Conservation and Optimum Utilization of
Southern Bluefin Tuna

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The paper predicts the outcomes of alternative management scenarios for the Southern Bluefin Tuna (SBT) fishery over the next twenty years. Two criteria are used to characterize outcomes: economic efficiency as measured by the present value of fishery rent generated; and conservation as measured by the predicted size of the SBT stock in twenty years’ time. A bioeconomic model incorporating a game theoretic framework is used to assess the effects of alternative management scenarios representing varying degrees of cooperation amongst the six countries currently harvesting SBT. The results suggest that while there are substantial gains from cooperation, there do not appear to be dire consequences if cooperation is not achieved. However this conclusion needs to be tested for a wider range of biological parameter sets.

1. INTRODUCTION

The aim of the Convention for the Conservation of Southern Bluefin Tuna (CCSBT) is to “…ensure, through appropriate management, the conservation and optimum utilization of southern bluefin tuna” (CCSBT, Article 3). This report examines the concepts of conservation and optimum utilization within an economic framework which can be used to assess the contribution of alternative harvesting strategies and management arrangements to meeting these goals. In Section 2, the report develops an interpretation of the two goals which fits readily within an economic framework. In Section 3 a bioeconomic model of the fishery is presented which ensures that all relevant biological and economic considerations are accounted for in the analysis. In Section 4 a game theoretic framework is outlined for modeling the impact on the economic performance of the industry of the various incentives which exist for cooperative and non-cooperative behaviour among participants. This kind of framework is particularly suitable for analyzing interactions among a small group of participants, such as the six countries currently involved in harvesting SBT. Section 5 reports and comments on the results of the analysis and Section 6 presents the conclusions of the report.

2. THE GOALS OF SBT MANAGEMENT

As noted above, the two principal goals of SBT management are conservation and optimum utilization. Optimum utilization was first noted as a marine resource management objective in the United Nations Law of the Sea Conference negotiations in 1975 (Burke, 1994 p.61). Since then the objective “to conserve and optimally utilize” has appeared in nearly all international environmental instruments which may impact fisheries management (Tsamenyi and McIlgorm, 1999). More recent conventions qualify the conservation and optimum utilization objective with guidelines found in a range of non-binding international agreements such as, for example, the precautionary principle (Tsamenyi and McIlgorm, 1999).

In this paper it is argued that the goal of conservation can be interpreted as a constraint which should be imposed on the utilization of the resource, although it need not be a binding constraint in all cases. It is also argued that optimum utilization means maximizing the value of the resource, and that in the case of SBT use, as opposed to non-use, values predominate.

The conservation objective can be fulfilled by setting a minimum stock level as a constraint on the exploitation of the fishery. An example of this approach is provided in Bertignac et al. (2000) where a bioeconomic model constrains exploitation of tuna stocks in the western and central Pacific to maintain stock levels of at least 40% of virgin population biomass. For a long-lived species, such as SBT, the age structure of the population, as well
as the size of the total biomass, can have important implications for conservation. Both these variables can be taken into account by specifying the SBT conservation constraint in terms of the spawning stock biomass (SSB).

In the early 1980’s it was recognized that the spawning stock biomass (SSB) of the SBT population had fallen to around 50% of the unexploited level. Given the long-lived nature of SBT, this figure was expected to fall further during the 1980s as a result of harvesting of juveniles, and the SSB was thought to be less than 20% of the unexploited level by the end of the decade (for details, see Campbell et al., 2000).

At the Eleventh Trilateral Meeting between Australia, New Zealand and Japan in Tokyo in 1992 the long-term goal of returning the SBT stock to its 1980 level (around 50% of SSB) was adopted. The CCSBT adopted this goal, setting a target date of 2020. This target level of SSB (144,000 tonnes) could be adopted as the conservation constraint.

3. THE BIOECONOMIC MODEL

A bioeconomic model incorporates two general processes: a biological process in which fish are recruited to the population, grow, spawn and eventually die; and an economic process in which fishing effort is generated by vessels and gear, and applied to the fish stock to produce a catch which is then sold to consumers.

