managed and considered to be beneficial. However, several species of Asian carp, introduced in Arkansas in the 1970s, have expanded their range and are considered ecologically destructive. Asian carp are now a threat, as their expansion continues into the Great Lakes (Reeves 2019).

Most fisheries management agencies categorized fish as threatened or endangered (all take is restricted), game (harvest is regulated), or nongame (harvest may be regulated). Unfortunately, many species are perceived to have low fisheries values and are referred to as "rough fish." As noted earlier, Rypel et al. (2021) argued for dropping the term "rough fish" because it is **pejorative** and reflects a cultural problem of viewing these fish as nuisances. The term was first used in the late 1800s to refer to fish that were gutted but not filleted. Often these "rough-dressed" fish were discarded when other higher-valued species were caught. Referring to fish as "rough" is not helpful or informative and obscures the unappreciated benefits of native species. Furthermore, the daily harvest or possession limits for these and nonnative fish are unlimited in many states. The use of the term "rough fish" was recently eliminated by one state (Minnesota), which has substituted the term "underused fish." With a growing demand for alternative fishing adventures, agencies need to create scientifically based fishing regulations for the undermanaged and underused fish.

***Question to ponder*:**

What descriptive name(s) would you suggest we adopt for nongame fish to better reflect their values?

10.5 Challenges in Managing Recreational Fishing

Management agencies often hear anglers express their concern that "fishing is not what it used to be." Anglers are relaying their experience in personal success rate, measured as either catch rates or size of catch. Maintaining high levels of fishing satisfaction is a challenge for a number of reasons. First, angler trip success and catch rates are dependent upon a fish's vulnerability to angling gear and often decline with increased fishing effort (Shaw et al. 2021). Second, access to innovative technology and specialized information increases vulnerability to capture and loss of harvestable-size fish. Although fishing success may be enhanced by hiring a fishing guide, the additional cost is often prohibitive for many anglers. Finally, the paradox of satisfaction is a common pattern where improved fish populations lead to higher expectations and, therefore, not higher fishing satisfaction.

Recreational fishing is also challenging to manage because of the ability of anglers to easily change target species or target fishing spots. Most anglers (86%) reported that other species would be acceptable substitutes for their preferred species (Sutton and Ditton 2005). As anglers become more experienced, they learn about fishing sites and social media, and other fishing communities provide access to changes in fishing success. Consequently, fishing effort can rapidly change in response to expected catch rates. For a region with multiple species and locations, angler behaviors of choosing fishing opportunities appear to be driven primarily by expenses and less by specialization (Shelby and Vaske 1991; Beardmore et al. 2013; Sutton and Oh 2015). If fishing regulations are uniform within a region, anglers will fish down stocks closest to home and then substitute more distant locations as catch quality declines close to home (Carpenter and Brock 2004). This creates a leapfrog exploitation pattern that spreads across a region. The substitutability problem means that management regimes must be flexible enough to avoid such cascades of fishery impacts across patchy environments.

Recreational anglers have dealt with animal welfare concerns and antifishing sentiments in recent years (Arlinghaus et al. 2012; Muir et al. 2013). (Chapter 5 discusses personal decision making about minimizing pain and suffering in recreationally caught fish.) The term "welfare" addresses physical and mental health and well-being of a fish or group of fish. Scientists and ethicists differ on how to approach animal welfare. For example, the animal welfare views held by individuals may be any of the following:

- **Function-based**, that is indicative of growth or fecundity,
- **Nature-based**, which relates to the ability to lead a natural life in the wild, or
- **Feelings-based**, which focuses on mental states rather than physical health and emphasizes not only the avoidance of stress or fear but also the opportunity to experience positive feelings.

Recreational anglers practice a mix of pursuit of fish for food, competition and trophies, leisure, and catch and release. The pain and suffering of fish are not the only morally relevant criteria considered. Recreational anglers may claim that the utilitarian benefits of sportfishing exceed any harm. Typically, they consider welfare considerations for fish from a functions-based view, which recognizes that angling induces stress and may cause injuries, but responsible fishing practices can minimize injuries.

Responsible fishing practices should be actively debated by recreational anglers so that values, beliefs, norms, and personal actions drive decisions rather than ill-advised policies. For example, the Swiss Animal Welfare Act makes voluntary catch and release of legally harvestable fish an offense. This act, passed in 2008, is based on the belief that the only valid reason to go fishing is to harvest fish. In Germany, fishing tournaments with voluntary catch and release are banned. Five ethical viewpoints are common in many parts of the world (Table 10.3; Arlinghaus et al. 2007; Arlinghaus and Schwab 2011).

Viewpoint	Description
Animal welfare	Focuses on how recreational fishing impacts the well-being, health, and fitness of individual fish and actions to minimize impairments.
Animal liberation	Takes a utilitarian view to weigh the benefits of recreational fishing to individual anglers and society against the pain and suffering of individual fish.
Animal rights	Holds that animals have an intrinsic right to life and a right not to be harmed. Therefore, recreational fishing is unethical.
Angler motivation	Examines intention of the recreational angler to either meet essential survival needs (i.e., food) or fish for fun. Angler's motive is what counts most in judging ethical permissibility. Therefore, catch-and-release fishing is unethical, whereas fishing for food is acceptable.
Biocentrism and ecocentrism	Recreational angling is a threat to natural wilderness processes and biological integrity and should be avoided.

Table 10.3: Five ethical viewpoints applied to recreational fishing.

Of these five viewpoints, only the animal welfare and ecocentric views do not involve the total abolition of recreational angling. Responsible angling requires better information on technologies to improve fish care (Cooke et al. 2021). Laws and policies that follow other viewpoints may greatly limit availability of conservation practices. In response to animal rights activists, 23 of the 50 states of the United States have passed constitutional amendments proclaiming a right to hunt and fish, subject to reasonable regulations and restrictions (Ballotpedia 2022).

***Questions to ponder*:**

Which of the five viewpoints are you likely to adopt to decide how to address welfare of fish caught by recreational anglers? Which of these viewpoints represent the biggest threat to the future of recreational angling?

10.6 Options for Regulating Recreational Fishing

Costs of enforcement of regulations of harvest and gear restrictions can be substantial. Therefore, voluntary adoption of fishing restrictions via promoting changes in behavior is preferable (Cooke et al. 2013). The most commonly employed regulations for recreational fishing include creel (or bag) limits, closed seasons, and length limits. Over time, these regulations have become more restrictive in response to increasing fishing.

Creel limits are simple and easy to understand and enforce. They restrict angler harvest per fishing event or day. Creel limits are widely applied to distribute the finite harvest among more anglers and reduce the harvest by more experienced anglers. These limits have historically been higher than the daily angler catch of most anglers (Cook et al. 2001; Radomski et al. 2001). For example, the Yellow Perch daily creel limit in Minnesota was once 100 fish. With high daily creel limits, few anglers harvest the daily limit. Often only “10% of the anglers harvest 50% of the fish” (Snow 1978). There are two reasons for the highly skewed distribution of success (Figure 10.5). One is that not all days are equally good for fishing. The second is the great variation in skill level among anglers (Wagner and Orth 1991).

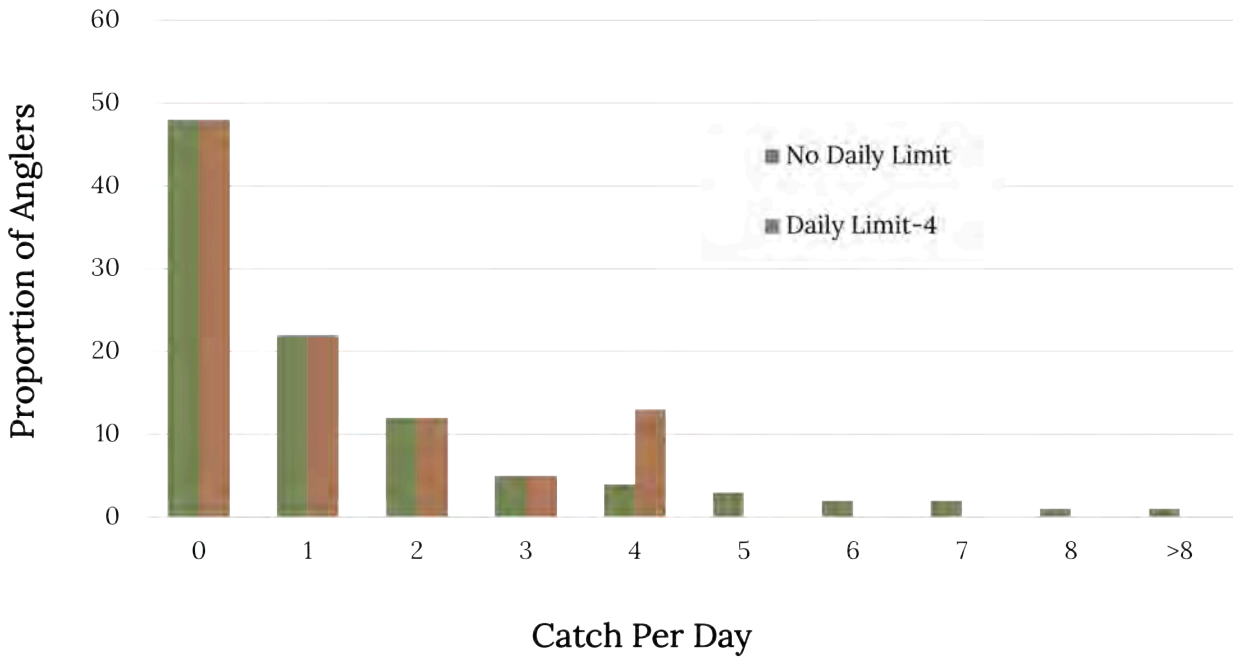

Figure 10.5: Frequency distribution displays the number of angler days resulting in differing catch per day for a hypothetical 8 fish per day creel limit and estimated change if creel limit is reduced to 4 fish per day. Long description.

Creel limits are one of many elements that may be used by anglers to define fishing success. When more fish are harvested per trip, anglers rate fishing higher. High creel limits may cause anglers to have unrealistic expectations about the potential supply of fish compared to the demand (Cook et al. 2001). Creel limit reductions may be unsuccessful in reducing angler harvest or affecting fish populations. The hypothetical angler success graph (Figure 10.5) demonstrates that a reduction in creel from 8 to 4 would affect only a few trips and result in a small harvest reduction. Furthermore, creel limits are applied on a per-angler basis, so they cannot control total harvest if total fishing effort increases or if noncompliance is high. Finally, since anglers have a variety of motivations, they likely respond differently to regulation changes (Beard et al. 2011).

The ethic of fairness is involved in setting creel limit regulations because many anglers do not harvest a single fish during an angling trip. In Wisconsin lakes, Walleye harvest was not equally distributed. Only 7.4% of Walleye angler trips were successful in harvesting at least one Walleye, and <1% harvested a limit during a fishing trip (Staggs 1989). In Minnesota, anglers were slightly more successful, where 27.2% of angler trips ended with a harvest of at least one Walleye and about 1% harvesting a limit. The ideal creel limit would distribute the catch among more anglers and prevent overuse by a few individuals.

Long-term trends in panfish populations (i.e., Bluegill, Yellow Perch, Black Crappie, Pumpkinseed, and Rock Bass) in Wisconsin lakes showed significant declines due to overfishing (Rypel et al. 2016). The daily limit for panfish was 50 aggregate per day from 1967 through 1998, which was reduced to 25 in 1998. Further reduction in daily limits for panfish (10) to improve undesirable small sizes of Bluegill populations increased both mean length and mean maximum length relative to sizes in control lakes (Jacobson 2005; Rypel et al. 2015).

Recreational fishing is often regulated with a variety of length-based regulations, based on the assumption that population size structure and trophy potential will improve as a result (Figure 10.4). Most common are minimum length limits; however, maximum length limits and protected and harvest slot limits are also very common. Minimum length limits are adopted to avoid growth overfishing, where the fish are removed before they attain quality size for anglers. Maximum length limits are adopted to protect the big, old, fat, fertile, female fish (BOFFFFs). A protected slot limit is designed to allow anglers to keep up to the daily creel limit of fish smaller than slot. This regulation has the dual purpose of allowing balance of harvest of small pan-size fish and trophy fish.

The big old fat fertile female fish hypothesis considers the many ways that the BOFFFFs benefit the long-term productivity of fish populations (Hixon et al. 2014). Often the larger fish in a population are more valuable economically (as trophies), and there are potential trade-offs between harvesting these fish or implementing management measures to protect them. There are five hypothesized effects of BOFFFFs on population productivity (Figure 10.6). Large females produce far more eggs than small females. Natural mortality of large females is low, meaning that the BOFFFFs will survive long periods of conditions unfavorable for reproduction. Larger females often produce larger eggs with higher amounts of yolk, thereby allowing the offspring to grow faster and survive better. Larger fish typically spawn earlier in the year and at different places than younger females. To the extent these relationships hold, recreational fishing tends to differentially remove BOFFFFs because fishing both elevates mortality and changes the age/size-selective pattern of mortality within fished populations.

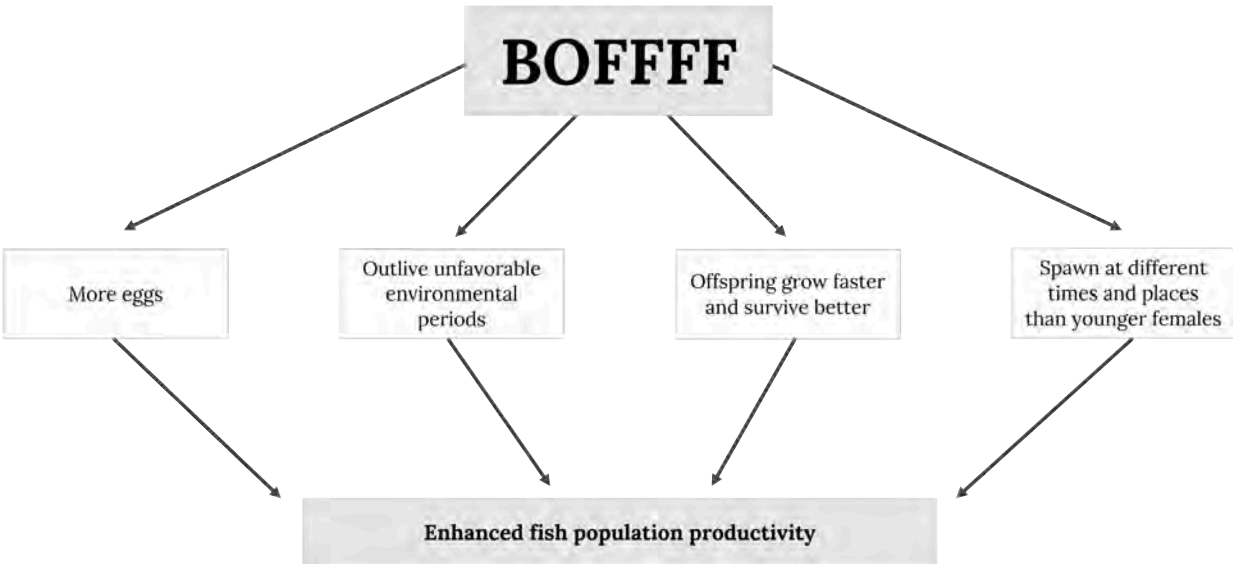

Figure 10.6: Hypothesized maternal effects of big, old, fat, fertile, female fish (BOFFFFs). Long description.

Fishing regulations may also close certain areas or locations to fishing. Closed seasons or catch-and-release fishing seasons during spawning are sometimes implemented. Protected areas refer to implementing some level of exclusion from the use of fish resources. Attempts to establish “no-take” marine reserves in Hawaii, California, and the Florida Keys have engendered strong opposition from sportfishing groups (Salz and Loomis

2004), which limits the use of the regulatory strategy. There tends to be more support for protected areas that for banning commercial fishing but allowing catch-and-release recreational fishing (Bartholomew and Bohnsack 2005). Marine protected areas (MPAs) are most effective when (1) MPAs are large, old, and isolated, (2) all fishing is prohibited, and (3) enforcement is strong (Edgar et al. 2014). Some anglers argue that if nonextractive activities, such as SCUBA diving and snorkeling, are allowed within no-take reserves, then catch-and-release angling should be permitted because it is not extractive. Consequently, best practice includes the recreational anglers in the design and implementation of protected areas to ensure that recreational values are incorporated into the management strategies (Danylchuk and Cooke 2011).

Catch-and-release practices have increased to reduce the effects of angling on fish populations, particularly where angler motivations are less harvest oriented (Arlinghaus et al. 2007). Voluntary release of Largemouth Bass exceeds 90% in certain waters and effectively "recycles" fish, thereby improving fishing quality (Myers et al. 2008). These trends reflect the values, beliefs, norms, and action causal change of influence (Figure 10.7). This theory helps to explain choices of actions based on habits and complex motives. At the core of the theory are notions of values and norms. Values are general principles that provide standards for assessing actions. These core values rarely change over a short time span. For example, one may value being active in the outdoors for feelings of relaxation and enhancing a sense of personal well-being. Both emotions and rational thinking lead to beliefs about best practices for recreational fishing. Beliefs in turn affect personal norms and action in a sequential fashion.

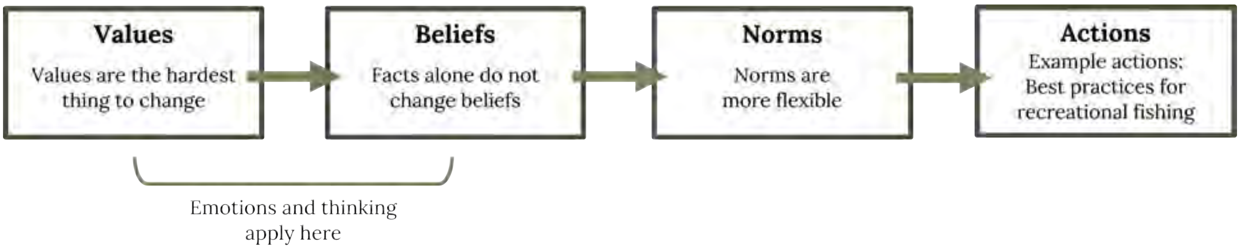

Figure 10.7: Values, beliefs, norms, and action causal change of influence. [Long description](#).

Many avid catch-and-release anglers begin by nudging others with the simple message, "You should release your catch." For example, fishing buddies had the largest effect on catch-and-release behaviors (Stensland et al. 2013). Norms are important because they are standards that serve to motivate individual behavior based on a sense of obligation rather than punishment. As such, norms become informal rules enforced by informal sanctions or internalized by the individual.

However, the benefits of catch and release are not guaranteed because angler behavior and gear choice can affect its success. Often, the responses to catch-and-release fishing on fishing mortality are species-specific (Allen et al. 2008; Sass and Shaw 2020). Success of this practice depends on reducing air exposure, hooking injury and mortality, and handling time. Implementing fishing regulations that require anglers to release fish are also associated with recommendations for use of differing gears, such as circle hooks, barbless hooks, or certain types of landing nets (Brownscombe et al. 2018).

Reliance on voluntary norms of proper behavior among anglers facilitates achieving management objectives (e.g., development of voluntary release of fish to reduce fishing mortality). Fly fisher Lee Wulff actively promoted voluntary catch-and-release fishing even when regulations allowed harvest, and his name continues to stand for catch-and-release fishing and the concept that "game fish are too valuable to be caught only once." In his biography of Wulff, Jack Samson (1995) wrote that "The father of catch-and-release angling and a pioneer in the conservation of Atlantic salmon, Lee Wulff may have been America's greatest fly-fisherman." Voluntary release of Largemouth Bass has become a commonplace norm that often aligns with management objectives of trophy and competitive tournament fishing (Siepker et al.; 2007; Myers et al. 2008). Ray Scott, the founder of the Bass Anglers Sportsman Society, introduced the catch-and-release ethic to bass fishing and was a staunch advocate for boating safety. At the time, Scott wrote that the "notion of releasing a bass was about as common as giving a steak back to the butcher after you'd bought it. In bass fishing, success was measured in numbers of fish on the dock." Ray Scott's persistent message was "Don't Kill Your Catch" in order to nudge bass fishing tournaments to adopt codes of conduct (i.e., social norms) that drive compliance (Boyle 1999; Thomas et al. 2016).

Raising angler awareness about the practice resulted in catch and release becoming a pervasive "social norm" for a variety of recreational fisheries (Stensland et al. 2013; Sass and Shaw 2019). Wisconsin's Muskellunge fishery management has focused on catch-and-release fishing due to low creel limits and restrictive length limits. Numbers of musky anglers have never been higher as catch and release has become a norm for Muskellunge anglers. In Wisconsin and elsewhere, the release rate for Largemouth Bass and Muskellunge often exceeds 90% in recent times, reflecting the current social norm. As release rates increased over time, the catch rates for Largemouth Bass have increased (Sass and Shaw 2019); however, the responses to catch and release are species specific, and promotion of the practice should not assume that "one size fits all" fisheries. Walleye fishing attracts many harvest-oriented anglers, and therefore catch and release has limited benefits over size limits.

How can we influence the behavior of recreational anglers? Fisheries management generally relies on deterrence via restrictive regulations. The low probability of being caught is one of the key drivers of noncompliance in recreational fisheries. Yet, nudges based on social norms may be more cost effective (Mackay et al. 2021). A nudge is an aspect of the choice that alters people's behavior in a predictable way without forbidding any options or significantly changing their economic incentives. To count as a mere nudge, the intervention must be easy and cheap to avoid. Nudges are not mandates. For example, "Putting fruit at eye level counts as a nudge. Banning junk food does not" (Thaler and Sunstein 2021).

Not all nudges will work, and therefore we must consider opportunities for changing norms in fishing practice. The theory of planned behavior models explains an individual's behavioral intentions as influenced by three questions: (1) Do I have the right skills to do this? (capability); (2) Do I like it? (motivation); and (3) What do others think of this? (opportunity or norm) (Figure 10.8; Ajzen 2005). Among the many behaviors that might be promoted as new social norms are more effective and less-harmful lures and hooks, use of landing nets, choice of fishing time or seasons, and reduced handling and air exposure. In an evaluation of the use of venting tools and descender devices to minimize **barotrauma** (injury resulting from changes in barometric pressure) in released reef fish, Crandall et al. (2018) found that the influence of others via social norms had the greatest influence on adopting new barotrauma mitigation tools.

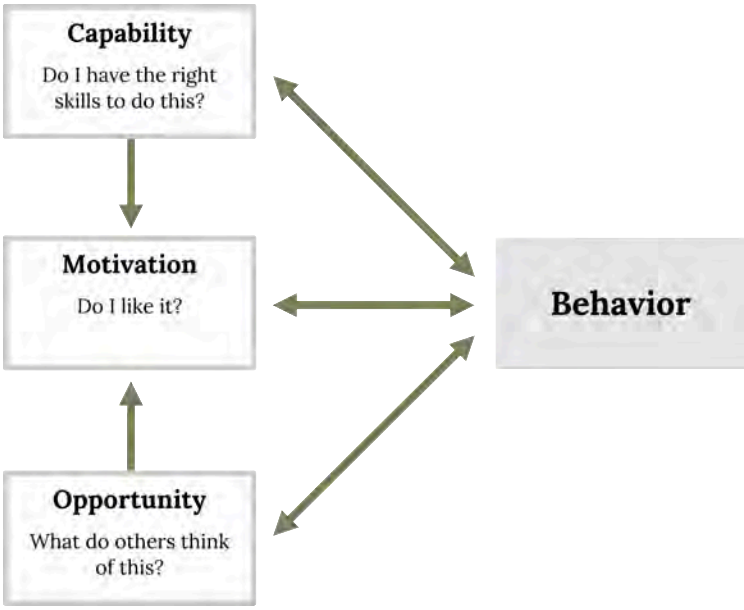

Figure 10.8: Three questions that determine behavior intentions according to the theory of planned behavior. [Long description](#).

Efforts to implement large-scale and long-term behavioral intervention strategies for recreational angling should include following simple steps (Geller 1989). These are Selection, Intervention, Evaluation, and Dissemination (Figure 10.9). Step one (Selection) is to identify the target behavior that is desired. Step two is Intervention. Change agents should apply Benjamin Franklin's principle, "Tell me and I forget, teach me and I remember, involve me and I learn," to their intervention communications. To encourage adoption of a new behavior, it should be Easy, Attractive, Social, and Timely (remember: EAST). Verbal and written messages alone are not sufficient. Rather the use of local, credible anglers to demonstrate the new behaviors is preferred. Conducting these demonstrations in pleasant, outdoor surroundings will increase participation by anglers. Step three is Evaluation, during which observations of baseline and after-intervention behaviors are compared to evaluate the effectiveness of the intervention on target behaviors. Step three may indicate the intervention was not effective and a new behavior is selected for change. If the intervention was effective, that leads to step four, Dissemination. Here the benefits of adopting the new behavior are shared with recreational anglers. Much can be learned from social marketing to make the target audience aware of the benefits of the behavioral change. For example, social marketing uses market segmentation to divide a market into small units with common characteristics. In promoting behavior change in recreational fishing, segmenting the angling population into different motivations (see Table 10.1) will help define different strategies appropriate for the target group of anglers.

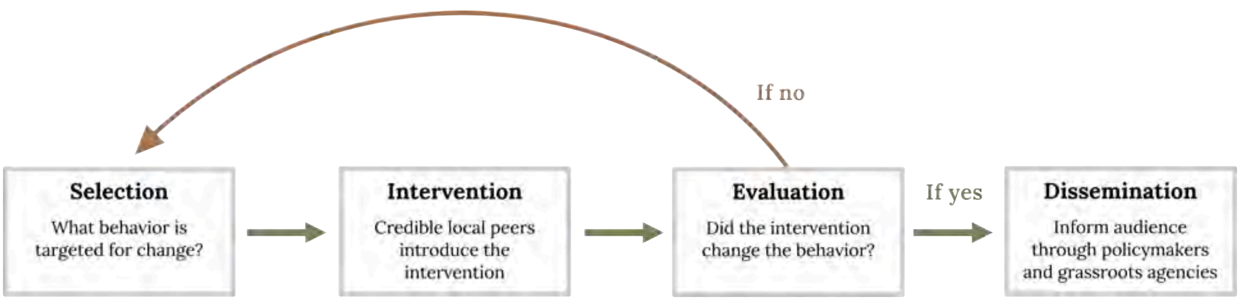

Figure 10.9: Steps in applied social marketing to change behavior of recreational anglers. [Long description](#).

Recreational fishing regulations via creel limits, length limits, and catch and release are still evolving as new research explores angler behavior and consequences of catch-and-release fishing. Ice fishing is a popular winter sport in northern climates; however, more detailed information is needed to develop fishing regulations for ice fishing that properly consider the effects of air exposure, freeze damage, and temperature shock on the fate of fish released (LaRochelle et al. 2021; Lawrence et al. 2022). Microfishing is a growing form of fishing where the angler is motivated by catching many species of fish with small hooks. Few appropriate studies have been conducted to inform fishing regulations suitable for microfishing (Cooke et al. 2020). Learning how to understand and influence behavior of recreational anglers remains a high priority.

10.7 Responsible Recreational Fishing and Keep Fish Wet Principles

Recreational anglers are important and effective conservation partners who may influence the behavior of other anglers (Granek et al. 2008; Cooke et al. 2019). Depending on the fishing gear used, the angler's skill and intentions, and environmental conditions, hooking mortality of released fish ranges from ~1% to over 90% (Bartholomew and Bohnsack 2005). Therefore, modifying angler choices and behavior may greatly reduce mortality of released fish (Arlinghaus et al. 2007). Keep Fish Wet is one program designed to encourage anglers to adopt strategies to minimize stress in hooked fish. Three Keep Fish Wet Principles address actions that are most under the angler's control and backed by scientific evidence.

- Principle 1: Minimize air exposure
- Principle 2: Eliminate contact with dry surfaces
- Principle 3: Reduce handling time

Additional tips provide simple and easy actions that every angler can do (Table 10.4). Proper use of tools and related tactics may include **terminal tackle**, retrieval tools, landing nets, unhooking tools, measuring devices, holding and recovery nets, and livewells (water tanks used to keep fish alive). Keep Fish Wet is an organization that works to build relationships with anglers who will rely on the organization to provide practical guidance for catch-and-release fishing. As such, it is a recognizable brand with the potential to influence angler behavior.

The general tips provided are generally applicable to recreationally caught species. However, there are differences among fishing locations and game species that require further species-specific studies (Cooke and Suski 2005; Kerr et al. 2017; Browncombe et al. 2017, 2019a, 2019b). For example, use of circle hooks when fishing for sailfish and coral reef fish reduced lethal injuries (Prince et al. 2002; Sauls and Ayala 2012), and replacing treble hooks with single barbless hooks reduced unhooking time (Trahan et al. 2021).

When	Tip
Before you go fishing	- Follow local regulations - Think twice before going after spawning fish - Be wary of warm water
Before your first cast	- Use barbless hooks - Consider using artificial baits - Use rubber nets - Limit use of lip grippers - Carry hook removal devices
When you hook a fish	- Limit fight time - Hold fish in or over water - Grip fish carefully - Photograph wet fish - Only revive fish that cannot swim

Table 10.4: "Keep Fish Wet" tips.

The claim that minimizing air exposure of caught fish enhances postrelease survival is supported by credible and authoritative scientific evidence (Figure 10.10). The scientific evidence comes from a number of studies that reveal the levels of stress, gill damage, and reduced recovery time induced by increased air exposure. In a study of Rainbow Trout, one minute of air exposure following exhaustive exercise promotes more severe acid-base disturbances than does exercise alone (Ferguson and Tufts 1992). One minute of air exposure is much shorter than the time most anglers take to admire the catch and pose for a photograph.

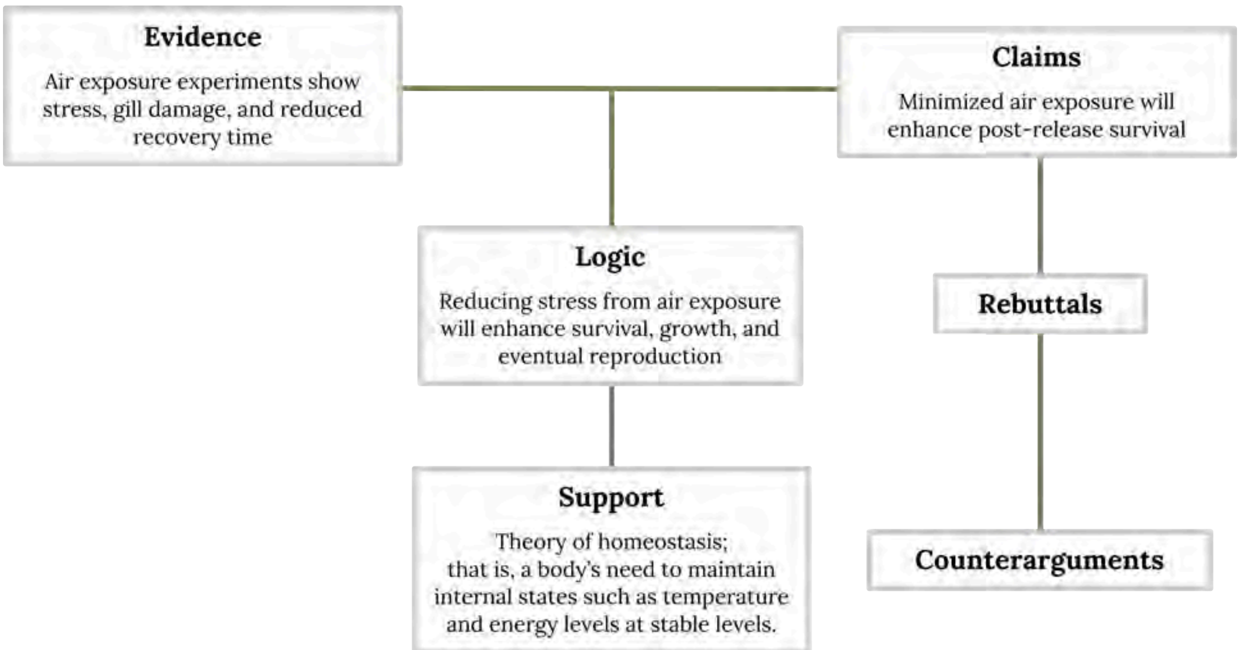

Figure 10.10: Structure of an argument supporting the premise that minimizing air exposure will reduce the mortality of released fish. Long description.

After catching a fish, it should be released as soon as possible to ensure survival. However, the angler can quickly test the reflexes of the fish with a few simple tests. These signs of impairment in the reflexes of captured fish are correlated with mortality and stress indicators, such as elevated cortisol and lactate levels (Davis 2010; Raby et al. 2012). Anglers who wish to release caught fish should learn to follow the steps for determining reflex action mortality predictors (Brownscombe 2018). If fight times are short and air exposure is minimized during handing, then one should expect the fish to show a strong escape response (Figure 10.11). If the angler grabs the tail of the fish with the fish submerged in water, an unimpaired fish will immediately attempt to swim away and the angler will feel the muscles flex. Additionally, if the fish is held out of water using two hands wrapped around the middle of the body, the unimpaired fish will actively attempt to struggle free. If a fish passes the escape response test, it should immediately be released to reduce any further handling. If it fails, the angler tests the righting response. Here, the fish is placed upside down in the water just below the surface and should right itself in a few seconds. If it passes the righting response, it should be immediately released. If a fish fails both the escape and right response tests, the angler checks for normal gill ventilation. Hold the fish in the water, observe for regular, consistent ventilation (opening and closing) of the operculum (gill covers). If a fish isn't ventilating at regular intervals, it fails this test, and is highly impaired and at high risk for mortality. Therefore, the fish should be held until it can be reassessed for the righting response and ventilation responses (Figure 10.11). In the final test, the angler holds the fish in water and rolls the fish side to side. If the eye remains level instead of rolling it with the body, the fish passes the test. With either outcome of the eye test, the fish should be held until it can be reassessed and released only after passing the righting response.

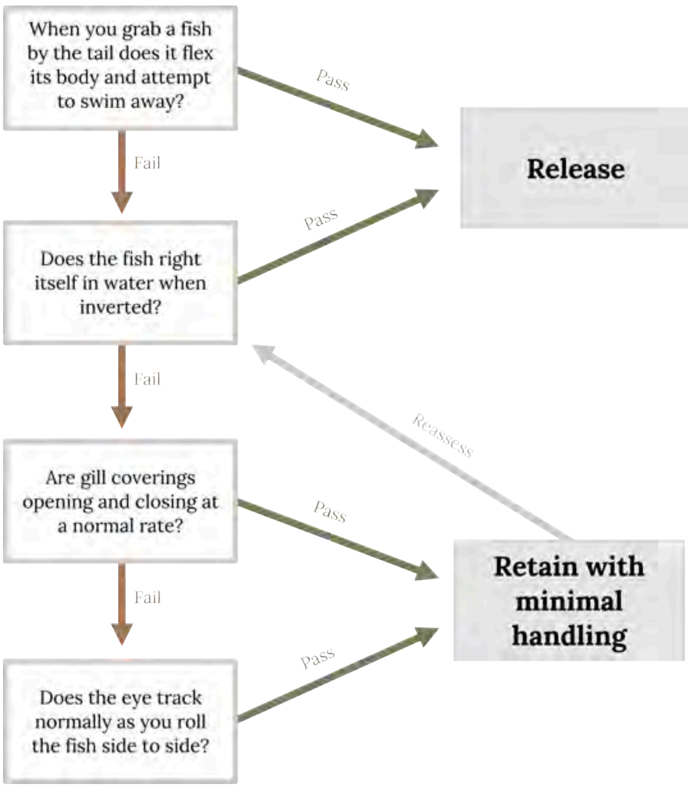

Figure 10.11: Steps in determining the reflex response in order to minimize the risk of mortality of a released fish. Long description.

Even shark anglers have become strong allies for the development, dissemination, and adoption of specific best practice catch-and-release guidelines. Ninety-three percent of recreational anglers from the United States have caught a shark at least once while fishing (Press et al. 2016). However, many lack knowledge of sharks and how to enhance their survival after capture, and guidelines from the National Marine Fisheries Service (NMFS) were not consistently applied. NMFS recommends that recreational anglers who catch and release sharks (1) use nonoffset circle hooks; (2) set the hook immediately in the lip or jaw to avoid gut hooking; (3) reduce fight times by using heavy tackle; (4) minimize handling of the animal, including not landing the shark; (5) use a dehooker to remove the hook; and (6) revive the shark if it is fatigued or near death. These guidelines must be better disseminated.

To increase the awareness of the important role we all play in protecting our fisheries, anglers are asked to embrace a Code of Angling Ethics to serve as a reminder of their stewardship role.

In one example Code of Angling Ethics, anglers make the following pledges:

- Have a valid fishing license for all members of your party.
- Understand and follow state and lake-specific regulations. Compliance to regulations directly plays a role in sustaining a healthy recreational fishery and benefits fishing for the future.
- Strive to keep the watershed clean and minimize the impact you may have when fishing. Avoid degrading stream and lake banks and properly dispose of debris and trash, including monofilament line.
- Respect property and share waters respectfully with others.
- Avoid the introduction of aquatic nuisance species to protect the integrity of Illinois lakes and streams. Prevent the transport of unwanted plants, fish, and other aquatic animals by thoroughly cleaning all recreational equipment and disposing of live bait in the trash.
- Practice best handling guidelines for catch-and-release fishing. Fish should be released with minimal harm to help ensure post-release survival and promote healthy fish populations.
- Keep no more fish than needed for consumption.
- Take care when anchoring to minimize damage to the aquatic environment. Be aware that there may be nesting fish close to the shore during the spawning season.
- Preserve the sportfishing tradition by sharing knowledge, skills, techniques, and ethics. Help others to understand sound fisheries conservation practices. (Illinois DNR, no date)

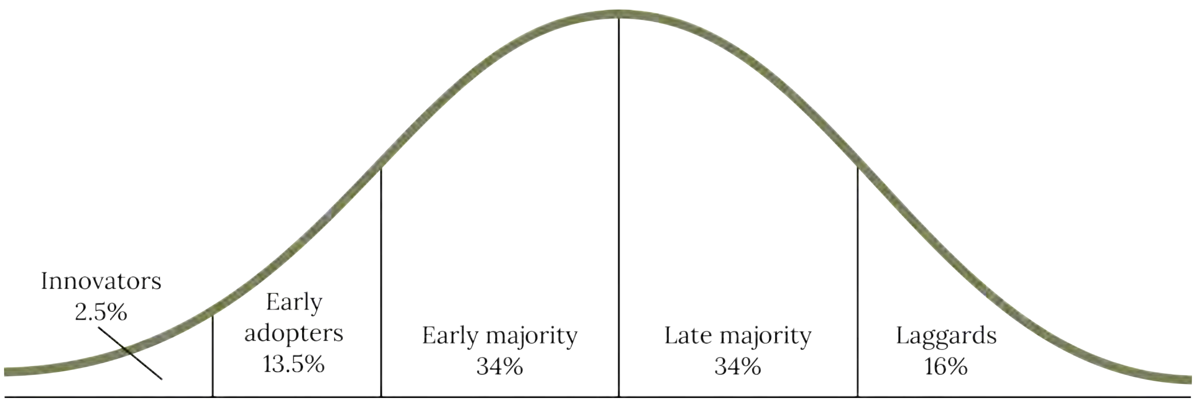

Figure 10.12: Diffusion of innovations graph based on adoption-diffusion model. [Long description](#).

Adoption of any new fishing practice behavior does not happen simultaneously among all participants. Rather, some people are more apt to adopt the innovation than others. When promoting a new behavior, it is important to understand the target population to help or hinder adoption of the innovation. Innovators are eager to try new ideas and demonstrate their effectiveness before early adopters eventually adopt them (Figure 10.12). Later, the early majority and late majority may learn and adopt the new practice, and the last group, called the **laggards**, applies the practice only if it is the only remaining method. According to adoption-diffusion theory, the greatest impact in implementing innovative fishing practices will come from seeking out and educating the innovators and early adopters (Rogers and Shoemaker 1971). The Keep Fish Wet brand uses ambassadors who serve as innovators and can demonstrate the correct application of Keep Fish Wet principles so that the new behaviors become new social norms.

***Question to ponder*:**

Can you think of "brands" that help foster social change?

10.8 Governing Conflict and Challenges

Management of recreational fishing has a strong moral dimension, while relying on scientific studies in informing responsible fishing practices. The ethical decisions deal with values, rules, duties, and virtues of relevance to both human well-being and ecosystems. Guidance on recreational fisheries recognizes that the right to fish carries with it the obligation to do so in a responsible manner so as to ensure effective conservation and management of the living aquatic resources (FAO 2012). Consequently, to govern fisheries we must engage all stakeholders and their potentially diverse views in decision making (Arlinghaus et al. 2005). Over time, if the recreational anglers form influential, conservation-conscious communities, they become a powerful force for the conservation of aquatic biodiversity. Boundary organizations can bring different people with variable backgrounds into routine contact. Examples include the Bonefish and Tarpon Trust in conserving flats habitats and fishing, Mahseer Trust supporting mahseer conservation in India, and Mongolia River Outfitters/Fish Mongolia for Taimen conservation in Mongolia (Adams et al. 2019; Brownscombe et al. 2019c; Cooke et al. 2016).

The number and catching capacity of recreational anglers globally are very substantial. Most recreational fisheries have no mechanism for limiting total fishing effort, which may result in negative effects on important fish populations and communities, in addition to traffic and congestion problems. Although some types of angling depend on group sociability (Olaussen 2010), excessive crowding at popular fishing locations, dubbed "combat fishing," is undesirable (Figure 10.13). Crowds and conflicting actions by other anglers were two of the most significant factors influencing angler satisfaction (Tseng et al. 2009; Birdsong et al. 2021; TenHarmsel et al. 2021). Anglers seeking solitude while fishing may desire remote public lands to be physically and legally accessible. In many congested fishing locations, site improvements may help to reduce the negative effects of crowding on the fishing experience.

With increasing demands for recreational fishing, more conflicts are anticipated and should be addressed by management actions (Coleman et al. 2004; Elmer et al. 2017; Arlinghaus et al. 2019). It is not possible to maximize the quality of fishing experiences for trophy and more harvest-oriented anglers simultaneously. Similarly, it is not possible to maximize the harvest in a commercial fishery while providing quality recreational fishing. Making a choice among competing objectives requires a value judgment informed by societal preferences (Arlinghaus et al. 2019). Key questions to consider include these:

- What do stakeholders want?
- What can the target population provide?
- What can the ecosystem sustain?

Figure 10.13: Combat fishing for king salmon near Montana Creek, Alaska.

The future of recreational angling depends on how well we foster sustainable use of species targeted by recreational anglers while minimizing conflicts. The challenges of maintaining sustainable recreational fishing into the future will require collaboration with multiple stakeholders and resolving multiple objectives. Collaborations are likely to enhance use of traditional ecological knowledge, leverage regional and local networks, and enhance sustainable fishing (Granek et al. 2008). People who fish develop an identity as an angler, which drives their engagement in conservation behavior and normative beliefs about responsible fishing (Mordue 2009; Landon et al. 2018). A more holistic engagement will contribute to making access to recreational fishing more equitable and responsive to changing motivations. Finally, there are many examples of interventions that have enhanced fishing satisfaction and provide for a more optimistic outlook for the future of recreational fishing (Elmer et al. 2017; Cooke et al. 2019). In the book *Fishing Through the Apocalypse: An Angler's Adventures in the 21st Century*, Matthew Miller explores many nontraditional types of fishing that are changing the expectations of recreational angling.

Profiles in Fish Conservation: Sascha Clark Danylchuk and Andy Danylchuk, PhD

Scan the QR code or visit https://doi.org/10.21061/fishandconservation to listen to this Profile in Fish Conservation.

Figure 10.14: Sascha Clark Danylchuk.

Sascha Clark Danylchuk and Andy J. Danylchuk might be called a power couple in the science of recreational fishing and the science of catch and release in particular. Both share a passion for fishing that drives their work and play. Sascha Clarke Danylchuk is the Executive Director of Keep Fish Wet, and Andy J. Danylchuk is Professor of Fish Conservation at the University of Massachusetts, Amherst. Both are fisheries scientists with strong credentials built upon their decades of innovative investigations that have informed the best practice for catch-and-release fishing. Together they taught themselves to fly fish and tie flies while living on a remote Caribbean island.

Sascha worked for a number of non-profit organizations before joining the Keep Fish Wet organization in 2016. As Executive Director, she works directly with anglers and conservation organizations. Keep Fish Wet promotes the use of science-based best practices to catch, handle, and release fish. Sascha says, “One of our goals is to unlock science and make it more accessible and understandable to all anglers.” Along with economic benefits that accrue from catch-and-release fishing, many anglers and organizations become influential in fish conservation. However, recreational anglers can learn much from scientists, and Keep Fish Wet helps make the science of recreational fishing accessible to a wide audience.

Figure 10.15: Andy Danylchuk, PhD.

Andy J. Danylchuk focuses his research on many factors that influence the life history and ecology of fish and other aquatic organisms, as well as how disturbances can influence the dynamics of their populations. His work on stress physiology, behavioral ecology, spatial ecology, predator-prey interactions, and adaptations in life history traits as a response to disturbance has been often cited by other scientists. He has also collaborated with numerous stakeholder groups to develop best practices for the recreational angling community to avoid overfishing.

Both Sascha and Andy are acutely aware that many fish die due to recreational fishing, including catch-and-release fishing. Catch-and-release practice has been used a long time, but the science is very new. Sascha says, “Fishing is a blood sport.” Yet, the fate of landed fish is determined largely by angler behavior that determines the health of released fish. They both help develop and advocate for adoption of Keep Fish Wet principles and tips to reduce the number of fish that die from fishing.

The principles and tips they advocate are different from many other fishing tips in two important ways. First, the principles and tips were selected because they are backed by substantial scientific evidence. Second, the principles and tips recognize that the fate of fish after release is primarily determined by angler behavior. For example, simple advice such as avoiding fishing spawning fish, using barbless hooks, avoiding grippers, and keeping air exposure to ten seconds or less can be easily followed by anglers and will result in enhanced survival of released fish. Other advice may be more specific based on the fish and location. Sascha’s research on Bonefish demonstrated that air exposure and handling time influenced whether a landed fish will swim away after release. In The Bahamas, where there are numerous predators such as sharks and barracuda, her research guided anglers to avoid releasing Bonefish in areas where predation threat is high.

Andy Danylchuk has pioneered the use of telemetry, biologgers, accelerometers (i.e., motion detectors), underwater video cameras, and associated emerging technological aids in the study of recreational angling. He also investigated physiological disturbance of captured sharks and other fish by measuring stress indicators in blood samples. This type of research was essential to supporting the “reduce handling time” principle. Andy’s studies of movement of Bonefish led to learning the sites where spawning Bonefish aggregate.

Although many research studies on proper handling of released fish have occurred, anglers are largely unaware of the findings because they are written for other scientists and inaccessible to most anglers. Sascha has examined how best to encourage behavior change in anglers. Social media shaming does not work. Her work is done through education, outreach campaigns, partnerships with fishing industry's biggest brands, and fishing demonstrations. Scientists talking to anglers and guides is a novel approach but directly benefits information transfer. Sascha has written a blog, *Finsights for Keep Fish Wet Fishing*, that translates the scientific journal articles to a form accessible to anglers. She is building a strong bridge between scientific findings and the practice of recreational angling. Keep Fish Wet recognizes that many of the best practices, such as learning how to hold a fish, take some proper on-water education and practice.

The outcome from releasing a landed fish is too often a sublethal or unrecognized effect, such as a wound from hooking or exhaustion. Recovery of the fish takes time, but the final fate is not known to the angler, and it may influence spawning success or cover-seeking behavior. Translating the scientific findings to simple memorable language, such as "minimize air exposure," tells the angler how to treat the fish to avoid sublethal effects. In demonstrations to anglers, the Danylchuks emphasize desired behaviors, such as "no knuckles in photograph," "no grip and grin," "protect the slime," and other essential actions for catch-and-release fishing.

