FAO Fisheries Circular No. 982 FIRM/C982(En)

ISSN 0429-9329

MANAGING FISHING CAPACITY OF THE WORLD TUNA FLEET

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MANAGING FISHING CAPACITY OF THE WORLD TUNA FLEET

by

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FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
Rome, 2003

TR/D/Y4499E/1/2.03/1300

PREPARATION OF THIS DOCUMENT

The purpose of this document is to explore means of implementing, with respect to tuna, the International Plan of Action for the Management of Fishing Capacity (adopted by the FAO Committee on Fisheries in 1999). The motivation for preparing it was the growing concern of nations and international tuna organizations that as the fishing capacity of tuna fleets grow, it will become increasingly more difficult to initiate and sustain effective measures to manage and conserve tuna resources. Because most stocks of tuna, with the exception of skipjack, are nearly fully exploited or overexploited, and a growing fleet capacity can cause adverse economic disruptions in the international market for tunas, the document is timely and its subject matter is of critical importance.

ACKNOWLEDGEMENT

The author thanks the FAO Fisheries Department for financing this publication and the reported study. He is particularly grateful to Dr Jacek Majkowski, Fishery Resources Officer, Marine Resources Service of that Department for organizing it and for his assistance and to Ms Anne Van Lierde of that Department for formatting this document for its publication.

The author also thanks Dr William Bayliff of the Inter-American Tropical Tuna Commission (IATTC) and Dr Dale Squires of the National Marine Fisheries Service (NMFS) for reviewing this manuscript. He also thanks Dr Squires for his contribution to the Data Envelopment Analysis presented in this report. He is grateful to Dr Michael Hinton and Mr Patrick Tomlinson of IATTC for providing data on the fishery in the eastern Pacific Ocean and to Dr Gary D. Sharp for environmental data. Thanks are also extended to Dr Alejandro Anganuzzi of the Indian Ocean Tuna Commission (IOTC), Dr Tony Lewis of the Secretariat of the Pacific Community (SPC) and Mr Papa Kebe of the International Commission for the Conservation of Atlantic Tunas (ICCAT) for providing valuable data on purse-seine vessels fishing in their respective regions. Finally, the author's deepest gratitude is extended to the tuna industries of France, Japan, Philippines, Republic of Korea, Spain, Taiwan, Province of China, and the United States of America for providing valuable information on their purse-seine fleets.

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FAO Fisheries Department
FAO Regional and Subregional Fishery Officers
Directors of Fisheries

Joseph, J.
Managing fishing capacity of the world tuna fleet.
FAO Fisheries Cicular. No. 982. Rome, FAO. 2003. 67p.

ABSTRACT

The catch of skipjack, yellowfin, bigeye, albacore and bluefin tuna accounts for about five percent of the world production of marine fish, but it represents a much higher proportion of the total value of the catch. With the exception of skipjack, most stocks of tuna are nearly fully exploited or overexploited. As the number and efficiency of vessels that harvest tuna increases, there is a growing concern on the part of nations and international tuna bodies that it will become increasingly difficult to implement and sustain effective conservation measures for tunas. As a consequence, most of the tuna bodies have initiated steps to evaluate the needs and means of limiting the capacity of the vessels in the fisheries with which they are concerned. Because of severe economic problems associated with excess fishing capacity, the fishing industry has initiated its own programmes to limit the capacity for purse-seine and longline fleets. Reasonably good catch statistics for tuna are available for most fisheries, but corresponding information on the numbers and characteristics of tuna vessels is frequently not. For one of the areas where information is available (the eastern Pacific) results of Data Envelopment Analysis suggest that the fleet of purse-seine vessels in the area could be reduced significantly without a corresponding reduction in the catch. So far, there has been very limited action taken by the fishery bodies to control the fishing capacity. The tuna fishery bodies must work together, and with FAO to resolve the problem of tuna fishing capacity. They also need to address the issues related to common property resources and property-rights based management, the allocation of catches and fleet capacities among participants, the rights of access on the high seas, the authority for regional tuna organizations to deal with some of these matters.

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EXECUTIVE SUMMARY

Nearly 70% of the world's fisheries are either overexploited or nearly fully exploited, due primarily to a growing world demand for fish and a harvesting capacity that is increasing more rapidly than is the catch of fish. Catch quotas and fishing effort limitations can reduce the overexploitation, but as fleets continue to grow, it becomes more and more difficult to sustain such measures.

Because of the widespread concern over this situation, the FAO Committee on Fisheries (COFI) recommended that FAO convene a series of technical meetings to address the issues of defining, measuring, and controlling fishing capacity. Two such meetings have been held. Additionally, in 1999 COFI adopted an International Plan of Action for the Management of Fishing Capacity, which calls on regional fisheries bodies and states to achieve worldwide an efficient, equitable, and transparent scheme for management of fishing capacity.

Although tuna fisheries were not specifically addressed in the plan of action, they are no exception to the problems of growing fleet capacity, which are so evident in other fisheries. The world fisheries for tunas are very complex. Vessels registered in more than 80 nations, many with divergent objectives, fish for tunas. Some of these are economically highly developed, while others are much less so. Both the tunas and the vessels that harvest them roam over wide expanses of the world's oceans both on the high seas and in the Exclusive Economic Zones of coastal nations. Many or most sets of the principal types of gear produce catches of more than one species of fish, some of which are overexploited and some of which are not. For these and other reasons it will be difficult to find a solution to the problem of a growing capacity that is just, equitable, and effective.

TRENDS IN THE PRODUCTION OF WORLD TUNA FISHERIES

Nearly 4 million tonnes of the principal market species of tuna (skipjack, yellowfin, bigeye, albacore, and bluefin) are taken annually. The Pacific Ocean accounts for about 65%, the Indian Ocean about 21%, and the Atlantic Ocean about 14% of this.

Skipjack tuna comprises about half of the world production of tuna, and is the number one species in every ocean in terms of catch. The world catch of skipjack has increased during the last several decades. In the Pacific, and perhaps the Indian Ocean, skipjack does not appear to be fully exploited, but in the Atlantic there is concern that it is.

Yellowfin is the second most important species of tuna, accounting for about 30% of the total catch of all species. The world catch of yellowfin trended upward until the early 1990s, and after that it stabilized. Yellowfin appears to be fully exploited in all areas where it is fished.

Bigeye accounts for a little more than 10% of the world catch of tunas. Prior to the mid-1980s most of the bigeye were captured by deep-fishing longline gear, and virtually all of them were large fish. After the mid 1980s surface fishing gear began to take large amounts of small bigeye. Longline catches significantly declined as surface catches increased. There is a great deal of concern that this change in fishing strategy has resulted in overfishing of bigeye in most areas.