The biological model of the SBT stock is deterministic, discrete and age-structured: deterministic refers to the fact that the model does not take account of the year to year fluctuations that occur in nature as a result of fluctuations in environmental conditions; discrete refers to the fact that changes in stock levels are calculated and reported on a yearly basis; and age-structured refers to the fact that the experience of each age class of fish is modeled separately. The model incorporates 21 age classes, or cohorts. Each cohort, with the exception of the last one, contains all the fish of a given year class. The 21st cohort contains the relatively small number of fish that live to be aged 21 or older. The life history of each fish is described by following its growth in weight and its experience of natural and fishing mortality. A fish which survives to sexual maturity at 8 years of age joins the spawning stock biomass (SSB) which is the combined weight of all the mature fish. The size of the SSB in any given year determines the size of the recruitment to the population in the following year.

The natural and fishing mortality experienced by the stock vary with age class. The natural mortality rate declines over the first 11 years, reflecting the fact that younger fish are more vulnerable to predators, and remains constant thereafter. The fishing mortality rate depends on the type of gear used as well as on the age of the fish. While each gear type may catch the same range of age classes of fish, long-line gear takes a higher proportion of older fish compared with purse-seine gear. Since fishing grounds and practices vary from one fleet to another, the fishing mortality rate inflicted by the long-line or purse-seine fleet of one country may differ from that inflicted by another.

The fishing mortality rate of each gear type on each age class per standardized unit of fishing effort is termed a selectivity coefficient. The weight of catch of each age class by each fleet is determined by a harvest function which is given by the amount of fishing effort, measured in standardized units, multiplied by the selectivity coefficient, and multiplied by the biomass of that age class of fish raised to a power with a value in the range 0-1. Total weight of annual catch by a fleet is the sum of its catches across age classes.

The reason the harvest function incorporates the biomass raised to a power in the range 0-1 is to reflect the schooling nature of SBT. While, for all species of fish, the catch per unit effort (CPUE) tends to fall as the size of the stock falls, the decline in CPUE is less marked for schooling species because of the continuing availability of significant concentrations of fish to the fishing gear. The value of the exponent on biomass in the harvest function determines the extent of the fall in CPUE as stock declines. As there is insufficient information to determine the appropriate value of the biomass coefficient, it will be set at unity in the base case, and it will be included along with the biological parameters in a sensitivity analysis.

Each fleet’s catch may attract a different market price per unit of weight because of differences in the size of fish marketed, or other perceived quality differences. The market price for the product of a given fleet depends on the quantity supplied by that fleet, as well as on the quantities supplied by the other fleets. The larger the quantity of fish supplied by a given fleet the lower the market price for that fleet’s product, and the lower the market price for the product of other fleets. These relationships reflect the standard laws of demand for consumer products and their close substitutes.
The gross value of the harvest of each fleet depends upon the demand and cost conditions. Gross value includes the value to consumers and producers. The net value of the harvest in a given year is the gross value less the fishing costs, which depend on the level of effort expended in catching the harvest for that year. The net value of the fishery in total is obtained by summing across fleets to give a total figure for the year. The annual figures for a series of years into the future can then be discounted to give a net present value which is a single summary measure of the net benefit generated by the fishery. This measure can be divided into the net benefits gained by each participating country, depending on the level of effort they contributed to the fishery.

The level of effort contributed by the fleet of each participating country can be regarded as a control variable – a variable the chosen level of which determines the net benefit they receive from the fishery. The net benefit accruing to any participating country depends upon the levels of effort chosen by all countries. The bioeconomic model generates a single outcome corresponding to each possible set of values of the control variables. That single outcome includes a unique value for the size and composition of the SBT stock, as well as unique values for the net benefits, or payoffs, accruing to the individual participating countries. The unique mapping of sets of values of the control variables into sets of values of the payoffs provided by the bioeconomic model is the basis of the game theory analysis described in the next section.