Andy Danylchuk is a Patagonia fly-fishing ambassador where he has a direct influence on fly-fishing globally. As an award-winning professor, he is a strong proponent of experiential, hands-on opportunities that can enhance learning for students of all ages. And this philosophy extends to education of anglers. He is a scientific advisor to Keep Fish Wet and was awarded the Excellence in Public Outreach from the American Fisheries Society, a nonprofit organization whose mission is to improve the conservation and sustainability of fishery resources and aquatic ecosystems by advancing fisheries and aquatic science and promoting the development of fisheries professionals. He also received the Flats Stewardship Award and is a Member of the Circle of Honor for his significant contributions to the stewardship of flats species and habitats. He has strong collaborations with researchers globally and advised Bonefish & Tarpon Trust, Indifly Foundation, Patogonia, and Fish Navy Films, among others.

Together, Andy and Sascha have had major influence in developing and promoting the best practices for the conservation and management of recreational fisheries. Anglers can make small changes in how they catch, handle, and release fish to help fish return to normal behavior as quickly as possible after release. Advocates show their support and commitment by becoming advocates for Keep Fish Wet and pledge to use best practices for catch and release by minimizing air exposure, eliminating contact with dry surfaces, and reducing handling time. Take the pledge at https://www.keepfishwet.org.

Key Takeaways

- In inland waters, recreational fishing is often the dominant use of fish.
- Larger fish in a population are more valuable as trophies, but the big, old, fat, fecund, female fish in a population have a disproportionate effect on productivity.
- Catch-and-release fishing is a growing conservation strategy beyond the domain of fly-fishing.
- Our ability to achieve sustainable fisheries with a positive effect on environmental conservation is highly dependent on forming and promoting a conservation-minded angling culture.
- Solving problems in recreational fishing requires that we build trust in an accessible, reliable, and solution-oriented framework for changing social norms.
- Human behavior is a key source of uncertainty in recreational fisheries management.
- Keep Fish Wet principles are best practices for catch-and-release fishing that address the elements of the angling event that are most in an angler's control.
- Technological innovations in recreational fishing have raised questions about "fair chase" and need for gear regulations.

This chapter was reviewed by Sascha Clark Danylchuk and Andy Danylchuk.

URLs

Keep Fish Wet: https://www.keepfishwet.org/

Keep Fish Wet Principles: https://www.keepfishwet.org/tips#keepemwet-tips

Long Descriptions

Figure 10.2: Catching my own food (12%); Reliving my childhood memories of going fishing (12%); Experiencing excitement/adventure (14%); Experiencing solitude (14%); The scenic beauty (16%); spending time with family or friends (29%); catching fish (31%); enjoying the sounds and smells of nature (32%); being close to nature (33%); getting away from the usual demands (34%). Jump back to Figure 10.2.

Figure 10.3: Four quadrants. Low priority: low satisfaction and low importance. Possible overkill: high satisfaction and low importance. Concentrate here: low satisfaction and high importance. Keep up the good work: high satisfaction and high importance. Jump back to Figure 10.3.

Figure 10.4: Vertical axis= number; horizontal axis= age (years); decline in number of fish and increase in weight in an unfished and fished population over time. Jump back to Figure 10.4.

Figure 10.5: Bar graph with catch per day on the x-axis and proportion of anglers on the y-axis. No daily limit and daily limit both increase as catch per day increases. Jump back to Figure 10.5.

Figure 10.6: BOFFFF: 1) more eggs; 2) outlive unfavorable environmental periods; 3) offspring grow faster and survive better; 4) spawn at different times and places than younger females. This leads to enhanced fish population productivity. Jump back to Figure 10.6.

Figure 10.7: 1) Values; values are the hardest thing to change; 2) beliefs; facts alone do not change beliefs; 3) norms; norms are more flexible; 4) actions; example actions: best practices for recreational fishing. Emotions and thinking apply here: Values and beliefs. Jump back to Figure 10.7.

Figure 10.8: 1) Capability; do I have the right skills to do this?; 2) motivation; do I like it?; 3) opportunity; what do others think of this. Arrows from each question directed to behavior. Jump back to Figure 10.8.

Figure 10.9: Steps: 1) Selection; what behavior is targeted for change?; 2) intervention; credible local peers introduce the intervention; 3) evaluation; did the intervention change the behavior? If yes, evaluation leads to 4) dissemination; inform audience through policymakers and grassroots agencies. If evaluation leads to no, arrow back to 1) selection. Jump back to Figure 10.9.

Figure 10.10: Top line connects 1) evidence; air exposure experiments show stress, gill damage, and reduced recovery time and 2) claims; minimized air exposure will enhance post-release survival. Claims leads to 1) rebuttals and 2) counter arguments. Line in between 1) evidence and 2) claims leads to 1) logic; reducing stress from air exposure will enhance survival, growth, and eventual reproduction and 2) support; theory of homeostasis, that is, a body's need to maintain internal states such as temperature and energy levels at stable levels. Jump back to Figure 10.10.

Figure 10.11: Steps: 1) when you grab a fish by the tail does it flex its body and attempt to swim away?; 2) does the fish right itself in water when inverted? If no, fail; if yes, then release. 3) are gill coverings opening and closing at a normal rate?; 4) does the eye track normally as you roll the fish side to side? If no, fail; if yes retain with minimal handling and reassess with 2) does the fish right itself in water when inverted? Jump back to Figure 10.11.

Figure 10.12: Normal distribution showing variation from innovators (2.5%), early adopters (13.5%), early majority (34%), late majority (34%), laggards (16%) to show lag in adoption and diffusion of new behavior. Jump back to Figure 10.12.

Figure References

Figure 10.1: Two young recreational anglers using familiar spinning fishing gear. Florida Fish and Wildlife. 2012. CC BY-ND 2.0. https://flic.kr/p/bR2GSZ.

Figure 10.2: Positive attributes reported by recreational anglers in the United States. Kindred Grey. 2022. CC BY 4.0. Data from "Chasing the Thrill or Just Passing the Time? Trialing a New Mixed Methods Approach to Understanding Heterogeneity amongst Recreational Fishers Based on Motivations," by Magee et al. 2018. https://doi.org/10.1016/j.fishres.2017.11.026.

Figure 10.3: Four quadrants of management priorities based on importance to anglers and angler satisfaction with fishing experience. Kindred Grey. 2022. CC BY 4.0.

Table 10.2: Benefits of fly-fishing and representative quotes by participants (from Craig et al. 2020). Data from "The Transformative Nature of Fly-Fishing for Veterans and Military Personnel with Posttraumatic Stress Disorder," by Craig et al. 2020. https://doi.org/10.18666/TRJ-2020-V54-I2-9965

Figure 10.4: Theoretical comparison of number of fish in an unfished and fished age group through time. Kindred Grey. 2022. CC BY 4.0.

Figure 10.5: Frequency distribution displays the number of angler days resulting in differing catch per day for a hypothetical 8 fish per day creel limit and estimated change if creel limit is reduced to 4 fish per day. Kindred Grey. 2022. CC BY 4.0.

Figure 10.6: Hypothesized maternal effects of big, old, fat, fertile, female fish (BOFFFFs). Kindred Grey. 2022. Adapted under fair use from BOFFFFs: *On the Importance of Conserving Old-Growth*

Age Structure in Fishery Populations, by Hixon et. al. 2014. https://sedarweb.org/documents/pw7-85-boffffs-on-the-importance-of-conserving-old-growth-age-structure-in-fishery-populations/.

Figure 10.7: Values, beliefs, norms, and action causal change of influence. Kindred Grey. 2022. CC BY 4.0.

Figure 10.8: Three questions that determine behavior intentions according to the theory of planned behavior. Kindred Grey. 2022. CC BY 4.0.

Figure 10.9: Steps in applied social marketing to change behavior of recreational anglers. Kindred Grey. 2022. Adapted under fair use from *Applied Behavior Analysis and Social Marketing: An Integration for Environmental Preservation*, by E. Scott Geller, 1989. https://doi.org/10.1111/j.1540-4560.1989.tb01531.x.

Figure 10.10: Structure of an argument supporting the premise that minimizing air exposure will reduce the mortality of released fish. Kindred Grey. 2022. CC BY 4.0.

Figure 10.11. Steps in determining the reflex response in order to minimize the risk of mortality of a released fish. Kindred Grey. 2022. CC BY 4.0.

Figure 10.12. Diffusion of innovations graph based on adoption-diffusion model. Kindred Grey. 2022. CC BY 4.0.

Figure 10.13: Combat fishing for king salmon near Montana Creek, Alaska. Frank Kovalchek. 2008. CC BY 2.0.

Figure 10.14: Sascha Clark Danylchuk. Used with permission from Sascha Clark Danylchuk. CC BY-ND 4.0.

Figure 10.15: Andy Danylchuk, PhD. Used with permission from Andy Danylchuk. Photo by Brian Irwin. CC BY 4.0.

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11. Integrating Fishers in the Management of *Arapaima*

Learning Objectives

- Investigate the significance of *Arapaima* fishing in the Amazon.
- Examine the role of the *Arapaima*, one of largest freshwater fish of the world, as an example of a flagship species.
- Appreciate the cultural significance of the *Arapaima*.
- Explain how we detect overfishing.
- Explain the benefits and successful application of principles for sustainable governance of common property resources.
- Explore gender differences in *Arapaima* fisheries.

11.1 People and Fish of Amazonia

The settlement of the Amazon region is a story of many people and their relationship with the rain forest and its resources. Fish were a dominant part of the diets of indigenous people. The Amazon River basin, also known as Amazonia, is one of the world's largest river systems, with approximately 12 times the volume of water carried by the Mississippi River. At its mouth, one cannot see across the Amazon from one bank to the other. The Amazonia region, which includes the Amazon, Orinoco, and rivers of Guyana, has the richest freshwater fish fauna in the world! Amazonia is a cradle of biodiversity, with over 3,000 fish species and likely many more yet to be discovered. For example, more than 100 new fish species were described between 2017 and 2019 (Jézéquel et al. 2020). The fish fauna in parts of the Amazon basin is still in a relatively good state of conservation (Reis et al. 2016), and fish provide for many ecosystem services, such as nutrient cycling, grazing, seed dispersal, and essential nutrition and livelihoods for many people of Amazonia. Sustainable fisheries are essential for the food security of people of this region, and unsustainable land and water use practices threaten this important hot spot for fish conservation (Pelicice et al. 2017).

The first humans to migrate across the land bridge from Siberia to Alaska during the Pleistocene (at least 16,500 years ago) settled in western North America. By the late Pleistocene and early Holocene (~12,000 years ago), humans had migrated from North and Central America to South America, likely via the **Isthmus** of Panama (Hester 1966). Early humans likely domesticated **manioc**, maize, squash, and beans in addition to hunting, fishing, and gathering (Lombardo et al. 2020). By the time that explorers from Portugal discovered present-day Brazil in 1500, there were hundreds of native tribes inhabiting the region. Some experts speculate that there may have been 15 million Amerindians in the basin before Europeans arrived (Smith 1999). Fish were important wild food, as revealed by bones of many fish species, including small **characiforms**, catfish, and *Arapaima*, at archeological sites from 11,200 to 8,000 years ago (Roosevelt 1999).

Portuguese colonists bartered with the native peoples and developed a profitable export trade for brazilwood and other commodities. However, tensions soon developed, and the Portuguese colonists turned to violent confrontations with indigenous tribes. The custom of native peoples of frequently moving villages to prevent damage to local flora and fauna conflicted with the European system of private ownership and permanent settlements. Indigenous people explored the many rivers and developed villages, passing on specialized local knowledge of fishing and other essential products from the rivers, lakes, and forests. The Native Amazonian people love and live successfully in rain forest communities. However, violence and exposure to novel diseases, such as smallpox, led to gradual replacement of indigenous people with colonists from Europe and Africa in the 17th century. Land surrounding large human settlements became highly modified due to logging, livestock grazing, and commercial agriculture.

Indigenous peoples of the Amazonian floodplains are themselves a diverse group, called *ribeirinho*, or river settlers. *Ribeirinhos* live alongside the Amazonian floodplains and have intimate knowledge about the river and forest resources upon which their livelihoods depend (Moran 1993). Indigenous people settled in the flooded forest ecosystem, where they continue to live today with little advanced technology and live largely on cassava manioc (to derive flour, tapioca, and bread), wild fish, bush meat, and **pequi** fruit (Dufour et al. 2016; Schor and Azenha 2017). All indigenous groups recognize many wild plants and animals, their relations to soil quality, and their useful properties. Increasingly via cash trading, they also purchase canned goods, frozen chicken, dairy, and other refrigerated foods.

Today, the people of Amazonia include indigenous peoples and colonists, each with differing cultures. Modern Brazilians descend from Portuguese colonists, African enslaved people, intermarriage of both races with indigenous peoples, and recent immigration by other Europeans and Asians (Hemming 2020). Colonists cleared the floodplains for farming and engaged in slash-and-burn tactics for profit-driven cattle grazing or soy plantations; hence it is difficult for each group to understand the other. Historically, the indigenous people have suffered genocide, violence, and exploitation of their lands for mining, cattle ranching, logging, hunting, and big agriculture.

Brazil was ruled by a Portuguese monarchy for more than three hundred years before becoming independent in 1822. Millions of enslaved people were imported to work on coffee plantations, until slavery was outlawed in 1888. When Brazil began democratic rule in 1985, groups fought to get rights for indigenous people. Brazil's constitution (1988) (1) declared that indigenous people were descendants of original Brazilians and hence owned lands, and (2) guaranteed respect for their way of life and provided exclusive use of the goods and resources on indigenous lands. Today every forest tribe has its land protected (Hemming 2020).

Approximately 89% of the population of Brazil now resides in urban areas, and strong rural-to-urban migration continues. Children of rural migrants are exposed to different food options in urban areas, leading to reduced fish consumption. Fishing pressure is focused on few species (Bayley and Petrere 1989), and overfishing is driven by the demand for fish from urban settlements (Tregidgo et al. 2017). Agriculture production has grown dramatically in Brazil, resulting in clear-cutting of mature forest to plant grains and raise beef cattle (Nepstad et al. 2014). Deforestation is only one of many threats to the Amazon region. Other threats to fisheries include overfishing, nonnative species, aquaculture, pollution, water diversions, habitat loss, mining, and poor management.

Fisheries, river and lake ecosystems, and wetlands of Amazonia support many regional economies and livelihoods of traditional and indigenous communities (Goulding 1996). Most fishing in rural communities is for subsistence to feed families, and only the surplus is sold. Fish are still the cheapest and most important source of animal protein in the central Amazon. Per capita fish consumption is high in the Brazilian Amazon, at 5.8 times the world average for riverine dwellers and 2.5 times the world average for urban dwellers (Isaac and Almeida 2011).

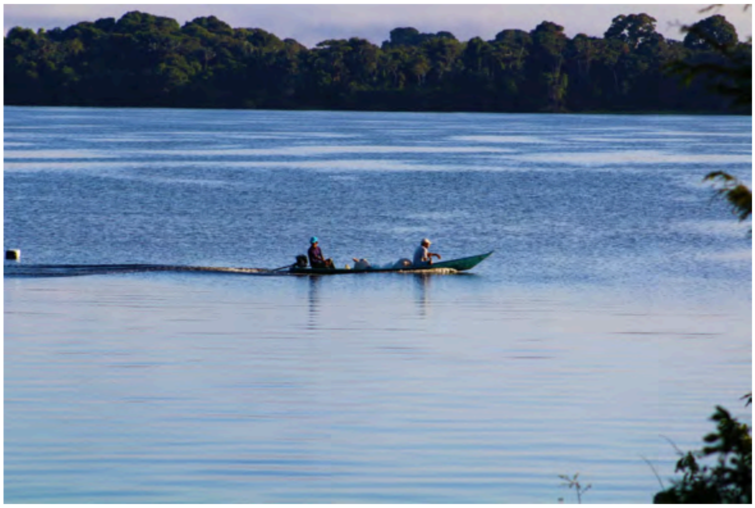

Figure 11.1: Indigenous and ribeirinho people travel on rivers of Brazil in a voadeira, a motorized canoe.

Subsistence fisheries are a large economic activity and livelihood component of rural communities. Globally, small-scale fisheries contribute to food security and employ 32 million fishers (World Bank 2012). However, fisheries management agencies collect incomplete statistics because small-scale fisheries tend to be physically remote and agencies lack sufficient human and financial resources (Berkes et al. 2001). *Arapaima* fishing illustrates how innovative approaches to fisheries governance may lead to recovery of overfished populations and alleviate poverty without major government intervention.

11.2 *Arapaima*: An Example Freshwater Megafauna and Flagship Symbol

Arapaima (pronounced "air-ah-pie-ma") is one of the most acclaimed fishery resources of the Amazon region and has considerable socioeconomic importance. In Brazil and Colombia, they are called Pirarucu, a Portuguese name meaning red fish. *Arapaima* are called Paiche in Peru, Ecuador, Venezuela, and Bolivia, and sometimes simply Giant Arapaima. Its large size (up to 3+ meters and >200 kg) and the high quality of its flesh make it one of the most historically important and overexploited fisheries in South America. The people of Guyana call *Arapaima* Oma, or the "mother of all fish," which serves as a local taboo against harvest.

Figure 11.2: Arapaima gigas displayed in the Siam Centre, Bangkok.

Arapaima is an important flagship genus for flooded forest ecosystem and human floodplain communities. Flagship taxa are used as a symbol to promote conservation awareness (Caro 2010). Their large size makes them a true freshwater megafauna like crocodiles, river dolphins, and other large fish. Freshwater megafauna face many threats, and 71% of these species are in decline (He et al. 2017, 2018). *Arapaima* continue to face intense fishing throughout their range (Watson et al. 2021). However, freshwater megafauna like the *Arapaima* have fewer conservation resources and efforts than marine or terrestrial megafaunas.

Fishing, in general, and fishing for *Arapaim*a in particular, is a central element of the local economy and culture in Amazonia. Because these fish are **obligate** breathers, they are traditionally harvested by fishers using harpoons at the time when they surface to breathe. Men typically fish from canoes and search for signs of *Arapaima* near the surface. As they near the *Arapaima*, the harpooner throws the harpoon by hand. This is a specialized type of fishing, and the local fishers possess knowledge of the behavior that increases their likelihood of catching one. With appropriate training, fishers' participation in management processes can contribute to the conservation and governance of these small-scale fisheries.

Many populations of *Arapaima* have been driven to local extinction due to overfishing (Castello et al. 2015a; Gurdak 2019a; Watson et al. 2021; Freitas and Sousa 2021). Much of the catch is illegal, with most specimens being caught below the minimum size limit or during the closed season (Cavole et al. 2015). The small-scale fishers are geographically dispersed, and governments in these regions have insufficient resources to devote to enforcing fishing rules. The riverine fishers who target *Arapaima* are **marginalized** and have limited formal education. Yet, compliance with regulations is essential to prevent overfishing and local extinction.

Arapaima represent only a small fraction of the fisheries harvest, but they are culturally important and symbolic as a flagship genus of tropical South American fisheries and floodplain management and conservation. Reducing the threats to *Arapaima* will also provide protections for many of the highly migratory fish of the Amazon basin. Collectively, the migratory fish contribute most of the fishery's landings in the basin (Duponchelle et al. 2021). Migratory fish depend on multiple, distant, but interconnected habitats during their life cycle. Any threat to one of the habitats or the corridor that connects them can influence these important food fish (Goulding et al. 2019).

11.3 Habits, Habitat, and Life History of *Arapaima*

Arapaima live in floodplain lakes that experience seasonal variation in water levels, ranging from 4 to 15 meters. The floodplain along the sediment-rich waters of the Amazon basin consists of seasonally inundated rain forests, lakes, and winding channels. The seasonal flood pulse creates a new and expanding **littoral** zone that moves with the rising waters. Seasonal flood pulses provide new nutrient, detritus, and sediment inputs from the main river channel and drive the high productivity of numerous prey fish of the *Arapaima* (Watson et al. 2013; Castello et al. 2015b; Carvalho et al. 2018). *Arapaima* are more abundant in deeper and larger lakes with more space and food (Arantes et al., 2013; Campos-Silva and Peres, 2016). Juvenile *Arapaima* in particular benefit from lakes with large littoral zones that move with rising water (Castello et al. 2019).

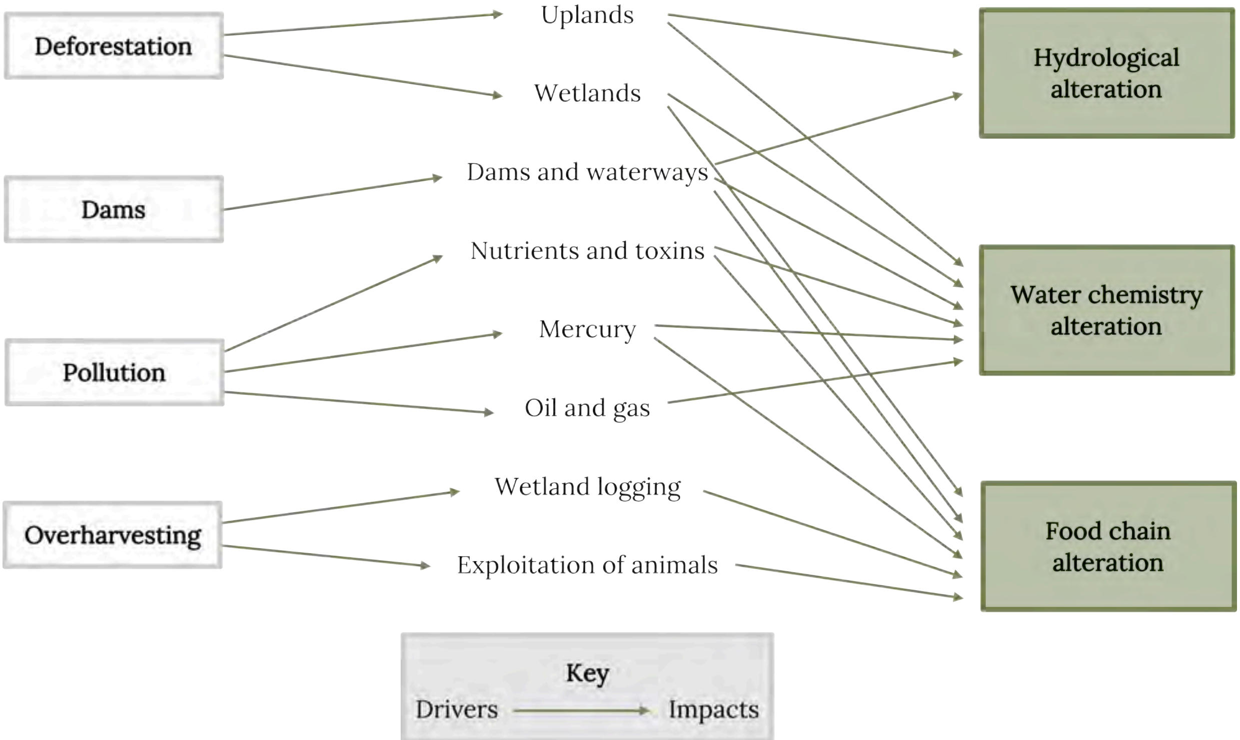

Figure 11.3: Schematic diagram of the main drivers influencing freshwater ecosystems in the Amazon. [Long description](#).

Large *Arapaima* are the ultimate ambush predators. They belong to a group of primitive bony fish known as bonytongue fish, because their tongues are used to crush prey against the roofs of their mouths. Smaller *Arapaima* are generalist feeders, consuming a variety of invertebrates, such as the Amazon River prawns, mayflies, and crickets, while larger *Arapaima* can consume larger prey, often catfish, cichlids, hatchetfish, and pacu (Watson et al. 2013; Carvalho et al. 2018; Jacobi et al. 2020). During low water periods, many isolated lakes can become hypoxic (i.e., low in oxygen). The air-breathing habit permits *Arapaima* to survive in such environments and prey on fish stressed by low oxygen.

In addition to overfishing of *Arapaima*, many of its essential habitats are modified by deforestation, dams, pollution, and logging in nearby wetlands (Figure 11.3; Castello et al. 2013b; Castello and Macedo 2016; Pelicice et al 2017; Gurdak et al. 2019a). Because freshwater ecosystems are highly sensitive to human activities on water and on land, these growing impacts are currently a major constraint to conservation (Pelicice and Castello 2021). Human influences cause a complex chain of effects that alter the hydrology, water chemistry, and food webs of Amazon floodplain rivers. Current government policies, guided by short-term economic profits, ignore the scientific evidence of environmental degradation and threaten efforts to conserve and protect aquatic ecosystems and the many fishes that depend on them.

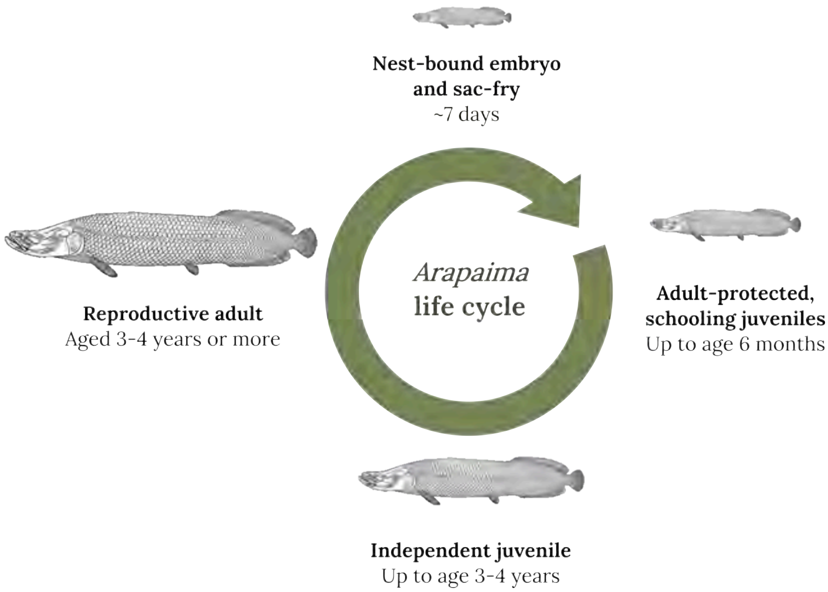

Figure 11.4: The generalized life cycle of the Arapaima can be divided into four main stages: (1) nest-bound embryo and sac fry, (2) adult-protected, schooling juveniles, (3) independent juveniles, and (4) reproductive adults. [Long description](#).

The life cycle of *Arapaima* is synchronized with the seasonal flooding cycle and consists of four main stages: (1) nest-bound embryo and **sac fry**, (2) adult-protected, schooling juveniles, (3) independent juveniles, and (4) reproductive adults (Figure 11.4). Although the *Arapaima* are among the largest freshwater fish in the world, their lifespan is only about 20 years. They attain reproductive maturity when they approach 150 cm in total length (TL) or age three or four. Size at reproductive maturity varies between 139 cm in the lower Amazon to 207 cm in the upper Amazon in Peru (Gurdak et al. 2019b). *Arapaima* migrate at the start of the rainy season in response to rising water levels and build nests in shallow, soft, sandy or muddy areas, usually under woody vegetation. Clearing a nest site likely serves to limit small predatory fish from eating eggs and larvae. Eggs are deposited in the nest by the female and fertilized by the male, and developing embryos are guarded by both parents. For such a large fish, fecundity is relatively low, with about 10,000 to 20,000 mature **oocytes** for an 80 kg female. However, the eggs are large (~2.5–3 mm) and hatch in about seven days to become sac fry.

The small fry are a dark color and stay near the parental male *Arapaima*'s head. The male's head turns dark to help hide the fry. Males release a pheromone that attracts his offspring and keeps them close by as he guides his offspring into zooplankton-rich areas for feeding. The substance is referred to by local people as "*Arapaima* milk," which may provide nutrition to young *Arapaima* as well as provide a means of chemical communications (Torati et al. 2017). Both parents continue to guard the juveniles as they school in search of food, but the female normally leaves after about one month, while the male stays with his offspring for up to three months. Juveniles are often preyed upon by other species of fish, particularly the abundant cichlid fish, such as the piranhas and Peacock Bass (*Cichla* or tucunaré).

Growth is fast, and juveniles disperse and live independent of parents at about 50 cm total length. In the central Amazon, *Arapaima* may grow to 30 cm TL in 3 months and 88 cm and 20kg in a year (Figure 11.5; Arantes et al. 2010), which may be the fastest juvenile growth of any fish (Schwenke and Buckel 2008; Sakaris et al. 2019). Growth is faster in the dry season, as more prey are concentrated. As adults, *Arapaima* have few natural predators because of their tough layer of scales. Only the rain forest caiman is known to prey on adults. *Arapaima* scales are among the toughest biological materials in nature, and they protect them from the abundant piranha (Sherman et al. 2017; Yang et al. 2019).

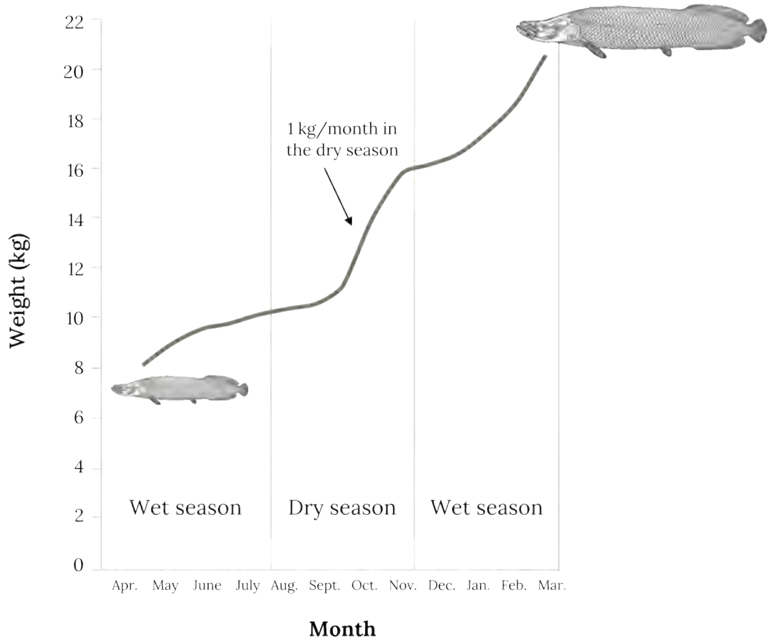

Figure 11.5: Juvenile Arapaima exhibit the fastest growth recorded in fish, reaching 15 kg or larger within the first year. Long description.

11.4 Biogeography and Conservation Status of *Arapaima*

Arapaima gigas is the most well researched species of *Arapaima*. Ichthyologist Albert Günther (1868) declared with no rationale that it was the only valid species, a view that persisted for over 100 years only because scientists never questioned his claim. However, as many as three other species of *Arapaima* have been recently named in Brazil, Peru, and Guyana (Stewart 2013a, 2013b). The most recent was *Arapaima leptosoma*, found in the Solimões River in Brazil. *Arapaima mapae* comes from the Lago do Amapá in Brazil, from which it takes its scientific name. *Arapaima agassizii* was named after famous biologist Louis Agassiz. Although these four *Arapaima* species were described in the 1800s, it was their different characteristics that have allowed Donald J. Stewart to classify them separately in his recent work. Although there is still no consensus on *Arapaima* **taxonomy** (Farias et al. 2019), ongoing studies indicate that there may be up to six valid species. Donald J. Stewart admonishes other scientists to "Beware of conventional wisdom—what we know might be completely wrong" (Stewart 2013a).

Available evidence indicates that *Arapaima* populations are likely decreasing in the entire Amazon basin (Castello and Stewart 2010). Where data do exist, there is a preponderance of juveniles, indicative of overfishing. Current distributions of the species cannot be accurately mapped due to uncertainty on the taxonomy and geographical distribution. However, the findings to date highlight the urgent need for caution in translocations of individuals. Conservation status is determined based on levels of reduction in population size, geographic range occupied, and number of populations. The Brazilian Environment Institute (IBAMA) classified *Arapaima* *gigas* as an overfished species or a species threatened with overfishing (Nogueira et al. 2020). *Arapaima gigas* was listed on the CITES Appendix II since 1975. Species listed in CITES Appendix II may be exported only after a nondetriment finding is affirmed. However, data are deficient for status assessment on most wild *Arapaima* populations. Populations from Guyana were classified as "near threatened" (Watson et al. (2021). Different species and different populations of *Arapaima* exhibit key life-history and ecological differences that may be relevant to their conservation (Watson et al. 2016; Watson and Stewart 2020). Two other species, *Arapaima agassizii* and *Arapaima leptosoma*, are recognized by the Brazilian Red List as "Data Deficient." Given the taxonomic uncertainties, fisheries management in this region currently refers to *Arapaima* only at the genus level (Arantes et al. 2021).

11.5 Vulnerability to Overfishing

Several characteristics of *Arapaima* make them highly vulnerable to overfishing. First, they are obligate air breathers and typically must surface every 5–15 minutes to gulp air; this makes them easy to locate. Second, the high-quality, boneless flesh is highly sought, making *Arapaima* a popular commercial food fish. Third, their skin can be used in the manufacturing of shoes, bags and clothing, and its scales and tongue are used in the manufacturing of nail files and ornaments. One hundred years ago, *Arapaima* dominated fisheries in the Amazon. Unregulated fishing with gill nets led to overfishing and many local extinctions, leading to a ban on fishing for *Arapaima* in 1986. Yet, gill nets are still used in the Amazon to capture other small fish and inadvertently capture juvenile *Arapaima*.

Characteristics of *Arapaima* that make them vulnerable to overfishing:

- Obligate air breathers
- High-quality flesh
- Skin and bones used in products

To protect rich native biodiversity in the Amazon, biological reserves were established. The largest is the Mamirauá Ecological Reserve, one-third of which is in flooded forest. This reserve is approximately half the area of New Jersey. The thrust of this reserve is the integration of local people into reserve management. In biological reserves, agreements guarantee indigenous fishers the exclusive right to fish (or to hunt) *Arapaima* but only with harpoons. Harpoons provide an efficient catch method for targeting *Arapaima*. The harpooners, referred to as *laguistas*, are specialists in handling harpoons and are familiar with the habits of the *Arapaima* (Sautchuk 2012). Searching for *Arapaima* involves catching the fish unaware, to facilitate approach and, ultimately, harpooning. Experienced fishers have an extraordinary ability to detect very subtle visual and acoustic information from surfacing *Arapaima* (Castello 2004).

Where management is weak or nonexistent and multiple fishers compete to catch fish, the large individuals are rapidly removed from the population and catch rates are barely sufficient to cover the costs of fishing, and fishers seek other areas. Remoteness of the fishing communities means that government presence and enforcement of regulations are lacking. Monitoring landings is practically impossible because of the decentralized and illegal nature of the trade. One survey from 81 fishing communities indicated that the local *Arapaima* stocks are depleted in 76% of the communities and overfished in 17% (Castello et al. 2015a). Only 5% were well managed and only 2% were unfished. Illegal fishing is still the principal threat to *Arapaima* populations (Castello and Stewart 2010; Cavole et al. 2015; Faria et al. 2018).

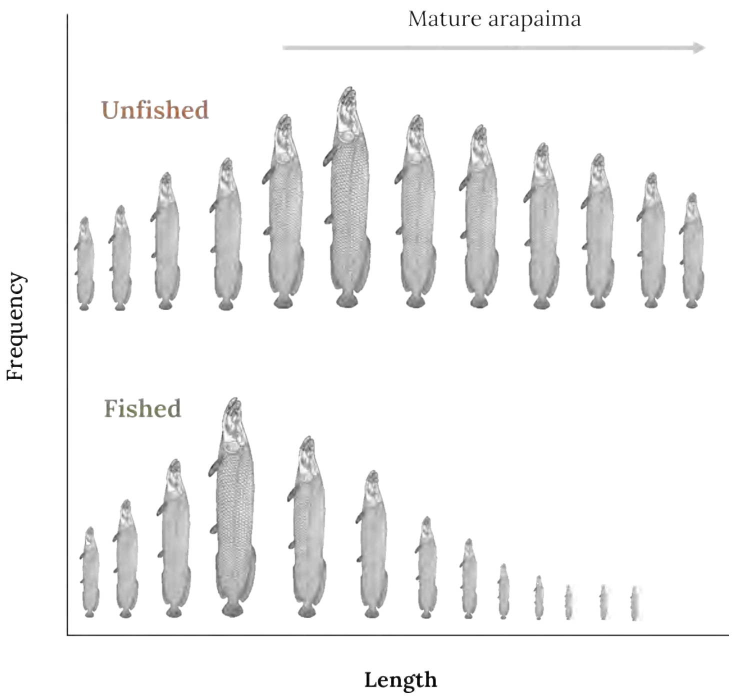

Figure 11.6: Theoretical length frequency for unfished (top) and fished (bottom) populations of Arapaima. [Long description](#).

In many areas, *Arapaima* are poached before they are able to mature and spawn; in some populations, 80–90% are killed long before they mature (Figure 11.6). A fishery that includes many small, immature fish in the catch is subject to growth overfishing, where the fish are removed well before they reach sexual maturity and their full growth potential. The result is size and age truncation, which is prevalent and often severe in exploited fish populations (Barnett et al. 2017).

Old fish have disproportionate effects on population growth, and scientists are beginning to recognize the benefits of big, old, fat, fertile, female fish in the population (BOFFFF; Hixon et al. 2014). Removal of too many immature fish reduces the number of BOFFFFs so that replenishment potential is restricted. Larger *Arapaima* are likely more effective at producing more offspring and protecting young from many predators.

Questions to ponder:

What characteristics of the Arapaima make them particularly vulnerable to overfishing? How might you develop a monitoring program to determine if overfishing is occurring for Arapaima?

The principle regulatory measures for *Arapaima* have been closed fishing season during the high-water spawning seasons (December 1 to May 31) and a 1.5-meter minimum length limit. *Arapaima gigas* is coveted in the leather fashion industry for their unique skin pattern, and the leather trade has increased in recent decades (Figure 11.7). CITES (Convention on International Trade in Endangered Species of Wild Fauna and Flora) is an international agreement between governments to ensure that international trade in specimens of wild animals and plants does not threaten their survival. In the United States, legal and illegal trade of *Arapaima* is monitored using Law Enforcement Management Information System (LEMIS) data from the U.S. Fish and Wildlife Service (USFWS). Legal harvest of *Arapaima* must be conducted with a specific management plan, and their international commercialization is also under control. In Brazil, *Arapaima* leather yields higher prices per unit on international markets than *Arapaima* meat, and the leather products are more likely to get exported. *Arapaima* leather trade has increased in recent decades as a substitute for decline in leather from pangolin, the most heavily trafficked wild mammal (Heinrich et al. 2019).

Figure 11.7: Boots made from Arapaima leather, by Lucchese Boots, advertised on U.S. eBay website.

Exports of *Arapaima* are only allowed if they are either wild caught from management areas or captive bred (Sinovas et al. 2017). However, a recent study from Brazil revealed that almost 80% of *Arapaima* landings were illegal (Cavole et al. 2015), which was observed to be the highest level of illegal fishing activity reported in the literature. Trade in *Arapaima* is still new and changing, and future trends and effects on populations need further study.

11.6 Incorporating Fishers in the Management of *Arapaima* Fishing in the Amazon

Small-scale fisheries are often poorly managed, yet they employ most of the world's 51 million fishers, produce about half of the global reported catch, and provide food, income, and livelihood to about 1 billion people. Hardin's "Tragedy of the Commons" argued that without government regulations or private ownership, overharvest of common property resources was inevitable. Federal governments own the fishery resources of the Amazon and, therefore, are responsible for setting rules that govern fish harvest. In Brazil, resource management is done by the Brazilian Institute of the Environment. Policies of this agency are based on a scientific management model in which government **technocrats** and field agents design, implement, and enforce fisheries management regulations. Consequently, fishing agreements made by local communities were initially thought to have no legal validity because communities had no right to regulate local fisheries (McGrath et al. 2015).

"Common property" refers to the right to use something in common with others. However, after collapse of major fisheries, some planners began to lose faith in government regulation of fishing. As an alternative, Elinor Ostrom in *Governing the Commons* (1990) advocated for community-based management (or comanagement) approaches to manage the common property resources. Community-based management has the potential to overcome the tragedy of the commons. One flaw in the tragedy of the commons idea is that it ignores the social relations that characterize fishers throughout the world. Fishers are subject to social pressures that shape their behavior. Therefore, efforts to reduce illegal fishing should focus on establishing and enforcing sanctions for fishers who violate rules and regulations.

Top-down policies, often referred to as Decide-Announce-Defend (DAD), as noted earlier, too often lead to abandoned or ineffective policies. The DAD method is ***not*** suited for fisheries where a wide range of technical, social, cultural, and economic factors are influencing the fishing status and alternatives. Implementation of regulations involves a lot of people, and most are not in an obvious command structure (Prince 2003; Walker 2009). The alternative participatory approach is Engage-Deliberate-Decide (EDD). Here the fishers choose whether to cooperate in a process to deliberate among alternative management interventions. Traditional knowledge held by the fishers may play important roles in creating alternative approaches. The approach is sometimes referred to as "two-eyed seeing" (Reid et al. 2021). An early proponent of two-eyed seeing, Dr. Albert Marshall, describes two-eyed seeing as "learning to see from one eye with the strengths of Indigenous knowledges and ways of knowing, and from the other eye with the strengths of mainstream knowledges and ways of knowing, and to use both these eyes together, for the benefit of all." Whether or not comanagement regimes will prevent the tragedy of the commons depends on strong commitment from leadership to work with local stakeholders to develop and enforce quotas (Gutiérrez et al. 2011; McGrath et al. 2015; Campos-Silva et al. 2017).

Two-Eyed Seeing

"Two-eyed seeing" means that we will be learning to see from one eye with the strengths from indigenous knowledge and indigenous ways of knowing, while the other eye is using mainstream knowledge or Western ways of knowing. We use both of these ways of knowing (i.e., eyes) simultaneously. Hopefully, we're learning more in this way. With indigenous people, the knowledge is all about transforming the holder of that knowledge. And then that holder will bear a responsibility to act on knowledge. It's not a Western approach to knowledge where the knowledge is just put in a book for others to find. However, knowledge is there to be acted upon. Indigenous ways of knowing are more interconnected because it's the people who are learning and sharing. It's more holistic learning and occurs in many different ways. Indigenous knowledge is not hierarchically structured. For example, in Western scientific organizations, we have high-level scientists and low-level workers. In indigenous ways of knowing, everyone is fully engaged in the traditions and experience by which most indigenous people learn new things, whereas the Western ways of knowing are individualistic. We compartmentalize knowledge, especially as we develop scientific disciplines. Sociology, biology, physics, chemistry, and other sciences are part of the work in different laboratories. The science and technology disciplines are often male dominated, objective, and scientific. Ways of knowing in Western science are not necessarily better or worse, just different from the ways of knowing in indigenous societies.

Comanagement is an efficient management scheme across fishery types to avoid the tragedy of the commons. In comanagement, fishers collaborate with managers and scientists. Fishers enact their own management by self-regulating under the advice of scientists. Scientists and fishers work together in enacting the management. For many small-scale fisheries, comanagement can be the only way to manage fisheries where other more institutional form of controls are absent or ineffective. This is true in most tropical coastal and developing nations. To be successful, comanagement should (1) develop practices embedded locally, historically, and culturally; (2) focus on fishers; and (3) empower fishers in decision making (Castello et al. 2009). When expected benefits of managing a fishery exceed the perceived costs of investing in better rules and norms, most users and their leaders are likely to organize around a comanagement scheme. The following eight principles were developed to guide effective comanagement of *Arapaima* fishing (Ostrom 1990; Castello et al. 2009):

1. Boundaries of resources and users are clearly defined.
2. Rules are established to permit the resource to be exploited sustainably.
3. Collective action is functional.
4. Resources and behavior of fishers are monitored.
5. Rule offenders are sanctioned.
6. Conflict resolution mechanisms exist.
7. Central governments authorize and recognize comanagement arrangements.
8. Management tasks are organized and distributed at different institution levels.

In the case of managing harvests of the *Arapaima*, the native fishers of the community provide much of the management and enforcement, as government attempts to restrict fishing have been unsuccessful due to a lack of enforcement. From 1993 to 1995, only 30% of the harvested *Arapaima* were longer than the legal length limit (Castello et al. 2011). Efforts to engage the *Arapaima* fishers in an experimental management process began in the newly created Mamirauá Sustainable Development Reserve in 1998. Part of the reserve was zoned for sustainable use and allowed local people to harvest resources if rules were in place to assure sustainable harvest. The first challenge was to replace the view that native peoples of Amazonia were "backward" with an attitude of respect for their role in stewardship of the ecosystem. The second was to overcome the lack of data on *Arapaima* populations so that harvest quotas could be developed.

Comanagement began in four fishing communities in one area of the reserve. Here a counting method was developed so that experienced harpooners could accurately count surfacing *Arapaima* soon after dawn based on subtle visual and **aural** cues. The counts proved to be highly correlated with abundance estimates conducted by scientists (Castello 2004). *Arapaima* are relatively sedentary during the first hours after dawn, reducing the chance of those individuals being double counted (Campos-Silva et al. 2018). This counting method was ~200 times faster and less expensive than the marking and repeated capture method used by scientists. By counting numbers of *Arapaima* before the harvest season, fishers learned to self-manage populations. Briefly, annual counts made in lakes during the dry season were used to determine the harvest quotas for the next year (Figure 11.8). Mathematical analysis of *Arapaima* populations demonstrated that catch rates of about 25% of adults were likely to maximize the sustainable harvest (Castello et al. 2011). Government officials visited the fishers and the experimental management areas and were convinced that the management scheme was sound.

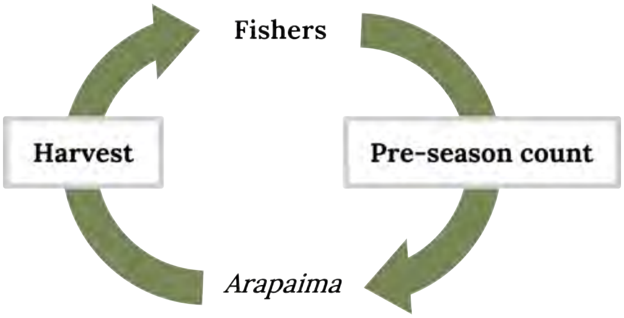

Figure 11.8: Integrating fishers who conduct counts of Arapaima prior to the fishing season in order to set harvest quotas.

The results of this first experiment with comanagement of *Arapaima* fishing were indisputable (Figure 11.9). The total population of *Arapaima* increased 9-fold, and the harvest quotas increased 10-fold within seven years. In addition, the number of fishers participating in management more than doubled, and the per capita income of fishers increased 8-fold (Viana et al. 2004; Castello et al. 2009). *Arapaima* fishers were more engaged in this new management scheme, and there were fewer violations of the newly formulated rules.

This type of comanagement scheme has proven successful in several different fishing communities that target *Arapaima*. For example, community-protected lakes in the western Brazilian Amazon had 33 times more *Arapaima* individuals than open-access lakes (Campos-Silva and Peres 2016). Similar responses to comanagement were observed elsewhere, leading to increases in the household income of *Arapaima* fishers (Oviedo et al. 2015, 2016; Petersen et al. 2016; Gurdak et al. 2019a; Watson et al. 2021; Gurdak et al. 2022). In addition, comanagement schemes resulted in time savings in fishing families, permitting more time for alternative pursuits, such as agriculture and cattle grazing (Schons et al. 2020). If the comanagement scheme could be implemented widely, the restored and well-managed *Arapaima* fisheries could yield as much as U.S. $30 million per year (Castello et al. 2011).

