Estimated target fleet capacity for the tuna fleet in the eastern Pacific Ocean, based on stock assessments of target species

Pablo Arenas
Inter-American Tropical Tuna Commission
8604 La Jolla Shores Drive
La Jolla, California 92037-1508, USA
E-mail: parenas@iattc.org

ABSTRACT

Tunas are exploited by purse-seine and longline gear in the eastern Pacific Ocean. Purse-seine sets are made on tunas associated with dolphins, tunas associated with floating objects and tunas in unassociated (free-swimming) schools. Sets made on tunas associated with dolphins catch almost entirely yellowfin tuna, and most of these are relatively large. Sets made on tunas associated with floating objects catch mostly skipjack tuna, but also significant amounts of yellowfin and bigeye, most of which are relatively small. Sets made on tunas in unassociated schools catch yellowfin and bigeye of intermediate sizes and skipjack. Longline gear takes large yellowfin, bigeye, albacore and billfishes. The extents to which the various species and the sizes of fish of those species are exploited can be controlled by limiting the effort expended by the various fisheries, but it would be difficult or impossible to exploit all the species at the optimum levels. In general, there is more than enough fishing capacity to fully exploit all the species except skipjack.

1. INTRODUCTION

The first meeting of the Working Group on Limiting the Growth in Capacity of the Purse-Seine Fleet in the Eastern Pacific Ocean (which later became known as the Permanent Working Group on Fleet Capacity) of the IATTC on 3-4 September 1998 formally examined for the first time the question of the "capacity" (meaning fish-carrying capacity) of the purse-seine fleet that fishes for the tunas in the eastern Pacific Ocean (EPO). The document *Considerations Regarding Limiting the Growth in Capacity of the International Tuna Purse-Seine Fleet in the Eastern Pacific Ocean* prepared for that meeting, based mostly on yellowfin tuna (*Thunnus albacares*) stock assessments, concluded that "the current carrying capacity of the fleet, 135,000 [metric] tons, is large enough to generate the amount of fishing effort or mortality required to catch the [average maximum sustainable yield (AMSY)] of yellowfin and the recommended catch of bigeye [*T. obesus*] from the EPO. It is also capable of generating the amount of fishing effort that produced the highest catch of all species combined in the history of the fishery."

As a result of the standardization of well volumes in the Regional Vessel Register of the IATTC, the figure of 135 000 tonnes has been converted into 158 000 m^3, using a multiplier of 1.17, and this rounded figure has been used since 1999 in various documents and resolutions of the IATTC as the maximum target carrying capacity for the purse-seine fleet. While the relationship between carrying capacity in ones and well volume depends on a variety of factors, including the size of fish loaded and the management of the wells, and, in fact, values of 1.4 are more common today, the conversion of 1.17 approximates the United States shipyard calculation of carrying capacity of most of the vessels whose data led to the target of 158 000 m^3.

This target figure of 158 000 m^3 has been reviewed and discussed at meetings of several IATTC working groups and at meetings of the IATTC. For example, at the fourth meeting of the Permanent Working Group on Fleet Capacity on 31 July-2 August 2000, the target capacity was extensively discussed, and alternative target capacities arising from different management regimes were considered. At the sixth meeting of the Permanent Working Group on Fleet Capacity on 7-8 March 2002, the target figure for the purse-seine fleet was again discussed, taking into account especially the developments in the fishery since 1998, particularly the increased catches of skipjack tuna (*Katsuwonus pelamis*). The 69th meeting of the IATTC on 26-28 June 2002, also considered the 158 000 m^3 target capacity of the purse-seine fleet, and endorsed it within the context of the *Resolution on the Capacity of the Tuna Fleet Operating in the Eastern Pacific Ocean (Revised)* adopted at that meeting.

The issue of establishing a target capacity for the longline fleet is a more recent one, and has been considered formally only in the last few assessments. The Permanent Working Group on Fleet Capacity, at its seventh meeting on 20-21 February 2004, requested that the fifth meeting of the Working Group on Stock Assessment on 11-13 May 2004 discuss target capacities for both the purse-seine and longline fleets. The group concluded that the 158 000 m^3 limit seemed appropriate for the purse-seine fleet, from the point of view of optimizing the purse-seine fishery for yellowfin tuna. The group looked also at the suitability of several methods for the control of longline capacity, and concluded that, given management trade-offs and the factors affecting the various tuna fisheries, and considering the potential increase in fishing power of the fleets, the optimal capacity for both components of the tuna fleet would continue to be a moving target. The 72nd IATTC meeting, which took place on 14-18 May 2004, endorsed these views. In summary, a target capacity for the longline fleet has not been established, although effort limits were applied to it during 2004 and 2005.