4. THE GAME THEORETIC MODEL

For game theory to be effective as a policy analysis tool, the game should be kept as simple as possible. The number of players and the number of strategies available to each player should be limited to facilitate obtaining a solution to the outcome of the game, and also to limit to a reasonable number the player/strategy combinations that must be considered in policy assessment. Six countries currently participate in the SBT fishery but for the purpose of the analysis they can be divided into three groups, each one of which can be treated as a player in the game. The three players are:

- Australia and New Zealand (ANZ): both are major resource-owners, both are harvesting SBT in their own EEZ, both are members of the CCSBT, and neither is a significant consumer of SBT;
- Japan is a major distant water fishing nation, a member of the CCSBT, and the major consumer of SBT;
- Korea, Indonesia and Taiwan (KIT): these countries are expanding their distant water fishing activities, are not significant consumers of SBT, and at the time of writing were not members of the CCSBT.

These three groupings capture the interests and characteristics of the stakeholders in the SBT fishery: as domestic or distant water fishing nations; as consumers and/or producers; and as members or non-members of the CCSBT.

In the framework of the game each of the three players chooses a strategy, and the interaction of the strategies chosen by the players determines the outcome of the game, described by the payoffs to the three players. In the case of the SBT fishery each player’s strategy is its choice of the level of fishing effort to be devoted to the fishery. It would be possible to consider choices among additional dimensions of strategy, such as the type of fishing technique used (long-line, purse-seine, or pole-and-line gear), the range of fishing grounds exploited, and the location and segment of the market supplied. However, in order to keep the game as simple as possible, certain existing choices will be built into the base case model: ANZ uses purse seine gear, and Japan and KIT use long-line gear; all countries fish in their current fishing grounds; and all players supply the Japanese SBT market.

Since one question addressed by the study is the effect of Australia’s decision to use its SBT quota to supply juvenile fish to tuna farms, a variant of ANZ’s strategy choice will be considered to analyze this question. This variant will be introduced in the form of a hypothetical question: what are the implications for conservation and optimum utilization if ANZ adopted long-line gear with costs and fishing power similar to the fleets of Japan and KIT? The game will be run with this alternative type of strategy choice for ANZ and the results compared with the base case scenarios.

The payoff to each player consists of the net benefit derived from harvesting and/or consuming SBT. Net benefit from harvesting SBT consists of the profit earned by the player’s fishing fleet, where profit is measured by total...
revenue less total cost (ignoring subsidies) resulting from the level of fishing effort chosen. Net benefit from consuming SBT is measured by the flow of consumer surplus, which is determined by the size of the market and the responsiveness of quantity demanded to changes in product price. Profit and consumer surplus flows are discounted to present values in order to provide a single measure of the pay off to each player.

The outcome of the game is reported in the form of the payoffs associated with the Nash equilibrium in which no player has an incentive to change its strategy choice, given the strategies chosen by the other players. Such an incentive would exist if, given the strategies chosen by the other players, a player could increase its payoff by altering its strategy choice. In simple terms the concept of Nash equilibrium means that each player is getting their maximum individual benefit from the resource, given the behaviour of the other players.

The game may be set up as a cooperative or a non-cooperative game. A cooperative game is one in which the players can make binding commitments concerning their choice of strategy. This normally means that agreement can be reached among the players on a combination of strategies that results in maximizing the sum of the payoffs. In the case of the SBT fishery a cooperative game would describe a situation in which the three players were members of the CCSBT, or a similar organization, and agreed on levels of fishing effort which maximized the sum of the payoffs or aggregate net benefit. If the strategy combination consistent with aggregate net benefit maximization would disadvantage one of the players in comparison with the payoff that player could earn by not cooperating, some form of side payment could be made. This could take the form of an exchange of cash or SBT quota, or some exchange outside the SBT fishery, such as a trade deal.

