Introduction

ANDREA BELGRANO AND CHARLES W. FOWLER

This volume had its origins just after we published our joint paper on pattern-based policy (Belgrano and Fowler 2008). We were approached by Cambridge University Press with the proposal to publish a book on Ecosystem-based Fisheries Management in marine systems. In agreeing to do so, the title we proposed was: "Ecosystem-based Management for Fisheries: Linking Patterns to Policy." To achieve holism, the mission of being interdisciplinary has been stressed throughout a growing body of literature that presents tenets, pillars, or commandments to which management should adhere. We both had an abiding interest in macroecology. It seemed time to weave macroecology into the folds of management in what we referred to as "pattern-based" management, or systemic management, wherein deviations or abnormality observed in macroecological patterns serves as the basis for restorative action, or standards for sustainable human interactions with the non-human. Management involves maintaining such sustainability. With this in mind, our plan was to produce an edited volume that would add macroecology to the other disciplines that were already being seriously considered. We circulated our proposal to prospective authors, stressing the objective of making use of macroecological patterns. We hoped to have chapters broadly representative – geographically, scientifically,

Ecosystem-Based Management for Marine Fisheries: An Evolving Perspective, eds. Andrea Belgrano and Charles W. Fowler. Published by Cambridge University Press. © Cambridge University Press 2011.

and across the spectrum of academic, governmental, and non-governmental organizations and authorship.

The chapters that materialized accomplished many of these objectives. We fell short, however, in the objective of having a book in which most, or all, chapters dealt directly with macroecological patterns – particularly as they can be used in management. In taking advantage of what we had to work with, it became clear that the fields of both science and management remain in a state of transition wherein ecosystem-based management for fisheries is still seen largely as the objective rather than as one of many steps toward fully holistic management. As in the evolution of anything, management has to move through its individual steps and it became clear to us that managers, scientists, and stakeholders have not fully grasped the essence of ecosystem-based management for fisheries in order to move on to more inclusive perspectives.

With this in mind, we had to address an important question: "Given the situation in our world, as represented by the chapters we have in hand, what is being accomplished?" The answer seemed to be that we are, in fact, moving forward and that a more complete grasp of ecosystem-based management for fisheries will help perceive more clearly the steps that lie ahead. There is progress. We decided to adopt a new title: "Ecosystem-Based Management for Marine Fisheries: An Evolving Perspective."

With this perspective, the chapters of this book treat various elements of management, various aspects of ecosystems, and contributions that research makes to understanding the complexity of both. Taylor's chapter (Chapter 8) exemplifies the evolutionary aspect of progress being made; we consistently expand our frontiers as we make progress in the evolution of our thinking. Agardy (Chapter 9) emphasizes the human element of carrying out management with an eye toward achieving holism in the process; non-governmental organizations can be quite effective in contributing to change and educating stakeholders. Casini *et al.* (Chapter 1), Link *et al.* (Chapter 2), and Livingston *et al.* (Chapter 3) describe research and management in different areas of the globe to exemplify how complexity is now taken into account, especially in terms of generating models of ecosystems – in part, to predict the effects of fishing. Ecosystems are recognized as complex systems. Zhang and Kim (Chapter 4) provide an example of similar work undertaken in the context of an intensive set of human factors – also incredibly complex. Eikeset *et al.* (Chapter 5) make it clear that if we ignore the complexity of ecosystems, including the human component, we face a very real risk of consequences completely unforeseen; higher-order interactions are part of the complexity of systems and result in unintended reactions to management. Lima (Chapter 6) emphasizes the risk of carrying out management that neglects the complexity of population dynamics and predator–prey systems; ignoring the subsystems of ecosystems is a source of serious risk. Similarly, Svedäng *et al.* (Chapter 7) emphasize the risk of ignoring the behavioral nature of species with populations that serve as integral components of ecosystems. Fowler and McCluskey (Chapter 11) use the declining trend in recommended fishing rates that accompany greater consideration of complexity, and relevant macroecological patterns, to estimate fishing rates that can be considered holistic – fishing rates that apply to individual species, species groups, ecosystems, or the marine environment. For further progress toward holism, Fowler and Hobbs (Chapter 10) show how to ask even more management questions and make use of macroecological patterns in each case, thus converting management to a process that is open to many options, each treated in a fully integral manner, including the option of treating the evolutionary impact of fishing directly.