Albacore comprise about 5% of world tuna production. There are six stocks of albacore, all of which are nearly fully exploited or overexploited. Substantial long-term increases in catch do not appear likely.

Southern bluefin and Atlantic bluefin are substantially overexploited. If the catches of small Pacific bluefin were reduced the total catch of that species would probably increase.

THE TUNA FISHING VESSELS OF THE WORLD

Purse-seine vessels, which range in size from small coastal vessels with carrying capacities of less than 100 tonnes to large vessels with capacities of nearly 4 000 tonnes, harvest about 60% of the world production of tuna. They are the most important type of fishing vessel, in terms of total catch, in every ocean of the world. Data on the numbers and specifications of the world purse-seine fleet is limited. The regional tuna bodies attempt to keep records on the numbers and characteristics of vessels fishing within their regions, but for many of those bodies the data are incomplete. In this paper, it is estimated that there are nearly 600 high-seas purse-seine vessels, with a total carrying capacity of nearly 600 000 tonnes operating in the world's oceans. There are even less data on longliners, baitboats, and other types of vessels that fish for tuna. There is a strong need for the regional tuna bodies to work together to collect and maintain records of the numbers and characteristics of tuna fishing vessels of the world.

FLEET CAPACITY AND PRODUCTION

A long series of reasonably good statistics of catches of tuna is available. However, corresponding information on the numbers and characteristics of tuna vessels making those catches is not available for most tuna fisheries. If such data were available it would be possible to examine the relationship between catch and fishing capacity on a global basis, and to further examine the possibility that there is more fishing capacity than needed to make the observed harvests.

Because a long time series of data on fleet carrying capacity is available only for the eastern Pacific Ocean (EPO), a detailed examination of purse-seine carrying capacity and tuna production for that area is presented. An annual catch quota was placed on yellowfin in the EPO in 1966. Because of good catch rates and high demand for tuna, the fleet of purse-seine vessels began to increase, and competition for the available resource increased. From 1966 to 1979 the purse-seine fleet increased from about 100 000 to 180 000 tonnes of capacity. The catch did not increase proportionately. Because of the fierce competition among tuna purse-seine fleets, it became difficult for governments to agree to continue the conservation programme designed to restrict fishing effort, and overfishing ensued. Catch rates and catches decreased, and much of the fleet transferred its operations to areas outside the EPO. Low fishing effort over the next few years allowed the population of yellowfin to recover to high levels of abundance, and many of the vessels returned to the EPO. Relatively low fishing effort kept the abundance and catch rates of yellowfin high, but this inevitably stimulated fleet growth. In the early 1990s, capacity averaged about 110 000 tonnes, and now it is at about the same level it was in the early 1980s, when economic and overfishing problems developed. This has caused concern among the governments in which vessels involved in the fishery are registered that events of the late 1970s and early 1980s will be repeated. This concern has resulted in steps to limit fishing capacity in the region, but finding a way to do this that is acceptable to all nations involved in the fishery is difficult.

The tuna fishery in the EPO, like those of other oceans, is a multi-species fishery. Some species are fully exploited, but others, notably skipjack, are not. Since the different species are taken in the same fishing operation, increased effort on the underfished skipjack can result in overfishing yellowfin and bigeye. Additionally, establishing that there is excess fishing capacity is difficult, and there have been few serious attempts to do this. The FAO working groups on fishing capacity proposed that a linear modelling approach, Data Envelopment Analysis (DEA), could be used to determine whether there is excess fishing capacity in a fishery. This was applied to the EPO fishery, and the results suggest that there are too many purse-seine vessels operating in this fishery, and that the carrying capacity of the fleet can be substantially reduced without a corresponding reduction in catch. Similar DEA analysis of other tuna fisheries could not be conducted because of lack of data on numbers of tuna purse-seine vessels.

CAPACITY LIMITATION EXPERIENCES IN TUNA FISHERIES

There are few cases in international tuna fisheries for which measures to limit fleet capacity have been successfully implemented.

The International Commission for the Conservation of Atlantic Tunas (ICCAT) has taken action to limit the number of vessels operating in the northern albacore fishery to 1993-1995 levels, and vessels greater than 24 meters in length operating in the bigeye fishery to 1991-1992 levels. The Inter-American Tropical Tuna Commission (IATTC) has implemented measures to limit the number of purse-seine vessels that can operate in the EPO, although the agreed-to limits are substantially in excess of what has been recommended by its staff. The Indian Ocean Tuna Commission (IOTC) has recognized that measures to limit capacity are necessary and is investigating means of limiting the fishing capacity of the fleet of large vessels fishing for tropical tunas in the Indian Ocean.

Because of economic problems, the fishing industry has initiated action to limit fishing capacity. The major longline fishing nations, led by Japan, have undertaken to reduce the number of longline vessels by 20%. Vessels removed from the fishery are scraped so that they cannot re-enter the fishery, and the owners are compensated for loss of their vessels. Similarly, most of the owners of purse-seine vessels have formed an organization, whose objectives are to keep the supplies of tuna in balance with demand, and to limit the number of vessels that can fish for tunas.

THE REALITIES OF LIMITING FLEET SIZE

It is clear that there is widespread concern over the size of the world’s tuna fleets, and that there is a desire on the part of governments and industry to limit or reduce the number and total capacity of vessels that harvest tuna. Setting capacity limits would mitigate many of the problems that arise in managing tuna fisheries that are associated with setting time and area closures, catch limits, and gear restrictions, and also the economic and political problems created by too much fishing capacity. However, setting limits on fleet size introduces other problems, such as how to harvest underexploited skipjack while protecting fully or overexploited yellowfin and bigeye, how to determine the optimum fleet size for a particular fishery, particularly when individual vessels may fish in more than one fishery during a given year, how to partition or allocate capacity limits among participants, how to measure and monitor vessel efficiency, how to accommodate the desires of states without fleets to acquire them, and so on.

THE ESSENTIAL AND INITIAL STEPS

Before a workable scheme to limit fleet capacity can be achieved, several issues must be addressed.

First, estimates of the amounts of fish available for harvest are a necessary prerequisite for setting capacity limitations. If the data are inadequate, a precautionary approach may be appropriate.

Second, information on the numbers and characteristics of vessels currently operating is needed. In many fisheries, purse-seine vessels harvest the majority of tunas, and in those fisheries priority should be given to the acquisition of data on purse seiners. However, for limitations to be fully effective, all major gear types should be included in the databases, and appropriate limitations applied. The longer the series of data available, the more readily it can be used to determine whether there is excess capacity in the fishery and, if so, what is the optimum fleet size.