A non-cooperative game is one in which binding commitments cannot be made. This means that no player can accept the promise of some kind of side payment in exchange for modifying its strategy choice. In that case the equilibrium outcome of the game will generally not be consistent with maximization of aggregate net benefit. One role of policy analysis is to look for changes in the institutional structure, such as the formation of organizations like the CCSBT, which can provide an outcome with a higher total value than that of the non-cooperative game.

The outcomes predicted by the model will be compared with a base case scenario in which current harvest levels under the CCSBT are continued into the immediate future. This is consistent with the fact that the CCSBT has maintained constant quotas for the past five years, and reflects the difficulty of achieving agreement to change policy. In constructing the scenarios it is necessary to make a decision about the likely action of non-CCSBT countries represented by the Player KIT. Alternative assumptions are that Korea, Indonesia and Taiwan act in concert, in which case KIT can be assumed to maximize its aggregate net benefit, or that these countries act individually, in which case KIT can be assumed to earn a zero net benefit. Both assumptions will be employed in the base case calculations to allow for the full range of responses by KIT.

The alternative scenarios need to take account of the following possibilities:

- All six countries (represented by the three players) cooperate in maximizing aggregate net benefit. In this case, we may wish to investigate the magnitude of side payments which could help to achieve this outcome;
- ANZ and Japan cooperate to maximize their aggregate net benefit, but KIT acts either to maximize its profits or as if the SBT stock were an open-access resource;
- There is no cooperation between ANZ and Japan within the CCSBT, but each player takes the behaviour of the other player into account in choosing a strategy, and KIT acts either to maximize its profits or as if the SBT stock were an open access resource.

When questions are asked about the efficiency and sustainability of the fishery, each of the above scenarios needs to be considered, in addition to continuation of the current arrangements under the CCSBT.

There are different views about the values of various biological and economic parameters, including the biological parameters of the SBT stock, the value for the stock coefficient in the harvest function, the spatial distribution of the SBT stock (which is the focus of Japan’s experimental fishing program (EFP)), the discount rate, and the values of the own- and cross-elasticities of demand for SBT supplied by the three players. It would be possible to introduce the above areas of disagreement into each of the possible scenarios analyzed in the game theory models, but this would substantially increase the number of comparisons required. Instead the sensitivity of the major conclusions of the analysis to these issues will be ascertained by conducting the sensitivity analysis on selected scenarios and the results reported.
5. RESULTS OF THE BIOECONOMIC MODEL

The structure of the bioeconomic model is based on Kennedy (1999) with extensions, details of which are available on request. A summary of results is provided in Table 1. Each run of the model is designed to provide an evaluation of the efficiency and sustainability of a particular exploitation regime. Where runs involve maximization of economic values, such as producer and consumer benefits, the timeframe for the maximization is 30 years. However the summary measures of efficiency and sustainability are the net present value of the fishery over a 20-year time horizon (NPV20), and the size of the spawning stock biomass after 20 years (SSB20). It should be noted that the model can also be run with an infinite planning horizon without changing any of the general conclusions.

The net present value of the fishery is defined as the present value of producer revenues plus consumer benefits less harvesting costs. Management considers that a stock level of 144,000 tonnes (the estimated 1980 stock level) in the year 2020 is a desirable target. The initial SSB in the model in year 1 is 43,631 tonnes (approximately the current level) and all scenarios considered involve growth of the biomass. It is undesirable that the stock fall below the initial stock level in any scenario.

