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Management of Fisheries as a Common Property Resource[1]

BACKGROUND: WORLD FISHERIES

Introduction

Man has always looked to the ocean as an important food source, and expectations as to what resources the oceans can bring have often been high: 'It is said that the last frontier of inner space lies in the oceans of the world, and that man, by thrusting back this frontier, may gain almost limitless resources to feed future generations' (Christy and Scott, 1965). However, as with any other resource, the ability to obtain maximum benefits from its exploitation rests on the ability to utilize it efficiently.

Traditionally most fisheries were common property resources characterized by free entry or open access. This meant that the resource was open to anybody, and no one had the right to preclude others from fishing. However, free access to any scarce resource inevitably leads to inefficient exploitation. For fisheries, this involves over-exploitation of the resource and the application of excessive amounts of productive resources such as capital and labour to the production process.

World catches of fish

World catches of fish, crustaceans and molluscs in marine areas for the period 1970–88 are given in Table 1. From 62 million tonnes in 1970, and a slight decline in the early 1970s, catches were fairly stable for the rest of the 1970s, but then increased gradually in the 1980s to almost 85 million tonnes in 1988. This increase of about 36 per cent in a 19-year period is substantial, and occurred after the introduction of 200-mile exclusive economic zones (EEZs) in the second half of the 1970s.

It has been estimated that, with proper management, the total yield from currently exploited fish resources can be increased to at least 100 million tonnes. Although this hardly involves the ability to obtain 'almost limitless resources to feed future generations' there is still potential for increased output. There is also further potential from the exploitation of resources that are currently

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TABLE 1 *World catches of fish, crustaceans, molluscs, etc. in marine areas, 1970–88*

Year	Quantity (tonnes)	Year	Quantity (tonnes)
1970	61 982 400	1980	64 467 700
1971	59 678 800	1981	66 628 000
1972	55 466 700	1982	68 350 700
1973	55 915 500	1983	68 318 100
1974	59 957 100	1984	73 810 600
1975	59 171 200	1985	75 403 300
1976	62 634 700	1986	80 961 100
1977	61 544 600	1987	80 501 200
1978	63 335 200	1988	84 560 700
1979	63 797 900		

Source: FAO *Yearbook Fishery Statistics, Catches and Landings*, vols. 46, 50, 64 and 66.

not being utilized, from ocean ranching and from aquaculture. In addition, there is scope for substantial savings from reducing inefficiences in fishing.

World production (including inland areas) of fish, molluscs and crustaceans from aquaculture increased from 7.6 million tonnes in 1985 to 10.8 million tonnes in 1988, a remarkable 42 per cent increase in a three-year period, and is dominated by carp, barbel and other cyprinids, representing 43 per cent of total output in 1988. This group of fish, along with shrimps and prawns, salmon and scallops, showed the largest relative increases in the 1985–8 period. For aquaculture, the potential for further increases in production is greater than for capture fisheries.

Catches of the ten most important fishing nations for 1970 and 1988 are shown in Table 2. The pattern has remained fairly stable over the past two decades, although the ranking of the different nations has changed. In 1970, Peru was the leading fishing nation in terms of quantity harvested, with a total catch of 12.5 million tonnes, representing 20.2 per cent of the world catch. The collapse of the anchoveta fishery in the early 1970s, however, dramatically reduced the Peruvian catch. The bottom level was reached in 1983, with a catch quantity of 1.6 million tonnes. Subsequently, Peruvian catches have increased, reaching a level of 6.6 million tonnes in 1988, placing Peru as the fourth largest producer of fish in the world.

After the collapse of the anchoveta fishery, Japan replaced Peru as the most important fishing nation. The Japanese catch of 11.9 million tonnes in 1988 represented 14.1 per cent of the world catch. It is remarkable that Japan has not only maintained its catch quantity in the period under consideration but even increased it, despite having lost access to many of its traditional high-sea fishing grounds in the late 1970s and early 1980s as the result of the imposition of 200-mile EEZs. This increase is due to greater catches in offshore areas, partly as a result of substantial stock-enhancement programmes.

TABLE 2 *Catches by Country of Fish, Molluscs, Crustaceans, etc. in Marine Area (Tonnes)*

Country	1970	1988
Japan	8 658 400	11 896 935
USSR	6 386 500	11 332 101
China	2 192 500	10 358 678
Peru	12 532 900	6 637 106
USA	2 729 300	5 965 598
Chile	1 200 300	5 210 201
India	1 085 600	3 145 650
Korea Rep.	725 500	2 727 059
Indonesia	804 000	2 703 260
Thailand	1 343 400	2 350 000

As noted above, the world catch of fish has been increasing. It is particularly noteworthy that China, which had an annual catch of about 3 million tonnes throughout the 1970s, reached a catch quantity of 10.4 million tonnes in 1988. With the exception of Peru, all other nations included in Table 2 increased their catch.