Once the measures for capacity limitation are implemented, the parties must establish an effective monitoring and enforcement scheme

SOME POSSIBLE OPTIONS FOR LIMITING FLEET CAPACITY

Several methods have been used to control the harvest of fish. These fall into two general categories, input controls and output controls. The latter are concerned with the results of fishing (*e.g.* catch quotas and/or size limits), while the former are concerned with the manner in which fishing is accomplished (*e.g.* limiting fishing mortality and/or fishing capacity). Most tuna fisheries management has involved output controls, and has been fraught with technical, economic, and political problems. The following principal input and output controls are considered as possible management options.

Maintaining the existing system of output controls. - In some fisheries, the regulations have become so complex that it is difficult for the fishermen to understand them, much less abide by them, and for management agencies to enforce them. This is part of the reason that nearly all of the regional tuna bodies, and also the industry in some tuna fisheries, have called for controls on the number of vessels allowed to operate.

Establishing a moratorium on fleet growth, *i.e.* allowing no new vessels into the fishery, except to replace those lost through sinking, attrition due to old age, or conversion to other uses. This might work for nations with well-established tuna fleets, but it would not address the problem of how nations without fleets could acquire them, or how nations with small fleets could expand them. Unless it was accompanied with a scheme to handle new entrants, a moratorium would probably be doomed to failure.

Industry programmes to limit fishing effort and/or capacity. - Because of severe economic hardship resulting from too much fishing capacity, the tuna industry has, in two cases, taken the initiative to limit capacity. These initiatives should be recognized and encouraged by governments and regional tuna bodies. It is a major first step in developing a "mind set" within the tuna industry that controls on fleet capacity are needed.

Intergovernmental regional programmes to limit fishing capacity offer a straightforward approach to setting capacity limitations. The problems facing each of the regional bodies would be essentially the same, too many players, including those in the game, those wanting a bigger share of the game, and those not yet in the game, but wanting to get in.

There are several approaches that can be developed by regional bodies for limiting fishing capacity, but nearly all will have to deal with the issue of allocating fleet capacities among participants. Additionally, using capacity limits as the sole mechanism for managing a fishery has certain shortcoming that will need resolution. It is likely that once limits are imposed, there will be a tendency for the fishing industry to improve vessel efficiency and increase the average number of days a vessel spends at sea. Coupling a catch quota with the capacity limitations could mitigate these shortcomings. If the catch quota were global most vessels would "race" to catch as much of the quota as possible before the period of unrestricted fishing ended. The adverse effect on stock productivity of concentrating fishing effort into a shorter period of time could be diminished somewhat by partitioning the year into a series of open and closed fishing periods. However, most vessels would still "race" to catch more fish during these shorter periods of time. Another alternative would be to assign quotas to individual nations. Partitioning the catch quota among nations would offer the opportunity for each nation to develop plans to manage its fishery within the framework of the vessel limits and catch quotas.

Alternatively, catch quotas could be assigned to individual vessel owners or vessels, instead of to nations. If the individual catch quotas were coupled with individual capacity quotas, many of the problems associated with national catch and capacity quotas would be eliminated. If these quotas were transferable, buy-back schemes could be used to reduce overall vessel capacity, and nations wishing to enter the fishery for the first time, or desiring to increase their fleets, could purchase quotas from those already in the fishery. Of all the schemes for resolving the problems of tuna management, particularly the problem of excess fishing capacity, those that tend to incorporate some form of property rights, which allows the recipient of those rights to trade or transfer them to other users, seems to offer the best opportunities for success. If the regional tuna bodies are to deal adequately with problems of excess fishing capacity, they will need to be authorized to deal with economic and social issues related to the fisheries for which they are responsible, including the authority to assume and assign property rights in the fisheries.

CONCLUSIONS AND RECOMMENDATIONS

It seems clear that the world fleet of purse-seine vessels could be substantially reduced without reducing catch. However, the fleet has been growing, and the individual vessels are becoming more efficient. The same seems to be the case for longline vessels. After suffering serious economic harm, the purse-seine and longline industries have initiated efforts to resolve the excess capacity problem, but so far with limited success. Baitboats and gillnet vessels account for about 20% of the world tuna catch, but there is little information on the numbers and characteristics of these fleets. Over the short term, most of the problems caused by too much fishing capacity could be resolved by considering only purse-seine and longline vessels, but for a long-term solution, all types of fishing vessels must be considered.

There are various actions that governments and international bodies must address before a long-term solution could become a reality. A proper international legal basis for limiting entry into tuna fisheries and assigning property rights to participants in those fisheries must be considered. The rights and obligations of states regarding the utilization of the sea's living resources, and also the authority for international bodies to limit entry and assign property rights, would have to be defined. In this respect, FAO can encourage these changes by convening a series of meetings to determine what changes are necessary and how they should be made.

The five regional tuna bodies would benefit from the establishment of a permanent coordinating body to harmonize their efforts to manage the world's tuna fisheries, particularly with respect to reducing fishing capacity. Such a coordinating body could be structured as an independent body or committee of the regional tuna organizations, or part of the FAO.

A second permanent body or coordinating committee, structured along the lines of the one above, dealing with compliance issues related to capacity limitation and tuna management programmes would be able to monitor programmes and coordinate actions regarding the establishment of common sanctions and compliance measures among the regional tuna bodies.

If there are to be effective programmes to manage fishing capacity the following technical matters must be fully studied: (1) monitoring efficiency changes in fishing vessels under management controls, (2) evaluation of the application and usefulness of vessel buy-back schemes for multinational tuna fisheries, and (3) development and application of methods to measure fishing capacity. The first two matters could be addressed through the format of technical working groups established by FAO. The second could be achieved by a Pacific-wide DEA analysis, which would be possible because individual vessel data are available in the archives of IATTC, the Secretariat for the Pacific Community, and the Forum Fisheries Agency. A joint analysis of these data by scientists affiliated with these fisheries bodies could provide an excellent opportunity to evaluate fully the applicability of this technique to the world tuna fisheries, as was recommended by the FAO working groups on fishing capacity.

1 INTRODUCTION

Widespread concern has been expressed over the state of world fisheries resources. Garcia and Newton (1997) reported that nearly 70% of the world's fisheries are either overexploited or nearly fully exploited. This serious state of affairs is the result of a growing world demand for fish, coupled with a fleet harvesting capacity that is increasing more rapidly than is the catch of fish. Gréboval and Munro (1999) have reported that from 1970 to 1990, world industrial fisheries harvesting capacity grew at a rate 8 times greater than the rate of growth of world catches. Milazzo (1996) reported that fishing fleets, taken on a global basis, have continued to grow while sustaining economic losses, and that such a situation could not have existed were it not for government subsidies to the fisheries. In a word, the world's fishing fleets are larger than needed to harvest the sustainable catch, and unless this situation is addressed, the fisheries resources of the world will be further overfished. Capture quotas and fishing effort limitations can serve to slow this over-exploitation, but so long as fleets continue to grow, the probability of sustaining such measures will decrease. As fishing success for individual vessels continues to decrease, and subsidies continue to be given to the fishing industry, pressure to ignore or circumvent management measures will mount to the point that governments will find it difficult to support them.