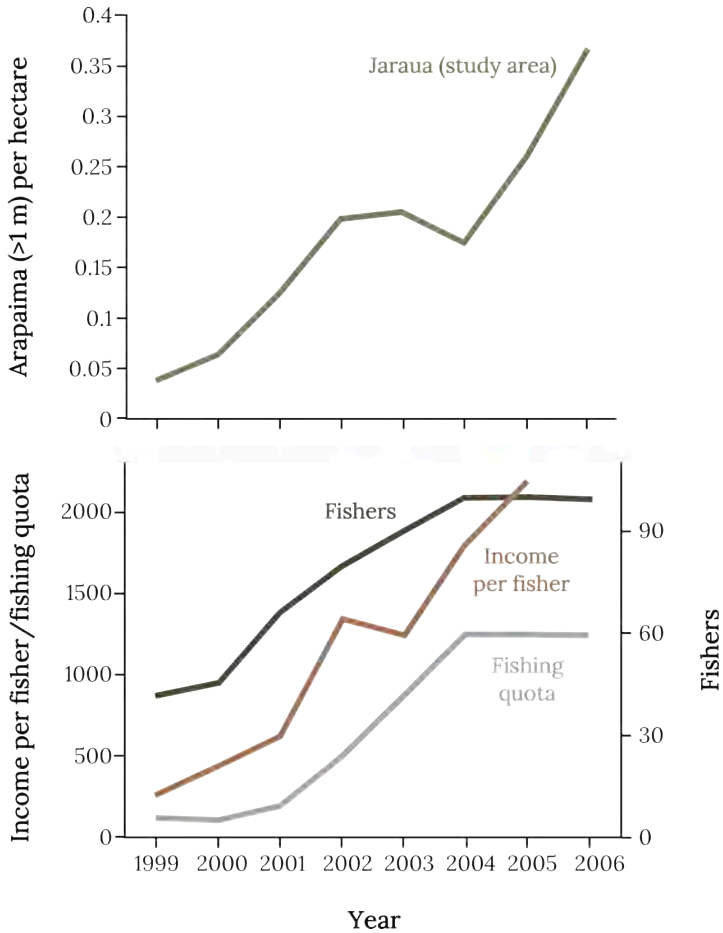

Figure 11.9: Responses of the Arapaima population, number of fishers, income per fisher, and fishing quota to the experimental comanagement process in the newly created Mamirauá Sustainable Development Reserve. [Long description](#).

Experiences with comanagement of *Arapaima* demonstrated the importance of bridging knowledge across stakeholders, such as inviting government officials to observe the monitoring practices. Also, the scheme would be ineffective if not for the melding of the unique skills fishers can offer in conducting fish counts with scientific knowledge to estimate allowable catch levels (Castello et al. 2011b). Comanagement of *Arapaima* fishing can promote a more just distribution of benefits while recognizing cultural and gender differences among fishers (Lopes et al. 2021). Incorporating Ostrom's design principles did increase the density of *Arapaima*, and future refinements should emphasize defining boundaries and formulating graduated sanctions for violators (Arantes et al. 2021).

Among the indigenous people, fishing and hunting are always done by males, whereas domestic tasks, such as getting water, gathering firewood, and childcare are principally performed by females (Meggers 1996). Processing of fish captured by males is a task done mostly by females. Because the most valuable catches are sold, *Arapaima* fishing provides one of the very few sources of income for females. After comanagement for *Arapaima* began, both men and women showed increased interest in participating in the local fishing association, and female income increased eightfold (Freitas et al. 2020).

Question to ponder:

What elements of comanagement of Arapaima do you think are most important for conservation?

11.7 Culture of *Arapaima*

Arapaima meat is in great demand because it is boneless, odorless, mild, low in fat content, and high in protein. Therefore, it demands a high price in the "gourmet" restaurant market. International market price is U.S. $20–25 per kilogram in Europe and the United States and $12–15 per kilogram in South American cities (FAO 2022). *Arapaima* are also pet traded in Europe, North America, South America, and Asia. Demand for juvenile *Arapaima* as ornamental fish is also high, partly because as obligate air breathers they tolerate hypoxic (low levels of dissolved oxygen) water uninhabitable by other fish (Ohs et al. 2021). As *Arapaima* were supplied to ornamental fish breeders in other countries, some escaped and established populations in Java and Sumatra in Indonesia (Marková et al. 2020). While threatened in its native range, the *Arapaima* populations elsewhere have spread rapidly and become invasive. This phenomenon is called the "biodiversity conservation paradox"—species at risk in their native range are abundant in other settings.

Aquaculture of *Arapaima* for food has been nonintensive and generally conducted in ponds or in net cages in reservoirs (dos Santos et al. 2014). The production cycle begins when breeding size fish are allowed to breed in ponds and offspring are stocked in tanks, net cages, or ponds and fed pellets. A major barrier to successful aquaculture of *Arapaima* is the production of a sufficient number of juveniles for stocking. Fry survival is high only in the early months of the flooding season (Núñez et al. 2011). Closed recirculating aquaculture systems show promise for increasing survival of fry and juveniles (Burton et al. 2016). Within 14 months after egg hatching, *Arapaima* attain a marketable size of 10–15 kg (22–33 pounds) and 110–120 cm (43–47 inches) (Núñez 2012; Ohs et al. 2021).

Brazil has invested in rapid expansion of new aquaculture facilities in public waters (Lima-Junior et al. 2018). However, poor aquaculture management practices and aquaculture of nonnatives and water use conflicts are troubling in this megadiverse region. Government support for aquaculture has decreased in the past decade (Nobile et al. 2020). Revised laws that foster aquaculture have encouraged farmers to raise tilapia and other nonnative fish without containment systems to prevent escapes (Padial et al. 2017).

Arapaima culture operations are still in the early phase of development, and many challenges remain. Aquaculture production in Brazil is based largely on nonnative species (Lima et al. 2018). As many as 501 nonnative species have been imported for the ornamental trade. Native species, such as *Arapaima*, have great, unrealized potential to contribute to food security and poverty reduction, if integrated with national and local development plans for biodiversity protection (Schaefer et al. 2012). Aquaculture production of *Arapaima* is still relatively low compared to the potential and represents about 6% of total farmed fish production in Brazil (Nobile et al. 2020). Exports of farmed *Arapaima* are sold in high-end supermarkets, such as Whole Foods Market®, which uses a "Responsibly Farmed" logo to promote farmed *Arapaima*.

Question to ponder:

What concerns would you have about culture of nonnative fish species in Brazil's aquaculture industry?

11.8 Fly-Fishing Tourism Targeting *Arapaima*

Sportfishing for *Arapaima* is not a part of local indigenous culture. Yet, *Arapaima* are already providing benefits from ecotourism, such as fish watching and catch-and-release sportfishing in the Rewa and Rupununi rivers of Guyana. Approximately 89% of *Arapaima* caught by fly-fishing survived release (Lennox et al. 2018). Obligatory air-breathing habits of *Arapaima* mean that fishing guides must always hold fish at the surface, enabling fish to access air for three or four breaths (typically) prior to release. Adopting similar comanagement principles, some indigenous peoples have developed ecotourism lodges, which cater to foreign visitors and provide employment and income to indigenous communities. This approach promotes support for local culture and local ecosystems while permitting sustainable tourism. Use of traditional ecological knowledge to develop tourism based on nature and recreational fishing represents an innovative approach to economic development in rural parts of Amazonia. Here the local people serve as fishing guides, and fly-fishing and catch-and-release practices assure that released *Arapaima* will survive. This type of nature tourism is likely to increase in popularity and participation in Guyana, where the *Arapaima* is protected by national legislation but recreational fishing is still permitted. The hope of conservationists is that recreational fishing will encourage anglers to support *Arapaima* conservation via protection of habitats, river-floodplain connections, and avoiding illegal trade.

Profile in Fish Conservation: Leandro Castello, PhD

Scan the QR code or visit https://doi.org/10.21061/fishandconservation to listen to this Profile in Fish Conservation.

Leandro Castello, is Associate Professor of Fish Conservation at Virginia Tech. He is from Brazil, and from an early age he loved to be in or near the water and wanted to work in a field that explored the roles of fish and fishing in aquatic ecosystems. His early exposure to fish showed him there were other worlds to explore. When diving, he loved the feeling of being underwater, where fish and other aquatic life often move slowly and make many sounds in this foreign world.

Figure 11.10: Leandro Castello, PhD.

Castello began to study *Arapaima* after the Mamirauá Sustainable Development Reserve was established. Here he developed a keen eye for seeing the big picture and making connections among different elements in the social and ecological parts of the region. In fisheries and fish conservation, too often people focus exclusively on the fish and ignore the connections between fish and people and the ecosystems that sustain them both.

Dr. Castello worked directly with local fishers to observe their fishing techniques and assist in training to determine if fishers could accurately count *Arapaima* before harvest season to derive a harvest quota. His collaborations with local *Arapaima* fishers led to the first evaluation of community-based management of *Arapaima* fishing. The initial findings from his and other evaluations of *Arapaima* comanagement have achieved remarkable social and ecological outcomes. As a result, poverty has been alleviated in many rural communities of Amazonia, as fishing benefits can now be sustained.

He has also studied the migration habits of *Arapaima*, which required many hours searching for tagged *Arapaima*. In doing so, he noticed the curiosity of *Arapaima*, as they would approach the canoe and watch what he and his field partners were doing. He also witnessed the learning capabilities in *Arapaima*. These fish prove to be very difficult to capture with seine nets. When corralled in a net, they either bury their bodies in bottom muds or jump over the seine net. Efforts to culture *Arapaima* have provided other opportunities to observe their habituation and social learning.

Translating scientific knowledge into workable policies and practices will serve to facilitate conservation in the face of the major environmental challenges of our times. Castello's developing body of research and outreach addresses the gap between science and policy. This "science-policy gap" is often considered in negative terms, thereby increasing anxiety among early career scientists seeking to influence policy. Through persistence in efforts to develop trusted relationships needed for participatory management, he has pioneered joint learning and reflection among stakeholders. Along with many collaborators, Castello has successfully influenced policy and practices in Amazonia, and the effects of comanagement of *Arapaima* fishing provide others with a sense of optimism. His influential studies of tropical, small-scale fisheries provide many lessons to apply to conservation and restoration of exploited fisheries. The small-scale fisheries he studies are extremely neglected by most scientists, society, and governments. Yet, these complex systems are filled with mysteries yet to be fully understood.

Leandro Castello teaches courses in fisheries techniques and systems ecology in conservation. He works diligently to instill a sense of service in his students. Consequently, his students and colleagues are making a difference in promoting better approaches to conservation. In addition to managing to prevent overharvest, his research has demonstrated the need for increased protection of floodplain forests to benefit food, income, and livelihood of local fishing. These advances made by Castello and his colleagues come at a time when environmental policies in Brazil are unfriendly to environmental protection and push for more mining, hydropower development, deforestation, and agribusiness. His research and writings provide a framework for reversing unprecedented degradation of freshwater ecosystems in the Amazon basin.

Leandro recognizes the many connections between existing and proposed hydropower dams and ongoing land cover changes and climatic shifts. For example, with other world-renowned scientists, he provided advice for balancing the need for hydropower with biodiversity conservation in some of the largest and most threatened rivers of the world. He and his scientific colleagues called for mitigation of environmental impacts from human developments in the Amazon, Congo, and Mekong rivers. These three river basins hold roughly one-third of the world's freshwater fish species, most of which are not found anywhere else. Consequently, the siting of future hydropower dams will be critically important for conserving biodiversity. Many other fish that feed and sustain us, such as less charismatic forage fish (often smelly and slimy), need more attention by scientists and conservationists. The strong role of hatcheries in fish conservation and management is a North

American legacy. However, in most other parts of the world, fish provide subsistence and a means for a livelihood and poverty reduction.

Key Takeaways

- *Arapaima* comprise a prime example of a threatened freshwater megafauna (i.e., animals ≥ 30 kg) for which conservation status evaluations are needed.
- *Arapaima* are highly vulnerable to overfishing due to obligate air breathing, large size, and high-quality meat.
- *Arapaima* prefer large floodplain lakes with abundant macrophytes for spawning and juveniles.
- Obligate air breathing means that *Arapaima* must surface every 5 to 15 minutes to gulp air, thereby exposing themselves to specialist harpoon fishers.
- With appropriate training, fishers' participation in management processes can contribute to the conservation of small-scale fisheries.
- *Arapaima* represent a culturally important, symbolic flagship genus that serves to support floodplain management and conservation.
- Illegal harvest and overfishing greatly reduce the economic returns from *Arapaima*, often leading to their local extirpation.
- Including local stakeholders in conservation planning of Amazonian floodplains leads to restoration of *Arapaima* populations while alleviating poverty among fisherfolk.
- Involvement of indigenous communities in management is a significant step (two-eyed seeing) toward sustainable fisheries that should continue to be promoted.

This chapter was reviewed by Leandro Castello.

Long Descriptions

Figure 11.3: 1) Deforestation impacts uplands and wetlands, which impacts water chemistry and food chain; 2) dams impact dams and waterways, which impact hydrological alteration; 3) pollution impacts nutrients and toxins, mercury, and oil and gas, which impacts water chemistry and food chain; 4) overharvesting impacts wetland logging and exploitation of animals, which impacts food chain alteration. Jump back to Figure 11.3.

Figure 11.4: Life cycle of arapaima divided into four main stages: 1) nest-bound embryo and sac fry (~7 days); 2) adult-protected, schooling juveniles up to age 6 months); 3) independent juveniles (up to age 3-4 years); 4) reproductive adult (aged 3-4 years or more). Jump back to Figure 11.4.

Figure 11.5: Growth of juvenile arapaima rises substantially during the dry season with a growth of 1 kg/month and heightened growth continues into the wet season. Jump back to Figure 11.5.

Figure 11.6: Two length frequency distributions contrasting fished and unfished arapaima populations. Length of fished arapaima reach their maximum frequency before unfished arapaima. Jump back to Figure 11.6.

Figure 11.9: Top graph: x-axis shows year, y-axis shows arapaima (>1 m) per hectare. Jaraua (study area) increases consistently, with a decrease from 2003-2004. Bottom graph: x-axis shows year, y-axis shows income per fisher/fishing quota. Fishers, fishing quota, and income per fisher all increase. Income per fisher decreases from 2002-2003 and passes fishers in 2005. Jump back to Figure 11.9.

Figure References

Figure 11.1: Indigenous and *ribeirinho* people travel on rivers of Brazil in a *voadeira*, a motorized canoe. Fernando C. C. Castro, 2020. CC BY-SA 4.0. https://commons.wikimedia.org/wiki/File:Parque_Nacional_de_Anavilhanas_Fernando_Carvalheiro_Coelho_Castro_(01).jpg.

Figure 11.2: *Arapaima gigas* displayed in the Siam Centre, Bangkok. Bjoertvedt, 2009. CC BY-SA 3.0. https://commons.wikimedia.org/wiki/File:Arapaima_gigas_01.JPG.

Figure 11.3: Schematic diagram of the main drivers influencing freshwater ecosystems in the Amazon. Kindred Grey, 2022. Adapted under fair use from The Vulnerability of Amazon Freshwater Ecosystems, by Castello et al., 2012. https://doi.org/10.1111/conl.12008.

Figure 11.4: The generalized life cycle of the *Arapaima* can be divided into four main stages: (1) nest-bound embryo and sac fry, (2) adult-protected, schooling juveniles, (3) independent juveniles, and (4) reproductive adults. Kindred Grey, 2022. CC BY 4.0. Adapted under fair use from Evidence of Recoveries from Tropical Floodplain Fisheries: Three Examples of Management Gains for South American Giant *Arapaima*, by Gurdak et. al., 2019. https://doi.org/10.47886/9781934874554.ch11. Includes *Arapaima gigas*, by Lankester Edwin Ray, 1908, public domain. https://commons.wikimedia.org/wiki/File:Arapaima_gigas1.jpg.

Figure 11.5: Juvenile *Arapaima* exhibit the fastest growth recorded in fish, reaching 15 kg or larger within the first year. Kindred Grey, 2022. CC BY 4.0. Data from Seasonality Influence on Biochemical and Hematological Indicators of Stress and Growth of Pirarucu (*Arapaima gigas*), an Amazonian Air-Breathing Fish, by Bezerra et. al., 2014. CC BY 3.0. https://doi.org/10.1155/2014/541278. Includes *Arapaima gigas*, by Lankester Edwin Ray, 1908, public domain. https://commons.wikimedia.org/wiki/File:Arapaima_gigas1.jpg.

Figure 11.6: Theoretical length frequency for unfished (top) and fished (bottom) populations of *Arapaima*. Kindred Grey, 2022. CC BY 4.0. Includes *Arapaima gigas*, by Lankester Edwin Ray, 1908, public domain. https://commons.wikimedia.org/wiki/File:Arapaima_gigas1.jpg.

Figure 11.7: Boots made from *Arapaima* leather, by Lucchese Boots, advertised on U.S. eBay website. Heinrich et. al., 2019. CC BY 4.0. https://doi.org/10.1111/csp2.75.

Figure 11.8: Integrating fishers who conduct counts of *Arapaima* prior to the fishing season in order to set harvest quotas. Kindred Grey, 2022. CC BY 4.0.

Figure 11.9: Responses of the *Arapaima* population, number of fishers, income per fisher, and fishing quota to the experimental comanagement process in the newly created Mamirauá Sustainable Development Reserve. Kindred Grey, 2022. CC BY 4.0. Data from Lessons from Integrating Fishers of *Arapaima* in Small-Scale Fisheries Management at the Mamirauá Reserve, Amazon, by Castello et. al., 2008. https://doi.org/10.1007/s00267-008-9220-5.

Figure 11.10: Leandro Castello, PhD. Used with permission from Leandro Castello. Photo by Jorge Pablo Castello. CC BY 4.0.

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12. Conserving Tuna: The Most Commercially Valuable Fish on Earth

Learning Objectives

- Describe the adaptive significance of biological characteristics of tuna.
- Describe how migratory patterns complicate tuna conservation.
- Summarize major historical changes in tuna fishing.
- Recognize and name the most common commercial tuna species of the world.
- Describe key elements of supply chains for industrial tuna fishing.
- Understand how national sovereignty influences international fisheries management.
- Relate current trends to future sustainability of tuna fisheries.

12.1 What's Special about Tuna?

Tuna are highly adapted for life in the open ocean. Their streamlined bodies, built for speed and endurance, make long-distance migrations possible. In fact, the name "tuna" comes from the Greek *thunnos*, derived from the verb *thuo*, which means "to dart" or "to rush." One cannot help but be mesmerized when watching tuna swimming—an experience hard to come by. Only a few public aquariums have exhibits large enough for the largest tuna. Divers swim with Bluefin Tuna in floating cages in Australia and Malta. Carl Safina, one writer who swims with tuna, described the Bluefin Tuna as "half a ton of laminated muscle rocketing through the sea as fast as you drive your automobile" (Ellis 2008).

Tuna regulate their core body temperature with specialized circulation near their swimming muscles, a condition known as *heterothermy*. Bluefin Tuna can elevate their core body temperature up to 20°C above surrounding ocean temperature to enhance swimming efficiency. The swimming mode of tuna involves high-frequency tail beats (1–2 Hz) with a stiff tail fin and extra-long tendons that connect the large muscles directly to the tail fin. Other metabolic adaptations lead to capacities exceeding those of other fish, such as an increased heart size, large gill surface area, high blood oxygen–carrying capacity, and elevated **hematocrit**. When speed is required, the tuna switches into high-speed mode: large dorsal and ventral fins retract into cavities, while the pectoral fins are pressed flat against the body. Consequently, tuna are among the fastest-swimming fish.

Heterothermy also allows tuna to migrate into cold waters to follow abundant prey fish. Bluefin Tuna swim in both subtropical oceans and cold seas. Tuna are also known for remarkable daytime vertical migrations to find abundant prey in deeper and colder waters. They migrate from spawning grounds to feeding grounds that may be separated by over 5,000 miles. Therefore, the tuna cross country borders, which makes drawing boundaries around populations nearly impossible. Arrival of tuna near coastal regions is predictable, and communities hold celebrations, festivals, and fishing tournaments when they arrive. Managing tuna is hard because they travel between many different jurisdictions.

The larger tuna species have long been targets of game fish enthusiasts, such as authors Ernest Hemingway and Zane Grey. Ernest Hemingway wrote, "It is a back-sickening, sinew-straining, man-sized job even with a rod that looks like a hoe handle." Hemingway and Grey wrote extensively about big-game fishing, thereby bringing awareness of these awesome yet hidden creatures. Sportfishing for large tuna was a transformational experience. Hemingway wrote, "But if you land a big tuna . . . and finally bring him up alongside the boat, green-blue and silver in the lazy ocean, you will be purified and will be able to enter unabashed into the presence of the very elder gods and they will make you welcome" (Hemingway 1922).

Current controversies about tuna relate to our relationship with them. For centuries, these fish have been an important ocean commodity. Today, tuna are an emblem of globalization—they swim across the globe, crossing boundaries of many countries that claim an interest in their harvest. Trade in tuna products has transformed the world into a more connected and interdependent place. At the same time, tuna (*Thunnus* spp.) have become a charismatic flagship genus to raise awareness of global conservation issues. Managing tuna fisheries involves substantial coordination among regional and international commissions and organizations that represent at least 48 countries. In 2017, the United Nations set May 2nd as World Tuna Day to focus on conserving the world's tuna. The story of fishing for tuna from prehistory to today's globalized society should prompt us to reflect on how a sustainable global economy based on tuna fishing should proceed.

12.2 Tuna of the World

Tuna are part of a large, diverse family of epipelagic (i.e., near-surface) dwellers. The ancestral fish that gave rise to these specialized fish was a deep-ocean dweller that lived and survived the Cretaceous-Paleogene mass extinction event, which eliminated approximately 80 percent of all species of animals about 66 million years ago (Miya et al. 2013). This deep-ocean dweller did not resemble tuna. The unique tuna traits did not appear in fish until the first tuna-like fish emerged about 40–50 million years ago.

Tuna are most closely related to mackerels and billfish, such as swordfish and marlins. They are members of the family Scombridae, which includes mackerels, tuna, Wahoos, and bonito (Collett and Graves 2019). There are 51 species of Scombridae, many of which are important and familiar food fish. Mackerels and tuna support very important commercial and recreational fisheries, as well as substantial artisanal fisheries throughout the tropical and temperate oceans.

All species in the family are specialized fast-swimming predators, often called the high-performance sports cars of the fish world. Their bodies show off swimming adaptations. Drag is reduced by their fusiform body shape, smooth skin made up of tiny cycloid scales, a crescent-shaped caudal fin, body depressions for tucking in their pectoral fins, finlets behind the rear dorsal fin and anal fin, and lateral keel on each side of the tail fin (Figure 12.1). The caudal fin is stiff without flexible fin rays. The keel provides greater area for attachment of ligaments that connect the huge muscle mass to the tail fin. Tuna provided inspiration for engineers interested in designing of autonomous underwater vehicles. A robotic swimming tuna, RoboTuna, was created by a doctoral student at Massachusetts Institute of Technology in 1995 to mimic the tuna's highly efficient propulsion. The earliest versions of the RoboTuna were not able to replicate the bursts of acceleration observed in real tuna.

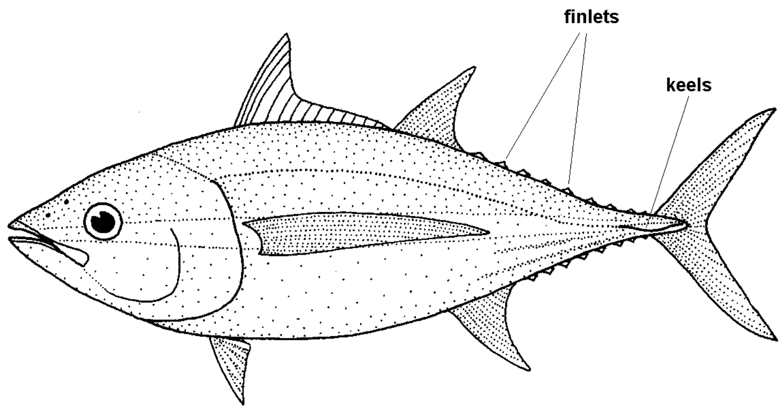

Figure 12.1: Body form of the Bigeye Tuna (Thunnus obesus) showing fins, finlets, and keels. Finlets are found between the last dorsal and/or anal fin and the caudal fin.

All of the 7 species of bonito and 15 species of tuna are harvested. Fishery statistics do not identify them all to species. Seven species of tuna dominate the global landings and values as they enter international trade as fresh, frozen, and canned products:

- Albacore (*Thunnus alalunga*)
- Atlantic Bluefin Tuna (*Thunnus thynnus*)
- Pacific Bluefin Tuna (*Thunnus orientalis*)
- Southern Bluefin Tuna (*Thunnus maccoyii*)
- Bigeye Tuna (*Thunnus obesus*)
- Yellowfin Tuna (*Thunnus albacares*)
- Skipjack Tuna (*Katsuwanus pelamis*)

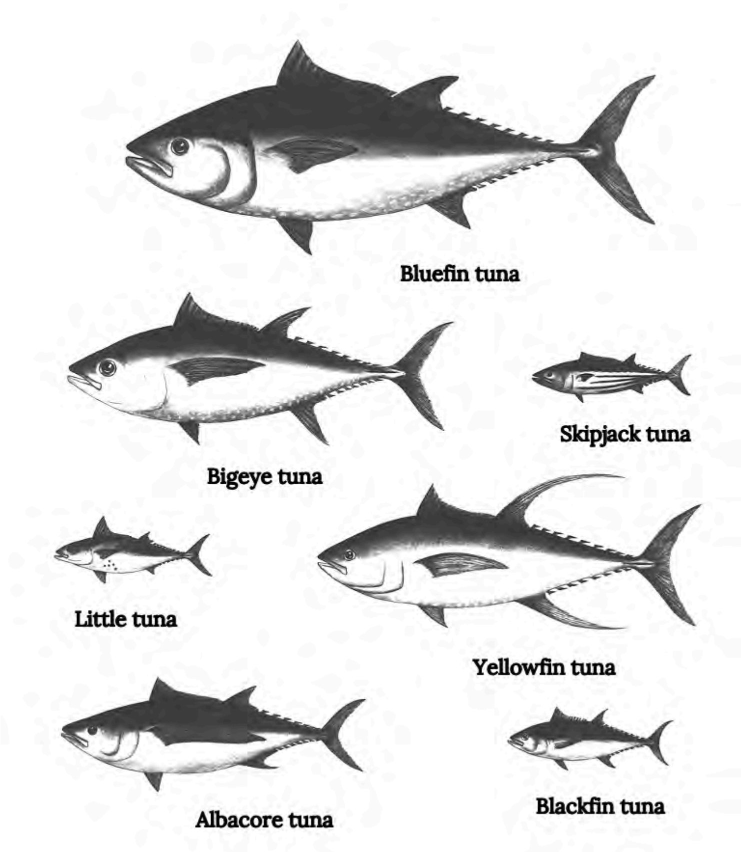

Figure 12.2: Relative sizes of seven common tuna, with the Atlantic Bluefin Tuna (top) at about 8 ft (2.4 m) in this illustration. Long description.

The largest species are Bluefin Tunas. Atlantic and Pacific Bluefin Tuna have a maximum recorded weight of 685 kilograms (1,510 pounds). The size of a species is related to the type of commodity the fish supports—namely sushi, loins, or canned (Figure 12.2.). At least three-quarters of all tuna landed is canned, and most of this is Skipjack, Yellowfin, and Albacore. Skipjack Tuna is the most caught species by number and weight, representing more than half of the global volume of tuna harvested (McKinney et al. 2020). Skipjack Tuna is marketed as “light” or “chunk light” tuna. Albacore is the most expensive canned tuna, marketed as “white” meat tuna. Large Bluefin Tuna and Bigeye Tuna are “red” meat tuna and are priced substantially higher because they are destined for sashimi and sushi markets, where they sell for $45 to $55 per pound. Bigeye Tuna and Yellowfin Tuna are known locally in Hawaii and in fish markets as ahi. Other tuna, such as the Little Tunny (*Euthynnus alleteratus*) and Blackfin Tuna (*Thunnus atlanticus*), are less important in global trade but are incredibly important to coastal artisanal and subsistence fisheries.

Water temperature preferences of tuna broadly predict their distribution on a global scale (Boyce et al. 2008). Bluefin Tuna, Bigeye Tuna, and Albacore have the widest temperature preferences and are found in waters as cold as 10°C. Skipjack and Yellowfin Tuna are tropical tuna and most abundant in waters with temperatures greater than 18°C. Consequently, the number of tuna species encountered by fisheries is highest in the largest and warmest ocean, the Pacific.

12.3 Historical Roots of Tuna Fishing

Tuna fishing is one of the oldest marine fishing traditions, often traced back 12,000 years. Other evidence confirms that indigenous people were tuna fishing off the northern Australian coast 42,000 years ago (O'Connor et al. 2011). Neanderthals knew that giant tuna moved through the Strait of Gibraltar every spring on their way to spawning grounds and in summer as they leave the Mediterranean. Tuna were followed by Orcas (*Orcinus orca*), whose breaching behavior revealed their locations. Orcas ambushed the migrating giant tuna as they swam the narrow channel at Gibraltar. Neanderthals caught Bluefin Tuna that beached themselves while trying to escape the Orcas (Adolf 2019). Extinction of the Neanderthals about 40,000 years ago corresponds to the arrival of *Homo sapiens* in Africa, who continued to exploit tuna as a food source.

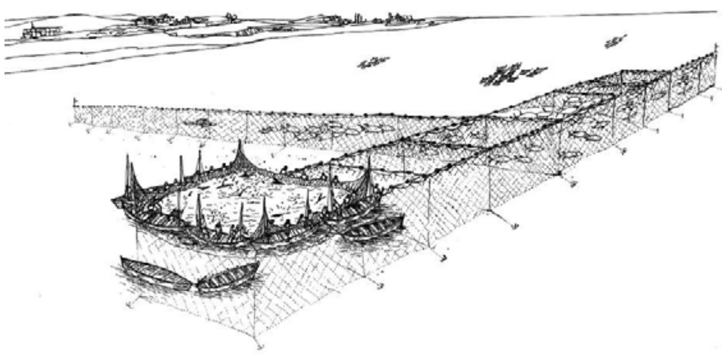

Figure 12.3: Tuna trap affixed to the sea bottom showing the long lead net to intercept migrating tuna and several chambers.

As visual predators, tuna choose to migrate along the shallower waters along the coast where they find more abundant prey. Consequently, early fishers learned of the predictable journeys and built large traps fixed to the seabed. The term for tuna fishing is *almadraba* in Spain, *tonnare* in Italy, and *madrague* in France. This technique uses a maze of nets, anchored to the seabed, to catch tuna as they follow their migratory route (Figure 12.3). Once tuna are trapped in the central chamber, fishers would lift the net to the surface to harvest them. Some brave fishers even jump in the tuna-filled net to harpoon and attach ropes to the tail of each fish so that they can be lifted from the water. The trap fishing methods were described in ancient Greek and Roman literature from 1500 BC (Vargas and Corral 2007), and they are the oldest form of industrial fishing in the world. Catching a large shoal of tuna in such traps results in enormous profit.

Tuna was the first fish in human history to be captured, processed, and sold on a large industrial scale. The ancient civilization of Phoenicia (1550 BCE to 300 BCE) became prosperous because they were adept in maritime arts and shipbuilding, thereby permitting trade with ancient Greeks and other settlements in the Mediterranean. Phoenicians first began an industry based on catching, preserving, and trading tuna in the Mediterranean. The ancient Greeks, like the Japanese today, showed preference for the fatty belly cuts. The Phoenicians also invented a salting technique to conserve large quantities for trade to distant markets. Garum, a liquid fish extract derived from aging a mix of the entrails of tuna with salt water, became and remains an exclusive delicacy. Tuna trade grew from a small-scale consumption to massive trade by the sixth century BCE. Industrial fishing for tuna has expanded and persisted through the turmoil of wars, from the Punic Wars and the Fall of the Roman Empire in the Mediterranean to World War II, when the United States deployed tuna clipper ships as minesweepers.

The Roman legal concept of *res communis* meant that coastal fishing grounds were initially open to all. Phoenicians brought large-scale tuna fishing from the east to the west of the Mediterranean. Throughout the various shifts in ruling dynasties in Mediterranean countries, these fisheries persisted. During the Middle Ages (approximately from the 5th to the late 15th centuries), tuna fishing enriched the fortunes of Spanish dukes, who held a fishing monopoly along Spain's southern coast.

After the Spanish Armada was defeated by the English navy in 1588, tuna catches dramatically decreased, and demand for the fish plummeted as continuing wars complicated trade. Many signs were emerging of local declines in Bluefin Tuna, which may represent the first documented fisheries collapse. In the 18th century, a monk, Brother Martín Sarmiento, referred to as the Tuna Saint, researched and wrote the first scientific study on sustainable tuna management. In the study, he warned of the decline in Bluefin Tuna and began to promote sustainable fishing, advocating for closed season and a ban on tuna fishing in the ocean. Spain had and still has the largest fishing fleet in Europe and the biggest industry for canning tuna. Tuna fisheries were on the verge of collapse as more and more *almadrabas* were discontinued. No one before Sarmiento had warned that overfishing was the cause of the tuna crisis. Warnings of the so-called Tuna Saint against fishing during the breeding season despite a ban were not effective at reducing fishing capacity.

The Tuna Saint's recommendations to the duke to create catch quotas and enforce measures to protect the juvenile tuna were not accepted. Lack of regulation continued through the 19th century because of prevailing views that ocean fisheries were inexhaustible. In 1883, eminent scientist Thomas Henry Huxley declared that "Probably all the great sea fisheries are inexhaustible; that is to say, that nothing we do seriously affects the numbers of fish. Any attempt to regulate these fisheries seems consequently, from the nature of the case, to be useless." The combined effects of fishing based on short-term profits and the increased availability of herring, cod, and salmon brought competition that doomed the giant tuna fisheries.

Despite their journeys back and forth the tuna . . . cannot avoid being eaten by larger fish, and especially by man.

—Brother Martín Sarmiento (1757)

Purse seines and longlines replaced beach seines and traps when tuna fishing effort expanded into the Atlantic Ocean. Japanese fisheries also expanded largely through pole and line fishing. Although canning methods were invented in the early 19th century, tuna were not canned until 1904, many decades after sardine, mackerel, herring, and salmon canneries became commonplace. Canning assured the consumer of a healthy protein that would keep a long time. The advent of canning and the wide distribution of tuna from tropical to subtropical oceans meant that people around the world and far from coastal areas became familiar with it. The rising demand for canned tuna at the start of the 20th century led to an expansion of the industrial fishing fleets, construction of many canneries, and control of prices by traders in the newly formed supply chain that exists to this day.

The labor-intensive *almadrabas* might have disappeared if not for the emerging demand in Japan for high quality Bluefin Tuna. During the 1960s, Bluefin Tuna were considered an undesirable food fish. Sport anglers caught them and sold them for cat food. Fishmongers would throw away the fatty belly meat. A restauranteur arranged to buy these for his sushi restaurant in Little Tokyo, Los Angeles. Japanese businessmen introduced American businessmen to sushi, and Hollywood, Chicago, and New York embraced sushi. Soon sushi restaurants were everywhere and sushi-quality tuna was in high demand. Improvements in freezing methods meant that tuna from around the world could be air shipped to Japan's largest fish market, the Tsukiji Market. Japan Airlines would deliver electronics, cameras, and textiles to airports in eastern North America and return to Tokyo with crates of frozen Atlantic Bluefin Tuna.

Figure 12.4: Photo of Yellowfin Tuna caught in the Seychelles.

Today, purse seines are the dominant gear used to target tuna, which form large, dense schools. The schools can be surrounded by a vertical net, after which the bottom of the net is drawn together to enclose the fish like tightening cords on a drawstring purse. Purse seines permit large catches of a single species, such as Yellowfin Tuna (Figure 1.3; Figure 12.4). Today, the demand for tuna has never been higher, and the largest super seining fishing vessel, the Albatun Tres, can net 3,000 tonnes in a single trip. As discussed in the following section, tuna fishing is highly industrialized and profit driven, depending on a complex, widespread supply chain.

12.4 Industrial Fishing, Supply Chains, and Status of the World's Tuna

Tuna support the world's largest global seafood companies. Commercial fisheries alone produced $40.8 billion in sales in 2018, making tuna the most valuable commercial fish on the planet. Other values include subsistence fisheries, sport fisheries, unreported catch, and ecosystem benefits. Tuna is the second-most-consumed seafood in the United States behind shrimp, and the second-most-eaten fish in Britain, behind salmon. Projected increased seafood demand in China will further complicate its management (Crona et al. 2020). Keeping tuna as an affordable seafood product requires accurate information about the supply chain. The tuna supply chain encompasses all the activities required to get a business's products to consumers, from catching, transfer to processors, transport to distributors, retailers and, finally, to consumers. It begins with the fishing boats and ends when the final product is sold to consumers far from the site of capture (Figure 12.5). An efficient supply chain saves money and helps processors and retailers produce and transport only what they can sell. Much of the tuna catch is exported from the country of origin, and the supply chain must be coordinated with regulations imposed by governments and regional fisheries management organizations (Kresna et al. 2017; Mullon et al. 2017).

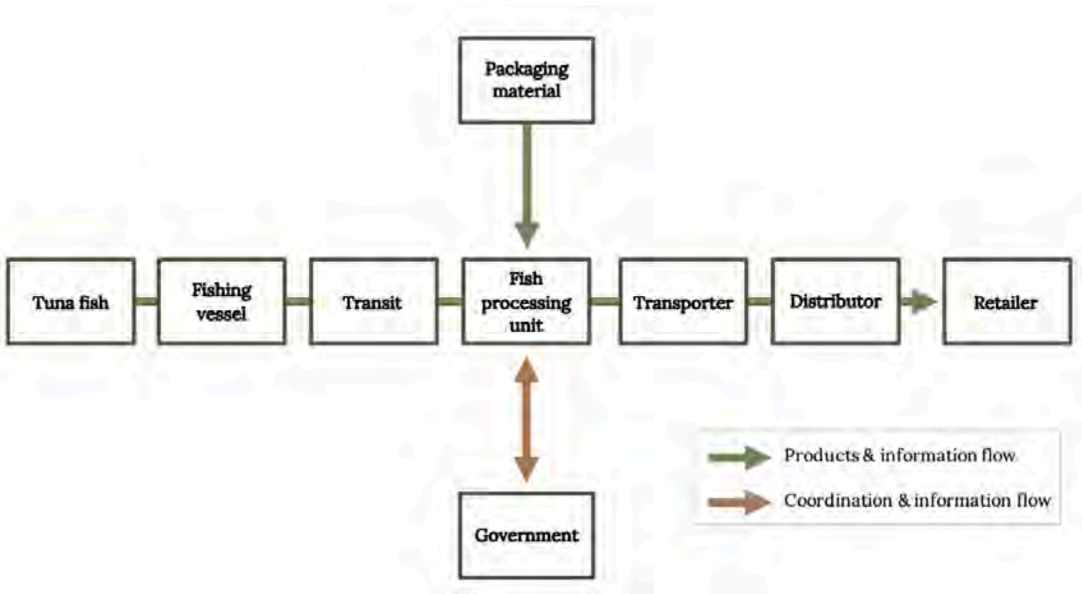

Figure 12.5: Representation of the flow of products, information, and coordination in the tuna supply chain. [Long description](#).

Three main distribution channels for captured tuna include (1) fresh fish landings to processing facilities from fishing vessels or carrier boats; (2) frozen fish landings directly from fishing vessels; and (3) frozen fish **transshipped** from fishing vessels onto carrier vessels and then to canneries. Because the tuna purchased in your local restaurant or fish market could originate halfway across the globe, consumers may be unaware of how and where it was captured. The long and complex supply chain makes it challenging to guarantee that the tuna on your plate is really the one that it is supposed to be. Furthermore, financial interests of distributors all serve to deprive actual fishers of profits while enriching middlemen and distributors. Consumers have many questions that are often difficult to answer. How can we ensure that the tuna we buy is slavery free? Do fishers have safe working conditions and fair pay? Were the fish captured with minimal bycatch of threatened species? Is the fishery managed sustainably? One tool to ensure the standard safety and quality is the traceability database system along the supply chain. It is very crucial, because every actor in the chain has a responsibility to ensure food safety and quality through handling, manufacturing, packaging, and transporting the product. Additionally, major tuna-consuming countries are adopting import controls to permit traceability of illegal, unreported, unregulated fishing and to support sustainability certification.

Tuna are highly migratory; therefore, a global and interconnected framework of organizations and policies is in place for managing stocks around the world. Commercial tuna fishing occurs in all the world's oceans and more than 70 countries. At least 580 industrial-scale tuna purse seine vessels are in operation globally (Hamilton et al. 2011). The largest companies, including Bumble Bee®, Chicken of the Sea®, and StarKist®, are pressured by consumers to adopt principles of responsible and sustainable fishing while keeping prices competitive. The global canned tuna market alone was valued at U.S. $8.57 billion in 2020 and is expected to grow up to $12.5 billion by 2028 (Grand View Research 2020).

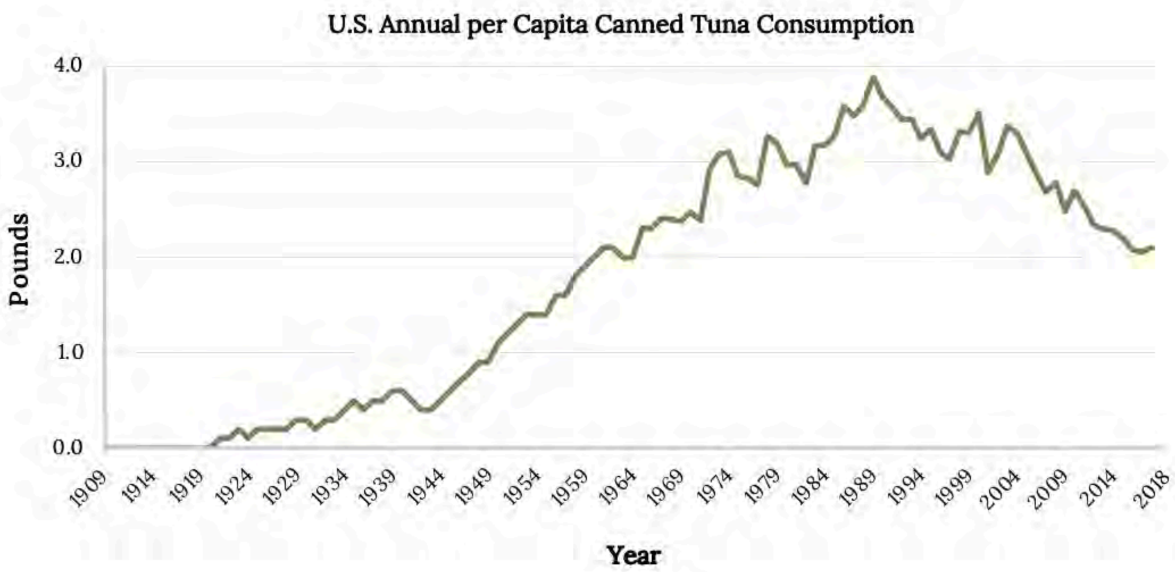

Figure 12.6: Trend in per capita consumption of canned tuna in the United States.

The trend in per capita consumption of canned tuna in the United States (Figure 12.6) shows a steady rise before, during, and after World War II, when the tuna industry touted the fish's health benefits and claimed that it tasted like chicken. By 1950, it had overtaken salmon as America's most popular fish. Charlie the Tuna was a cartoon character created in 1961 to advertise StarKist® tuna. Charlie resembled the beatnik of the day, with a beret to show his hip, cultured tastes (Figure 12.7). The popular catch phrase was, "Sorry Charlie, StarKist doesn't want tuna with good taste, but tuna that tastes good!" Consumption peaked at nearly 4 pounds per person in 1989, when Americans consumed between half to two-thirds of the global supply of canned tuna. Clearly, decades of advertising, such as Charlie the Tuna, worked on American consumers. However, since the peak, consumption has fallen by half. One reason for this recent and substantial decline is changing consumer preferences for convenience foods. Additionally, consumer concerns over the killing of dolphins may have played a role.

Dolphin-safe labeling began in the United States, in response to consumer reactions to dolphins killed in purse seines. Commercial tuna fisheries in the tropical oceans began to catch Yellowfin Tuna by spotting large aggregations of dolphins and seabirds associated with shoals of tuna and encircling them with purse-seine nets. These dolphin sets deployed very large nets (1,500–2,000 m long and 120–250 m deep) to encircle entire schools of tuna. Incidental take of dolphins was estimated at 550,000 in 1961 alone, and population estimates of spinner and spotted dolphins declined by more than half. Dolphin mortality was a problem for the purse-seine tuna industry, and many modifications in fishing methods and gears were tested. Principal innovations that were responsible for mortality reduction were "backing down" the net to allow dolphins to escape; and the Medina panel, which prevented dolphins from getting their snouts entangled in nets. The passage of the U.S. Marine Mammal Protection Act (1972), international agreements to limit dolphin mortality, and economic incentives, such as the dolphin-safe label, encouraged fishers to adopt improved fishing methods to minimize dolphin fatalities during fishing for tuna destined for canning. By 1988, a coalition of environmental groups called for a consumer boycott of the tuna caught by purse seines. Demonstrators carried signs saying, "Sorry Charlie—StarKist Kills Dolphins."

Figure 12.7: Charlie the Tuna character appears on a can of StarKist® tuna.

In 1990, Bumble Bee, Chicken of the Sea and StarKist, the three largest tuna canners, voluntarily declared that they would no longer purchase tuna captured in association with dolphins. Soon the Marine Mammal Protection Act was amended to mandate that U.S. retailers exclude tuna caught using methods that set nets on schools of dolphins. Dolphin-safe tuna fishing must meet several standards: (1) no use of drift gill nets to catch tuna; (2) no accidental killing or serious injury to any dolphins during net sets; (3) no mixing of dolphin-safe and dolphin-deadly tuna; and (4) an independent observer must be on board attesting to the compliance. Recent observations show that entanglement mortality of dolphins has been reduced by 99% (Balance et al. 2021).

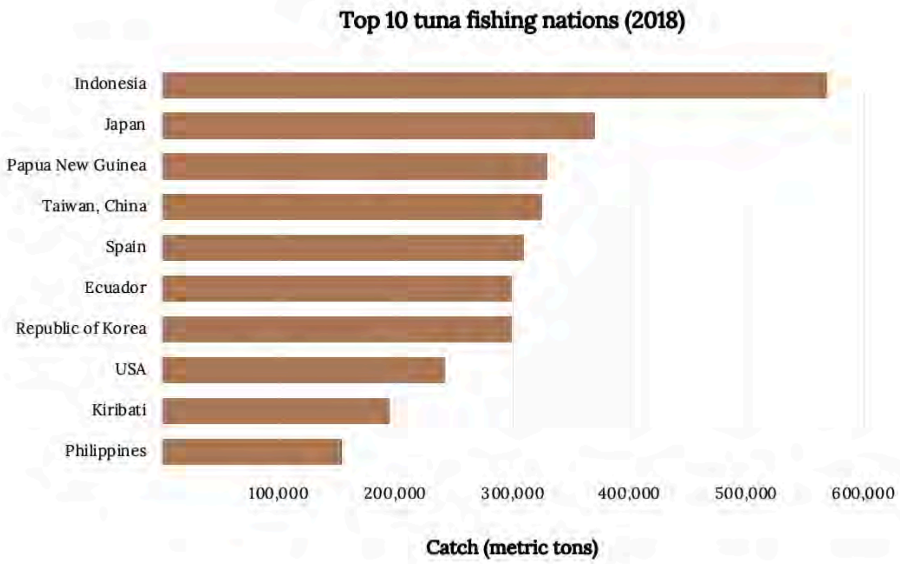

Figure 12.8: Top tuna fishing nations based on landings of seven tuna species in 2018. Long description.