Fish consumption and trade

Reduction into fish meal and oil is the major usage of fish. In 1988 27.1 million tonnes of fish, corresponding to 32 per cent of the world catch, were used for this purpose. The species generally used for reduction purposes are clupeids such as herrings and sardines, for which there has been an upward trend in catches for the past 15 years.

Frozen usage has shown a substantial upward trend in this period, and fresh usage, while remaining stable for quite a long period, has shown substantial increases in the last few years. Combined, fresh and frozen usage represented 44.0 million tonnes in 1988, or 52 per cent of the world catch. On the other hand, curing and canning exhibited lower upward trends. As prices for fresh and frozen products in general are higher than for most other usages, this development indicates that increases have been most important for the higher-valued usages.

Major fish markets are found in Japan, North America and Europe. Japan, the USA and the European Community (EC) import substantial quantities of fish, although the EC and the USA have considerable fish exports. In terms of total fish trade, the EC is the most important market. However, Japan is most important in terms of net imports, with a value of $9.6 billion in 1988, followed by the EC and the USA.

In Japan, the most important fish market in the world, consumption has increased substantially in the 1980s to a level of 72.5 kg per capita in 1988.

Compared to Japan, US per capita fish consumption is low, but has also been increasing. Owing to the size of its population, the USA is a very important fish market. The trend towards increased fish consumption is also seen in European markets. Increased fish consumption may be due to changes in consumer preferences towards a healthier diet. This effect is also likely to be increasingly important in the future. For some fish products, increased consumption may be a result of increases in real income. On a world-wide basis, population increases have also led to shifts in the demand for fish.

Management issues

While property rights in the course of history have been extended to most natural resources, this has proved difficult in the case of fish. Common property is still associated with many fisheries, largely because the fish do not respect man-made boundaries.

In the postwar period, substantial attempts have been made to reduce the undesirable effects due to common property exploitation, culminating in the extended fisheries jurisdiction, with introduction of 200-mile exclusive economic zones (EEZs) in 1977. As more than 90 per cent of all catches are taken within the EEZs of all coastal nations (Eckert, 1979, p. 116), this new institutional arrangement may appear to have the potential for solving important management problems by assigning property rights to both national and international fish stocks. However, common property is still associated with the utilization of fish stocks in the EEZs of most countries. Moreover, the fact that many fish resources migrate or are spread across national boundaries causes substantial management problems.

Even if the problem of optimal exploitation of fish resources can be solved, for example through cooperation between countries sharing a resource about the fixing of quotas, the problem remains as to the efficient management of a given quota. This involves keeping the fishing effort at an efficient level through regulatory arrangements. This issue has in practice proved to be very difficult. However, extended fisheries jurisdiction has facilitated the adoption in some countries of new institutional arrangements for regulating fisheries. In particular, individual transferable quotas (ITQs) appear to be promising in terms of improved fisheries management.

BIO-ECONOMIC MODELLING

A fish stock is a renewable resource. Accordingly, through proper management, it can provide harvests indefinitely. Furthermore, stock size may be increased by reducing harvests below natural growth for some time period: that is, by investing in the resource. In an analogous manner, one can disinvest by increasing harvest quantities. In other words, the resource may be considered a capital stock. What distinguishes fisheries managements from the exploitation of most other renewable resources, such as forests, is that fish resources traditionally constitute common property. This institutional arrangement has profound consequences for fisheries management.

Economic analyses of fisheries are based on a biological model. The investment problem referred to above can be considered as follows:

$$\text{Net Growth of the Stock} = \text{Natural Growth} - \text{Harvest}$$

Natural growth is sometimes referred to as nature's production function, being zero for non-renewable resources. Harvesting represents the 'regular' production function.

Optimal management

The objective of this paper is to study the management of fisheries as common property resources. However, first, optimal management will be considered. This will be a 'yardstick' against which common property, that is non-optimal exploitation, can be compared. It is assumed that the fishery is managed by a social planner or sole owner whose objective is to maximize the present value of net revenues from the fishery by determining optimal time-paths of effort for boats in the fishery.

