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Alternative Futures for Southern Bluefin Tuna

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Abstract

The paper examines the outcomes of alternative management scenarios for the Southern Bluefin Tuna (SBT) fishery over the next thirty years. Two criteria are used to characterize outcomes: economic efficiency as measured by the present value of net benefits generated; and conservation as measured by the predicted size of the spawning stock biomass in twenty years' time (SSB20). A bioeconomic model, incorporating the results of recent stock assessment analysis, is used to assess the effects of alternative management scenarios representing varying degrees of cooperation amongst the eight countries currently harvesting SBT. The results of the model are compared with the results of an earlier model based on a more favorable stock assessment. The results of the current model cast doubt on the prospects of achieving the SSB20 target, and suggest that significant cuts to current catch rates are required on both economic and conservation grounds.

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 Website). A recent paper (Campbell, Kennedy and McIlgorm (2002)) examined the concepts of conservation and optimal utilization within an economic framework which was used to assess the contribution of alternative harvesting strategies and management arrangements to meeting these goals. In that paper the conservation objective was interpreted as the CCSBT goal of returning the SBT stock to its 1980 level of around 50% of unfished spawning stock biomass (SSB) within a 20 year time horizon, and optimal utilization was interpreted as maximizing the use-values of the fishery. The relative effectiveness of various strategies in contributing to the objective of optimal utilization was assessed by comparing the present values of the net benefits generated. Net benefits were defined as the sum of producer profits and consumer surplus.

The Campbell, Kennedy and McIlgorm (2002) paper concluded on a reasonably optimistic note. Most modeling runs, reflecting alternative management arrangements, resulted in the stock being built from the initial level towards the objective of 144,000 tonnes, although few runs met the 144,000 tonnes target within a 20 year time horizon. Nevertheless over two-thirds of the run results had year 20 stock levels in excess of 100,000 tonnes. The exploitation regime under the CCSBT was found to be reasonably efficient from an economic viewpoint, generating 93-98% of the potential maximum net present value, and hence close to optimal utilization.

Some significant changes have occurred in the management and modeling of the SBT fishery since that earlier work was completed. On the management side, Korea and Taiwan have now joined the CCSBT as cooperating members and have been allocated catch quotas. Indonesia remains outside the quota system as do The Philippines and South Africa which have now been identified as harvesting nations[1]. Recent stock assessments (Kolody et al. (2004)) have tended to be less favourable than earlier results, particularly in terms of the recruitment of juveniles to the SSB. The aim of the present paper is to re-evaluate the performance of the management regime in the light of these changed circumstances.

The Biological Model

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 year to year 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 natural fishing mortalities and annual weight gain in 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 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 10 years of age joins the spawning stock biomass 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. Recruitment is described by a Beverton-Holt stock recruitment relationship.

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.

Recent experience of one or two years of reduced catches of small fish in the Japanese and Korean longline fleets suggests poor recruitment to the stock and this underlines both the variability of year to year recruitment performance and the uncertainty about the parameters in the stock recruitment function. Following recent stock assessments (Kolody et al. (2004)), the biological modeling in the present paper is based on revised estimates of weight, maturity, numbers and mortality of fish by age, virgin spawning stock biomass, and selectivity coefficients in the SBT fishery as discussed in CCSBT (2004). The revised estimates are based on three different values of the steepness parameter, h, which is the slope of the stock recruitment function at low levels of SSB and reflects the intrinsic growth of the stock[2]. The different h values generate different estimates of the stock structure and of recruitment to the stock. Figure 1 shows the relationships between recruitment and stock in the revised biological model as compared with that used in Campbell, Kennedy and McIlgorm (2002).

While biologists caution that other changes in the fishery, such as changes in selectivity of fishing gear, may explain the recent change in catch composition it would seem to be prudent to re-examine the likely performance of the SBT fishery in terms of the twin goals of conservation and optimal utilization. Compounding the uncertainty about recruitment is uncertainty about the relationship between reported catches (which are the data used in the stock assessment models) and actual catches which some industry sources[3] have claimed may be higher by a factor of three. An audit of the Japanese market was recently conducted to investigate this issue[4], and, as a result, the Japanese Fisheries Agency admitted that the Japanese 2005 SBT quota had been overfished by 25% and that regulations would be introduced to remove the problem of over fishing.

