Foundations of Fisheries Science

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Dr. Greg G. Sass

Greg Sass is a Northern Unit Fisheries Research Team Leader and the Director of the Escanaba Lake Research Station with the Wisconsin Department of Natural Resources. Sass earned his B.S. with honors in Biology from the University of South Florida in 1999. He earned his M.S. (2001) and Ph.D. (2004) in Zoology from the Center for Limnology, University of Wisconsin-Madison (Jim Kitchell, major advisor). Sass was a Research Associate at the Center for Limnology with Jim Kitchell and Steve Carpenter during 2004-2006. He is the former Director of the Illinois River Biological Station with the Illinois Natural History Survey, University of Illinois at Urbana-Champaign (2006–2011). Sass currently holds Adjunct Professor appointments at the University of Illinois at Urbana-Champaign (Associate), Eastern Illinois University, Western Illinois University, and the University of Wisconsin-Stevens Point. He maintains an Honorary Fellowship at the University of Wisconsin-Madison, Center for Limnology. He has advised six M.S. students and one Ph.D. student. He served as vice president and president of the Mississippi River Research Consortium in 2009 and 2010, respectively. Sass has published over 30 peer reviewed journal articles, along with several book chapters. His primary interests include ecosystem-based fisheries management, invasive species ecology, bioenergetics, restoration ecology, fish predator-prey interactions, whole-lake experiments, and fish habitat ecology.

Dr. Micheal S. Allen

Mike Allen is a Professor of Fisheries at the University of Florida. He obtained his B.S. from Texas A&M University in fisheries ecology, his M.S. from Auburn University in fisheries, and his Ph.D. at Mississippi State University in fisheries and statistics. His research evaluates problems in recreational fisheries and fish ecology. He uses a combination of field collections and computer modeling to draw inferences about management actions (e.g., regulations, habitat manipulations, stock enhancement) that can improve fisheries and fish communities. He has served as the advisor for twenty-two M.S. students and six Ph.D. students. Allen has over 100 peer reviewed journal articles and book chapters, and he served as the President of the Southern Division, American Fisheries Society in 2013. He has done extensive fisheries work in the United States and Australia. Dr. Allen received the Award of Excellence from the Fisheries Management Section of the American Fisheries Society in 2011.

Dr. Robert Arlinghaus

Robert Arlinghaus is a Professor for Integrative Fisheries Management at Humboldt-Universität zu Berlin and is a fisheries scientist and group leader at the Leibniz-Institute of Freshwater Ecology and Inland Fisheries in Berlin. Since the completion of his doctoral degree in Human Dimension of Fisheries at Humboldt-Universität zu Berlin in 2004, Robert has worked at the interface of natural and social science, focusing on recreational fisheries. His main interests involve studying fisheries from a social-ecological research perspective, and he strives to understand how recreational anglers interact with fisheries resources. He has authored over 130 peer-reviewed journal articles and has produced over 250 publications, including books, edited books, and popular scientific monographs on recreational fisheries. In 2011–2012, Arlinghaus led the development of the United Nations guidelines for sustainable recreational fisheries on a global scale. He is an Associate Editor of the *North American Journal of Fisheries Management*, and serves on the Editorial Boards of *Human Dimensions of Wildlife* and the *Journal of Outdoor Recreation and Tourism*. Arlinghaus has been the recipient of various awards, including the Award of Excellence from the Fisheries Management Section of the American Fisheries Society (2008), the Medal for Young Scientists of The Fisheries Society of the British Isles (2012), and is a member of the German Dream Team of Young Scientists (2006). For his outreach activities, Robert received the Bscher Media Award in 2004.

Dr. James F. Kitchell

Jim Kitchell received his B.S. from Ball State Teachers College (1964), his Ph.D. from the University of Colorado (1970), and completed a post-doc with the International Biological Program. In 1974, he joined the Department of Zoology faculty of the University of Wisconsin-Madison. He served as Director of the Center for Limnology (2000–2009) and is currently the A. D. Hasler Professor (Emeritus). In 2003, the American Fisheries Society selected him for the Award of Excellence in Career Achievements. In 2010, the American Society of Limnology and Oceanography presented him with the Redfield Lifetime Achievement Award. In 2011, the Great Lakes Fishery Commission presented him with the Christie/Loftus Award. His peer-reviewed publications total a bit more than 200, include serving as editor of *Food Web Management: a Case Study of Lake Mendota*, and as co-editor of *The Trophic Cascade in Lakes*. His research projects include food webs in the lakes of Wisconsin, the Laurentian Great Lakes, Africa's Lake Victoria, the Central Pacific, and most recently, climate change in Lake Superior. He retired in August 2010 but continues to profit from interactions with highly motivated, smart colleagues such as those represented by the contents of this volume. He also goes fishing when he can.

