

Chapter 1

Introduction

Systematic fisheries research that can develop and test hypothesis relating alternative management and regulation structures with fishery performance requires the integration of resource biology and ecology with the economic factors that determine fishers' behavior in space and time. The distinction between management and regulation will be discussed below. The inherent characteristics of fish resources create different contexts of human interdependencies, and thus the same institution or management or regulation structure can result in a different performance when applied to fisheries having different resource and community contexts. The degree of resource mobility in space and time as well as the degree of fishing autonomy of small-scale and industrial vessels provides direction to those human interdependencies in resource use.

Modern fisheries bioeconomics can provide insight into developing approaches to deal with the complexities of overcapacity and overexploitation in marine fisheries where most are affected by natural fluctuations, changing coastal ecosystem dynamics, and lack of solid governance. In this introductory chapter, we answer the basic question of why fisheries management is needed, and discuss the characteristics of fish stocks and the resultant participant behavior that prevents the market from optimally allocating this type of resource. We also define fisheries bioeconomics, and provide a short introduction to the topics covered in the book.

1.1 Why is fisheries management and regulation needed?

There are many reasons why fisheries utilization can be improved by controlling the activities of actual and potential participants. Given that this is a book on bioeconomics, the lack of appropriate system of property rights is of particular importance. Although the topic cannot be discussed in detail here, it is generally

agreed that in order to create incentives to put resources to their highest valued uses, property rights should have the following characteristics (Randall, 1981; Schmid, 1987; Scott, 1989, 2008; Anderson and Holliday, 2007):

- *Exclusivity*: This refers to the degree to which the outputs produced as a result of owning and using the resource for which the property right is defined are under the complete control of the owner to use or relinquish. Similarly, the degree to which all costs associated with the use of the resource is the responsibility of the owner. The ability to enforce these claims is an important aspect of exclusivity, and sometimes enforceability is listed as a separate characteristic. It also refers to the ability to use and manage the resource without outside interference.
- *Permanence*: This refers to the length of time that the right can be maintained. It is important because incentives for proper use will depend on how long the owner can claim benefits or be responsible for costs.
- *Security or quality of title*: This refers to the degree to which the right is free from involuntary seizure or encroachment.
- *Transferability*: This refers to the ability to transfer the right to someone else. This is also important for making it possible to put the resources to their highest valued use.

As will be discussed in more detail below, even in cases where there is active government intervention in fishery utilization under open access, these characteristics do not apply to fisheries resources, especially not to the degree that they do to other natural resources. Basically this means that participants have little incentive to utilize a fish stock so as to take full advantage of its reproductive potential. As we will demonstrate below, designing regulation procedures such that they provide incentives similar to those provided by property rights can prove very successful.

When thinking about fisheries management and regulation, it is important to consider other aspects and attributes of fisheries resources that can affect short- and long-term fishing behavior and exploitation patterns, both with and without regulation. Among these, high exclusion costs, high transaction costs (information costs and enforcement costs), free rider behavior, and a social trap situation must be acknowledged (Seijo *et al.*, 1998; Caddy and Seijo, 2005).

High exclusion cost. It means that the use of an existing fish stock cannot easily be limited to those who have the right to fish it. Just because there are provisions whereby only a specified number of participants are nominally allowed to fish does not mean that all others can be effectively excluded. Because of the mobility and migratory nature of most fish resources, enforcing rights and regulations in marine fisheries is not only logistically difficult but also very costly. Fisheries management and regulation involve *high enforcement or policing costs* in order to keep participation limited to permitted individuals and fishing activities limited to those that are permitted. For oceanic (and many shelf) fisheries, the areas to be policed are extensive, and conventional patrol vessel operations are ineffective and costly. Under these circumstances, a nonenforceable right becomes an empty right.

High information costs. The complexity of fisheries management is increased by the major uncertainties inherent in natural systems, as well as by a range of other biological, social, political, and economic factors, requiring a precautionary approach to fisheries management (FAO, 1996). In general, it is very expensive to obtain useful information sufficient enough to know what is the right management strategy and corresponding regulations even in the context of stakeholders' cooperation. In addition, the multidisciplinary nature of the required information to assess the state of the fishery and the ecosystem that sustains it require interdisciplinary approaches linking natural and social sciences. This book is an attempt to foster the needed interdisciplinary analysis in fisheries by merging biological and ecological principles and methods with the economics of fisheries to further develop the field of fisheries bioeconomics.

