GLOBAL CHALLENGES IN RECREATIONAL FISHERIES

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Chapter 9

A bioeconomic analysis of different management regimes in recreational fisheries

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Abstract

The chapter analyses various management regimes in recreational fisheries within a bioeconomic framework. It demonstrates how bioeconomic modelling may be used to reveal the different forces that must be taken into account when managing recreational fisheries. The key point of this approach is that ecological and economic objectives, as well as trade-offs between the two, have to be considered to accurately measure the effects of management actions. We show how four different management regimes, ranging from the myopic price-taking management scheme to the social planner solution affect the overall surplus, the allocation of benefits between anglers and landowners (or the property right holder) and the harvest and stock abundance. The model is illustrated using an example from a Norwegian Atlantic salmon fishery.

Introduction

Various management regimes in recreational fisheries yield different outcomes with respect to harvest, stock size, overall surplus, landowner surplus and angler surplus. In this chapter, four management regimes for a recreational fishery are presented and discussed. As in all modelling, we stick to stylized representations, well aware of the more complex and often mixed regimes one faces in the real world. However, by cultivating these stylized examples, more general insights on the economic and biological forces involved are obtained. This type of modelling is phrased bioeconomic modelling. For an easily understood introduction to bioeconomic modelling in general, the reader is referred to Conrad (1999). Further, the reader will appreciate the thorough presentation of bioeconomic modelling in the more advanced work of Clark (1990) and Conrad and Clark (1987).

A comprehensive and in-depth presentation of the required mathematics and comparative statistics involved are given in Silverberg (1990).

Bioeconomic models are commonly applied to analyse recreational fisheries. One of the first studies was a model on marine recreational fishing by McConnell and Sutinen (1979). The conceptual article on recreational fishing by Anderson (1993) also provides a good example of the power of bioeconomic modelling. One of the most important new issues Anderson analysed was how to incorporate catch and release and bag limits into recreational fishing models by introducing a distinction between landings and catch. In addition, many authors have been dealing with bioeconomic models of commercial and recreational fisheries harvesting the same fish stock (see Bishop and Samples 1980; Rosenman 1991; Cook and McGaw 1996; Laukkanen 2001). The key point of all bioeconomic modelling is that ecological growth conditions are taken as restrictions when the objective function is maximized by the fishery management authority. The managing authority may be private landowners or official authorities while the objective function may be the landowner profit function or the total surplus generated in the fishery (more details follow). This last type of objective function is typically found if the national authorities manage the fishery. For simplicity, it is assumed that the natural system is in biological equilibrium in the cases presented in this chapter.

Throughout the chapter, the analysis applies examples from a typical Atlantic salmon (*Salmo salar*) recreational fishery in Norway. However, the insights from these examples can be generalized to similar management situations worldwide. For example, while Norwegian Atlantic salmon fisheries are predominated by private ownership, the state is also a large landowner in some rivers. On the contrary, while national or state authorities provide most fishing permits in the United States, exceptions where riparian right holders possess exclusive rights to fish also exist [e.g. the well-known Supreme Court decision in the Craft versus Burr case in the Jackson River in Virginia 1996. See Murphy and Stephenson (1999)]. Cox and Walters (2002, p. 117) state that access and effort limitations also occur across North America. In fact, increasingly, closed seasons and closed areas are used in the United States in both freshwater and saltwater. The variety of management regimes considered range from the type characterized by strong rights to public access of fishing opportunities in New Zealand opposed to the strong protection of private property rights in all freshwater fisheries in Scotland.

The Atlantic salmon recreational fishery

Biological equilibrium

The size of the salmon population in biomass, or number of fish, at the beginning of the fishing season in year t is X_t. Both a coastal and a river fishery act on

the salmon during the spawning run from its offshore environment to the coast, where reproduction takes place in its parent or home river. However, in the following section the marine fishery is ignored to make the exposition as tractable as possible [see Olaussen and Skonhoft (2005) for a full model with marine harvest]. Accordingly, the stock entering the home river is X_t. The recreational river fishery exploits this spawning population along the upstream migration. When the exploitation rate is $0 < y_t < 1$, the spawning stock becomes $(1 - y_t)X_t = S_t$. This spawning stock hence yields a subsequent recruitment $R(S_t)$ to the stock in year $t + \tau$, where τ is the time lag from spawning to maturation age (see e.g. Hvidsten *et al.* 2004).[1] Throughout the analysis, it is assumed that the stock–recruitment relationship $R(S_t)$ is of the Shepherd type (Shepherd 1982), with $\partial R(S_t)/\partial S_t = R'(S_t) \geq 0$, $R''(S_t) \leq 0$ and $R(0) = 0$. More salmon in the stock increases the recruitment, but at a decreasing rate. Hence, a small increase in the spawning salmon stock may lead to a substantial increase in the recruitment if the initial stock level is low, but only modestly or not at all if the initial stock is high (more details follow).