Table 1: Run Results for a Planning Horizon of 30 years

<table>
<thead>
<tr>
<th>Run No.</th>
<th>ANZ PS</th>
<th>KIT PS</th>
<th>JAPAN PS</th>
<th>CS</th>
<th>Total NPV20</th>
<th>ANZ PS</th>
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<th>Total NPV30</th>
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<td>0.6</td>
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<td>1.3</td>
<td>5.7</td>
<td>7.1</td>
<td>7.9</td>
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</table>

Notes:
All values are in billions of dollars
PS = NPV of annual Producer Surplus (Total Revenue minus Total Cost)
CS = NPV of annual Consumer Surplus
Total = sum of Japan’s PS and CS
NPV20 = NPV of all nations’ PS and CS over 20 years
NPV30 = NPV of all nations’ PS and CS over 30 years
SSB20 = spawning stock biomass after 20 years (thousands of tonnes)
Totals may not add up due to rounding

While economic efficiency involves maximizing the sum of producer and consumer benefits, there are two problems in applying this notion to the evaluation of various exploitation regimes. First, primary producers are often given disproportionate weight relative to consumers in formulating policies for the food producing industries. The possibility that Japan, the only consumer of SBT in the model, acts to maximize the benefits to its producers only is allowed for by placing a zero weight on consumer benefits in one run of the model. This does not mean that consumer benefits are zero, or are excluded from the efficiency measure, but only that they are a by-product of a policy of acting so as to maximize producer benefits. Second, the measurement of consumer benefits is based on estimates of market elasticity of demand which are obtained from analysis of current consumption patterns. These estimates are only approximate, and they become increasingly less reliable as the scenario being considered departs from the consumption levels currently observed. For this reason, the consumer benefits estimates presented should be interpreted with caution.

The procedure that will be adopted in reporting the results is as follows: the question to be considered will be stated; the run number or numbers which address the question will be identified for reference to Table 1; a brief
description of the features of the model run that address the question will be provided; the measures of efficiency and sustainability will be reported, and the results briefly discussed.

5.1 What will be the outcome if the current arrangements under the CCSBT continue? (Runs 1 and 2)

Under the current arrangements Japan and ANZ have agreed to annual catch quotas, and KIT operates outside the CCSBT. Japan uses longline gear to take its quota, while ANZ uses purse seine gear to catch younger age classes of fish to stock its tuna farms. Two possible assumptions about the strategy followed by KIT are: KIT sets its fishing effort level so as to maximize its profit, given the levels of effort supplied by Japan and ANZ; or KIT makes no attempt to regulate its effort, in which case its vessels will contribute effort up to the point at which total revenue equals total cost (zero profit). Run 1 incorporates the former assumption about KIT’s strategy, and Run 2 the latter.

Run 1: NPV$_{20} = $8.0 billion; SSB$_{20} = 136.4$ thousand tonnes.
Run 2: NPV$_{20} = $7.6 billion; SSB$_{20} = 74.4$ thousand tonnes.

By comparison of Runs 1 and 2 it can be seen that the stock levels are higher in terms of conservation objectives if KIT manages its effort level (Run 1) so as to maximize its returns. If KIT does not manage its effort level (Run 2) the net benefits to producers are reduced, but this reduction is partially offset by the benefit of the lower prices to consumers as a result of the higher catches as compared with Run 1. It can seen from the detailed results reported in Table 1 that Japanese consumers are overwhelmingly the largest beneficiaries under the current arrangements, receiving between 69% (Run 1) and 92% (Run 2) of the net benefits generated by the fishery. Japan’s producers receive between 16% (Run 1) and 3% (Run 2). The 20-year stock levels are in excess of the initial 43,631 tonne stock size and Run 1 almost meets the year 2020 stock objective.

5.2 What is the most economically efficient outcome and how does it compare with the outcome of the current management regime? (Run 3)

The results of Runs 1 and 2 demonstrated that a more efficient outcome can be achieved under the current regime if KIT regulates its level of fishing effort to maximize the returns to its producers. However efficiency can be improved further if each player agrees to contribute the level of effort which maximizes the combined total net present value of the fishery. Under this cooperative game scenario the efficiency and conservation outcomes are:

Run 3: NPV$_{20} = $8.2 billion; SSB$_{20} = 149.3$ thousand tonnes.