The social planner aims to maximize the sum of net present values over all boats subject to stock dynamics and initial conditions. For each boat effort should be determined so that the marginal product of effort, evaluated at present value market price minus shadow price of the resource, should be equal to present value marginal cost. The optimal level of effort depends on output and input prices as well as stock size. The solution to the optimization problem will give an optimal time-path for the stock which will converge on the target stock level.

Although efficient management is a prerequisite for maximizing the economic returns from fishing, most fisheries have traditionally been common property and characterized by over-exploitation.

Common property exploitation

Traditionally, most fisheries were common property characterized by free entry or open access. The consequences of free entry have been analysed by many authors. The institutional arrangement can be considered the polar extreme of the sole owner case considered above.

Bionomic equilibrium is defined as the individual firm, the industry and the stock being in equilibrium simultaneously. The fleet will be in equilibrium when there is no incentive for further entry to or exit from the fishery. For the marginal firm, the present value of profits will be zero. If fishing effort is homogeneous, this condition applies to all boats. When stock size in bionomic equilibrium is compared to the sole owner case, it may be noted that the shadow price of the resource is set to zero in the free entry fishery. Thus, in bionomic equilibrium, the stock will be over-exploited compared to the social optimum and all resource rent will be dissipated. However, if fishing effort is heterogeneous, some fishing firms may be earning intra-marginal rents.

Biologists commonly recommend that a fishery should be regulated to achieve a stock size yielding maximum sustainable yield (X_{msy}). When economic considerations are included in the analysis, the optimal stock level is equal to X_{msy} only under very special conditions. Whether the optimal stock level is greater than, equal to or less than X_{msy} is found to be an empirical question.

ECONOMIC INEFFICIENCIES IN COMMON PROPERTY EXPLOITATION

In the above analysis, optimal management has been compared to common property exploitation. Open access to a fish resource was seen to involve over-exploitation of the stock with too much fishing effort (capital and labour) being applied to the fishery. However, in a purely 'technical' sense, bionomic equilibrium does not involve over-capacity. This is because, for the given stock level, the associated fishing effort (and cost) is the minimum required to catch the open-access harvest quantity. The inefficiency of bionomic equilibrium is due to too much effort being devoted to the fishery from society's point of view and the concomitant over-exploitation of the stock. This is caused by what is denoted the stock externality; that is, the failure of individual fishermen to take into consideration the effect of their own harvest on all other fishermen. This externality is internalized by a sole owner.

In principle, a quota system can be used to achieve the optimal (or 'desirable') stock level. The problem to be addressed here is that the introduction of catch quotas, without regulating effort, will lead to over-capacity in the fleet. This is another way in which the resource rent can be dissipated and gives rise to what Munro and Scott (1984) denote the Class II common property fishery.[2]

The Class II common property fishery can be illustrated with reference to a simple seasonal model for a fishery due to Clark (1976). In the model, it is assumed that the fishery is regulated by a total allowable catch (TAC) quota, and that stock size is stabilized so that surplus growth is equal to the quota. The stock size in question could, for example, be the sole owner optimum stock level. Maximum season length is assumed given by nature. The fishery remains open until the TAC is harvested and is then closed by the fisheries authorities. With maximum season length given, it is a straightforward matter to find the minimum fleet size that would maximize resource rent from the fishery.

If actual fleet size initially is equal to minimum fleet size, fishermen will be making pure profits (provided the fishery is not marginal). If effort is not regulated, this will attract new entry to the fishery. In order to prevent overfishing, regulation of season length will have to be introduced. Season length will have to be reduced, and the boats will be idle for a greater and greater part of the season. The fleet will expand up to the point where total costs equal revenue. The resource rent is dissipated through over capacity in the processing industry. As the same quota of fish will be landed in a shorter period of time, larger storage and processing facilities will be required. As with fishing effort, this capacity will be idle for part of the season.

Although simple, this model is fairly realistic as a positive description of real-world fisheries management. Many fisheries are regulated by TACs. When the quotas are strictly enforced, this instrument can be used to maintain stock size at a level higher than the one associated with bionomic equilibrium. However, unless effort is regulated, over-capacity will develop in the fleet and cause rent dissipation.