Since concluding the modelling and analysis reported in this paper, however, further allegations of significant under reporting of the Japanese catch over the past 20 years have surfaced[5]. If these turn out to be true, this would have important implications for the accuracy of recent biological, and hence bioeconomic, modeling. Initial thoughts might be that the SBT stock is less vulnerable to extinction than prognoses based on recent stock assessments (such as CCSBT 2004 and 2005) might suggest. However, it will take time to reassess the catch history and generate a new set of parameters for the SBT biological model, and no conclusions can presently be offered[6]. This means that more than the usual uncertainty surrounds the projections of SSB over the next 20 years and the present values of net returns reported in this paper and also in the earlier study by Campbell, Kennedy and McIlgorm (2002). Comparisons of SSB and present values of net benefits under different management regimes and different competitive behaviours are still of interest for indicating likely trends in outcomes, and the results reported in the paper should be viewed in this light.

The Bioeconomic Model

The bioeconomic model relates current and future catches to sustained levels of fishing effort by each fleet. With the addition of tuna price and fishing cost information, the bioeconomic model can be used to predict the annual profits of each fleet and the net benefits to consumers in the form of consumer surplus, thereby providing the basis for assessing the efficiency with which the stock is being utilized. The price and cost information used in the present paper is the same as in the earlier paper in order to facilitate comparison: fishing cost per unit effort is set at a fraction of market price[7].

The link between the biological and bioeconomic models is provided by the harvest function which determines the weight of catch of each age class by each fleet. The harvest function used in the analysis is 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. Total weight of annual catch by a fleet is the sum of its catches across age classes.

In Campbell, Kennedy and McIlgorm (2002) an alternative form of the harvest function was also considered which incorporated biomass raised to the power 0.6 instead of unity. 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 may be less marked for schooling species, such as SBT, 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. A comparison of the results of the earlier model under the two different values of the biomass coefficient indicated that the qualitative conclusions of the model were not significantly different, and in the interests of brevity only a biomass coefficient of unity will be considered in the present paper.

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. In the absence of information about the responsiveness of market prices to catch levels own-elasticities of demand of unity will be assumed (implying that a one percent rise in quantity sold of a product is associated with a one percent fall in price), and cross-elasticities of demand will be set at zero (implying that the demand for a product is not affected by the price of competing products). In Campbell, Kennedy and McIlgorm (2002) the qualitative nature of the results was found not to be significantly affected by incorporating alterative values of these elasticities in the model.

The gross value to consumers of the harvest of each fleet depends upon the demand and the level of the catch. 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. Net value consists of the net benefits to consumers (gross benefits less expenditures) plus the profits of producers (revenues less costs). The net value of the fishery in total is obtained by summing consumer and producer net values across countries 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. The consumer benefits accrue almost entirely to Japan, where the SBT catches are mainly marketed, and the producer net benefits can be divided into the net benefits gained by each participating country, depending on the level of effort they contribute to the fishery.

The level of effort contributed by the fleet of each participating country can be regarded as a *control variable* the value of which determines the net benefit they receive from the fishery. Greater effort, and hence harvesting, by one country increases the harvesting costs of all harvesting countries through the stock effect, and reduces the price of tuna received by the other countries supplying the same market. 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. The outcome includes the size and composition of the SBT stock for each of the 30 years of the planning period, as well as 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 analysis described in the economic model.

The Economic Model

The economic model is used to analyse the behaviour of each of the participants in the fishery in response to economic incentives in the form of consumer and producer benefits, and in response to the behaviour of other participants. It determines the values of the control variables in the bioeconomic model.

Eight countries currently participate in the SBT fishery but for the purpose of the analysis they can be divided into three groups:

- Australia and New Zealand (ANZ): both are major resource-owners, both are harvesting SBT in their own EEZs, using predominantly purse seine gear with most of the catch going to Australian SBT aquaculture operations, both are members of the CCSBT, and neither is a significant consumer of SBT;
- Japan, Korea and Taiwan (JKT) are major distant water fishing nations, using longline gear to harvest SBT, and are members of the CCSBT. Japan is the major consumer of the total harvest of SBT;
- Indonesia, The Philippines and South Africa (IPSA): 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. For simplicity it will be assumed that each group continues to fish in its current grounds and to sell its catches in the Japanese sashimi market.