By comparison with the results of Runs 1 and 2, it can be seen that this outcome represents a modest improvement in efficiency (3%), and yields a conservation outcome similar to that of Run 1 and higher than the year 2020 objective of 144,000 tonnes. It can be seen from Table 1 that Japanese consumers receive 72% of total benefits under this scenario. It can also be seen that ANZ producer benefits fall as compared with the results of Run 2, and KIT producer benefits fall as compared with the results of Run 1. This means that in order to induce a change from the current regime to the NPV maximizing regime either ANZ or KIT will need to receive a side payment; in terms of net present value, ANZ might require $0.4 billion and KIT $0.1 billion.

5.3 How important is full cooperation between ANZ and Japan, assuming that KIT remains outside the CCSBT? (Runs 4 and 5)

In Runs 4 and 5 it is assumed that KIT remains outside the CCSBT and, as in Run 2, does not regulate its fishing effort to maximize its returns, with the result that its payoff is zero irrespective of the strategies adopted by ANZ and Japan. ANZ and Japan can choose to cooperate to maximize their joint returns (Run 4), or to adopt the strategy of maximizing individual profit (Run 5). Comparison of Runs 4 and 5 reveals the value of cooperation in these circumstances:

Run 4: NPV$_{20} = $7.7 billion; SSB$_{20} = 103.9$ thousand tonnes.
Run 5: NPV$_{20} = $7.7 billion; SSB$_{20} = 102.2$ thousand tonnes.
It can be seen that there is very little difference between the results of the two runs. However, in the absence of side payments, the distribution of the benefits of cooperation is very much in favour of Japan’s producers and consumers, with ANZ producer benefits actually falling by $0.1 billion, or 17% as compared with the non-cooperative outcome. Stock levels are probably sustainable, but lower than the year 2020 objective.

5.4 What effect does Australian tuna farming have on the efficiency and sustainability of the fishery? (Runs 6, 7, 8, 9 and 10)

To answer this question it is assumed that, instead of purse seining and farming, ANZ chooses to exploit the fishery by means of longline gear with similar selectivity and catchability coefficients to those of Japanese longliners operating off Tasmania. Under this assumption ANZ will be catching older age classes of fish and this may have an impact on the stock level as well as on the net present value of the fishery.

Runs 6 and 7 repeat the base case Runs 1 and 2, but with ANZ using its quota for longlining instead of purse seining and farming:

Run 6: NPV$_{20}$ = $7.4$ billion; SSB$_{20}$ = 104.1 thousand tonnes
Run 7: NPV$_{20}$ = $6.5$ billion; SSB$_{20}$ = 49.2 thousand tonnes.

It can be seen, by comparison with Runs 1 and 2, that both the net present value of the fishery and the size of the stock in year 20 falls as a result of ANZ switching to longlining: net present value falls by 8-14%, and spawning stock biomass falls by 24-34%, depending on whether KIT regulates its fishing effort to maximize the profit of its fleet. The returns to ANZ producers fall significantly as a result of switching from tuna farming to longlining.

It could be argued that the current arrangements represented by the base case are temporary and that, in future, equilibrium in the fishery will be determined by the outcome of a game as described by Runs 3, 4 and 5, which are based on different assumptions about the level of cooperation among the players. Runs 8, 9 and 10 recalculate the outcome of these games, but with ANZ constrained to using longline gear, and the results of these Runs can be compared with Runs 3, 4 and 5 respectively. In Runs 3 and 8 all three players cooperate to manage the fishery optimally; in Runs 4 and 9 ANZ and Japan cooperate and in Runs 5 and 10 ANZ and Japan act so as to maximize individual returns:

Run 8: NPV$_{20}$ = $7.9$ billion; SSB$_{20}$ = 149.5 thousand tonnes
Run 9: NPV$_{20}$ = $7.4$ billion; SSB$_{20}$ = 109.9 thousand tonnes
Run 10: NPV$_{20}$ = $7.2$ billion; SSB$_{20}$ = 91.1 thousand tonnes.