Today most tuna are captured in purse seines, and longlines are the second-most-common gear. Indonesia and Japan are consistently the top-two fishing nations (Figure 12.8). Five of the top tuna fishing nations—Japan, Taiwan (Republic of China), Spain, Korea, and the USA—have large fishing fleets that operate far from their home waters, whereas the others have large local or regional fleets. New technologies, such as sonar, have made tuna fishing much more effective. In response, the use of spotter planes is banned for fishing Atlantic Bluefin Tuna in the Mediterranean (Di Natale 2020). Many recreational tuna boats also use spotter planes in the eastern Atlantic Ocean, although the traditionalist harpoon fishers shun the technology (Whynott 1995; Decker 2016).

The Pacific Ocean has consistently had the highest landings, about 66% of the world's tuna catch. The western and central Pacific Ocean is where many artisanal and industrial fisheries overlap. For the small island nations, fishing provides a major source of income, jobs, and food security (Bell et al. 2019). Yet, Pacific island nations have not fully realized the economic potential with the global tuna industry, despite the fact that 80% of it is caught within their exclusive economic zones (EEZs, i.e., within 200 miles). The 1982 United Nations Convention on the Law of the Sea awarded coastal states sovereign rights to (1) exploit and manage all living resources within their EEZ, (2) exclude distant water fleets in favor of developing their own fleets, and (3) charge distant water fleets rent for access. Eight island nations—the Federated States of Micronesia, Kiribati, Marshall Islands, Nauru, Palau, Papua New Guinea, Solomon Islands and Tuvalu, which support 80% of the purse-seine catch in their waters—formed an alliance and require collective bargaining to set rents for access by foreign vessels. The alliance also prioritized domestic over foreign vessels and set limits on the number of purse-seine vessels. The issue of sovereignty over tuna that migrate freely among EEZs remains a concern for small island nations (Bailey et al. 2012). Working to establish fair and equitable allocations of total allowable catches to the many parties will require more equitable sharing with the larger tuna-fishing nations.

Supply-chain management of tuna focuses mostly on the at-sea operations and marketing and processing standards. Throughout the world, tuna fishing is a male-dominated activity. Yet, women play essential roles in different nodes of the supply chain (Barclay et al. 2021). Management organizations typically exclude women for policy making, and existing policies fail to recognize women's work in tuna supply chains and in supporting men who fish at sea. Weak gender-based policies make women more vulnerable or easily subjected to sexual harassment, exploitation, and abuse in the workplace.

The tuna fishing industry has long been plagued by overfishing, corruption, human rights abuses, fraud, and illegal, unreported, and unregulated fishing, all of which compromises the well-being of environments and communities. Pacific island fisheries are particularly imperiled by corruption and lack of strong governance (Hanich and Tsamleyi 2009). Additionally, illegal, unreported, and unregulated tuna fishing is a major problem, especially in the Pacific Ocean, where estimates show the value lost annually to coastal nations is approximately $333.5 million (MRAG Asia Pacific 2021).

12.5 Recent Advancements in Tuna Fisheries

High-profile tuna brands have adopted corporate social responsibility guidelines to ensure that issues such as sustainability, IUU fishing, and social welfare are considered in business operations. French explorer Jacques Cousteau (1910–1997) had a way of making people passionate about marine life via his documentaries on underwater life and consequences of human negligence. After Cousteau visited an *almadraba* in action and dove in the innermost chamber surrounded by Bluefin Tuna and bonito, he wrote, in *The Silent World* (French: *Le Monde du silence*, 1956), that it was one of the "most horrible and grand" marine spectacles to be seen (Adolf 2019). Subsequently, nongovernmental organizations developed campaigns to reduce large-scale industrial fishing and promote sustainable fishing practices and the need for traceable tuna products (Bailey et al. 2016).

The supply-chain harvesters and retailers are playing a much larger role in shaping the international governance of tuna fishing. The number of fisheries that hold or are seeking sustainability certification have greatly increased over the past decade (Schiller and Bailey 2021). For example, the Marine Stewardship Council certifies pole-and-line–caught tuna (Figure 12.9), such as the Maldives Skipjack Tuna fishery of the Indian Ocean. Here the tuna are captured one by one and have low levels of bycatch and fish at levels that are sustainable. Tuna fishing is the second major source of income for the Maldives, after tourism. Fair Trade-certified fisheries meet a set of rigorous, audited criteria that work to protect the fundamental human rights of fishermen, as well as the ecosystems impacted by the trade. Consumers are willing to pay more for ecofriendly canned tuna, and sales at supermarkets have been trending upward (Sun et al. 2017).

Despite growing public concerns and efforts across the seafood sector to address corporate social responsibility, corruption and price fixing among the big-three tuna canning companies was recently exposed in a lawsuit brought by 25 major U.S. retailers. The big-three tuna brands control almost three-fourths of the shrinking American consumer market. Cans of tuna on grocery shelves were getting smaller and quality was dropping, yet prices increased. Guilty pleas were filed by all three tuna companies and several of their executives. The CEO of Bumble Bee Foods was sentenced to a 40-month prison sentence. Bumble Bee admitted to price fixing and agreed to pay a $25 million fine as part of a plea agreement, and StarKist was sentenced and ordered to pay a $100 million fine.

Figure 12.9: Fishermen catching Skipjack Tuna using pole-and-line fishing in the Maldives.

Globally, the abundance of tuna has declined by more than 50% over the past century, with steepest declines observed in the largest, longest-lived, highest-valued tuna (Juan-Jordá et al. 2011). Stocks are either overfished or fished at levels near the maximum sustainable yield levels, preventing further expansion of catches. Tuna fisheries that are overfished must be rebuilt with stricter measures to reduce overcapacity in the face of rising demand.

Two sources provide assessment of conservation status. The International Union for Conservation of Nature (IUCN) provides a global classification based on population decline and threats other than fishing pressure (Collette et al. 2011; Collette 2017). The status of world fisheries is periodically assessed for the seven species of major commercial tuna stocks. The assessment is challenging because of their migratory behavior and often differing spawning locations. Regional fisheries management organizations (RFMO) are responsible for stock assessment and management of 23 tuna stocks (6 Albacore, 4 Bigeye, 4 Bluefin, 5 Skipjack, and 4 Yellowfin stocks). Ideally, sustainable fishing means spawning-size fish abundance is at or above the level that produces maximum sustainable yield, fishing mortality is less than that which would produce the maximum sustainable yield, and there is minimal bycatch of nontarget species (ISSF 2022; Medley et al. 2022). There are five tuna RFMOs, which are responsible for assessing and managing the 23 stocks of the seven major commercial oceanic tuna species:

- IATTC: Inter-American Tropical Tuna Commission
- ICCAT: International Commission for the Conservation of Atlantic Tuna
- CCSBT: Commission for the Conservation of Southern Bluefin Tuna
- IOTC: Indian Ocean Tuna Commission
- WCPFC: Western and Central Pacific Fisheries Commission

Albacore are not overfished or experiencing overfishing. However, lack of reporting remains a concern, and the IUCN classifies them as Near Threatened. Atlantic Bluefin Tuna are rebuilding and classified as Near Threatened in eastern stock and Endangered in the smaller western stock. Both stocks are in a rebuilding phase. See section 12.6 for more details. Pacific Bluefin Tuna are overfished and down to 4.5% of their historic biomass (ISC 2022) and in need of a rebuilding plan. The Atlantic Bluefin Tuna (*Thunnus thynnus*) moved from Endangered to Least Concern, while the Southern Bluefin Tuna (*Thunnus maccoyii*) moved from Critically Endangered to Endangered. The Albacore Tuna (*Thunnus alalonga*) and Yellowfin Tuna (*Thunnus albacares*) both moved from Near Threatened to Least Concern. The Pacific Bluefin Tuna (*Thunnus orientalis*) moved from Vulnerable to Near Threatened in this update due to the availability of newer stock assessment data and models. Other tuna species reassessed for this Red List update include the Bigeye Tuna (*Thunnus obesus*), which remains Vulnerable, and the Skipjack Tuna (*Katsuwonus pelamis*), which remains Least Concern. Harvesting Bigeye Tuna with purse seines near FADs (fish aggregating devices) targets smaller Bigeye Tuna. Yellowfin Tuna are fully fished or overfished, and overfishing continues in the eastern Pacific and Indian oceans.

Currently, the traceability system in the tuna industry, even in the largest exporting country of Indonesia, is conducted through a paper-based system. However, a computer-based network, known as the blockchain, could revolutionize catch documentation and traceability through real-time data acquisition and integrated data access and transparency at every step along the supply chain. Under a blockchain-based system, fishing vessels are tracked with satellites (Taconet et al. 2019), and, from the time of capture, each tuna can be given a unique identification that is permanent and fully traceable across the blockchain database. At its core, blockchain technology is simply a digital, tamper-proof record of information that is accessible to businesses, restaurants, supermarkets, and, ultimately, even consumers. By tracking the fish from the moment it's caught, blockchain would make it nearly impossible for any illegal or unreported tuna to enter the market over time. The traceability allowed by blockchain technology would allow consumers to be confident about what they are eating, where it came from, how it was produced, and how it got to them. Such new technology was piloted by the World Wildlife Fund (WWF) in 2017 and remains under development across several fisheries. Fisheries specialist Bubba Cook with WWF says, "If you have the opportunity as a consumer to know with confidence that you're buying from a fishery that engages in sustainable and ethical practices, then of course you would want to do that" (Whiting 2020).

Thanks to demand for the highest-quality tuna for sushi and sashimi, the Japanese developed a new and more humane killing method that maintains the quality of the flesh. Any stress to a recently captured fish reduces the eating quality and shortens the storage life of the flesh (Poli et al. 2005). Some fish consumers have changed eating patterns as they learn that fish have consciousness, experience pain, are social, know how to use tools, and are able to communicate (see Chapter 5 in this book). Yet, even if the consumer is not concerned with the welfare of the tuna, preventing muscle spasms in dying tuna will improve the flesh quality. Spasms cause muscles to release lactic acid, which in turn leads to bacterial changes that acidify muscular tissue and give the meat a brownish tint and bitter taste.

The *ikejime* killing method is similar to pithing a frog. A spike is inserted quickly and directly into the hindbrain, thereby causing immediate brain death. Then, a thin needle or wire is inserted into the spinal column ceasing all muscle movement. The tuna is then bled and placed on ice. Tuna killed in this way have better flesh quality than those killed by suffocation or bleeding.

***Questions to ponder*:**

What aspects of tuna fishing are most important to you as a consumer? What additional information would you prefer to be added to labels for all tuna products on the market?

12.6 Atlantic Bluefin Tuna

Atlantic Bluefin Tuna are one of three different species of Bluefin Tuna (Figure 12.10). The other very similar species are the Pacific Bluefin Tuna and the Southern Bluefin Tuna. Bluefin Tuna is one of the sea's most valuable species, a highly migratory fish that has been harvested for many centuries. After a long history where fishing was primarily in the Mediterranean, new fisheries emerged throughout the Atlantic Ocean. The new fisheries adopted purse seines and longlines instead of beach seines and traps. The new gears were more effective, and increased fishing effort after World War II led to substantial declines in the harvest of Atlantic Bluefin Tuna and calls to develop an improved governance system to regulate fishing.

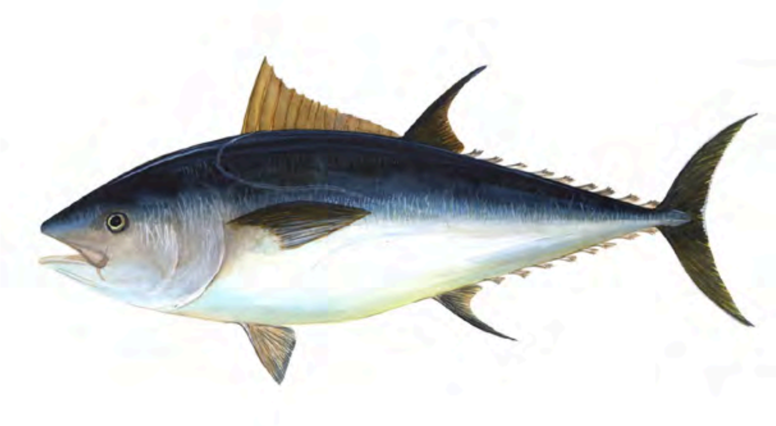

Figure 12.10: Atlantic Bluefin Tuna, Thunnus thynnus. It is also known as Bluefin Tuna, toro, Giant Bluefin, and Northern Bluefin Tuna.

Bluefin Tuna were not always popular food fish. In the 1800s, the Japanese referred to tuna as *neko-matagi*, meaning "fish that even a cat would disdain." Until recently, the red flesh and robust taste of Bluefin Tuna were not desirable for consumption. It was primarily a sport fish caught for fun along the Atlantic Coast from Nova Scotia to Massachusetts in the 1940s, 50s and 60s. The big tuna were weighed and photographed, then sent to landfills or sold for under $1 per pound to be turned into pet food. Chasing giant Bluefin Tuna always attracted big-game anglers to tournaments, such as the International Tuna Cup Match, which began in 1937. Atlantic Bluefin Tuna recreational fishing increased as a specialized sport, some with hook-and-line fishing and others devoted to the use of harpoons (Decker 2016). The record Atlantic Bluefin Tuna landed in 1979 weighed 1,496 pounds—a record that continues to stand today. Television series, such as Wicked Tuna, brought broader attention to rod-and-reel fishing for Atlantic Bluefin Tuna.

Growth in market demand for Bluefin Tuna exploded in the 1970s, after Kobe beef, a fatty, well-marbled product, was first introduced and marketed in Japan (Longworth 1983). This resulted in appreciation of strong flavors and dark flesh, and Japanese developed a taste for *toro*, the fatty belly flesh of the Bluefin (*toro* means "to melt," in reference to its buttery texture). Fish wholesalers wear masks and sanitize their hands as they examine the texture of tail meat from fresh and frozen tuna by touching, smelling, and sometimes tasting pieces of it. Sushi chefs handle and serve different cuts of Bluefin Tuna flesh. Every cut has a different name and purpose. The cuts from the cheeks and top of head are found only at a few high-end Japanese restaurants.

Figure 12.11: A tuna seller at Japan's Tsukiji Market, the biggest wholesale fish and seafood market in the world.

Japanese fishmongers were the first to store and age tuna to soften the rich flavor (Goulding 2000). When Bluefin Tuna was introduced to high-end restaurants, demand continued to skyrocket. Demand for high-quality sushi led to another expansion in Bluefin Tuna fishing well before tuna management was ready to adapt. Soon a heavily subsidized European Union fleet of giant, specialized purse-seining vessels vastly expanded the catch of Atlantic Bluefin Tuna. Bluefin Tuna caught from the Pacific, Atlantic, and Southern oceans were flash-frozen and shipped for auction at Japan's Tsukiji Market, the biggest wholesale fish and seafood market in the world (Figure 12.11). At the first auction of the year, the first Bluefin Tuna auctioned receives special attention. The owner of a Japanese sushi restaurant chain set a record by paying more than $3.1 million for a 278-kg (613-lb) Bluefin Tuna. These high bids receive a lot of press attention, which inspires customers to flock to sushi restaurants. However, the auction price is highly symbolic and not an accurate measure of the price of tuna.

Landing records for Atlantic Bluefin Tuna date back to 1525, from *almadrabas* in the western Mediterranean and the Strait of Gibraltar (Ganzedo et al. 2016). Landings have always shown short-term and long-term fluctuations associated with conditions that modify fishing conditions or spawning behavior and early survival of young Bluefin Tuna. One constraint to management of the Atlantic Bluefin Tuna has always been the lack of certainty over the spawning locations and migratory path. Atlantic Bluefin Tuna feed in the productive waters off the coasts of North America, Europe, and Africa (Block 2019). Each year mature fish make long migrations so they can reproduce in warm waters >24°C suitable for eggs and larvae. Tuna from each spawning ground mix during the rest of the year (Rooker et al. 2007). Therefore, an Atlantic Bluefin Tuna caught anywhere in the Atlantic cannot be identified to its spawning stock. The mid-Atlantic region has the highest mixing levels (Siskey et al. 2016).

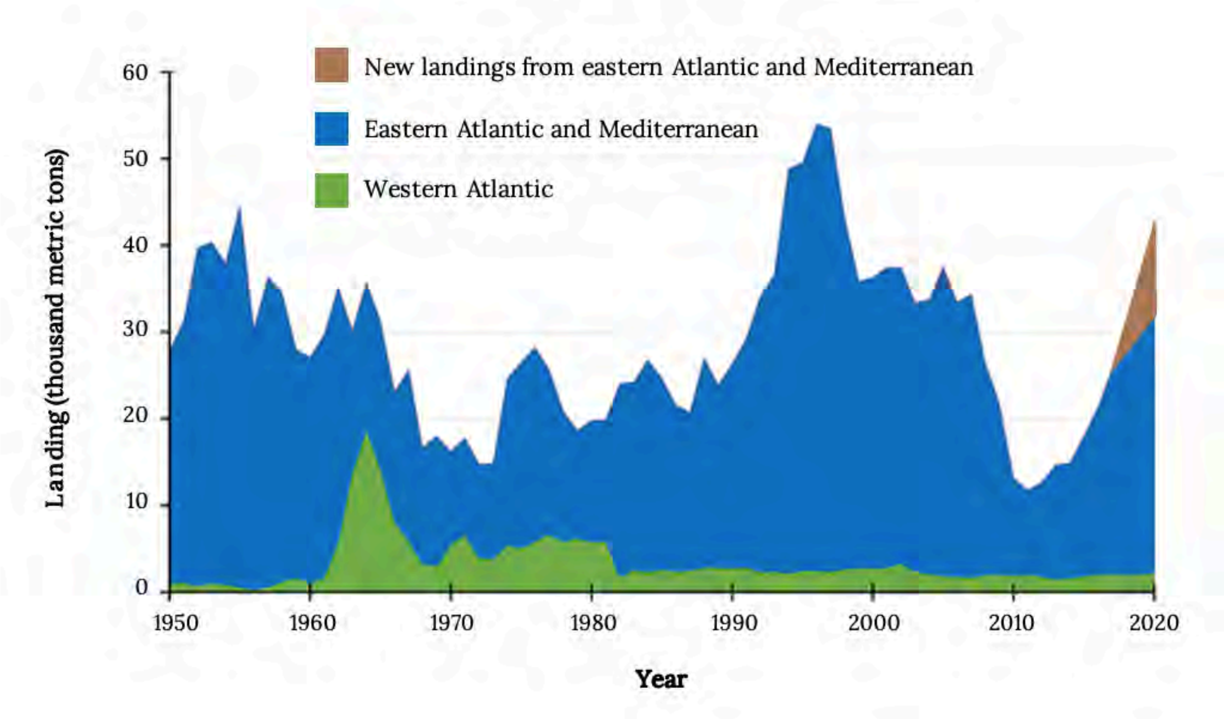

Figure 12.12: Landings of Atlantic Bluefin Tuna from 1950 to 2020 (Sun et al. 2019). Note: this graph does not include unreported landings, which in some years may exceed 20,000 metric tonnes for the eastern stock. Long description.

Since 1950, landings of both stocks fluctuated, but landings demonstrated that the Eastern stock was larger (about 10-fold) (Figure 12.12). The Japanese fishing fleet started to actively fish Bluefin Tuna in the Atlantic in the 1950s. In 1966, tuna fishing nations formed the International Commission for the Conservation of Atlantic Tuna (ICCAT), and management decisions were made by representatives from 51 countries. Few regulations were in place in the early years of ICCAT. While ICCAT does not have regulatory or enforcing powers (Korman 2011), it is entrusted with collecting and compiling statistical data, generating scientific reports, proposing nonbinding management recommendations based on its findings, and creating an arena for contracting parties to meet and discuss recommendations. Scientific advice from ICCAT has often been watered down or manipulated for political purposes (Telesca 2020). Member states are responsible for the implementation of regulations, monitoring, sanctioning, and collection of data. It was 1975 before ICCAT recommended a minimum size of 6.4 kg (~age two and still immature), reflecting recommendations by the Tuna Saint in the 1800s (Mather et al. 1995). One of the most significant changes occurred in 1981, when ICCAT elected to divide governance into Eastern and Western management units using an effectively arbitrary boundary of 45°W longitude. In the 1990s, longliners and purse seiners with spotting planes were prohibited in Mediterranean Sea at vulnerable times of year when ICCAT and others recognized that the Atlantic Bluefin Tuna were overfished (MacKenzie et al. 2009).

It was 1998 before ICCAT would establish the first country-based quotas for Bluefin Tuna. Quotas were set too high in response to economic and political pressures. The period from 1997 to 2007 (Figure 12.12) was time of fraud, blatant overfishing, and rule breaking, with catches over twice the annual quota. At this time of peak landings, a black market worth an estimated $4 billion caught more than one out of every three Atlantic Bluefin Tuna (Guevara et al. 2012). Not surprisingly, by the turn of the century, the spawning stock hit a new low. Countries were forced to reveal their true catches; for example, France revealed its true catch was almost double the ICCAT quota. In 2010, some sushi consumers boycotted Bluefin Tuna over concerns about population declines.

Atlantic Bluefin Tuna are large as adults, have high fecundity, low early survival, and moderate longevity (>30 years). A 5-year-old female produces about 5 million small eggs (~1mm), while a 15-year-old female can carry up to 45 million (Rodriguez-Roda 1967). However, environmental conditions during early life greatly influence survival of the eggs and larvae. Therefore, Atlantic Bluefin Tuna depend on a broad representation of multiple age groups because not all spawning seasons provide favorable conditions for spawning and larval conditions to lead to large year classes. Spawning biomass of both stocks of Atlantic Bluefin Tuna dropped below the limits set by management organizations (Figure 12.13), triggering more regulations (Fromentin and Powers 2005; Fromentin 2009; Taylor et al. 2011; Fromentin et al. 2014; Cort and Abaunza 2015; Porch et al. 2019; Lauretta et al. 2020; Telesca 2020).

Illegal and unreported tuna fishing meant that catch statistics (Figure 12.13) were underreported, and stock assessments were biased toward estimating steep declines. Unreported catches from the Mediterranean (19,400 in 2006 and 28,600 in 2007) significantly contributed to the rapid decline in the stock (Agnew et al. 2009). Because of the mixing in the Atlantic, the successful rebuilding of the western population was tied to controlling the much larger fishing mortality rates that occur on the eastern stock (Taylor et al. 2011; Porch et al. 2019). For example, continued high fishing mortality rates in the Mediterranean Sea and eastern Atlantic compromise rebuilding efforts for the western Atlantic population.

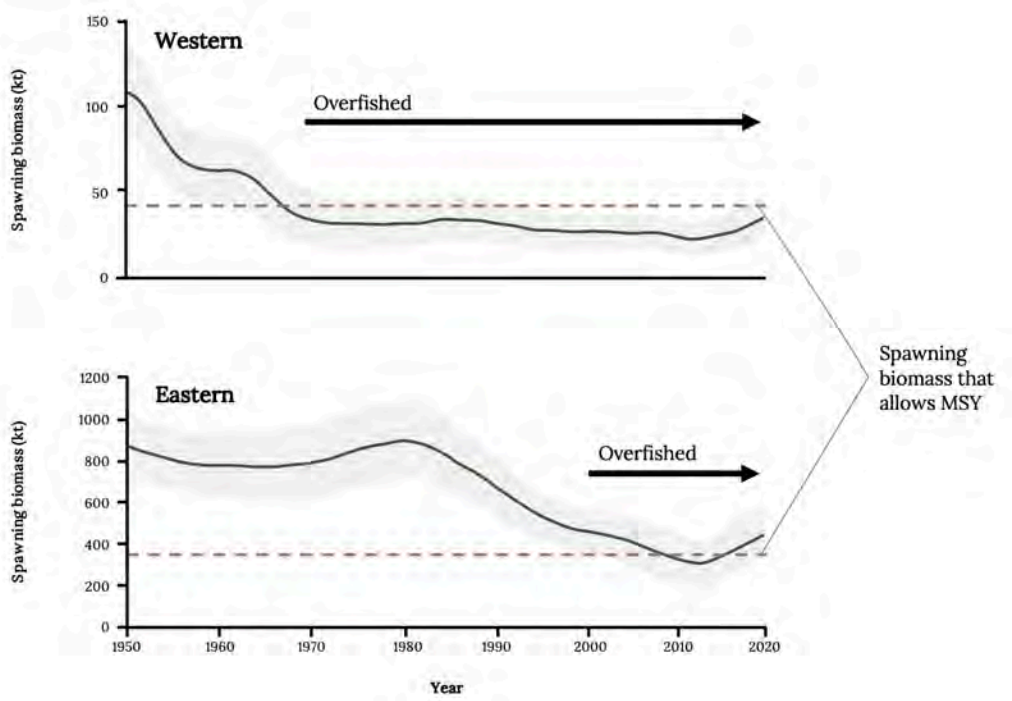

Figure 12.13: Estimated spawning biomass of western and eastern stocks of Atlantic Bluefin Tuna since 1950. Shaded band shows uncertainty associated with estimates. Long description.

Nongovernmental organizations also started campaigns to reduce fishing of Atlantic Bluefin Tuna. In 2007, ICCAT developed a plan to increase the minimum weight limit to 30 kg and implement surveillance and enforcement of quotas, with funding support from the European Unions. Nongovernmental organizations petitioned the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) to restrict international trade in 2010. With 183 member states (including the EU countries), CITES is an unwieldy international group. Moreover, big tuna-fishing nations objected to the petition at the 2010 annual CITES conference, making deals with developing countries in return for their objecting to the proposal. The deciding incident was the screaming from the delegate from Libya over "imperialist nations" depriving Libya of its fair share of tuna. At the time, Libyan leader Muammar Gaddafi's family was deeply involved in massive illegal tuna fisheries and smuggling and had expanded its EEZ to keep other countries out. The proposal to CITES was voted down by a clear majority, leaving ICCAT to enforce existing quotas to recover Mediterranean stock.

Also in 2010, the Center for Biological Diversity petitioned the National Marine Fisheries Service (NMFS) to list the Atlantic Bluefin Tuna (western stock) as endangered (Atlantic Bluefin Tuna Status Review Team 2011). The review by NMFS acknowledged the threats to coastal habitats but concluded that they do not represent a substantial risk to long-term persistence of the species. Furthermore, they judged that lowered quotas would allow for an increase in abundance. The ICCAT plan included an emergency clause that specified that if serious threat of stock collapse is detected in future stock assessments, ICCAT shall suspend all Atlantic Bluefin Tuna fisheries in the western Atlantic for the following year.

The path to eventual recovery of the Atlantic Bluefin Tuna is far from certain (Lauretta et al. 2020). Although overfishing is not occurring, the abundance measures are still below targets set by the ICCAT. If landings continue to stay below the total allowable catch, the population should grow. However, the giant specimens of tuna, as well as other newsworthy ginormous fish, are now rarer than in previous decades and centuries (Francis et al. 2019). There are signs that Atlantic Bluefin Tuna are expanding in the North Sea, Norwegian Sea, and northeast Atlantic as herring and mackerel have increased in abundance (MacKenzie et al. 2022). Hopeful signs for the Atlantic Bluefin Tuna may encourage adoption of similar strategies to recover the Southern Bluefin Tuna, the population of which was just 2.6% of the original unfished stocks (Nickson 2016).

The case of the Atlantic Bluefin Tuna highlights the challenge of managing fish populations in a complex global fishing supply chain. What has emerged may be viewed as a sociological and political problem or a "wicked problem," difficult to solve because of the complex and interconnected nature and competing goals. Regional fisheries management organizations are reactive instead of proactive and respond to complaints from powerful constituencies with effective or ineffective policies, while marginalized peoples have little power to effect change (Webster 2015; Nakatsuka 2017). A large global and borderless economy easily leads to overcapacity of subsidized fishing fleets and competing interests and indifference. Marginalized groups have less political clout to mobilize efforts to address problems. Japan is the largest importer of Bluefin Tuna and considers sushi from them an acquired right. Consequently, when quotas are reduced, each country must adjust to meet the quota, creating incentives for fraud in reporting catches.

Consumption of Bluefin Tuna is an example of conspicuous consumption, which is the display of ostentatious wealth to gain status and reputation. Bluefin Tuna is a **Veblen good**, meaning the demand for it increases as one's income rises (Veblen 1912). A Veblen good has an upward-sloping demand curve, which runs counter to the typical downward-sloping curve (Figure 12.14, top portion of curve). A rational consumer would consider alternative goods available in the market, and when the price for certain goods decreases, the demand should increase, and vice versa (Figure 12.14, bottom portion of curve). However, consumers have increasingly prized Bluefin Tuna as a status symbol as it becomes more and more uncommon and thus more expensive. The fewer Bluefin there are, the more sushi made, and so the more consumers want it, and thus the more it is overfished. Consumer behavior—that is, demand for a rare and expensive commodity—contributes to the decline in Bluefin Tuna abundance (Barclay 2015).

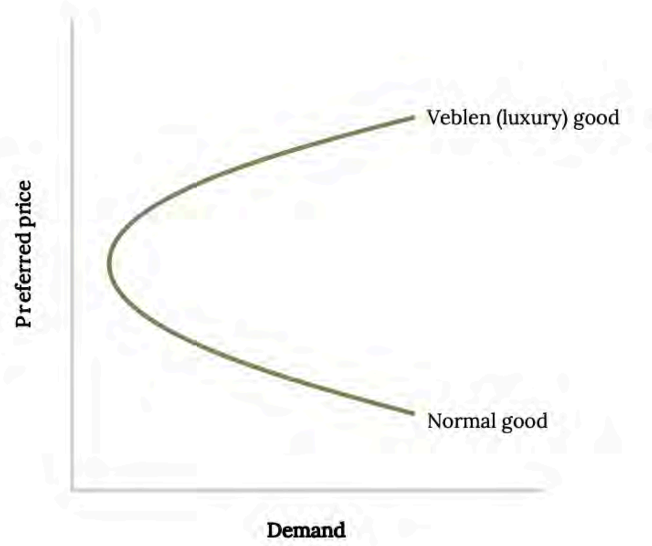

Figure 12.14: Demand curves for Veblen or luxury goods (top portion) and normal goods (bottom portion).

12.7 Tuna Ranching

Tuna ranches may have revolutionized the Bluefin Tuna industry, bringing fantastic profits. Increasingly, captured Bluefin Tuna are destined for aquaculture (Metian et al. 2014). However, they are controversial and have not reduced demands on wild stocks. Rather, tuna ranches became a point of conflict in the 1990s during the height of overfishing on all three species of Bluefin Tuna. An estimated 67 ranches spread across the Mediterranean, along with other ranches in Japan, Australia, and Mexico. Australia piloted tuna ranching in 1991 with funding from the Australian government, a Japanese fisheries foundation, and tuna boat owners in Australia. Tuna ranching is based on the capture of young Bluefin Tuna in purse seines. Because the entire process happens underwater, ranching made it impossible to verify the weight or number caught, leading to undersized tuna captured. These juveniles were transferred to large circular pens where they were fattened by feeding them sardine, herring, and mackerel. Tuna ranching has economic advantages: the fish are sold to ranches instead of being sold cheap to the Japanese; also, they have grown large enough (>25 kg) for the market to have improved fatty flesh quality.

Financing for many of the tuna ranches was traced largely to Japanese fish trading houses and Mitsubishi Corporation, a corporate giant that owns subsidiary companies that control much of the Bluefin Tuna market in Japan. Laundering tuna allowed the new industry to dodge quotas. Catches were underreported or traded with ranches in less-regulated countries and mixed with legal catches (Center for Public Integrity 2012). Some visionaries see a time when Bluefin Tuna aquaculture will not require harvesting young tuna to stock pens. Efforts to breed Bluefin Tuna in captivity have been successful in establishing a domestic population (Ortega and de la Gándara 2019). Selective breeding programs may reduce the feed requirements and grow-out times (Klinger and Mendoza 2019). Bluefin Tuna farming still presents many environmental concerns associated with other farmed carnivores, including the need to harvest forage fish for feed (Naylor et al. 2021). Time will tell if aquaculture can solve the problems of meeting the demands for the most expensive fish in the world today.

12.8 Outlook for Sustainability of Tuna Fisheries

Our relationship with tuna will continue to focus on these fish as a commodity and not a key part of the ocean ecosystems. Tuna fisheries continue to provide an important source of employment and foreign exchange for major fishing countries. Problems, such as overfishing, subsidies, human rights abuses, and fraud, as well as illegal, unreported, and unregulated fishing, are well recognized, and the experts have differing views of the future for sustainable tuna fisheries (Adolf 2019; Telesca 2020). The difference of opinions is due to a mix of positive signs and continuing challenges:

- Improved governance
- Traceability and ecocertification of tuna products
- Mercury contamination

- Oil spills
- Climate change and shifting baselines
- Ecosystem connections

Improved Governance

Countries that subsidize tuna fishing fleets can overfish stocks, while smaller subsistence fisheries are disadvantaged (Sumaila et al. 2014; Bush and Roheim 2018). Larger tuna fleets also target high-value species for export to the luxury market (Willis and Bailey 2020). Fishing fleets can target fishing in countries with little enforcement, and once the fish are landed at a port, it is very difficult to determine where, how, and by whom the fish were caught.

The FAO Code of Responsible Fisheries sets out international principles and standards of behavior to ensure effective conservation, management, and development of living aquatic resources (FAO 1995). These principles are intended to prevent overfishing, while meeting the needs of present and future generations in the context of food security, poverty alleviation, and sustainable development. Limiting access to tuna fishing via individual transferable quotas is controversial, as it focuses only on the aggregate economic performance through profit generation and not the well-being of tuna-fishing communities (Hallman et al. 2010). For example, led by powerful ranching investors, tuna fisheries in Malta transitioned from an open-access artisanal activity to an industrial one with an individual transferable quota system. The shift raised questions over who had legitimate fishing rights and decreased profitability for artisanal due to competition with industrial fishing (Said et al. 2016). The artisanal fishing of Bluefin Tuna in Malta has been ongoing since the 1700s, yet the future livelihood of artisanal fishers is now at risk. Furthermore, tuna ranching, owned by only five foreign companies, dominates much of the fishing for Bluefin Tuna in Malta. In Malta, the transition to industrialized tuna fishing resulted in very unequal benefits and was not aligned with FAO's principles of responsible fishing.

Future decisions over tuna fishing can be improved by enhancing the function of the existing regional fisheries management organizations to counteract overcapacity of fishing fleets (Aranda et al. 2012). Some form of right-based management is being debated across multiple RFMOs, raising ethical questions in a world where food security, not profits, may become a top priority (DeBruyn et al. 2012; Dueri et al. 2016).

Question to ponder:

What factors should one consider when making a transition from artisanal and open-access fishing to a limited entry?

Policy changes that facilitate industrialization of tuna fishing and use of transferable quotas may be the beginning of the end for the artisanal tuna fishers. An alternative to individual transferable quotas was adopted by a coalition of eight island nations, dispersed over thousands of islands and atolls (Yeeting et al. 2018). The combined EEZs of the coalition support half of global catches of Skipjack Tuna and a quarter of all total global tuna catches. This agreement was designed to cap the number of purse-seine vessels by setting a benchmark price and allocating tradable fishing days. After this agreement was implemented, the price of fishing licenses rose, and tuna stocks increased (Adolf 2019). This partnership protects the food sovereignty of the island nations and may be the first step toward managing ownership of tuna resources.

There are signs from the most recent decade that more major stocks are being fished sustainably. Tuna stocks were more depleted for stocks with high commercial value, large size, and long lifespans. In addition, implementing and enforcing total allowable catches (TACs) had the strongest positive influence on rebuilding overfished tuna (Pons et al. 2017). RFMOs have made progress in implementing stock assessments for a wide range of taxa (Heidrich et al. 2022).

Traceability and Ecocertification of Tuna Products

The efforts to manage highly migratory tuna stocks have taught us that different governance arrangements, from state-based, public regulation to market-based, private initiatives, each have a role to play. Many consumers are concerned about illegal and unsustainable tuna fishing and will pay a premium price if they can verify the source of the product. Changes in management come from fishing companies that seek to differentiate their tuna products with a certification of sustainable fishing and global initiatives, such as the World Wildlife Fund's Smart Fishing Initiative (Bailey et al. 2018). New tools, such as certification, recommendation lists, and traceability increasingly play important roles in modifying the purchasing behavior of consumers (Bush and Roheim 2018).

Figure 12.15: A tuna fisherman entering data on local tuna catch with a digital device.

Improvements come from promoting the use of technology in fishing operations that permits both transparency and traceability of tuna products. Market incentives such as ecolabels can reduce illegal and unsustainable fishing by driving buyers toward more ethical and transparent producers while simultaneously excluding the rest. Electronic monitoring using cameras and other sensors on industrial tuna fishing boats supplements catch and effort information collected through logbooks, port sampling, and observer data. These procedural and technological advancements detect a vessel's position and activity (Whiting 2020), while cameras record key aspects of fishing operations, such as observing bycatch of at-risk species. Local fishers and processors along the supply chain may then enter data into a database, such as a blockchain, via their mobile electronic devices (Figure 12.15). Consequently, the consumers at the end of the chain can see mobile-accessible information about location of the catch and suppliers along the entire supply chain. As of 2019, approximately 47% of the global tuna catch came from fisheries that either held or were seeking ecocertification from the Marine Stewardship Council (Schiller and Bailey 2021). An increase in certified tuna fisheries is expected as standards are established for electronic monitoring systems (Murua et al. 2022).

Mercury Contamination

Mercury is a persistent substance that can build up, or bioaccumulate, in living organisms. Bacteria and other living organisms convert mercury in the water to methylmercury, a highly toxic organic compound. Fish absorb methylmercury from their food as well as from water as it passes over their gills. As mercury-contaminated organisms are eaten and transformed at higher trophic levels, the concentration of methyl mercury increases through a process known as biomagnification (Figure 12.16). Because tuna are top predators as adults, they have high concentrations of mercury (Moura Reis Manhães et al. 2020). All three species of Bluefin Tuna have high concentrations of methylmercury that increase with age (Tseng et al. 2021). For example, the biggest Atlantic Bluefin Tuna ever caught off Delaware (873 pounds) had 2.5 parts per million, making it 2.5 times higher than the FDA action level for commercial fish (Absher 2005).

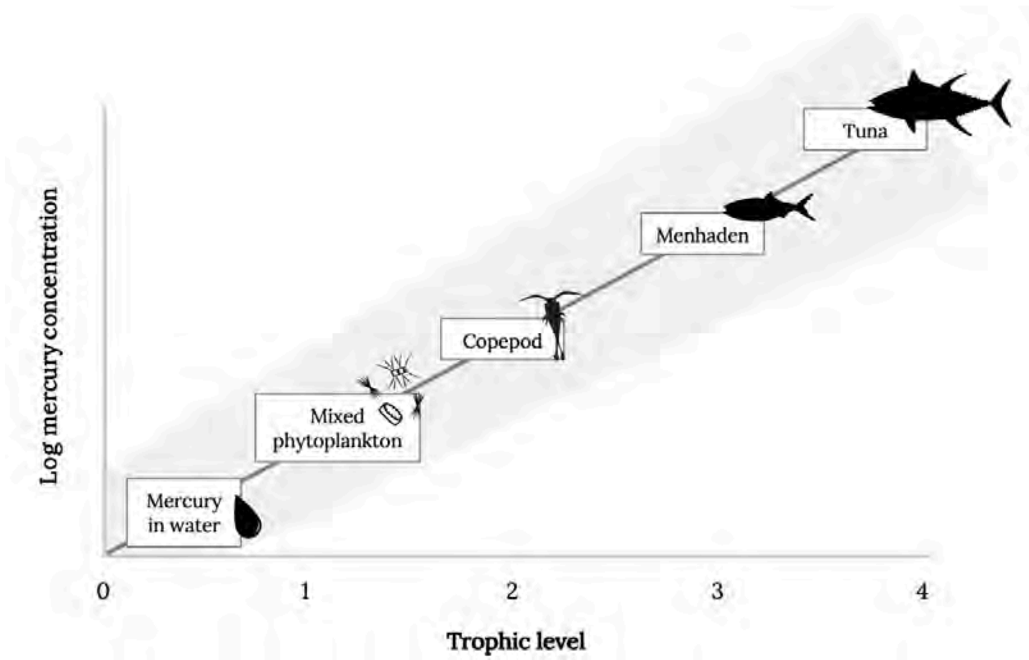

Figure 12.16: Bioaccumulation and biomagnification of mercury in water, primary producers, and three trophic levels. [Long description](#).

Mercury in fish is bound to proteins in fish tissues, including muscle. There is no method of cooking or cleaning fish that will reduce mercury levels. Both elemental and methylmercury can cross the blood-brain and placental barriers. The adult and fetal brains are targets for elemental mercury, and the brain and the kidneys are critical target organs for methylmercury. Methylmercury interferes with a cell's ability to divide, and its effects on brain development can be permanent. Chronic exposures to children and developing fetuses show up later in the form of reduced performance on some tests of language, coordination, and intelligence. Chronic exposure to mercury in adults may be associated with an increased risk of cardiovascular diseases, reproductive harm, kidney disease, risk of dementia, and cancer (Ye et al. 2016).

Unfortunately, few consumers are aware of the mercury content in the tuna they eat. Some grocery chains now include FDA warnings to limit consumption of fresh or frozen tuna. California passed Proposition 65, which required warning about exposures to chemicals, including mercury, that cause cancer, birth defects, or other reproductive harm. However, tuna companies appealed the ruling requiring warning labels, and the court ruled that mercury in canned tuna is "naturally occurring" and therefore exempt from Proposition 65. However, whether the mercury is naturally occurring or added by human actions is irrelevant to the consumer. Jane Hightower, MD, found that many of her fish-loving patients had chronic methylmercury poisoning, which caused numerous symptoms that were not thought to be due to mercury until mercury levels were measured in the patient's blood (Hightower 2008).

Concerns over mercury contamination will continue in the future, as the human health impact of chronic exposure to mercury is a topic of great controversy. Although aggressive regulation of mercury in North America and Europe since the 1970s reduced mercury emissions (Conniff 2016), the warming of the oceans will increase accumulation of mercury in tuna and other top predators (Shartup et al. 2019). Consumers should choose to substitute other lower-mercury fish for tuna. According to the FDA and the EPA, canned light tuna is the better, lower-mercury choice. Canned white and Yellowfin Tuna are higher in mercury, but still okay to eat one time per week. Bigeye Tuna and Bluefin Tuna, not typically used in canned tuna, should be avoided completely (Ballance et al. 2021).

Questions to ponder:

How much tuna can the average person eat? Apply the EPA/FDA advice of 0.7 ug/mercury/kg body weight per week to determine your safe weekly consumption of mercury. Use the calculator available at https://www.omnicalculator.com/ecology/fish-mercury#what-is-my-weekly-limit-for-mercury-intake.

Does your current consumption of tuna put you at risk for mercury poisoning?

Oil Spills

The Deepwater Horizon oil spill released ~4 million barrels of oil in the northern Gulf of Mexico in areas of known for spawning of Atlantic Bluefin Tuna. Oil can cause deformities and death in tuna eggs and larvae. Even short-term exposure of adults interferes with heart function in Atlantic Bluefin Tuna, which may lead to life-threatening **arrhythmias** (Brette et al. 2014). The Deepwater Horizon spill influenced less than 10% of the spawning area for Atlantic Bluefin Tuna and influenced only a single-year class (Hazen et al. 2016; Gracia et al. 2019).

Climate Change and Shifting Baselines

Long-term shifts in tuna are expected with climate change. Like other fish, the distribution of tuna has shifted northward in the Northern Hemisphere and southward in the Southern Hemisphere (Erauskin-Extramiana et al. 2019; Townhill et al 2021). These shifts will undoubtedly influence productivity of tuna and potential yields. Additionally, seafood rating systems (e.g., Monterey Bay Aquarium Seafood Watch) and seafood certifications (e.g., MSC) to inform purchasing decisions may consider the rising costs of fossil fuels in their rating systems (McKuin et al. 2021). Furthermore, setting appropriate baselines for recovery of tuna populations present a new challenge as old data sets are abandoned or forgotten. The average size of harvested tuna has been reducing over time. It is unlikely we will see a return of abundant giant tuna in our lifetimes. Shifting baselines affect our vision for the future.

Ecosystem Connections

Finally, the management of tuna seldom considers that they are also preyed upon in ocean ecosystems. Yet, predators such as large pelagic sharks and Orcas feed on tuna. Predators also depredate tuna caught in longline fisheries. Survival of killer whale calves was reduced and recruitment ceased when tuna stocks declined near the Strait of Gibraltar (Esteban et al 2016). Consequently, future stock assessments should consider the tuna predators when setting harvest quotas.

Profile in Fish Conservation: D. G. Webster, PhD

Scan the QR code or visit https://doi.org/10.21061/fishandconservation to listen to this Profile in Fish Conservation.

Figure 12.17: D. G. Webster, PhD.

D. G. Webster is Associate Professor of Environmental Studies at Dartmouth University. Her major research interest is understanding feedbacks within global-scale social-ecological systems in order to improve environmental governance. Thus, she brings an important yet underutilized perspective from political science and organizational theory to bear on preventing collapse of international fisheries. She is author of two books, including *Beyond the Tragedy in Global Fisheries*, which explains the evolution of global fisheries governance through a responsive governance lens. Her research showed how fisheries all over the world may cycle through periods of effective and ineffective governance in what she calls the "management treadmill." Her first book, *Adaptive Governance: The Dynamics of Atlantic Fisheries Management*, which won the International Studies Association's Harold and Margaret Sprout Award, tested her vulnerability-response framework. Her contributions are relevant to the competition for fish associated with open access and declining fish stocks.

Webster's concept of the governance treadmill helps to understand barriers to change and informs a wide range of crises. The concept was applied to the Maine lobster fishery, where governance shifted back and forth between effective and ineffective periods of management over a 200-year period. Recently, this concept helped scientists to demonstrate factors that help or hinder the alignment of government capacities toward prevention during public health crises, such as the COVID-19 pandemic. Stagnation in governance includes **maladaptive** responses by government, economy, and society that are ineffective. Often the very people with access to information and resources lack understanding to be effective. This was also evident in the response of ICCAT parties during the low ebb in Atlantic Bluefin Tuna populations.

Dr. Webster has explored new methods for exploring social-ecological systems as the lead investigator on a multi-institutional project called *Fishscape: Modeling the Complex Dynamics of the Fishery for Tropical Tuna in the Eastern Pacific Ocean*. This research focuses on international tuna fisheries, which are very difficult to manage. In the eastern Pacific alone, an area of about 10 million km^2, over 200 purse-seine vessels from more than 10 countries fish for tuna. In this project, her research team uses a unique form of analysis, called "agent-based modeling," to better model vessel search processes and better understand how different types of regulations will affect the fish and tuna fishers who rely of them. This project wrapped up in 2015.

Dr. Webster teaches courses related to global environmental governance, green business, marine policy, and environmental economics. She earned her PhD from the University of Southern California's Political Economy and Public Policy program in 2005.

Key Takeaways

- Tuna are highly migratory species and, therefore, management of tuna fisheries involves substantial coordination among regional and international commissions and organizations.
- Oldest marine commercial fisheries targeted tuna in the eastern Mediterranean Sea.
- The principle of sovereignty over food demands that fisheries must be conceived as part of complex social and ecological systems where small-scale fishers play a central role in decision making.
- Popularity of tuna along with the far-distant fishing leads to increased demands, higher prices, illegal fishing, and incentives to invest in fishing fleets.
- Tuna stocks are more likely to be depleted for species with high commercial value and long lifespans.
- Subsidies for fishing fleets lead to overcapitalized and overfished tuna fisheries.
- Implementing, monitoring, and enforcing quotas have the strongest positive influence on rebuilding overfished tuna stocks, such as Atlantic Bluefin Tuna.
- Oversight and monitoring of tuna fisheries via vessel tracking and electronic monitoring are essential to prevent overfishing and illegal, unregulated, and unreported fishing.
- Future challenges to sustainable tuna fisheries include improved product tracing, concerns over mercury contamination, climate change, oil spills, and addressing ecosystem services provided by tuna.