In fisheries models, fishing effort is commonly assumed to be homogeneous, with a fixed relationship between all inputs. In other words, a Leontief production function is assumed, with no substitution possibilities between inputs. Many fisheries are regulated not only by a TAC, but also by some measure of effort such as the number of boats, possibly in combination with, for example, boat size. If again it is assumed that stock size is stabilized at some level greater than bionomic equilibrium and fleet size (initially) is at the minimum level, boats will again be making pure profits. As the number of boats is assumed to be fixed, and if there were no substitution possibilities, there would be no further entry to the fishery and boats would be enjoying pure profits *ad infinitum*.[3]

This scenario, however, hardly fits the real world. In reality, substitution possibilities exist and, when pure profits are made, boats will substitute unregulated inputs for the regulated one, for example substituting unregulated engine size for regulated cargo capacity. Boats will be faced with an optimization problem where the objective is to maximize its share of the resource rent. Additional investments will be undertaken as long as expected returns exceed the cost. As all boats face the same problem, this process will continue until the resource rent is dissipated in added input costs.

This adjustment process may in part explain the proliferation of fisheries regulations. Initially, only one or a few elements of effort may be regulated. With pure profits being earned, there will be investments in some other element of effort. To prevent total effort from expanding, fisheries authorities must introduce additional regulations. This process may well continue as long as substitution possibilities exist.

In addition to dissipating the resource rent, this kind of incentive structure also has other undesirable effects. First, boats will be unable to choose the least-cost combination of inputs and will thus be unable to operate at the minimum point on their long-run average cost curves. Second, research and development may be directed towards circumventing regulations rather than towards 'pure' technological research.

MANAGEMENT ISSUES

The exploitation of international fish resources, which traditionally were considered common property, has been characterized by over-exploitation and excessive use of effort. While biologists and conservationists have been concerned about over-exploitation, economists have been concerned about the associated inefficiencies. Attempts to regulate fisheries were primarily aimed at stock conservation and, in some cases, also at reducing conflicts between fishermen competing for the dwindling resources (resulting for example from externalities such as gear collisions and over-crowding).

The objective of fisheries management, both nationally and internationally, was generally to achieve the stock level that would yield maximum sustainable yield (MSY). A number of international bodies were set up to regulate fisheries, for example, the North East Atlantic Fisheries Commission (NEAFC) and the International Commission for the Northwest Atlantic Fisheries (ICNAF). Although membership of these organizations included all major countries participating in the fisheries they monitored, they had no power to implement their recommendations.

The international bodies were not successful in terms of achieving the objectives for which they were set up, such as desirable stock levels and controlling fishing effort. This could be considered the Prisoner's Dilemma applied to fisheries (Dasgupta and Heal, 1979). These international organizations were primarily concerned with stock management, with little attention given to economic considerations. However, as problems of over-exploitation became more evident, the same was true for economic inefficiencies. The need for improved management was therefore evident both to biologists and to economists.

Extended fisheries jurisdiction (EFJ)

As international fisheries resources are common property resources, exclusive property rights could not be assigned to them; only by capture could property rights be established in fish. Thus the attempts to regulate international fisheries were largely unsuccessful. The results were felt to be particularly unsatisfactory by coastal states, with closest access to the fishing grounds.

In the post Second World War period, several conflicts arose between coastal and distant-water fishing nations, as the former attempted to assert greater control over resources close to their shores by extending territorial waters or declaring extended fishing zones. The 'cod wars' between the United Kingdom and Iceland are just one example.

Extended Fisheries Jurisdiction (EFJ) is based on the 1982 United Nations Convention on the Law of the Sea. Although to date this has not been ratified by the required number of countries, it has acquired the status of customary international law. According to this Convention, the coastal state has 'sovereign' rights for exploiting and managing natural resources in its 200-mile EEZ. In practice, this means that the coastal state has the sole right to determine TACs for fish stocks in its zone and whether or not it has sufficient harvesting capacity to catch these quotas. Moreover, if other countries are allowed to fish in the EEZ of a country, the coastal state determines under what conditions this may take place. The coastal state may, for example, impose fees on catches by foreign vessels. McRae and Munro (1989) trace the development towards EFJ in the past decades and the nature of the rights of a coastal state over the resources in its 200-mile EEZ.

Trans-boundary and migratory resources

As most fish catches are made within the EEZs of coastal states, EFJ may superficially appear to have the potential of 'solving' all important management problems. However, fish do not respect man-made boundaries, and for this reason considerable management problems remain, particularly with respect to trans-boundary and migratory resources.

Trans-boundary resources are those where a fish stock is divided between the EEZs of two or more coastal states. In the case of migratory resources, the stock migrates between the EEZs of two or more states, for example, according to a seasonal pattern or over the life cycle of the fish. Thus, in one period, a stock may be under sole control of one state, while in another it is fully in the EEZ of another country. Although this distinction between trans-boundary and migratory resources may not be clear-cut in real life, it is convenient for analytical purposes.