As compared with Runs 3, 4 and 5, the net present value of the fishery is lower by around $0.3-0.5 billion (around 4-7%) if ANZ switches to longlining. It can be seen from the results reported in Table 1 that the loss is borne mainly by Japan’s consumers. The effects on producers depends on the level of cooperation: with cooperation ANZ producers are worse off as a result of the switch, whereas in the non-cooperative case it makes no difference. Turning to the sustainability measure it can be seen that stock levels are marginally increased if ANZ targets older fish and some measure of cooperation is achieved, but slightly reduced if ANZ and Japan act so as to maximize individual returns. In the model ANZ locks itself into either the strategy of farming or of longlining for a thirty year time period. It should be recognized that as the stock size increases there may be cost reductions in longlining and the net benefits ANZ can obtain through farming may fall relative to those that can be obtained from longlining. While these changes are incorporated in the model, their effect on ANZ’s optimal strategy could only be ascertained by re-running the model starting from some future date.

5.5 How important are the benefits to Japanese consumers to the results obtained on the economics of the fishery? (Run 11)

In Run 11 it is assumed that the players act cooperatively to maximize the producer benefits they jointly receive from the fishery, ignoring the benefits to consumers. Run 11 can be compared with Run 3 in which the players cooperated to maximize aggregate producer and consumer benefits:

Run 11: NPV$_{20}$ = $6.6$ billion; SSB$_{20}$ = 260.9 thousand tonnes.
It can be seen that ignoring consumer benefits in the net present value maximizing calculation reduces the net benefits of the fishery by around 20%. Producer benefits double, rising to 68% of total benefit. Consumer benefits fall to 36% of the level in Run 3, although consumers still derive significant benefit from the fishery. In the absence of the incentive to increase catches to lower prices and benefit consumers, the predicted stock level is substantially increased, well beyond the target set by management for the year 2020.

6. SENSITIVITY ANALYSIS

A number of runs of the model were conducted to determine the sensitivity of the results to the choice of values of economic and biological parameters. The values reported in Table 1 were obtained using a 5% real rate of discount, but use of a 10% rate of discount does not change the qualitative conclusions of the model. The results reported in Table 1 are based on own-price elasticities of demand set at -1 and cross-price elasticities set at 0.2. However runs incorporating lower absolute values of own- and cross-price elasticities suggests that varying the parameters of the demand curves within reasonable limits does not change the qualitative conclusions of the model. In all the runs reported in Table 1 a neutral position was taken on the effect of higher stock levels on catch per unit effort: it was assumed that effort experiences a proportionate increase in catch as the stock level increases. However when the coefficient on stock in the harvest equation is set at 0.6 instead of 1 the qualitative conclusions of the model do not change.

A twenty-year time horizon was chosen for assessing the size of the stock variable because of the CCSBT’s objective of returning the SSB to the 1980 level by the year 2020. However a longer time frame might be relevant in the evaluation of the economic benefits of various outcomes. While the Runs discussed above report the results, over a twenty-year period, of running the models over a thirty-year time horizon, the net present value results for the entire thirty-year period can also be considered. These results are reported in Table 1 for all Runs of the model. Taking Run 3 as an example, it can be seen that consumer benefits are 78% of the total (as compared with 81% for the twenty year horizon), but that producer benefits are unaffected. Hence the choice of a twenty year time horizon for reporting results, as compared with the thirty-year planning horizon, does not affect the qualitative findings to any significant degree.

The model run results reported in Table 1 are based on a biological parameter set which incorporates a set of assumptions about the spatial distribution of the stock referred to as GEO98. This set of assumptions is intermediate between two extreme positions, one of which holds that the stock is spatially concentrated (the variable squares assumption), and the other that it is spatially diverse (the constant squares assumption). Some Japanese modelers have favoured the latter assumption, and testing it is one of the objectives of Japan’s Experimental Fishing Program. Changing the biological parameter set to incorporate the constant squares assumption makes little difference to the net present value of the fishery. The equilibrium stock values predicted by models incorporating the different assumptions are not strictly comparable because of the different initial stock numbers and recruitment parameters implied by the two parameter sets. However stock levels predicted by runs incorporating the constant squares assumption were well above management’s year 2020 target level.