This document reviews again the question of the target capacity of the tuna purse-seine fleet of the EPO, and offers some views on a possible target capacity for the longline fleet that fishes for tunas and billfishes in the EPO, based mostly on the results of the annual stock assessments carried out by the IATTC staff.

2. FACTORS AFFECTING THE FISHERIES AND MANAGEMENT TRADE-OFFS

The management objectives of the IATTC were established by its 1949 Convention, which states that its principal objective is to "keep the populations of fishes covered by [the] Convention at … levels of abundance which will permit the maximum sustained catch." In the 1949 Convention there is no specific mention of controls for fishing capacity, but it refers to "the effects of [both] natural factors and human activities on the abundance of the populations of fishes supporting all of these fisheries." Various instruments to implement this management goal have been established, especially recently, including establishment of effort or capacity controls for the tuna fleet in the EPO.

The most important management instruments regarding control of tuna fishing capacity in the EPO currently include the *Resolution on the Capacity of the Tuna Fleet Operating in the Eastern Pacific Ocean (Revised)* of June 2002, and the *Plan for Regional Management of Fishing Capacity* of June 2005. Both of these instruments rely upon the vessel register established by the *Resolution on a Regional Vessel Register* of June 2000, and the *Resolution on the Establishment of a List of Longline Fishing Vessels over 24 Meters (LSTLFVs) Authorized to Operate in the Eastern Pacific Ocean* of June 2003.

A new convention, the "Antigua Convention" (open for ratification or accession since 2003) preserves the general objective of maintaining populations of harvested species at levels that can produce the maximum sustainable yields, while introducing more specific provisions regarding the application of the precautionary approach, the possibility of different management objectives for species belonging to the same ecosystem and management references to levels of fishing capacity. Specifically, it refers to "measures to prevent or eliminate … excess fishing capacity and to ensure that levels of fishing effort do not exceed those commensurate with the sustainable use of the fish stocks covered by this Convention."

Considering management goals and the factors affecting the fishery, it is difficult to establish a size to which the tuna fleet in the EPO should be limited. In the EPO this is complicated by the fact that there are two main types of fishing gear (purse-seine and longline). More complexity is added by the fact that there are three main modes of purse-seine fishing (for unassociated schools of tunas and for tunas associated with dolphins or with floating objects) and that more than one species is frequently caught in a single set.

One possible approach to the establishment of a target capacity would be to keep it at a level that could take the maximum harvest from the fishery, while at the same time ensuring the sustainability of each stock. However, in the multi-species and multi-gear situation of the EPO this objective could be realized only by developing independent species-specific fishing methods and management objectives. The question of an "optimal" fleet capacity depends largely on management objectives.

Given the current mix of fishing gears, set types and species in the fishery, it is logical and prudent to take into account in the establishment of target figure limits the status of the yellowfin stock and the fishery-related connections between the bigeye and skipjack stocks, particularly considering the fact that a large part of the fleet is not targeting yellowfin, and the fact that the catches of skipjack have increased considerably since 1995.

Another important factor, when considering any index leading to tuna fishing capacity control, is the efficiency of the fleet. Because improvements in fishing gear, equipment and techniques generate more effective effort and more fishing mortality, any figure for the "current" optimal fleet capacity must be considered as an upper limit for the desired target. In the case of the purse-seine fisheries, it also depends to a large extent on the size composition of the fleet, as vessels of different capacity classes usually have different fishing efficiencies.

The target fleet capacity will also clearly depend on the productivity of the stocks, which changes over time. In the EPO, regime shifts have occurred at decadal intervals, which might have affected productivity of fish stocks, especially yellowfin tuna, and other components of the ecosystem.

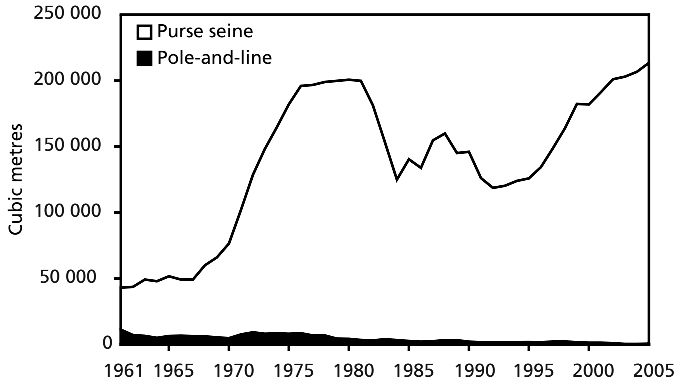
3. TARGET CAPACITY OF THE PURSE-SEINE FLEET

One reason for limiting the capacity of the fleet is that otherwise the catches per vessel will decline, and the economic pressures on individual vessels will be so great that it would be very difficult to sustain an efficient conservation programme. In general, two approaches to establishing a target capacity for the purse-seine fleet could be considered, one based simply on historical fleet capacity and its management repercussions, and the other on data on catches and assesssment indicators, such as catch per unit of effort, yield per recruit and total spawning biomass.

