MANAGEMENT OF STRADDLING FISH STOCKS: A BIOECONOMIC APPROACH

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Contents

Summary

This chapter discusses the management of straddling fish stocks – a special category of internationally shared fishery resources that straddle exclusive economic zones and the adjacent high seas. A historical perspective is provided followed by the characterization of the present situation. Special attention is paid to the difficulties in achieving and sustaining cooperative management agreements.

The overall approach to straddling fish stocks management is based on bioeconomic models, which combine both biological and economic dimensions of fisheries. In particular, a standard dynamic bioeconomic model is used to determine the outcomes of cooperative and non-cooperative management scenarios. The results show that in general cooperation yields significant gains to be shared among fishing agents when compared to non-cooperation. Nonetheless, cooperative agreements achieved through regional fisheries management organizations are frequently undermined by the possibility of new members joining the organizations following stock recovery, and other forms of free-riding such as illegal, unreported and unregulated fishing.

In order to illustrate the model results, two fishery case-studies are presented: the Northeastern Atlantic bluefin tuna and the Norwegian spring-spawning herring. Both show the problems associated with non-cooperative harvest of straddling fish stocks. Furthermore, the studies show the importance of bioeconomic modeling in predicting the outcome of different management regimes and in setting optimal fishing strategies.

1. Introduction

Straddling fish stocks are a special category of internationally shared fishery resources that straddle exclusive economic zones (territorial seas claimed by coastal states) and the adjacent high seas. These species, usually targeted by both coastal states and distant water fishing states, became increasingly disputed after the establishment of exclusive economic zones by the United Nations Convention on the Law of the Sea (1982). Lack of cooperation between coastal states and distant water fishing states has led to the overexploitation of many stocks worldwide. A paradigmatic example, analyzed later in this chapter, is the Northern Atlantic bluefin tuna.

The economic and biological overexploitation of straddling fish stocks and the increasing conflicts among countries, often called “international fish wars”, induced the United Nations to convene the United Nations Conference on Straddling Fish Stocks and Highly Migratory Fish Stocks (1993-1995). In 1995 the conference adopted an agreement, commonly known as the United Nations Fish Stocks Agreement, which entered into force in 2001. The core of the agreement consists of placing regional fisheries management organizations as the basic cells for the management of these marine resources. These organizations should integrate both the coastal states and the distant water fishing states effectively interested in the fisheries.

The United Nations Fish Stocks Agreement left a few problems unsolved that may undermine cooperative management achieved under the aegis of regional fisheries management organizations. One problem is the possibility of prospective new members wanting to join these organizations and share the harvest following recovery of the stocks, thus reaping the benefits of stocks’ management without having borne any of the cost of the investment (free-riding). Another problem is the one posed by non-members who do not follow the management regime set by regional fisheries organizations and thus behave non-cooperatively when exploiting the fishery resources in their exclusive economic zones or in the high seas.

This chapter approaches the management of straddling fish stocks through the use of bioeconomic modeling. This consists of representing fisheries through models that include biological and economic dimensions, simultaneously. The main aim of the chapter is to show the potential of these models in straddling fish stock management. The analysis is centered on aspects such as the use of bioeconomic models to define optimal fishing strategies, forecast the impact of different management policies and analyze the strategic interactions between fleets.

The chapter is organized as follows. Section 2 addresses the bioeconomic modeling of straddling fish stocks. It presents a standard model which includes both the fishery dynamics and the strategic interaction between fishing agents. The recent advances in bioeconomic modeling are also discussed. Section 3 addresses the main threats to the cooperative management of straddling fish stocks, namely, illegal, unreported and unregulated fishing as well as prospective new members. Sections 4 and 5 provide two straddling stock fishery case-studies: the Northeastern Atlantic bluefin tuna and the Norwegian spring-spawning herring. Finally, Section 6 concludes with a discussion of the main results.

2. Bioeconomic Modeling of Straddling Fish Stocks

In the analysis of straddling fish stocks, the most commonly used bioeconomic models are a combination of fishery dynamic models and fishing agents' strategic interaction models, usually known as games. This section presents the standard bioeconomic model that has been used to derive the fundamental principles of straddling fish stocks management. The dynamic model of the fishery is first introduced, followed by the fishery game. Furthermore, the main limitations of the model are pointed out and recent advances in bioeconomic modeling outlined.

2.1. Dynamic Model of the Fishery

The static Gordon-Schaefer model (1954) has been a fundamental tool in fisheries economics. Among other aspects, it has been used to show that open-access leads to the economic over-exploitation of fish stocks, that is, fishing effort levels higher than the ones that maximize economic gains. Nonetheless, this is an equilibrium model which only shows steady-state or long-run values. Showing what happens in the adjustment period to key variables such as fishing effort, catches, stock and profits was a central challenge for economists for many years. In 1975, Clark and Munro approached this issue through a dynamic bioeconomic model, which has since become the standard model in fisheries economics. A brief presentation of this model follows.