These issues have been the subject of discussion among many governments and international organizations. At the Twenty first Session of the FAO Committee on Fisheries (COFI), held in Rome in 1995, it was noted that overexploitation, due primarily to excess capacity of fishing fleets, was threatening the sustainability of the living marine resources of the ocean. The meeting called on governments and international organizations dealing with fisheries to urgently review the capacity of fishing fleets under their jurisdiction and, where appropriate, to reduce that capacity.

Acting on the recommendation of the 1997 session of COFI, the FAO Fisheries Department convened a Technical Working Group on the Management of Fishing Capacity. This group met in La Jolla, California, on 15 - 18 April 1998 (FAO, 1998), and addressed the issues of how to define, measure, and control fishing capacity. Technical documents, prepared by invited experts, dealt with such questions as defining fishing capacity, determining the optimal capacity for any particular fishery, and deciding the objectives of a limited access programme. Following this action the Second Session of COFI, held in 1999, stressed the importance of holding a technical consultation to discuss the measurement of fishing capacity. As a result, a Technical Consultation on the Measurement of Fishing Capacity was held in Mexico City, on 29 November – 3 December 1999 (FAO, 2000). The objectives of the consultation were "to review various issues related to the measurement of fishing capacity with a view to facilitating the monitoring and assessment of fishing capacity world-wide, and to advice on simple and practical methods for the measurement of fishing capacity and the assessment of any imbalance between actual and desired levels of capacity". Building on the work of the La Jolla Working Group, the Technical Consultation arrived at the following definitions:

<u>Fishing capacity</u> is the maximum amount of fish that can be produced over a period of time by a fishing fleet if fully utilized, given the biomass and age structure of the fish stock and the present state of the technology. Fishing capacity is the ability of a vessel or vessels to catch fish.

Target fishing capacity is the maximum amount of fish that can be produced over a period of time by a fishing fleet if fully utilized, while satisfying fishery management objectives designed to ensure sustainable fisheries.

Relative fishing capacity is the ratio between the current fishing capacity and the target capacity.

Furthering their earlier initiative to address the problem of excessive fishing capacity, the 1999 session of COFI adopted an International Plan of Action (IPOA) for the Management of Fishing Capacity, to be elaborated in the FAO Code of Conduct for Responsible Fishing. The objective of the IPOA is for states and regional fisheries organizations, to achieve worldwide an efficient, equitable, and transparent management of fishing capacity, preferably by 2003, but not later than 2005.

These actions are the first steps in clearing a path and setting a series of standards for the community of nations to undertake action to reverse the trends of a growing fishing fleet and expanding overexploitation of the sea's living resources. Although not addressed specifically, tuna fisheries are no exception to these conditions of high demand, heavy exploitation, and growing capacity. Nearly all of the major tuna stocks of the world are fully exploited and some, such as Atlantic bluefin and southern bluefin, are severely overexploited (Deriso and Bayliff, 1991). The only region which might support a significant expansion of tuna fishing is the western and central Pacific (Klieber, Argue and Kearney, 1987). In other areas tuna fleets are apparently larger than needed to take the available harvest. In many of those areas where the stocks are fully exploited, the same amount of fish could most likely be harvested with smaller fleets, resulting in lower costs of production, greater economic returns, and on occasion lower prices for consumers. It seems clear that if there is to be rational management of the world's tuna resources programmes to control the size of the global tuna fleet must be evaluated, and where necessary instituted.

However, because of the complex nature of world fisheries for tunas, it will be difficult to develop a system of controls and measures to which all nations will agree. Additionally, even though the Mexico City consultations arrived at a series of definitions of fishing capacity, consensus on these is so far lacking. Tuna fishing is prosecuted by a variety of vessel sizes and types, and unless output can be measured in economic terms it will be difficult to equate the output of one class of vessel with that of another. Also, about 80 nations are involved in tuna fishing, some catching tunas only in their coastal waters and others wherever tunas occur. However, the raw materials from these divergent fisheries enter a common market and derive from common stocks, which migrate over expansive areas of the world's seas. The apparent objectives of many of these nations can be quite different as well. Some nations may wish to maximize employment, while others may wish to maximize economic returns. Many times these objectives can be confused or frustrated, particularly in those cases where foreign investors bring vessels under the flag of a coastal state, but few or none of the profits from such operations are kept in that coastal state. This complicates interpretation and application of economic models such as the Gordon-Schaefer model described by Greboval and Munro (1999), which state, as an objective, maintaining fishing capacity at the levels that will provide maximum economic rents. Finally, tuna fisheries are multi-species fisheries. Normally a single vessel will capture at least two species during a single trip, and many vessels capture up to three or four species during a trip. Frequently one of the species being captured is overexploited or fully exploited, while the other species are under exploited and capable of sustaining greater yields if greater fishing pressure is applied. Any programme to control fishing capacity must deal with all of these issues if it is to be acceptable and successful.

The purpose of this paper is to examine several of these problems. In doing so, trends in the production of tuna over the last several decades will be presented, and information on the status of the various stocks of tuna, where available, will be discussed. A discussion will also be given of the fleets that capture tuna, including the types of vessels and where available, some indication of their numbers.

For certain fisheries, where data are available, the relationship between production and capacity will be examined in order to identify situations that might indicate a need for capacity controls. Based on these results, a general discussion of what mechanisms might be available for designing such controls will follow. Finally, areas will be identified where data and information for examining the capacity problem is lacking, and recommendations made for filling those gaps.

There are of course, many approaches to managing fisheries such as catch quotas, closed areas and seasons, and restrictions on the types and amounts of fishing gear that can be employed to catch fish. Controlling capacity is only one means of managing fisheries, and it is this approach that will be the focus of this paper.

2 TRENDS IN THE PRODUCTION OF WORLD TUNA FISHERIES

Tunas have been important to mankind for several thousand years. Archaeological evidence shows that early humans harvested tuna more than 6 000 years ago, and tuna products may have been among the earliest manufactured fisheries commodities traded among ancient civilizations. Currently, fishermen of nearly 80 nations harvest tuna from the world’s oceans. The harvest is consumed in many forms: raw, cooked, smoked, dried, and canned. More than half of all the tuna consumed is canned.

The following discussion, which is taken mostly from Joseph (2000), deals with the populations of the principal market species of tuna: skipjack (*Katsuwonus pelamis*), yellowfin (*Thunnus albacares*), bigeye (*Thunnus obesus*), albacore (*Thunnus alalunga)*, northern bluefin (*Thunnus thynnus*), and southern bluefin (*Thunnus maccoyi*).