3.1 Fleet carrying capacity and management repercussions

In the EPO, the past management of tuna fisheries can be considered in relation to historical purse-seine tuna fleet carrying capacity. This carrying capacity increased rapidly during the early 1970s, reaching 196,500 m^3 in 1980-1981. It then decreased to 121,650 m^3 in 1984, and remained at an average of about 135 000 m^3 until the mid-1990s, when it began to increase again. The fleet carrying capacity was 182 000 m^3 in 1999, and increased to 213 000 m^3 by the end of 2005 (Figure 1).

FIGURE 1
Carrying capacities of tuna purse-seine and pole-and-line vessels in the eastern Pacific Ocean



Restrictions on fishing for yellowfin in the Commission's Yellowfin Regulatory Area (CYRA), which includes the portion of the EPO that produces most of the catches of tunas, were imposed during the late 1960s, and from 1969 and through 1976 the fishery was open to unrestricted fishing for only 3 or 4 months per year. This coincided with the period of fleet expansion during those years. The fishing season was somewhat longer during the late 1970s, and there were no restrictions from the early 1980s until 1997. Again, this coincided with drastic reductions in fleet carrying capacity, followed by a period of relatively low fleet carrying capacity. Tellingly, when the size of the fleet began to increase again in recent years, there was a need for restrictions once more, beginning in 1998.

The techniques for purse-seine fishing continued to evolve during 1980-1997. In particular, the development of fish-aggregating devices (FADs) provided much greater access by purse-seiners to skipjack and bigeye tuna, and thus part of the fleet's capacity was directed at those species. As well, the technologies available for fishing for yellowfin with dolphins improved, and the productivity of yellowfin appeared to increase after 1983 (Hoyle and Maunder, 2006). While conservation problems began to appear at roughly the same fleet carrying capacity, the catches were greater during the 1990s than they were during the years leading up to 1980.

Although there are variations in the closures by species and set types, restrictions averaging about 58 days (up to 2005) have been recommended for each year since 1999, the year in which the fleet carrying capacity grew considerably beyond the target carrying capacity of 158 000 m^3, to 180 000 m^3. Under this simple reasoning, the purse-seine fleet is therefore at least 16 percent (58/365) above the carrying capacity that would produce the effort necessary for the season to last the whole year. For example, the fleet carrying capacity was 213 000 m^3 by the end of 2005; reducing this by 16 percent would result in a total carrying capacity of 179 000 m^3, which is greater than the target level of 158 000 m^3.

As the closures are the result of the interaction of stock status and fleet performance, the results of this simple analysis are consistent with the original conclusion that a purse-seine fleet carrying capacity of a maximum of about 158 000 m^3 is capable of producing the amount of effort that would keep the fishery and the stocks in good condition. If the purse-seine fleet carrying capacity were at levels of the early 1980s and early 1990s, there would probably be no need to shorten the fishing season to conserve yellowfin tuna.

This simple approach could be refined if the number of sets that the purse-seine fleet makes is considered as a proxy for purse-seine capacity. During 1999-2003 about 40 percent of purse-seine effort, or 10 800 sets per year, was directed at tunas associated with dolphins. This mode of fishing is conducted exclusively by large vessels, defined as vessels with carrying capacities of more than 363 tonnes, and the catches (221 800 tonnes on average) consist predominantly of medium to large yellowfin. Reducing this by 16 percent would bring the annual number of sets on tunas associated with dolphins to about 9 000, a level commensurate with the 158 000 m^3 total carrying capacity target.

During the same period, almost 40 percent of the effort (10 300 sets per year) took fish in unassociated schools. This type of set is conducted by a mixture of small (55 percent) and large vessels (44 percent), and the annual average catch of 150,500 tonnes is also a mixture of small yellowfin (60 percent) and skipjack (39 percent). Very few bigeye are taken by this mode of fishing. Reducing this by 16 percent would bring the annual number of sets on unassociated schools to about 8,700, also a level commensurate with the 158 000 m^3 total carrying capacity target.