In our overview chapter "On the path to holistic management: ecosystem-based management in marine systems" (Chapter 12), we show how the work represented by the other chapters fits into the evolution of management as it progresses, bit by bit, toward holism. The chapters of this book help substantiate the basic principles upon which progress toward holistic management depends. That progress includes progress toward the fully integrative aspects of holistic management that can be achieved by weaving use of macroecological patterns into the goal-setting process. The change that can happen, as facilitated through education (Chapter 9), has yet to be realized.

We chose to organize the chapters of this book in a way that characterizes the progress being made as steps toward bringing macroecology, along with evolutionary ecology, into the realm of management. The first four chapters provide examples in which the complexity of ecosystems is known to include a large collection of different factors involving the physical environment, trophic interactions, food webs, and other ecological relationships. These chapters represent steps toward including the effects of humans in such systems. They also illustrate the kinds of science that are currently being used to make management decisions – often seen as very sophisticated attempts to bring ecosystems into the management process.

The next five chapters present arguments for progress toward greater holism. Several stress the importance of including, or accounting for, greater complexity than is currently accomplished. In Chapter 5, Eikeset *et al.* argue that imperfections in the ways we account for complexity (including the complexity of human systems) result in unforeseen reactions to our management – many of which can be recognized as problematic. Evolutionary reactions to fishing are real and need to be accounted for in management. Lima (Chapter 6) argues that interactions among species that involve their basic population dynamics are elements of complexity that cannot be ignored in progress toward any form of ecosystem-based management. Svedäng *et al.* (Chapter 7) add behavior to the list of factors that have to be considered as fundamental elements in the complexity of ecosystems. Agardy (Chapter 9) describes how stakeholders, especially non-governmental organizations, are involved in management. This involvement is a critical component of both change toward greater holism in management (e.g., through education) and the means of weaving macroecology and macroecological patterns into the management process. Taylor (Chapter 8) makes a strong case that something like a different paradigm is needed in order to accomplish holistic management. This may occur as a stepwise process (pushing forward our boundaries) of which ecosystem-based management is a step in the right direction.

Fowler and Hobbs (Chapter 10) draw upon the principles emergent from work such as that represented in the first nine chapters to bring added complexity into the management process. This is accomplished, in this case, by addressing as many management questions as possible with carefully chosen patterns, especially macroecological patterns in the case of ecosystem-based management. Fowler and McCluskey (Chapter 11) provide illustrative examples of how holism is involved in the setting of goals by addressing a number of specific management questions with macroecological patterns. Finally, our overview chapter (Chapter 12) synthesizes the structure of the book as it leads to the weaving of macroecological patterns into the management process and, at the same time, achieves holism heretofore not seen.

In our 2008 paper, we used the symbol "∞" intentionally. Fully holistic means that nothing is excluded in the way management is carried out, in what is taken into account, and in the things to which management applies. The risk of extinction, all evolutionary processes, and the full spectrum of ecological dynamics are included – as are all behavioral, hormonal, physiological, and molecular processes. All aspects of factors listed in the chapters of this book are included. In our paper, it was our strong contention that the integrative nature of natural patterns permits their being used for holistic management. It is our sincere hope that this book will provide material helpful to achieving holism in the management process – not simply in regard to marine fisheries, but in terms of management as it applies in all realms. We intend the meaning of the term holism to be that of the fully integral nature of natural patterns – it excludes nothing.

When, and if, global society can get to a point of managing holistically, it is our hope that we have learned from experience in today's world and that the lesson will be to remain open-minded about the possibility that even further steps will be necessary.

We extend our sincere thanks to all who contributed to the production of this volume. Our gratitude includes an appreciation of the work by all of the authors, as well as by all of the people whose help and support they received along the way. In our cases, these special contributions include our wives, Elisabeth and Jean. Alec MacCall very kindly agreed to write the Foreword and Keith Brander the Afterword; we very much appreciate their contributions. We are deeply thankful to the editorial staff at Cambridge University Press for all of their efforts, help and advice in the publication process (particularly: Denise Cheuk, Joanne Endell-Cooper, Jacqueline Garget, Helen Flitton, Chris Hudson, Dominic Lewis, Hilary Mead, and Lynette Talbot). Finally, we want to extend special compliments to Lesley Bennun (copy editor) for hours of work that greatly improved the quality of this book.

Reference

Belgrano, A. and C.W. Fowler. 2008. Ecology for management: pattern-based policy. In Munoz, S.I. (ed.), *Ecology Research Progress*. Hauppauge, NY: Nova Science Publishers, pp. 5–31.