Various assumptions about the behaviour of the groups will be considered, particularly in relation to the extent to which they cooperate in the efficient utilization of the SBT stock. While the CCSBT facilitates cooperation among the member nations in agreeing to annual catches, not all participants in the fishery are members, the degree of cooperation among members is limited, and there is the possibility of some level of cooperation between member and non-member nations. To represent this range of possibilities the following set of models will be considered:

- no SBT fishing by any nation;

- the CCSBT regime: the two groups within the CCSBT (ANZ and JKT) and the group outside the CCSBT (IPSA) observe the catch quotas set by the CCSBT. These quotas, in tonnes, are ANZ 5685, JKT 8345 and IPSA 895. Alternatively, ANZ and JKT observe the quotas but IPSA determines its own catch at either a restrained level agreed amongst its members to maximize profit, or at a higher level allowing all its potential profit to be competed away to zero under open-access conditions;

- full cooperation: the three groups combine to agree on the level and structure of fishing effort that maximizes the net present value of their combined returns. The maximum value is then divided among the groups according to some formula to be decided among themselves;

- non-cooperation: the three groups are considered as players in a non-cooperative game. Each group chooses a strategy (its choice of level of fishing effort) and the interaction of the strategies in the context of the bioeconomic model determines the outcome of the game in terms of the payoffs to the three groups. Each group chooses the strategy which will maximize its payoff given the strategies chosen by the other groups; alternatively, ANZ and JKT act as players in a non-cooperative game and IPSA follows policies leading either to profit maximization or zero profit.

Results of the Bioeconomic Model

In the bioeconomic model the initial value of SSB was based on the mean stock numbers by age for 2003 for each of the three values of the steepness parameter, h. From data provided by CSIRO (Kolody et al. (2004)) the initial biomass estimates are: 45,700 tonnes for h=0.4, 41,300 tonnes for h=0.55, and 41,200 tonnes for h=0.8. The main aim of the modelling is to find solutions to problems reflecting alternative behavioural interactions of the fishing parties over a period of 20 years which would be close to the optimal solutions for planning horizons significantly longer than 20 years. The present value of net returns accruing to the fishing parties over 20 years, and the SSB at year 20, are the key indicators of efficiency and conservation respectively. The period of 20 years is chosen because it is the time-frame of the conservation objective. To achieve these results the model planning horizon is 30 years, for reasons discussed shortly.

Given the pessimistic nature of the revised stock recruitment functions reported in Figure 1, it was decided first to run the model with no exploitation of the stock. The results of Runs 1-3, reported in Table 1 and illustrated in Figure 2, suggest that, even with no fishing, the conservation objective can be achieved only under the most optimistic assumption about the stock recruitment function (h=0.8). Under this assumption stock rises to just exceed the conservation target of 144,000 tonnes in year 20, and continues to rise slowly to reach a value of 161,000 tonnes in year 30. Under less favourable assumptions about the stock recruitment function the stock rises at first, based on the mean stock numbers estimated for 2003, but declines thereafter as the new recruits determined by the stock recruitment function begin to predominate in the population; for h=0.55 the stock is estimated to remain close to its current level, whereas for h=0.4 it declines significantly, and perhaps irretrievably.

Stock recruitment functions which lead to a decline in the stock in the absence of fishing are obviously of serious concern. From a modeling perspective it can be argued that such relationships could be valid only if they reflected a change in the biology of the stock from some earlier and more favourable stock recruitment relationship. Otherwise it would have to be asked how the stock had managed to survive to its present state. While the unfavourable stock recruitment relationships are open to question, especially given the possibility noted earlier that the catch data which have been used in the biological modeling are seriously flawed, it does not seem prudent to exclude them from the set of scenarios considered even although they will have serious consequences for the predicted outcomes for the fishery.

The next set of runs was based on the assumption that all parties, whether CCSBT members or not, observe the CCSBT quotas described in Footnote 1. The problem set was to find the level of effort for each year for each of the three participants over 30 years which would result in catches equal to the quotas. No feasible solutions could be found for h values of 0.4 or 0.55 because recruitment dependent on SSB was too weak to generate the catches required. In these cases the longest period over which the quotas could be met was 5 years for h=0.4 and 9 years for h=0.55. A solution for the 30 year planning horizon was found for h=0.8 (Run 4, Table 1) showing a year 30 stock level close to zero. In this case all producers start to make significant losses as catching costs rise due to the stock decline. This suggests that the fishery would become commercially non-viable and that fishing would cease before year 30. The net present value (NPV) of the fishery over a 20 year time horizon (the period before significant losses to producers start to set in) is around $3.4 billion (all values reported are in 1997 Australian dollars).

When we turn to models in which the participants choose effort levels to maximize net returns, either jointly or individually, the use of a finite (30 year) planning horizon poses the problem of what value to impute to stock remaining at the end of the horizon. Cao et al. (2001) have outlined various methods for estimating terminal values for stock at the end of the planning horizon, and have conducted sensitivity analysis on outcomes for models similar to the model used in the present paper. They conclude that model parameter values, initial stock conditions and policy controls can have a significant influence on the choice of an appropriate planning horizon.