7. CONCLUSIONS

The CCSBT requires parties to “...ensure, through appropriate management, the conservation and optimum utilization of southern bluefin tuna”. The paper has addressed some of the key elements in interpreting the “optimum utilization” and “conservation” objectives in the context of current management issues.

The broad findings are that current management measures are addressing the appropriate issues and that alternative management options can be appraised through the bioeconomic modeling approach described in the paper. The modeling also demonstrates the extent to which all parties stand to lose if KIT stays outside a cooperative CCSBT framework, and non-cooperative strategies are adopted.

The model is proposed as being an appropriate exploratory tool to assist with appraising policy options. The sensitivity of the results of the analysis to changes in assumptions about parameter values has been tested by various runs of the model. Clearly many additional runs could be undertaken to investigate this issue, but so far it seems that the broad conclusions reached in the paper are reasonably robust. However it should be borne in mind that the model is deterministic and based on the past history of the fishery. Stochastic influences, or changes in either the biological or economic structure of the fishery could result in outcomes different from those predicted by the model.
The main conclusions of the analysis can be summarized as follows:

- 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 (see Runs 1&2). As compared with an optimal regime (Run 3), the current arrangements generate 93-98% of the potential maximum benefit, depending on whether or not KIT regulates its fishing effort so as to maximize its benefits. Bringing KIT into a fully cooperative arrangement would generate additional total benefits with a present value of $0.2-0.6 billion (Runs 1, 2 and 3). These results illustrate the potential improvement in utilization through altering management arrangements.

- ANZ farming 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. This result represents an improvement in utilization through altering production methods. A switch by ANZ to longlining would reduce the value of the total fishery substantially under the current CCSBT arrangements, and significantly under alternative scenarios (Runs 6&7). It would also lower the benefits to ANZ’s producers. Tuna farming by ANZ also tends to be associated with marginally lower stock levels, but this result depends on the strategies taken by other players (Runs 8, 9, 10). Tuna farming as modeled does not pose any threat to conservation of the SBT stock. In the long-run, rebuilding the stock may alter the relative price and cost structures of longlining and tuna farming and this may change ANZ’s preferred strategy.

- The issue of sustainability of the stock requires more clarification from scientists on acceptable stock levels from a conservation viewpoint. Most modeling runs built the stock from the initial level towards the year 2020 objective of 144,000 tonnes. No run had a 2020 stock level below the initial level. However few runs met the 144,000 tonnes target for the year 2020, although over two-thirds of the run results had year 2020 stock levels in excess of 100,000 tonnes. More information on acceptable conservation stock levels would assist the policy and decision process in the matter of conservation. In addition, a wider range of biological and economic parameters, and a stochastic modeling approach should be considered to determine how robust the stock predictions are.

- Japan’s consumers are significant beneficiaries of the SBT fishery. Optimum utilization requires consideration of the interests of consumers as well as producers, and this issue could be further investigated. Under all scenarios in which players act so as to maximize the sum of producer and consumer benefits, the latter constitute more than half of the net present value of the fishery. Even under a scenario in which the players ignore consumer benefits (Run 11), consumers still receive a significant share of net present value, with consumer benefits remaining above 30% of the total. The equilibrium stock levels are lower when players include consumer benefits in their objective functions because lower prices to consumers are achieved by higher catch rates which lead to lower stocks. However the inclusion by players of consumer benefits in the objective function does not appear to pose a threat to conservation of the stock (All Runs except 11).

The modeling builds on the scientific work undertaken by past management to improve sustainability of the SBT stock and the economic viability of the fishery. It has examined a range of issues facing the CCSBT in the pursuit of its optimum utilization and conservation objectives. Modeling confirms that continued cooperation among all SBT fishing nations will best contribute to achieving both objectives, and that there is no inherent conflict between them.

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9. REFERENCES