This chapter was reviewed by Alfred "Bubba" Cook.

Long Descriptions

Figure 12.2: Illustration of seven common tunas; largest to smallest: 1) bluefin, 2) yellowfin, 3) bigeye, 4) albacore, 5) blackfin, 6) little, and 7) skipjack. Jump back to Figure 12.2.

Figure 12.5: Key: Green arrow – products and information flow; brown arrow – coordination and information flow; packaging material, vertical green arrow points to fish processing unit within a horizontal green arrow that includes, 1) tuna fish, 2) fishing vessel, 3) transit, 4) fish processing unit, 5) transporter, 6) distributor, 7) retailer; fish processing unit vertical brown arrow points both ways from fish processing unit to government. Jump back to Figure 12.5.

Figure 12.8: Top 10 tuna fishing nations (2018): 1) Indonesia (575,000 metric tons); 2) Japan (474,000 metric tons); 3) Papua New Guinea (325,000 metric tons); 4) Taiwan, China (320,000); 5) Spain (305,000); 6) Ecuador (300,000); 7) Republic of Korea (300,000); 8) USA (240,000); 9) Kiribati (195,000); 10) Philippines (150,000). Jump back to Figure 12.8.

Figure 12.12: Trends from 1950 to 2020, including 1) brown: new landings from eastern Atlantic and Mediterranean; 2) blue: eastern Atlantic and Mediterranean; 3) green Western Atlantic. Highest landing in 1995 with 55,000 metric tons of Eastern Atlantic and Mediterranean tuna. Jump back to Figure 12.12.

Figure 12.13: Two graphs show estimated spawning biomass; 1) Western: overfished 1970-2020; shaded line band is highest (105) in 1950 and declines through approx 2015; 2) Eastern: overfished 2000-2020; shaded line band is highest (900) in 1950 and 1980, then declines in 2010. Jump back to Figure 12.13.

Figure 12.16: Line graph shows increase in mercury with increasing trophic level with, 1) mercury in water, 2) mixed phytoplankton, 3) copepod, 4) menhaden, 5) tuna. Jump back to Figure 12.16.

Figure References

Figure 12.1: Body form of the Bigeye Tuna (*Thunnus obesus*) showing fins, finlets, and keels. Finlets are found between the last dorsal and/or anal fin and the caudal fin. Dr. Tony Ayling, 1982. CC BY-SA 1.0. https://commons.wikimedia.org/wiki/File:Thunnus_obesus_%28Bigeye_tuna%29_diagram.GIF.

Figure 12.2: Relative sizes of seven common tuna, with the Atlantic Bluefin Tuna (top) at about 8 ft (2.4 m) in this illustration. NOAA Central Library Historical Fisheries Collection, 1950–60s. Public domain. https://commons.wikimedia.org/wiki/File:Tuna_Relative_Sizes.jpg.

Figure 12.3: Tuna trap affixed to the sea bottom showing the long lead net to intercept migrating tuna and several chambers. NOAA, unknown date. Public domain. https://web.archive.org/web/20180413120529/http://www.photolib.noaa.gov/htmls/fish2059.htm.

Figure 12.4: Photo of Yellowfin Tuna caught in the Seychelles. Seychelles Nation, 2017. CC BY 4.0. https://commons.m.wikimedia.org/wiki/File:Yellow_fin_tuna_caught_in_Seychelles.jpg.

Figure 12.5: Representation of the flow of products, information, and coordination in the tuna supply chain. Kindred Grey. 2022. Adapted under fair use from "Developing a Traceability System for Tuna Supply Chains," by Marimin Marimin (2017). https://www.researchgate.net/publication/320262859_Developing_a_Traceability_System_for_Tuna_Supply_Chains.

Figure 12.6: Trend in per capita consumption of canned tuna in the United States. Kindred Grey. 2022. CC BY 4.0. Data from USDA, 2018. https://www.ers.usda.gov/webdocs/DataFiles/50472/mtfish.xls?v=0.

Figure 12.7: Charlie the Tuna character appears on a can of StarKist® tuna. Kai Schreiber, 2006. CC BY-SA 2.0. https://flic.kr/p/c6uR9.

Figure 12.8: Top tuna fishing nations based on landings of seven tuna species in 2018. Kindred Grey. 2022. CC BY 4.0. Data from "Netting Billions: A Global Valuation of Tuna," by Macfadyen et.al., 2020. Page 9. https://www.pewtrusts.org/-/media/assets/2020/10/poseidon_tunavalue_technicaldocuments_merged_final.pdf.

Figure 12.9: Fishermen catching Skipjack Tuna using pole and line fishing in the Maldives. Paul Hilton, 2008. CC BY-SA 3.0. https://commons.wikimedia.org/wiki/File:GP01PJT.jpg.

Figure 12.10: Atlantic Bluefin Tuna, *Thunnus thynnus*. It is also known as Bluefin Tuna, *toro*, Giant Bluefin, and Northern Bluefin

Tuna. NOAA, unknown date. Public domain. https://commons.wikimedia.org/wiki/File:Bluefin-big.jpg.

Figure 12.11: A tuna seller at Japan's Tsukiji Market, the biggest wholesale fish and seafood market in the world. User: Fisherman, 2006. CC BY-SA 3.0. https://commons.wikimedia.org/wiki/File:Tsukiji_Fish_market_and_Tuna.JPG.

Figure 12.12: Landings of Atlantic Bluefin Tuna from 1950 to 2020 (Sun et al. 2019). Kindred Grey. 2022. CC BY 4.0. Adapted from "More Landings for Higher Profit? Inverse Demand Analysis of the Bluefin Tuna Auction Price in Japan and Economic Incentives in Global Bluefin Tuna Fisheries Management," by Sun et. al., 2019. CC BY 4.0. https://doi.org/10.1371/journal.pone.0221147.

Figure 12.13: Estimated spawning biomass of western and eastern stocks of Atlantic Bluefin Tuna since 1950. Kindred Grey. 2022. CC BY 4.0. Data from "Atlantic Bluefin Tuna: A Novel Multistock Spatial Model for Assessing Population Biomass," by Taylor et. al., 2011. CC BY 4.0. https://doi.org/10.1371/journal.pone.0027693.

Figure 12.14: Demand curves for Veblen or luxury goods (top portion) and normal goods (bottom portion). Kindred Grey. 2022. CC BY 4.0.

Figure 12.15: A tuna fisherman entering data on local tuna catch with a digital device. USAID Digital Development, 2018. CC BY 2.0. https://flic.kr/p/2mAoAXW.

Figure 12.16: Bioaccumulation and biomagnification of mercury in water, primary producers, and three trophic levels. Kindred Grey. 2022. CC BY-SA 4.0. Includes "Drop of Water," by Marco Livolsi, from Noun Project (Noun Project license); "Mixed Phytoplankton Community Coloured," by Tracey Saxby, from https://ian.umces.edu/media-library/mixed-phytoplankton-community-coloured/ (CC BY-SA 4.0); "copepod2," by Jane Hawkey, from https://ian.umces.edu/media-library/copepod2/ (CC BY-SA 4.0); "*Brevoortia tyrannus* (Atlantic Menhaden)," by Tracey Saxby, from https://ian.umces.edu/media-library/brevoortia-tyrannus-atlantic-menhaden/ (CC BY-SA 4.0); and "*Thunnus albacares* (Yellowfin Tuna)," by Tracey Saxby, from https://ian.umces.edu/media-library/thunnus-albacares-yellowfin-tuna/ (CC BY-SA 4.0).

Figure 12.17: D. G. Webster, PhD. Used with permission from D. G. Webster. CC BY-ND 4.0.

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13. Grouper and Spawning Aggregations

Learning Objectives

- Describe the life history, characteristics, habitats, and behaviors of grouper that influence their vulnerability to overharvest.
- Define the many roles of grouper in the ecosystem.
- Recognize how conspicuous consumption patterns contribute to overfishing in grouper.
- Describe movements of different stages in the grouper life cycle.
- Suggest appropriate management strategies to restore overfished grouper populations.

13.1 The Grouper: Their Remarkable Life History and Behavior

Grouper are a diverse group of marine fish, which are characterized by their large size and relatively low reproductive rates. The common name, grouper, applies to 175 fish species in the family Epinephelidae, formerly tribe Epinephelini under subfamily Epinephelinae and family Serranidae (Sadovy de Mitcheson and Liu 2022). In other parts of the world, grouper are variously called *cabrillas*, *garropas*, *gropers*, *lapu-lapu*, *pugapo*, *hapuku*, or *hammour*. The name "grouper" is believed to derive from the Portuguese *garoupa*. There are sixteen genera of grouper, the most diverse being *Epinephelus* with 87 species and *Mycteroperca* with 15 species. Some smaller species of grouper are classified in several other genera, such as *Alphestes*, *Cephalopholis*, *Cromileptes*, *Dermatolepis*, and *Variola*.

One allure of the grouper is the massive size reached by some species. The taxon includes the largest of all reef fish (among teleosts), the Giant (*Epinephelus lanceolatus*), the Pacific Goliath (*E. quinquefasciatus*), and the Atlantic Goliath (*E. itajara*) Grouper that can exceed 2 m in total length, although few exceed 1 m (Craig et al. 2011). The Giant Grouper grows up to 2.7 m (8.9 ft) in length and 400 kg (880 lbs) in weight.

The morphologies of grouper are similar in that they typically have a stout body, large head, and large mouth with impressive suction volume. The body form allows them to act as **rover** predators or ambush predators, usually swallowing a single large prey whole.

Many, but not all, grouper are **protogynous hermaphrodites**, which means that they first mature and reproduce as females and then transition to males later. Consequently, the sex ratio is typically skewed in favor of females, especially in exploited populations. Large males maintain territories on the coral reefs, rocky outcroppings, or artificial reefs, while females may remain at shallower depths before migrating to these sites during the spawning season. Juvenile grouper typically have a different color pattern and occupy different habitats than adults. They have an **episodic** life history strategy, with many small offspring, slow growth, late reproduction, large size, and long life spans (Kindsvater et al. 2017; Figure 13.1).

One of the common behaviors of grouper is the formation of large spawning aggregations that occur at consistent locations at specific times of year, times of day, and phases of the moon. Spawning aggregations serve to synchronize spawning time and maximize fertilization success. Elaborate courtship behaviors have been observed during spawning (Erisman et al. 2007), which often occurs near sunset, presumably to minimize mortality of the pelagic eggs from visual predators. Grouper spawning aggregations are also a strong draw for SCUBA divers in many popular tourist destinations, including Palau, Belize, and French Polynesia. Despite the many ecological, social, and economic benefits provided by the grouper, there is often little government interest in management and documenting landings and values in the many small island states. Furthermore, there have been too few studies on effects of pollutants, habitat degradation, and climate change on grouper populations.

13.2 Grouper Habitats

Figure 13.1: Red Grouper (Epinephelus morio) is commonly caught by recreational and commercial fishers from southern Brazil to North Carolina, including the Gulf of Mexico and Bermuda. Long description.

Grouper typically occupy coral and rocky reefs found predominantly in tropical and subtropical areas of the Atlantic and Indo-Pacific regions (Craig et al. 2011; Sadovy de Mitcheson and Liu 2022). Most occur in relatively shallow coastal waters where they are easily fished by locals familiar with the reef structure, but some species extend farther offshore on deeper reefs down to about 300 meters. Like many coral reef fish, adult and juvenile grouper often use very different habitats that are threatened from human modification (Sambrook et al. 2019). Managers must protect the connected, interacting collections of **juxtaposed** habitat patches to preserve the life cycle of grouper (Mumby 2006). It's a truism in fish conservation that to conserve fish species, we must conserve their habitat. However, the reality of habitat conservation is for more complex because habitats are dynamic and vary in space and time.

The Atlantic Goliath Grouper is a case in point (Figure 13.2). Their eggs are pelagic, and developing embryos are transported via currents to shallow-water habitats, such as mangroves and seagrass meadows, where they first settle in mangrove leaf litter (Lara et al. 2009). The juvenile habitats are essential for growth and survival to maintain steady recruitment of new adults to the coral reefs. However, these shallow-water habitats are often degraded or transformed to less-productive habitats (Valiela et al. 2001; Aronson et al. 2003; Coté et al. 2005; Waycott et al. 2009; McKenzie et al. 2020). Some grouper make long migrations between nursery habitats and reefs (McMahon et al. 2012). Coral reefs throughout the world are changing due to overfishing, climate change, water quality, ocean acidification, and coral diseases and bleaching (Arundsen et al. 2003). Any declines in coral reef fish or invertebrates directly limit the food base for adult grouper (Russ et al. 2021). Consequently, the recovery of overfished populations, such as the Goliath Grouper populations in Florida, depends on availability of high-quality mangrove habitat in southwest Florida as well as controls on harvest (Koenig et al. 2007; Shideler et al. 2015b).

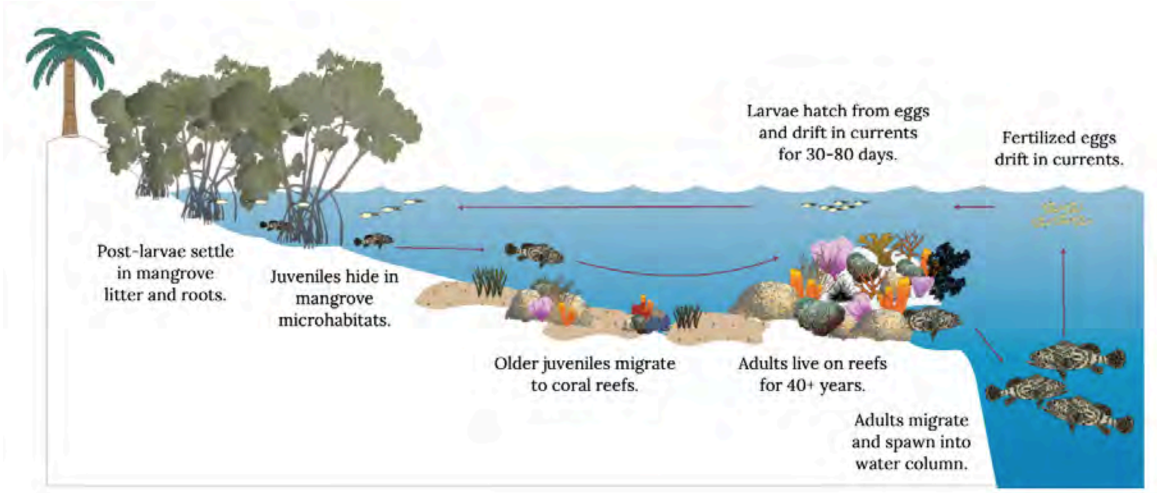

Figure 13.2: Conceptual diagram illustrating the Goliath Grouper life cycle and movement of various life stages throughout the nearshore and reef environments. Long description.

13.3 Spawning Aggregations and Implications for Fishing

If slow life history and high value create a double jeopardy for grouper, one additional trait adds a triple jeopardy condition. Grouper display spawning aggregations, temporary gatherings of large numbers of grouper for spawning at specific times and places. Location and timing are known by local fishers. In some species, aggregations may be transient—that is, made up of fish that travel long distances and persist for only days or weeks. Others are resident spawning aggregations that involve fish that travel short distances and persist for minutes or hours. These resident aggregations are often timed during the winter full moon (Colin 1992). Male grouper typically arrive at the site first and spend longer than females. Strong spawning-site **fidelity** is displayed by grouper. One individual returned to the very same spawning site for eight consecutive years (Washckewithz and Wirtz 1990).

These spawning aggregations make grouper extremely vulnerable at the same time that reproductive values are highest (Erisman et al. 2017). As grouper move around, local fishers learn their patterns and can use GPS (global positioning systems) to relocate these spots and target the spawning aggregations. Fisher knowledge influences the extent to which aggregations are perceived as predictable (Robinson et al. 2015). In some cases, fishers have known for centuries where and when aggregations form (Erisman et al. 2017). More of the grouper population can be harvested when fish aggregate to spawn. It's a phenomenon that fisheries professionals have named *hyperstability* (Erisman et al. 2011). Because fishermen can't catch them fast enough, the catch per unit effort remains high even as populations plummet. This results in faulty information on the abundance of grouper stocks (Robinson et al. 2015). Heavy selective fishing pressure on grouper aggregations removes mature older individuals (Coleman et al. 1996). In the case of the Nassau Grouper (*Epinephelus striatus*), declines were first noticed when spawners failed to show at historical spawning aggregation sites (Coleman et al. 1996; Aguilar-Perera 2006; Aguilar-Perera et al. 2014).

Therefore, effective management requires understanding and consideration of life history and ecological and **socioeconomic** drivers, as well as strong enforcement of fishing regulations. Active spawning aggregations, due to their discrete nature and high productivity, are clearly important source areas for grouper populations. Hence, these isolated sites support abundance of grouper and represent focal points for establishing no-kill marine reserves (Sadovy and Domeier 2005; Sadovy de Mitcheson 2016; Paxton et al. 2021).

13.4 Grouper and Ecosystem Services

Grouper provide many direct and indirect services in coral reef ecosystems. Spawning aggregations have indirect effects on marine ecosystems. Egg boons are the large, though temporary, egg concentrations that provide highly nutritious fatty acids and support multiple trophic levels (Figure 13.3; Fuiman et al. 2015). Whale sharks also aggregate seasonally to feed on eggs from fish spawning aggregations, attracting tourism that depends on conservation and provides economic returns far more valuable than the capture fisheries (Colman 1997; Sala et al. 2001; Heyman et al. 2001, 2010). Loss of grouper translates to a loss of trophic redistribution via egg boons.

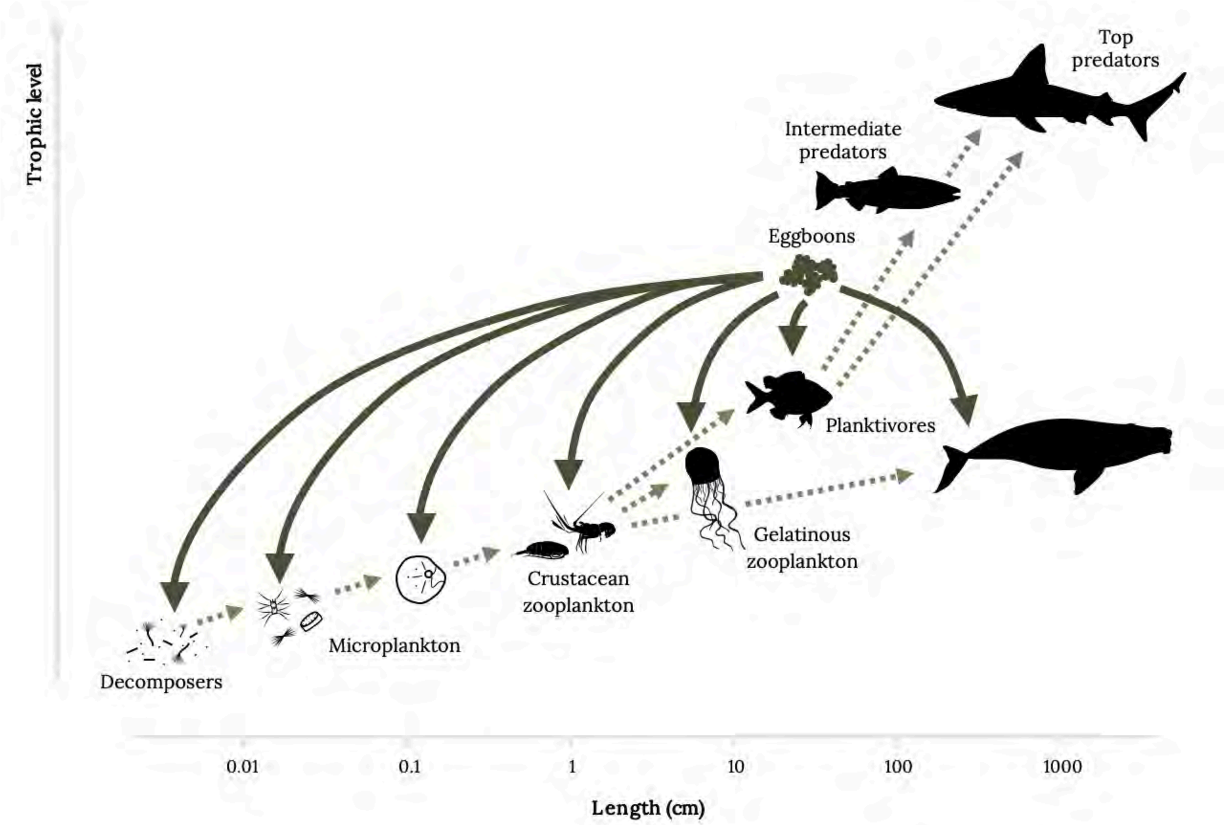

Figure 13.3: Flow energy from grouper eggs to components of the coral reef ecosystem (solid arrows) and trophic transfers through the food web (dashed arrows). [Long description](#).

Grouper are among the largest apex predators on coral reefs and are critical for balancing the abundance of many other fish (Hensel et al. 2019), typically damselfish (Pomacentridae) and wrasses (Labridae). Grouper predation may provide some level of biocontrol for invasive lionfish (Maljkovic et al. 2008; Mumby et al. 2011). Spawning aggregations also support high local abundance of sharks (Mourier et al. 2016). Some grouper species, such as the Red Grouper (*Epinephelus morio*), create habitat structure by clearing away sediment, thereby creating refuges for other fish and invertebrates from predation in these complex habitats (Coleman et al. 2011).

As large predators, grouper contribute to overall high fish abundance, especially on complex reefs (Hensel et al. 2019). Removal of predators from coral reefs releases many invertebrates from predation control. For example, the Crown-of-Thorns Starfish (*Acanthaster planci*) increased threefold after a 61% decline in reef fish predators, resulting in a reef dominated by turf algae instead of reef-building corals (Dulvy et al. 2004).

Grouper also display unique collaborative hunting behavior with moray eels. When hungry, the grouper will approach the moral eel with a head-shaking gesture, signaling "Let's hunt together." The grouper and moray eel then hunt together to facilitate more frequent prey capture. The large-bodied, slow-moving predators use burst speed and vacuum action of the large buccal cavity to capture fish chased out of crevices of coral reefs (Bshary et al. 2006).

13.5 Fisheries, Management, and Conservation Status of Grouper

Grouper are among the most heavily exploited high-priced reef fish. They have excellent white meat flesh with a light, sweet taste and large chunky flakes that work well with any cooking method. As one of the best ocean fish to eat fresh, grouper are highly sought after by commercial, recreational, and subsistence fishers. They are typically sold fresh in local seafood markets, where they are often the highest-priced fish. They are also part of the live reef fish trade in Southeast Asia, where plate-sized fish may sell for $180 per kilogram.

The annual market value of grouper worldwide has been estimated between U.S. $350 million (Pauly and Zeller 2015) and $1 billion (Sadovy de Mitcheson et al. 2020). However, the economic value of live Nassau Grouper for tourism was 20 times higher than the landed value (Sala et al. 2001). Recreational fishing for grouper is worth hundreds of millions of U.S. dollars in the Gulf of Mexico, where they are often one of the top targets of recreational fishers (Southwick et al. 2016).

Factors such as distance to fish markets and local human population density are often associated with overfishing. Early investigators revealed that many grouper populations displayed signs of both growth overfishing and recruitment overfishing and called for management interventions (Sadovy 1994). Local fishers may assist in instituting restrictions to conserve these most vulnerable populations because they know the time and location of spawning aggregations. Effective management of grouper requires understanding and consideration of their life history and ecological and socioeconomic drivers.

Grouper are caught by gill nets, hook and line, spears, trawls, and traps. There are only a few species that are well studied, and remarkably few official landing records exist for many small-scale grouper fisheries in some tropical and subtropical nations. Lack of detailed catch and effort data makes the assessment of risks of overfishing these valuable fish quite challenging. Larger more economically valuable grouper are often overfished, and fishers switch to harvesting other fish, including smaller grouper species. Partnerships of local fishers and scientists are essential to restore local populations, such as the Nassau Grouper and Atlantic Goliath Grouper. Often the only available information is from recollections of fishers who report that grouper catches were abundant many years ago (Aguilar-Perera et al. 2009; Bender et al. 2014; Amorim et al 2018). Without detailed monitoring, managers must struggle to manage without a fair determination of historical baseline conditions (Bunce et al. 2008; Knowlton and Jackson 2008; Pinnegar and Engelhard 2008).

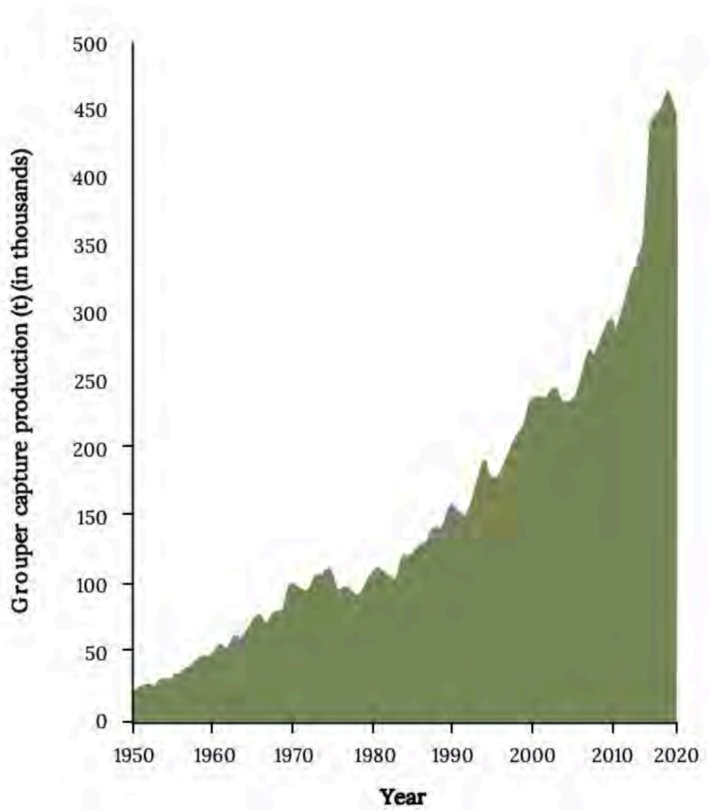

Figure 13.4: Grouper capture fisheries catches reported to FAO from 1950 to 2018. Long description.

At least 35 different species are harvested to support small-scale, localized commercial and recreational fisheries. Since 1950, the global catches of grouper have increased about 30 times (Figure 13.4). Since the 1980s, most of the catch and the increase was from Asian countries, which accounted for more than 80% of recent landings. Indonesia and China have the largest grouper landings. Many countries that harvest them vastly underreport landings to the FAO. Landings from Cuba, which once had a productive grouper fishery, declined since the 1990s (Claro et al. 2009). Landings in North, Central, and South America are an order of magnitude lower than Asia's. Therefore, the USA is a net importer of grouper (Sadovy de Mitcheson and Yin 2015). Consequently, as demand increased, many local fishing communities have seen rapid depletion and overfishing (Coleman et al 2000; Sadovy de Mitcheson et al. 2013).

Vulnerability to overfishing is related to ease of capture and a slow life history. For many of the larger grouper species, the combination of slow growth, long life (exceeding four decades), late sexual maturity (up to eight years), and strong site fidelity contribute to this vulnerability. They can easily be approached by divers and captured by spear, hook and line, and even cyanide (Wilcox 2016). Fisheries target adults that are marketed directly for food, as well as juveniles for mariculture grow-out operations (Sadovy and Pet 1998). Catches of many species have declined, and there is "no sign of any slowing down" of declines (Sadovy de Mitcheson et al. 2013). In response to reduced grouper supplies, restaurants often substitute other, less-expensive fish, prompting development of quick **assays** to identify mislabeled species (Ulrich et al. 2015).

If slow life history and high value create a double jeopardy for grouper, one additional trait creates a triple jeopardy condition. Grouper spawning aggregations, as noted, make them extremely vulnerable at the same time that reproductive values are highest. Furthermore, fishing can cause rapid depletion of sex-changing species due to selection for large adults. Males are usually larger, older, and less numerous than females. Recruitment in grouper is highly variable, and loss of reproductive potential has long-term consequences (Chong-Montenegro and Kindsvater 2022).

There is no question that fishing is the major factor driving grouper stocks on the downward spiral, but those that have large spawning aggregations are most vulnerable to declines (Coleman et al. 1996; Asch and Erisman 2018; Sadovy de Mitcheson et al. 2020). Because it takes a long time for scientists to obtain needed life history information, fisheries-independent survey data, and catch history, grouper populations may be overfished long before data are even available for a stock assessment. Without formal stock assessments, general indicators of population status are based on catch trends. Very few grouper stocks that have spawning aggregations are managed sustainably. In a recent global analysis of the status of populations that form spawning aggregations, 45% were unknown, 33% were decreasing, and 5% were already gone (Figure 13.5). Only 12% had stable populations, and 5% were increasing.

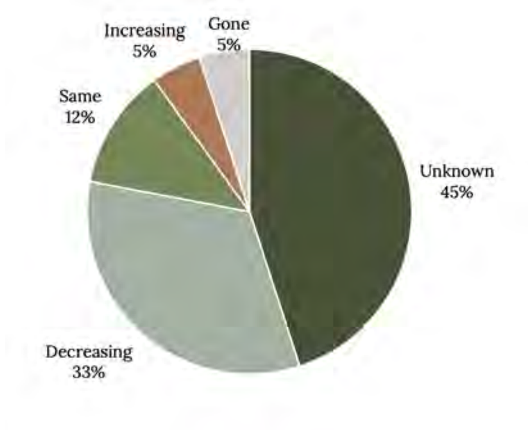

Figure 13.5: Current known status reflecting changes of exploited grouper aggregations globally, as noted by fisher interviews, monitoring, or underwater surveys (N = 509). Long description.

Of the 167 species of grouper, 9.6% are vulnerable, 4.8% are near threatened, 1.2% are endangered, and 0.6% are critically endangered (Figure 13.6). The majority of species (68.9%) are classified as least concern and 15% are data deficient, with insufficient data for classification. The larger (>50 cm total length) and long-lived (>20 years) species of grouper that also had smaller geographic ranges were most likely to be endangered or critically endangered (Luiz et al. 2016). Market prices for grouper are escalating, and other lower-valued fish are often mislabeled or substituted.

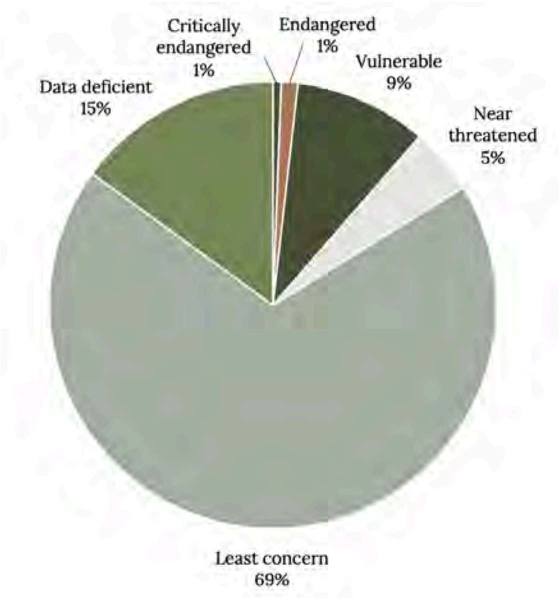

Figure 13.6: Categories of all grouper species (N = 167) *according to the IUCN Red List (IUCN Red List Assessments, updated November 2018).* Long description.

To protect grouper from overfishing, many measures are being implemented, such as minimum and slot-size limits, recreational bag limits, commercial fishing quotas, gear and seasonal controls, marine protected areas, and limited entry (Rocklin et al. 2022). The effectiveness will depend on traits of the species and the local context. Regulations to prevent marketing of undersize fish will mitigate growth overfishing. Allowing smaller fish to reach maturity at least once before harvest will mitigate recruitment overfishing. Size-limit regulations focused on protecting spawning-size fish may be ineffective for deepwater recreational fishing. Grouper have a physoclistous (i.e., closed) swim bladder, making them particularly susceptible to ruptured swim bladders, bloating, stomach distention, and protruding eyes caused by rapid decompression when hauled to the surface (Brulé et al. 2015). The proportion of grouper with distended stomachs was 70% in one study of commercial hook-and-line fishing and as high as 95% for Red

Grouper in water deeper than 41 m (Bacheler and Buckel 2004). Consequently, minimum size limits may be ineffective regulations (Rudershausen et al. 2007).

Lack of data collection for many species of grouper leaves important knowledge gaps that prevent effective management. Identifying and protecting sites of known spawning aggregations with closed seasons are recommended to prevent the rapid declines or allow for population recovery (Coleman et al. 2000). Since experienced local fisheries can detect the declines in grouper abundance, the locations of aggregations are often known. No-take marine fishery reserves represent a viable means to protect resources while simplifying enforcement. Grouper show significant increases in size and biomass within no-take marine protected areas (MPAs), especially for smaller and medium-sized species and those that do not migrate (Chiappone et al. 2000; Nemeth et al. 2005; Howlett et al. 2016; Erisman et al. 2017; Belharet et al. 2020; Chollette et al. 2020; Rojo et al. 2021). It takes a long time for them to recover to preharvested levels after full protection, often 20 or more years (Russell et al. 2012).

Because some grouper populations have been exploited for millennia, it is a challenge to establish realistic conservation targets (Guidetti and Micheli 2011). Large individuals are often rapidly **extirpated** from shallow reefs and restricted to deep waters. Coastal fishers usually have detailed knowledge on diet and trophic relationships of exploited fish (Ribeiro et al. 2021). Often the local ecological knowledge of coastal fishers is the only source of information on sites of historical spawning aggregations.

Question to ponder:

Compare and contrast the life history traits of Pacific Salmon with those of grouper. Which traits make each group particularly vulnerable to overfishing?

13.6 Live Reef Fish Trade

A specialty at many top restaurants in some Asian countries is live fish for the consumer to select for their menu item. The live reef food fish trade has a long history, but it has grown substantially since the 1990s as the number of superaffluent people in Asia grows. Improved airline connections also spurred the expansion, allowing for the more rapid transport necessary for live animals. The destination for the live reef fish trade is centered in Hong Kong, which has more billionaires than any other city (Philips et al. 2008). In 2017, the financial center of Hong Kong posted rapid growth in its ultrawealthy population to overtake the New York metropolitan area as the world's largest ultrawealthy city (Wealth-X 2018). The Asian affluent are outgrowing the conventional definitions of luxury. It's not just about owning luxury materials but often more importantly experiencing it—often before others do. Plate-sized live grouper held for sale at restaurants are examples of what economists call Veblen goods (Veblen 1912). Unlike normal supply-demand relationships, even as the price of Veblen goods increases, the demand increases. High prices associated with certain size classes and species may make it worthwhile for fishermen to focus their fishing effort on that size class.

Harvest of live grouper to meet the demands of the live reef fish trade is primarily in the Coral Triangle region (Sadovy de Mitcheson 2019). This is one of the most important reef systems in the world, encompassing Indonesia, Malaysia, the Philippines, Papua New Guinea, the Solomon Islands, and Timor-Leste. Indonesia and the Philippines are the largest exporters of grouper (Khasanah et al. 2020). The coral reef fishers learn to "free the size that does not pay" and are able to be very selective by choice of hook, location, and depth. The supply chain for the live reef fish trade is not well monitored from the fisher to first buyers, exporters, importers, wholesalers, retailers, and consumers. Up to 80% of the live fish on sale may be juveniles, and many larger species are rare (To and Sadovy de Mitcheson 2009).

The growing demand for live grouper has increased the interest in capture-based culture of the fish. Here, large numbers of juveniles are harvested and raised in cages to the most profitable size (Pierre et al. 2008). This type of fish culture depends on unchecked harvest of juvenile grouper, and the resulting fisheries are likely to be unsustainable (Sadovy de Mitcheson and Liu 2008; To and Sadovy de Mitcheson 2009). The unfortunate reality is that the demand for live grouper for international trade far outstrips the sustainable supply (Sadovy et al. 2003). Strong enforcement of fishing regulations is lacking, and underreporting of harvest is common.

Whether this unique market demand affects profits or fish populations depends on biology, particularly the sex and maturity of the target size. Many grouper populations near Hong Kong were virtually extirpated, forcing suppliers to seek fish from distant locations. Market-driven, size-selective fishing can result in decreases in the catch of large, disproportionately fecund fish—the big old fat fertile female fish (BOFFFFs)(Reddy et al. 2013). A fishery that targets large grouper would influence male abundance, leading to concerns of sperm limitation on productivity (Koenig et al. 1996; Heppell et al. 2006). However, a fishery that targets the plate-size grouper (20–40 cm) is taking subadult fish, which can quickly extirpate local populations (Reddy et al. 2013; Kindsvater et al. 2017). Therefore, these fisheries need strong enforcement of regulations limiting catch of juveniles and adults. While lucrative fisheries target live reef fish markets (Sadovy de Mitcheson et al. 2017), overfishing by harvesting juveniles threatens the livelihoods of many who rely on fish as their primary protein source.

Questions to ponder:

In what ways are the marine tropical fish trade similar to the live reef fish trade? Are there similarities in approaches to regulate these two industries?

13.7 Culture of Grouper

High prices paid for plate-sized grouper and a short **culture** time have driven many Asian countries to invest in culture facilities (Pierre et al. 2008; Tupper and Sheriff 2008). At least 47 species of grouper are raised in culture grow-out pens and fed until they reach a marketable size (Rimmer and Glamuzina 2019). Full life-cycle aquaculture is not yet possible for most species. Rather, juveniles are harvested from the wild at sizes ranging from 2 to 112 cm (Sadovy and Pet 1998).

Mass production of fry from Giant Grouper was first achieved in Taiwan in 1996 and was soon followed by other Asia-Pacific countries. In Taiwan, grouper production depends on hatcheries for approximately two-thirds of its output. Milt from Giant Grouper has been used to fertilize eggs of Tiger Grouper to produce a hybrid (Tiger Grouper ♀ × Giant Grouper ♂). The hybrid has improved growth rate. In Vietnam, hybrid grouper is the second-most-important crop for nursery farms due to strong market demand and sales prices, fast growth rate, and higher survival compared to other grouper crops (Dennis et al. 2020).

Grouper farms employ numerous workers for spawning, larval rearing, and grow-out phases of their operations. The largest production comes from China, Taiwan, and Indonesia (Rimmer and Glamuzina 2019). Although some farms use formulated feed, many still rely on harvesting other marine fish to feed grouper. Disease outbreaks are common and result in reduced survival to market size. Culture of grouper does not reduce fishing pressure on them, and millions of fishers globally will continue to depend on wild capture. The process is a relatively new venture, and prospects are still uncertain (Sadovy and Lau 2002). Yet, recent data shows that about 50% of live grouper imported to Hong Kong are from fish farms (Rimmer and Glamuzina 2019). Future advances in selection of improved strains, first foods, feed formulation, full-life-cycle hatcheries, and water quality enhancements are expected.

13.8 Case Study: Nassau Grouper

The Nassau Grouper (*Epinephelus striatus*) is the most important finfish in The Bahamas and valued culturally, economically, and ecologically. It occurs in rocky bottoms and coral reefs in over 30 countries and territories from the Gulf of Mexico and along the tropical western Atlantic and Caribbean south to Brazil. The name *striatus* refers to the pattern of light background and irregular dark brown bars, which helps it blend into its habitat (Figure 13.7). People in The Bahamas rely on Nassau Grouper as an important food as well as a target for a thriving dive and tourism industry. Grouper supported many Bahamians for centuries, providing over $1 million in landings per year. Nassau Grouper is the essential ingredient in the local comfort food, Bahamian boiled fish, or simply "boil," which is eaten for breakfast, lunch, or dinner.

Figure 13.7: Large Nassau Grouper at The Pinnacle, Saba, Netherlands Antilles. Long description.

Nassau Grouper were once plentiful across shallow coastal zones of Bermuda, Florida, The Bahamas, the Yucatán Peninsula, and throughout the Caribbean. The first-ever eye-witness account described a spectacular gathering of 30,000 to 100,000 large adult Nassau Grouper (Lavett-Smith 1972). Despite an increase in observers, this observation remains the largest grouper aggregation ever recorded. In a six-day survey of this same site 40 years later, only five Nassau Grouper were observed (Erisman et al. 2013). As early as the 1990s, available evidence showed that Nassau Grouper were overfished and many spawning aggregations had disappeared (Sadovy 1994; Aguilar-Perera and Aguilar-Dávila 1996; Chiappone et al. 2000; Claro and Lindeman 2003; Claro et al. 2009; Aguilar-Perera 2014). The collapse of the Nassau Grouper throughout its range was due to overfishing on spawning aggregations (Sadovy and Eklund 1999; Sala et al. 2001; Aguilar-Perera 2006). Historical landing records in The Bahamas and elsewhere show that much of the annual harvests of Nassau Grouper was taken from spawning aggregations during the winter months. The population decline resulted in a drop in commercial landings of 86% over the past 20 years (Sherman et al. 2016). Over 60 Nassau Grouper spawning aggregation sites were identified globally, but many of these have been lost due to overfishing (Sadovy and Eklund 1999; Sadovy de Mitcheson et al. 2008). Nassau Grouper is classified as endangered by the International Union for the Conservation of Nature (Bertoncini et al. 2018) and is listed as threatened under the U.S. Endangered Species Act (81 FR 42268, June 29, 2016).

Nassau Grouper are solitary reef dwellers. However, mature individuals migrate during the full moon to spawning aggregation sites. Movements of Nassau Grouper are highly synchronized to specific spawning sites at predictable times (Bolden 2000; Starr et al. 2007; Stump et al. 2017). First, they leave territories in shallow water near winter full moon, then migrate to their spawning site in water ~100 m deep (Washckewithz and Wirtz 1990). Synchronization is helped by sounds produced by migrating Nassau Grouper (Hazlett and Winn 1962; Rowell et al. 2015). One explanation for the consistency of migration routes and spawning locations is that younger fish learn migration routes from more experienced migrators and their unique sounds. Different color patterns develop when Nassau Grouper are ready to spawn. A bicolor pattern indicates a nonaggressive submissive state acquired by both males and females near the time of spawning. The dark phase is acquired by females who are followed by numerous bicolor fish during courtship (Colin 1992). The courtship occurs in late afternoon, followed by a spawning rush near sunset, where the bicolor female swims upward and releases eggs while the males follow behind releasing sperm (Sadovy and Eklund 1999).

A mix of habitats is important for the life cycle of the Nassau Grouper. After spawning in deep water, their fertilized eggs float and reach the surface within three to five hours of spawning, and newly hatched embryos are also positively buoyant within two to three days after hatching (Colin 1992). Wind-driven currents likely influence the transport of small larvae during the first days after spawning. Larval Nassau Grouper are adapted for life in near-surface waters and have elongated dorsal spines that resemble small underwater kites. Larvae feed on plankton for 35 to 40 days before settling in seagrass meadows, macroalgal beds, or mangrove nursery habitats. Juvenile Nassau Grouper may be supported by feeding on crabs from adjacent seagrass beds (Eggleson et al. 1998). As the young grow, they move to offshore reefs.

Belize was one of the first countries to protect the Nassau Grouper via closed fishing seasons at sites of spawning aggregations. The effect of seasonal closures is evident in comparison of size distributions of exploited sites with unexploited sites (Figure 13.8). Nassau Grouper begin to mature at approximately 48 cm in length, and by the time they reach 56 cm, 75% are mature (Carter et al. 1994; Sadovy and Colin 1995, Sadovy and Eklund 1999). Fishing has eliminated many of the largest and most fertile individuals (Figure 13.8).

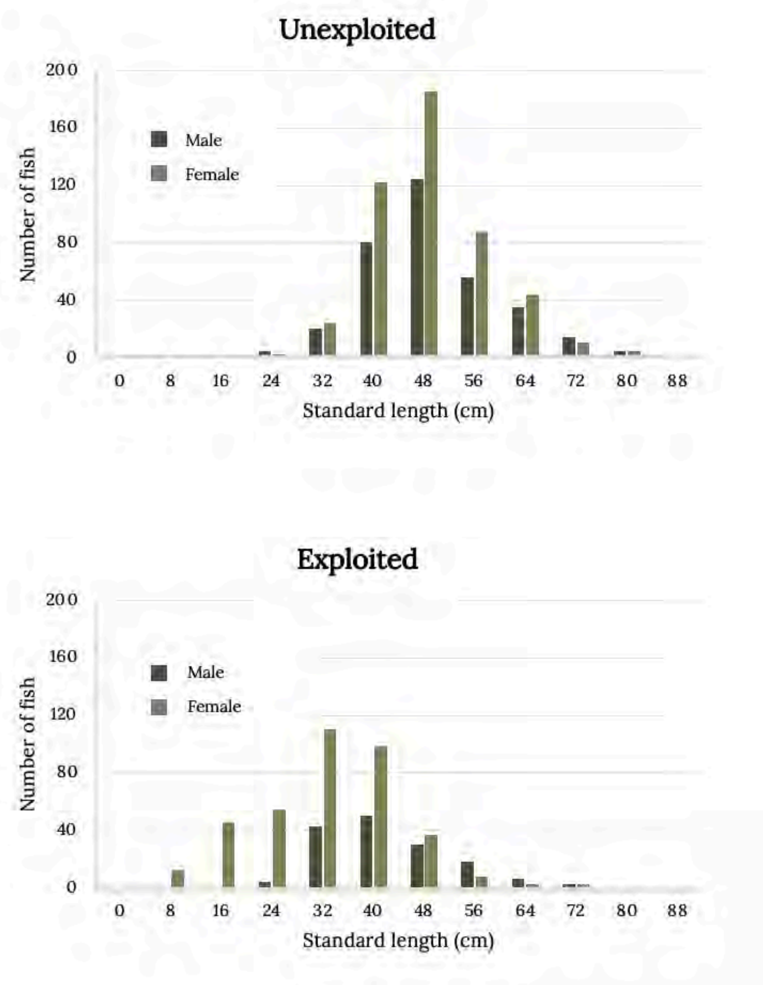

Figure 13.8: Length-frequency distributions by sex for unexploited and exploited sites in Belize. [Long description](#).

In The Bahamas, the fishing industry contributes approximately $85 to 90 million annually, with Nassau Grouper sales of approximately $1.5 million. Nassau Grouper populations are much more abundant in the Exuma Cays Land and Sea Park, where all fishing has been prohibited since 1986. Protection of their spawning aggregations began in 1998 with seasonal closures of two sites during the winter months. During the closed season, the capture or sale of Nassau Grouper is prohibited. Beginning in 2004, the closed season was extended countrywide. By 2010, a majority of the fishers (82%) still had concerns about the future of The Bahamas' Nassau Grouper fishery, as the catch per day remained low (Cheung et al. 2013). Problems with enforcing the seasonal closure and poaching, as well as the introduction of air compressors by spear fishers, meant that they remained overfished in The Bahamas. Existing management measures, such as the small 3-pound (1.4-kg) size limit and noncompliance with fishing regulations in The

Bahamas, likely prevent recovery of these fish (Sherman et al. 2016). Tourist visitation effectively stopped during the COVID-19 pandemic from spring through the autumn of 2020, resulting in an increase in large Nassau Grouper in one marine protected area (Kough et al. 2022).

In 1985, the Cayman Island government, responding to fishermen's concerns over declining numbers and size of Nassau Grouper, restricted fishing on five known spawning aggregations to only residents using hook-and-line gear. In 2003, the government passed legislation to establish no-take during spawning months and bag and slot limits away from aggregation sites in the rest of the year to allow recreational and artisanal catch outside the spawning season.

The protections initiated by the Cayman Islands government resulted in sustained recovery of a population of Nassau Grouper previously on the brink of extirpation (Figure 13.9). More individuals are larger than 65 cm, and spawning biomass and recruitment have increased (Stock et al. 2021). Little Cayman now has the largest-known spawning aggregation for Nassau Grouper, and Cayman Brac is markedly improved (Sadovy de Mitcheson 2020; Waterhouse et al. 2020). Management interventions to safeguard the Little Cayman spawning aggregation provide other countries a ray of hope for grouper recovery.