During the same period, purse-seiners that fish for tunas associated with floating objects accounted for about 21 percent of the effort, or about 5 800 sets per year (13 percent on flotsam, 85 percent on FADs and 2 percent unknown). Almost 90 percent of this mode of fishing is carried out by large vessels, and the catch of marketable tunas (232 500 tonnes, on average) is a mixture of the three main species (18 percent small yellowfin, 63 percent skipjack and 18 percent small bigeye). Reduction in fishing effort on floating objects, especially for large vessels fishing on FADs, is needed to conserve bigeye. The most recent assessment for bigeye (Maunder and Hoyle, 2006) indicated that a 16 percent capacity reduction would not be not enough. Unless some way were found to avoid bigeye, a reduction of up to about 50 percent would be necessary for this sector of the purse-seine fleet, reducing the number of sets per year to around 2,900.

The resulting total of about 20 600 sets represents a reduction of about 23 percent from the annual average of 26 900 sets of all types during 1999-2003. Applying this reduction to the average fleet capacity at the end of 2005 yields a target fleet carrying capacity of about 164 000 m^3, a level more in line with the results of recent assessments.

3.2. Stock assessments and simulations

The issue of an optimal capacity for the EPO purse-seine fleet can also be studied by simulating various levels of fishing mortality for the three set types, and then examining fishery indicators, such as yield per recruit, spawning biomass and catches of the three main species of tuna (yellowfin, skipjack and bigeye) in the different set types. These simulations have been part of the regular assessment work of the IATTC staff for the last few years.

The approach was first specifically used to examine the issue of target carrying capacity for the purse-seine fleet in an analysis of the maximum number of sets on floating objects that the fishery could support, prepared for the 68th meeting of the IATTC (19-20 June 2001), and in a study of alternatives to the proposed carrying capacity target of 158 000 m^3 reported in the background paper for the fourth meeting of the Permanent Working Group on Fleet Capacity, held in Panama on 31 July-2 August 2000. Similar studies have been carried out regularly since 2000.

In these studies, typically, the sustainable yields are estimated for each of the three species, for both the surface and longline fisheries, because management decisions taken for the purse-seine fleet affect other components of the fishery. The estimates for yellowfin, skipjack and bigeye have been made using the A-SCALA stock assessment model of Maunder and Watters (2003). (A simpler procedure that assumes that the catch is proportional to fishing effort was used earlier for skipjack.) The results of these studies have been very consistent.

For example, in one of the more detailed studies (Maunder and Watters, 2002), the 1999 levels of fishing effort were used as the base case, and the effort that would maximize the yellowfin catch was estimated, using combinations of various levels of effort for the three modes of fishing. In another set of simulations in the same study, effort levels of 40 percent greater than the 1999 level and 40 percent less than the 1999 level were used for the three types of purse-seine sets.

Results of this study showed that if the capacity of the part of the fleet fishing only for tunas associated with dolphins were increased by 90 percent the fishery would still be sustainable. However, this would reduce the spawning biomass to only 16 percent of its unexploited level, increase the catch of yellowfin tuna by only 5 percent (11 000 tonnes) and reduce the average catch per vessel fishing for tunas associated with dolphins by about 50 percent. Thus, while the fishery would still be sustainable if the capacity of the fleet fishing for tunas associated with dolphins were allowed to increase, the catch per vessel would be significantly reduced, and the catch would be only slightly increased. If, in addition, the effort on floating objects and unassociated schools were reduced to 75 percent of the 1999 level, the catch of skipjack would decrease by 66 000 tonnes, while that of bigeye (by purse seiners and longliners combined) would increase by only 2 000 tonnes.

In general, because the curve that relates yield to fishing effort for yellowfin tuna is flat near the average maximum sustainable yield (AMSY), increases or decreases in fleet capacity would have relatively little effect on the AMSY of yellowfin. Thus, these results (and the consistent simulations carried out each year as part of the regular assessment work of the IATTC staff) show that there are advantages for the fishery in maintaining a fleet size that maximizes the combined catch of yellowfin, skipjack and bigeye, while keeping catch per vessel and longline catches at healthy levels. A total capacity of 158 000 m^3 for the purse-seine fleet would achieve this result.

4. TARGET LONGLINE FLEET SIZE

What is usually considered to be the longline tuna fleet in the EPO consists mostly of "industrial" vessels with overall lengths greater than 24 m, with freezing capability. These are referred to in recent IATTC documents as LSTLFVs (large-scale tuna longline fishing vessels).