Dr. Kai Lorenzen

Dr. Kai Lorenzen is a Professor of Integrative Fisheries Science at the University of Florida. He received his M.S. from Kiel University, Germany and his Ph. D. from the University of London. Lorenzen started his career as a fisheries development consultant, working mostly in Asia. He joined the faculty of Imperial College London in 1997 and moved to his current position in 2010.

Dr. Lorenzen conducts interdisciplinary, problem-oriented fisheries research that integrates quantitative ecology with human dimensions and often engages closely with management initiatives. A particular focus of his research has been the development of methods for assessing and managing fisheries enhancement and restoration programs involving hatcheries. In the course of this research, he also developed empirical generalizations about size and density-dependent processes in fish populations that have found wide application in fisheries science. Lorenzen has also conducted research on the governance of small-scale and recreational fisheries, conservation of fisheries in agricultural landscapes, and the design of aquaculture systems.

Lorenzen's research has been published widely in peer-reviewed journals, book chapters, manuals, and a software package (*EnhanceFish*). He serves on the editorial boards of *Reviews in Fisheries Science* and *Open Fish Science* and on the Scientific Committee of the Gulf of Mexico Fisheries Management Council. Dr. Lorenzen was the 2007–2008 Mote Eminent Scholar at Florida State University and the Mote Marine Laboratory.

Dr. Daniel E. Schindler

Daniel Schindler is the Harriet Bullitt Endowed Chair of Conservation in the School of Aquatic and Fishery Sciences at the University of Washington. Most of his research focuses on understanding the functioning of watersheds that support Pacific salmon in western Alaska, and the dynamics of fisheries that operate in these ecosystems. He is a principal investigator of the UW-Alaska Salmon Program that has studied salmon ecosystems in Alaska since the 1940s, and he spends several months of the year in the field in the Bristol Bay region. Schindler has been a recipient of the Distinguished Research Award from the UW College of Ocean and Fishery Sciences, and of the Carl R. Sullivan Fishery Conservation Award that was awarded to the UW-Alaska Salmon Program from the American Fisheries Society in 2012. He has provided service to a wide variety of governmental and non-governmental organizations, and serves on the editorial boards of the journals *Ecology* and *Ecosystems*. He earned a B.S. with Honours from the University of British Columbia (1990), and a M.S. (1992) and Ph.D. (1995) from the University of Wisconsin-Madison. He joined the faculty at the University of Washington in 1997 and teaches undergraduate and graduate students in Limnology, Aquatic Sciences, and Ecology.

Dr. Carl J. Walters

Dr. Carl Walters is currently a Professor of Zoology and Fisheries at the University of British Columbia, Vancouver, Canada. Walters received his B.S. from Humboldt State College, and his M.S. and Ph.D. from Colorado State University. He has worked at the University of British Columbia since 1969.

Dr. Walters is a specialist in fisheries stock assessment, adaptive management, and ecosystem modeling. He uses mathematical modeling and computer simulation techniques to better understand the dynamics of exploited marine ecosystems and to find more effective methods to manage them in the face of natural variability and high uncertainty. He advocates cooperative arrangements between governments and fishing industries to provide improved

information for stock assessment and management via methods such as industry-based surveys. His main research is on the theory of harvesting in natural resource management, with a primary interest in the basic problem of how to behave adaptively in the face of extreme uncertainty. He is one of the main developers of the ecosystem simulation program known as EcoSim, which is being used to test ideas about organization of trophic interactions in marine systems, and the implications of these interactions for sustainable harvesting theory.

He has written over 190 peer-reviewed journal articles and three books, including *Adaptive Management of Renewable Resources* (MacMillan Publishing Company), *Quantitative Fisheries Stock Assessment and Management* (with Ray Hilborn, Chapman-Hall Publishing Company), and *Fisheries Ecology and Management* (with Steve Martell, Princeton University Press). He also serves on the Editorial Boards of a number of journals, including the *Canadian Journal of Fisheries and Aquatic Sciences*, *Conservation Ecology*, *Ecosystems*, *The Open Fish Science Journal*, and *Marine and Coastal Fisheries*.

Dr. Walters is a Fellow of the Royal Society of Canada (1998) and a Pew Fellow in Marine Conservation (2001). He was also the 2001–2002 Mote Eminent Scholar at Florida State University and the Mote Marine Laboratory. He has received the Volvo Environment Prize, American Fisheries Society Award of Excellence, Timothy Parsons Medal, and the Murray A. Newman Award.

