Recommended Best Practices for

Regional Fisheries Management Organizations: Technical Study No. 3

The Relevance of Bioeconomic Modelling to RFMO Resources

A Survey of the Literature

Trond Bjørndal and Sarah Martin

CHATHAM HOUSE

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List of acronyms

ACFM	Advisory Committee on Fishery Management
AFZ	Australian Fishing Zone
CCSBT	Commission for the Conservation of Southern Bluefin Tuna
CPUE	Catch-per-unit effort
DWFN	Distant water fishing nation
EEZ	Exclusive economic zone
FBNE	Feedback Nash equilibrium
CCAT	International Commission for the Conservation of Atlantic Tunas
ICES	International Council for the Exploration of the Sea
ITQ	Individual transferable quota
IVQ	Individual vessel quota
NEAFC	North East Atlantic Fisheries Commission
MSY	Maximum sustainable yield
NPV	Net present value
OCS	Other coastal states
RFMO	Regional Fisheries Management Organization
SBT	Southern bluefin tuna
SSB	Spawning stock biomass
TAC	Total allowable catch
WCPFC	Western and Central Pacific Fisheries Commission
WCPO	Western and Central Pacific Ocean
WCPTF	Western and Central Pacific Tuna Fishery

1

Introduction

According to the UN Fish Stocks Agreement, the management of straddling and highly migratory fish stocks is to be carried out through Regional Fisheries Management Organizations (RFMOs), composed of relevant coastal states and distant water fishing nations with a 'real interest' in the fishery. An important objective in the management of such fish stocks under the governance of RFMOs is that the resources should provide through time the maximum flow of economic rents to the members of the RFMO. The purpose of this report is to provide a survey, and an assessment, of bioeconomic modelling exercises pertaining to straddling fish stocks and highly migratory fish stocks.

The usefulness of any theory, whether applied in the natural or the social sciences, is measured by its predictive power. If the theory is to be taken seriously, it must be tested against the real world. In economics, this is done through constructing empirical models, referred to as econometric models, which are based on real-world data. The term econometrics refers to statistical methods applied to economics. If the economic theories prove to be valid, the econometric models can be used further to assess the implications of alternative policy options, often through the use of simulation models. Thus, for example, in the field of macroeconomics, central banks rely, *inter alia*, on econometric models when assessing policy options.

In the field of fisheries economics, the relevant models are referred to as *bioeconomic* models. This is because the economic model of a fishery resource must rest on an explicit model of fish population dynamics. If the model of population dynamics for the fishery resource in question is mis-specified, then the empirical economic model of the resource built on it will, at best, be worthless.

The economic theory of RFMO resource management can be briefly summarized as follows. The theory states that, if the RFMO is unsuccessful in bringing about effective cooperative resource management among its members, the consequence will be dissipation of the net economic benefits (broadly defined) from the resources, and overexploitation of the resources themselves. The theory further postulates that effective cooperation may require the broadening of the scope for bargaining among the RFMO members, by allowing for what in economics is referred to as 'side payments'. These so-called side payments are basically transfers in monetary or non-monetary form. The side payments will, *inter alia*, help to ensure an equitable allocation of the net economic benefits from the fishery resources among the RFMO members.

Next, the theory predicts that the prospects for effective resource management cooperation will be undermined if non-compliance is not held in check. The theory further predicts that effective cooperative resource management will be undermined if the problem of resilience through time, and the linked problems of prospective new members and unregulated fishing, are not adequately addressed.

How valid is the theory? If the theory is valid, then how serious are the consequences of ineffective cooperative resource management in quantitative terms? Are the economic losses from ineffective cooperative resource management truly substantial, or are they not? Which of the various policy options open to RFMO managers are likely to be the most effective? These are the types of questions that the applied bioeconomic modelling analyses are designed to answer.

Bioeconomic analyses have been undertaken for a number of fisheries. Numerous studies have been devoted to tuna fisheries in the Pacific, but also in the Atlantic. These are all classified as highly migratory fish stocks. In addition, several straddling fish stocks in the North Atlantic, including Norwegian spring-spawning herring, mackerel and blue whiting, have been subjected to bioeconomic analysis.

This report describes and assesses the different analyses developed in various recent bioeconomic studies and their relevance to the management of fisheries resources. It is organized as follows. Section 2 looks at straddling fish stocks in the North East Atlantic. Sections 3–5 are devoted to various tuna resources, namely the tuna resources under the governance of the Western and Central Pacific Fisheries Commission (WCPFC), southern bluefin tuna, and East Atlantic/ Mediterranean bluefin tuna, respectively. The final section will draw conclusions from the bioeconomic analyses surveyed, which are of importance for the successful management of highly migratory fish stocks and straddling fish stocks.

2

Straddling fish stocks in the North East Atlantic

The North East Atlantic straddling fish stock considered in this section is managed by the North East Atlantic Fisheries Commission (NEAFC).

2.1 Norwegian spring-spawning herring

Norwegian spring-spawning herring is potentially the most abundant fish stock in the North Atlantic. The fishery is important for employment and revenue in many countries in the region, including Norway, Iceland, Russia, the Faroe Islands and some members of the EU. It is potentially a very valuable fish stock. During the early 1950s its total biomass ranged between 15m and 20m tonnes, and its spawning stock averaged 10m tonnes. Average fishing mortality was generally less than 0.1, but it produced annual catches in excess of 1m tonnes, peaking at 2m tonnes in 1966. In the late 1960s the stock collapsed, as the introduction of new technologies caused overfishing and worsening environmental conditions. A moratorium on fishing was imposed in 1969, but the stock continued to decline, reaching a nadir of 71,000 tonnes and a spawning stock of 2,000 tonnes in 1972. The fishing moratorium was imposed to rejuvenate and restore the stock; however, it took until the 1990s for the stock to reach a point where total allowable catch (TAC) levels could be increased. The spawning stock is currently back to its previous size of 10m tonnes.

Management of the herring fishery is complicated by its multi-nation exploitation, as the straddling nature of the species causes it to move between several coastal state zones (exclusive economic zones, EEZs) and the high seas ('Ocean Loop'). The authority for fisheries management lies with the individual countries when the stocks are in their coastal waters, but on the high seas the stock is open for harvesting by many fishing nations. This presents a serious challenge for international fisheries management if the consequences of open access are to be avoided.

Herring spawns off the coast of Norway, then passes through its EEZ into international waters to feed. The stock forms dense schools during this feeding period, making it particularly vulnerable to fishing. If the stock of fish is abundant, an international migratory cycle is maintained, which extends from Norwegian coastal waters through the EEZs of the EU, the Faroe Islands, Iceland and the international waters called the Ocean Loop to the summer feeding area near Jan Mayen Island. However, when the stock becomes depleted, as it did in the 1960s, the species remains solely in Norwegian coastal waters, under Norwegian fisheries management jurisdiction. Consequently, Norway plays a pivotal role in deciding fisheries management policies for spring-spawning stock, and may maintain this role by keeping the stock in a non-migratory state.

In 1995 the Advisory Committee on Fishery Management (ACFM) recommended a TAC of 513,000 tonnes for Norwegian spring-spawning herring. This was ignored, resulting in a collective harvest of almost twice this amount. Nonetheless, progress towards cooperation continued, so that an agreement between Norway, Russia, Iceland and the Faroe Islands for a combined TAC of

1.267m tonnes was reached in 1996. A year later the EU became a signatory to an agreement limiting the TAC to 1.498m tonnes, which was gradually reduced to 1.25m tonnes by 2000. Cooperative management was maintained until 2002, with TACs set in line with recommendations made by the International Council for the Exploration of the Sea (ICES).

In 2003 cooperation broke down, as Norway demanded a larger share of the TAC, arguing that the herring appeared to spend more time in its EEZ than the calculations underlying the zonal principle on which the original agreement was based seemed to indicate. For a number of years quotas were set unilaterally by the different countries, and in 2005 and 2006 the total exceeded the TAC recommended by the ICES. For the 2007 season a new agreement has been reached, giving Norway a slightly larger share of the TAC than before. There are also bilateral arrangements, primarily allowing other countries to harvest part of their quota in the Norwegian EEZ, where the stock is most abundant.[1] These may be considered side payments.

The recovery of the Norwegian spring-spawning stock offers the opportunity for substantial annual harvests on a sustainable basis for the benefit of all nations involved. However, recent developments show that if the current cooperative arrangement among the countries fails and there is a return to open-access conditions, increased international competition for harvest shares will be biologically, economically and politically damaging.

Two analyses are considered below.

Arnason, Magnusson and Agnarsson (2000), 'A Game Theoretic Model of the Atlanto-Scandian Herring Fishery'

In this paper a migratory model is developed, based on the life-cycle of herring. Exploitation by different nations is represented by a game theoretic model. A great number of game simulations are run using different specifications regarding biomass growth, migrations, harvesting costs, number of players and coalitions.

The results derived from these general experiments lead to the following conclusions.

- Cooperation always leads to more profit than competition.
- The presence of many exploiters often leads to the virtual (or complete) depletion of the stock after a short period of time, provided the stock has initially spent a good deal of time in the high seas.
- If a particular exploiter has a relatively small zone to fish from, he will fish very aggressively whenever the stock wanders into his possible zone of fishing.
- The higher the rate of discount, the more aggressive the fishing.
- A high-cost exploiter (one that is located far from the area where the fish roam) generally does not have a great effect on the behaviour of the other exploiters.

A model was employed to determine the possible outcomes of the harvesting game for the Norwegian spring-spawning herring fishery, simulating the exploitation by the five players, namely Norway, Iceland, Russia, the Faroe Islands and the EU countries. It assumed, in each of the simulations, that the players begin with a virgin stock.

[1] Norway suspended these rights in the period when there was no agreement among the parties.

Results suggest that player cooperation is needed to save the stock from (near) extinction, since the competitive game always resulted in the stock being (almost) fully depleted. The cooperative game also offers substantially higher profits than the competitive situation, and the higher the level of cooperation, the greater the profits. However, despite its suboptimal nature, the competitive game yields substantial present value of profits to the players, because of the assumption that the stock is a virgin stock at the start of the game. Large profits can be made from the initial large catches, as the stock is being depleted.

Full cooperation generates considerably higher net value of profits than competition, but even the fully cooperative solution involves intense harvesting at the outset, with a quick reduction to the long-run optimal level of about 4.4m tonnes. After that, the harvesting continues at approximately the level needed to keep the stock unchanged, with some variability as a result of migration. The initial stock reduction is rapid in both the competitive and the cooperative scenarios, requiring a great deal of harvesting and processing capacity, which may well be in excess of what is actually available, as aggregate capacity constraints were not included in the model.

There is a substantial difference between the long-run levels of quarterly catch and biomass under the two game solutions; in particular, the stock becomes extinct quite rapidly when no cooperation is assumed. Nevertheless, harvest rates and stock levels fluctuate when cooperation is assumed, even in the long run. This is caused by migrations that move the stock between exclusive fishing zones and affect the profitability of fishing. Therefore, since the migrations are stochastic, the fluctuations are also stochastic.