The model planning horizon is set at 30 years, with a zero terminal value of fish stock, implying that no value is placed on any stock that might accrue after the terminal date. This means that the model provides less incentive to maintain stocks beyond the 30 year horizon than would be the case if the terminal values were positive. The use of the 30 year planning horizon with zero terminal value means that the effective terminal value assigned to stock at the end of year 20 is the present value from harvesting over the remaining 10 years to year 30. As is argued later, results suggest that the solution for the first 20 years of a model run for a planning horizon significantly longer than 30 years would not be much different from the solution for the first 20 years obtained from the model using the 30 year planning horizon, given a discount rate of 5 percent per annum.

If the planning horizon is really much longer than 30 years, but is not to be extended on computational grounds, a steady-state year, “year 31” can be added to the time horizon, with the requirement that the numbers of fish in each age group at the end of “year 31” are at least as large as those at the end of year 30. If the fishing mortalities for “year 31” which satisfy this requirement are applied for all further years, the stock at the end of year 30 can be maintained indefinitely. The terminal value at the end of year 30 can then be calculated as the present value of the perpetual stream of rents from the steady state fishery with a good degree of accuracy (see Kennedy (2003) for a description and evaluation of this solution method). The method applies to multi-cohort fisheries where steady state stock numbers by age and harvest are eventually reached in the solution to the infinite planning horizon problem. The method does not apply to cases where it is optimal to eventually cease fishing over a finite planning horizon.

Results are reported for the 30 year planning horizon, and for the infinite planning horizon using the method described for joint net return maximisation with h = 0.8. As explained later, in many of the runs with h = 0.4 or 0.55, the optimal solution for the 30 year planning horizon problem is the same as that for an infinite planning horizon problem in which it is optimal to cease fishing before year 30, after which stocks continue to decline indefinitely.

For the two less productive recruitment functions used in the study, however, a steady state combination of catch and harvest maintained indefinitely was not optimal for the infinite planning horizon problem. For recruitment functions with h set equal to 0.4 and 0.55, solutions to the problem of maximising joint net returns over 30 years showed catch decreasing to zero before year 30. Harvesting by JKT and IPSA ceased after year 11 and by ANZ after year 5 for h=0.4 (after years 21 and 14 respectively for h=0.55). There was still stock left to catch, but the low stock level resulted in an increase in harvesting costs sufficient to make it not profitable to continue harvesting. Despite the cessation of harvesting, however, stock did continue to decline in these cases because, as illustrated in Figure 2, recruitment was not sustainable. In these cases, the solutions to the model would remain the same, whether the planning horizon were 30 years or an infinite number of years and the infinite planning horizon solution could not be a steady state solution. For the more productive recruitment function (*h*=0.8), solutions for the infinite planning horizon problem are reported in Table 1.

As an alternative cooperative model to the CCSBT quota regime, the objective of maximizing joint returns to consumers and producers was considered. Runs 5-7, Table 1, represent the economically most efficient exploitation regime for each assumption about the stock recruitment function, leaving aside the issue of conservation. It can be seen from Table 1 that the NPV over a 20 year time horizon varies from $1.42 billion for the most pessimistic assumption about the stock recruitment function to $3.69 billion for the most optimistic assumption. The latter estimate is around 45% of the equivalent value calculated in the Campbell, Kennedy and McIlgorm (2002) paper. Estimated stock levels are low and declining over the 20 year period for *h*=0.4 and *h*=0.55.

In the case of *h*=0.8, SSB increases by 50% over its 2003 level over the 20 year target period. Subsequent to year 20, however, the SSB is predicted to decline to around 120% of the 2003 level by year 30, given a 30 year planning horizon. As noted above, an infinite time horizon solution (Run 7b) is also obtained in the *h*=0.8 case which estimates the stock in year 30 at 63.41 thousand tonnes. This result, which is considerably higher than the 30 year time horizon estimate of 48.53 thousand tonnes, does not incorporate the fishing down effect associated with the finite planning horizon model. In the case in which *h*=0.8, a stock of at least 63 thousand tonnes can be maintained indefinitely from year 30 onwards[8] by following the efficient infinite planning horizon solution.