Between 1975 and 1992 the total world catch of tuna increased (Figure 1), as did those for most of the individual species (Figure 2). However there were periods of slow growth that alternated with periods of fast growth. From 1991 through 1996 catches stayed relatively steady, between about 3.1 and 3.2 million metric tonnes. In 1997 the catch reached 3.4 million tonnes, and it has continued to increase through 1999, when it reached about 3.9 million tonnes.

The large increases in the 1970–1978 period were the result of expansion of the fisheries in the eastern Atlantic and the development of new offshore fishing areas in the eastern Pacific. Subsequently, after six years of little increase in world production, many vessels transferred to the western Pacific and western Indian Ocean, where they developed new fishing grounds. The catches during this period showed the greatest rate of growth seen in the fishery in many decades. No new major fishing grounds have been developed since 1990, and from then until 1997 the fishery showed almost no growth. From 1996 through 1999 the catch increased by about 19%, due mostly to the improvement and increased use of fish aggregating-devices (FADs).

2.1 By Oceans

The annual catches of the principal market species, by ocean, during 1970-2000 are shown in Figure 1. The Pacific Ocean currently produces about 2.5 million tonnes, or 64% of all the world's annual tuna catch and, with the exception of bluefin, also produces the greatest quantities of each of the principal market species (Figures 3, 4, 5, and 6). Of this 2.5 million tonnes, about 65% is taken by purse-seine vessels, slightly less than 14% by pole-and-line vessels, slightly more than 10% by longline vessels, and the remainder by miscellaneous other gears. The fishery in the western Pacific, west of 150°W, accounts for the large majority of these 2.5 million tonnes. The west-central tropical Pacific, the area studied by the scientists of the Secretariat of the Pacific Community (SPC; formerly the South Pacific Commission), has produced more than one million tonnes, or about 30% of world production, during the last few years; of this, nearly 800 000 tonnes, or about 24% of the world total, is caught by the purse-seine fishery, the single largest tuna fishery in the world. The Japanese home island tuna fishery, which operates within a few hundred miles of the home islands of Japan, also produces large quantities of fish; in recent years the Japanese catches of the principal market species in this area have fluctuated between 150 and 300 000 tonnes, while the catches around Indonesia may even exceed those of Japan, and those of the Philippines approach those of Japan.

Prior to the 1980s, the Indian Ocean accounted for less than 8% of world production of tuna. Most of the catch came from artisan fisheries in Sri Lanka and the Maldives, augmented by distant-water longline fleets. In the early 1980s French and Spanish purse-seine vessels, faced by poor catch rates and problems of access in the Atlantic Ocean, moved to the western Indian Ocean, and as they expanded their operations there, catches of skipjack and yellowfin increased rapidly. Over the last several years the catches of tuna from the Indian Ocean have averaged about 20% of the world total. Following this rapid increase in the catch, annual production stayed around 700 000 tonnes until 1999, when it increased to nearly 900 000 tonnes (Figure 1). The catch in 2000 was only slightly behind that of 1999. More than 75% of this is caught in the western Indian Ocean by purse-seine vessels and by the fisheries of the Maldives and Sri Lanka. Two species, skipjack and yellowfin, account for about 80% of the total catch from the Indian Ocean.

Although artisanal and small-scale fisheries for tunas have existed in the Atlantic Ocean for many centuries (significant trap fisheries have existed in the Mediterranean Sea since the 12^{th} Century), large-scale commercial exploitation of tunas in that ocean did not begin until the 1950s. Tunas were caught mainly with pole-and-line and longline gears until purse seining was introduced in the early 1960s. Catches increased slowly until the early 1980s, when they started to decline because of the shift of fishing fleets to the Indian Ocean. They were stable for several years, and then began to increase again, peaking in the early 1990s. Since then they have been relatively stable at around 500 000 tonnes per year (Figure 1). The Atlantic Ocean currently accounts for about 14% of the world production of tuna. The principal species caught in the Atlantic, in terms of quantities landed, are skipjack and yellowfin, with nearly 80% of the landings coming from the eastern Atlantic. Most of this catch is made by large purse-seine vessels, which also catch bigeye.