The difficulties in meeting the basic assumptions of exclusivity and low information and enforcement costs are serious obstacles to effective property rights allocation. The inherently high exclusion and transaction costs, the characteristics of fisheries described above, require us to look beyond the simple solution of providing for "proper allocation of individual rights." The allocation of resources between stakeholders is the problem area where progress is most urgently required, both nationally and internationally.

1.2 The social trap and free rider behavior in fisheries

In addition, it should be recognized that fisheries are usually confronted with a social trap situation that is directly related to the lack of exclusivity in the rights to open access fish stocks. Applying Shelling's (1978) terminology, a social trap exists when the micromotives of an individual fisher in the short run are not consistent with the macroresults he and other fishers desire in the long run. The short-run micromotives consist of catching as many fish as possible in order to increase individual marginal benefits, while the long-run desired macroresults may involve achieving the maximum economic yield or maximum sustainable yield. Uncertainty as to future stock availability determines that long-run results are usually dominated by short-run marginal benefits. Allowing for temporal fluctuations in resource productivity and preferences of resource use, a sustainable yield from a fishery will tend to be attainable only when the number of fishers is limited, and they act in concert to implement some form of effort regulation (Seijo, 1993). However, if the group is large, a fisher may be an unintentional free rider or a noncontributing user. This type of individual usually occurs when there is no voluntary collective action by the majority of community members to prevent resource depletion, and also when uncertainty exists as to stock abundance (which is the usual case in marine fisheries).

1.3 Stock fluctuations due to natural causes

Independently of fishing, stocks can also fluctuate in the short and long run because of natural causes. For pelagic resources, major stock fluctuations occurred

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even prior to human exploitation, as shown by the work of Soutar and Isaacs (1974). Productivity fluctuations related to the El Niño Southern Oscillation in the eastern Pacific have been documented by Lluch-Belda *et al.* (1989), and similar climatic forcing factors have been affecting marine production systems on the global level (Kawasaki, 1992; Klyashtorin, 2001). It should be pointed out that decadal periodicities are frequently mentioned in the fisheries literature (e.g., Zwanenberg *et al.*, 2002), but Klyashtorin (2001) suggests that natural cycles in the productivity of around 50–60 years' duration are likely to be dominant, and that long-term fluctuations are likely to be reinforced by climate change.

Modern fisheries bioeconomics should integrate principles, concepts, and analytical and numerical techniques to deal with the dynamics of natural fluctuations.

It should also be acknowledged that coastal fishery resources are also vulnerable to other human activities that may affect critical habitats and/or biological processes. In fact, the role of environmental change has become more evident in recent years as fisheries data series of all but the longest established fisheries exceed half a century in duration, but our ability to discriminate between natural environmental changes, the effects of fishing, and other human activities seems to remain poor.

Within this context, the problem of fisheries management, which comprises the choice of a target stock size and a harvest time path to achieve or maintain it, can be a difficult and complex process. However, just as troublesome is the problem of fisheries regulation which comprises the determination of how to control harvest such that the desired and actual catches in any year coincides. One of the problems is that although the regulation objective can be stated in terms of annual catch, as stated in the previous sentence, a fishery is not a static phenomenon, as evidenced by the time-path trajectories that will be shown in the initial chapters of the book. Human interventions or natural events that happen in one period can have repercussions in the future. This is also true of regulations. Human actions that are done in one period can have such effects on both the stock and fleet that will affect the efficacy of current regulations and the general ability to control harvest in the future.

In summary, the lack of an appropriate property right system is perhaps the main reason why fish stocks tend to be misused under an open access regime. However, there are other reasons as well, some of which are related to and exacerbated by the misspecification of property rights. A more complete analysis of this will be provided throughout the following discussion. We will describe below what exactly the “misuse” of fisheries resources really means, and elaborate on why it occurs under open access, and on the range of things that can be done to address the problem.