Consider that the stock level dynamics can be expressed by differential equation (1). According to it the stock variation in time is given by the difference between stock growth and harvest. The harvest is assumed to be a function of fishing effort and stock level (2).

$$\frac{dX}{dt} = G(X) - H(t) \tag{1}$$

$$H(t) = qE(t)X(t) \tag{2}$$

where X represents fish stock biomass; t the time; $G(X)$ the stock growth function; H the harvest; q the catchability coefficient; and E the fishing effort – an aggregate measure of inputs devoted to harvesting such as days at sea.

The economic dimension of the fishery is represented through the profits (3). It is assumed that price and cost per unit of effort are constant, that it, fish demand and fishing effort supply are perfectly elastic.

$$\Pi = pH - aE = \left(pqX - a\right)E \qquad (3)$$

where Π represents economic profits; p the price; and a the cost per unit of effort.

This model is usually applied to two paradigmatic institutional settings. In the first, the stock is managed by a social manager who aims to achieve a social optimum fishing strategy. In the second, the stock is common-property and harvested under open-access.

2.1.1. The Social Manager

In this section, the model is used to derive the optimal fishing strategy from the society's point of view. For this purpose, assume that the stock is managed by a social manager who acts in the global interest of the society. This is considered to be the maximization of the gains from the fishery, which in the present model are given by the net present value of profits.

There are also restrictions on this problem (4): the stock dynamics, the initial value of the stock and effort capacity. It is worth explaining what is meant by net present value of profits. According to economic theory, individuals, and consequently society, do not value equally cash-flows that occur in different time periods.

On the contrary, the closer to present the more valuable is a cash-flow. For example, would an individual be indifferent between receiving €1000 today or the same amount in ten years time? The individual would certainly prefer to receive the amount today.

One of the arguments could be that by receiving €1000 today he or she could invest it in a risk free asset, for example a government bond, and as result obtain a larger amount after ten years. In order to make profits earned at different time periods comparable, these are usually discounted to the present using a discount rate − a measure of the agent's preference towards the present.

The discounted value, or present value, of a profit earned in a given period is obtained by multiplying it by a discount factor. Finally, the net present value is computed by summing the present value of profits through time − this sum is given by an integral because the model assumes continuous time.

$$\begin{aligned} &\max\ NPV = \int_0^{\infty} e^{-rt}\left(pqX(t) - a\right)E(t)dt \\ &\text{s.t.}\quad \frac{dX}{dt} = G(X) - qE(t)X(t) \qquad (4) \\ &\qquad X(0) = X_0 \\ &\qquad 0 \le E(t) \le E^{max} \end{aligned}$$

where NPV denotes the net present value; e^{-rt} the discount factor for period t and r discount rate; X_0 the initial stock level (at period $t=0$); E^{max} the maximum effort capacity available, which is determined by the fleet size.

Problem (4) has a unique optimal steady state stock level X^*, which is determined by the following equation:

$$G'\left(X^*\right)+\frac{-c'\left(X^*\right)G\left(X^*\right)}{p-c\left(X^*\right)}=r \qquad (5)$$

where $c\left(X\right)=\frac{aE}{H}=\frac{a}{qX}$ denotes the cost of catching one unit of fish stock.

According to (5), the optimal solution is characterized by the equality between the discount rate (right hand side) and the return rate associated with the stock (left hand side). The latter is the sum of the marginal stock growth (first term) with the cost saving due to a marginal stock increase (second term).

The optimal fishing effort strategy, assuming perfect effort flexibility, can be represented as:

$$E^*\left(t\right)=\begin{cases} E^{max} \quad \text{if} \quad X\left(t\right)>X^*\left(t\right) \\ \dfrac{G\left(X^*\right)}{qX^*} \quad \text{if} \quad X\left(t\right)=X^*\left(t\right) \\ 0 \quad \text{if} \quad X\left(t\right)<X^*\left(t\right) \end{cases} \qquad (6)$$

This means that there is equilibrium fishing effort that corresponds to the equilibrium stock level.

The optimal approach to the equilibrium is done through a most rapid approach path. That is, if the stock gets higher than the equilibrium then full capacity fishing effort should be applied until the stock returns to the equilibrium.

If, on the contrary, it falls below the equilibrium, the fishing effort should cease until the stock recovers.

However, it should be noted that a most rapid approach to the equilibrium would not be optimal if some simplifying assumptions of the model were relaxed, namely, if price depended on harvest or cost per unit of effort on fishing effort.

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Biographical Sketches

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