The next case considered is the situation in which ANZ and JKT observe the CCSBT quotas but IPSA chooses its effort level to maximize the NPV of the profits of its producers. This model again failed to find a feasible solution for the two lower *h* values (see footnote 6). In the case in which *h*=0.8 (Run 8, Table 1) the solution is slightly more favorable in NPV terms than in the case in which all parties observe the CCSBT quotas because the profit maximizing requirement does not allow IPSA to continue fishing once losses start to be made due to low stock levels (NPV20 is $3.48 billion compared with $3.41 billion). However the conservation outcome is still very poor with the stock virtually extinct by year 30 (SSB30 is only 7.12 thousand tonnes under a 30 year planning horizon).

Another possibility is that while ANZ and JKT continue to observe the CCSBT quotas there is no control over the effort of IPSA producers who, instead of choosing their effort level to maximize their profits, contribute effort up to the point at which profit falls to zero. This would be the outcome if IPSA producers were not organized and acted as a competitive open-access fringe. This situation is expected to lead to worse economic and stock outcomes than the previous situation in which IPSA controlled its effort level, and, in fact, no solution was found for all three values of *h*.

The model is now used to predict the outcome of a non-cooperative game in which each of the three players chooses its effort level to maximize its net returns, given the stock conditions resulting from the behaviour of the other two players. Runs 9-11 in Table 1 report the three-party Nash Equilibria generated by the non-cooperative game for each of the *h* values. The NPV results are very similar to, but slightly lower, over the model time horizon of 30 years, than the results of the joint net returns maximization case (Runs 5-7). The closeness of the results of this model to those of the joint profit maximization model is partly due to the game having only three players. The results for an infinite planning horizon (Run 11b) show a lower long run SSB, implying overall higher catches. These result in lower prices and an increase in JKT consumer surplus at the expense of JKT producers.

Finally the model is used to predict the outcome of a non-cooperative game between ANZ and JKT, with IPSA acting as a fringe player allowing its vessels open-access to the SBT fishery. While a Nash Equilibrium to this non-cooperative game could not be obtained under the most pessimistic assumption about the stock recruitment function (h=0.4)[9], solution values were obtained for the other two cases. The results for Runs 12, 13a and 13b show a similar but more accentuated departure from the results of the joint profit maximization model than was found in the case of the three party Nash Equilibrium, but with zero rents for the IPSA fringe player. In the long-run total catch is greater, the tuna price is lower with a consequent gain to consumers, and NPV is lower.

Conclusions

The results obtained from the models raise concerns about the prospects for conserving the SBT stock. The no fishing case is obviously the regime most favorable to the conservation objective but the SSB20 objective is achieved only under the most optimistic of the three assumptions about the stock recruitment function. On less favorable assumptions about the stock recruitment function, a 20 year moratorium on fishing is predicted to result in the stock remaining roughly at its current level or to experience a significant decline.

Continuation of current quota levels under the CCSBT regime, either with the full cooperation of all parties, or with IPSA remaining outside the quota system and either regulating or not regulating its fishing effort, is predicted to lead to virtual extinction of the stock within 30 years. Joint net returns maximization by the parties currently involved in the fishery would lead to stock levels 50% above current levels over the long-run, but only under the most optimistic assumption about the stock recruitment function. A similar result also holds for the situations in which the three players engage in a non-cooperative game, or in which JKT and ANZ engage in a non-cooperative game with IPSA acting as a fringe player. 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.

The revised stock recruitment functions illustrated in Figure 1 suggest that the productivity of the stock is lower than was previously thought. The lower productivity will be reflected in lower economic values under all exploitation regimes. The most efficient exploitation regime is joint maximization of consumer and producer surplus, which, under the most favorable assumption about the stock recruitment function, is estimated to generate, over a 20 year period, a net present value around $3.6 billion, which is just under half of the value estimated from the previous stock recruitment function used in the Campbell, Kennedy and McIlgorm (2002) paper. Under the most likely recruitment function (*h*=0.55) the NPV estimate is about 20% of the previous estimate. Similar net present value results are obtained from the non-cooperative game models involving all three players or ANZ and JKT plus a fringe operator. Under the CCSBT regime NPV is similar to the joint net returns maximization case, with the difference that, even under the most favorable assumption about the stock recruitment function, the NPV is obtained by virtually liquidating the asset over the 30 year time horizon.