Preface

The critical social, economic, and ecological implications of fisheries have made this science an increasingly popular, complex, and multi-disciplinary field. Fish provide protein to much of the world's population (about three billion people rely upon fish for >20% of their animal protein; FAO 2012), have the highest biodiversity of any vertebrate (over 32,700 species and counting, www.fishbase.org), can be strong indicators of aquatic ecosystem health, and provide highly valuable subsistence, commercial, recreational, and aesthetic opportunities for humans. Ecosystem services provided by fishes will continue to be challenged as the world's population grows and aquatic and marine environments are altered by anthropogenic perturbations. As such, the challenge of managing fisheries in the future will require well-trained and multi-disciplinary students and professionals with the capability of understanding quantitative aspects of fisheries, human dimensions and socio-economic perspectives, and a strong background in aquatic and basic ecology. As students and fisheries professionals, we should always consider the roots of our field and the research that helped shape the discipline of fisheries science.

With this critical need of understanding seminal works from various disciplines within fisheries science in mind, in January 2010, we were fishing on a Florida lake in the Ocala National Forest trying to fool trophy Largemouth Bass *Micropterus salmoides floridanus* into eating a live Golden Shiner *Notemigonus crysoleucas* when discussion of this book began. Very simply, we discussed whether marine and freshwater fisheries researchers were reading the classic fisheries works. Not knowing the answer, we reasoned that a book compiling seminal articles from all areas of fisheries science, similar to *Foundations of Ecology* (Real and Brown 1991), would be beneficial for our discipline.

In today's world, much of our communication is rapid and brief. A great amount of focus is placed upon recent articles that garner media attention and are published in high impact factor journals. Clearly, it would be unwise as a discipline to ignore the foundational studies that served as the basis for what fisheries science is today. Using a retrospective view of foundational articles, we may be better able to address fisheries challenges today and in the future.

The purpose of *Foundations of Fisheries Science* is to identify and bridge gaps in the field of fisheries science to help students and professionals appreciate the seminal works in this discipline. Recognition of such foundational articles will be essential for tackling challenging and emerging issues in the management of fish stocks, populations, and communities. With the help of fisheries students and professionals from around the world, we present 43 reprinted articles and 30 honorable mention full citations and abstracts that have helped to mold the discipline of fisheries science. We and our five section editors hope that you find the syntheses and articles included in *Foundations of Fisheries Science* helpful for advancing this discipline.

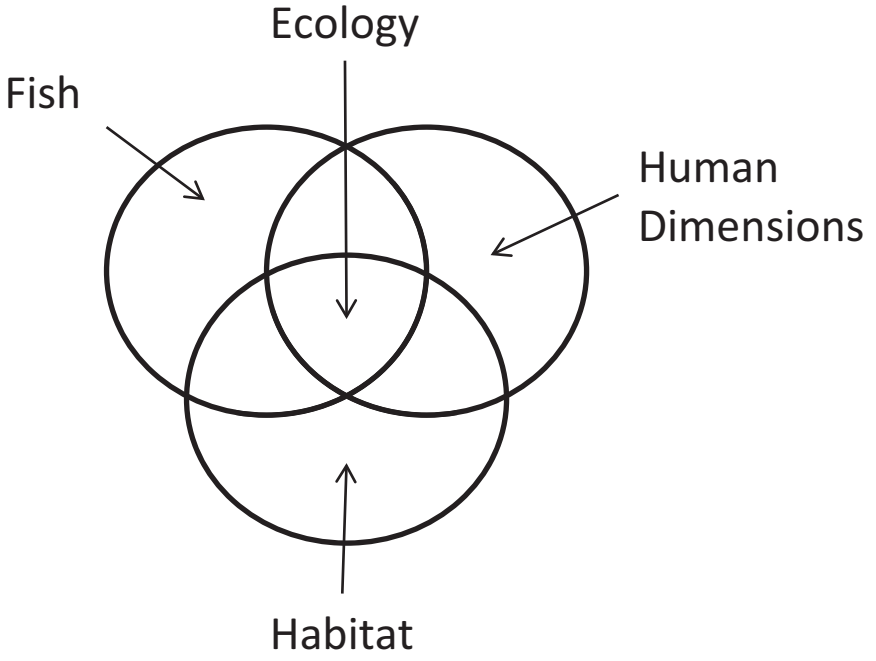
Greg G. Sass
Micheal S. Allen
April 2014

Introduction

Greg G. Sass and Micheal S. Allen

1.1. SYNTHESIS

A fishery is a system that includes the target organisms (fish, decapods, shellfish), the community of species on which the target organism depends, the habitat in which they exist, and the humans who exploit or affect the target organism within the ecosystem. Management of a fishery system requires an interdisciplinary skill set that includes quantitative methods to assess fish stocks, understanding human behavior and economics, and applied aspects of ecology. An elegant depiction of a fishery system was created by Nielsen (1993), and we adopted a similar conceptual framework to define the five sections used in *Foundations of Fisheries Science*; managing fish stocks, managing people, managing fish habitat, managing fish communities and ecosystems, and managing fisheries enhancements.