Despite varying details, the same broad characteristics are exhibited in each case. The more extensive the cooperation between the players, the greater the aggregate present value of profits and the equilibrium stock level. The higher the rate of discount, the less benefit to coalitions, as the initial high state of the stock implies that the competitive and optimal harvesting paths are initially quite similar. Therefore, the great benefits from cooperation are primarily realized later, when the optimal and competitive harvesting paths diverge.

Without side payments few coalitions seem to be stable, in the sense that each player benefits from participating, which is not the case in a competitive situation. Thus Norway cannot be induced to enter into a coalition without side payments, as it will find it beneficial to break the agreement. However, with side payments the coalition seems very stable, yielding almost three times more aggregate benefits than the competitive path. Thus, in the Norwegian spring-spawning herring case, stable coalitions are only likely to be achievable if side payments or other ways of inducing players to participate in coalitions are possible.

Bjørndal, Gordon, Kaitala and Lindroos (2004), 'International Management Strategies for a Straddling Fish Stock'

In this paper a model is developed consisting of stock dynamics, described by a discrete-time age-structured population model, and an economics component, represented by a rent-maximizing model with a constant price of herring and different costs of harvesting and efficiency levels for the different national fleets. A dynamic bioeconomic model characterizes the harvest strategy for three national fleets – Norway, Iceland and the EU[2] – differentiated by costs and efficiency, to evaluate five alternative management strategies.

[2] On the basis of observed characteristics in the fishery, the player Norway is assumed to represent the coalition of Norway and Russia, while the player Iceland represents the coalition of Iceland and the Faroe Islands.

The first management strategy is the open-access case, showing the cycle of stock collapse and recovery. The second case is defined by imposing a simple regulatory scheme of complete fishery closure on the open-access case, as the stock reaches critically low levels. This has substantial positive benefits for both the stock level and potential net profits for all participants in the fishery. The third strategy restricts the stock to a depleted non-migratory state remaining only in Norwegian waters, solely under Norwegian jurisdiction. This strategy shows minimal benefits in terms of net profits to the Norwegian fishery when compared with the competitive open-access fishery with closure. The fourth case investigates the consequences of sharing among the three agents the rents obtained from monopoly harvesting over an abundant migratory fish stock, and the fifth case envisages sharing the total catch among the three agents for an abundant migratory fish stock under international fisheries management (cartel solution).

Management under either a monopoly or a cartel solution such as these can bring significant benefits to all participants in the industry. Under a monopoly, the largest potential profits are earned in the fishery, but international agreement is required to share the rent among the non-participants who would allow the monopoly to exist. Under a cartel, potential profits are smaller than under a monopoly, but larger than under open access with fishery closure, although this requires international agreement to share the monopoly harvest level.

Model simulations show that the benefits of international cooperation far exceed the returns of a competitive open-access fishery on a timescale of several decades. Whether international agreement allocates shares of rent or catch levels, management cooperation in the spring-spawning herring fishery can achieve substantial economic benefits for all participants to the fishery under sustainable stock levels.

Discussion

In important areas, these two papers give qualitatively similar results. Cooperation is seen to yield significant benefits in terms of rent generation, as compared with open access. Also, the more extensive the cooperation, the higher the net present value of rents.

When the TACs could be substantially increased in the mid-1990s and traditional migration to the Norwegian Sea resumed, the stock was at a very high level. Therefore, transitory rents under open access were found to be substantial. This kind of result is not to be anticipated for other fisheries under consideration.

While cooperation is seen to give rise to an optimal stock at a very high and sustainable level, open access is seen to lead to (near) extinction of the stock. This latter prediction is in line with what was observed in the fishery in the 1960s.

The stability of coalitions is analysed by Arnason et al., who find that in many situations side payments are necessary to achieve this objective. Side payments are also part of the actual management arrangements for the stock, as described above. Owing to a different modelling approach, Bjørndal et al. do not explicitly consider stability of coalitions. It is, however, shown that no country will have an incentive to break out of the cartel solution.

2.2 Other straddling stocks in the North East Atlantic

Two analyses are considered below.

Ekerhovd (2007), *Increased Fishing Pressure on Unregulated Species*

An important fishery in the North East Atlantic is the blue whiting fishery (*Micromesistius poutassou*), one of the most abundant fish species in the Norwegian Sea. Until recently it has been unregulated. The blue whiting is a straddling stock, migrating through the EEZs of several nations as well as the high seas, complicating management of the stocks. The blue whiting fishery was dominated by Russia and Norway from 1970 to 1997, but since the late 1990s there has been more interest in the fishery, increasing total landings from approximately 650,000 tonnes in 1997 to 2.3m tonnes in 2003. Iceland, which had previously ignored the blue whiting fishery, began to increase landings substantially from 1998. After many failed attempts, in 2005 the EU, the Faroe Islands, Iceland and Norway signed a management agreement for annual reductions in the landings to reach agreed management goals.

For Norwegian vessels, individual vessel quotas (IVQs) are allocated for the stocks of spring-spawning herring (straddling stock), North Sea herring (shared stock), mackerel (straddling stock) and capelin (shared stock). Non-quota species such as blue whiting are also allowed to be fished, provided the vessel holds a blue whiting fishing licence. As quota species and non-quota species are targeted on a species-by-species basis, bycatch is not an issue.

A subfleet of Norwegian purse-seiners licensed to fish blue whiting and other species, regulating the outputs of blue whiting and other non-quota species, was studied to analyse the effects of the quota-restricted fisheries on the landings of blue whiting.

The catch of blue whiting showed no statistically significant relationships with the quota-regulated species, except for capelin, for which it is a substitute, although this is far from being a one-to-one relationship. However, the catches of other non-quota species were in an almost one-to-one substitute relationship with the quota on spring-spawning herring, and in a strong complementary relationship with mackerel and North Sea herring. The quota levels of spring-spawning herring, mackerel, North Sea herring and capelin have little effect on the fishing effort and catch of blue whiting, which appears to be influenced by the price of fuel and the price of other non-quota species.

Although blue whiting and other non-quota species all are unregulated fisheries, there are clearly differences in the behaviour of fishermen towards the respective species. Catches of the non-quota species (other than blue whiting) are strongly linked to the spring-spawning herring, mackerel and North Sea herring quotas, as well as being responsive to changes in their own price and the price of fuel. In contrast, the blue whiting fishery is not influenced by its own price, and is only affected to a certain degree by the quotas set for capelin stock.

Kennedy (2003), 'Scope for Efficient Multinational Exploitation of North-East Atlantic Mackerel'

The introduction of EEZs was originally thought to be the solution to allow nations to maximize rents. However, it was subsequently realized that this was not necessarily true for straddling stocks. This paper investigates the scope for multinational cooperation in setting national and international TACs in order to maximize rents for the North East Atlantic mackerel fishery. The mackerel is harvested by nations when it migrates between the coastal EEZs of Scotland, Ireland and Norway, and mainly by Russia when it enters international waters.

North East Atlantic mackerel consists of three separate stocks referred to as the North Sea, Western and Southern components, based on different spawning grounds, but as the stocks often overlap when they are harvested, they are managed as one stock. The North Sea stock is currently heavily depleted. Total catches of the three stocks have fluctuated over the last ten years, averaging about 400,000 tonnes per year, with the EU and Norway harvesting similar amounts.

Recommendations for annual TACs for mackerel are made by the ICES, based on biological sustainability. These recommendations are discussed by the coastal players in order to reach an agreement on the distribution of the TACs, which are generally based on recent catch levels or claims of relative proportions of stock in EEZs. This policy leads to inefficient catch behaviour and misreporting, which can have an undesirable effect on policy. The NEAFC plays the role of a regional fisheries management organization in arranging negotiations between the coastal and non-coastal players on the distribution of the TAC in international waters.

A bioeconomic, age-structured model of the North East Atlantic fishery is developed for the three major harvesters of North East Atlantic mackerel, i.e., Russia, Norway, and Scotland and Ireland together. Comparisons are drawn between a model of the current situation, a cooperative rent-maximization situation, and a non-cooperative situation. The scenario modelling shows that for a wide range of parameter values the all-player coalition is unstable if joint rents cannot be redistributed among the players. Without transfers, the outcome is the type of non-cooperative fishing that is currently observed. However, if transfers of joint rents are possible, side payments can be used to sustain the efficiency gains of joint maximization of the mackerel fishery. These transfers can be arranged by an RFMO to increase the likelihood of joint maximization, all-player coalition methods being accepted by players. It may even be the case that self-enforcing transfers could be agreed between the parties without an RFMO.

The current negotiations for allocation of TAC shares tend to lead to allocations that, while possible to manipulate, are generally accepted. Moving to a system of negotiating with specific goals, such as rent maximization, might lead to more desirable social outcomes, but agreement may be more difficult to achieve.

Despite these proposed economic benefits, some policy-makers may consider the increase in total social rent to include consumer surplus as well as producer surplus: e.g., if the catch is exported, lower prices benefit foreign consumers, not domestic ones, and normal practice in cost-benefit analysis is to accord such benefits zero weighting. However, in this application Russia is a net importer, so there is an argument for including Russian consumer surplus in the objective functions of coalitions that include Russia.

The model assumptions of perfect knowledge of each player committing to future harvesting decisions, each player's understanding of the biology of the fish stock and the decision-making processes of other players are not realistic. This means that returns for competing coalitions are likely to be lower than those modelled. Restricting the model to only three players, when there are in fact more, is another simplification that leads to the overestimation of returns. Harvesting by the three main players is also likely to be greater in the short run, because they face competition for access to stocks from other players. No density-dependent effects are included in the biological modelling.

Discussion

Blue whiting is an important fishery in the North East Atlantic. The stock is straddling, and until recently the fishery was unregulated. Unlike most other papers presented in this report, the focus of Ekerhovd's analysis is not on the game-theoretic aspects of the fishery. The purse-seine fleet analysed also harvests other species, some of which are regulated while others are not. In an empirical application the study analyses how landings of blue whiting depend on their own price, prices of other species, and the price of fuel as well as quotas and landings of other fish stocks. Results presented are, of course, fishery-specific. Nevertheless, a fleet harvesting a straddling stock may also exploit other stocks, outside or inside an EEZ. The contribution of this paper is to show that knowledge about these interactions is necessary for efficient management.

Kennedy's topic is the fishery for another straddling stock in the North East Atlantic, namely mackerel, and his approach is game theoretic. Comparisons are made between the current situation, a cooperative rent-maximizing situation, and a non-cooperative situation. For a wide range of parameter values the all-player coalition is unstable if joint rents cannot be redistributed among the players. Without transfers, the result is the type of non-cooperative fishing currently observed. However, if transfers of joint rents are possible, side payments can be used to sustain the efficiency gains of joint maximization of the fishery.

3

The tuna resources under the governance of the WCPFC

The Western and Central Pacific Fisheries Commission (WCPFC) was established in 2004 to ensure the long-term conservation and sustainable use – in particular for human food consumption – of highly migratory fish stocks in the Western and Central Pacific Ocean.