Further, we assume that none of the spawners survive,[2] that is,

$$X_{t+\tau} = R(S_t) \tag{1}$$

Following the approach of Anderson (1983, 1993), McConnell and Sutinen (1979) and Lee (1996), the recreational fishing effort is measured in number of daily fishing permits sold.[3] In real life, fishing permits may be for 1 day, 1 week or a whole season. However, all these possibilities are combined in 1-day permits as this is the most common type (Fiske and Aas 2001). Thus, the fishing effort is directly expressed in terms of the number of day permits, D_t. When assuming that the catch in the river follows the instantaneous Schaefer-type harvest function, the river yield Y_t is

$$Y_t = qD_tX_t \tag{2}$$

where q is the catchability (productivity) coefficient. In a recreational fishery, this productivity parameter is typically affected by various types of gear restrictions, for example, with respect to types of bait and fishing equipment that are allowed. Moreover, the total catch in the river is per definition

$$Y_t = y_tX_t \tag{3}$$

From equations (2) and (3) it follows that the river exploitation rate is $y_t = qD_t$. The biological equilibrium version of (1) may then be written as:

$$X = R(S) = R((1 - qD)X) \tag{4}$$

For $R'(S) > 0$, equation (4) yields a negative relationship between X and D, that is; more harvest effort D reduces the equilibrium stock X [see Olaussen and Skonhoft (2005) for more details].

Demand and cost functions

We now introduce a market for sport fishing in our representative spawning river. On the *supply* side there is a fixed number of landowners who are given the right (by law) to sell fishing permits (NOU 1999). The competition from landowners in other rivers may vary. Crucial factors are the distance between the rivers, which may range from some few kilometres to over a hundred kilometres, transportation costs and various river-specific attributes like the quality of the fishing (see below).[4] In most instances, the market situation is probably something between price-taking and monopoly behaviour (Skonhoft and Logstein 2003). However, both these market forms are studied as stylized extremes.

Price-taking simply means that the landowners take the fishing permit price as exogenous. This market situation arises if there are many landowners providing fishing permits in fairly similar (homogeneous) nearby rivers. Therefore, if one of the landowners decides to set a higher price in a given river, none of the anglers will fish there because they have a large supply of substitute rivers with similar characteristics. As demonstrated in the Appendix to this chapter, under price-taking market conditions, the permit price will be equal to the marginal cost of providing fishing permits. The marginal cost is the cost of providing one extra fishing permit. Therefore, if the landowner instead tries to lower his permit price, he or she will operate below his or her marginal cost, and hence, the landowner is forced to increase the price to avoid selling at a loss.

A monopolistic landowner, on the other hand, operates under quite different market conditions. A monopolistic landowner is able to influence the permit price directly by determining how many permits to be sold as demonstrated in the Appendix to this chapter. Monopolistic power arises when the landowner faces no competition from nearby rivers, either because the substitutes are too distant or because the nearby rivers are not good substitutes due to some river-specific attributes, like catch rates or other measures of trip quality. Hence, there is a specific demand for buying permits in this specific fishing river, which the monopolistic landowner takes advantage of.

On the *demand* side, there are a large number of potential recreational anglers demanding fishing permits. Demand is a function of the angler preferences for the attributes of the fishing experience. Economic theory states that price per day is one of the most important attributes and Anderson (1983), among others, has expanded this list to include the average size of the fish caught, the total amount of fishing effort by all individuals, the anglers' income, the market price of fish,

companions and the nature of the surroundings [see also Rudd *et al.* (2002) for a more general overview]. Empirical evidence shows that two of the most important determinants of fishing trip satisfaction in the Norwegian Atlantic salmon fishery are the price of permits and, as a notion of the quality of the river, the size of the catch (Fiske and Aas 2001).[5] In the following we focus on just these two factors. In line with McConnell and Sutinen (1979), the quality effect is expressed as average catch per day, and for a given number of fishing days, a higher catch per day shifts the demand function upwards. The inverse market demand for fishing licences (when suppressing the time notation) is hence given as

$$P = P(D, v) \tag{5}$$

where P is the fishing permit price per day and v is the catch per day induced demand effect defined as $v = \theta Q$, with $Q = Y/D = qX$ from equation (2). Therefore, the parameter $\theta > 0$ indicates how catch per day translates into demand. Obviously, the quality effect will vary between rivers and it may change over time. For these and others reasons, it is difficult to assess the strength of the quality effect, but on the whole we may interpret θ as a parameter measuring how important the catch is compared to other factors influencing demand (see also discussion section below). Hence, in addition to $\partial P/\partial D = P_D < 0$, we have $P_v > 0$. $P_D < 0$ which means that the more fishing permits the anglers have already bought, the less they are willing to pay for an additional permit as illustrated by the downward sloping demand schedule depicted in Figure 9.1. $P_v > 0$ simply means that anglers are willing to pay more for each fishing permit if the quality of the fishing experience in terms of average catch per day is higher as illustrated by the upward shift of the demand curve in Figures 9.2 and 9.3.