Analysis of the management of trans-boundary resources is closely associated with the name of Munro (1979, 1990, 1991a; see also McRae and Munro, 1989). Munro considers the case where a resource is shared between two countries, assuming each country to have full control over its fishing effort. Stock size in bionomic equilibrium and under optimal management depends on economic and biological parameters. Thus, with differences in economic parameters, the two countries will have different perceptions about optimal stock size and bionomic equilibrium. For the case of competing exploitation of a resource, Munro's analysis is based on non-cooperative game theory. The author demonstrates how the outcome with respect to stock size and rent dissipation depends on economic configurations in the two countries involved. Under all conditions, competitive exploitation is found to involve stock depletion and rent dissipation. Thus a *prima facie* case exists for cooperative exploitation of the resource. For the case of cooperative management, Munro's analysis is based on cooperative game theory. If economic parameters are the same in both countries and they are willing to enter into a binding agreement, the two owners would maximize total profits and negotiate the sharing of returns.

The more interesting (and realistic) situation arises when economic parameters differ, owing to differences in prices, discount rates, costs of effort or fishing technology. The outcome of the cooperative game depends on whether harvest shares are constant over time and whether side-payments are allowed. When economic parameters differ, this means that the two countries put a different value on the resource. If the price of fish is higher in country 1 than in country 2 (and there is no trade in fish), or the unit harvesting cost or the discount rate is lower in country 1, then country 1 will place a greater value on the resource than country 2. For the case of cooperative management with a binding agreement, this would involve country 1 being sole manager of the resource, buying out country 2. This is feasible, as the resource is worth more to country 1 than to country 2. In the words of Munro, this would represent the *optimum optimorum*.

Commonly, side-payments are not feasible, and harvest shares are usually constant over time, based on historical catch records or the dispersion of the stock between the EEZs of the two countries, for example. Munro considers in detail the case where the discount rates in the two countries differ (assuming prices and costs of effort to be equal). For cooperative management with a binding agreement, the (compromise) optimal stock level is found to be a function of time. Greater weight is placed on the preferences of the high-discount country in the near future and less in the more distant future, as a consequence of its time preferences. The converse is true for the low-discount country. In the long run, the compromise stock level approaches the optimal stock level of the low discount country asymptotically. When side-payments are not allowed and harvest shares are to be fixed over time, these can be considered constraints to the optimization problem. Therefore the outcome in this case will be less than in the *optimum optimorum* described above.

Under more complicated game-theoretic conditions involving non-binding agreements, the possibility of a stable equilibrium is somewhat more doubtful (see Kaitala, 1985, on cooperative management and the consequences of non-binding agreements). However, even in those cases, an equilibrium bargaining solution may exist. Nonetheless, a fundamental conclusion of the economic theory of trans-boundary resources is that the parties involved are always better off in a bargaining solution than under open access.

Although trans-boundary issues are very important, only a few empirical applications have been undertaken. Munro (1991b) describes the problems involved in the exploitation of the highly migratory and very valuable tropical tuna and Pacific salmon stocks. Both of these cases provide prime examples of the problems of cooperative management of fish stocks. This is especially true for the tropical tuna, which is found in the EEZs of several diverse Pacific island states, with distant-water fishing nations harvesting the resource. Munro describes the setting, that is, the problems facing both the owners and the harvesters, the subsequent negotiations and their ultimate resolution. Having described how the Pacific island states greatly benefited from extended fisheries jurisdiction, the paper concludes on a rather optimistic note. It appears from these examples that mutually beneficial cooperative fisheries management is possible even when the parties involved are apparently facing formidable bargaining obstacles.

The analysis of Armstrong and Flaaten (1991) is set in the framework of a trans-boundary species exploited by Norway and the Soviet Union, which share the Arcto-Norwegian cod stock as a result of migratory behaviour over the life cycle of the species. While the nursery and adolescent grounds are primarily within Soviet fisheries jurisdiction, the spawning grounds are almost exclusively in Norwegian waters. The migratory behaviour is not explicitly modelled. Rather, exploitation is defined in trans-boundary terms, and a model of the bargaining situation due to Munro is employed. Based on economic parameters for the two countries, the authors find that the actual agreements reached by Norway and the Soviet Union concerning the utilization of this stock are reasonably efficient and conform broadly with the predictions of Munro's theory. Although the management of trans-boundary resources has received much attention in the literature (see also Levhari and Mirman, 1980), this is less the case for migratory resources. The consequences of migration may require refinements or modifications to the transboundary model.