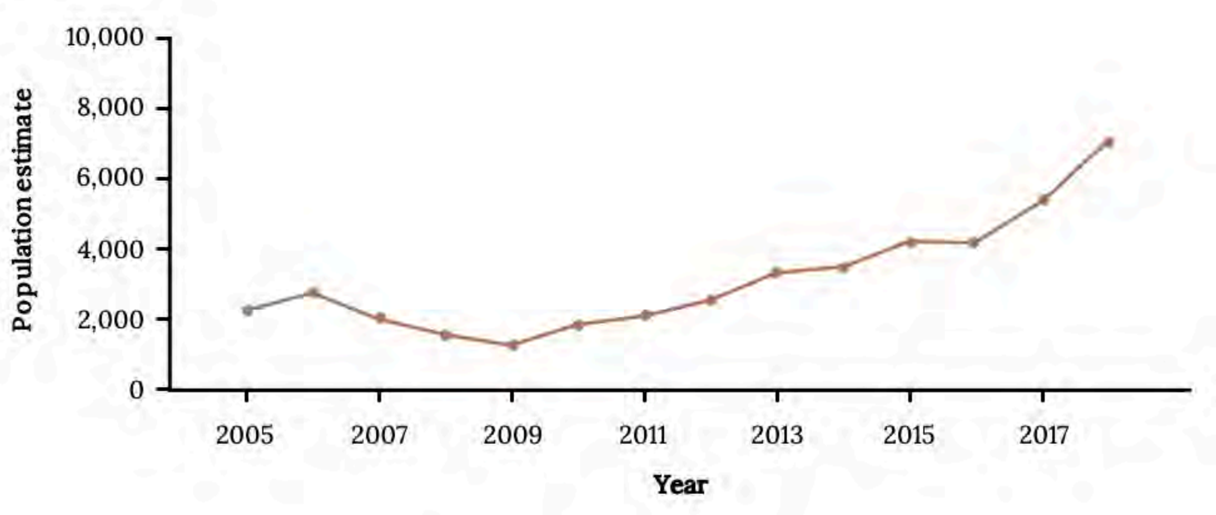

Figure 13.9: Population estimates of Nassau Grouper at the spawning aggregation on Little Cayman Island from 2005 to 2018. Long description.

Strict regulations on fishing can diminish livelihoods of subsistence fishers. Dive tourism may provide alternative livelihoods and mitigate the negative effects of closures for displaced fishers (Sala et al. 2001; Heyman et al. 2010; Usseglio et al. 2016). To learn more about the incredible long-term work underway in the Cayman Islands to protect the Nassau Grouper as part of the Grouper Moon Project, watch the video https://youtu.be/TfsUsCgCH0A.

13.9 Case Study: Goliath Grouper

The Goliath Grouper is the largest grouper in the Atlantic Ocean and one of the two largest species of grouper in the world, reaching ~2.5 m (7–8 ft) in total length. In the western Atlantic Ocean, it ranges from North Carolina to southern Brazil, including the Gulf of Mexico and the Caribbean Sea. Advertisers tout Florida as the only place in the world where Goliath Grouper can be found on a regular basis throughout the year and in their spawning aggregation sites in late summer. Goliath Grouper were intensively overfished long before landing records were kept so that old photographs from fishing marinas provide hints to the past (Figure 13.10). They have several traits that make them vulnerable to overfishing, including high longevity, late maturation, site fidelity, aggregative spawning, and a lack of fear of humans (Sadovy and Eklund 1999).

The largest grouper ever caught and certified by the International Game Fishing Association was a 680-pound (309-kg) Atlantic Goliath Grouper. This record fish was taken off the coast of southern Florida in 1961 after decades of overfishing (McClenachan 2009). One analysis revealed that increasing fishing effort and widespread use of fish finders reduced the abundance of adults to only 5 to 10% of virgin levels (Porch et al. 2006). The Goliath Grouper has been severely overfished throughout its range, and a fishing **moratorium** was initiated in U.S. and state waters in 1990 and throughout the Caribbean in 1993 (Aguilar-Perera et al. 2009). In the Caribbean Sea in Mexico and Belize, few people even remember the presence of this giant fish (Graham et al. 2009; Bravo-Caldero et al. 2021). Similarly, in Brazil even low levels of spearfishing led to depletion of Goliath Grouper, which are considered functionally extinct despite a ban imposed in 2002 (Giglio et al. 2017).

Figure 13.10: A postcard with six large Atlantic Goliath Grouper hanging in front of a sign for the Office Meteor Boat Company, ca. 1940. Haffenreffer Collection.

Goliath Grouper live at least 37 years or more and reach sexual maturity after four years (males) and six years (females) (Bullock et al. 1992). Each year, they migrate to gather in reproductive aggregations of up to 100 individuals. They spawn during the summer (January to March) in the Southern Hemisphere, similar to summer spawning (July to September) in the Northern Hemisphere. Sounds produced serve to synchronize timing of migration (Mann et al. 2009). Juveniles and adults often return to the same site to spawn year after year, making them particularly susceptible to overfishing (Colin 1994). Spawning occurs at night, presumably to avoid egg predation by opportunistic egg predators, such as scad and herring. In many regions, the spawning aggregations are known only from anecdotal recollections by veteran fishers, and others have disappeared without having been documented (Aguilar-Perera et al. 2009; Bueno et al. 2016).

The Origins of the Atlantic Goliath Grouper Common Name

Scientists who describe new species are responsible for giving it a valid Latinized binomial name. According to the International Code of Zoological Nomenclature (ICZN), the first part identifies the genus to which the species belongs, and the second part identifies the species within the genus. Only scientific names are covered by the ICZN. Common, or vernacular, names often vary among regions. In North America, common names are standardized by a committee of the American Society of Ichthyologists and Herpetologists (ASIH) and the American Fisheries Society (AFS). The common name for *Epinephelus itajara* was formerly the jewfish. I observed my first jewfish in the John G. Shedd Aquarium when I was a young boy. I thought it was a strange and nondescriptive name for such a ginormous fish. The historical origins and meaning of "jewfish" are unclear because scientists did not have to explain common names when describing fish species. A story that jewfish were so named because they were an inferior fish, fit only for Jews, persisted since the 1800s (Grossman 2015). The Common and Scientific Names Committee of AFS received complaints about the offensive jewfish name, as well as the squawfish name, derogatory toward women. The Names Committee changed the accepted common name of the squawfish to the pikeminnow in 1998. Soon complaints about the jewfish name led to a formal petition signed by senior fisheries scientists sent to the committee. Clearly names and their meaning have tremendous power, and associating Jews with a large-jawed grouper extended to members of the Jewish faith. After committee deliberations in 2001, they declared that the new accepted common name would be Atlantic Goliath Grouper.

Although most fishing for Goliath Grouper is offshore near reefs and structures, the species is mangrove dependent and shows a distinct size-related habitat shift. Juveniles are found exclusively in spatially complex, fringing Red Mangrove (*Rhizophora mangle*) shorelines (Frías-Torres 2006; Koenig et al. 2007). The mangrove forests support a high diversity of fish and invertebrates and are threatened worldwide. Mangroves create a narrow fringe habitat between land and sea at tropical latitudes (25°N to 30°S). Since 1980, at least 35% of mangrove forests were lost to coastal development (Valiela et al. 2001). High-quality mangrove habitat in southwest Florida is the key to recovery (Frías-Torres 2006; Koenig et al. 2007; Koenig and Coleman 2009). Juveniles spend their first five to six years of life in mangroves, and it was here in the juvenile population that the first signs of recovery appeared (Cass-Calay and Schmidt 2009).

The functional extinction of the critically endangered Atlantic Goliath Grouper in many parts of the range has attracted much attention, and fishing moratoria are common. Recovery of populations depends on conditions in nursery areas (Koenig et al. 2007; Shideler et al. 2015b; Lobato et al. 2016) and far-distant spawning aggregations. Research that combines local ecological knowledge and takes advantage of technologies, such as bioacoustics, biotelemetry, sonar, and remote and autonomous underwater vehicles, may lead to more accurate information on grouper spawning aggregations (Erisman et al. 2017). Photo-identification is widely used for noninvasive mark-recapture analysis and appears to be well suited for the sedentary, large Goliath Grouper in marine parks frequented by divers (Hostim-Silva et al. 2017).

Recovery of the critically endangered Atlantic Goliath Grouper will require actions to (1) protect coastal lagoons with fringing mangrove nursery areas; (2) locate spawning aggregations and learn from traditional ecological knowledge; (3) adopt large no-take protected areas and evaluate diving tourism alternatives (Heyman et al. 2010; Shideler and Pierce 2016); and (4) halt poaching (Giglio et al. 2014). However, given the strict nature of regulations needed, leadership, social networks, and comanagement at the local level are often the glue that will make these conservation plans successful (Gutiérrez et al. 2011).

There are signs of recovery in Florida waters after thirty years of a fishing moratorium on Atlantic Goliath Grouper (Figure 13.11; Koenig and Coleman 2011). Grouper represent only one of many valuable residents of threatened coral reef ecosystems. Restoring coral reef ecosystems will require reducing and reversing carbon emissions that are driving global climate change (Knowlton and Jackson 2008).

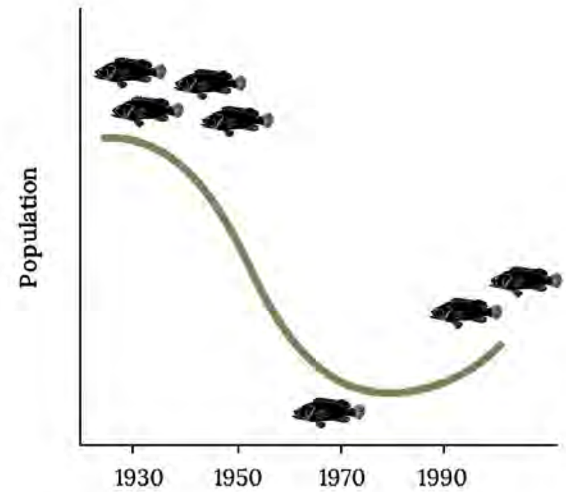

Figure 13.11: Conceptual diagram illustrating the biomass and population numbers of Goliath Grouper in south Florida. Long description.

While full recovery is still uncertain, sport fishers are aware of the increase in large Goliath Grouper. Return of a spawning aggregation near Jupiter, Florida, is one encouraging sign of recovery (Frías-Torres 2013). Many people unfamiliar with the history of changes in Florida reefs now consider Goliath Grouper to be novel and intolerable because of the moratorium on fishing for them. Some recreational anglers called for the lifting of the fishing moratorium. However, the reasons given to support this petition (below) are not supported by scientific evidence (Koenig et al. 2020).

False claims in support of lifting the moratorium:

- Goliath Grouper compete directly with recreational reef fish fishermen for and substantially reduce the populations of grouper and snappers on reefs in south Florida.
- Goliath Grouper are dangerous to divers.
- Goliath Grouper interfere with fishing by taking baited hooks, or hooked or speared fish.
- Goliath Grouper compete directly with lobster fishermen by eating many lobsters in south Florida.
- Goliath Grouper, because of their large size, require huge amounts of food to survive and eat indiscriminately, reducing biodiversity on reefs.
- Our reefs are "out of balance"; Goliath Grouper have to be "thinned out" to regain that balance.
- There must be a periodic kill of hundreds of adult Goliath Grouper to obtain data on size, age, and reproductive condition necessary for stock assessment.

Furthermore, Goliath Grouper hold the unfortunate distinction of having the highest levels of liver and muscle mercury of any commercially important shallow-water grouper species. Mercury levels in the muscle tissues of most adults and many juveniles from Florida samples exceeded safe levels for human consumption (Malinowski 2019). The large size of Goliath Grouper adds to the interest and pressure by sport anglers to lift the current harvest moratorium on them. Divers and scientists, however, oppose lifting the moratorium. Despite opposition by scientists and divers, Florida officials lifted the Goliath Grouper ban in 2022 (Collins 2022). The new rules prohibit spear fishing and limit annual harvest to 300 fish between 24 and 36 inches. Time will tell if the fishery is sustainable.

Grouper spawning aggregations are also a strong draw for SCUBA divers in many popular tourist destinations, including Palau, Belize, and French Polynesia. Consequently, future developments may focus on creating tourist adventures based on diving with grouper. Divers are willing to pay more for Goliath Grouper encounters (Shideler and Pierce, 2016), making them more valuable as diving attractions than for harvest (Shideler et al. 2015a).

***Question to ponder*:**

What do you suspect are the principal reasons for opposing the creation of no-take marine reserves to protect grouper populations?

Profile in Fish Conservation: Yvonne Sadovy de Mitcheson, PhD

Scan the QR code or visit https://doi.org/10.21061/fishandconservation to listen to this Profile in Fish Conservation.

Figure 13.12: Yvonne Sadovy de Mitcheson, PhD.

Yvonne Sadovy de Mitcheson has been Professor at the University of Hong Kong for 30 years and is well known as the foremost expert on grouper conservation and ecology. She teaches many courses that deal with the biology, fisheries management, and conservation of fish. Her research and scholarly writings leave an important global legacy, providing a roadmap for conservation and fisheries management of grouper and other marine fish.

Dr. Sadovy's early studies were based in the Caribbean and represent many of the first investigations into the exploitation of sex-changing coral reef fish, especially grouper that form spawning aggregations. Her first investigations in this region revealed that many grouper populations were overfished and that the monitoring and assessment activities were inadequate. For five years, she served as the Director of the Fisheries Research Laboratory of the government of Puerto Rico and then as biologist with the Caribbean Fishery Management Council of the National Marine Fisheries Service (NOAA, USA).

She is the author or coauthor of more than 160 publications that investigate the biology and conservation of marine fish, with particular emphasis on the grouper and other reef fish vulnerable to fishery exploitation. Studies that focus on the trade in live tropical food and ornamental fish, locally, regionally, and globally, revealed several global threats from fishing. Additionally, she and her collaborators added significantly to our knowledge of reproduction, including sex differentiation, maturation and gonadal development, and age and growth of many reef fish. She spearheaded investigations of the live reef fish markets and trade in Hong Kong and their role in supporting imports of many highly valued species, several of which are threatened. Her efforts led to adoption of scientific protocols for documenting and monitoring fished and unfished grouper spawning aggregations throughout the world.

Yvonne's keen interest in public education on marine conservation issues has expanded the impact of her studies to effect awareness and facilitate policy changes. Professor Sadovy de Mitcheson founded and is currently co-Chair of the IUCN World Conservation Union Specialist Group on Grouper and Wrasses. She shares her expertise with conservation groups such as the World Wide Fund for Nature Hong Kong, Wildlife Conservation Society, TRAFFIC–East Asia, and the Food and Agriculture Organization of the United Nations. She is Director of the Science and Conservation of Reef Fish Aggregations, a nonprofit organization that seeks to raise awareness about the vulnerabilities of fish spawning aggregations and improve their protection and management. This collaborative effort resulted in books including *Reef Fish Spawning Aggregations: Biology, Research and Management*, *Manual for the Study and Conservation of Reef Fish Spawning Aggregations*, and training modules. She coauthored *Groupers of the World: A Field and Market Guide*, which is a comprehensive and colorful description of over 150 species of grouper.

Recent research efforts focused on the development of a scientific model for sustainable exports of the endangered Napoleon Wrasse (*Cheilinus undulatus*), the largest coral reef species and a part of the live reef food fish trade. Her early work on the Nassau Grouper in the tropical western Atlantic was a major impetus for sustainable management planning, and she recently completed a major management plan on this species for FAO. Recently, she has investigated the threats and opportunities for the growing international demand for dried swim bladders and is leading a team to develop a facial recognition app to aid enforcement in the trade for the Napoleon Wrasse.

Key Takeaways

- Large body size, slow growth, high longevity, late reproductive maturity, and the reproductive behavior of forming spawning aggregations all contribute to the vulnerability of grouper stocks.
- Length or creel limits are often ineffective for grouper in deep waters, where they develop barotrauma after deepwater capture.
- Long time periods are required to recover larger grouper species, such as the Goliath Grouper and Nassau Grouper.
- Local management interventions may include bans on fishing during reproductive seasons, marine protected areas, shift to grouper tourism via SCUBA diving, and adopting international standards for the trade in international live reef food fish.
- Poor fisheries governance structures are in place in less-developed countries, and many grouper stocks are data deficient.
- Protective management actions will take decades to evaluate because of the long time to maturity and long recovery times for grouper.
- Goliath Grouper were protected in Florida waters by a fishing moratorium since 1990, and signs of recovery are emerging.

This chapter was reviewed by Felicia Coleman.

Long Descriptions

Figure 13.1: Red Grouper with robust body and small scales. Their head and body are dark reddish brown, shading pink or reddish below with occasional white spots on the sides and black spots on the cheeks. Jump back to Figure 13.1.

Figure 13.2: Diagram of habitats used at different life stages for Goliath Grouper; 1) post larvae settle in mangrove litter and roots; 2) juveniles hide in mangrove microhabitats; 3) older juveniles migrate to coral reefs; 4) adults live on reefs for 40+ years; 5) adults migrate and spawn into water column; 6) fertilized eggs drift in currents; 7) larvae hatch from eggs and drift in currents for 30-80 days. Jump back to Figure 13.2.

Figure 13.3: Length (cm) on x-axis and trophic level on y-axis. From smallest length (0.01 cm) and lowest trophic level to longest length (1000 cm) and highest trophic level: Decomposers, Microplankton, crustacean zooplankton, gelatinous zooplankton, planktivores, intermediate predators, top predators. Eggboons point to all groups except for predators. Jump back to Figure 13.3.

Figure 13.4: X-axis shows years from 1950-2020. Y-axis shows grouper capture production (t) in thousands from 0 to 500. Increases consistently with a higher rate of increase from 2010-2020. Jump back to Figure 13.4.

Figure 13.5: Pie chart shows that status of exploited grouper aggregations is often unknown or declining; gone (5%), unknown (45%), decreasing (33%), same (12%), increasing 5%. Jump back to Figure 13.5.

Figure 13.6: Pie chart shows conservation status of groupers; data deficient (15%), critically endangered (1%), endangered (1%), vulnerable (9%), near threatened (5%), least concern (69%). Jump back to Figure 13.6.

Figure 13.7: Nassau grouper with large eyes and a robust body. Light beige with five dark brown vertical bars, a large black saddle blotch on top of the base of the tail, and a row of black spots below and behind each eye. Jump back to Figure 13.7.

Figure 13.8: Two bar graphs. Standard length (cm) on x-axis from 0-85. Number of fish on y-axis from 0-200. Top graph: Unexploited. There are more females than males for almost every length. 48cm have the most fish (170). Bottom graph: Exploited. There are more females than males for almost every length. 32cm have the most fish (120). Jump back to Figure 13.8.

Figure 13.9: Line graph shows population estimate for Nassau Grouper at Little Cayman from 2005 to 2018. Population grows from 2,000 in 2005 to 7,000 in 2018. Population decreased from 2006-2009. Jump back to Figure 13.9.

Figure 13.11: Diagram of goliath grouper population from 1930-2000. Population is highest in 1930, declines until 1970, then starts to increase again until 2000. Jump back to Figure 13.11.

Figure References

Figure 13.1: Red Grouper (*Epinephelus morio*) is commonly caught by recreational and commercial fishers from southern Brazil to North Carolina, including the Gulf of Mexico and Bermuda. Simões et. al., 2014. CC BY 4.0. https://commons.wikimedia.org/wiki/File:Epinephelus_morio_in_Madagascar_Reef.jpg;

Figure 13.2: Conceptual diagram illustrating the Goliath Grouper life cycle and movement of various life stages throughout the nearshore and reef environments. Kindred Grey. 2022. CC BY-SA 4.0. Adapted from Goliath Grouper Life Cycle, by Jane Hawkey, Integration and Application Network, https://ian.umces.edu/media-library/goliath-grouper-life-cycle/. CC BY-SA 4.0.

Figure 13.3: Flow energy from grouper eggs to components of the coral reef ecosystem (solid arrows) and trophic transfers through the food web (dashed arrows). Kindred Grey. 2022. CC BY-SA 4.0. Adapted from Egg Boons: Central Components of Marine Fatty Acid Food Webs, by Fuiman et. al., 2015. https://doi.org/10.1890/14-0571.1. Includes Mixed Phytoplankton Community Coloured by Tracey Saxby, Integration and Application Network from https://ian.umces.edu/media-library/mixed-phytoplankton-community-coloured/ (CC BY-SA 4.0), Feather duster worm by Diana Kleine, Marine Botany UQ from https://ian.umces.edu/media-library/feather-duster-worm/ (CC BY-SA 4.0), *Paraclanus spp* by Kim Kraeer, Lucy Van Essen-Fishman, Integration and Application Network from https://ian.umces.edu/media-library/paraclanus-spp/ (CC BY-SA 4.0), *Panulirus argus* (spiny lobster): side view by Caroline Donovan, Integration and Application Network from https://ian.umces.edu/media-library/panulirus-argus-spiny-lobster-side-view/ (CC BY-SA 4.0), *Moerisia spp.* (Jellyfish) by Tracey Saxby, Integration and Application Network from https://ian.umces.edu/media-library/moerisia-spp-jellyfish/ (CC BY-SA 4.0), *Chromis chromis* (Mediterranean Chromis) by Tracey Saxby, Integration and Application Network from https://ian.umces.edu/media-library/chromis-chromis-mediterranean-chromis/ (CC BY-SA 4.0), *Carcharhinus plumbeus* (Sandbar Shark) by Tracey Saxby, Integration and Application Network from https://ian.umces.edu/media-library/carcharhinus-plumbeus-sandbar-shark/ (CC BY-SA 4.0), *Oncorhynchus tshawytscha* (Chinook Salmon): adult by Emily Nastase, Integration and Application Network from https://ian.umces.edu/media-library/oncorhynchus-tshawytscha-chinook-salmon-adult/ (CC BY-SA 4.0), *Eubalaena glacialis* (Right Whale) by Jamie Testa, Integration and Application Network from https://ian.umces.edu/media-library/eubalaena-glacialis-right-whale/ (CC BY-SA 4.0), and Turtle eggs by Kim Kraeer, Lucy Van Essen-Fishman, Integration and Application Network from https://ian.umces.edu/media-library/turtle-eggs/ (CC BY-SA 4.0).

Figure 13.4: Grouper capture fisheries catches reported to FAO from 1950 to 2018. Kindred Grey. 2022. CC BY 4.0. Data from The Importance of Grouper and Threats to Their Future, by Yvonne Sadovy de Mitcheson and Min Liu Biology, *in* Ecology of Grouper, 2022. https://doi.org/10.1201/b20814.

Figure 13.5: Current known status reflecting changes of exploited grouper aggregations globally, as noted by fisher interviews, monitoring, or underwater surveys (N = 509). Kindred Grey. 2022. CC BY 4.0. Data from The Importance of Grouper and Threats to Their Future, by Yvonne Sadovy de

Mitcheson and Min Liu Biology, *in* Ecology of Grouper. 2022. https://doi.org/10.1201/b20814.

Figure 13.6: Categories of all grouper species (N=167) according to the IUCN Red List (IUCN Red List Assessments, updated November 2018). Kindred Grey. 2022. CC BY 4.0. Data from The Importance of Grouper and Threats to Their Future, by Yvonne Sadovy de Mitcheson and Min Liu Biology, *in* Ecology of Grouper, 2022. https://doi.org/10.1201/b20814.

Figure 13.7: Large Nassau Grouper at The Pinnacle, Saba, Netherlands Antilles. Aquaimages, 2006. CC BY-SA 2.5. https://commons.wikimedia.org/wiki/File:3846_aquaimages.jpg.

Figure 13.8: Length-frequency distributions by sex for exploited and unexploited sites in Belize. Kindred Grey. 2022. CC BY 4.0. Data from NOAA, 2013. Public domain. https://www.fisheries.noaa.gov/resource/document/nassau-grouper-epinephelus-striatus-bloch-1792-biological-report.

Figure 13.9: Population estimates of Nassau Grouper at the spawning aggregation on Little Cayman Island from 2005 to 2018. Kindred Grey. 2022. CC BY 4.0. Data from Recovery of Critically Endangered Nassau Grouper (*Epinephelus striatus*) in the Cayman Islands Following Targeted Conservation Actions, by Waterhouse et. al., 2020. https://doi.org/10.1073/pnas.1917132117.

Figure 13.10: A postcard with six large Atlantic Goliath Grouper hanging in front of a sign for the Office Meteor Boat Company, ca. 1940. Haffenreffer Collection. Florida Keys History Center, Monroe County Public Library, 2016. CC BY 2.0. https://flic.kr/p/PKAodm.

Figure 13.11: Conceptual diagram illustrating the biomass and population numbers of Goliath Grouper in south Florida. Kindred Grey. 2022. CC BY-SA 4.0. Adapted from Goliath Grouper Population (Florida), by Kris Beckert, Integration and Application Network (2008, CC BY-SA 4.0, https://ian.umces.edu/media-library/goliath-grouper-population-florida/). Includes *Epinephelus itajara* (Atlantic Goliath Grouper) 2 by Kim Kraeer, Lucy Van Essen-Fishman, Integration and Application Network, from https://ian.umces.edu/media-library/epinephelus-itajara-atlantic-goliath-grouper-2/ (CC BY-SA 4.0).

Figure 13.12: Yvonne Sadovy de Mitcheson, PhD. Used with permission from Yvonne Sadovy de Mitcheson. Photo by Alan Lai Kin Lun / Good Show Photography. CC BY-ND 4.0.

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14. Menhaden and Forage Fish Management

Learning Objectives

- Describe the historical development of Atlantic Menhaden fishing.
- Summarize key characteristics of life history and ecological role of Atlantic Menhaden.
- Articulate the special challenges of managing fisheries on small, pelagic forage fish that are low on the food chain and make them vulnerable to both environmental change and overfishing.
- Highlight the false assumptions of single-species management for maximum sustainable yield.
- Explain the benefits of adopting a fishery policy that uses ecological reference points.
- Describe value preferences of key stakeholders in the Atlantic Menhaden fisheries.

14.1 Early Lessons Learned from Menhaden Fishing

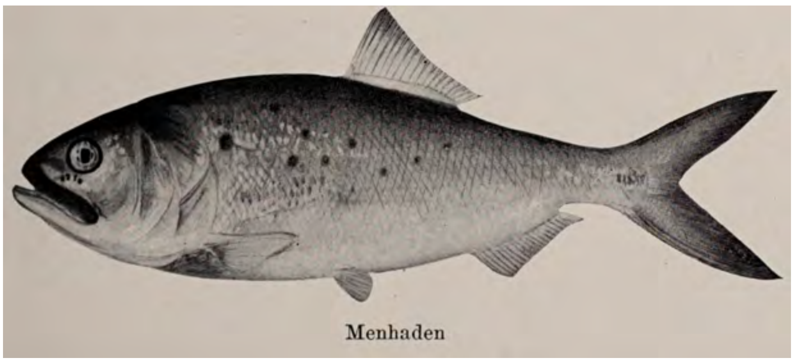

Figure 14.1: Illustration of the Atlantic Menhaden adult.

Indigenous people along the Atlantic Coast and early European colonists relied heavily on abundant Atlantic Menhaden (*Brevoortia tyrannus*) (Figure 14.1). At least 30 popular names are used to describe the menhaden. In Maine and Massachusetts, the names "pogy" and "hardhead" are used. In New York and New Jersey, the name "mossbunker" (with a variety of spellings) is common, whereas in Delaware and Chesapeake Bay, the names "old-wife," "alewife," "greentail," and "bug-fish" are also used. In the Carolinas, they may be referred to as "fat-back," "yellow-tail," or "yellow-tailed shad." "Pogy" and "menhaden" were likely derived from Native American dialects of New England. Somehow, the name "Munnawhatteaûg," which means "fertilizer" or "manure," was corrupted to menhaden. As early as 1661, the name "mossbanker" was in use based on Jacob Steendam's poem "Praise of New Netherland":

The black and rock-fish, herring, mackerel,

The haddock, mossbanker, and roach, which fill

The nets to loathing; and so many, all

Cannot be eaten.

The history of menhaden management reveals challenges of breaking from long-standing traditions in fisheries management. The Atlantic Menhaden was labeled as the “most important fish in the sea” by author and historian Bruce Franklin because of its utility to Native Americans and European colonists in the Atlantic coastal regions (Figure 14.2). Native Americans instructed early colonists how to plant their crops with abundant menhaden as manure. Later, colonists often plowed excess harvest of menhaden in the soil of farms along the shore, until new products utilizing them were discovered, initiating a large industrial fishery.

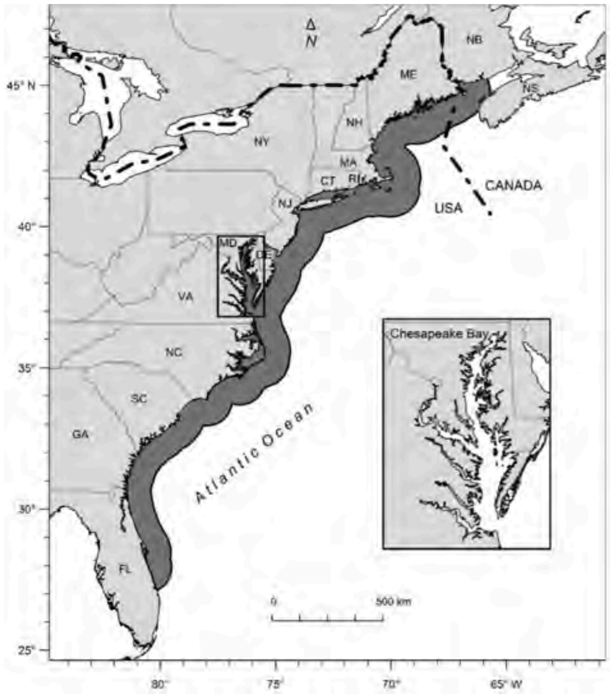

Figure 14.2: Map of the range of Atlantic Menhaden from Nova Scotia, Canada, along the nearshore and coastal waters of the United States Atlantic Coast to Florida.

Soon colonists realized the value of the menhaden as a baitfish, as well as an important source of oil, manure (guano), and **fish meal**. From 1850 to 1870, numerous factories from Maine to North Carolina began to manufacture oil from menhaden. Soon the yield of oil from menhaden would exceed yield of oil from whaling. Fish scrap, or waste after oil was pressed out of the fish, was sold as manure for fertilizer.

A large industry based on menhaden developed along the Atlantic Coast in the late 19th century. Although there were no fishing regulations at the time, the U.S. Oil and Guano Association monitored companies and total catch. By 1876, menhaden yields were 462 million pounds and valued at $1,657,790 (Goode 1880). At the time, Marshall McDonald, Commissioner of Fisheries for Virginia, wrote that “this industry is yet in its infancy.” The early landings exceeded the volume of recent menhaden landings from both the Gulf of Mexico and Atlantic Coast of 1,581,578 pounds, valued at $161 million (National Marine Fisheries Service 2020). Currently, the landings of menhaden are second in volume behind Alaska Pollock, and they are higher than landings of salmon and cod combined. Value of menhaden landings ranks 10th after high-valued seafoods. Estimates from 1878 indicated that 279 sail vessels caught nearly 900 million menhaden, which were processed by 56 factories and yielded 4 million barrels of fish oil and 30,000 tons of guano (Goode 1880).

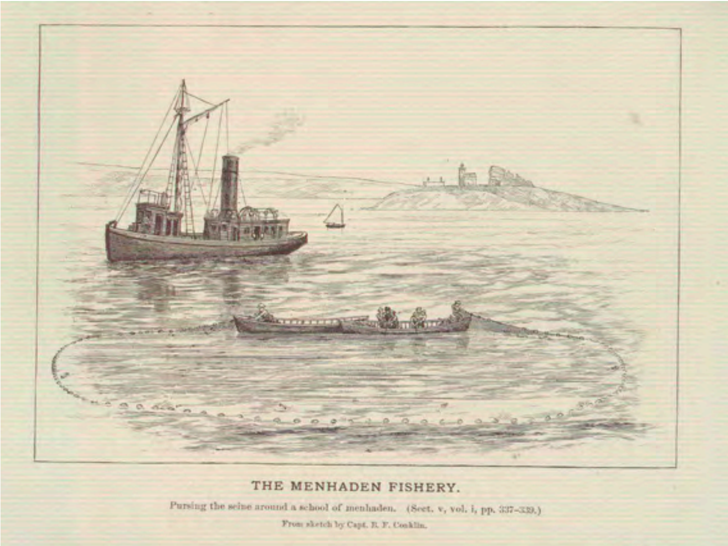

Figure 14.3: Purse seines were adopted early on as a preferred method for harvesting menhaden. Long description.

The reduction factories that were once widespread along the Atlantic Coast were smelly operations. In the 20th century, many states banned them in the interest of coastal development and odor abatement. The only states on the Atlantic Coast that still permit reduction fishing are North Carolina and Virginia. Since 2005, all harvested menhaden are processed at one facility at Reedville, Virginia, owned by Omega Protein, a subsidiary of Canadian-based Cooke Aquaculture. While there are four species of menhaden, the most abundant are the Atlantic Menhaden, distributed from Maine to Florida, and the Gulf Menhaden (*Brevoortia patronus*), distributed in the Gulf of Mexico. Two other species are distributed in the Gulf of Mexico and the Atlantic Coast of Florida.

Early commercial vessels learned that the purse seine is more effective than any other fishing apparatus for catching menhaden (Figure 14.3). A school of almost any size may be surrounded by the net, resulting in a catch composed entirely of menhaden. Factory fleets exclusively rely on the purse seine. Early versions extended 90 to 180 feet below the surface and from 800 to 1,500 feet in length (Goode 1880); some boats carried both long and short purse seines to adapt to the size of menhaden schools.

14.2 Life History of Menhaden

Menhaden have an opportunistic life history strategy, characterized by many small offspring, small body size, rapid growth, early maturity, and short life span relative to other fish. Menhaden spawn offshore from fall through spring, with peak spawning in fall and winter. Atlantic Menhaden exhibit **indeterminate** batch spawning, which means that the eggs in the female continue to mature during the spawning season for release in later spawns. Mature menhaden may spawn up to 10 times per season. The fertilized eggs are small (~1.6 mm), and mature females may produce about 240 eggs per gram of body weight, and sometimes as many as 700. Total **fecundity** is difficult to know because eggs continue to mature during a long spawning season, fish spawn multiple times, and the number of eggs is strongly influenced by menhaden size (Figure 14.4). Because of variability in spawning time and growth, some Atlantic Menhaden may become sexually mature by age 1 (~20–24 cm), while most become fully mature at age 4. In the absence of fishing, Atlantic Menhaden can live 10 to 12 years and attain a length of 38 cm (i.e., 15 inches). The larger menhaden are big enough to become the preferred prey of large Striped Bass and Ospreys.

Eggs are buoyant in sea water and drift with currents. After hatching, the larval (~1–2 cm) and juvenile (~3.0–3.5 cm) Atlantic Menhaden drift with currents, grow rapidly, and return to bays and **estuaries**, which are important nursery areas. After less than one year in bays and estuaries, most of the juveniles return to sea. Atlantic Menhaden grow rapidly in the first year, and the smallest menhaden caught in the fishery will include some age-0 fish. Growth rates are also strongly influenced by densities and water temperature, and high landings in one year may permit faster growth the following year. In addition, wind and climate conditions have a large influence on growth (Midway et al. 2020). Consequently, environmental conditions that lead to large year classes or **year-class** failure may occur at a variety of times and locations.

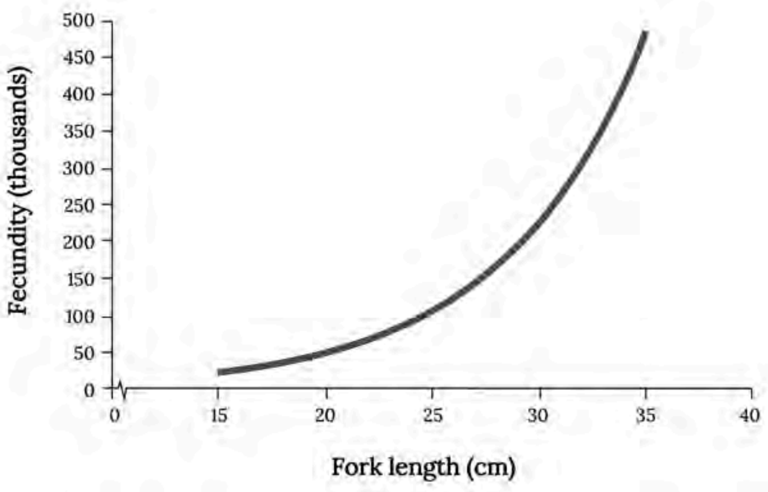

Figure 14.4: Relationship between fork length (cm) and predicted number of ova (fecundity) for Atlantic Menhaden. Ova refers to mature female reproductive cells, which can divide to give rise to an embryo usually only after fertilization by a male cell. Long description.

The life history characteristics result in highly variable **recruitment** where there may be no discernible relationship between abundance of spawners and the resulting recruitment of offspring (Schaaf and Huntsman 1972). Further, the biological reference points used to adjust fishing quotas are also highly uncertain (Schueller and Williams 2017). This means that a harvest quota that was at one time sustainable may lead to the collapse of a fishery after climatic conditions become less favorable for reproduction and growth.

Many other small, **pelagic** fish, such as sardine and anchovy, also support large coastal fisheries that are known to show dramatic fluctuations in abundance. High levels of commercial fishing on these small pelagic fish increase the chance for collapse (MacCall et al. 2016). Well-documented and widespread collapses of Pacific Sardine (*Sardinops sagax*) occurred in the 1940s and again from 2008 to the present. Recruitment in other **clupeiform** (herring-life) fish is driven largely by environmental variation or climatic regime shifts (Essington et al. 2015). For example, Atlantic Menhaden recruitment is strongly influenced by sea surface temperature (Deyle et al. 2018), which leads to high catch variability in the youngest adult age classes and variability in the commercial harvest. Consequently, aspects of the life history of Atlantic Menhaden may translate to poor prediction of trends with classical fisheries models (Szuwalski and Thorson 2017).

14.3 Ecological Role of Menhaden

Atlantic Menhaden swim through the water column with their mouths wide open, thereby trapping food particles on the gill rakers. Gill structures of the Atlantic Menhaden (Figure 14.5) create an effective sieve for efficient filter feeding. Both plant and animal plankton are consumed by Atlantic Menhaden. When smaller, they feed primarily on phytoplankton; however, they shift their diet to primarily consume zooplankton as they grow. By one oft-cited estimate, Atlantic Menhaden are capable of filtering 23–27 liters of water per minute (Peck 1894). Consequently, they manage the large algal bloom occurrences in the bay because they eat vast quantities of phytoplankton, thereby reducing concentrations of nutrients. Watch this video to observe feeding behavior (Filter-Feeding Menhaden Caught on Camera, https://www.youtube.com/watch?v=WhprcLcGGBs).

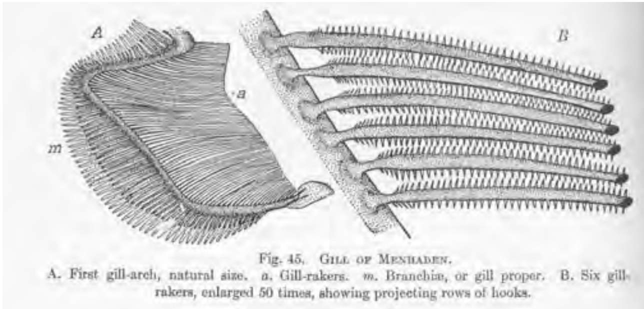

Figure 14.5: Illustration of the (A) first gill arch, showing gill rakers (a) and gill lamellae (m); and (B) enlarged section of six gill rakers, showing fine rows of hooks for filter feeding. Lamellae refers to thin layers of living tissue.

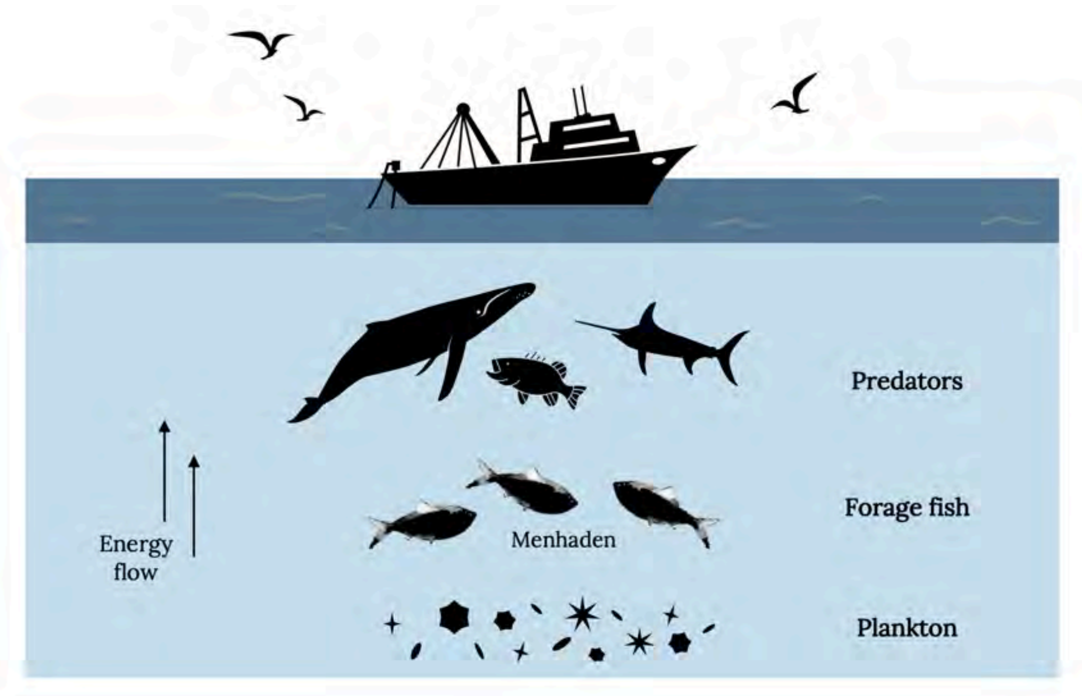

Figure 14.6: Simplified food web showing the links that Atlantic Menhaden provide between plankton and carnivorous animals.

All carnivorous sea mammals, fish, and seabirds are potential predators of menhaden. Consequently, whales, dolphins, sharks, tuna, swordfish, bonito, Striped Bass, Weakfish, Tarpon, and bluefish likely consume large numbers of menhaden. Atlantic Menhaden are an important link between the plankton and numerous carnivorous predators (Figure 14.6).

The feeding behavior of predators on large schools of menhaden provides an impressive display, which is easily seen from a distance. Consider the sharks entering a large school of menhaden captured with this drone-mounted video camera off the coast of New York Hampton in 2017.

Fish predators force the menhaden to move near the surface, where they are more easily eaten by **piscivorous** birds. Ospreys, along with Bald Eagles, feed on menhaden, which are easily captured from the water surface (Figure 14.7). Chesapeake Bay once supported the largest concentration of breeding Ospreys in the world, and breeding populations of both Bald Eagles and Ospreys have been recovering since DDT was banned. The high **lipid** content of Atlantic Menhaden nourishes Ospreys, which breed throughout the coastal waters of the mid-Atlantic and northeastern United States (Spitzer and Poole 1980). One study indicated that Atlantic Menhaden comprised 24% of fish brought to Osprey nestlings in lower estuarine sites (Glass and Watts 2009).

Figure 14.7: Osprey in flight with a menhaden held in its talons.

Until recently, few investigations have quantitatively linked abundance of menhaden predators to their abundance. However, after regulation of the Atlantic Menhaden fishery, the fish rebounded and expanded back into their historic range while Humpback Whales were recovering after the ban on whaling in 1955 (Stevick et al. 2003; Brown et al. 2018; Lucca and Warren 2019). Observations by Gotham Whale (GothamWhale.org), a New York City–based whale research organization, have shown an increase in whale sightings in the New York–New Jersey Bight in the last 10 years (Brown et al. 2022). Watch this video of pilot whales and Humpback Whales feeding on pods of menhaden: Menhaden Conservation Works, New York, by Timothy Del Grosso, https://vimeo.com/239293026.

Black Skimmer, a widely distributed tern-like bird, is uniquely adapted to feeding on surface-dwelling fish. As the bird flies low, its long lower mandible plows the water, snapping the bill shut when it contacts a fish. Black Skimmers consume many species of small fish, and Atlantic Menhaden makes up one-fourth of its diet (Gordon et al. 2000). Watch this video: Black Skimmers–003, 2007, https://www.youtube.com/watch?v=7USpTc6MUoc. Populations of Black Skimmers have declined 86% between 1944 and 2015, leading to its listing as a Species of High Concern for conservation.

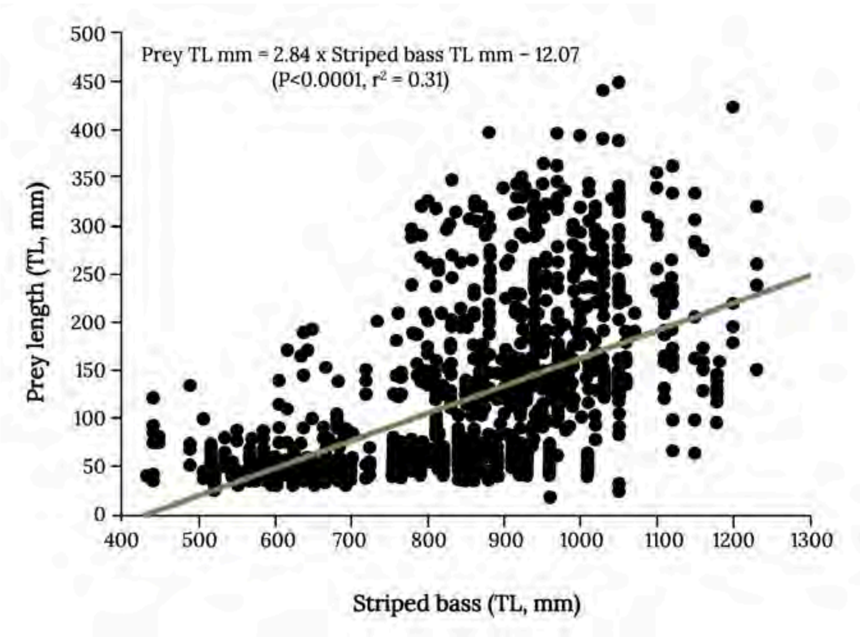

Figure 14.8: Relationship between the size of Striped Bass (total length, mm) and the size of prey fish (total length, mm) consumed.

Strong overlap often occurs with size of forage fish eaten by birds, such as cormorants, boobies, pelicans, and those caught by commercial fishing (Pikitch et al. 2012, 2014, 2018). However, the impact that fishing on forage fish has on their predators will depend on number and types of alternative prey and the size overlap between fish taken by fishing and predators (Hilborn et al. 2017). For example, there is strong overlap with size of menhaden harvested and size eaten by Atlantic Bluefin Tuna. Striped Bass eat a wider range of menhaden sizes, and the larger Striped Bass can eat larger menhaden, which are targeted by commercial fishing (Walter et al. 2003; Overton et al. 2008; Figure 14.8). Watch this video to see Bluefin Tuna feeding on menhaden: Bluefin Tuna Near Shore Attacking Menhaden 2020, https://www.youtube.com/watch?v=e-0JAodI2A0.

***Question to ponder*:**

What considerations are most important when setting Atlantic Menhaden harvest regulations?