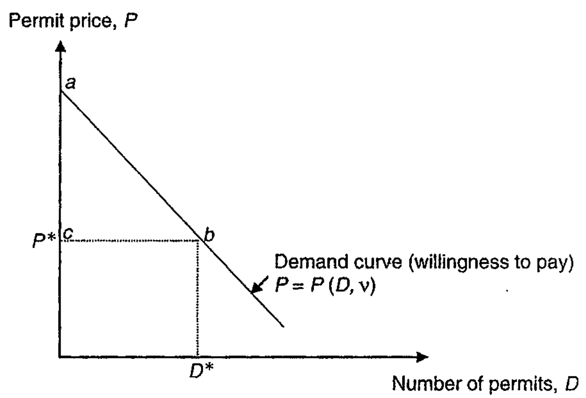

Figure 9.1 Angler surplus.

When inserting catch per day into the inverse demand condition (5), the current profit of the landowner reads:

$$\pi = P(D, \theta qX)D - C(D). \quad (6)$$

The first term on the right-hand side of equation (6) is the total income of fishing permit sales and is simply the permit price multiplied by the number of permits. The latter term $C(D)$ is the cost function, covering fixed as well as variable costs with $C'(D) > 0$ and $C''(D) \geq 0$. Fixed costs include various types of costs associated with preparing the fishery (constructing tracks, fishing huts and so forth), whereas variable costs include the costs of organizing the fishing permit sales together with enforcement. In the following, we will assume constant marginal costs [$C'(D) > 0$ and $C''(D) = 0$) as depicted in Figures 9.4 and 9.5. This means that the cost of providing one extra permit is the same irrespective of how many permits that are offered initially. Before we analyse how different market conditions affect the way the fishery is managed when maximizing the profit function [equation (6)], we demonstrate how angler, landowner and total surplus in the fishery is calculated.

Angler surplus, landowner surplus and total surplus

The *angler surplus* is defined as the difference between the amount the anglers are willing to pay (wtp) for the fishing permits and what is actually paid (the going permit price). For example, if the wtp is NOK 100 (Norwegian kroner, NOK 1 ≈ €0.12) for a fishing permit and the actual permit price is NOK 50, the surplus is NOK 50. By summing up all anglers who have a willingness to pay that exceeds the actual permit price, we have the total angler surplus. This is illustrated in the permit–price diagram in Figure 9.1, where the total angler surplus is given by the area *abc* when the permit price is P^* and D^* permits are sold.

Note that the demand curve in Figure 9.1 is depicted for a given stock size. What if the stock changes? The complicating factor when measuring angler surplus is that the demand curve is dependent on the stock size [see equation (5)] which is the aforementioned quality effect (see Anderson 1983). Hence, a higher stock size means that the demand curve shifts out as depicted in Figure 9.2, and where the angler surplus increases by the area *abb`a`* due to the stock increase when the price is still P^* and the number of permits sold increases.

From the biological equilibrium condition (4) we recall that an increased number of fishing days D, or increased market demand, reduces the stock. As demonstrated by Anderson (1983), in order to measure consumer (angler) surplus correctly in such a setting, constant stock externality demand curves should be introduced. These are denoted as constant quality demand curves in the following and all demand curves depicted in Figures 9.1–9.5 are of this type. Hence, angler

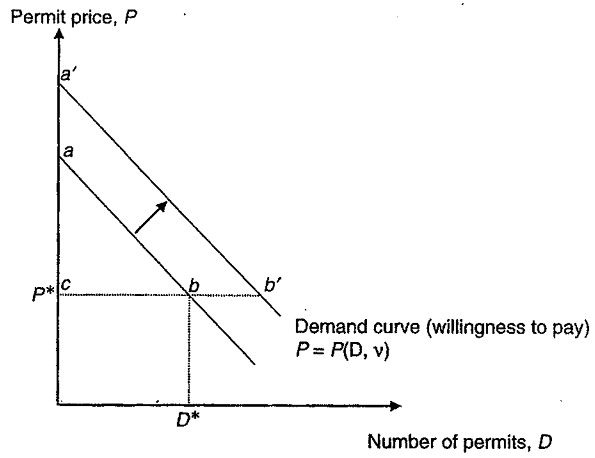

Figure 9.2 The quality effect and angler surplus.