Arnason (1991) analyses the exploitation of migratory species. The migratory behaviour means that harvesting conditions change over time even when the size of the biomass is constant. This non-autonomous nature of the situation significantly increases the complexity of the optimal harvesting problem. Among other things, Arnason shows that, with continuous migrations, the optimal stock level generally does not converge to a constant equilibrium level. Moreover, a general characterization of the nature of the optimal biomass and harvesting paths does not appear to be easily available. The situation becomes even less tractable in the case where the migratory stock periodically moves between EEZs. In those cases, the nations in question are periodically faced with intervals when their access to the resource is blocked, while their competitors have temporarily exclusive access to the resource. Obviously, this makes for a very complicated game.

It appears that further research in this field will be directed towards analysis of the management of migratory resources and empirical research into the exploitation of both trans-boundary and migratory resources.

Individual transferable quotas (ITQs)

Extended Fisheries Jurisdiction (EFJ) and the establishment of 200-mile EEZs have meant that most fish stocks are now under the control of coastal states. EFJ provides a new basis for the management of fisheries, with potential for substantial improvements, although to date in many instances these remain to be realized.

For stocks under the sole control of a coastal state, the latter has full control over its management. Essentially, the coastal state is a sole owner and may optimize resource use. For the case of trans-boundary resources, the states involved are the combined sole owner and may cooperate over resource management. This may take the form of setting a joint TAC for the stock, which in turn is divided into national quotas. The coastal state will then have full control over its share of the TAC. This arrangement is predominant, for example for the management of shared resources in the North-east Atlantic. In other words, one may envisage the management of fisheries as being undertaken in two steps. First, the TAC is determined through an optimization procedure. Second, the quota must be allocated among fishermen in a way that ensures harvesting efficiency in order to avoid the Class II common property problem. Harvesting efficiency is a requirement for capturing the rent that the resources can yield.

An individual transferable quota (ITQ) is a legal right to catch a quantity of fish over a certain period of time. The ITQ is divisible and transferable in a quota market. Thus it is to be considered a private property right. It is considered a right to a certain fraction of the *surplus production* from a given stock, but not to the stock itself. Over time, most natural resources that originally were characterized by open access have come under private ownership. The reason this did not happen to fish earlier was that it appeared both unnecessary and impossible to assign property rights to fish in the sea. This was because fisheries resources were believed to be inexhaustible, and because property rights could not be enforced (Grotius, 1608; quoted in Christy and Scott, 1965, p.155). With modern technology, many fish stocks are exhaustible, but at the same time enforcement is more practicable than in earlier times, although enforcement remains a very serious problem in the management of many fisheries.

The changes that have taken place in the last decades have thus been in two stages. In the first stage, through the Law of the Sea, property rights to fish stocks were assigned to coastal states. In the second stage, a number of countries, including New Zealand, Australia, Canada and Iceland, have 'privatized' some of their resources through the establishment of ITQs in an attempt to ensure harvesting efficiency. This represents a fundamental institutional change and will make the management of fisheries more 'similar' to that of other resources, such as forestry.

From a management perspective, important objectives may be achieved through a combined TAC–ITQ system.[4] First, by setting the TAC, the country can achieve a sustainable harvest level that maximizes the net economic benefits from the fishery. Second, by introducing a harvest quota for each individual fisherman, the incentive problem facing the fisherman is changed from competitive behaviour to that of cost minimization. Even in the short run, with no other institutional changes, this could improve harvesting efficiency. However, with transferability of quotas, each boat will, over time, find the effort level that will minimize its long-run harvesting costs, provided the quotas are of sufficient duration to permit long-run investments in capital equipment. Thus quotas will improve harvesting efficiency in both the short run and the long run, although important benefits can only be achieved in the long run.

A further objective is to achieve management goals at minimum cost. In a sense, with ITQs, a greater part of the enforcement of fisheries may now be left to the industry itself. From the fishermen's perspective, ITQs permit flexibiity in terms of which species to fish. Moreover, they permit easy entry and exit to the fishery, which is another precondition for harvesting efficiency.

NOTES

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[2]In the terminology of Munro and Scott (1984), the Class I common property fishery is the one analysed in Section 2.

[3]The rents from the fishery would, of course, become capitalized in the value of the boats.

[4]Essentially, economic optimization is here assumed to take place through a two-stage procedure. Arnason (1989) analyses the way in which ITQs can simultaneously achieve both these objectives.

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