14.4 Industrial Fishing, Marine Pelagic Fish, and Menhaden

The industrial menhaden fishery is an example of what is happening in many parts of the world in fisheries that target small pelagic forage fish. Many products are produced from small pelagic forage fish, including canned anchovy and sardine, fish sauce, moisturizers, human health supplements, bait, fish oil, and fish meal. Globally, these marine fisheries are significant sources of livelihood, with over three-fourths of the production coming from developing countries. Fisheries for marine pelagic fish often have low levels of bycatch and greenhouse gas emissions because of the schooling behavior of fish and the use of purse seines that target them. However, some of these pelagic fisheries also take squid, seabirds, mammals, and carnivorous fish, raising concerns from conservationists. Of further concern, demand for small pelagic fish is likely to increase in the future for use in aquaculture feeds (Merino et al. 2010).

Anchovy and sardine, which make up 52% of landings of marine pelagic fish, share a similar life history pattern with Atlantic Menhaden. They produce numerous small offspring, reach a small body size, grow rapidly, mature early, and live a short life. Like menhaden, anchovy and sardine eat phytoplankton and zooplankton at or near the base of the food web by filtering particles or biting individual particles. Sardine and anchovy also have extensive coastwide migrations. These traits mean that marine pelagic forage fish show speedy and sometimes dramatic reactions to environmental change. Furthermore, overfishing and climate change in combination may drive collapse of anchovy and sardine fisheries (Checkley et al. 2017; Izquierdo-Peña et al. 2020).

Figure 14.9: Purse seine boats encircling a school of menhaden.

Because Atlantic Menhaden undergo extensive migrations and are mostly harvested from inshore (state) waters, their management is coordinated through the Atlantic States Marine Fisheries Commission (ASMFC), a deliberative body of fisheries management agencies from the Atlantic Coast states. After Maryland banned the use of purse seines to harvest Atlantic Menhaden in 1931, Virginia and North Carolina were the only states to permit reduction purse-seine fishing. This fishery is concentrated in Virginia waters of Chesapeake Bay and offshore to stay close to the only surviving menhaden reduction plant in Reedville. Large purse seines are used to harvest menhaden for reduction to fish meal to oil (Figure 14.9). Smaller purse-seine rigs, called “snapper rigs,” are used for capture of menhaden for bait. In 1999, the lower Chesapeake Bay was the center of the Atlantic Menhaden fishery, with the bay, Virginia’s eastern shore, and Virginia Beach accounting for 67% of the total harvest of Virginia and North Carolina fleets (Smith 1999).

To assist ship captains in locating schools of menhaden, an airplane pilot in a spotter plane directs the ship’s two smaller purse boats, whose mission it is to trap the fish in an ever-tightening net. A hydraulic rig lifts the net to bring the catch closer to the surface, where a large vacuum hose sucks the fish into the ship’s hold. The crew’s pay is determined by the catch, so fishing crews work from Sunday night to Friday night. The oily catch is unloaded in Reedville each night, after which the crew returns to fishing grounds to catch more menhaden.

14.5 Demand for Products From Small Marine Pelagic Fish

Small marine pelagic fish, often herring or sardine, consume and process marine algae and incorporate omega-3 fatty acids in their bodies. Foods that are high in omega-3 fatty acids are essential for humans because these fatty acids cannot be synthesized in the body. Therefore, they must be consumed in the diet. Omega -3 fatty acids have many effects on the heart and blood vessels of humans, including reduction in **triglycerides**, irregular heartbeat, **arterial** plaque, and blood pressure. Therefore, their health benefits of omega-3 fatty acids have been promoted for heart health in patients with coronary heart disease to reduce the risk of heart attacks (Manson et al. 2020). More recent studies focus on the potential influence of omega-3 fatty acid consumption on cancer, depression, inflammation, cognitive decline, and ADHD (Arellanes et al. 2020).

Demand for small pelagic fish is likely to increase to meet growing demands for bait, aquaculture, and fish oil supplements. Forage fish are captured and sold as bait for sportfishing and crab and lobster traps. Global demand for use of fish meal in aquaculture feeds is rising dramatically, and fish oil is a growing global industry (Merino et al. 2010; World Bank 2013). In 1997, the Food and Drug Administration approved the use of refined menhaden oil for use in foods and supplements. Omega Protein, Inc., which operates the only marine oil refinery in the United States, produces several grades of refined menhaden oil.

Future demands for menhaden soluble fats, oil, and meal, while expected to be higher, are uncertain for several reasons. First, because of rising fish meal costs, feed industries are replacing fish meal with fermented soy and soybean protein concentrates. Globally, a surplus of soy depresses the demand for and price of fish meal. Second, similar products can be naturally derived from other sources. For example, marine algae chorella and spirulina, which can be cultured, are also high in omega-3 fatty acids, minerals, and **antioxidants**. Similarly, krill, **flax**, soybeans, nuts, and other plants also contain high levels. Some food companies are working to create a plant-based oil, LatitudeTM, that is high in omega-3. Finally, since the use of menhaden to produce omega-3 supplements is classified by the FDA as food, there is less regulatory oversight, there are no clinical trials, and supplements may contain harmful levels of mercury, PCBs, and dioxins (Hong et al. 2015; Sherratt et al. 2020).

14.6 Menhaden Population Dynamics

By 1876, menhaden yields already exceeded 200,000 metric tons (Figure 14.10). After World War II, menhaden fisheries went through a boom, bust, and recovery, which forced coastwide coordination of harvest quotas in the 1980s and 1990s.

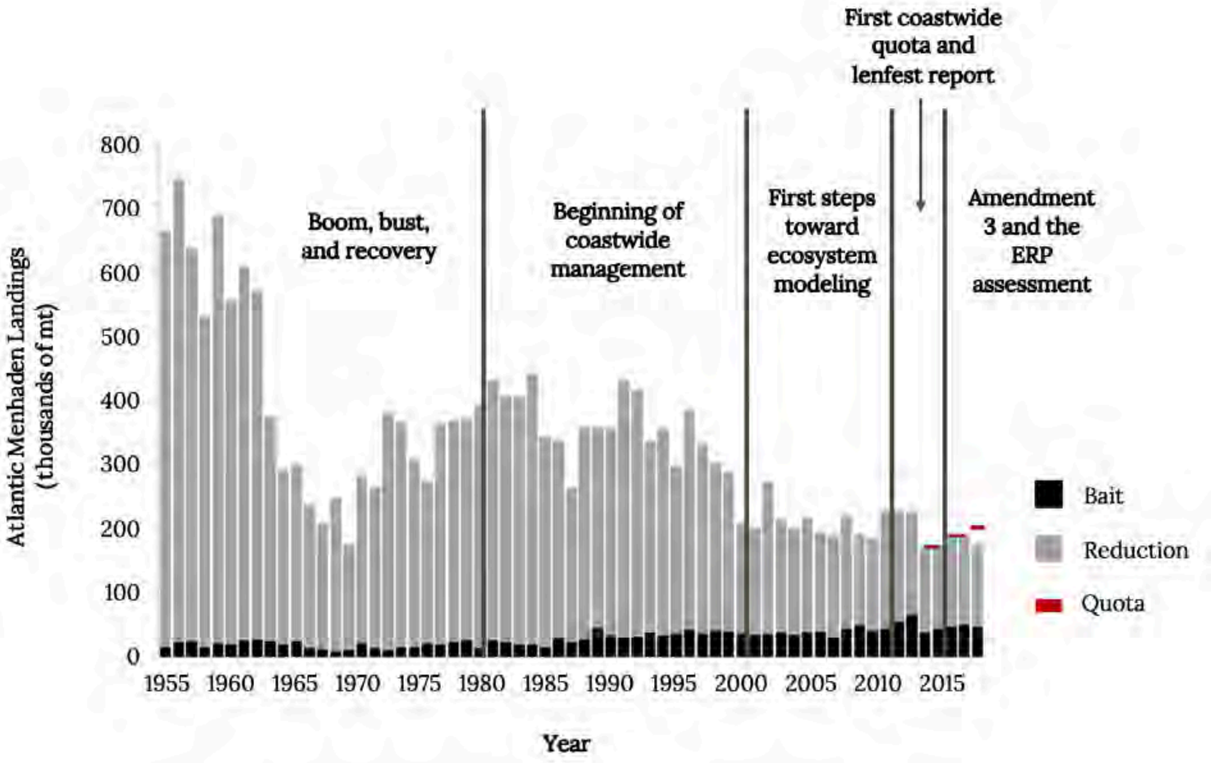

Figure 14.10: Atlantic Menhaden landings (thousands of metric tons, mt) from the reduction and bait fisheries during each of the five periods of assessment and management history. Coastwide harvest quotas began in 2013 and are indicated on the graph in red. [Long description](#).

Early studies of population dynamics of Atlantic Menhaden applied single species population analysis tools, such as **equilibrium yield** and stock recruitment. With these mathematical tools, scientists can predict, theoretically, the largest catch that can be taken from a species' stock over an indefinite period (Finley 2011). These models predict a dome-shaped relationship between long-term average yield, or equilibrium yield (Y), and population biomass (Figure 14.11). This result is because the rate of increase (r) declines in a linear manner as population approaches carrying capacity. Fisheries managers monitor catch per unit effort as a primary index of abundance because abundance is difficult to quantify. From the 1950s and through the 1960s, catch per unit effort decreased as fishing effort increased, as was expected (Figure 14.12 A; Schaff and Huntsman 1972). During the 1950s and 1960s, a dome-shaped relationship was evident from the scatterplot of the data (Figure 14.12 B). Since 1966, the data points diverged from the expected dome-shaped relationship between catch and effort to a linear relationship between catch per unit effort and fishing effort (Figure 14.12).

This linear decline in catch per unit effort was not reversed with reductions in fishing. Examine the data scatter, which shows how the reduction in effort after 1965 results in similar measures of catch per unit effort and total catch (Figure 14.12). There is a time lag in the response of menhaden populations to fishing reductions, related to their life history as well as changes in environmental conditions and/or predator abundance, which may also influence dynamics of the fish.

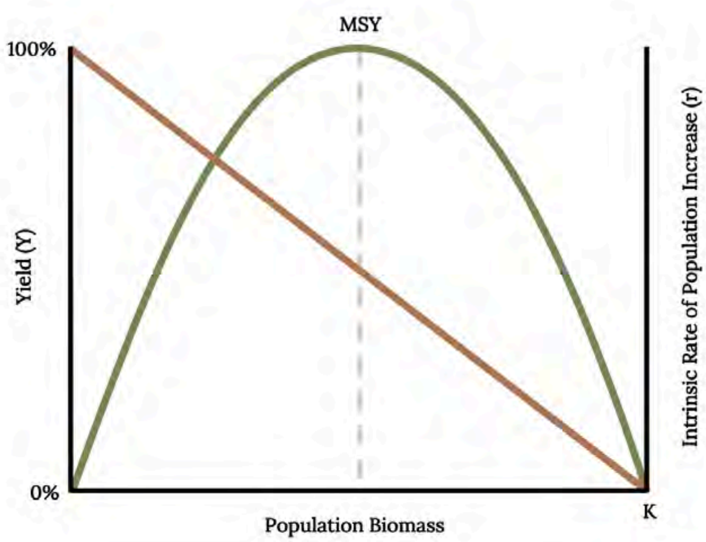

Figure 14.11: Relationship between equilibrium yield (Y, green curve) and intrinsic rate of population increase (r, tan line) and population biomass with the maximum sustainable yield (dashed line). [Long description](#).

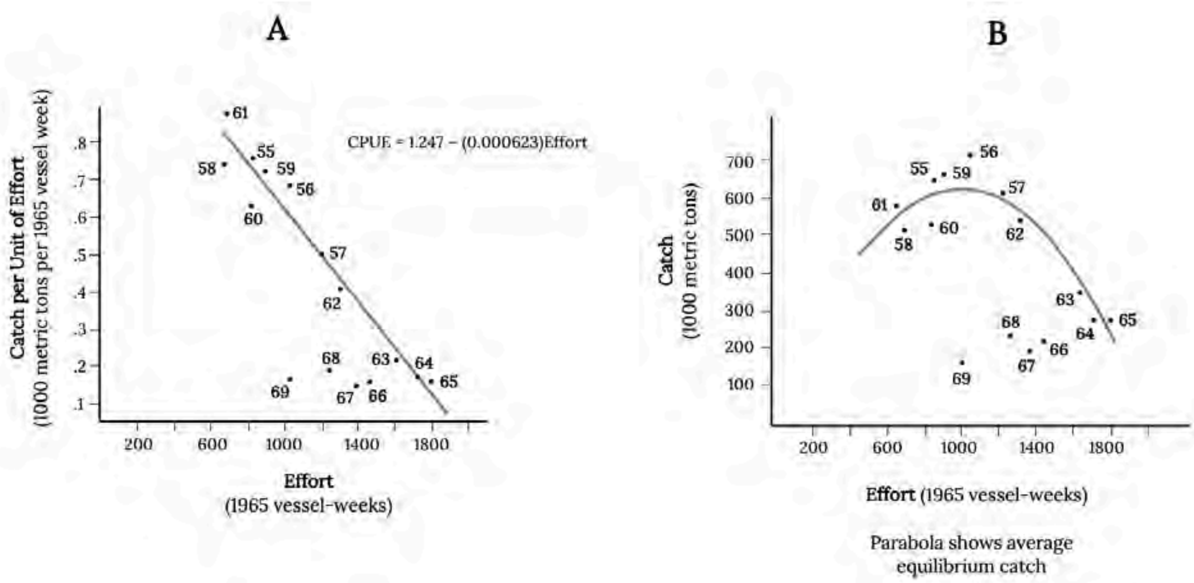

Figure 14.12: (A) Straight line fitted to fisheries data on catch per unit effort and effort (measured in vessel-weeks) for Atlantic Menhaden from 1955 to 1969. (B) Total catch plotted against effort. [Long description](#).

Without fishing, the mortality of Atlantic Menhaden is about 25% per year. However, with typical levels of fishing observed, mortality was between 65 to 85% per year (Figure 14.13). Predicting the population dynamics and estimating mortality of Atlantic Menhaden are also complicated by movements along the coast. One tagging study indicated that during May and June, an estimated 91% of Atlantic Menhaden from North and South Carolina moved northward. In the winter, an estimated 55% of the sample tagged north of Chesapeake Bay moved southward to the bay and North and South Carolina (Liljestrand et al. 2019). Therefore, it is difficult to measure abundance of a mobile population.

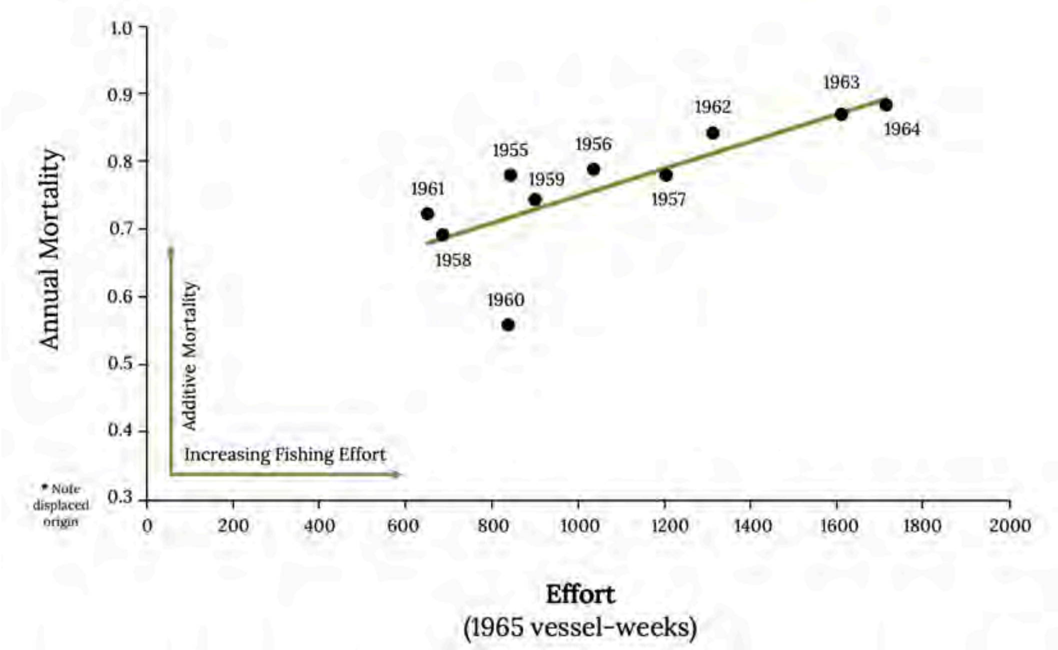

Figure 14.13: Annual mortality against fishing effort for 1955–1966.

If fishing mortality gets too high, few fish in the largest size classes will survive to reproduce, and biomass of spawning fish will decrease. The first management plan was developed in response to major changes in the fishery efficiency at capturing menhaden, enhanced processing capacity, as well as the development of new markets for products. Recognizing that seasons and mesh size restrictions had not prevented decline in menhaden, the first plan focused on determining the appropriate age to first harvest them (ASMFC 1981). Only later did plans estimate target and threshold levels used to determine if quotas should be adjusted (ASMFC 1999).

Monitoring records of juvenile Atlantic Menhaden in Chesapeake Bay indicate that reproductive success has been low for many decades (Figure 14.14 top). Fishing mortality for Atlantic Menhaden has been below the single-species management threshold in recent decades (Figure 14.14 bottom). Consequently, the Atlantic Menhaden stock status was not overfished, and overfishing is not occurring (SEDAR 2020a).

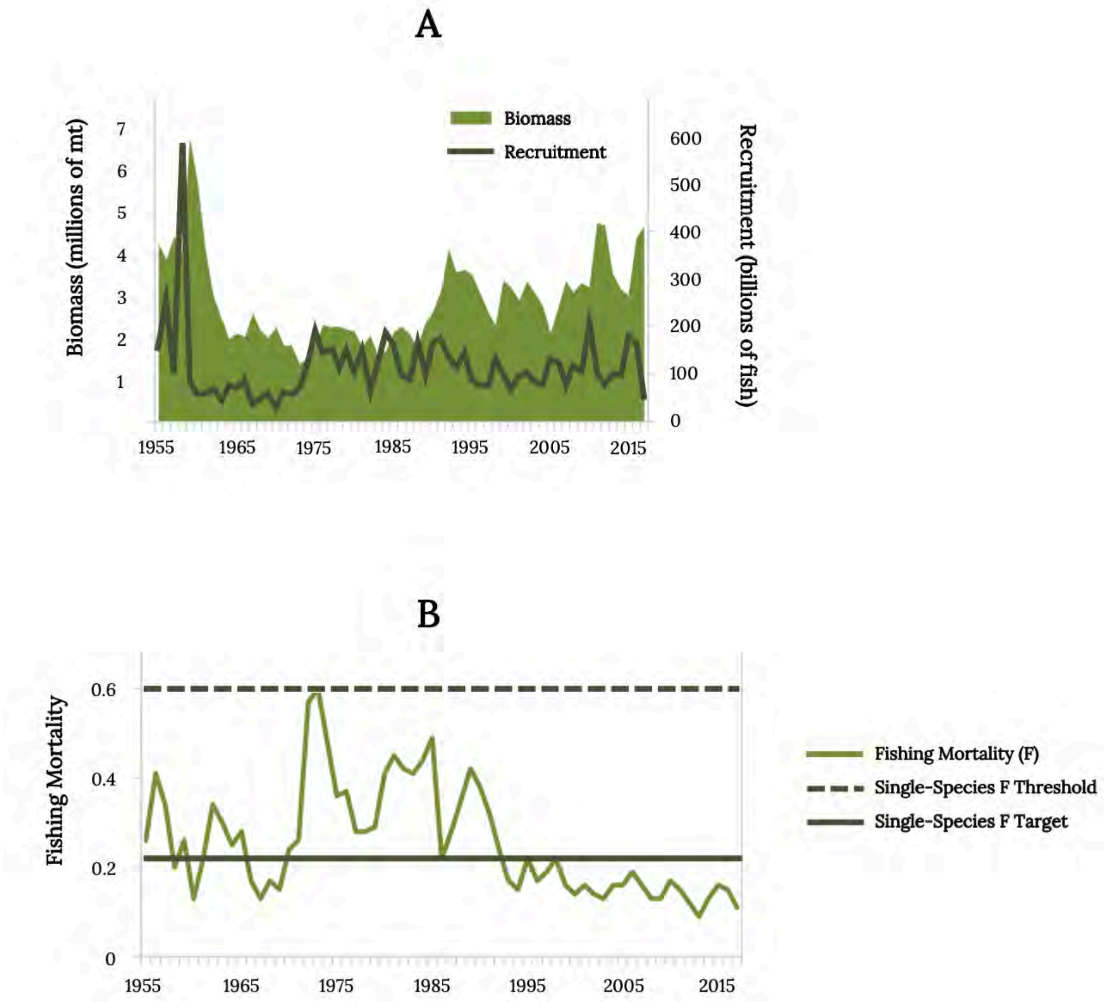

Figure 14.14: (A) Estimated Atlantic Menhaden biomass and recruitment from 1955 to 2016. (B) Atlantic Menhaden fishing mortality (ages 2–4) from 1955 to 2016, with lines depicting management target (solid) and threshold (dashed). [Long description](#).

Questions to ponder:

What risks are of most concern to you if fishery management continues to make harvest decisions based on single-species analysis? Who is most likely to be harmed by menhaden overharvest?

14.7 Shift from Maximum Sustainable Yield to Ecosystem-Based Management

Fish resources cannot be stored in the sea, they die.

—Chapman 1955, cited in Finley 2011

Early studies of population dynamics of Atlantic Menhaden determined biological reference points, such as maximum sustainable yield, based on a false assumption that they were unaffected by predator abundance and that their natural mortality was a constant. For example, analysts assumed that 36% of Atlantic Menhaden would die each year in the absence of fishing, based on extensive tagging studies during a period when stocks of Striped Bass and other piscivores were at moderate-to-low levels (Ahrenholz et al. 1987). It is hard to imagine or justify that the death rate from predators, diseases, and parasites would be constant over a longer time frame and fixed for all ages. The menhaden story illustrates the scientific principle that *Everything Is Connected to Everything Else* (the First Law of Ecology) and, therefore, single-species management is ill advised (Pikitch et al. 2012).

By 2000, modern forage fish management recognized that menhaden, herring, and sardine indirectly influenced multiple organisms dependent on forage fish. Management of menhaden had become complicated by many stakeholders concerned with the status of large fish, such as cod, salmon, Striped Bass, sharks, and tuna, as well as seabirds, sea lions, whales, and dolphins that feed on forage fish. Industrial fishing and predators both rely on menhaden, which are more vulnerable to collapse from fishing when predators become more abundant. While early ASMFC management documents acknowledged menhaden's role as a forage fish, ecological objectives were not added until 2001 (ASMFC 2001). For the next two decades, managers and scientists worked on collecting data and developing models that would assess the species with consideration for the role it plays in the ecosystem. In 2020, the ASMFC (SEDAR 2020) provided ecological reference points to permit the management to protect and maintain the important ecological role Atlantic Menhaden play along the coast (Chagaris et al. 2020; Drew et al. 2021). This was the beginning of a precedent-setting shift from single-species maximum sustainable yield management to ecosystem-based management.

Similar forage fishery management controversies exist worldwide, where forage species such as anchovy, sardine, and other forage species support large industrial fisheries, and needs for supporting fish, mammal, and bird predators is poorly quantified (Pikitch et al. 2012, 2018; Grémillet et al. 2016, 2018; Hilborn et al. 2017). Chesapeake Bay supports a large biomass of age 1 and 2 menhaden as well as age-0 juveniles that recruit to the bay as larvae from ocean spawning. Although Atlantic Menhaden are highly productive, their short life spans mean that sudden changes in population sizes can occur, and the risk of collapse is enhanced by overfishing.

The current demand for Atlantic Menhaden for fish oil and meal is filled largely by one company, Omega Protein, a subsidiary of Cooke Aquaculture. Consequently, the benefits of the fishery are concentrated in the local economy. Reductions in menhaden quotas influence local jobs, county economic outputs, and profits to the company (Kirkley et al. 2011). Quota reductions would reduce local benefits but lead to potential increases in recreational angling, charter boat income, and other jobs. Yet, this menhaden monopoly has not proven to be protection from competition. Just as other products replaced fertilizers and industrial oils produced from menhaden, we can expect the fish oil and fish meal products from menhaden to be replaced by cheaper alternatives. When the need for products produced by menhaden can be met by other products, demand will decrease.

The Atlantic Menhaden at one time ranged from Nova Scotia to Florida. However, immense schools of the fish became less commonplace to many observers. The contraction in the range of Atlantic Menhaden led many environmental groups to become vocal advocates for reducing quotas. In other forage fish, size of fish harvested by the fishery is very similar to the size eaten by seabirds (Pikitch 2012, 2014). In Chesapeake Bay and on the Atlantic Coast, many fish consume Atlantic Menhaden, including Striped Bass (*Morone saxatilis*), Atlantic Weakfish (*Cynoscion regalis*), Bluefish (*Pomatomus saltatrix*), and Bluefin Tuna (*Thunnus thynnus*). These fish vary in size, so that any fishing on Atlantic Menhaden will likely influence some predators. Models used in previous analysis were frequently inadequate for estimating the impact of fishing forage species on their predators (Pikitch et al. 2017; Hilborn et al. 2017).

Those working to rebuild populations of whales, Bluefin Tuna, Bluefish, Striped Bass, and. Atlantic Weakfish have long challenged the goals of Atlantic Menhaden management. In the 21st century, managers are in the process of transitioning to a new management goal that recognizes that Atlantic Menhaden provide important ecosystem services, including (1) supporting predators as a food resource, (2) supporting a large, directed fishery, and (3) filtering phytoplankton from the water column, mostly as age-0 juveniles.

Incorporating such ecosystem-based goals in management means that quotas will need to be set to provide more forage fish for Striped Bass, Bald Eagles, and other predators. In August 2017, the ASMFC Atlantic Menhaden Management Board approved Draft Amendment 3 to the Fisheries Management Plan. The decision was influenced by a study of the northwest Atlantic ecosystem model, which showed that "birds, highly migratory species, sharks, and marine mammals were . . . negatively affected by increased fishing on menhaden," though none so much as the Striped Bass (Buchheister et al. 2017a, 2017b). This important scientific finding emphasized that menhaden abundance significantly impacts predator population abundance. Higher fishing mortality on menhaden would mean fewer large menhaden to feed an enhanced population of Striped Bass, as well as reduced abundance of large menhaden during spawning. If Striped Bass were capable of depleting prey populations (Uphoff and Sharov 2018), then they are competing with the menhaden fishery for the very same fish. The draft amendment was the first proposal that considers the use of ecological reference points (ERPs) to manage the resource and changes to the allocation method. In addition, it presents a suite of management options for quota transfers, quota rollovers, incidental catch, the episodic events set aside program, and the Chesapeake Bay reduction fishery cap.

The timeline for key elements in Atlantic Menhaden management are summarized below.

Timeline of Important Management Actions Affecting Atlantic Menhaden

August 2005: First harvest limit on menhaden in Chesapeake Bay imposed by Atlantic States Marine Fisheries Commission (ASMFC)

October 2012: Chesapeake Bay Foundation (CBF) calls for reductions in catch

December 2012: ASMFC adopts a new management plan aimed at reducing harvest

February 2013: Virginia General Assembly passes bill reducing menhaden harvest

March 2014: Virginia Marine Resources Commission creates harvest allocation for bait fishery and reporting requirements for menhaden harvested in Virginia

May 2015: Chesapeake Bay Foundation urges ASMFC to consider ecological reference points in management plan

August 2016: ASMFC delays decision on menhaden harvest cap

October 2016: ASMFC increases the menhaden harvest quota despite lack of data to support an increase

October 2017: A group of more than 100 top ecologists urged the ASMFC to move forward with ecosystem-based management for Atlantic Menhaden

November 2017: ASMFC decreases the cap menhaden harvest and continues to evaluate ecological reference points

February 2018: Coalition of conservation and recreational fishing interests supports new legislation that would ensure Virginia avoids the consequences of falling out of compliance with the menhaden fishery management plan

March 2018: Menhaden legislation is stalled in Virginia General Assembly

August 2018: ASMFC postpones a motion to declare Virginia out of compliance with menhaden plan

December 2018: CBF opposes the certification of Omega Protein's sustainable menhaden fishery

February 2019: ASMFC commits to further study of ecological effects of menhaden harvest

March 2019: CBF objects to seafood sustainability certification for Omega Protein's Atlantic menhaden fishery

August 2019: Omega Protein application for sustainability certification challenged

September 2019: Omega Protein knowingly violates the menhaden harvest cap

October 2019: ASMFC finds Virginia out of compliance with harvest cap

November 2019: Virginia governor asks U.S. Secretary of Commerce to impose moratorium on Virginia's menhaden harvest

December 2019: U.S. Secretary of Commerce supports ASMC, announces deadline for compliance

February 2020: Virginia General Assembly passes legislation to transfer management authority from General Assembly to the Virginia Marine Resources Commission

April 2020: VMRC imposes new menhaden harvest cap to bring Virginia into compliance

August 2020: ASMFC adopts new ecological reference points to guide menhaden management

Source: Chesapeake Bay Foundation. https://www.cbf.org/about-the-bay/more-than-just-the-bay/chesapeake-wildlife/menhaden/timeline-of-menhaden-conservation.html.

The argument that was developed during the period of menhaden controversy can be summarized as follows:

An Argument for Reduced Menhaden Quota

Premises:

- Menhaden are a keystone species; their filter feeding clarifies the water, allowing sunlight to reach eelgrass beds, thereby promoting scallop and juvenile fish habitat.
- Menhaden provide one source of food for Striped Bass, Bluefish, Weakfish, and fluke, as well as whales, all of which are valuable to the recreational economy of the region.
- Products from menhaden can be naturally derived from other sources:
    - Chorella and spirulina are high in Omega-3 fatty acids, minerals, and antioxidants.
    - Manufacturers are working on canola, which is high in omega-3 fatty acids.
- Marine recreational fishing on sportfish is dependent on menhaden for food and produces high economic benefits and more jobs than commercial fishing.

Claim:

- Quota on menhaden should be reduced to benefit other parts of the ecosystem and the local economy.

The argument for reduced menhaden quotas implies that fisheries management targets for predator and prey cannot be developed in isolation (Drew et al. 2021). Rather, there are tradeoffs in fisheries management due to the simple law that a fish can only die once. A fish harvested by the menhaden reduction fishery cannot also feed Striped Bass. If commercial fleets harvest menhaden at higher rates, there will be lower abundance of predators, such as Striped Bass. Alternatively, reduced fishing mortality for Striped Bass will result in higher predation mortality on menhaden.

When the reduction industry asks, "Can we harvest more menhaden?" the answer appears to be "Yes." However, higher fishing on Atlantic Menhaden will likely reduce the biomass of Striped Bass (Figure 14.15) and other high-profile fish that people eat and love to catch, such as Bluefish and Weakfish.

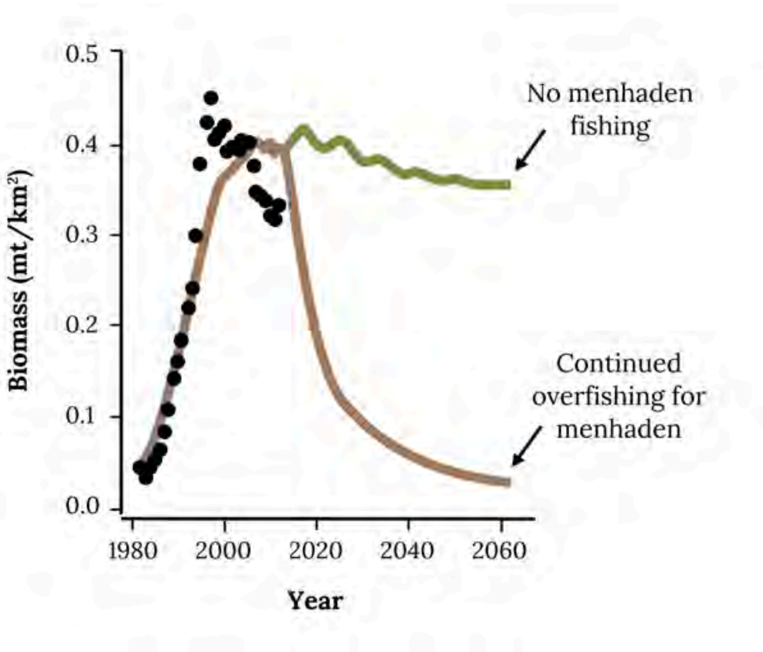

Figure 14.15: Projected biomass of Striped Bass in future under different fishing mortality for Atlantic Menhaden. Long description.

On August 5, 2020, at their meeting in Arlington, the Atlantic States Marine Fisheries Commission voted to implement ecological reference points (ERP) to manage Atlantic Menhaden. ERPs are numeric benchmarks used by managers to promote not only the sustainable harvest of menhaden but also broader ecosystem needs, such as supporting key predators (SEDAR 2020b). Three ecological reference points were adopted in the management of Atlantic Menhaden:

1. **ERP target**: the maximum fishing mortality rate (F) on Atlantic Menhaden that sustains Atlantic Striped Bass at their biomass target when Striped Bass are fished at their F target
2. **ERP threshold**: the maximum F on Atlantic Menhaden that keeps Atlantic Striped Bass at their biomass threshold when Striped Bass are fished at their F target
3. **ERP fecundity target and threshold:** the long-term equilibrium fecundity that results when the population is fished at the ERP F target and threshold, respectively

The adoption of menhaden ecological reference points resulted from a transparent and balanced approach that was informed by science and consistent investments in objective, peer-reviewed research. The menhaden may provide a prime example of ecosystem-based management for other fisheries to strategically plan and implement (Chagaris et al. 2020).

14.8 Stakeholders and Conflicting Values

At a time of precedent-setting change in management, in 2019, the Atlantic Menhaden fishery achieved approval for meeting the Marine Stewardship Council (MSC) certification standards. Fisheries that carry the council's blue checkmark are required to follow internationally recognized best practices for operating healthy, sustainable fisheries. The MSC standards are considered perhaps the strictest and most reliable, with 28 indicators of seafood sustainability. Atlantic Menhaden fishing with purse seines collects minimal amounts of bycatch, and harvests have been monitored effectively for many decades, thereby permitting estimation of reference points and adjustment of quotas. The MSC fishery standards are based on three core principles that every fishery must meet:

1. Sustainable fish stocks: Fishing activity must be at a level that ensures it can continue indefinitely.
2. Minimizing environmental impact: Fishing operations must be managed to maintain the structure, productivity, function, and diversity of the ecosystem.
3. Effective management: The fishery must comply with relevant laws and have a management system that is responsive to changing circumstances.

However, special interest groups objected to the certification on the grounds that it recognized only the health of the Atlantic Menhaden fishery and not the species' role in the ecosystem. The Theodore Roosevelt Conservation Partnership paid $6,500 to the MSC to formally contest the certification. In particular, the certification process does not consider the role that Atlantic Menhaden play in supporting Striped Bass, and declines in Striped Bass are a major concern of recreational fishing interests. The fight against MSC certification is a conflict that is best understood in terms of the stories told by stakeholders.

The Atlantic Menhaden conflict is similar to others in which forage fish are harvested in places where valuable sport and commercial fisheries depend on forage fish. The conflict has persisted for decades. As it played out with Atlantic Menhaden, stories told by managers, stakeholders, and scientists each conveyed differing reasons why we needed to account for menhaden's role as a forage species. However, until recently fisheries management of predators and prey was not well coordinated. Commercial landings of Striped Bass peaked in 1973, and then recreational fishing increased (Richards and Rago 1999). Quotas were changed for Atlantic Menhaden and Striped Bass, but scientists were not able to predict the effects of predator-prey links. The demand for fish oil and fish meal products increased, and menhaden harvesters lobbied for higher quotas. After decades of careful management of harvest for Striped Bass, recovery of their populations influenced predation pressure on Atlantic Menhaden (Uphoff and Sharoff 2018). The recreational Striped Bass anglers had fished before and after the fishing moratorium witnessed changes and told the story of the expected link with menhaden. Vocal activists played a significant role in criticizing Omega Protein's operations and mobilizing support for reduced quotas, especially in federal waters off New York and New Jersey (e.g., Menhaden Defenders and Theodore Roosevelt Conservation Partnerships). Listening to the many stories that were brought to the Atlantic States Marine Fisheries Commission meetings emphasizes the importance of dealing with conservation conflicts over forage fish as stories to understand and not problems to solve (Harrison and Loring 2020).

The dynamics of the menhaden story will be important to follow in the future, as it is one of the first pelagic, forage fisheries to adopt ecological reference points and at the same time receive sustainability certification. Globally, small pelagics contribute over 15% of the marine fisheries yields, and over three-fourths of that contribution is from developing countries. The future of sustainability certification for menhaden and others will require that management systems are in place to safeguard forage fish in order to protect the stability of top predators from widely fluctuating food levels (Essington et al. 2015; Izquierdo-Peña et al. 2020). The menhaden management story is ongoing, and the future responses will inform managers of the validity of the approach that was adopted in 2020.

***Questions to ponder*:**

What stakeholders in menhaden management are represented? Which stakeholders were not included? What are the stories told by different stakeholders? How do these stories help understand conflict and select appropriate intervention? Can you associate each stakeholder with a preferred management action?

Profile in Fish Conservation: Kristen Anstead, PhD

Scan the QR code or visit https://doi.org/10.21061/fishandconservation to listen to this Profile in Fish Conservation.


Figure 14.16: Kristen Anstead, PhD.

Kristen Anstead, PhD, is Stock Assessment Scientist with the Atlantic States Marine Fisheries Commission. In this role, she is responsible for periodically analyzing the status of fished populations, including the horseshoe crabs, American Eel, Atlantic Sturgeon, Atlantic Menhaden, and others. In addition to her work for the ASMFC, since 2013 she has been Science Editor and, since 2019, Co-Chief Editor for *Fisheries*, a leading fisheries science publication.

Dr. Anstead grew up in Maine and attended Bates College, a small, liberal arts college in Lewiston, where she earned a B.S. degree in biology. After graduating from Bates, she worked as a field biologist in several jobs. In the Mpala Research Center, Nanyuki, Kenya, she assisted in an ecology program to improve understanding of the effects of cattle grazing on the diversity and abundance of plants and wild animals. As a field biologist with the University of Georgia Marine Institute, located on Sapelo Island, Georgia, she was able to contribute to the Georgia Coastal Ecosystems Long-Term Ecological Research.

As a Fisheries Observer in Alaska, she worked onboard commercial fishing boats operating in the Bering Sea and Gulf of Alaska. Fisheries observers are the eyes and ears on the water and witness new findings in commercial fisheries. Many fisheries specialists report that their experiences as a fishery observer was a great stepping-stone to a successful fisheries career.

After 10 years of experience as a field biologist, Kristen enrolled in graduate studies at Old Dominion University. She led a novel study to investigate the contribution of multiple nursery areas to the population of Atlantic Menhaden before joining the ASMFC as a Stock Assessment Scientist.

Since 2015, her work has contributed to numerous stock assessments conducted by the Atlantic States Marine Fisheries Commission. Her knowledge, skills, and abilities from her years as a field biologist, along with her specialties, mean that she brings a unique balance to her work in stock assessment. As a Stock Assessment Scientist for Atlantic Menhaden, she is frequently reminded how much people care about menhaden, a noncharismatic fish that people will never see on a restaurant menu.

Dr. Anstead encourages students to pursue fieldwork positions to get some hands-on experience and an understanding of how science interacts with communities. For students interested in the management process, everything produced by the ASMFC is in the public domain to ensure that decisions are made in the public interest. See more about the Atlantic States Marine Fisheries Commission here.

Key Takeaways

- Menhaden sustained a large and important fishery for Native Americans and later early European colonists.
- Landings of menhaden fisheries are the largest by volume on the Atlantic Coast.
- Menhaden fishery supports jobs, and menhaden are transformed to useful products, most importantly fish oils and meals.
- Life history of Atlantic Menhaden represents an opportunistic strategy characterized by many small offspring, fast growth, early maturity, and small adult body size.
- Menhaden are grouped with other fish that eat plankton and are eaten by predatory fish, squid, birds, and mammals.
- Menhaden and other small, pelagic forage fish are highly responsive to climate variation.
- High levels of fishing effort increase the risk of collapse of menhaden.
- Management of Atlantic Menhaden recently adopted ecological reference points in order to adjust quotas in response to abundance of predators, such as Striped Bass.

This chapter was reviewed by Kristen Anstead.

URLs

Sharks entering a large school of menhaden: https://www.nationalgeographic.com/news/2017/08/shark-feeding-frenzy-menhaden-school-hamptons-drone-video-spd

Draft Amendment 3: http://www.asmfc.org/files/PublicInput/%20AtlanticMenhadenDraftAmendment3_%20PublicComment.pdf

Atlantic States Marine Fisheries Commission: http://www.asmfc.org/

Long Descriptions

Figure 14.3: Illustration of purse seine: large wall of netting deployed around an entire area or school of fish. The seine has floats along the top line with a lead line threaded through rings along the bottom. Jump back to Figure 14.3.

Figure 14.4: Line graph with x-axis as fork length (cm) from 0-40 and y-axis as fecundity (thousands) from 0-500. Line show exponential curve with lowest point at 15 cm/0 fecundity, increasing to 35cm/500 fecundity. Jump back to Figure 14.4.

Figure 14.10: Landings of Atlantic Menhaden over time; 1) 1955-1980, boom, bust, and recovery; 2) 1980-2000, beginning of coastwide management; 3) 2000-2010, first steps toward ecosystem modeling; 4) 2010-2015, first coastwide quota and lenfest report; 5) 2015- ;amendment 3 and the ERP assessment. Jump back to Figure 14.10.

Figure 14.11: Population biomass increases as yield decreases. MSY shows parabolic relationship between equilibrium yield, population biomass, and intrinsic rate of population increase. Jump back to Figure 14.11.

Figure 14.12: Two scatter plots with fitted lines. A: As effort increases, catch per unit of effort decreases. B: Parabolic shape opening downward shows highest point at effort=1000, catch=600. Jump back to Figure 14.12.

Figure 14.14: Top graph shows Atlantic Menhaden biomass and recruitment from 1955 to 2016. Biomass and recruitment peak in 1955. Bottom graph shows atlantic menhaden fishing mortality from 1955 to 2016. Single species F thresholh remains at 0.6 mortality; single species F target remains at 0.2 mortality. Fishing mortality peaks at 1971. Jump back to Figure 14.14.

Figure 14.15: Biomass has continually increased from 1980-2020. If overfishing continues for menhaden, the graph will begin to trend downwards. If there is no menhaden fishing, graph will level out. Jump back to Figure 14.15.

Figure References

Figure 14.1: Illustration of the Atlantic Menhaden adult. Artemas Ward, 1923. Public domain. https://commons.wikimedia.org/wiki/File:Menhaden,_photo_from_The_Encyclopedia_of_Food_by_Artemas_Ward.jpg.

Figure 14.2: Map of the range of Atlantic Menhaden from Nova Scotia, Canada, along the nearshore and coastal waters of the United States Atlantic Coast to Florida. NOAA via The Path to an Ecosystem Approach for Forage Fish Management: A Case Study of Atlantic Menhaden, by Anstead et. al., 2021. CC BY 4.0. http://dx.doi.org/10.3389/fmars.2021.607657.

Figure 14.3: Purse seines were adopted early on as a preferred method for harvesting menhaden. Benjamin Franklin Conklin, 1887. Public domain. https://commons.wikimedia.org/wiki/File:FMIB_45912_Menhaden_Fishery.jpeg.

Figure 14.4: Relationship between fork length (cm) and predicted number of ova (fecundity) for Atlantic Menhaden. Kindred Grey. 2022. CC BY 4.0. Data from Fecundity of Atlantic Menhaden,

Brevoortia tyrannus, by Lewis et. al., 1987. https://doi.org/10.2307/1351894.

Figure 14.5: Illustration of the (A) first gill arch showing gill rakers (a) and gill lamellae (m); and (B) enlarged section of six gill rakers showing fine rows of hooks for filter feeding. Hugh McCormick Smith, 1907. Public domain. https://commons.wikimedia.org/wiki/File:FMIB_51375_Gill_of_Mehnaden.jpeg.

Figure 14.6: Simplified food web showing the links that Atlantic Menhaden provide between plankton and carnivorous animals. Kindred Grey. 2022. CC BY 4.0. Includes Brevoortia Patronus, by SEFSC Pascagoula Laboratory; Collection of Brandi Noble, NOAA/NMFS/SEFSC, 2008 (CC BY 2.0, https://commons.wikimedia.org/wiki/File:BrevoortiaPatronus.jpg), Bluefin-big, by NOAA, 2004 (public domain, https://commons.wikimedia.org/wiki/File:Bluefin-big.jpg), fishing ship, by Gan Khoon Lay, 2019 (Noun Project license, https://thenounproject.com/icon/fishing-ship-2760125/), seagull, by Daniela Baptista, 2016 (Noun Project license, https://thenounproject.com/icon/seagull-781412/), Humpback Whale, by Philipp Lehmann, 2017 (Noun Project license, https://thenounproject.com/icon/humpback-whale-957308/), and bass fish, by Phạm Thanh Lộc, 2019 (Noun Project license, https://thenounproject.com/icon/bass-fish-3385868/).

Figure 14.7: Osprey in flight with a menhaden held in its talons. Russ, 2016. CC BY 2.0. https://flic.kr/p/KV7Yym.

Figure 14.8: Relationship between the size of Striped Bass (total length, mm) and the size of prey fish (total length, mm) consumed. Kindred Grey. 2022. CC BY 4.0. Data from Interactions between Adult Migratory Striped Bass (*Morone saxatilis*) and Their Prey during Winter off the Virginia and North Carolina Atlantic Coast from 1994 through 2007, by Overton et. al. 2008. http://hdl.handle.net/1834/19906.

Figure 14.9: Purse-seine boats encircling a school of menhaden. Robert K. Brigham, 1968. Public domain. https://commons.wikimedia.org/wiki/File:Menhaden_fishing_-_purse_seine_boats.jpg.

Figure 14.10: Atlantic Menhaden landings (thousands of metric tons, mt) from the reduction and bait fisheries during each of the five periods of assessment and management history. Coastwide harvest quotas began in 2013 and are indicated on the graph in red. Kindred Grey. 2022. CC BY 4.0. Data from The Path to an Ecosystem Approach for Forage Fish Management: A Case Study of Atlantic Menhaden, by Anstead et. al. 2021. https://doi.org/10.3389/fmars.2021.607657.

Figure 14.11: Relationship between equilibrium yield (Y, green curve) and intrinsic rate of population increase (r, tan line) and population biomass with the maximum sustainable yield (dashed line). Kindred Grey. 2022. CC BY 4.0. Data from Maximum Sustainable Yield, by Tsikliras and Froese, 2018. https://doi.org/10.1016/B978-0-12-409548-9.10601-3.

Figure 14.12: (A) Straight line fitted to fisheries data on catch per unit effort and effort (vessel-weeks) for Atlantic Menhaden from 1955 to 1969. (B) Total catch plotted against effort. Kindred Grey. 2022. CC BY 4.0. Data from Effects of Fishing on the Atlantic Menhaden Stock: 1955–1969, by W. E. Schaaf and G. R. Huntsman, 1972. https://doi.org/10.1577/1548-8659(1972)101<290:EOFOTA>2.0.CO;2.

Figure 14.13: Annual mortality against effort for 1955–1966. Kindred Grey. 2022. CC BY 4.0. Data from Effects of Fishing on the Atlantic Menhaden Stock: 1955–1969, by W. E. Schaaf and G. R. Huntsman, 1972. https://doi.org/10.1577/1548-8659(1972)101<290:EOFOTA>2.0.CO;2.

Figure 14.14: (A) Estimated Atlantic Menhaden biomass and recruitment from 1955 to 2016. (B) Atlantic Menhaden fishing mortality (ages 2–4) from 1955 to 2016 with lines depicting management target (solid) and threshold (dashed). Kindred Grey. 2022. CC BY 4.0. Data from Maximum Sustainable Yield, by Tsikliras and Froese, 2018. https://doi.org/10.1016/B978-0-12-409548-9.10601-3.