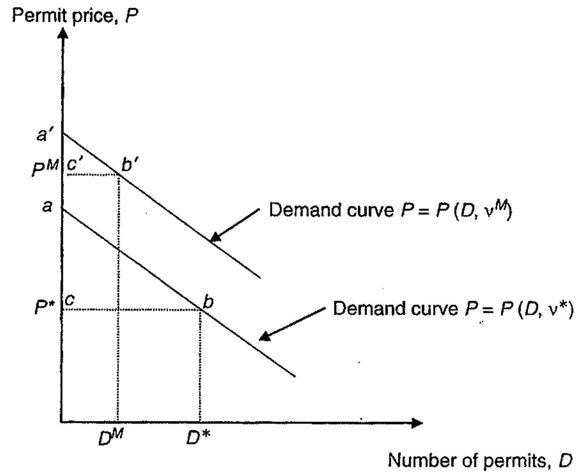

Figure 9.3 Measuring angler surplus when quality and price increase, $v^M > v^*$.

surplus is measured under the demand curve when all anglers are familiar with the total number of permits sold, and hence, they know the harvest pressure and the accompanying stock size. In other words, when, say D^* permits are sold as in Figure 9.3, the accompanying stock size is X^* and the relevant demand curve is the curve for which the given stock is exactly X^*. Hence, the angler surplus when D^* permits are sold is given by the area abc. Consider next a situation where only D^M fishing permits are offered in the market. Then the accompanying stock is X^M and where $X^M > X^*$. As the stock is higher than when D^* permits

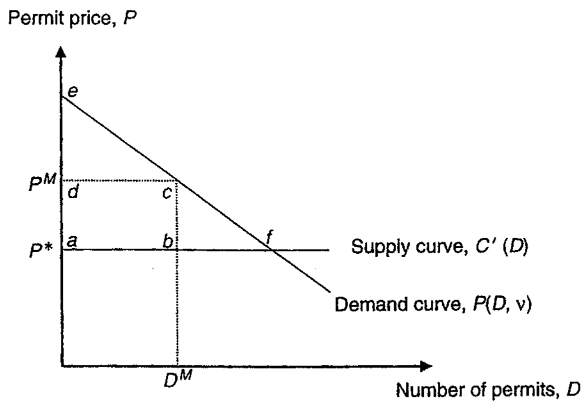

Figure 9.4 Landowner and total surplus.

were sold, the $P = P(D, v^*)$ curve is no longer relevant when measuring the angler surplus. Rather, we must measure the area below the new constant quality demand curve $P = P(D,v^M)$. Hence, if the anglers buy D^M fishing permits at the price P^M the new angler surplus is given by the area *a'b'c'*.

The *landowner surplus* (profit) is given by the difference between the actual price charged in the market and the cost of providing a fishing permit which is the marginal cost of providing permits (or the supply curve of the landowners). When assuming that the marginal cost is constant, $C''(D) = 0$, the supply is given by a horizontal curve in Figure 9.4. If the permit price is P^M as in Figure 9.4, the profit (landowner surplus) described by equation (6) is hence simply the difference between total income and total cost as illustrated by the area *abcd*. On the other hand, if the permit price is P^* as in Figure 9.4, then the permit price is equal to the marginal cost of providing permits, and hence, the landowner surplus is zero.

The *total surplus* in the fishery is simply the sum of angler and landowner surplus, and hence, if P^* is the going permit price as in Figure 9.4 then the total surplus and angler surplus coincides (because the landowner surplus is zero) and is given by the area *aef*. On the other hand, if P^M is the permit price, then the angler surplus is given by the area *cde*, and together with the landowner surplus *abcd*, the total surplus is given by the area *abce*.

Surplus under monopolistic versus price-taking supply

To understand why different market conditions generally lead to different total surplus as well as differences in the distribution of surplus between anglers and landowners, we now compare the surplus under price-taking and monopolistic supply.

As already mentioned, price-taking supply may happen when there are many other rivers with similar quality located nearby. In the case of a price-taking

landowner, or perfect competition, the landowner surplus is zero because competition drives the price of permits equal to the marginal cost it takes to provide them. As explained earlier, the permit price is in reality determined by the marginal cost since demanding a higher price means that anglers will fish in substitute rivers (see the Appendix for technical details). This situation is already depicted in Figure 9.4 where P^* and D^* now refer to the permit price and number of permits sold under price-taking supply, respectively.