The problem of establishing a target carrying capacity for this fleet is, in some respects, similar to that for the purse-seine fleet. However, the data for the purse-seine fleet are much more extensive and detailed; for example, only recently have catch and effort data been available for all the major longline fleets fishing in the EPO, and those data only for the last few years. Annual data for some large-scale fleets and for the numerous artisanal vessels in the EPO are unavailable, and the IATTC's Regional Vessel Register is more nearly complete for purse-seine vessels than for longline vessels. However, even if it were complete, the Register, in many cases, simply lists all longline vessels authorized to fish in the EPO, and would not be useful for determining which vessels were actually fishing in the EPO during any given period.

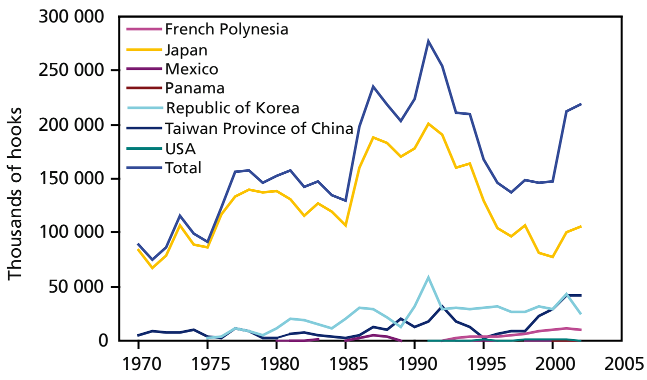
One important difference between the purse-seine and longline fisheries is that the latter generally catch large fish, so most of their catches in the EPO consist of bigeye and, to a lesser extent, yellowfin and albacore (*Thunnus alalunga*) tuna. Only small amounts of skipjack are taken by the longline fleet. Some longline vessels direct their effort at swordfish (*Xiphias gladius*), and significant amouts of marlins and sharks are taken by the longline fishery directed at tunas.

Although the issue of longline effort has been discussed extensively in recent years, the question of the number of LSTLVs and of the "optimal" longline carrying capacity has not been approached formally. However, the declining catches and catch rates, and the status of some of the stocks, have led some governments to seek ways to reduce the capacity of the longline fleet. In this regard, Japan's initiative to reduce the number of LSTLVs in its fleet by 20 percent by scrapping 132 vessels, in accordance with the FAO *International Plan of Action for the Management of Fishing Capacity*, is noteworthy. In recent resolutions by the IATTC, states and fishing entities with LSTLVs have been encouraged to undertake similar initiatives and to not increase their fishing effort in the EPO. During 2005-2006 the Taiwan Province of China has been carrying out a fleet reduction programme, which involves scrapping 160 large-scale vessels, including vessels that were or are currently operating in the Pacific Ocean. The Republic of Korea and other states with longline vessels have taken, or are considering taking, similar steps.

4.1 Fleet size and conservation

FIGURE 2

Longline fishing effort in the eastern Pacific Ocean



The annual longline catches of bigeye by the Japanese fleet, which is larger than any other longline fleet in the EPO, fluctuated around 50 000 tonnes during 1970-1985. The longline catches increased during the late 1980s and the early 1990s, reaching a peak of 85 000 tonnes for Japan and 104 000 tonnes for all fleets combined in 1991. Thereafter they declined, to a low of 36 000 tonnes for all fleets combined in 1999, and have fluctuated between that and 73 000 tonnes since then. The annual combined catch of yellowfin remained relatively stable between 13 000 and 29 000 tonnes during 1985-2004.

The nominal effort for Japan was more than 100 million hooks from 1976 to 1996, ranging from 104 million to 200 million in 1991, and then declining to 79 million in 2000. The nominal effort for Japan, the Republic of Korea and the Taiwan Province of China combined was 133 million hooks in 2000. However, in 2001 the effort by Japanese vessels increased to 102 million hooks, and that for Japan, the Republic of Korea and the Taiwan Province of China combined increased to 230 million hooks. In 2002 the effort for those three countries combined increased to 279 million hooks (Figure 2).