The joint returns NPV maximization model clearly suggests that there is a trade-off between the conservation and optimal utilization goals. The only regime which met the SSB20 stock level objective was a moratorium on fishing over a 20 year period, and that result was obtained for the most favorable stock recruitment function. Having said that, there are exploitation regimes which yield similar net present values but have quite different outcomes for the stock: the CCSBT regime, the joint net returns maximization model, and the non-cooperative game models all yield NPVs of around $3.5 billion over a 20 year time horizon under the most favorable assumption about the stock recruitment function, yet the SSB20 level, under either the full CCSBT regime (incorporating Indonesia, The Philippines and South Africa (IPSA) as members) or the current CCSBT regime, with ANZ and JKT observing the quotas and IPSA maximizing its profit, is around only 50% of the stock level achieved under the other regimes, with further significant declines predicted to year 30. This suggests that, to further both the economic and conservation objectives, the combined CCSBT annual catch quota needs to be cut from its present level of around 15,000 tonnes to a level closer to the combined catch levels under these other regimes, which are all well below 10,000 tonnes per annum. This is consistent with the recommendation recently made by the CCSBT on conservation grounds that:

> “the global SBT catch should be reduced to 9,930t for 2006, which corresponds to a 5,000 tonne reduction in the assumed global catch of 14,930t for 2004 and 2005. This level of catch reduction was chosen so that, when coupled with the implementation of a management plan, it would provide an estimated 50% probability that the spawning stock biomass in 2014 (when a minimum is forecast) would be no lower than 2004 spawning stock biomass which is currently the lowest estimated.” (CCSBT (2005), excerpt from paragraph 37)

It must be noted that these conclusions drawn from the bioeconomic model and the recommendation of the CCSBT are predicated on historical reported Japanese catches. They are obviously subject to change if the reported catches and the biological model are revised at some future date.

While no solution could be obtained for the model in which ANZ and JKT observe the CCSBT quotas but IPSA fails to regulate its fishing effort, it can be inferred from the solutions to the other models that the IPSA’s membership in a revised CCSBT regime is very important to both the economic and conservation aims.

It must be emphasized that the models used to generate the results reported in the paper are deterministic. If the stochastic draws of initial stock numbers, mortality and selectivity coefficients for each of the three *h* values used by the CSIRO in modeling were incorporated in a stochastic version of the economic model, economically efficient effort levels would likely be even lower. For example, if the disturbance term on SSB were symmetric about the mean, the concave recruitment schedules to the SSB axis in Figure 1 would mean that the expected values in a stochastic model would show lower stocks, and hence lower optimal levels of fishing effort.

There are significant uncertainties about the accuracy of the catch data which need to be resolved and this may lead to further revisions. Nevertheless the current estimates of the steepness parameter are the best available and have to be taken into account in evaluating the prospects for the fishery and the SBT stock. Based on the subjective probabilities reported in Footnote 2 it can be concluded that h=0.55 is currently the best guess for assessing the stock status and biological parameters. When this value is used in the bioeconomic model, and where solutions could be obtained, the size of the year twenty spawning stock biomass ranges from around 50% above the current level, in the no fishing case, to less than 50% of the current level in the other cases, and the value of the fishery is estimated at just under $2 billion which is around 25% of the estimate obtained from the earlier stock recruitment model.

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Figure 1: SBT Stock Recruitment Functions

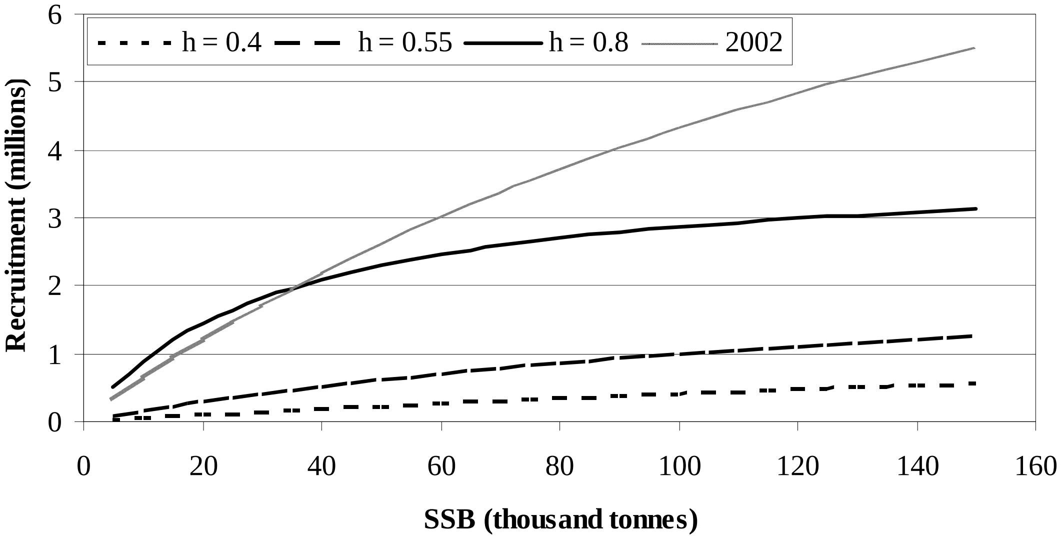

Figure 2: Trends in SBT Spawning Stock Biomass for Alternative Stock Recruitment Functions in the Zero Harvest Case