As discussed earlier, monopolistic permit supply means that the landowner is able to take advantage of the downward sloping demand schedule for permits. Exactly how the monopolistic manager determines the number of permits and permit price and the accompanying consequences for the equilibrium stock size is demonstrated in the Appendix. The key point is that the monopolistic landowner is able to restrict the supply of fishing permits (which the price-taking landowner per definition is unable to do). The landowner charges the amount per permit that the anglers are willing to pay, which is the monopolistic price P^M, where permits are sold until marginal revenues equal marginal costs (marginal revenue is defined as the revenue of selling one more permit – see the Appendix). The reason why the monopolistic landowner has the power to set price where marginal revenue equals marginal cost is that the anglers cannot get the same good from anyone else. Under monopolistic supply then, the landowner surplus (profit) is the net income of providing fishing permits, and is hence given by the difference between total income and total cost. As the total cost is the area below the supply curve, the monopolistic landowner surplus is given by the area *abcd* in Figure 9.4 when D^M (hereafter the number of permits under monopolistic supply) permits are sold at the monopolistic permit price P^M.

Figure 9.5 demonstrates another feature of the differences between price-taking and monopolistic supply of permits by the landowner. As just explained, the price-taking landowner ends up providing a total of D^* permits at the price P^*, while the monopolistic landowner provides D^M permits at the price P^M. To make Figure 9.5 as simple as possible, the figure is drawn for two stock sizes. First, $P = P(D,v^*)$ is drawn for X^*, which is the actual stock size when the landowner is a price-taker. Second, $P = P(D,v^M)$ is drawn for X^M which is the actual stock size when the landowner is a monopolist. As we typically see that the monopolistic landowner finds it more economically rewarding to sell less fishing permits at a higher price than the price-taking landowner, the monopolistic landowner holds a larger stock than the price-taking landowner such that $X^M > X^*$ [due to the ecological equilibrium condition (4)]. Hence, the quality of the fishing experience is higher under monopolistic than under price-taking management meaning that the demand curve under monopolistic management shifts out compared with the demand curve under price-taking conditions.

We are now able to consider the differences in angler surplus, landowner surplus and total surplus under price-taking and monopolistic supply conditions when the demand for angling is affected by the quality in terms of the stock size.

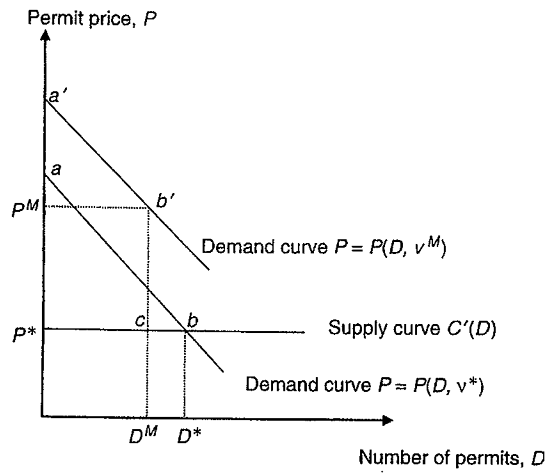

Figure 9.5 Angler surplus under monopolistic and price-taking management.

In Figure 9.5, angler surplus have changed from abP^* under price-taking supply to $a'b'P^M$ under monopolistic supply. It turns out that it is generally unclear whether the angler surplus is higher under monopolistic than under price-taking management. The figure is drawn for a situation where the angler surplus is highest under price-taking supply of fishing permits, $abP^* > a'b'P^M$. This will always be the case as long as the slope of the demand function is unaffected by the quality effect like in Figure 9.4. However, we cannot generally rule out the possibility that the slope is steeper after the quality shift, and if so, the angler surplus may be higher under monopolistic than under price-taking management. Hence, if anglers respond strongly to the quality effect, we may have a situation where the angler surplus is lower under the price-taking than under the monopolistic management. The intuition is clear cut and may be illustrated by an example: Think of a situation where 1000 fishing permits are sold in a small river at the price of NOK 50 per permit. It may very well be the case that none of the anglers are willing to pay more than NOK 50 because the harvesting pressure is relatively high (low fish stock and hence low quality in terms of catch per day). The aggregate angler surplus is hence NOK 0. But what if only 50 permits are sold in the same river at the price of NOK 500 per permit? As the harvest pressure is significantly lower and we presumably have a higher fish stock, we may find that some of these 50 anglers are willing to pay even more than the 500 NOK, and if so the angler surplus is >NOK 0. Generally, as the demand curve has shifted, it is not possible to say whether the angler surplus is highest under price-taking or monopolistic supply of permits.