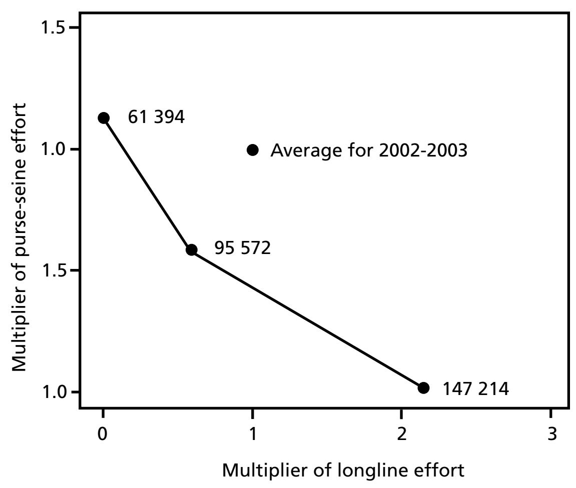
Until recently, there have been no restrictions on the longline fishery in the EPO. Thus, in considering a target fleet size for the EPO, the approach of calculating target capacity based on recent closures used for the purse-seine fleet would not work. The first management measures of this kind were implemented in 2004 and 2005, with the objective of ensuring that the annual longline catches of bigeye in the EPO would not exceed the level of 2001.

4.2 Stock assessments and simulations

In general, the assessment simulations described in Section 3, in which the effort of the different purse-seine set modes was varied, have consistently shown that the longline catch of bigeye would increase if the purse-seine effort on floating objects were reduced, and that the longline catches of yellowfin would increase appreciably if the purse-seine effort were drastically reduced. The studies have shown that reducing purse-seine effort directed at small fish would increase the spawning biomasses of yellowfin and bigeye, and the yields per recruit and catches of those two species taken by the longline fleets. However, such a reduction would also reduce significantly the large purse-seine catch of skipjack.

The most detailed study to date of the purse-seine and longline fisheries in the EPO was carried out by Maunder and Hoyle (2006). This study takes into account low levels of recruitment and increased mortality, considers effort reductions for purse seiners and longliners separately and together, and thus provides insight into the interactions of the two gears. The projections indicated that if the fishing mortality continues at the 2002 and 2003 levels, the longline catches and the spawning biomass ratio (ratio of current spawning biomass to that of the unfished population) of bigeye would decrease to extremely low levels. The purse-seine fishery on floating objects has the greatest impact on the bigeye stock, so various combinations of levels of purse-seine and longline effort could be used to produce the average AMSY. Restrictions that applied

FIGURE 3
AMSYs, in tonnes, of bigeye at various combinations of multipliers of the average longline and purse-seine fishing effort for 2002-2003



only to the longline fisheries would be insufficient to allow the stock to rebuild to levels that would support the AMSY. However, if either purse-seine or longline fishing were eliminated, the fishery would be sustainable at near maximum levels for the other fishing gear. If both longline and purse-seine fishing were reduced by the same fraction, a reduction to 57 percent of the 2002-2003 effort would produce conditions at which the AMSY could be achieved. The results, based on the assessment of Maunder and Hoyle (2006: Table 5.3), are summarized in Figure 3, which shows the optimal fishing effort for bigeye for the purse-seine and longline fisheries. For any given level of longline effort, the graph shows the corresponding purse-seine effort that would allow the AMSY to be taken, and vice versa. If only the purse-seine fishery were operating, the AMSY would be considerably less, but the current effort would be at about the level corresponding to the AMSY. This suggests that if there were no longline fishery, the current purse-seine effort would be near optimal with a smaller AMSY. If bigeye were caught only in the longline fishery, the AMSY would be almost double that estimated for the two gears combined. To achieve this AMSY level, the longline effort would have to be doubled, to more than the levels observed in the late 1980s and early 1990s. This suggests that, prior to the expansion of the purse-seine fishery on floating objects, the bigeye stock was probably near a level that would have produced an AMSY of more than 100 000 tonnes.

The level of fishing effort by the two gears corresponding to the AMSY shown in the middle of the graph is about 57 percent of the average for 2002 and 2003 level of effort, assuming that fishing mortality is proportional to fishing effort, and the patterns of age-specific selectivity in both fisheries are maintained. Reducing combined effort by 43 percent increases the long-term average yield of bigeye, and would increase the spawning biomass of the bigeye stock significantly.

As Maunder and Hoyle's (2006) study and similar assessments and simulations show, the implications for fleet capacity in the EPO depend on how reductions in effective effort are made. The main target species for longlines is bigeye, and changes in fishing mortality are roughly proportional to changes in the number of vessels or the numbers of hooks deployed. Greater sustained catches of bigye are obtainable with greater reductions in purse-seine effort. However, the purse-seine fishery on floating objects catches mostly skipjack, and it may be possible to reduce its effective effort on bigeye by changing fishing practices, as Harley, Tomlinson and Suter (2004) showed that a few vessels were responsible for a relatively large portion of the catch of small bigeye. Although it could be an effective overall conservation measure, simply reducing the fleet size is probably not the best way of reducing effective fishing effort on bigeye.