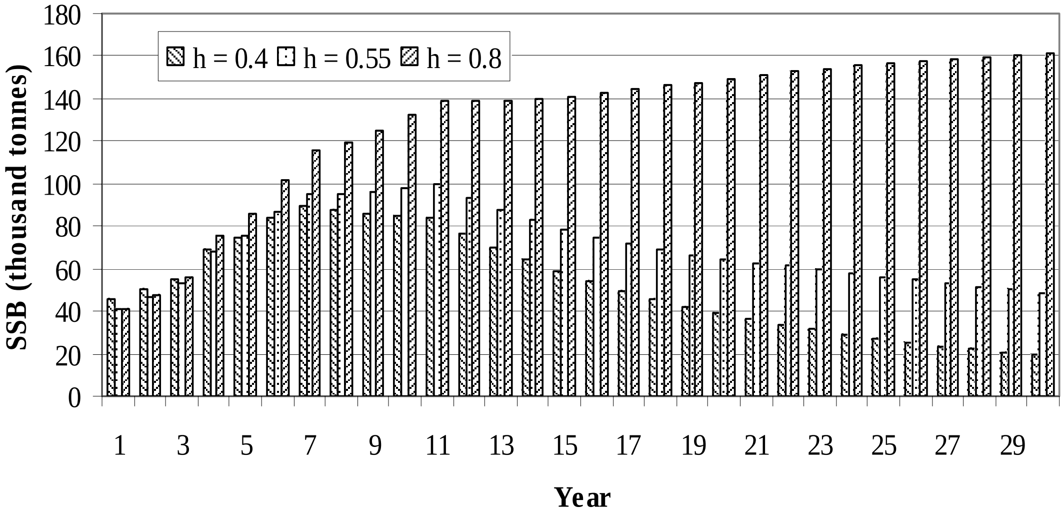

Table 1: Results of the Model Runs

Run	h	Years 1 to 20							Years 1 to 30							
		ANZ	IPSA	JKT				SSB20	ANZ	IPSA	JKT				SSB30	
No.	Value	PS	PS	PS	CS	Total	NPV20		PS	PS	PS	CS	Total	NPV30		NPV∞
No harvests																
1	0.40	0.00	0.00	0.00	0.00	0.00	0.00	39.09	0.00	0.00	0.00	0.00	0.00	0.00	19.15	
2	0.55	0.00	0.00	0.00	0.00	0.00	0.00	64.53	0.00	0.00	0.00	0.00	0.00	0.00	48.90	
3	0.80	0.00	0.00	0.00	0.00	0.00	0.00	149.52	0.00	0.00	0.00	0.00	0.00	0.00	161.38	
All parties observe CCSBT quotas																
4	0.80	0.09	0.03	0.51	2.77	3.28	3.41	29.41	-0.16	-0.17	-2.69	3.42	0.73	0.40	1.70	
Joint net return maximization																
5	0.40	0.14	0.04	0.59	0.65	1.24	1.42	16.82	0.14	0.04	0.59	0.65	1.24	1.42	8.33	
6	0.55	0.19	0.05	0.87	0.73	1.60	1.84	24.91	0.19	0.05	0.87	0.73	1.60	1.84	21.57	
7a	0.80	0.53	0.10	1.51	1.55	3.06	3.69	63.15	0.61	0.11	1.74	2.00	3.74	4.46	48.53	
7b	0.80	0.53	0.10	1.55	1.47	3.02	3.64	65.52	0.64	0.12	1.89	1.72	3.61	4.36	63.41	5.46
ANZ and JKT observe CCSBT quotas, IPSA maximizes profit																
8	0.80	0.11	0.08	0.60	2.70	3.30	3.48	32.39	-0.05	0.08	-0.74	3.32	2.58	2.61	7.12	
Three-party Nash Equilibrium																
9	0.40	0.15	0.04	0.58	0.65	1.23	1.42	16.72	0.15	0.04	0.58	0.65	1.23	1.42	8.31	
10	0.55	0.20	0.05	0.81	0.77	1.58	1.84	24.49	0.20	0.05	0.81	0.77	1.58	1.84	21.24	
11a	0.80	0.53	0.10	1.47	1.61	3.07	3.71	61.00	0.64	0.12	1.68	1.99	3.67	4.43	49.04	
11b	0.80	0.53	0.10	1.51	1.54	3.06	3.69	61.24	0.63	0.12	1.83	1.79	3.61	4.37	59.41	5.43
ANZ and JKT form a duopoly, IPSA operates on an open-access basis																
12	0.55	0.00	0.00	0.94	0.72	1.65	1.65	31.52	0.00	0.00	0.94	0.72	1.66	1.66	25.03	
13a	0.80	0.53	0.00	1.48	1.66	3.13	3.66	59.28	0.64	0.00	1.69	2.03	3.72	4.36	47.36	
13b	0.80	0.53	0.00	1.51	1.61	3.12	3.64	59.59	0.63	0.00	1.82	1.84	3.66	4.29	57.97	5.30