1.4 Fisheries bioeconomics

Fisheries bioeconomics (Clark, 1985; Anderson, 1986; Hannesson, 1993; Seijo *et al.*, 1998) is a field that integrates resource biology and ecology with the

economics of fisher behavior, considering space, time, and uncertainty dimensions. The relative importance of including some or all of the above-mentioned dimensions in the bioeconomic modeling and analysis of fisheries will depend on the fishery-specific management questions, the degree of stock mobility and sensitivity to environmental factors, and the likely behavior of fishers over time and space.

In order to address the above definition of fisheries bioeconomics, this book covers the following set of topics. In Part I called Single Stock—Single Fleet Models, six chapters are presented in addition to this introduction. Chapter 2 presents the fundamentals of fishery bioeconomics with the aggregate Schaefer–Gordon model. The main purpose is to understand the open-access bioeconomic process that leads fisheries to biological and economic overexploitation and to answer the questions of what biologic and economic overexploitation means. And why will individual choice not lead to economic efficiency? In Chapter 3, we formally introduce the concept of fishery dynamics, which shows the analysis of how stock and effort change over time in response to biological and economic conditions. It also introduces a disaggregated model in order to consider the decision-making process of individual vessel operators. This disaggregated model provides a more robust picture of the exploitation of a fishery. It is especially important when considering the effects of regulation. Chapter 4 presents a formal mathematical discussion of the dynamic optimal utilization of a fish stock in the context of commercial utilization, showing the optimal combination of stock and fleet size and the necessary time path of moving from other combinations to the optimal one. In Chapter 5, the discussion is expanded to provide a better picture of population dynamics by presenting an age-structured format where recruitment, individual growth, and natural mortality are treated independently. For the most part, the economic and fishery management lessons that follow from the Schaefer model can be stated in terms of the age-structured model. In fact, although it requires numerical rather than analytical techniques, it is possible to derive sustainable revenue and cost curves as well as population equilibrium and economic equilibrium curves. It does provide something extra in that it allows for analysis of age at first capture regulations and for the peculiarities of different stock recruitment relationships. But for the most part, the purpose of introducing it is not to learn more fisheries economics per se. The purpose is to ensure that economic principles can be applied to answer management questions using a potentially superior bioeconomic model.

In Chapter 6, we discuss the tasks of fisheries management and regulation. The first one is the selection of what is the desirable amount of harvest to take, given the current biological and economic status of the fishery. The second is to implement regulations such that actual harvest corresponds to the desired harvest taking into account management agency and participant costs as well as the short- and long-term effects of how the regulations will affect participant behavior. We will call the first task fisheries management and the second task fisheries regulation. Chapter 7 describes, analyzes, and compares and contrasts the various types of regulations that have been and could be used to manage fisheries. It shows the short- and long-run bioeconomic effects of these

regulations taking into account how participants will likely react and the biological and economic interconnections of fisheries utilization. This chapter stresses that the analysis of a regulated fishery is analogous to that of an open-access fishery. The difference is in demonstrating how the time paths will differ, given the constraints imposed by regulation.

In Part II, Multi-Stock—Multi-Fleet Models, and chapters dealing with ecosystems, space, seasonal and stochastic fluctuations, and uncertainty have been presented. Chapter 8 introduces a new section of the book where some of the assumptions of analytic and numerical bioeconomic developments presented for single species and single fleet distributed homogeneously over space in a deterministic context are relaxed. Managing fisheries with ecosystem considerations involves relevant ecological interdependencies among species along the trophic web. Understanding their dynamics may become essential to further understand fisher behavior over time. Nevertheless, how far bioeconomic modeling and analysis should go in incorporating multispecies and their bioecological interdependencies will depend on (1) the relevant fisheries and ecosystem management questions posed to address stock recovery and sustainability strategies within an ecosystem framework, (2) the bioecological and economic data availability for serious parameter estimation of increasingly complex mathematical models required to address the identified relevant questions, and (3) the assumptions and associated uncertainties of such complex models. With the selected species to be considered in the relevant ecosystem, we have to also consider the heterogeneity of fleets targeting or harvesting them incidentally over time.