The Western and Central Pacific Tuna Fishery (WCPTF) is the world's largest and most valuable tuna fishery, yielding 2.1m tonnes valued at more than US$3bn in 2005. This compares with US$1.9bn in 1998. These coastal marine resources are of significant economic and cultural importance to the Polynesian and Micronesian Pacific island communities, providing a source of food, income, culture and recreation. As domestic fishing fleets are poorly developed, they receive fees from distant water fishing nations, which dominate the benefits accruing to the Pacific island countries. Distant water fishing operations are based on industrial purse-seine, pole-and-line and longline operations in the EEZs of Pacific states and on the high seas. These fisheries target four main species: skipjack tuna (*Katsuwonus pelamis*), yellowfin tuna (*Thunnus albacares*), bigeye tuna (*T. obesus*) and albacore tuna (*T. alalunga*).

Although skipjack accounts for 65% of total catch, this species is valued at a lower price than other species supplied to the premium Japanese sashimi market. Yellowfin tuna contributes 22% of total catch and is sold to both the canning market at a low price and to the premium sashimi market at a higher price. Bigeye represents only 6% of the total catch in the region, but mainly supplies the premium sashimi market, so it is still extremely profitable.

Four analyses are considered below.

Bertignac, Campbell, Hampton and Hand (2001), 'Maximizing Resource Rent from the Western and Central Pacific Tuna Fisheries'

Over the last 20 to 30 years the tuna fisheries in the Western and Central Pacific Ocean (WCPO) have undergone a period of rapid restructuring and expansion driven by market conditions. The pole-and-line fishery went through its growth phase in the early 1970s, with vessel numbers peaking in 1978, partially in response to the growth of the canned tuna market, and partially in response to the Japanese government's subsidization of its distant water fleet. The purse-seine fishery developed rapidly in the late 1970s and 1980s in response to improved technologies, poor fishing conditions, dolphin bycatch in the Eastern Pacific Ocean, and the emergence of the Korean, Taiwanese and Japanese purse-seine fleets. The longline fleet, which predominantly supplies the Japanese sashimi market, has declined in terms of its percentage of the total catch. However, because sashimi fetches prices much in excess of those paid for canning-grade tuna, revenues are almost as high as those of the purse-seine fishery.

It is clear that strong bioeconomic interactions exist among the fleet categories, suggesting that it may be possible to increase fishery rent, or some other measure of economic performance, by varying the mix of effort levels.

This paper estimates the level and composition of effort which maximizes rent in the WCPO tuna fisheries, with particular emphasis on the returns to the countries of the region. To address this issue of optimal fleet composition, a multi-species, multi-fleet bioeconomic model of the WCPO tuna fishery is used. Rent generated by the tuna fisheries occurring in the waters of Pacific island nations is estimated for various levels and combinations of purse-seine, pole-and-line, frozen tuna longline and fresh tuna longline fishing effort.

The underlying population model integrates available information on the population dynamics of the four tuna species in the Pacific Ocean: yellowfin, bigeye, albacore and skipjack. The economic model utilizes data on fishing effort costs for the purse-seine, pole-and-line and longline fleets, further separated by the nationality of those operating in the Western and Central Pacific Ocean, reflecting the differences in productivity and cost structure among the diverse range of vessels operating in the fishery. Recent estimates of prices by species, method of capture and market, and estimates of demand elasticities are also used. This differentiation of the fleets in terms of cost structure and prices is made to improve the accuracy of the profitability estimates. It will also enable more flexibility in examining the effects of different policy decisions, such as the licensing arrangements for particular fleets.

On the basis of the bioeconomic simulations, some preliminary conclusions can be drawn about the rent-maximizing level of effort in the WCPO tuna fisheries, the optimal fleet composition, and the access fee structure that will maximize returns to the resource-owning countries. The results suggest economic, rather than biological, overfishing. While current levels of effort do not appear to threaten the viability of fish stocks, they appear to be excessive in the sense that reductions in effort will reduce costs by more than the reduction in revenue.

Both fishery rent and private profit are shown to be maximized when effort is reduced in equivalent proportions across all fleets to approximately 50% of the 1996 effort level. While a reduction of this scale lowers total revenue to two-thirds of the 1996 level, total harvesting costs fall to half of the 1996 level. The reduction in harvesting cost is achieved partly by reducing total catch, but also through the lower unit cost of catching fish resulting from the higher fish stocks in the new, long-run equilibrium. The effect of changing effort of individual fleet categories on the profitability of that fleet and of the other fleets, holding the effort of the other fleets constant at the 1996 level, is consistent with the other findings, i.e., that the overall level of effort is significantly above the optimal level, so that the profitability of each fleet, except the frozen tuna longline fleet, rises as its effort level falls. These results suggest that higher access fees could be sustained at lower levels of effort.

If the resource-owning nations could capture a significant share of fishery rent by means of access fees, it appears that it would be to their advantage to alter both the level and the structure of the fees. Fees as a percentage of catch value could be raised for all fleets, and a fee structure that recognizes the different revenue and cost structures of different fleets could be introduced.

In conclusion, the results of the model indicate that fishery rent could be increased substantially above the current level by decreasing the size of all fleets, with the possible exception of the tuna longline fleet. The results also suggest that the countries of the region could benefit significantly from changing the level and structure of access fees levied as a percentage of total catch revenue. The model supports the tentative conclusions of earlier work, but is based on more detailed and reliable evidence, and it seems unlikely that the directions of change it suggests will be altered as a result of further research.

Chand, Grafton and Petersen (2003), 'Multilateral Governance of Fisheries Management and Cooperation in the Western and Central Pacific Fisheries'

There are two major concerns with regard to the current governance of the Western and Central Pacific tuna fisheries: first, that the Pacific island nations receive only a small percentage of the benefits from exploitation of their tuna resource (13% of gross revenue in 1996), and second, that the current governance structure will not ensure the long-term sustainability of the resources. There have been signs of economic overexploitation, and also signs that the most lucrative of the four tuna species harvested, bigeye tuna, is being biologically overexploited, with similar concerns expressed over levels of yellowfin tuna. This paper derives a model to show that the sustainability of the resource may be improved when a single policy-maker maximizes steady state rents through the use of a tax or an equivalent quantity instrument.

The need for cooperation has been recognized in the UN Fish Stocks Agreement, which requires both coastal states and distant water fishing nations to cooperate in managing the fisheries bilaterally, multilaterally, or through the establishment of RFMOs. In 2000 all Pacific island nations and distant water fleets (except Japan) signed the Multilateral High Level Convention on the Conservation and Management of Highly Migratory Fish Stocks in the Western Central Pacific Ocean, which came into force in 2004. The Commission (WCPFC) is responsible for promoting cooperation and coordination between members to ensure the conservation of fish stocks.

At present, ten distant water fishing nations that fish in the Western Central Pacific Ocean region account for 86% of the total tuna harvest. Coastal states allocate fishing entitlements to distant water fleets through international treaties, owing to the cost advantage distant water fishing nations have in harvesting and marketing over the Pacific island countries. These agreements potentially allow both parties to benefit. However, with the exception of a multilateral treaty negotiated between the US and the 16 Pacific island countries, all treaties between distant water fishing nations and Pacific island countries are bilateral, as the island countries have been reluctant to enter into multilateral agreements. This is attributable to the perception that such agreements may compromise their sovereign rights, the lack of supporting institutions that could impose an agreement among the Pacific island countries, the fact that the benefits and costs of implementing new institutions are unlikely to be evenly distributed between the island countries, and the fear of some Pacific island countries that multilateral agreements may jeopardize bilateral aid.

It is argued that existing bilateral treaties do not reflect the true value of the resource rent, are not transparent, give incentives to underreport, and do not ensure that the least-cost harvesters are allocated the access right. Decisions about defining protocols for fishing rights, the negotiation of the rights, and the means by which the rights are enforced are the responsibility of the individual Pacific island countries. While all vessels fishing in the region must be licensed, few restrictions are placed on the number of vessels; hence licensing acts predominantly as a mechanism for monitoring fishing activity.

It is clear that Pacific island countries are not maximizing net returns from the tuna fisheries, and that current management is not ensuring the long-term sustainability of fish stocks. A new model is developed, which illustrates that the long-term net revenue of highly migratory and straddling fish stocks can be maximized by a sole policy-maker. Increasing any positive tax or reducing the total allowable catch for harvesting to the point where revenue is maximized provides increased rents and improved sustainability of the resources. The assumption of a single policy-maker is crucial, supporting results of game-theoretical models of straddling stock fisheries which show that competitive games lead to the exhaustion of the fishery, whereas cooperative games (which produce single-policy-maker-type conditions) can maximize long-term returns from the fishery. It is proposed that a multilateral governance structure is required for the Western and Central Pacific tuna fisheries to achieve the desired outcomes of the model, to encourage cooperation among Pacific island countries and distant water fishing nations to achieve sole-policy-maker-type outcomes. This should offer substantial benefits to both Pacific island countries and distant water fishing nations.

The proposed multilateral governance mechanism for tuna would create a Tuna Commission that would be answerable to participating member countries and comply with the UN Fish Stocks Agreement. Initial membership would be granted to Pacific island countries with EEZs in the region and to current distant water fishing nations through allocated annual, transferable and divisible tuna harvesting rights on a negotiated formula. The harvesting rights could be used by any legally registered vessel of the member country that complies with all management and monitoring regulations set down by the Tuna Commission.

To promote a competitive market for harvesting rights, a small percentage of annual allocated rights would enter an automatic auction, to be purchased from each member by the highest bidder. All countries would have the option of tendering up to 100% of their annual allocation if they believed it would generate a higher return than using the rights themselves or leasing them on a bilateral basis. New country entrants into the tuna fisheries would be admitted for a negotiated fee, but they would need to lease tuna harvesting rights from existing members to be able to fish. Initial allocation of tuna harvesting rights and setting an appropriate level of total allowable catch present obstacles to the system, but further research should prove useful to these issues. This multilateral governance structure for the management of tuna is intended to provide the first step towards a rent-maximizing, but sustainable, governance framework for the region.

Reid (2006), 'Economic Implications and Trade-offs in Achieving Maximum Sustainable Yield for Bigeye and Yellowfin Tuna in the Western and Central Pacific Ocean'

While current fishing mortality on bigeye and yellowfin tuna in the Western and Central Pacific is believed to be exceeding that associated with maximum sustainable yield (MSY), fishing mortality on albacore and skipjack is significantly below that associated with MSY. With regard to bigeye and yellowfin tuna, the Scientific Committee of the WCPFC has recommended that fishing mortality on the stocks be reduced by 25% and 10% respectively from the average levels of 2001–04, to ensure that stocks are not fished above the MSY.

This paper considers the economic implications of this policy and considers four other possible management options that may reduce fishing mortality on bigeye and yellowfin tuna. The implications of these measures are compared between the three areas for which the WCPFC is responsible: Pacific island country national waters, other national waters and international waters; and between the three major fleets operating within the WCPFC Convention Area, that is, purse-seine, fresh longline and frozen longline.