Notes:

The planning horizon is 30 years for all runs except for runs 7b, 11b and 13 b for which the horizon is infinite.

Net Present Values (NPVs) are calculated using a 5% rate of discount and are in billions of 1997 Australian dollars (one 1997 $AUS=$US 0.76);

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;

NPV∞ = NPV of all nations’ PS and CS over an infinite period;

SSB20 = spawning stock biomass after 20 years (thousands of tonnes);

SSB30 = spawning stock biomass after 30 years (thousands of tonnes);

Totals may not add due to rounding.

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[1] The 2005-06 quotas (in tonnes) are: Japan 6065, Australia 5265, New Zealand 420, Korea 1140 and Taiwan 1140. If other participants in the fishery become cooperating members their proposed quotas are: Indonesia 800, The Philippines 50, South Africa 45.

[2] The Beverton-Holt stock recruitment function is: $R = \alpha X/(\beta + X)$ where R is recruitment numbers and X is SSB in tonnes. The values of the parameters α and β depend on the value chosen for the steepness parameter, *h*, according to $\beta = SSB_{unfished}(h-1)/(1-5h)$ and $\alpha = R^*(\beta + SSB_{unfished})/SSB_{unfished}$, where R* is recruitment numbers given for the start of model year 1. Three values of *h* are considered: 0.4, 0.55 and 0.8, with subjective probabilities (assigned by scientists from the CCSBT Scientific Committee) of 0.2, 0.6, and 0.2 respectively.

[3] Hagen Stehr, quoted in The Weekend Australian February 11-12, 2006.

[4] The audit found that the Japanese 2005 SBT quota had been overfished by 25%. For details see http://www.taipeitimes.com/News/world/archives/2006/03/03/2003295497.

[5] The chief executive of the Australian Fisheries Management Authority has been reported as alleging that Japan has illegally caught well in excess of its quota over the past 20 years, based on an investigation by the CCSBT (Andrew Darby and Penelope Debelle in The Age, 19 August 2006).

[6] During August 2006, under 'Recent News' on the CCSBT website, the CCSBT stated that independent reviews of Japanese SBT market data and Australian SBT farming operations would be taken into account in a stock assessment which would be discussed at the annual meeting in October. No conclusions had been reached and all matters were still under consideration.

[7] Market prices, in 1997 yen/kg, for the various fleets are: Japan – 3485; Australia and New Zealand (ANZ) – 2018; and 1753 for the other fleets. The price obtained by Japan, Korea and Taiwan (JKT) is taken to be an average, weighted by the quota shares, of the prices received by the Japanese and the Korean and Taiwanese fleets – 3012 yen/kg. Cost per unit effort is set at 96% of the initial year's revenue for the longline fleets (all fleets except ANZ) and at 75% for ANZ whose vessels are predominantly purse seiners. An exchange rate 90.03 yen/$AUS is used to convert values to Australian dollars (International Monetary Fund 1999, International Financial Statistics, Vol LII, No.3, IMF Publication Services, Washington).

[8] Note that SSB20 for run 7a (30 year planning horizon) is 95 per cent of SSB20 for run 7b (infinite planning horizon), indicating that the 30 year planning horizon problem gives SSB20 values which are a reasonable approximation to SSB20 under an infinite planning horizon.

[9] This suggests, but does not prove, that a Nash Equilibrium does not exist for this case. This would not be surprising given the very low SSB solutions obtained for the three-party case.