Hence, in Chapter 9, we will expand on the single-species, single-fleet biomass dynamic and age-structured bioeconomic models discussed in Chapters 2 through 5 to consider multifleet and multispecies fisheries with ecological and/or technological interdependencies among species and fleets. In a parsimonious process toward an ecosystem approach to fisheries management, identifying and considering the relevant bio/ecological relationship present in a fishery or a set of interdependent fisheries becomes a priority. Also, of importance is to consider possible technological interdependencies among fleets and among fisheries. That is the situation of fleets that compete for a stock, multispecies fisheries that harvest incidentally stocks that constitute targets to other fishery, and sequential fisheries where fleets with heterogeneous fishing power, gear selectivity, and costs of effort affect different components of the population structure over time.

Chapter 10 reviews the need for understanding the spatial heterogeneity in marine resource abundance and the corresponding spatial behavior of fishing intensity over time. The recognition of the implications of dynamic pool assumptions in overestimating stock abundance is discussed together with spatial modeling efforts aimed at relaxing this unrealistic assumption for sedentary species and many low mobility demersal resources. Responsible spatial management and modeling of fisheries require understanding the spatial behavior of species with the corresponding abundance heterogeneity in space and time and the ecological interdependencies within an ecosystem framework. It also involves proper understanding of fisher behavior driving their spatial fishing

intensity. This last aspect is fundamental to fisheries economics which focuses on the motivation of fisherman in their fishing behavior over space and time. This chapter discusses the use of marine-protected areas for spatially managing single stocks as well as for interdependent stocks in metapopulations with source–sink configurations.

Chapter 11 presents ways of incorporating seasonality and long-term patterns of fluctuating stocks in the bioeconomic analysis of fisheries. In the first part of this chapter, we address the problem of seasonal regulation of effort under open access using an age-structured bioeconomic model with seasonal spawning, hatching, and recruitment processes built in. In the second part, we model the long-term dynamics of stock fluctuations, using a periodically varying carrying capacity. We also present an age-structured bioeconomic model for environmentally driven fisheries that respond to long-term oceanic patterns of productivity and environmental conditions. This is done by using an environmentally driven recruitment function.

Finally, Chapter 12 deals with uncertainty and risk analysis in marine fisheries. We acknowledge that fisheries management in the last few decades has learned that population dynamics is affected by factors about which information is usually incomplete. Bio/ecological factors that play a role in population dynamics and bioeconomic analysis are often unknown or their relevance unclear. As shown in Chapter 9, fishing a specific target species may be affected by ecological as well as technological interdependencies occurring between species and fleets. Spatial complexities, like the ones presented in Chapter 10, involve not only understanding and estimating resource and fisher behaviour over space and time but also studying the dynamics of oceanographic processes dispersing larvae that will eventually settled in source or sink areas where habitat and food availability are critical for defining the dynamics of metapopulations. The extent to which population dynamics are affected by the surrounding ecosystem is often very complex and should be accounted for. How environmental fluctuations, as discussed in Chapter 11, affect fish populations on a local or global scale is largely unknown. Besides the observed periodicities of such fluctuations and the correlations with fish harvesting recently identified, the underlying cause–effect mechanisms are yet to be identified with reasonable certainty.

But not only should fisheries management acknowledge that fish population dynamics are complex and influenced by factors that are usually poorly understood, it should also recognize that fishers' behavior over space and time is difficult to predict and more so to effectively avoid or mitigate overexploitation and over capacity. Managing fisheries requires detailed knowledge regarding factors that influence fishing behavior, which in turn can vary depending on fishermen's cultural background and context, fishing technology used, and perceptions and strategic behavior affecting compliance to the regulatory scheme in place.

Another important part of the book is the series of exercises that have been developed to accompany, amplify, and expand on the material in the text. They are presented in the form of Excel spreadsheets that are prepared to produce graphical analyses. This allows for an understanding of how the analytics are affected by changes in the parameters. In many cases, simulation models are

presented to show the dynamics of open access and regulated fisheries in more detail. In addition to being useful for pedagogical purposes, it is hoped that the simulation models can provide the springboard for further dynamic modeling studies.

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