The analysis is conducted by comparing the equilibrium yields for the status quo with five management scenarios:

1. A 25% across-the-board effort reduction, including in the Philippine and Indonesian domestic fisheries.
2. A ten-week ban on associated fishing sets in the purse-seine fishery.
3. A 25% reduction in effort in the longline fishery.
4. A closure of high seas waters to the purse-seine fishery.
5. A six-week closure of the purse-seine fishery.

The biologically optimal scenario is the across-the-board effort reduction, which is the only option analysed to result in a lower fishing mortality than the option that would achieve MSY. However, economically, scenario 1 reduces the gross value of the purse-seine fishery by 18%, the fresh longline fishery by 7%, and the frozen longline fishery by 4%. Given that this is associated with a 25% reduction in effort, the major benefits of such a management measure in terms of profitability are likely to accrue first to the frozen longline fishery and then to the fresh longline fishery, with relatively marginal gains made in the purse-seine fishery. Scenarios 4 and 5 result in increases in the value of the longline fishery, but are more than offset by the declines in the value of the purse-seine fishery. Scenario 2 has little impact on all fisheries, but it also has little biological impact, and scenario 3 has the greatest impact on the fresh longline fishery. In this way, each scenario results in a number of trade-offs.

The analyses indicate that constructing management regimes which do not result in a disproportionate burden being imposed on Pacific island countries, and which achieve an outcome whereby all stocks are maintained at or above the level associated with MSY, is likely to be extremely difficult. This is because the value of the fisheries of Pacific island countries is largely derived from skipjack and albacore, whereas the majority of benefits of increased catch-per-unit effort (CPUE) driven by stock recovery as a result of possible management measures are likely to be gained by the bigeye longline fishery.

Management measures adopted by the WCPFC are likely to have substantially different economic outcomes for the various fleets and Commission members, so are unlikely to be agreed on and accepted as they stand. To overcome these difficulties, and to ensure that any management measures benefit all members equally, the WCPFC will need to consider negotiation 'facilitators' (side payments) to distribute the costs and benefits between members equitably.

Kompas and Che (2006), 'Economic Profit and Optimal Effort in the Western and Central Pacific Tuna Fisheries'

In the WCPO, the purse-seine fishery developed rapidly between 1970 and 2000, with total boat days increasing at a rate of 10% per year, reflecting an improved technical capability to fish the deeper thermocline, poor fishing conditions in the Eastern Pacific Ocean, and the emergence of the Korean, Taiwanese and Japanese fleets. The shift of US purse-seine fishing effort from the

Eastern to the Western Pacific Ocean also increased the Western fleet substantially, owing to the introduction of the 1990 Dolphin Protection Consumer Information Act, which required that tuna be caught without a dolphin bycatch, a problem only encountered in the Pacific Ocean. Although the longline fishery only accounts for 10–12% of the total WCPTF catch, it rivals the much larger purse-seine catch in landed value. This is because the purse-seine fleet is more efficient at supplying canning-grade tuna, whereas the longline fleet predominantly supplies the premium Japanese sashimi market.

A stochastic optimal control model is used in order to maximize discounted profits across different regions, gear types and species in the WCPTF. This paper provides solutions for optimal effort levels and their allocation across species over a 50-year time frame. Solutions are obtained for the three main species in the fishery (yellowfin tuna, bigeye tuna and skipjack tuna) and the most important gear types (purse-seine, fresh longline and frozen longline).

In order to maximize economic profits, results indicate that a substantial effort reduction is needed in the WCPTF for the three main species, as stock sizes required for maximum economic yield are significantly larger than stock sizes that produce MSY. Obtaining these optimal effort levels is calculated to increase profits in the fishery by roughly 30% a year.

Modelling the optimal allocation of effort across species indicates that for purse-seine, effort for yellowfin should decrease slightly, and more so for bigeye, whereas for skipjack, effort levels should be increased slightly. For the frozen longline fisheries, effort levels should be reduced overall, but effort allocation between species should continue at current levels. For fresh longline fisheries, effort should be increased for yellowfin, and fall for bigeye.

The purse-seine fishery requires the largest total cuts in effort (68% of effort levels in 2004 over 50 years). It is also optimal to reduce effort in the frozen and fresh longline fisheries to allow stock recovery and increased profits through increases in CPUE. This increase in profits is estimated at 30% per year, potentially allowing Pacific island states to increase their licence fees. However, an institutional mechanism that will allow all WCPTF participants to manage the fishery at optimal effort levels has yet to be established. This is a particular challenge, since full optimality also implies a reallocation of effort across existing nations in the WCPTF. However, pursuing these optimal effort levels would help to increase profit substantially and ensure sustainability of tuna in the Pacific Ocean.

Discussion

On the basis of bioeconomic simulation exercises, Bertignac et al. find that WCPO tuna fisheries are characterized by economic, rather than biological, overfishing. Rent is maximized when effort is reduced across all fleets to about half the 1996 level. Countries in the region could benefit significantly by changing the level and structure of access fees as a percentage of revenue.

The paper by Chand et al. is premised on two concerns with the current governance of WCPO fisheries. First, Pacific island states receive only a small percentage from the exploitation of their tuna resources. Second, the current governance structure does not ensure the long-term sustainability of the resources. It is argued that existing bilateral treaties between Pacific island states and distant water fishing nations do not reflect the true value of the resources. As an alternative, the authors recommend management by a sole policy-maker, as a means of maximizing economic benefits and ensuring sustainability. It is proposed that a new Tuna Commission be established to achieve a multilateral governance mechanism.

Current fishing mortality on bigeye and yellowfin tuna in the WCPO is believed to exceed that associated with maximum sustainable yield. Reid considers alternative management options that may reduce fishing mortality on bigeye and yellowfin tuna. Results indicate that constructing management regimes which do not result in a disproportionate burden being imposed on Pacific island countries, and which achieve an outcome whereby all stocks are maintained at or above the level associated with MSY, is likely to be extremely difficult. Management measures adopted by the WCPFC are likely to have substantially different economic outcomes for the various fleets. To overcome these difficulties, the WCPFC will need to consider side payments to ensure an equitable distribution of costs and benefits.

Kompas and Che maximize discounted profits across regions, gear types and the three main species in the area, namely yellowfin, bigeye and skipjack tuna. A substantial effort reduction is needed as part of an optimal policy; however, this will increase profits in the fishery by 30% a year. This would potentially allow Pacific island states to increase their licence fees. A new institutional mechanism would be required to facilitate this.

4

Southern bluefin tuna

Southern bluefin tuna (SBT) spawn off the north-west coast of Australia and may live up to 20 years, although the majority are caught before they reach the age of 12. Most of the juvenile fish of up to six years of age school in the coastal waters around the southern coast of Australia, where they are caught by the Australian fleet. As the SBT do not reach sexual maturity until around eight years, a high proportion of this catch is made up of immature fish. The more mature fish inhabit the West Wind Drift, in high seas areas between South Africa and New Zealand, where they are harvested by Japanese fleets and other distant water fishing nations at a greater depth. The fishing nations harvest the majority of their catch in the two separate areas, although there is some overlap of Australian and Japanese fleets.

SBT is a highly migratory fish stock. Japan and Australia were the only harvesters of SBT until the 1970s, with harvests peaking in 1961 at 78,000 tonnes and 4,000 tonnes respectively. By the early 1980s it was clear that the stocks were severely overfished, and with such a low spawning stock biomass, the fishery was in danger of recruitment failure. Over time, the number of countries participating in the fishery has increased.

In the light of this, agreements on total allowable catch were reached between Japan, Australia and New Zealand. The TAC initially totalled 40,000 tonnes, but was progressively reduced to 11,750 tonnes in 1997. The system was formalized in 1993 with the formation of the Commission for the Conservation of Southern Bluefin Tuna (CCSBT) between the three countries. Disagreements over the exploitation status of the stocks led to a breakdown in the negotiations, as Japan initiated an 'experimental fishing programme', thereby increasing its annual catch. Japan was subsequently excluded from the EEZs of Australia and New Zealand.

One of the factors leading to this breakdown in the agreement was the emergence of new entrants taking an increasing share of the total harvest of the fishery. Currently, eight countries participate in the southern bluefin tuna fishery. Australia and New Zealand are both major resource owners; they harvest in their own EEZs and are members of the CCSBT. Japan, Korea and Taiwan are major distant water fishing nations and are also members of the CCSBT. Indonesia, the Philippines and South Africa are expanding distant water fishing nations. They are significant consumers of southern bluefin tuna and at the time of writing were not members of the CCSBT.

The tuna are mainly sold on two distinct markets. Fish harvested by Australian fleets are canned in Australia or exported, primarily to Italy, at a low price, and shortfalls are replaced by imports. In contrast, Japanese harvested tuna are sold on the sashimi market, where the fish must be very carefully processed and of a very high quality, as they are sold for ten times as much.

In the following section, seven papers published in the last two decades or so will be reviewed. It is interesting to note how the fact that the number of players in the fishery has increased over time is reflected in the papers.

Kennedy and Watkins (1986), 'Time-Dependent Quotas for the Southern Bluefin Tuna Fishery'

This paper describes a dynamic programming model, which aims to maximize the present value of economic flows of welfare. The model is applicable to multi-cohort fisheries for finding approximately optimal time-dependent quotas.

Models were run for three policies:

(A) No policy, open-access fishery.

(B) Maximize Japanese and Australian welfare flow.

(C) Maximize Australian economic welfare only.

For model A, the combined present value of economic welfare is A$722m. In model B, Australia does not fish at all for a ten-year period, the stock level rises, and so the costs of fishing fall. Harvests double over the ten-year period, so this provides not only the maximum combined welfare, but also the maximum welfare for Japan alone, at A$1.134bn. In Model C, for Australia to maximize rents alone, the fleet needs to fish in the deeper zones in order to maximize yield. The present value of economic welfare for Australia is A$13m, and for Japan it is A$930m.

Model findings suggest that restricting or eliminating the Australian catch of tuna under four years of age would be beneficial to both countries. The other precondition for Australia maximizing its welfare is that Australian harvesting of other fish should be restricted for two to three years, but gradually increased up to 15,000 tonnes or 20,000 tonnes by year ten, depending on which recruitment hypothesis applies. Japan could profit even more by compensating Australia to reduce harvests further or to cease harvesting altogether. A more likely outcome, however, is that Australia will increase it profits by adopting Japanese technology for harvesting and processing tuna to fetch a higher market price, and there are signs that this is already beginning to happen.

Kennedy (1987), 'A Computable Game Theoretic Approach to Modelling Competitive Fishing'

Fish stocks within an EEZ may be directly related to stocks outside the zone if the stock straddles the boundary, if the fish are within the zone for only part of their life cycle, or if the population of one species of fish within the zone affects the population of another species outside the zone through predator–prey interactions. Fishing effort outside the zone may affect the relevant nation's optimal catch by influencing the market price, the abundance of future fish stocks within the zone, or the cost of harvesting through a stock effect. Harvesting within the EEZ may likewise affect stocks outside the zone exploited by foreign fleets. These interdependencies provide problems for the fisheries management of each nation to ensure optimal catches. It may therefore be rational for nations to cooperate by agreeing on side payments, as demonstrated in the southern bluefin tuna fishery.