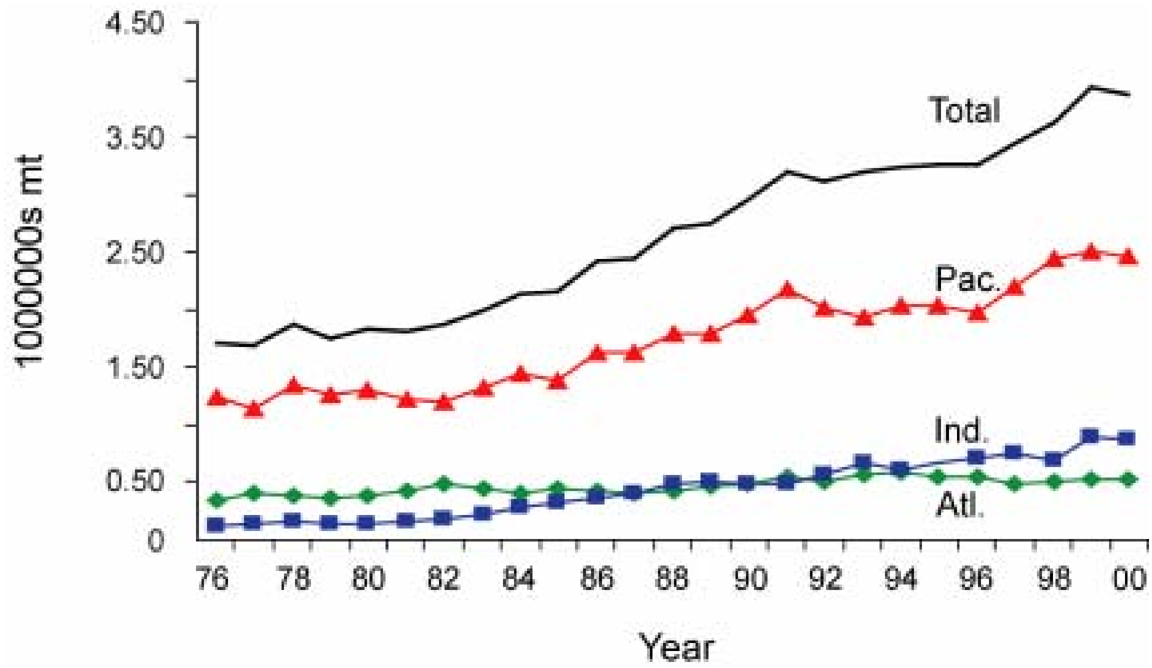

Figure 1. Trends in the catch of the principal market species of tunas by ocean

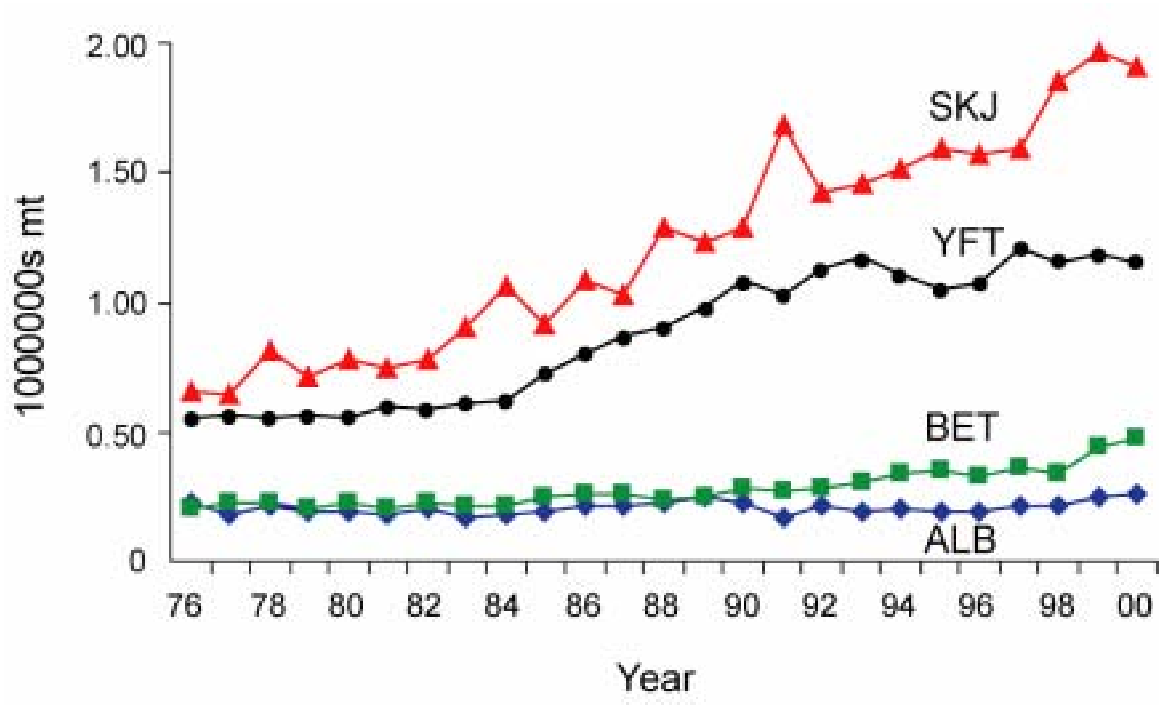

Figure 2. Trends in the world catch of tunas by species

2.2 By Species

2.2.1 Skipjack

During the last several years, skipjack tuna has accounted for about 50% of the total world catch of the principal market species of tuna (Figure 2). It is among the most widely distributed of all tuna species, being found in commercial quantities between 45°N and 40°S; it inhabits the upper mixed layer of the ocean, and is caught mostly with purse seines and pole-and-line gear. Most of the catch is used for canning. Skipjack is a short-lived species, with high rates of natural mortality and population turnover. These characteristics of skipjack, together with their wide distribution, results in a huge biomass of fish, and very high levels of potential production. Ever since the beginning of heavy commercial exploitation in the early 1970s, the consensus among scientists had been that the populations of skipjack in all oceans of the world were lightly exploited and capable of sustaining much higher catches. This has been borne out by the fact that annual catches increased from about 400 000 tonnes in 1970 to around 1.9 million tonnes in 1998. They remained near that level during 1999 and 2000.

Pacific Ocean

In terms of weight skipjack is the dominant species in the catch of the Pacific (Figure 3). Genetic studies of the Pacific population of skipjack suggest that there is some mixing of fish across the Pacific Ocean, but for management purposes the stocks in the western Pacific have been considered by most scientists to be independent of those in the eastern Pacific. Tagging data, showing limited movement of skipjack from the eastern Pacific to the western Pacific, supports the same conclusion. The Pacific-wide catch of this species increased from slightly more than 200 000 tonnes in 1970 to highs of about 1.4 million tonnes in 1998, 1999, and 2000.

About 1.2 million tonnes per year was taken from the western Pacific in 1998 to 2000. Studies based on tagging experiments conducted by the SPC suggest the stock of skipjack in the western Pacific is under exploited and that it may be possible to increase catches significantly over levels experienced during 1991–1997, perhaps by as much as 200 to 300 000 tonnes per year (Klieber, Argue and Kearney, 1987). Such increases would, of course, depend on demand for raw material, price, the ability of the fishermen to locate additional fishing areas, and the vulnerability to capture of the fish in these new areas. The 1998–2000 catches did surpass the previous high catch level of 1991, but only slightly. However, if the estimates from the tagging experiments are correct, additional increases in skipjack catch could be sustainable.

Prior to 1999, catches of skipjack from the eastern Pacific ranged between about 40 and 160 000 tonnes, with a peak of about 170 000 tonnes taken during the late 1970s. During the last few years catches have reached record highs: 262 and 208 000 tonnes during 1999 and 2000, respectively. It is likely that catches of skipjack could be sustained at higher levels than those of the 1970s. However, because of the variability of skipjack abundance catches as great as those of 1998 and 1999 could not be expected every year (IATTC, 2001). Purse-seine vessels fishing on FADs, a method which normally catches a very high proportion of small fish, have taken much of this increased catch in recent years. There is concern that increasing fishing effort on FADs in the eastern Pacific, and elsewhere, in order to increase the skipjack catch, could result in increased catches of small yellowfin and bigeye, which might affect the abundance and future catches of those species.