PART I CURRENT FORMS OF MANAGEMENT

Chapters 1 through 4 set the stage for the trend represented in this book; a trend in which more and more of the complexity of real-world systems is recognized and involved in management. The chapters of this section typify the sophistication brought to the process of science in support of management as it is currently implemented in many parts of the world. This sophistication often involves numerous elaborate models and complicated management plans. Such approaches exemplify a focus on ecological processes (e.g., predator–prey interactions, competition, trophic dynamics, and food webs) in which we humans inject ourselves by harvesting fish. Much of this work involves overt recognition of the complexity of natural systems and substantiates our understanding of complexity as a fundamental principle. Complexity is recognized, for example, in lists representing the numerous species with populations in ecosystems affected by human activities such as commercial fishing, pollution, and changes in acidity. Inherent to the factors important to the structure and function of ecosystems are environmental dynamics involving temperature, the circulation of currents, and a wealth of other physical and chemical factors. Such work is crucial to substantiating a variety of principles that are fundamental to progress toward more holistic management.

1

Food-web and climate-related dynamics in the Baltic Sea: present and potential future applications in fish stock assessment and management

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Abstract

The human influence on marine ecosystems is being recognized as a basis for extending the horizons of management. Historical anthropogenic influence has involved a wide variety of factors, including the effects of fishing on the dynamics of individual resource species. More inclusive complexity includes the interactions among species, and their interactions with other aspects of their biotic and physical environment. In this chapter, we review these elements of complexity for the central Baltic Sea. This ecosystem has a long history of human influence and its own special characteristics, due to its geographic location, geomorphic traits, and socio-political context. More and more of the complexity of this ecosystem is being recognized as scientists add to the wealth of documentation regarding the influence of surrounding terrestrial activities, monitor the dynamics of component populations, establish the effects of weather and climate, and illuminate the relationships among the various elements of the ecosystem. There is a great deal of historical information to characterize the changes that have occurred, not only among the various species making up the ecosystem, but also at the ecosystem level. Some of these have involved regime shifts, in part owing to climatic factors. Such

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significant changes involve more than one of the ecosystem's trophic levels as well as physical features such as salinity, temperature, and oxygen concentration. We begin to understand some of the complexity of ecosystems when we recognize that such factors are not alone, however, and realize that trophic cascade dynamics and feedback loops are also involved. Of particular importance for fisheries management is the clarity with which we have observed, documented, and explained some of the effects of fishing, not simply as an influence on individual resource species, but on the ecosystem as a whole. Some of these ecological aspects are currently used in fish stock assessment and management in the central Baltic Sea, but recently acquired additional knowledge could be potentially used in the future to reach the goal of a sustainable exploitation of fisheries resources in this area.

Introduction

Human activities influence marine ecosystems in multiple and interactive ways (Jackson *et al.* 2001, Hughes *et al.* 2003, Halpern *et al.* 2008). Not only has commercial fishing a substantial impact on ecosystem structure and function by removing target fish biomass (Folke *et al.* 2004, Frank *et al.* 2005), but it also influences non-target species and habitats (see e.g., Browman *et al.* 2004). In addition, fish stock dynamics are influenced by variations in climate, introduced species, and water quality (Daskalov *et al.* 2007). The Baltic Sea is situated in a region where human impacts on the marine ecosystem have been substantial for over a century (Österblom *et al.* 2007, Eero *et al.* 2008). Extensive seal hunting, nutrient runoff from agriculture and municipalities, toxic compounds with a significant impact on top predators, high fishing mortality resulting from commercial and recreational fishing, and changes in climate, all have influenced this semi-enclosed sea. The Baltic is a particularly sensitive sea, being characterized by low salinities whose annual variations can have a large impact on species abundance, composition, and distribution (Voipio 1981). At the same time, as it is severely impacted by human activities and hydro-climatic conditions, it is also a sea with clear political boundaries. All nine bordering countries (except Russia) are part of the European Union (Fig. 1.1), leading to a common policy framework being available for joint action. The framework includes the Common Agriculture Policy, the Common Fisheries Policy, the Water Framework Directive (EC 2000) and the Marine Strategy Directive (EC 2008). These policies and directives all have a substantial impact on the sectors influencing the marine environment. The Marine Strategy Directive, in particular, has laid the foundation for integrating these tools toward the