Book Objectives

The objective of *Foundations of Fisheries Science* is to highlight the classic and critical works associated with fisheries management. The book is organized into five sections (1. Managing Fish Stocks, 2. Managing People, 3. Managing Fish Habitat, 4. Managing Fish Communities and Ecosystems, and 5. Managing Fisheries Enhancements), which represent the critical components of fisheries (fish, humans, habitat) and the most common management approaches (regulations, stocking, habitat protection/restoration). *Foundations of Fisheries Science* is solely focused on articles with direct relevance to fisheries management. *Foundations of Fisheries Science* can be used as a reference or text book to lead undergraduate and graduate courses and discussions. Our goal for *Foundations of Fisheries Science* was to provide a compilation of the most influential articles in order to better understand how fisheries science has progressed as a discipline and to identify challenges in the future.

Managing Fish Stocks

Fishes have been exploited since the beginning of human civilization. Overfishing and the challenge of sustaining fish stocks have become critical over the past century as technology has advanced and the human population has expanded. Currently, about two-thirds of marine fisheries in developed countries are below their target biomass (Worm et al. 2009), and there is reason to believe that the situation is worse in developing countries (Costello et al. 2012) and freshwater fisheries (Allan et al. 2005). Use of regulations to manage fisheries has created new insights. Quantitative methods have become powerful tools used to predict sustainable yields and prevent overfishing. This section of the book highlights the critical works developed for stock assessment and to predict and evaluate the effects of regulations (quota, size limits) to provide benefits to humans and allow sustainable harvest.

Managing People

Because fishes are exploited for food and other products, human behavior influences fisheries sustainability. Understanding human behavior and the economic aspects of fisheries have become a critical consideration in fisheries management. This section of the book highlights the critical works developed to assess human behavior, motivation, satisfaction, beliefs, and the socio-economic considerations that are required for effective fisheries management. This section also includes sub-disciplines of human dimensions and economics, which span a broad spectrum of investigations that are critical to fisheries science.

Managing Fish Habitat

All fish stocks require certain environmental conditions to complete their life cycle in order to sustain their populations. Anthropogenic effects on fish stocks are not restricted to harvest and include degradation or loss of appropriate physical and chemical attributes of fish habitat. These influences can occur within systems and across landscapes, and often include perturbations at the land/water interface. Recent fisheries management policies emphasize the importance of habitat in sustaining fish stocks. This section of the book highlights the

critical works developed to understand essential fish habitat and to evaluate habitat manipulations as a management tool.

Managing Fish Communities and Ecosystems

The sustainability of a fish stock is integrally linked to aquatic and terrestrial communities and the trophic dynamics of the system. Perturbations to aquatic and terrestrial communities can change food webs and directly influence fishery attributes (e.g., yield, species composition). Single species management actions may also change community dynamics. Thus, managers have recognized that fisheries cause food web alterations, and that deliberate food web manipulations can be used as a management tool. This section of the book highlights the critical works developed to understand how management of fish communities and ecosystems are important for the overall sustainability of fish stocks.

Managing Fisheries Enhancements

Artificial propagation and stocking are long-standing management tools that have been used to create fisheries, offset the effects of harvest, and to manipulate ecosystem properties (e.g., invasive species introductions). The efficacy of stocking to enhance or sustain fisheries has been debated for decades, and the ecological and genetic implications of the practice (e.g., outbreeding depression) have been emphasized as problems. This section of the book highlights the critical works developed to examine the positive, null, and/or negative effects of artificial propagation and stocking in the management of fisheries.

Article Selection

We used a hierarchical approach to select the seminal articles included within *Foundations of Fisheries Science*. The first and primary decision for article selection was to solicit nominations by popular vote from the American Fisheries Society membership and other fisheries societies around the world. Using this approach, we remained objective in the article selection process and aimed to broadly represent the diversity of people (e.g., students, consultants, professionals, managers, scientists) actively involved in fisheries management and their opinions about the most influential articles within the discipline. We purposely chose a survey for article selection to remain as objective and unbiased as possible in the process. Still, a level of subjective selection was required by the editors and section editors in the case of equally-ranked articles, space limitations within the book, maintaining a balance of topics, and/or whether enough articles were received for each section of the book within our survey. Thus, we used the discretion of the editors and section editors when necessary to reach a final decision on article inclusion within *Foundations of Fisheries Science*.