The southern bluefin tuna fishery is exploited jointly by Australia and Japan. Australia harvests young fish within the Australian Fishing Zone (AFZ), and Japan harvests adult fish usually caught outside the AFZ, although 10% is obtained within the AFZ through a fee-on-access agreement. In 1983 it was agreed by both nations that the fishery was overexploited and its future threatened. The Australian government introduced a preliminary catch quota of 21,000 tonnes for the 1982–84 season, but decided that the Japanese harvest had not been reduced sufficiently, so banned the Japanese from harvesting within the AFZ altogether. The Australian government later decreased the quota further to 14,500 tonnes for the 1984–85 season, and the Japanese fleets were readmitted following a resolution of the differences between the two countries.

This paper outlines a multi-period model of the two nations alternately harvesting from different life stages of a common fish stock. The results suggest that under joint maximization, it is optimal for Australia to leave harvesting completely to Japan, owing to the high average weight of fish in the Japanese stocks and the high Japanese market return.

Under duopoly, Japan maintains a harvest of 9,000–11,000 tonnes per year, and Australia 5,000–8,000 tonnes per year, whereas under joint maximization Japan harvests 11,000–12,000 tonnes per year, while Australian harvests are zero for all years. Australia obtains a present value of social return equal to A$14m under duopoly, compared with zero under joint maximization. Japan obtains a present value of social return under duopoly at A$937m, compared with A$1.084bn under joint maximization. These results show that gains from joint maximization as against duopoly are not symmetric for the two nations. Nonetheless, management under joint maximization would enable Australia to argue for at least a A$14m share of the joint social return in return for acting cooperatively to harvest the tuna, resulting in a net gain in social return for both countries.

Kennedy and Pasternak (1991), 'Optimal Australian and Japanese Harvesting of Southern Bluefin Tuna'

This paper uses a model to compare Japanese and Australian social rent and harvest levels through time under joint maximization and duopoly. It does this by exploring the harvesting strategies through time to determine the optimal solution for the two countries. The southern bluefin tuna stocks are modelled using a multi-cohort approach, as they live for up to 20 years, while being fished by different nations using different harvesting technologies through different phases of their life cycle. A game-theoretic approach is used to obtain non-cooperative harvesting strategies for Australia and Japan.

The results of the model highlight the bargaining position of Australia and Japan in the SBT fishery. Following cooperative policies to maximize joint social rents shows significant gains over policies of duopoly. It would be advantageous for Japan to buy Australian individual transferable quotas (ITQs) but not to use them in the early years, as long as the total allowable catch remains constant. The results also suggest it may be in Australia's interest to move to using the Japanese longlining method of harvesting adult southern bluefin tuna, causing less damage to the fish, which can then be sold for a higher price.

Nevertheless, the results for duopoly do not indicate a calamitous outcome for the fishery. When modelled under a duopoly situation, the combined harvest is 16,500 tonnes annually, rising to give an average combined annual harvest of 25,000 tonnes over 20 years. Although this is low compared with aggregate catches that have been achieved in the past, it is high in comparison with the 1991 aggregate quota of 11,750 tonnes. The model results also suggest that there would be no threat to the biological productivity of the fishery for the biological parameters used. However, caution is required, as the parameter estimates are uncertain and do not reflect the stochastic nature of processes such as recruitment. Harvesting strategies for both maximization of total social rents and for duopoly appear to be highly sensitive to the uncertain estimates of key biological parameters, so caution is required in the interpretation of the results.

Kennedy (1999), 'A Dynamic Model of Cooperative and Non-cooperative Harvesting of Southern Bluefin Tuna with an Open Access Fringe'

This paper takes a game-theoretic approach to modelling the SBT fishery in light of the disagreements over stock recovery and the growing significance of new entrants. The model compares the outcomes for the three country groupings of Japan, Australia and New Zealand, and for new entrants, in terms of their net returns and future stocks of SBT under joint maximization, Cournot oligopoly and the continuation of 1997 harvesting effort in order to identify incentives for cooperation or non-cooperation.

Results suggest that if new entrants to the SBT fishery currently outside the CCSBT act as an open-access fringe, then there is little incentive for Australia and New Zealand to act cooperatively with Japan in setting future harvest levels. If Australia and New Zealand cooperate to maximize joint net returns instead of acting as duopolists, they lose 0.2% of the present value of producer surplus, and Japan gains only 3%. This undermines the attempts of the CCSBT to conserve stocks owing to the lack of formal agreements between the new entrants, who act as fringe players.

All parties would be expected to gain substantially from agreeing on harvests to maximize joint net returns, which could be achieved without the need for side payments. However, if cooperation is not chosen, then the consequences do not appear too disastrous. Even if the goals of players are to maximize producer surplus, if the net benefits of harvesting SBT are judged to include consumer surplus, the sum of consumer and producer surplus is larger under oligopoly behaviour.

The CCSBT has set a target of rebuilding the spawning stock biomass to 1980 levels by 2020, and model results suggest this will be achieved or nearly achieved under both joint maximization and oligopoly. For the case of duopoly with new entrants acting as an open-access fringe, the spawning stock biomass by 2020 is 141,000 tonnes, just short of the target of 144,000 tonnes. However, this is too optimistic a conclusion, as the model requires running for a much wider range of biological parameters. Also, while the oligopoly outcomes are the best for the oligopolists, the outcomes are unlikely to be achieved in practice in a non-cooperative situation, because of the complexity of the assumed maximizing behaviour, in which a player must have perfect information about economic and biological parameters, and because of the responses of the other non-cooperating players.

International agreements are therefore still likely to have an important role in the allocation of total allowable catches, but require improvement in the criteria used for such decision-making. The CCSBT places much emphasis on setting TACs for the sustainability of stocks; however, as there are many sustainable levels of effort, decisions should include increasing economic efficiency. Model results showed that the continuation of 1997 fishing effort would be sustainable in leading to an increase in the spawning stock biomass (SSB) over 20 years, though not to 1980 levels, and all parties would experience producer losses. Instead, maximum present value of rents could be obtained by immediately reducing harvesting to half of the 1997 levels for five years, and then increasing this to 10,000 tonnes after about ten years, by which time the SSB would have recovered to 1980 levels.

In the interests of economic efficiency, and to increase the attractiveness of membership of the Commission, it would be optimal to have a flexible rolling time horizon system of planning a future sequence of TACs, with annual adjustments to take account of changes in technical and economic parameters.

Kennedy, Davies and Cox (1999), 'Joint Rent maximization and Open Access Competition in the Southern Bluefin Tuna Fishery'

Heavily declining catches in the southern bluefin tuna fishery through the 1980s and the risk of stock and industry collapse prompted an informal trilateral agreement between Australia, Japan and New Zealand in 1984. Catch limits were introduced and progressively reduced from around 40,000 tonnes in 1984 at the start of the informal management arrangement to 11,750 tonnes in 1990. Between 1990 and 1997 the total allowable catch for the three nations remained fixed at this level, divided between Japan (6,065 tonnes), Australia (5,265 tonnes) and New Zealand (420 tonnes). The CCSBT was formed in 1994 as a management body with the objective of achieving recovery of the parental biomass to 1980 levels by 2020. Annual harvests were set by the Commission from 1994 to 1997, but a number of issues led to the abeyance of this agreement.

A primary issue was the increasing catch of southern bluefin tuna by countries not party to the CCSBT. The CCSBT quota arrangements had been successful in reducing the catch of southern bluefin tuna by Australia, New Zealand and Japan. However, despite this reduced catch, the total global catch of southern bluefin tuna increased between 1988 and 1998 owing to the huge increase in catch by countries outside the agreement. The main countries responsible have been Indonesia (2,000 tonnes per year), the Republic of Korea (1,500 tonnes), and Taiwan (650 tonnes). The CCSBT has been taking measures to encourage these countries to participate in achieving the objectives of the Convention, suggesting a combined total catch for current non-members of no more than 2,550 tonnes annually. However, as the non-member catch was approximately 3,400 tonnes in 1996, the proposal may not provide a sufficient incentive for those countries to join the Commission.

The other main issue leading to the breakdown in relations between countries of the CCSBT was the disagreement between member nations over the status of the stock. There is a general consensus between the scientific authorities of the CCSBT member countries that the parental stock of southern bluefin tuna is less than 10% of the 1960 level, but there are highly contrasting views regarding the future trends in stock size, subject to the continuation of recent catch levels. Japanese scientists believe the stock size is increasing, while Australian and New Zealand scientists consider that there is a declining trend in the stock size. Both groups use the same modelling methodology based on virtual population analysis, with largely the same data inputs, but the different weights they have each attached to the range of uncertainties underlying the modelling have produced these markedly different results.

The divergent scientific assessments are, as could be expected, producing similarly divergent management proposals. At the fourth meeting of the CCSBT in September 1997 Japan proposed that the global quota should be increased and that its share of the quota should be increased by 3,000 tonnes a year, while Australia and New Zealand argued for a decrease in, or at least the maintenance of, the previous TAC. This dispute over the stock assessment led to no TAC being set for 1998; the establishment of an experimental fishing programme by the Japanese; the exclusion of the Japanese fleets from the Australian and New Zealand EEZs; and a breakdown in the CCSBT management arrangements.

These problems have prompted questions regarding the feasibility of finding incentive systems to maximize joint rents from the fishery, or even to ensure the survival of the species. This paper attempts to help answer these questions by describing a multi-cohort bioeconomic model of the fishery, allowing for strategic interaction between three groups of harvesting nations, namely Australia and New Zealand; Japan; and the Republic of Korea, Indonesia and Taiwan. The model is used to determine cooperative and non-cooperative harvesting schedules over 20-year periods, updated from previous models by allowing for the group consisting of the Republic of Korea, Indonesia and Taiwan to be characterized as either a cooperative player or an open-access fringe. The model is deterministic, discrete-time- and age-structured, with equations for annual catch and updating of stock in each cohort based on the Beverton and Holt model.

The model is used to find time profiles of fishing effort for three scenarios in order to determine the extent to which harvesting returns could be increased on a sustainable basis. In the first of these, all players cooperate jointly to maximize rents from the fishery, while in the second Japan, Australia and New Zealand cooperate jointly to maximize rent while facing the other countries acting as an open-access fringe. In the third, all players continue with 1997 harvest efforts for the next 20 years. A number of simulations were also undertaken to assess the sensitivity of the model to changes in key economic parameters.