In summary, it is clear that the fishing effort for both fleets combined is more than what would be desirable for bigeye conservation. However, the choice of what changes in each of the fleets to reach an optimal position on the graph is a management decision to be made by the Commission.

5. PARTITIONING FISHING EFFORT

The multi-species, multi-gear issues in the EPO might be simplified by separating two aspects of the fishery. The first is simply the purse-seine fishery for yellowfin associated with dolphins. The second is a combination of the longline fishery targeting bigeye tuna and the purse-seine fishery on floating objests that catches mostly skipjack and bigeye tuna. Together these take about 80 percent of the yellowfin, skipjack and bigeye catches in the EPO. The fisheries are largely separate, as different nets are used by purse-seiners directing their effort towards tunas associated with dolphins and those directing their effort towards tunas associated with floating objects. For a first approximation, the optimization of fishing effort for the EPO can be addressed separately for these two fisheries. The approach does not take into account the effect on the total yield and sustainability of the stock of the yellowfin caught in sets on floating objects or sets on unassociated schools, nor in the longline fishery. These would be affected by controls on the vessels directing their effort at tunas associated with dolphins or floating objects, as the larger vessels, at least, target primarily tunas associated with either dolphins or floating objects, and make sets on unnassociated schools opportunistically. An approach to this type of analysis is described briefly below.

5.1 Purse-seine vessels taking yellowfin associated with dolphins

Since 1993, each purse-seine vessel that fishes for yellowfin associated with dolphins in the EPO has been required to have a dolphin mortality limit (DML). The number of such vessels has been relatively stable. An average of about 100 purse-seine vessels held DMLs during each year from 1993 to 2006, and during 2002-2006 the number has ranged from 93 to 108.

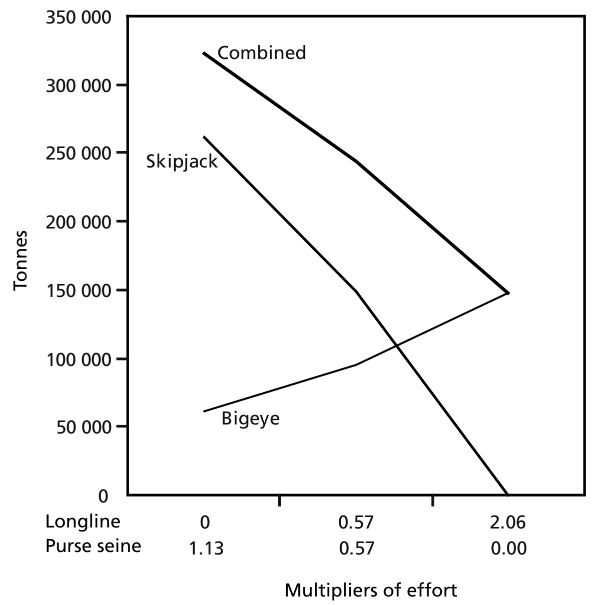
Carrying capacity limits on the purse-seine vessels with DMLs could be used as the principal control directed at bringing the carrying capacity of the fleet into line with the productivity of the yellowfin stock. Carrying capacity controls on the vessels with DMLs would, of course, also limit the catches that those vessel could make on tunas not associated with dolphins. The analyses described in Section 3.1 above suggest that a relatively modest reduction of fishing for tunas associated with dolphins is desirable.

5.2 Purse-seine vessels using FADs and longline vessels targeting bigeye tuna

The AMSYs of bigeye corresponding to different combinations of fishing mortality for longline and purse-seine fishing effort are shown in Figure 3. The AMSY of skipjack in the EPO is not known, but at levels near or below current purse-seine effort (in view of the assessment of Maunder and Harley, 2005) it seems reasonable to assume that the catch is roughly proportional to the fishing effort. Using that assumption and the estimates of the AMSY of bigeye from the purse-seine and longline fisheries, Figure 4, showing the AMSY of bigeye and the corresponding sustained yield of skipjack as a function of longline (or purse-seine) effort, can be constructed.

FIGURE 4

Catches of bigeye, skipjack and both species combined at various combinations of multipliers of the average longline and purse-seine fishing effort for 2002-2003



An approach like this could be elaborated as an aid to making decisions about the levels of longline and purse-seine fishing effort to catch skipjack and bigeye.

6. DISCUSSION

It is clear that trade-offs of many types must be carefully considered in the management of fishing capacity based on the results of stock assessments for target species, and particularly in establishing target capacities for the two major fleets of the EPO. This is especially important in the case of bigeye, because the optimal size of one fleet depends on that of the other. It is also true for yellowfin, as the longline fleet takes large individuals that are not vulnerable to the purse-seine fleet, although the longline catches of yellowfin are not as important as those of bigeye.