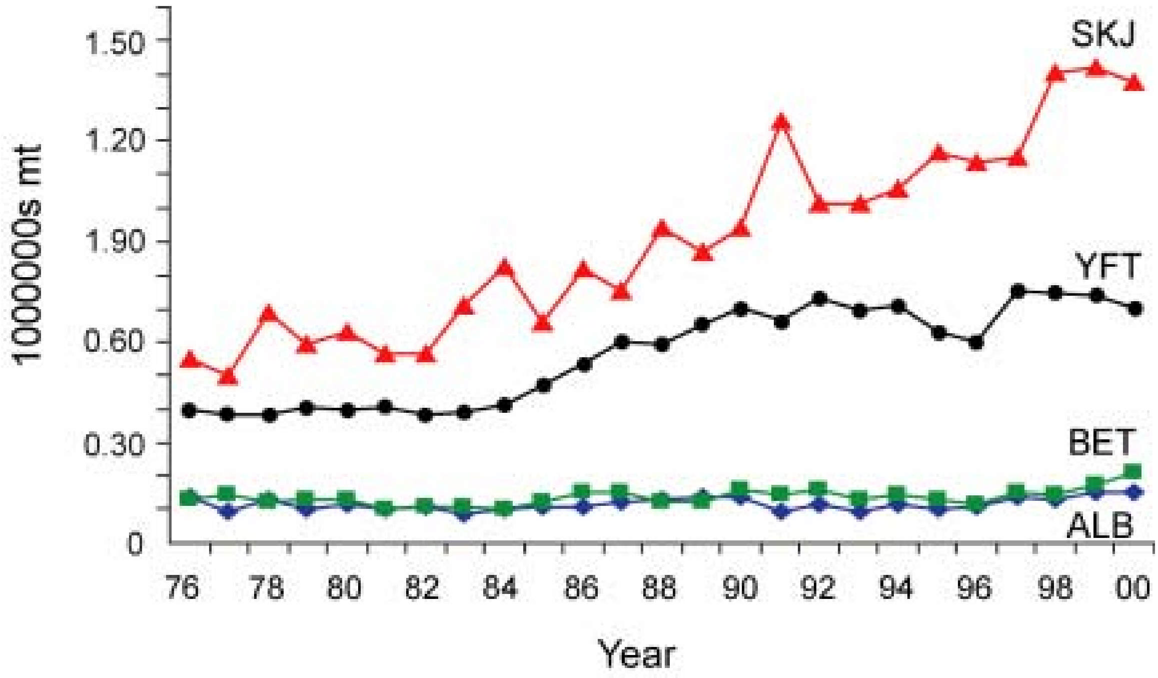

Figure 3. Trends in the catch of tunas from the Pacific Ocean

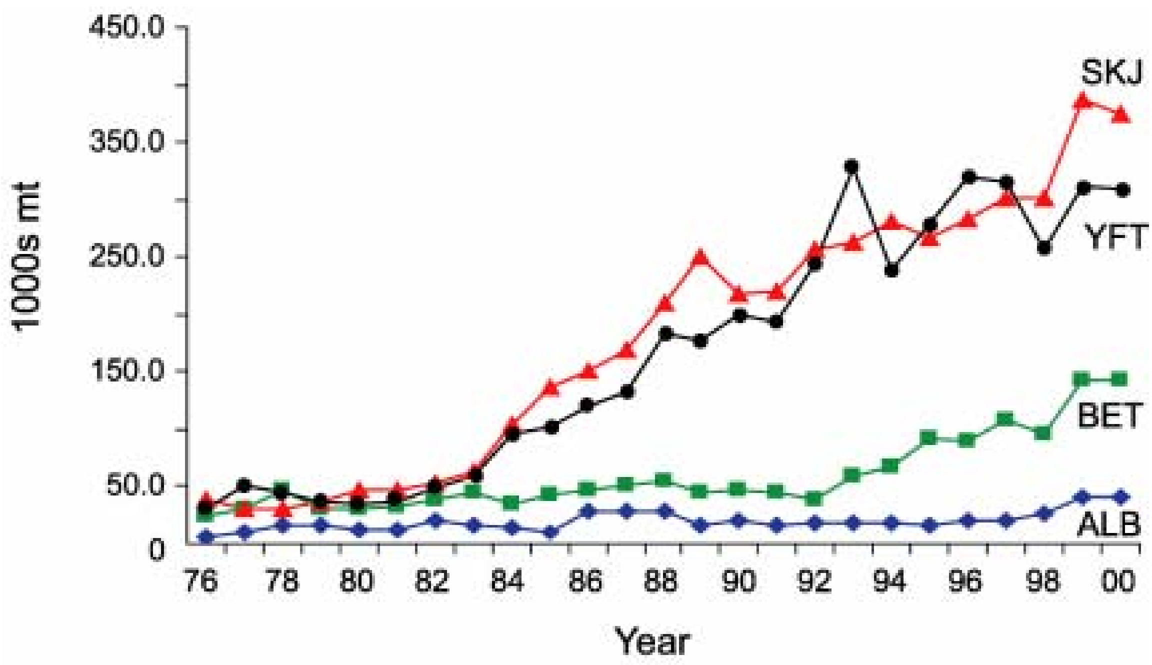

Figure 4. Trends in the catch of tunas from the Indian Ocean

Indian Ocean

Catches of skipjack in the Indian Ocean, like those in the Pacific, have shown a steady increase since the entry of purse-seiners from other areas (mostly from France and Spain) into the fishery during the early 1980s (Figure 4). The 1999 catch reached an all-time high of nearly 390 000 tonnes. The Indian Ocean is the only ocean in which skipjack has not regularly formed the greatest proportion of the tonnage landed. Since 1990 the annual average landings of yellowfin and skipjack have been about the same, about 265 000 tonnes each, with the exception of 1999 and 2000 when the skipjack catch substantially exceeded that of yellowfin. Skipjack in the Indian Ocean are considered to comprise a single stock, so that any management and conservation measures enacted would have to apply over the entire ocean. Although studies of the stock do not show clear evidence that it is fully exploited, scientists have expressed some concern about the possibility of increased fishing levels adversely affecting stock abundance (Anganuzzi, Stobberup and Webb, 1996). Nevertheless catches have shown a steady annual increase since 1983, reaching a peak of about 390 000 tonnes in 1999.

Atlantic Ocean

In terms of weight of fish caught, skipjack is the most important tuna species in the Atlantic; in both 1999 and 2000, about 165 000 tonnes were landed. This is somewhat less than the average for the previous few years, and well below the record landings of about 200 000 tonnes in 1991 (Figure 5). About 85% of the catch is taken in the eastern Atlantic, and the rest is taken primarily off Brazil. Although there is no conclusive evidence concerning the stock structure of this species, scientists have treated skipjack in the eastern and western Atlantic as separate stocks. No Atlantic-wide assessments of skipjack have been made since 1984, when scientists working cooperatively under the auspices of the International Commission for the Conservation of Atlantic Tunas (ICCAT) concluded that the resource was underexploited in both the western and eastern Atlantic. However, a recent analysis by these scientists, for the central area of the eastern Atlantic fishery, where more than one-half the Atlantic catch is taken, shows decreasing average size and decreasing catch rates (ICCAT, 1999). These scientists considered that, in spite of the high turnover rates of the Atlantic skipjack population and the fact that nominal fishing effort for this species has been declining in recent years over-exploitation of skipjack in some areas of the fishery is occurring and fishing mortality may exceed levels that would maximize the yield per recruit (Even though the nominal fishing effort has declined, the fishing mortality may be increasing, because of increased fishing power of the vessels). Since 1990 the use of FADs has increased greatly. This has most likely led to an increase in the catch of unmarketable skipjack that are discarded at sea dead, so the total catch may be underestimated. For all these reasons, any increase in the fishing mortality of Atlantic skipjack, particularly in the eastern area, should be carefully monitored.