Figure 14.15: Projected biomass of Striped Bass in future under different fishing mortality rates for Atlantic Menhaden. Kindred Grey. 2022. CC BY 4.0. Adapted from Evaluating Ecosystem-Based Reference Points for Atlantic Menhaden (*Brevoortia tyrannus*), by Buchheister et. al., 2017. CC BY 4.0. http://dx.doi.org/10.1080/19425120.2017.1360420.

Figure 14.16: Kristen Anstead, PhD. Used with permission from Kristen Anstead. CC BY 4.0.

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15. Takeaways for Successful Fish Conservation

15.1 In Search of Principles

The arc of the moral universe is long, but it bends toward justice.

—Dr. Martin Luther King Jr.

There are few **inviolate** laws of fisheries conservation and management. One such law is "Fish Die!" Its witty **corollary** is, "If your parents had no children, odds are good that you will not either." The first Great Law of Fishing — "Fisheries that are unlimited become unprofitable"—has persisted since formulated by Michael Graham (1943). Scientists search for guiding principles to help organize our knowledge. A principle, when it is understood and accepted, serves to guide our thinking and assist in guiding actions. In the first chapter, I proposed the working principle, "***Passionate and persistent people who understand the fish and the place will find a way to create partnerships to conserve valued fish in perpetuity***." This principle highlights the importance of groups of people because groups are collectively smarter than individual experts in problem solving, decision making, innovating, and predicting (Arminpour et al. 2020). Recovery stories of collapsed fisheries highlight the importance of people and partnerships (Krueger et al. 2019). In fact, the common traits of important leaders in nature conservation are passion, persistence, and engagement in partnerships (Nielsen 2017).

Here I summarize key takeaways for implementing successful fish conservation organized as Fisheries Systems, Ecological Systems, and Management System principles.

Decisions are made in context that includes ecological systems, social systems, and institutions or management systems.

Fisheries are continually changing as the many actors, institutions, and fish resources are influenced by the social-ecological setting (Figure 15.1). Each of these interacting systems may contribute to success or failure. In some cases, the habitat may be degraded. In others, the management system fails to respond to declines in catches in a timely manner. In others, the social system fails to support efforts to protect fish. Furthermore, understanding social systems, including cultural norms and institutions, local knowledge, and social learning, provides more options for enhancing well-being of fishing communities (Carlson et al. 2020).

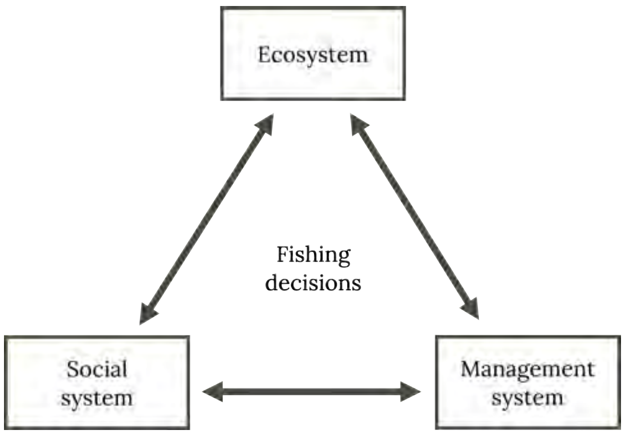

Figure 15.1: An improved understanding of coupled social-ecological system dynamics will yield more effective fisheries and marine conservation decisions.

15.2 Fisheries Systems Principles

Fisheries that are unlimited become unprofitable.

Russell (1931) derived a simple equation for overfishing by expressing sustainable yield as the sum of recruitment and individual growth minus mortality (Figure 15.2). This simple equation means that what comes in must go out if you ever intend to get the population stabilized. Russell's equation has had a profound influence on early thinking to classify fish stocks as overfished when their population is below the level that would maximize harvest. Consequently, much of fisheries science in the mid-20th century focused on estimating parameters and maximum sustainable yields for stocks (Schaefer 1954). Yet this simplistic single-species model underestimates the risks of harvesting on populations and ecosystems (Lichatowich and Gayeski 2020).

Fishing remains the last major hunting and gathering industry. As such fishing supports human livelihoods, food security, human health, and recreation., the tremendous diversity of fishing activities and styles complicates management. Because fisheries are often public resources where access cannot be easily controlled, overfishing and fisheries collapse are common. Famous collapses of the Northwest Atlantic Cod and California abalone and sardine fisheries highlight the failures of weak regulations on fishing (Radovich 1982; Tegner 1993; Mason 2002; Bavington 2010; Kurlansky 2010) and subsequent ecological, economic, and social disruptions. Widespread and well-publicized fisheries collapses generated substantial public awareness (Clover 2008; Hilborn and Hilborn 2012), leading to the passage of new amendments to the Magnuson-Stevens Fishery Conservation and Management Act in 1996 and 2007. The recent amendments made overfishing illegal, while mandating the rebuilding of all depleted fish stocks.

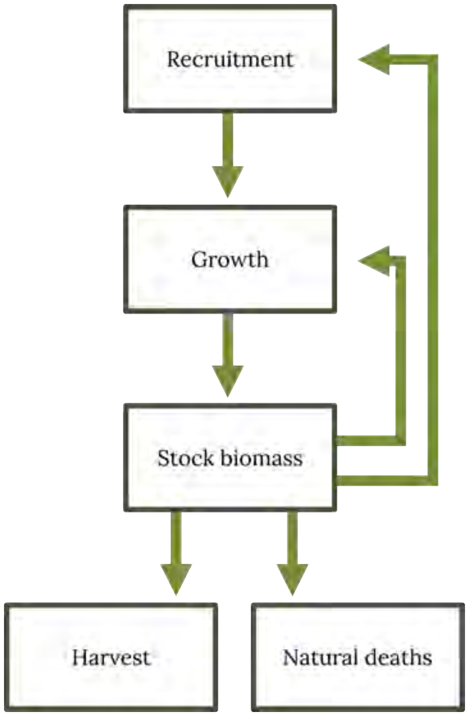

Figure 15.2: Conceptual model depicting key factors that decrease or increase fish stock biomass according to Russell's 1931 equation. [Long description](#).

Overfishing is common across the full spectrum of fish life histories, not just top predators (Pinsky et al. 2011). Furthermore, overfishing is often exacerbated by illegal, unreported, and unregulated (IUU) fishing, leading to food and nutritional insecurity, loss of jobs, and loss of income to local fishers and economies (Agnew et al. 2009; Sumaila et al. 2020). Progress toward sustainable fisheries requires a global commitment to environmental, economic, and social goals over time (Duarte et al. 2020). Use of commonsense reforms could result in recovery of overfished stocks and increases in fish abundance, profits, and food security from marine fisheries (Costello et al. 2016; Cabral et al. 2018).

Anthropocene era will be a time of uncertainty.

Concern for the decline of biodiversity in the world's oceans has never been higher as the combined failures of science, governance, subsidies, overcapitalization, and international cooperation have revealed (Costello et al. 2010; Sala et al. 2021). Nowhere is the biodiversity crisis more acute than in freshwater ecosystems, which cover less than 1% of Earth's surface yet host approximately one-third of vertebrate species and approximately half of all fishes (Fricke et al. 2022). Twenty-eight percent of freshwater fishes are at risk globally (Dudgeon 2019; Tickner et al. 2020). Given recent dramatic declines in freshwater biodiversity, which far exceed declines observed in terrestrial or marine ecosystems, priority actions must be taken to reverse this trend (Ahmed et al. 2022). Yet many forms of freshwater life are valued more for their **utilitarian** value than their ecological and intrinsic value. Many fish are given unpopular or misleading labels, such as "trash fish," "rough fish," or "bait," and receive little conservation attention (Monroe et al. 2009; Rypel et al. 2021).

The future will bring uncertainty associated with rapid change in climate regimes worldwide (Davies 2016). As ocean temperatures warm, fish move poleward or upstream to find suitable temperatures. For example, fewer Atlantic Cod are caught in U.S. waters compared with historical levels, and sustainable yields for many exploited populations are declining (Free et al. 2019). Climate warming will result in a shift in some tropical tuna beyond traditional prime fishing grounds. Warming of inland waters will challenge current fisheries management priorities, as cold-water specialists are relegated to new habitats (Lynch et al. 2010; Dauwalter et al. 2020; Gallagher et al. 2022). Inland fisheries are important sources for food and sport, and collapses induced by recreational fishing and climate change will be challenging to predict (Cooke and Cowx 2004). While uncertainty can contribute to inaction, we should accept uncertainty as an inevitable reality that calls for continual learning and adaptive management. Given the growing uncertainty, alternative approaches to creating and applying new knowledge in collaboration with many partners will be needed to fill the gap that exists in applying evidence-based conservation in fish conservation (Toomey et al. 2016; Kidd et al. 2019; Nguyen et al. 2019).

Learning from past successes, we can get off the pathological management treadmill that impedes recovery.

Successful examples of fish conservation often share similar elements of governance structures that include successful and trusted partnerships. Partnerships are key to effective responses to management problems. Without engagement, governing bodies respond to problems with interventions that fail to solve the problem. Instead, the signals of problems increase, leading to further political concern (Figure 15.3; Webster 2015). For example, once overfishing is recognized as a problem, it is difficult to stop. Typically, when fish populations are severely overexploited, fishing effort increases with diminishing returns. While demand increases, fishing fleets have few alternatives and oppose new fishing restrictions. As conditions worsen, more and more intense signals are received by scientists, decision makers, firms, the public, and other actors. Political concerns grow until the political will supports new governance measures that permit a shift to the effective management cycle (right-hand side of Figure 15.3). A more effective vision of fishing often means catching fewer fish with greater value, less effort, and less habitat alteration. Over the long term, fisheries governance cycles between periods of effective and ineffective management. Strong and effective governance structures can prolong periods of effective governance.

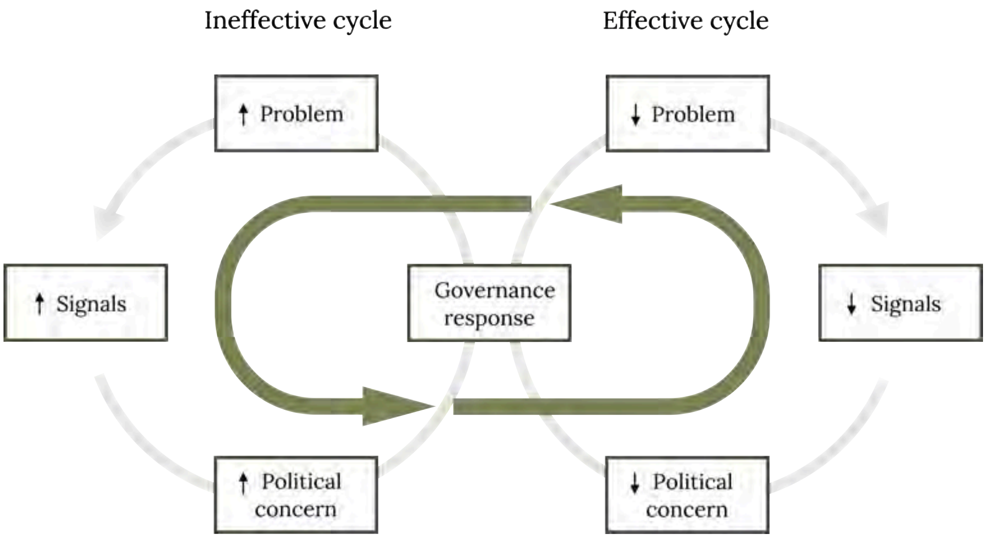

Figure 15.3: The management or governance treadmill. The left-hand side shows an ineffective cycle, in which environmental problems send out socioeconomic signals that lead to increasing political concern. Strong governance leads to an effective cycle (right-hand side), where the problem decreases, signals weaken, and political concerns decline during a process of crisis rebound.

It's time to stop pretending that fish don't feel pain and formulate animal welfare guidance for fishing and aquaculture.

Currently, many are engaged in lively debates regarding the welfare of fish in recreational and commercial fisheries, as well as fish farms. Fish are capable of certain higher cognitive processes, which raises questions regarding ethics and welfare. The fundamental question whether and why fish matter in our moral deliberations is an applied ethics question (Bovenkerk and Meijboom 2012). New research is devoted to the difficult goal of establishing whether fish have awareness and can suffer (Browman et al. 2019; Hubená et al. 2022; Mason and Lavery 2022). The debate will continue, as some remain unconvinced that fish are **sentient** and call for higher standards for evidence, while others advocate for welfare protections for fish. An argument presented by Arlinghaus et al. (2020) bypasses the debate by promoting welfare based on the functions of natural populations of fish. This argument is summarized as follows:

> Premise: Well-being is important to the conservation of populations and fisheries, regardless of whether the animal is able to think and feel.
>
> Premise: Animal welfare can be considered without invoking or relying on concepts such as consciousness, sentience, or pain.
>
> Claim: Therefore, recreational angling welfare and ethics relies on measurable endpoints of fish well-being other than pain.

Oversight and sanctions are needed to encourage compliance with regulations.

Noncompliance with fishing regulations is a pervasive problem in recreational, commercial, and subsistence fisheries (Boonstra and Österblom 2014; Cepic and Nunan 2017; Bergseth and Roscher 2018). Without oversight, knowledge of fishing regulations may be lacking. Without oversight, illegal, unreported, and unregulated fishing will lead to overfishing. Subsidies for fishing fleets lead to **overcapitalized** and overfished fisheries. Advances in vessel tracking and electronic monitoring continue to improve our abilities to monitor for compliance.

Comanagement holds great promise for successful and sustainable fisheries.

Comanagement respects the rights of stakeholders to organize and establish institutions (including regulations) for long-term sustainability that are recognized by higher authorities (Ostrom 2009). Moving from top-down decision making based on Decide-Announce-Defend (DAD) to Engage-Deliberate-Decide (EDD) may lead to better decisions for complex fish conservation issues. DAD approaches may lead to quicker decisions but often results in ineffective policies. The DAD method is not suited for fisheries where a wide range of technical, social, cultural, and economic factors are influencing the current situation. Also, successful implementation involves a lot of people, and these people are not in an obvious command structure, but they can choose whether to cooperate (Walker 2009; Prince 2010). Comanagement of fisheries leads to enhanced interaction, deliberation, learning, and participation of stakeholders from the fishing community and government (Gutiérrez et al. 2011; Wamukota et al. 2012; McCay et al. 2014; Berkes 2015; Botto-Barrios and Saavedra-Díaz 2020; Arantes et al. 2021; Gurdak et al. 2022; Silver et al. 2022).

Ecocertification of products from capture fisheries and aquaculture contributes to more sustainable, socially responsible seafood.

The United States is the world's largest fish importer, with 90% of seafood consumed by Americans coming from foreign fisheries (NOAA 2017). Yet, 25–30% of wild-caught seafood imported into the country is illegally caught (Pramod et al. 2014). Therefore the U.S. demand contributes to illegal, unreported, and unregulated (IUU) fishing worldwide. The power of this market demand can be used to encourage socially responsible fishing and seafood guides that affect retailers' choice of what they will sell (Kittinger et al. 2017). To leverage the power of the market, fisheries must develop reliable systems for tracing seafood products so that labeling is possible (Willette and Cheng 2018).

The Marine Stewardship Council's theory of change describes how certification influences responsible fishing and marketing practices in ways that combat illegal fishing and provides greater benefits to fishers (Figure 15.4; Adolf et al. 2016; Arton et al. 2018; Willett and Cheng 2018).

Figure 15.4: The Marine Stewardship Council's theory of change describes how the organization envisages itself contributing to more sustainable seafood practices. Long description.

15.3 Social Systems Principles

Fisheries management in poorer nations should have a much stronger emphasis on human health and well-being.

People in the developing world heavily rely on fish for nutrition and fishing to support their livelihoods. Unfortunately, many of these developing countries have weak governance and are often net exporters of seafood to well-nourished countries with strong governance (Golden et al. 2016). Fish and other seafood will be essential to feed the estimated 10 billion people expected to be living on Earth by 2050. Industrialization of fishing, poor governance, and the expansion of foreign fishing threaten fisheries of small nations. Sensitivities to food insecurity in tropical ecosystems will be exacerbated by climate change and other human-induced habitat alterations (Free et al. 2019). Consequently, the historical rights of small-scale fishing communities to marine and inland resources, as traditional users for thousands of years, should be recognized to allow equitable allocation of fishery benefits (Schreiber et al. 2022). Currently, fishing incomes are below national poverty lines in 34% of the countries with data (Teh et al. 2020). In many artisanal fisheries (Figure 15.5), most of the catch is consumed domestically. Coral reefs and mangroves, which are essential ecosystems for many tropical coastal subsistence and artisanal fisheries, will be heavily degraded by coastal development, warming, and ocean acidification.

Rights, equity, and justice are mainstream principles of good fisheries governance.

New norms of practice in the form of governmental laws and regulations, voluntary codes of conduct, trade agreements, and market-based tools have emerged in response to global concerns about overfishing and unjust distribution of fishery benefits (Lam 2016). Consequently, we apply ethical reasoning in fisheries management. Rights, equity, and justice are mainstream principles of good fisheries governance. The ethical matrix (table 15.1) combines consequentialist and rights-based ethics along with Rawls' theory of justice as fairness, while considering all interest groups. Better compliance with the FAO code of conduct for responsible fishing will lead to enhanced fisheries sustainability.

Figure 15.5: Small-scale artisanal fisheries target many species using handlines, and most fish landed are sold and eaten domestically.

Interest group	Ethical principle		
	Well-being (consequentialist or utilitarian theory: welfare and health)	**Autonomy** (rights-based or deontology theory: freedom and choice)	**Justice** (social contract theory and Rawlsian "justice as fairness")
Producers	Satisfactory income and working conditions	Managerial freedom	Fair trade laws and practices
Consumers	Food safety and quality of life	Democratic and informed choice	Availability of affordable food
Organisms	Animal welfare	Behavioral freedom	Intrinsic value
Environment	Conservation	Biodiversity	Sustainability

Table 15.1: Ethical matrix from Lam (2016) showing outcomes for interest groups by following three ethical principles. Deontology refers to the study of the nature of duty and obligation. Rawlsian refers to a theory of justice, developed by John Rawls, that aims to constitute a system to ensure the fair distribution of primary social goods.

Effective governance of fisheries depends on effective community leaders.

Leaders who can build legitimacy and find ways to balance the concerns of competing interest groups help make the shift to effective governance responses. For example, the fisheries commissioner in Maine, who is credited with establishing more effective lobster management, built social networks and won the trust of lobster fishers while keeping abreast of scientific studies of the lobster fishery. Consequently, when difficult times emerged, the political will was sufficient to support governance responses instituting a conservation ethic to prevent overfishing (Acheson 1997).

Transform arguments into partnerships because facts don't win arguments.

The popular press often unwittingly spreads misinformation and misunderstanding about fish conservation issues (Orth et al. 2020; Shiffman et al. 2020). Increasingly, citizens are ready to deny findings from science that contradict their opinions (Schmid and Betsch 2019). Many of us do nothing to correct false or unsubstantiated beliefs, based on the presumed "backfire effect" myth, in which attempts to correct false beliefs increase misperceptions among the group in question (Nyhan 2021). However, it is preferable to form partnerships and develop trust among all stakeholders. The guidance to "build trust and listen" leads to group efforts focused on seeking the right answer together rather than defending one view. Formation of viable, long-term partnerships is more likely to lead to lasting policy changes.

A nudge may be more effective in changing behavior than forced compliance.

A nudge, unlike forced compliance, uses subtle changes and indirect suggestions to make certain decisions more **salient**, thereby improving voluntary compliance (Thaler and Sundstein 2008). For example, scientists know that keeping fish in or over the water and holding them with clean, wet hands or a soft rubber net will help keep their slime layer and scales intact and the fish disease free. The nonprofit organization Keep Fish Wet works to change social norms about the practice of catch-and-release angling. Prominent anglers and guides demonstrate how to land fish with minimal air exposure and handling, thereby nudging others to adopt the new behavior. Social norms are important drivers of human behavior and are known to influence how fishers interact with animals and their environment. The role of social norms within the context of recreational angling is of particular interest, given that angling behavior is seldom formally or easily monitored and enforced (Mackay et al. 2018). Increasingly, findings from psychological science may serve to promote behaviors that support conservation (Clayton and Myers 2015).

Conflicting value orientations are common in many fisheries.

Throughout this book, we have seen many ways in which fish and fishing matter to people. Relational values comprise a broader framework for including all values, not simply economic values, that can arise from a person's or society's relationship with nature (Chan et al. 2018). The ecological, spiritual, cultural, financial, academic, and recreational significance of a fish in human experience reflects pluralistic values to consider when formulating conservation strategies. We may think about the values-beliefs-norms-action causal chain when evaluating potential conservation interventions. For example, consider how biocentric values support beliefs, norms, and actions regarding shark conservation (Figure 15.6). Those with strong biocentric, **altruistic**, and **egoistic** values are likely to believe in an ecological worldview that sharks are at risk and they have the ability to effect change. From these beliefs, a sense of obligation to take actions becomes a norm, which leads to certain specific actions to protect sharks. Similarly, biocentric values lead to beliefs about harms to individual fish and implementing welfare actions in aquaculture and in fisheries. Successful conservation requires that we acknowledge and consider pluralistic values from biocentric to anthropocentric.

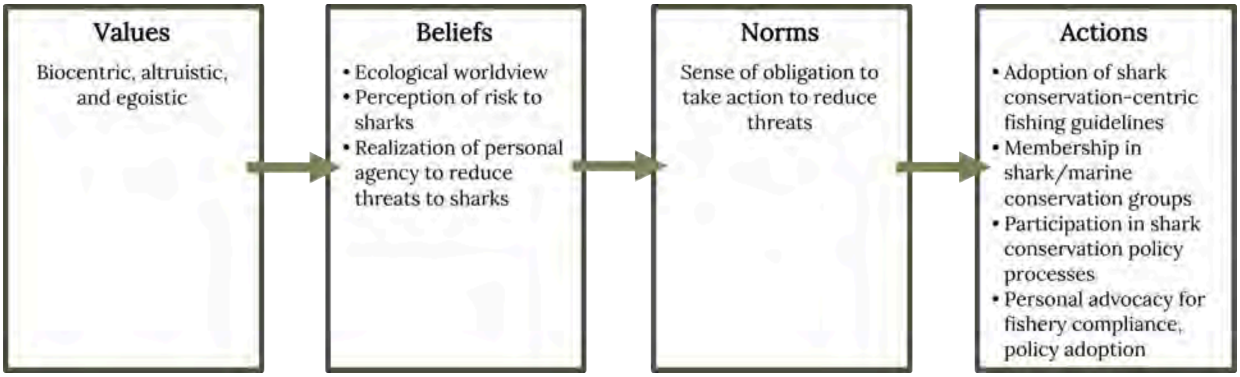

Figure 15.6: Values-belief-norms-actions framework for depicting the chain of causality liking relational values to beliefs, norms, and actions in the context of shark conservation. Long description.

Values drive selection of management objectives, policies, and practices.

A wide variety of conservation and management approaches naturally emerge as a result of differing values (Figure 15.7). Heterogeneous values among stakeholders translate to differing priority for objectives, policies, and practices. **Laissez-faire** approaches arise from strong values of autonomy and belief in the workings of the free market. Utilitarian values lead to selecting an objective of maximum sustained yield, precautionary policies, and practices such as closed seasons or quotas. Conservation and wise use of fishery resources may in some cases greatly alleviate poverty and improve the well-being in fishing communities. In other cases, recreational fishing and diving provide largely unexamined psychological benefits to participants whose values focus on spending time in unspoiled natural systems. Laissez-faire approaches arise from strong values of autonomy and belief in the workings of the free market. Utilitarian values lead to selecting an objective of maximum sustained yield, precautionary policies, and practices such as closed seasons or quotas. Conservationists have put considerable hope into the idea that we may be able to defend ecosystem services by translating them into monetary terms. A fundamental criticism of this approach is that it may lead to marginalizing certain social groups (Sorlin 2012). In other cases, ecological reference points are emerging when stakeholders hold ecocentric values, such as we saw with new policies and practices implemented for Atlantic Menhaden management. Over long time horizons, we should anticipate shifts in how people value fish. For example, the change in anglers' values from utilitarian self-interest toward **biocentric**, ecosystem-based conservation is evident among fly fishers and rough fish anglers. Biocentric value orientations contribute to greater support for stewardship objectives, policies, and practices, while at the same time contributing to less support for the use of technological angling aids (Bruskotter and Fulton 2007).

The tragedy of the commons is not inevitable if we embrace pluralism and pragmatism.

When fishers act solely in their own interests when accessing a public fishery, they ultimately overfish. The primary roles of government at the local, state, national, and international levels is to define and manage shared fisheries resources. However, notable failures have led many to adopt some type of participatory approach to involve fishers in management. Adopting **pragmatism** means that we emphasize actionable knowledge and practical experiences of all stakeholders. For these participatory programs to be effective, it must be clear how stakeholder input is used in decision making (Crandall et al. 2019). **Pluralism** emphasizes respect for multiple ways of knowing and thinking about fish conservation issues. Plurality means we examine perspectives and understandings from traditional Western and Indigenous knowledge systems to support decisions (Bingham et al. 2021; Reid et al. 2021).

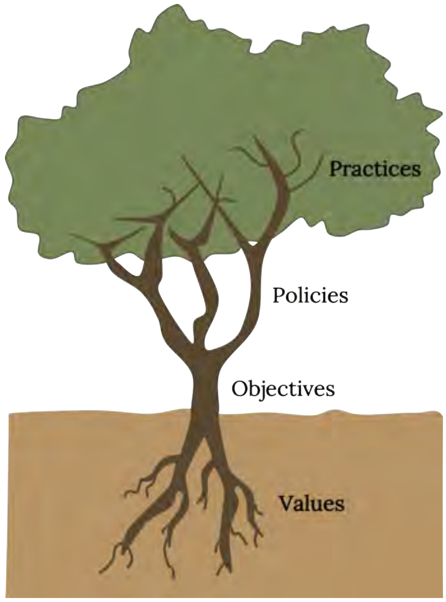

Figure 15.7: Values drive selection of management objectives, policies, and practices.

Building trust among various stakeholders is critical to effective governance and conservation.

Conservation programs require substantial interagency coordination, collaboration, and knowledge sharing. Yet, many fisheries institutions have a history of conflict and discrimination against women, Black, Indigenous, and people of color. Although historical injustices cannot be undone, changes in treatment may reduce discrimination in the future. Differing value orientations often lead to distrust. Distrust is often recognized as a major obstacle to effective natural resource management, leading to fear or opposition (Stern and Coleman 2015). Procedural fairness and technical competency are keys to developing stakeholder trust. Procedural fairness exists when stakeholders believe they have a voice in the decision process regardless of outcome (Riley et al. 2018). Direct, frequent, and timely communication is essential to demonstrate that stakeholder input is valued. Also, dialogue with stakeholders should focus on conversations that allow stakeholders to share their concerns and fears. New norms are emerging for stakeholder engagement with a greater attention to diversity, equity, inclusion, justice, and accessibility (Arismendi and Penaluna 2016; Worm et al. 2021).

15.4 Ecological Principles

Big, old, fat, fecund female fish, or "BOFFFFs," contribute substantially to population productivity and stability.

The examples presented in fishing for living dinosaurs, *Arapaima*, and grouper highlight the importance of BOFFFFs for conservation. Larger females are far more productive than the same weight's worth of smaller females (Barneche et al. 2018). Management practices that ignore the value of large females contribute to declines seen in some fish stocks, such as the Atlantic Cod *Gadus morhua* (Figure 15.8). In a broad range of fishes, older females spawn earlier and may have more protracted spawning seasons than younger females (Francis et al. 2007).

Increasingly, modern methods for aging fish reveal longevity estimates far exceeding those from earlier studies. Fish having long life spans with repeated spawning is a bet-hedging response to life in variable environments where larval survival and successful recruitment may be uncommon. More large fish are living life in the slow lane. Recent studies revealed that Bowfins live ~2–3 times longer than previously estimated for wild populations. With Bowfin, over the past two decades, there has been increased demand for roe for caviar, increased participation in recreational angling, and increased harvest through modern bowfishing (Lackman et al. 2019, 2022; Scarnecchia et al. 2019). Ecological functions of Bowfin and other rough fish must be considered (Rypel et al. 2021).

Sometimes it's the habitat.

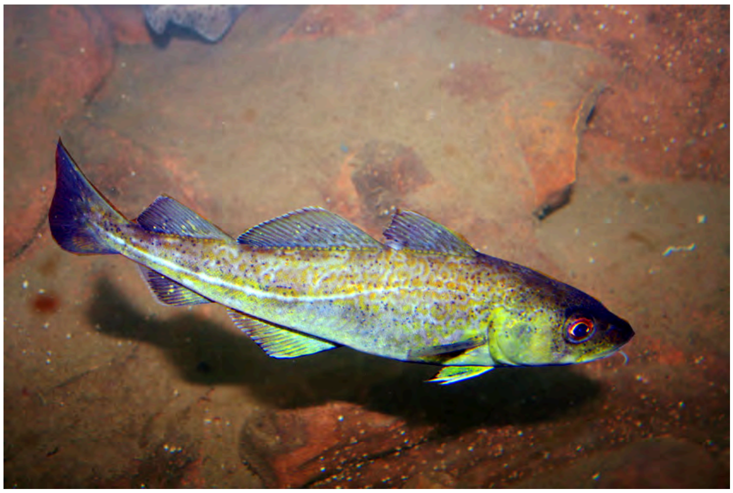

Figure 15.8: Atlantic Cod is one of many fish where large females play a disproportionate role in producing future offspring. Long description.

Initiatives to "protect the habitat" are common among supporters of bonefish, tarpon, trout, char, grouper, salmon, sharks, sturgeon, and many others. In fish that use multiple habitats to meet different resource needs throughout their lives, a loss of an essential habitat may limit the ability of an overfished population to recover. For example, many studies demonstrate the key function of mangroves and seagrass beds as reef fish nurseries and freshwater streams as salmon nurseries. Increasingly, marine protected areas (MPA) are used to protect essential habitats (Giakoumi et al. 2018; Sala and Giakoumi 2018; Gilchrist et al 2020). More than 17,000 MPAs protect almost 11.2 million square miles (29 million square kilometers) of ocean. In other words, nearly 8.2% of the ocean, an area the size of North America, is under some kind of protection (UNEP-WCMC 2020).

Although there are few freshwater protected areas, the enforcement of the U.S. Clean Water Act and water quality standards led to improvements in diversity and abundance of riverine fish and other biota in many large rivers (Yoder et al. 2019). Scientific management of the Chesapeake Bay crab population that has called for cleaner water and improved habitat also will help crabs. Reducing the levels of nutrients reaching the bay from farms and lawns and better managing of polluted runoff before it gets into rivers and streams will help improve water quality and contribute to the recovery of both Blue Crabs and bay grasses. Habitat restoration is the most effective tool for conservation of nongame fish, which are often hardly visible, small bodied, co-occurring with a large number of species over their distributional range, and sharing essential habitat requirements. Because of these characteristics, freshwater (especially stream) habitat protection should achieve conservation for multiple species.

Recovery of fish populations is possible but takes long-term effort and partnerships.

Well-documented case studies demonstrate this principle for Eastern Brook Trout, Goliath Grouper, Lake Erie Walleye, and Snail Darter, as well as others (Kraft 2019; Vandergoot et al. 2019; Koenig et al. 2020). In all successful recoveries, there is substantial effort in developing coordinated, multiagency approaches with stakeholder input. In 2022, the U.S. Fish and Wildlife Service announced an important milestone in fish conservation. The most famous darter in the world, the Snail Darter, was considered recovered (Loller 2022), demonstrating that the Endangered Species Act is working to recover endangered species.

15.5 Final Takeaway

It is easy to become disillusioned with the magnitude of the global challenges for recovering at-risk fish populations or maintaining valuable fisheries. However, if we focus on the principle that *passionate and persistent people who understand the fish and the place will find a way to create partnerships to conserve valued fish in perpetuity*, we can work to implement actions at local levels. Many inspiring stories exist about the recovery of overfished or collapsed highly degraded ecosystems (Krueger et al. 2019). Collectively, these stories revealed that no single silver bullet worked. Rather, strategies that engaged and nurtured partnerships with stakeholders led to increased trust and effective collaboration.

Profile in Fish Conservation: Emmanuel A. Frimpong, PhD

Scan the QR code or visit https://doi.org/10.21061/fishandconservation to listen to this Profile in Fish Conservation.

Emmanuel A. Frimpong is currently Professor in the Department of Fish Conservation at Virginia Tech. He grew up in Ghana, a country where fish were, first and foremost, food. He began fishing with his dad at the age or nine and recalls that every fish caught came home to be eaten by the family. This reminds us of the priority of food for human survival before humans can consider the role of fish, fishing, and conservation in a broader context. He recalls that for centuries, the indigenous people of Ghana have loyally guarded patches of forest and accompanying streams where freshwater fish are protected from harvest.

Figure 15.9: Emmanuel A. Frimpong, PhD.

Dr. Frimpong received his BS from the University of Science & Technology in Ghana, MS from the University of Arkansas at Pine Bluff, and PhD from Purdue University. Later he earned a second MS in statistics from Virginia Tech. He joined the faculty at Virginia Tech in 2007. He collaborates with the U.S. Agency for International Development's AquaFish Innovation Lab on research and development projects in Ghana, Kenya, and Tanzania. He is a significant contributor to research and development in Ghana and sub-Saharan Africa and was named to the prestigious Carnegie African Diaspora Fellow program. As a fellow, he is actively engaged in educational projects proposed and hosted by faculty of higher education institutions in Ghana, Kenya, Nigeria, South Africa, Tanzania, and Uganda. His research in the United States is funded by the National Science Foundation's Division of Environmental Biology and the U.S. Geological Survey's Aquatic Gap Analysis Program.

Dr. Frimpong and his students study the ecology and conservation of freshwater fish, with emphasis on how anthropogenic alterations to habitats and landscapes differentially affect species as a result of differences in their life history traits and the nature of biotic, especially mutualistic, interactions. Findings of his research team demonstrated how specific landscape and habitat changes, such as agriculture and aquaculture, urban development, introduction of nonnative species, and climate change, drive current conditions for stream fish. Frimpong developed a comprehensive database describing more than 100 biological traits of 809 freshwater fish, which is available to scientists everywhere. This improved understanding of determinants of fish distributions helps us predict how the distribution of species will respond to anthropogenic changes to their environment, while suggesting solutions to declining populations. In addition to studies of stream fish ecology, he has examined approaches to encouraging sustainable production aquaculture (especially in sub-Saharan Africa) as an alternative to overexploitation of natural fisheries.

Dr. Frimpong has demonstrated that unremarkable streams and common fish can reveal many ecological principles, such as the existence of important mutualistic interactions among stream fishes. These small, common fish are also important to fish conservation initiatives. Lack of information about common fish perpetuates ineffectual conservation practices. Frimpong recommends that we put ourselves in the fins of a fish to better appreciate their special underwater capabilities and threats to their continued existence. Particularly, aquatic biodiversity in West and Central Africa is grossly undersampled and unstudied. In Ghana and elsewhere, many undocumented, undescribed, and cryptic clusters of species are lumped into one species due to lack of detailed study. These taxonomic oversights influence our understanding of rarity, a key to conservation status. Yet, he explains to his students and colleagues that people are unaware of fish in local waters, and fish appreciation remains an untapped need for fish conservation.

This chapter was reviewed by Francesco Ferretti and Emmanual A. Frimpong.

Long Descriptions

Figure 15.2: Flow chart depicts key factors in fish stock biomass; 1) recruitment; 2) growth; 3) stock biomass (leads back to recruitment and growth). Stock biomass points to either harvest or natural death. Jump back to Figure 15.2.

Figure 15.4: 1) fisheries which meet the MSC standard are independently certified as sustainable; 2) consumers preferentially purchase seafood with the MSC ecolabel; 3) retailers and restaurants choose MSC certified sustainable seafood; 4) a traceable supply chain assures consumers that only seafood from an MSC certified fishery is sold with the MSC ecolabel; 5) market demand for MSC certified seafood increases; 6) more fisheries choose to improve their practices and volunteer to be assessed against the MSC standard. Jump back to Figure 15.4.

Figure 15.6: 1) Values: biocentric, altruistic, and egotistic. 2) Beliefs: ecological worldview, perception of risk to sharks, realization of personal agency to reduce threats of sharks. 3) Norms: sense of obligation to take action to reduce threats. 4) Actions: adoption of shark conservation-centric fishing guidelines, membership in shark/marine conservation groups, participation in shark conservation policy processes, personal advocacy for fishery compliance, policy adoption. Jump back to Figure 15.6.

Figure 15.8: Atlantic cod that is gray green with reddish brown spots. Their lateral line is pale, almost white. Cod are streamline in shape, have a broad square tail fin, three rounded dorsal fins, two anal fins and no fin spines. Jump back to Figure 15.8.

Figure References

Figure 15.1: An improved understanding of coupled social-ecological system dynamics will yield more effective fisheries and marine conservation decisions. Kindred Grey. 2022. Adapted under fair use from Bridging the Divide between Fisheries and Marine Conservation Science, by Salomon et. al., 2011. http://dx.doi.org/10.5343/bms.2010.1089.

Figure 15.2: Conceptual model depicting key factors that decrease or increase fish stock biomass according to Russell's 1931 equation. Kindred Grey. 2022. CC BY 4.0.

Figure 15.3: The management or governance treadmill. Kindred Grey. 2022. CC BY 4.0. Adapted from Scapegoats, Silver Bullets, and Other Pitfalls in the Path to Sustainability, by D. G. Webster, 2017. CC BY 4.0. http://dx.doi.org/10.1525/elementa.212.

Figure 15.4: The Marine Stewardship Council's theory of change describes how the organization envisages itself contributing to more sustainable seafood practices. From What Do We Know About the Impacts of the Marine Stewardship Council Seafood Ecolabelling Program? A Systematic map, by Arton et. al., 2020. CC BY 4.0. https://doi.org/10.1186/s13750-020-0188-9.

Figure 15.5: Small-scale artisanal fisheries target many species using handlines, and most fish landed are sold and eaten domestically. Photography by Dino Sassi – Marcel Fayon, Photo Eden LTD, 1977. Public domain. https://commons.wikimedia.org/wiki/File:Fisherman_and_his_catch_Seychelles.jpg.

Figure 15.6: Values-belief-norms-actions framework for depicting the chain of causality linking relational values to beliefs, norms, and actions in the context of shark conservation. Kindred Grey. 2022. CC BY 4.0. Adapted from Introducing Relational Values as a Tool for Shark Conservation, Science, and Management, by Skubel et. al., 2019. CC BY 4.0. http://dx.doi.org/10.3389/fmars.2019.00053,

Figure 15.7: Values drive selection of management objectives, policies, and practices. Kindred Grey. 2022. CC BY 4.0.

Figure 15.8: Atlantic Cod is one of many fish where large females play a disproportionate role in producing future offspring. Peter. 2011. CC BY 2.0. https://commons.wikimedia.org/wiki/File:Atlantic_cod_%281%29.jpg.

Figure 15.9: Emmanuel A. Frimpong, PhD. Used with permission from Emmanuel A. Frimpong. CC BY-ND 4.0.

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Glossary

Altruistic

Showing a selfless concern for the well-being of others; unselfish

Anthropocentric

Regarding humankind as the central or most important element of existence, especially as opposed to God or animals

Antioxidant

Substance that removes potentially damaging oxidizing agents in a living organism

Arrhythmias

Condition in which the heart beats with an irregular or abnormal rhythm

Arterial

Bright red blood present in most arteries that has been oxygenated in lungs or gills

Artisanal

Harvested in a traditional or non-mechanized way

Assay

Test for measuring content

Aural

Relating to the ear or the sense of hearing

Barotrauma

Injury to gas bladder caused by a change in air pressure

Bio-piezoelectric generator

A type of generator that converts one form of energy to another form

Biocentric

View or belief that the rights and needs of humans are not more important than those of other living things

Built aquatic habitats

Constructed by humans

Characiform

Large order of freshwater fish that occur in Africa, South America, and Central America

Cilia

Short microscopic hairlike vibrating structures found in large numbers on the surface of certain cells causing currents in the surrounding fluid

Clupeiform

Large group of pelagic fish including herring, shad, menhadens, sardine, anchovy, and their relatives

Concomitant

Naturally accompanying or associated

Consequentialism

The doctrine that the morality of an action is to be judged solely by its consequences

Corollary

Proposition that follows from (and is often appended to) one already proved

Creel

Originally a wicker basket for harvested fish

Culture

Use of a water body for production of coldwater or warmwater fish in a hatchery or rearing station

Deontological

Regarding the study of the nature of duty and obligation

Deontology

Study of the nature of duty and obligation

Deposition

Laying down of sediment carried by wind, flowing water, the sea or ice

Disaggregated

Separated into its component parts

Egoism

An ethical theory that treats self-interest as the foundation of morality

Egoistic

Treating self-interest as the foundation of morality

Episodic

Regarding reproduction. occurring occasionally and at irregular intervals

Epitaph

Something by which a person, time, or event will be remembered

Equilibrium yield

Catch that could be taken every year by a fixed amount of fishing effort, maintaining the stock at a constant level, assuming a steady-state situation "at equilibrium" with the total fishing effort in the long term

Equity

The quality of being fair and impartial

Estuary

Tidal mouth of a large river, where the tide meets the stream

Exsanguination

Action of draining a person, animal, or organ of blood

Extirpated

Eliminated from existence in the wild

Extrinsic

Not part of the essential nature of someone or something

Fallacy

Mistaken belief, especially one based on unsound argument

Fecundity

Ability to produce an abundance of offspring, new growth, or number of eggs

Fidelity

Faithfulness to a reproductive partner

Fish

Limbless cold-blooded vertebrate animal with gills and fins and living wholly in water

Fish meal

Ground dried fish used as fertilizer or animal feed.

Fishing

The activity of catching fish, either for food or as a sport

Flax

Plant grown for its fiber, from which linen is made, and for its seed, from which oil and livestock feed are obtained

Habituate

Make or become accustomed or used to something

Hatchery effluent

Wastes discharged from fish hatchery

Hegemony

Leadership or dominance, especially by one country or social group over others

Hematocrit

Ratio of the volume of red blood cells to the total volume of blood

Hermaphrodite

An organism having both male and female sex organs or other sexual characteristics, either abnormally or (in the case of some organisms) as the natural condition

Heterogeneous

Diverse in character or content

Holistic

Belief that the parts of something are interconnected and can be explained only by reference to the whole

Homologous

Similar in position, structure, and evolutionary origin but not necessarily in function

Hydroponically

Process of growing plants in sand, gravel, or liquid

In situ

Situated in the original place

Indeterminate

Not known in advance or precisely fixed in extent

Inertial

Keeping something in same position or moving in same direction

Integrated species conservation plans

Addresses multiple species with one action plan

Intrinsic

Belonging naturally or essential

Inviolate

Never wrong or violated

Isinglass

A kind of gelatin obtained from fish, especially sturgeon, and used in making jellies, glue, or clarifying ale

Isthmus

Narrow strip of land with sea on either side, forming a link between two larger areas of land

Juxtaposed

Place or deal with close together for contrasting effect

Laggard

Person who makes slow progress and falls behind others

Laissez-faire

Letting things take their own course or abstention by governments from interfering in the workings of the free market

Lamellae

Thin layers of living tissue

Laudable

Deserving praise or commendation

Lipid

Class of organic compounds that are fatty acids or their derivatives and are insoluble in water but soluble in organic solvents

Littoral

Relating to or denoting the zone of the seashore between high- and low-water marks, or the zone near a lake shore with rooted vegetation

Maladaptive

Not providing adequate or appropriate adjustment to the environment or situation

Manioc

Starch or flour obtained from the root of cassava, a tropical tree

Marginalized

Treated as insignificant or peripheral

Moratorium; moratoria

Test(s) for measuring content

Myriad

A countless or extremely great number

Nociceptors

A sensory receptor for painful stimuli

Normative

Establishing, relating to, or deriving from a standard or norm, especially of behavior

Noxious

Harmful, poisonous, or very unpleasant

Obligate

Restricted to a particular function or mode of life

Oocyte

Cell in an ovary which may undergo meiotic division to form an ovum

Organochlorine

Any of a large group of pesticides and other synthetic organic compounds with chlorinated aromatic molecules

Ova

Mature female reproductive cells, which can divide to give rise to an embryo usually only after fertilization by a male cell

Overcapitalize

Possessing more capital than is advisable or necessary

Panacea

A solution for all difficulties

Paradigm

A typical pattern

Pathological management

Involving or caused by compulsive or obsessive responses

PCBs

Polychlorinated biphenyls: carcinogenic contaminants

Pedagogy

Method and practice of teaching, especially as an academic subject or theoretical concept

Pejorative

Expressing contempt or disapproval

Pelagic

Inhabiting the upper layers of a water body

Pequi

Citrus-and-cheese-flavored fruit from a native tree of Brazil's highlands

Pheromone

A chemical substance produced and released into the environment by an animal, affecting the behavior or physiology of others of its species

Photoreceptor

A sensory cell or sense organ, that responds to light falling on it

Pineal

Tissue in the brain that secretes a hormone-like substance

Piscivorous

Feeding on fish

Pliosaur

An extinct reptile, specifically a plesiosaur with a short neck, large head, and massive toothed jaws

Pluralism

Condition or system in which two or more states, groups, principles, sources of authority, coexist.

Postulate

To suggest or assume as true as the basis for reasoning, discussion, or belief

Practitioner

Person actively engaged in an art, discipline, or profession

Pragmatism

Approach that assesses the truth of meaning of theories or beliefs in terms of the success of their practical application

Protogynous

Having the female reproductive organs come to maturity before the male

Quasi-governmental organization

A business entity that provides specific governmental services

Rawlsian

Relating to theory of justice, developed by John Rawls, that aims to constitute a system to ensure the fair distribution of primary social goods

Recruitment

Increase in a natural population as progeny grow and immigrants arrive

Refract

Change direction when it enters at an angle

Rover

Traveling aimlessly from place to place

Sac fry

Recently hatched fish larva that is still too immature to achieve motility and relies on yolk sac for nutrition

Sadistic

Deriving pleasure from inflicting pain, suffering, or humiliation on others

Salient

Most noticeable or important

Satiety

The feeling or state of being full or satisfied

Schistosomiasis

Disease caused by parasitic worms

Sentient

Capacity to experience feelings and sensations

Sheikhs

Leaders in a Muslim community or organization

Socioeconomic

Relating to or concerned with the interaction of social and economic factors

Supererogatory

Observed or performed to an extent not enjoined or required

Taxonomy

Branch of science concerned with classification of organisms

Technocrat

Advocate for or member of a technically skilled elite

Teleological

Relating to or involving the explanation of phenomena in terms of the purpose or consequences they serve rather than of the cause by which they arise

Terminal tackle

Type of hook or lure at the end of fishing line

Transgressing

Infringing or going beyond the bounds of a moral principle or other established standard of behavior

Transitive inference

The ability to infer social relationships between individuals

Transshipped

Transferred cargo from one ship or other form of transport to another

Triangulate

Position oneself in such a way as to appeal to or appease both left-wing and right-wing standpoints (as used in ethics)

Triglyceride

Main constituent of natural fats and oils, and high concentrations in the blood indicate an elevated risk of stroke

Truncate

Shorten the duration or extent of

Ubiquitous

Occurring everywhere

Utilitarian

Relating to or adhering to the doctrine of utilitarianism: an act is good if it benefits the majority

Veblen good

Good for which demand increases as the price increases

Year-class

Those fish that occur in same calendar year

Zoocentrist

One who holds the viewpoint or theory that focuses on animals, giving them preference above all other considerations