The landowner surplus changes from *zero* under price-taking supply to $P^M b' c P^*$ > 0 under monopolistic supply. Regarding total surplus, the sum of angler and

landowner surplus, we see that it unambiguously increases under monopolistic management as long as the angler surplus is at least as large as under price-taking supply of permits. However, in cases where the angler surplus decreases as discussed earlier, the total surplus effect is ambiguous.

Management regimes and results

Myopic landowners

We will consider two types of time horizons that managers may take into account when they make their management decisions, the myopic (short sighted) and the long-term planning horizon. Assume firstly that the landowners supply fishing permits based on *current* economic and biological conditions. When landowners act myopic, it means that they ignore all possible future effects of their actions today. For example, the landowner just considers the present stock size and does not take into account how the current fishing pressure will affect the future fish stock through recruitment. There may be various reasons leading to such myopic management, one important reason being insecure property rights due to the marine harvest activity (which is not modelled explicitly here). Other factors such as ecological and environmental uncertainties may also play a role. It may also be that the landowners act 'as if' they were myopic simply because they believe that their fishing permit sales today do not influence the future stock size. Myopic behaviour seems to fit with the stylized management situation in many Norwegian salmon river fisheries (Skonhoft and Logstein 2003). Probably, this is due to the traditional view that even a small number of spawners will be sufficient to fully recruit a salmon river. As will be discussed below, it turns out that this reasoning makes sense: The extent to which the myopic behaviour is important for the stock size depends strictly on the recruitment relationship.

Myopic monopolistic landowner

The first result column in Table 9.1 reports the results in the myopic monopolistic case [all parameter values are based on Olaussen (2007)]. The equilibrium stock (*X*) is 15.9 (all numbers hereafter in 1000) salmon while 11.1 permits (*D*) are sold. The resulting fishing permit price (*P*) is NOK 0.38. The accompanying angler surplus (AS) is NOK 1841, landowner surplus (LS) is NOK 3686 and total surplus (TS) is NOK 5527.

Myopic price-taking landowners

We next consider price-taking landowners; that is, the landowners take the fishing permit price as exogenous. It is still myopic management and so future effects

Table 9.1 Results, different management regimes in a typical Norwegian salmon river.

	Myopic		Long-term planning (infinite planning period)	
	Monopolistic	Price-taking	Monopolistic	Social planner
X	15.9	14.9	15.9	15.4
D	11.1	20.7	10.8	18.0
P	0.38	0.050	0.39	0.15
AS	1841	6438	1735	4862
LS	3686	0	3687	1819
TS	5527	6438	5422	6681

Notes: *X* is stock size (in 1000), *D* is number of fishing permits (in 1000), *P* is permit price (in 1000 NOK), AS is angler surplus (in 1000 NOK), LS is landowner surplus (in 1000 NOK), and TS is total surplus (in 1000 NOK).

on the fish abundance are ignored as well. Technically, this means that the landowners maximize the profit function (6) with respect to number of permits, while taking the price and the stock as given. Again, the details are found in the Appendix while the numerical results are shown in Table 9.1. Not surprisingly, the stock size is driven down by an increasing number of permits sold compared to the previous monopolistic case. Notice, however, that the substantial increase in permits (from 11.1 to 20.7 permits) only reduces the equilibrium stock by about 1000 salmon per year. To a large extent, this owes to the recruitment function being of the Cushing type which means that quite few spawners are able to fully recruit the river. The reason why the number of permits sold increases so much is the substantial fall in the permit price when the landowners are no longer able to restrict the supply of permits. Thus, a lower permit price means more angler days and the angler surplus (AS) increases substantially compared with the monopolistic case. On the other hand, the landowner surplus (LS) is competed away and decreases to zero. The zero landowner surplus follows directly from the assumption of a constant marginal cost curve as the price-taking landowner faces a permit price equal to his marginal costs (see the Appendix). Note, however, that even with increasing marginal costs, the market supply curve would still be equal to the constant marginal cost curve depicted in Figure 9.5 as long as all landowners are price-takers (perfect competition), and hence, the landowner surplus would still be zero.

Long-term planning

The case where the landowners take into account that their permit sale decision this year affects future stock abundance is now considered. This means that landowners have a long-term planning horizon, that is, they are aware of the future consequences of current harvest activity.