Sensitivity analysis shows that model results are insensitive to the rate of discount, but sensitive to the price elasticity of demand for southern bluefin tuna. Results from the base model suggest that continued application of current fishing effort over the next 20 years would be only marginally sustainable on biological and economic grounds. If all harvesting countries were to act cooperatively to maximize combined net returns over the next 20 years, substantial increases in net returns and spawning stock biomass could be achieved. If the goal were maximization of combined producer rents alone, it would be optimal to nearly halve current harvest levels for the first three years, and approach current harvest levels towards the end of the 20-year period. If the goal were maximization of combined producer rents plus consumer surplus, again harvest levels would be lower in the early years, but would approach current levels by year eight, and continue to climb to over 20,000 tonnes by year 20. If the non-CCSBT countries continue to act as an open-access fringe and drive their producer rents to zero, total harvests would be significantly increased, and combined producer rents would be reduced to 25% of the rent for the cooperative solution. Combined producer rents and spawning stock biomass in 20 years would still be higher than under continuation of the current fishing effort.

These results indicate the significant economic benefits that may be gained through cooperation of the harvesting players.

Campbell, Kennedy and McIlgorm (2002), 'Conservation and Optimum Utilization of Southern Bluefin Tuna'

The CCSBT requires parties to '… ensure, through appropriate management, the conservation and optimum utilization of southern bluefin tuna'. This paper addresses some of the key elements in interpreting the 'optimum utilization' and 'conservation' objectives in the context of current management issues within an economic framework.

A modelling approach is used to predict outcomes of alternative management scenarios for the SBT fishery over the next 20 years, using the criteria of economic efficiency in terms of the present value of fishery rent generated, and conservation as measured by the predicted size of the SBT stock in 20 years' time. A bioeconomic model incorporates a game-theoretic framework to assess the effects of alternative management scenarios representing varying degrees of cooperation among the six countries currently harvesting SBT.

Model results suggest that it is undesirable for the stock to fall below the current stock level (43,631 tonnes) in any scenario. If the current management situation persists, in which Japan and Australia and New Zealand operate under agreed catch quotas, while fringe groups operate outside the CCSBT, stock levels will increase if the fringe groups operate so as to maximize returns. However, if they do not operate to maximize returns, effort will increase until total revenue equals total profits. This will provide zero returns, so will be extremely inefficient in economic terms. The most economically efficient outcome of all scenarios would be that of cooperation of all groups, in which each operates at the level of effort required to maximize joint gains. If the fringe groups choose to remain outside the CCSBT, then it does not matter whether the other groups operate individually or together to maximize returns.

Modelling of various scenarios provides the following conclusions.

- The current exploitation regime under the CCSBT is reasonably efficient from an economic viewpoint (close to optimum utilization), and probably poses no threat to the conservation of the stock.
- Fish farming by Australia and New Zealand of purse-seine-caught fish, as opposed to longlining and selling the catch directly on the Japanese market, is an efficient use of the resource and does not pose a threat to the sustainability of the resource.
- The issue of sustainability of the stock requires more clarification from scientists on acceptable stock levels from a conservation viewpoint.
- Japan's consumers are significant beneficiaries of the SBT fishery. Optimum utilization requires consideration of the interests of consumers as well as producers.

Modelling confirms that cooperation among all SBT fishing nations will best contribute to achieving both the economic and the conservation objectives, and that there is no inherent conflict between the two. However, while there are substantial gains from cooperation, there do not appear to be dire consequences if cooperation is not achieved, although this conclusion needs to be tested for a wider range of biological parameter sets.

Campbell and Kennedy (forthcoming), 'Alternative Futures for Southern Bluefin Tuna'

This paper examines the outcomes of alternative management scenarios for the southern bluefin tuna fishery over the next 30 years. The outcomes are characterized as economic efficiency, measured by the net present value (NPV) of benefits generated, and conservation as measured by the predicted size of the SSB in 20 years' time.

The CCSBT facilitates cooperation among the member nations in agreeing to annual catches, aiming to ensure the conservation and optimum utilization of southern bluefin tuna. This goal has been defined as returning the southern bluefin tuna stock to its 1980 level of around 50% of unfished SSB within a 20-year timeframe, while maximizing use-values of the fishery. Previous modelling runs for the fishery have concluded on a reasonably optimistic note; however, significant changes in the management and modelling of the fishery have changed this. Korea and Taiwan have joined the CCSBT as cooperating members with allocated catch quotas. Indonesia, the Philippines and South Africa have recently been identified as harvesting nations, but at the time of writing were not members of the CCSBT, so are not restricted to a catch quota. Recent stock assessments have been less favourable than earlier results with respect to the recruitment of juveniles to SSB, which has also led to less optimal predictions.

The eight countries currently participating in the southern bluefin tuna fishery were split into three groups for the purpose of modelling:

- Australia and New Zealand are both major resource-owners harvesting in their own EEZs. They are members of the CCSBT.
- Japan, Korea and Taiwan are major distant water fishing nations and are members of the CCSBT.
- Indonesia, the Philippines and South Africa are expanding distant water fishing nations. They are significant consumers of southern bluefin tuna and were not members of the CCSBT at the time of writing.

A bioeconomic model incorporating the results of recent stock assessment analysis was used to assess the effect of alternative management scenarios representing varying degrees of cooperation among the eight countries currently harvesting southern bluefin tuna. To represent this range of possibilities, the following scenarios were considered.

- No fishing of southern bluefin tuna by any nation.
- The CCSBT regime: the two groups within the CCSBT and the groups outside the regime all observe the catch quotas set by the CCSBT.
- Full cooperation: the three groups combine to agree on the level of effort required to maximize the NPV of their combined returns.
- Non-cooperation: players choose an individual strategy to maximize their respective payoffs, given the strategies chosen by other groups.

The results have raised serious concerns about the prospects for conserving the stock. An outright moratorium is obviously the most favourable regime for conservation, but the 20-year objective for SSB is only achieved under the most optimistic assumptions about the stock recruitment function. For less favourable assumptions, a 20-year ban is expected to result in the stock remaining at the same level or experiencing a significant decline. Continuation of current quota levels under the CCSBT regime, either with the full cooperation of all parties or with Indonesia, the Philippines and South Africa remaining outside the quota system, is predicted to lead to virtual extinction of the stock within 30 years. Full cooperation to maximize joint NPV by the parties currently involved in the fishery would lead to long-term stock levels 50% above current levels, but again only under the most optimistic stock recruitment function. When all three players engage in a non-cooperative game, the results are very similar. For the less optimistic assumptions about the stock recruitment function, the players would cease fishing in less than 30 years, and stocks would continue to decline.

These outcomes are the result of the revised stock recruitment functions, suggesting that the productivity of the stock is much lower than previously thought; this is reflected in lower economic values under all exploitation regimes. The CCSBT, joint returns maximization and non-cooperative game model exploitation regimes all yield NPVs of around A$3.5 billion over a 20-year period, under the most favourable stock recruitment estimates. The highest of these is the joint maximization of benefits regime, estimated to generate an NPV of A$ 3.6 billion, which is still less than half the value of previous estimates.

Despite the similarity in economic benefits, the regimes have radically different outcomes for the stock. The SSB level under the CCSBT regime, with all countries involved or only the current countries involved, results in only 50% of the stock level of other regimes, with further predicted declines. There are significant uncertainties about catch data accuracy, which may lead to further revisions, but it is clear that there is a trade-off between the conservation and optimum utilization goals. The only regime to meet the conservation goal was the outright moratorium for the most favourable stock recruitment estimates.

These results cast doubt on the prospects for achieving the target of a 1980-level SSB in 20 years, suggesting that significant cuts to catch rates are required. It is vital for both economic and conservation aims that the combined CCSBT annual catch quota is cut from its present level of approximately 15,000 tonnes to a level closer to 10,000 tonnes per year, and that all participating countries are included in a revised CCSBT regime.

Discussion

The early paper by Kennedy and Watkins (1986) considers three policies, namely open access, maximizing Japanese and Australian welfare flows, and maximizing Australian economic welfare only. Optimal policies involve restricting harvests for a number of years to permit the stock to rebuild and allow for higher sustainable catches in the long run. Interestingly, under optimal policies the present value of economic welfare is substantially higher for Japan than for Australia. This reflects the much higher price fetched by Japanese-harvested tuna and the high average weight of fish in the Japanese catch.

Kennedy (1987) develops a multi-period model of the two nations alternatively harvesting from different life stages of a common fish stock. Under duopoly, Australia obtains a present value of social returns of A$14m, compared with A$937m for Japan. Under joint maximization, Australia obtains zero and Japan A$1.084bn. This implies that, in principle, Japan could buy out Australia. Again, these results are largely driven by the higher value of the Japanese catch.

Kennedy and Pasternak use a model to compare Japanese and Australian social rents and harvest levels through time under joint maximization and duopoly. Non-cooperative harvesting strategies are also considered. Qualitatively, the results largely confirm those of Kennedy (1987). It is, however, stressed that harvesting strategies appear to be highly sensitive to the uncertain estimates of key biological parameters. Therefore, caution is needed when interpreting the results.

The model of Kennedy (1999) compares the outcomes for Japan, Australia and New Zealand and new entrants to the fishery in terms of net returns and future stock levels. This is done for joint maximization, Cournot oligopoly and the continuation of 1997 harvesting effort in order to identify incentives for cooperation or non-cooperation. Importantly, if new entrants act as an open-access fringe, there is little incentive for Australia, New Zealand and Japan to cooperate. Nevertheless, this result is in line with bioeconomic theory. That said, all parties would be expected to gain substantially from agreeing on harvests to maximize joint net returns. The paper also underlines the possible impact of biological uncertainty on future stock recovery.

In the 1990s new countries entered the fishery but did not join the CCSBT. At the same time there was disagreement between member countries over the status of the stock. Kennedy et al. (1999) develop a bioeconomic model that allows for strategic interactions between three harvesters: Australia and New Zealand; Japan; and the 'fringe' nations. If all harvesters cooperate, substantial increases in net returns and spawning stock could be achieved. However, if new entrants continue to act as an open-access fringe, combined producer rents would be considerably reduced compared with the cooperative solution.

In addition to analysing economic returns from the fishery, Campbell et al. explicitly consider conservation issues. The latter is measured by the predicted size of the stock in 20 years' time. The analysis confirms previous results with regard to economic benefits of cooperation. It also points out that optimal utilization requires consideration of the interests of consumers, in particular in Japan. The current exploitation regime appears not to pose a threat to the conservation of the stock. Nevertheless, cooperation will also best contribute to achieving conservation objectives.

Campbell and Kennedy examine the outcomes of alternative management scenarios over the next 30 years. Economic efficiency is measured by the net present value of benefits, while conservation is measured by the predicted size of the spawning biomass in 20 years' time. In the analysis it is recognized that some distant water fishing nations (DWFNs) – Japan, Korea and Taiwan – are members of the CCBST, while others – Indonesia, the Philippines and South Africa – are not. Recent less favourable stock assessments are also taken into account. The most striking result is that the only regime to meet the conservation goal is an outright moratorium for 20 years, but then only for the most favourable stock estimates. In contrast, continuation of current quota levels under the CCBST regime is predicted to lead to virtual extinction of the stock within 30 years. In other words, drastic measures are called for.