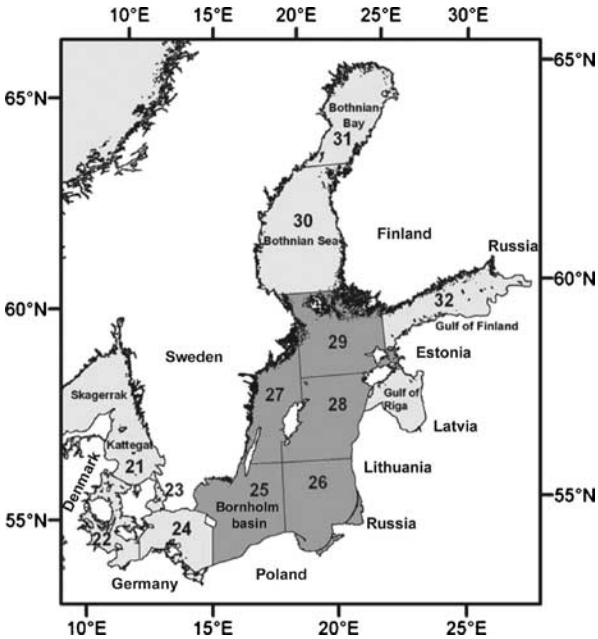

Fig. 1.1. Map of the Baltic Sea. The central Baltic Sea (Baltic Proper) is marked in dark gray.

end of sustainable management of European seas. Management in the Baltic Sea is already ahead of the timetable laid out in the directive. The Helsinki Commission (HELCOM), the international governing environmental body for the Baltic Sea (also including Russia) has developed a joint action plan (the Baltic Sea Action Plan: HELCOM 2007), addressing several of the relevant issues. Nevertheless, much remains to be done. There is however a relatively strong political will in the region to address marine issues and the Baltic can thus be said to be well poised to become a pilot area for implementing an ecosystem approach in a European context.

In this chapter, we treat the concept of ecosystem-based management for fisheries (EBMF) focusing on its ecological aspects (food web and climate impact). In other words, EBMF is handled by taking into consideration the effects of fisheries on the ecosystem, *and* the effects of ecosystem on exploited fish and fisheries. We shortly present an account of the existing knowledge of the Baltic Sea ecosystem functioning and how this knowledge is currently used in fish stock assessment and fisheries management advice. Furthermore, we propose the potential use of additional information in the forthcoming assessment and management activities. We focus on the central Baltic Sea (the so-called Baltic Proper) because of the more detailed knowledge of this region if compared with other areas of the Baltic Sea. However, other areas will be also taken into consideration for comparison and completeness.

Current ecosystem knowledge

This section describes briefly the present knowledge of the general ecosystem functioning and specific ecological links in the Baltic Sea. The information provided here is based on data from the recent three decades (1974–2008), this choice being dictated by the fact that stock assessment data in the Baltic Sea are available for all the three main species – cod (*Gadus morhua*), herring (*Clupea harengus*), and sprat (*Sprattus sprattus*) – only during this period.

Fish stock dynamics

In general, a high cod population is accompanied by low sprat population (ICES 2009a), since sprat is the main fish prey for cod. During periods of low cod biomass, a consequence of adverse hydro-climatic conditions and/or fishing, sprat is released from cod predation (Casini *et al.* 2008). During the last three decades, following the collapse of the cod stock, the sprat stock increased fourfold, shifting the Baltic from being cod-dominated to being sprat-dominated (Fig. 1.2A). However, the sprat population is also favored by mild weather which supports sprat egg production and survival (Nissling 2004) and larval growth (Baumann *et al.* 2008) as well as the development of the main prey for larval sprat, the copepod *Acartia* spp. (Voss *et al.* 2003, Alheit *et al.* 2005). On the other hand, the decrease of the herring population during the past three decades is likely due to the synergistic effects of high fishing pressure (ICES 2009a), eutrophication-related degradation of coastal spawning grounds (Cederwall and Elmgren 1990), and decrease in mean body growth (Casini *et al.* 2010a; see next section) (Fig. 1.2B).

The period considered here is characterized by low abundance of aquatic mammals, resulting from declines observed through most of the 1900s due to human activities (Österblom *et al.* 2007). Therefore, the potential effect of a large population of aquatic mammals on the fish community is not well understood. However, a modeling work by Österblom *et al.* (2007) predicted that in the presence of seals and harbor porpoises, as in the first half of the 1900s, both cod and clupeid populations could be maintained low by predation, at least at low levels of system productivity.

Overall ecosystem change

Recently, Integrated Ecosystem Assessments (IEA) have been conducted for the central Baltic Sea (ICES 2008a) revealing a regime shift in the pelagic ecosystem during the late 1980s and early 1990s (Möllmann *et al.* 2009; Fig. 1.3),