Monopolistic landowner with long planning horizon

The problem of the monopolistic landowner is now to maximize the profit function [equation (6)] while taking the effort–stock equilibrium relationship given by equation (4) into account (again, see the Appendix for details). The outcome following this management scheme yields more or less the same results as under myopic monopolistic management (Table 9.1). This is obviously not a general result, but hinges critically on the given recruitment function as well as the given parameter values. Briefly speaking, there is not much to gain in terms of restricting the number of permits compared with the myopic monopolist. The reason is that the myopic monopolist restricts the number of permits sold sufficiently to secure a high equilibrium stock level; hence there is not much to gain in terms of a higher stock by restricting it further.

Social planner solution

As opposed to the monopolistic landowner, the social planner aims to maximize the total surplus (TS), that is, the sum of angler surplus (AS) and landowner surplus (LS) while taking the stock–effort equilibrium relationship (4) into account. As indicated, this may typically be the objective if the national authority, or a non-profit organization, manages the river. Fishing permits provided by the national authorities are common practice in a number of countries (see above). The same type of management may occur when, for example, a fishing association is given the authority to provide fishing permits in a specific lake or river under conditions determined by the authority or a landowner association. The results presented in Table 9.1 may seem surprising at first glance. It turns out that the social planner management is less stock conserving than both monopolistic regimes considered. However, the interpretation is straightforward. The overall gain obtained by lowering the permit price and hence increasing the number of permits sold outweigh the loss in terms of driving the stock down. In addition, again due to the specific recruitment function at hand, the stock decrease is quite small. As expected, the total surplus (TS) is higher than under the other management regimes (NOK 6681), but note that neither the anglers nor the landowners strictly prefer the social planner solution over the other management regimes. The anglers as a group are better off under the myopic price-taking management while the landowners prefer both monopolistic regimes instead of the social planner regime. From the angler group point of view, they are facing a higher permit price than in the myopic price-taking case. This means that those anglers that are willing to pay less than the social planner permit price (NOK 0.15), but more than the myopic price-taking permit price (NOK 0.05) lose their surplus. However, the landowners gain more than the anglers lose by charging NOK 0.15 instead of NOK 0.05 compared with the price-taking situation. Even so, they will prefer the monopolistic cases in which they are able to maximize their surplus by charging higher prices. Note also that although the difference in total surplus between, for example, the social planner and myopic price-taker management is quite small, the distributional differences are substantial. This seems also to be a more general lesson from the present example since, although the stock size differences between the different management regimes under consideration here are quite small, the distributional consequences depend critically on the type of management.

Discussion

Through different market conditions, like perfect competition or monopolies, different property rights regimes, like privately held resources versus publicly held, and different planning horizons, such as myopic or long term, different management regimes arise. In this chapter we have shown how different management regimes in a recreational fishery, ranging from the myopic price-taking management scheme to the social planner solution, affect overall surplus, the allocation of benefits between anglers and landowners (or the property right holder) and the harvest and stock abundance. As bioeconomic models incorporate the economic consequences (in terms of benefits) and the biological consequences (through the size of the fish stock), some crucial trade-offs facing a recreational fishery manager are highlighted. For example, a typical economic trade-off occurs when selling more permits comes at the cost of bringing down the permit price while a typical ecological trade-off occurs when fishing more today decreases the future fish stock. To what extent does it pay off to restrict access to a given fishery in order to raise the fish stock and profits? It is not surprising that it depends critically on the underlying biological and economic factors.

As mentioned in the introduction to this chapter, modelling is about making simplifying assumptions. To what extent the results survive when the assumptions are relaxed tell us whether it is a good model or not. For example, including more factors influencing the demand for fishing permits seems necessary. One important issue to be mentioned is to what extent the number of anglers fishing the beat at the same time affects the demand [see Anderson (1980) for a theoretical exposition]. Generally, there seems to be at least two contradictory hypotheses about how this would affect the demand. On one hand, increasing the number of anglers may lead to crowding at the site and thereby reducing the demand. This pulls in the direction of a reduced angler surplus in the price-taking and social planner regimes compared with the monopolistic regimes in our analyses. However, sociability may be an important part of the angling experience too, and hence, the angler satisfaction may in fact increase with the number of participants, at least to some point. If this is the case, the angler surplus in the price-taking and social planner regimes will be higher than suggested by our results. Another fruitful hypothesis seems to be the one argued by Schuhmann and Schwabe (2004), who found empirical support for a non-linear utility–congestion relationship

among recreational anglers. Analysing the Roanoke River striped-bass fishery in North Carolina, they found a positive linear term for congestion on recreational demand, while the quadratic term was estimated to be negative. They argued that some degree of aggregate use was viewed favourably, perhaps for social reasons, but that after a particular level of aggregate use was reached, further increases reduced the site quality and thereby its utility. See also Boxall *et al.* (2003).