The set of papers are agreed on the following. First, if tuna resources are to provide over time anything approaching maximum economic returns to the members of the CCSBT, substantial resource investment is called for. Second, the inability of the CCSBT to address effectively the problem of new entrants acts as a severe hindrance to effective resource management.

5

East Atlantic and Mediterranean bluefin tuna

The East Atlantic bluefin tuna stock is a highly depleted fishery. This is largely attributable to perverse economic incentives. Tuna are a highly migratory stock, fished by a large number of countries, and effective management is therefore problematic. These problems have resulted in the fishery being virtually open-access, leading to considerable overexploitation.

Bluefin tuna is the most valuable fish in the ocean, increasing in price owing to the recent decline in catches and fewer quality fish. A single tuna fetches up to US$100,000 in the Japanese sashimi market. Depending on the method of catch, and therefore the size and quality, tuna fetches a price of US$5–25/kg. Good management of the fishery would therefore provide substantial economic rent.

Historically, over 50 countries used to participate in the fishery for bluefin tuna, whereas currently only 25–30 participate, including European countries such as Italy, France and Spain, as well as distant water fishing nations such as Japan.

A wide variety of vessel types and fishing gears from many different countries are used to fish the stocks, with the purse-seine, longline, trap and bait boat most commonly used.[3] Annual catches varied between 10,500 tonnes in 1970 and 22,300 tonnes in 1976. Catches subsequently increased and reached a maximum of 52,737 tonnes in 1997; however, since then there has been a decrease to 30,000 tonnes in 2000, primarily as a result of lower stock levels. Stock size decreased from 210,000 tonnes in 1971 to 133,000 tonnes in 1981 and remained fairly stable thereafter, reaching 150,000 tonnes in 2000.

Tuna farming has become fairly widespread in the Mediterranean, where farms capture wild juveniles, which are then fattened for subsequent shipment to the Japanese market. This has contributed to the high pressure on the fishery.

The 1995 UN Fish Stocks Agreement requires both coastal states and distant water fishing nations to cooperate directly or through the establishment of an RFMO to ensure sustainability of stocks. The International Commission for the Conservation of Atlantic Tunas (ICCAT) is considered an RFMO in the context of the UN Fish Stocks Agreement. The number of contracting parties has been increasing and includes coastal states in Europe and Africa as well as distant water fishing fleets from countries such as Korea and Japan. Official fishing regulations were implemented by ICCAT in 1975, but these were disregarded by fleets and therefore had little impact on fishing effort. Present regulations include catch limits, prohibition of juvenile landings and closed seasons, but all have proved ineffective owing to the inability of ICCAT to monitor and enforce them. This is compounded by the large number of participants in the fishery, some of which are members and some of which are not members of ICCAT.

There are currently a reduced number of participants in the fishery, reflecting the low stock

[3] A number of other gear types are also used. These are collectively denoted 'remainder'.

levels and the reduced distribution of the stock. As a result, countries such as Norway, Iceland and Russia are not active in the fishery. The profitability of the stock is such that if it were to recover and extend its distribution pattern, there would be many potential new entrants to the fishery. Therefore, the success of a recovery programme will depend on controlling new entrants into the fishery as well as harvest levels.

Duarte, Brasao and Pintassilgo (2000), 'Management of the Northern Atlantic Bluefin Tuna: An Application of C-Games'

The UN Fish Stocks Agreement can be interpreted as establishing a legal obligation to cooperate within an RMFO. Therefore, cooperative games can be used to examine the economics of cooperative management.

What is called a characteristic function game (c-game) approach can be used to study this problem. The c-game approach is based on the fundamental assumption that the players have already agreed to cooperate, and that side payments among the players are possible. Thus, the problem to be solved is the distribution of the gains of cooperation, or what is also called the cooperative surplus, in a fair way. Three solution concepts are proposed as possible solutions for this problem: the Nucleolus, the Shapley value, and the egalitarian, or Nash, bargaining solution. These solutions are based on different fairness concepts. The Nucleolus maximizes the benefits of the coalition that presents the minimum gains, the Shapley value divides the gains in accordance with each player's average contribution to the coalition payoffs, and the Nash bargaining solution yields an egalitarian imputation of the gains.

In this study, three players are defined, namely the EU, other coastal states (OCS) and distant water fishing nations (DWFNs). The players do not differ in costs (or efficiency), but in dimension and composition of gear structure. The case study points out one possible source of weakness in the UN Agreement. None of the solutions is in the core of the game, meaning that some players can do better outside the grand coalition consisting of all three players. This may be a serious threat to the cooperative arrangement, and it certainly creates an incentive to cheat. Note, however, that in the UN Agreement it is established that nations which do not follow the RMFO regime will not have access to the resource. This legal restriction is, therefore, essential for increasing the effectiveness of this management solution.

Brasao, Duarte and Cunha-e-Sa (2000), 'Managing the Northern Atlantic Bluefin Tuna Fisheries: The Stability of the UN Fish Stock Agreement Solution'

Several authors have suggested cooperative games as an adequate framework to study the negotiation process of cooperative agreements. Nevertheless, it is well known that these cooperative solutions require a high degree of commitment to follow the agreed policies. In fact, if players can negotiate effectively only at the beginning of the game, then we can assume that the equilibrium that is actually achieved is efficient, in the sense that there is no other equilibrium that gives higher expected payoffs to the players. Nonetheless, we should not expect that players would focus on this equilibrium if at some later stage in the game a similar negotiation process would lead them to focus on a different equilibrium, since free-riding incentives may be present along the way. Thus, once an international agreement has been reached, the problem of stability arises as a result of possible free-riding incentives.

The purpose of this paper is to examine this agreement solution within the RFMO, as well as two alternative non-cooperative solutions: the myopic, open-access solution and the time-consistent feedback Nash equilibrium (FBNE) solution. This last case is based on non-linear Markov perfect strategies, which are subgame perfect – that is, the strategy chosen initially is still optimal for any possible subgame of the original game.

Examples in the literature assume that all the players are symmetric. In this analysis of bluefin tuna three players are defined, namely the EU, OCS and DWFNs. The players are assumed to behave asymmetrically, as they represent distinct technologies. Moreover, it is also considered that each player has independent choices and has to determine the best combination of gears for itself.

It is possible to find a distribution of the gains that guarantees stability of the agreement, assuming that the players commit themselves to that specific redistributive rule. However, when the gains are distributed according to a fair sharing rule, such as the Shapley value, the stability of the agreement is not guaranteed.

Focusing first on the open access, the agreement is shown to be unstable, assuming that side payments are redistributed according to the Shapley value. The free-riding incentives exist for the DWFNs and the OCS, but are not considerable. As the stock increases, these free-riding incentives also increase, worsening the instability problem.

Comparing the cooperative agreement solution with the FBNE, the instability is still present, as there are still free-riding incentives. However, in contrast to the open-access case, the only source of instability is the DWFN, although the free-riding incentives are not significant. The FBNE ensures preservation of bluefin tuna and allows a higher net return to all the players, whereas in open access some of the players experience losses and the stock is depleted in five years.

Instability of the agreement implies that the agreement solution will hardly be implemented with success. Nevertheless, the UN Fish Stocks Agreement provides a legal framework that allows the members of the RFMO to ban DWFNs from harvesting bluefin tuna unless they are members of that RFMO and abide by its rules. If this legal restriction is enforced, the problem of instability is eliminated in the case of the FBNE solution, but not in open access. In this case, the FBNE, based on non-linear Markov strategies and with side payments, almost replicates the agreement solution.

Pintassilgo and Duarte (2000), 'The New-Member Problem in the Cooperative Management of High Seas Fisheries'

The main objective of this paper is to discuss the threat that new members pose to the cooperative agreement and the possible solutions to this problem. Cooperative solutions to highly migratory fisheries are challenged by the potential instability of the nature and number of the players, as opposed to their natural stability in shared fish stock problems.

This study deals specifically with the new-member problem. The authors conclude that if the only bar to achieving membership in the organization is the willingness to accept its management programme, then cooperative management could most certainly be at serious risk. It is also argued that the UN Fish Stocks Agreement does not provide guidance to solve this problem.

Three main solutions for the new-member problem are discussed. The first is 'transferable membership', i.e., the new member has to acquire the right to fish from the initial members. This solution will always preserve the latter's payoffs, eliminating the threat from new members. If an ITQ system is used, it not only eliminates the free-rider incentives of prospective new members, but can also solve, in theory, other inefficiency problems. Nonetheless, it demands a set of changes in the fishery, which may be difficult to achieve. It also requires international quota trade, which is still not a common practice in world fisheries.

The second solution is the introduction of a 'waiting period' for new members, which can be used to protect binding agreements, especially in the presence of high discount rates. Regarding agreements that are not binding through time, the new-member threat can be diminished if there are significant permanent costs of being part of the cooperative agreement.

The third solution is the implementation of a 'fair sharing rule'. It is concluded that this solution is effective to protect the cooperative agreement, in the context of a small number of players.

The analysis of the bluefin tuna fishery with three players – the EU, OCS and DWFNs – shows that, at present, the threat from new members is not sufficient to cause the breakdown of the cooperative agreement. This is attributable to the very low level of the stock, which makes non-cooperation a low-payoff strategy. As the optimal cooperative strategy calls for an initial harvest moratorium, the threat becomes progressively more relevant, showing that this is a dynamic problem, which is aggravated in the long run.

Simulating the solutions for this case study shows that both the transferable membership and the fair sharing rule solutions solve the potential new-member threat. In addition, an unrestricted ITQ system will not only solve the new-member problem, but also change the gear composition to one that yields a higher payoff. It is also more favourable in terms of stock preservation.

The main conclusion of this paper is that the new member can create a threat to the cooperative management of straddling and highly migratory fish stocks. The solution scheme should be selected according to the specific nature of the fishery. The ITQ system, despite some possible problems, is generally the most efficient solution.

Pintassilgo (2003), 'A Coalition Approach to the Management of High Seas Fisheries in the Presence of Externalities'

A characteristic function game (c-game) approach has often been suggested for the analysis of cooperative solutions within RFMOs, as illustrated by a number of papers in this review. The bargaining strength of the different players depends on the power of the coalitions that can be established. In fisheries models, the strategy of each coalition does not depend on the way other players divide themselves into coalitions. Therefore, externalities are not present. Moreover, a merger of coalitions does not produce external effects on non-members, so that free-rider incentives do not exist.

However, the free-rider behaviour of non-member fleets, which tends to occur in the presence of externalities, has been pointed out as one of the main problems faced by RFMOs. A non-member of an RFMO may be better off when more players become members, as it can adopt a free-rider strategy.

This paper uses a coalition approach to the management of high-seas fisheries in the presence of externalities. A two-stage game is used. The payoffs are represented by a partition function. This function assigns a value to each coalition as a function of the entire coalition structure, and not just the coalition in question. Therefore, it captures the externalities across coalitions, which are assumed to be present in the characteristic function.