The most important results from assessments and simulations performed by the IATTC staff during the past few years, assuming that the effort for one mode of fishing is drastically reduced, are summarized in Figure 5. Effects of effort reductions are shown in the columns for the three modes of purse-seine fishing and for the longline fleet. The effects of these reductions on the catches and spawning biomass ratios are shown in the rows for the three main species. Large increases or decreases are shown as circles with plus or minus signs inside them, respectively.

In general, simulations have shown that a large decrease in effort on floating objects by the purse-seine fleet would bring about a relatively large increase in bigeye spawning biomass, and have also shown that reduction in purse-seine fishing effort directed at unassociated schools would increase the spawning biomass of yellowfin, but cause moderate decreases in the purse-seine catches of bigeye and skipjack. Studies have also shown that fishing on dolphin-associated schools essentially affects only yellowfin. Large decreases in longline fishing effort alone would bring about only moderate increases in the spawning biomass of bigeye, but large reductions in the longline catches of bigeye and yellowfin.

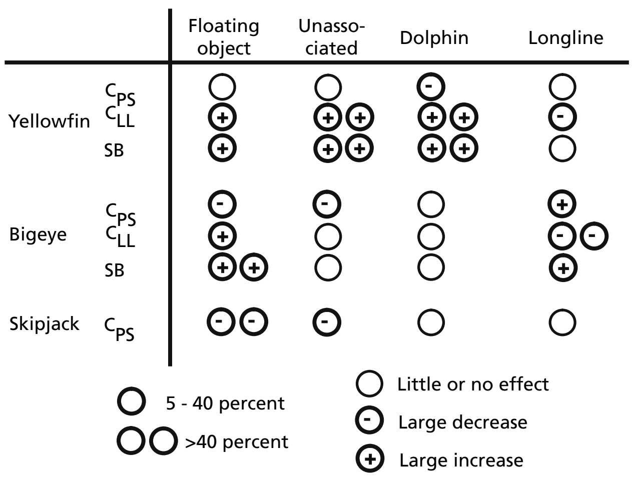
It is clear from the assessment results and simulations that the current carrying capacity of the purse-seine fleet, estimated at 213 000 m^3 in 2005, is above the level appropriate for proper management and conservation of yellowfin and bigeye tuna. Similarly, the current longline fleet size is above the level appropriate for bigeye tuna, given the current fishing practices of the purse-seine vessels using floating objects.

As we have seen for yellowfin tuna, a target capacity of 158 000 m^3 still seems appropriate from the point of view of optimizing the capacity of the purse-seine fleet to fish for this species.

For bigeye tuna the situation is more complex, both because longline and purse-seine fishing are important, and because it is possible that the effective effort on bigeye could be reduced by means other than reducing the capacity of the fleet. The choice of what reduction in fishing effort should be used as targets is purely a management one that the Commission should make. However, the 2005 assessment

FIGURE 5

Effects of reduction in three types of purse-seine fishing effort and of reduction of longline fishing effort on the purse-seine and longline catches (C_{PS} and C_{LL}) and on the spawning biomasses (SB) of yellowfin, skipjack and bigeye tuna in the eastern Pacific Ocean



showed that, if equal reductions were to be made in both the purse-seine and longline effort, the target capacity for the longline fleet would be 57 percent of the 2002-2003 average, or a fleet that could deploy about 160 000 thousand hooks.

For skipjack, it is also clear that a different set of considerations would be needed if the purse-seine fleet were to be optimized to fish for that species. With current fishing practices, a target fleet capacity in that case would need to take into account the interactions between bigeye and skipjack in the purse-seine fishery.

However, the optimal capacity for both fleets combined will continue to be a moving target. This is clear from assessment results, but also when taking into account other factors not considered here in depth, such as the limited data available, especially for the longline fleet (annual detailed data on some large-scale fleets and on the artisanal vessels in the EPO are mostly unavailable), the composition of the fleet by individual vessels, current and future changes in efficiency and bycatch issues, among others.

Until a consistent multi-species management objective can be developed and implemented, or in the case of bigeye, species-specific selective fishing methods that are economically efficient and technically feasible can be implemented, it would be advisable to develop rules of thumb as fishing capacity management guidelines, particularly some based on reference points derived from assessment studies consistent with the precautionary approach. The management choices regarding these rules and the fishing capacity targets should be made by the Commission, of course.

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