On the other hand, in a Norwegian survey, Atlantic salmon anglers reported strictly decreasing willingness to pay levels as the number of anglers at the beat was increased (Olaussen 2006), indicating that any potential sociability effects were dominated by crowding. It seems therefore clear that making general assumptions about how anglers respond to congestion are not very fruitful, as this may vary between different types of recreational fisheries. However, case-specific knowledge about how congestion affects the anglers are crucial if angler (consumer) surplus is to be measured correctly, and hence it is also crucial if overall surplus to be maximized.

We have demonstrated how total surplus and the distribution of surplus between landowners (property right holders) and anglers are distributed under different management regimes. In addition, this analysis calls attention to the fact that there are many ways of managing a recreational fishery. It turns out that some apparently very different management regimes may yield quite similar results with respect to some of the potential objectives of the manager, and also large differences with respect to others. We have concentrated on typical economic objectives in this chapter, but it should be noted that managers may have other objectives in mind as well. However, the analysis provided here indicates what consequences one may expect of changing management regimes, and what differences may be expected when comparing different management schemes.

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APPENDIX: TECHNICAL NOTE

Myopic monopolistic landowner

The myopic monopolistic landowner maximizes the profit function (6) with respect to number of permits sold while taking the stock as given. The first-order condition in this case is written as:

$$P_D'(D,\theta qX)D + P(D,\theta qX) = C'(D) \tag{A1}$$

The left-hand side is the marginal income while the right-hand side is the marginal cost of selling fishing permits. Hence, the monopolist offers more fishing permits until the extra income of selling one more fishing permit is equal to the extra cost. Differentiating the economic equilibrium condition (A1) yields

$$\frac{dX}{dD}=\frac{C''(D)-2P_D'(D,\theta qX)-P_D''(D,\theta qX)D}{P_{Dv}''(D,\theta qX)D+P_v'(D,\theta qX)} \quad (A2)$$

The numerator on the right-hand side is positive because of the second-order condition for a maximum to be fulfilled. Under the reasonable assumption that the quality effect dominates the potentially negative cross-effect in the demand function, such that $P_{Dv}''(D,\theta qX)D+P_v'(D,\theta qX)>0$, we find that the economic equilibrium condition, if existing, is positively sloped in a X–D diagram, and hence a bioeconomic equilibrium exists as long as the ecological equilibrium schedule is negatively sloped in the X–D plane.

Myopic price-taking landowners

Price-taking landowners maximize the profit function (6) with respect to number of permits, while taking the price as well as the stock as given. The first-order condition is, therefore, written as

$$P(D,\nu)=C'(D), \quad (A3)$$

and hence they simply sell permits until the permit price equals the marginal cost of providing permits. Differentiation of the first-order condition yields $dX/dD = [C''(D)-P_D'(D,\ \theta qX)]/P_v'(D,\theta qX)$. Again, the numerator is positive due to the second-order condition for the maximum, and we hence find that this equilibrium condition is positively sloped in the X–D plane as well.

Long-term planning monopolistic landowners

The maximization problem facing a landowner maximizing over an infinite planning period under monopolistic conditions may be written as the current value Hamiltonian (Conrad and Clark 1987)

$$H=P(D_t,v_t)D_t-C(D_t)+\rho^{\tau}\lambda_{t+\tau}\left(R\left((1-qD_t)X_t\right)-X_t\right) \quad (A4)$$

where ρ is the discount factor, $\rho = 1/(1+\delta)$, δ is the yearly rate of discount and λ is the shadow value of the resource constraint. As the time lag in recruitment is 5 years, the stock dynamics is given by a fifth-order differential equation, and

hence no analytical solutions are obtainable. However, although beyond the scope of this text, the equilibrium conditions may be derived (see e.g. Clark 1976, 1990).

Notes

1 See Clark (1976) for an analysis of the dynamics of a delay-difference recruitment model.
2 Hvidsten *et al.* (2004) find that only 0.3–3.8% of the spawners survive justifying this simplifying assumption.
3 Others have used a different approach – for instance, Bishop and Samples (1980), Cook and McGaw (1996) and Laukkanen (2001) use the actual catch.
4 Note that there may be many landowners in each river competing with each other as well. In such cases, the degree of homogeneity between the products the various landowners offer will determine the degree of monopolistic price setting, and where more homogeneity means more price-taking behaviour. However, in the following we focus our attention to the competition between rivers, implicitly assuming that the landowners in our representative river act as one landowner when determining the permit price.
5 In a survey of Norwegian rivers, 92% of sport fishermen reported that the quality of the river in terms of average catch per day was important. In addition, 72% reported that the price of fishing permits was important (Fiske and Aas 2001).

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