It is assumed that an RFMO is set up to manage a straddling or highly migratory stock with a given number of players. In the first stage, each player has to decide whether or not to become a member of the RFMO. Non-members are assumed to act as singletons. Regarding coalition formation, 'open membership' is assumed, i.e., coalitions are open to all players who will abide by their rules. In the second stage, the members of the grand coalition are assumed to act cooperatively by choosing a strategy that maximizes the net present value of the fishery. All other coalitions choose the strategy that maximizes their own payoffs given the behaviour of the remaining players. This non-cooperative behaviour leads to a non-cooperative solution for each coalition structure, which is assumed to be unique. Thus, the coalition payoffs in the second stage can be defined as a partition function, which assigns a value to each coalition that depends on the entire coalition structure.

An important issue with regard to RFMO management in the presence of externalities is the stability of the coalition structures. A special interest is centred on the stability of the grand coalition and whether any sharing rule can make it stable. This issue is made the topic of empirical analysis for the East Atlantic bluefin tuna fishery. In this case the sum of the values of the unilateral deviations from the grand collation exceeds the value of the grand coalition. Therefore, there is no sharing rule that can make the grand coalition stand-alone stable. Accordingly, a successful cooperative agreement on the management of this fishery seems an unlikely outcome. However, the legal setting provided by the UN Fish Stocks Agreement is expected to strengthen the cooperative management of straddling and highly migratory fish stocks. Moreover, if players are not allowed to free-ride, then there are sharing rules that make the grand coalition stand-alone stable.

Bjørndal and Brasao (2006), 'The East Atlantic Bluefin Tuna Fisheries: Stock Collapse or Recovery?'

A discrete-time, multi-gear and age-structured bioeconomic model was developed to analyse the alternative management strategies of the East Atlantic bluefin tuna fishery, to provide guidelines for the RFMO policies. The optimal stock level was determined as well as an investment (recovery) path for the resource. As the tuna is harvested by several different gears targeting different age classes by a number of different countries, a number of different scenarios were analysed.

The analysis indicates overexploitation of the fishery, producing an optimal stock level varying between 500,000 tonnes and 800,000 tonnes, compared with the actual stock level of only 150,000 tonnes in 2000. This presents a very strong case for rebuilding the stock, as the sustainability of the stock is threatened and the costs of not instituting a recovery programme are substantial. Complete stock collapse is predicted if there is no recovery programme, such as a moratorium on fishing or possibly a more gradual approach to a steady state given by an extremely low TAC.

The current gear structure of the fishery is inefficient and, if maintained, would result in a loss in present value when compared with the optimal policy structure. The optimal policy to maximize rents requires the complete elimination of the purse-seine and the bait boat, and the reduced effort of the longline and trap. Non-constant harvesting policies are also called for, with a mild form of pulse fishing for optimal rents.

Recommendations for policy are for immediate action to reduce the severe overexploitation. Despite this, several countries continue to harvest, while others are considering entering the fishery. The implementation of these recommendations requires cooperation and enforcement by the RFMO.

Discussion

The point of departure for Duarte et al. (2000) is that the UN Fish Stocks Agreement can be interpreted as establishing a legal obligation to cooperate within an RFMO. Therefore, cooperative games can be used to examine the economics of cooperative management. What is called a characteristic function game (c-game) approach can be used to study this problem. The c-game approach is based on the fundamental assumption that the players have already agreed to cooperate, and that side payments among the players are possible. Thus, the problem to be solved is the distribution of the gains of cooperation, or what is also called the cooperative surplus, in a fair way. Three solution concepts, based on different fairness concepts, are proposed as possible solutions for this problem.

Three players are defined, namely the EU, OCS and DWFNs, which differ in terms of gear structure. The case study points out one possible source of weakness in the UN Agreement. None of the solutions is in the core of the game, meaning that some players can do better outside the grand coalition consisting of all three players. This may be a serious threat to the cooperative arrangement, and it certainly creates an incentive to cheat. Note, however, that in the UN Agreement it is established that nations that do not follow the RFMO regime will not have access to the resource. This legal restriction is, therefore, essential for increasing the effectiveness of this management solution.

The purpose of the paper by Brasao et al. (2000) is to examine the cooperative agreement solution within the RFMO, as well as two alternative non-cooperative solutions: the myopic, open-access solution and the time-consistent FBNE solution.

It is possible to find a distribution of the gains that guarantees stability of the agreement, assuming that the players commit themselves to that specific redistributive rule. However, when the gains are distributed according to a fair sharing rule, the stability of the agreement is not guaranteed.

Instability of the agreement implies that the agreement solution is unlikely to be implemented with success. Nevertheless, the UN Fish Stocks Agreement provides a legal framework that allows the members of the RFMO to ban DWFNs from harvesting bluefin tuna unless they are members of that RFMO and abide by its rules. If this legal restriction is enforced, the problem of instability is eliminated in one case, but not in another.

According to Pintassilgo and Duarte (2001), cooperative solutions to highly migratory fisheries are challenged by the potential instability of the nature and number of the players, as opposed to their natural stability in shared fish stock problems. This study deals specifically with the new-member problem. The authors conclude that if the only bar to achieving membership in the organization is the willingness to accept its management programme, then cooperative management could most certainly be at serious risk.

The main conclusion of this paper is that new members can pose a threat to the cooperative management of straddling and highly migratory fish stocks. For bluefin tuna, at present the threat from new members is not sufficient for the breakdown of the cooperative agreement. This is owing to the very low level of the stock, which makes non-cooperation a low-payoff strategy. As the optimal cooperative strategy calls for an initial harvest moratorium, the threat becomes progressively more relevant, showing that this is a dynamic problem, which is intensifying in the long run.

In his paper Pintassilgo (2003) shows that, generally, in order to guarantee the stability of the cooperative agreements, it is not sufficient to implement a fair sharing rule for the distribution of the cooperative surplus. Stability requires a legal regime preventing the players that engage in non-cooperative behaviour from having access to the resource. Therefore, the restrictions of the UN Fish Stocks Agreement, which prohibit non-member states that do not abide by the rules of the RFMO from fishing the resource, clearly point to the protection of the cooperative agreement.

Bjørndal and Brasao show that the optimal stock level is in the range of 500,000–800,000 tonnes, as against an actual stock level of 150,000 tonnes in 2000. Furthermore, continued open access may lead to complete stock collapse. Optimal management also has the potential to generate substantial rents, partly as a result of a more efficient gear structure.

Whereas historically over 50 countries participated in the fishery for bluefin tuna, currently 25–30 are active. Should the stock improve and, as a consequence, the distribution area be extended, there will be a strong incentive for more countries to join the fishery. This incentive is compounded by the high value of the tuna.

The large number of actual and potential countries in this fishery, including distant water fishing nations, is an important reason why management of bluefin tuna has proved so challenging.

6

Summary and conclusions

Management of straddling fish stocks and highly migratory fish stocks brings with it the promise of substantial returns to the owners of the stocks if they are managed so as to maximize rents. This, however, represents a challenging task for the RFMOs.

On the basis of a survey of the literature a number of conclusions can be drawn, all of which serve to validate the economic theory of RFMO management, outlined in the Introduction.

For each conclusion presented, a brief justification will be provided based on the literature review.

A. *For several stocks, non-cooperation may lead not only to overexploitation, but also to near or total stock extinction.*

   Continuation of current management practices for bluefin tuna, in the Pacific as well as in the Atlantic, may cause total stock depletion. For Norwegian spring-spawning herring, open access may lead to virtual stock extinction.

B. *Cooperation always leads to higher rents and higher equilibrium stock levels than non-cooperation. The differences may be quite substantial.*

   Under cooperative management, all fisheries surveyed would generate substantial rents, often measured in billions of dollars in net present values. This is obtained through investment in the stocks, generally involving substantial reductions in effort. Fisheries currently characterized by non-cooperation yield very low rents or none at all. Moreover, in the long run cooperation is in general seen to involve high stock levels, with corresponding sustainable harvest levels.

C. *Effective monitoring and control by RFMOs and their member countries is essential to prevent overexploitation and loss of fishing rents.*

   In the case of East Atlantic bluefin tuna, ICCAT – the relevant RFMO – is seen to be ineffective in terms of monitoring and control of regulations, with detrimental effects on the sustainability of the fishery.

D. *The migratory pattern and the rate of migration take on great significance, in particular the amount of time spent in international waters outside EEZs.*

   The time spent outside EEZs, as well as the proportion of the stock that migrates outside EEZs, have direct consequences for the accessibility of the stock to distant water fishing nations and make effective management more difficult. Atlantic bluefin tuna represents a prime example of this.

E. *For some fisheries, side payments are important for achieving and maintaining a cooperative agreement.*

   This result was originally derived in the bioeconomic literature. It is seen to be highly relevant both for Norwegian spring-spawning herring and for Pacific tuna.

F. *Interactions between fisheries on the high seas and in EEZs may have an impact on the effective management of straddling and highly migratory fish stocks.*

Landings of blue whiting were found to depend on prices of fish stocks harvested inside the EEZ. This result is likely to be applicable to a number of fisheries. Kennedy (1987) points out that there may be biological interactions between straddling/highly migratory fish stocks and stocks in the EEZ.

G. *Cooperative management depends on a solution to the new-member problem.*

This result is clearly illustrated by the situation in the Pacific bluefin tuna fishery, where the existence of a 'fringe' of open-access distant water fishing nations appears to undermine effective management. For Atlantic bluefin tuna, new entrants may jeopardize stock recovery. Moreover, as the stock size increases as part of a stock rebuilding programme, the incentive to enter the fishery increases.

H. *The larger the number of actual and potential players, the more difficult it is to achieve a cooperative solution, and the greater the incentive for some players to free-ride. These outcomes will be aggravated if more time spent is in international waters.*

This result is also known from the literature, but has probably not received the attention it requires. Atlantic bluefin tuna, which is currently harvested by 25–30 nations, a number that under given circumstances could conceivably be doubled, clearly illustrates this point. Arnason et al. show that many exploiters often lead to the virtual extinction of the stock.

I. *The 'resilience' through time of the cooperative resource management arrangement is important.*

This point is illustrated by Norwegian spring-spawning herring, where the management agreement broke down as a consequence of changes in the distribution pattern for herring over time. For Atlantic bluefin tuna, incentives facing different countries will change as the stock increases as part of a recovery programme. As a consequence, free-riding may become more profitable, which may lead to a breakdown of the cooperative agreement.

J. *Stability.*

There are situations when players (countries) can do better on their own than by participating in a coalition including all players. This is a threat to the cooperative agreement, as it creates an incentive to cheat. According to the UN Fish Stocks Agreement, countries that do not follow the RFMO regime will not have access to the resource. This legal restriction may be essential for increasing the effectiveness of the management solution. In addition, the UN Fish Stocks Agreement may be important to ensure the stability of the cooperative agreement.

In the Introduction, the economic theory of RFMO resource management was briefly summarized. This theory is clearly validated by the current survey of bioeconomic modelling of straddling fish stocks and highly migratory fish stocks in different parts of the world. Moreover, the bioeconomic analyses can be used to quantify some of the qualitative predictions of the theory. In particular, the empirical studies show that economic losses from ineffective cooperative resource management can be truly substantial.

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