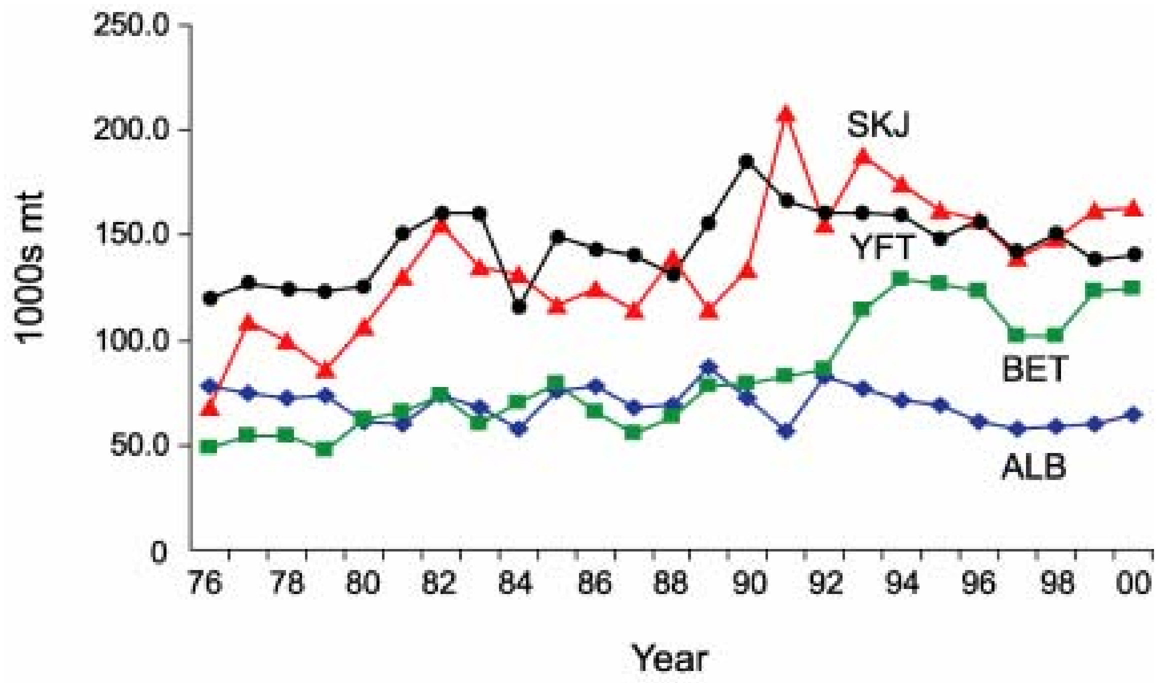

Figure 5. Trends in the catch of tunas from the Atlantic Ocean

2.2.2 Yellowfin

In terms of weight of catch, the second most important species of tuna is yellowfin, which accounts for about 30% of the world catch (Figure 2). This species, like skipjack, is widely distributed, but is confined to slightly more tropical latitudes. Yellowfin live longer and reach larger sizes than skipjack. Most of the commercial catch is used for canning, and fish over 10 kg are considered prime raw material for this purpose. Like skipjack, most yellowfin is taken at the surface by purse-seine vessels but, unlike skipjack, significant catches, particularly of large fish, are made in subsurface waters by longline vessels. From the early 1970s until about 1984 world catches of yellowfin increased only slightly, but in 1985, with the development of new fishing grounds in the western Pacific and western Indian Oceans, the catch increased sharply. This increasing trend continued through 1993, but since then catches have shown no upward trend.

Pacific Ocean

Yellowfin tuna are widely distributed throughout the tropical Pacific Ocean, and are caught by longline vessels throughout their area of distribution. However, most of the approximately 750 000 tonnes taken annually is caught by purse-seine vessels, which fish in much of the western Pacific as far to the east as about 170°W, and in the eastern Pacific from the coastline of the Americas to about 150°W.

After relative stability in production from 1972 to 1984, annual catches of yellowfin in the Pacific increased from about 400 000 to about 700 000 tonnes by 1990. Since 1990 they have averaged about 700 000 tonnes, showing no upward or downward trends (Figure 3).

In the western Pacific, yellowfin catches averaged slightly over 200 000 tonnes per year prior to the late 1970s. With the arrival of the distant-water purse-seine fleets in the area after 1980, catches increased rapidly, and during the last several years have averaged about 450 000 tonnes per year. Although the results of mark-and-recapture experiments conducted by the SPC suggest that exploitation rates on yellowfin are low, indicating that the western Pacific stock can sustain increased yields, any expectations of increased yellowfin production should be viewed with caution, as the longline catches and catch rates have declined and catches of small yellowfin appear to be increasing. In fact, recent analysis suggests that the yellowfin stock is probably fully exploited (Hampton, Lewis and Williams, 2000).

In the eastern Pacific, catches of yellowfin have averaged about 250 000 tonnes over the last decade. Analyses by scientists of the Inter-American Tropical Tuna Commission (IATTC) indicate that the yellowfin resource in this area is fully exploited and is producing near the maximum it can sustain, so increasing fishing effort will not result in a sustained increase in catches (IATTC, 2001). Yellowfin in the eastern Pacific are considered to be a separate stock from those to the west. The IATTC has adopted catch quotas and closed areas for yellowfin in the eastern Pacific during recent years. Scientific analyses have also shown that if the fishing effort currently directed at large yellowfin associated with dolphins were to be redirected to fishing on floating objects, particularly FADs, in an effort to minimize the mortality of dolphins in the fishery, the catch of yellowfin would decrease. This decrease would result from a reduction in the yield per recruit, because large yellowfin are taken in association with dolphins, while fishing with FADs takes mainly smaller fish.

Indian Ocean

In the Indian Ocean catches of yellowfin, like those of skipjack, increased rapidly after the arrival of the French and Spanish purse-seine fleets. They hit a peak of 330 000 tonnes in 1993, but since then have remained at about that level (Figure 4). Although the scientific evidence is not incontrovertible, it seems likely, based on production models, that the stock in the western Indian Ocean is fully exploited, or perhaps overexploited. Scientists have urged caution regarding expansion of fishing effort in the surface fisheries of the western Indian Ocean, and have expressed concern over the fact that the increased use of FADs has increased the catch of small yellowfin, which could be reducing the yield per recruit, and hence the total potential yield (Anganuzzi, Stobberup and Webb, 1996). It is not known whether yellowfin from the eastern and western Indian Ocean belong to the same stock, but if the two are independent of each other it may be possible to increase yellowfin catches somewhat in the eastern area.

Atlantic Ocean

In the Atlantic about 60% of the commercially-caught yellowfin is taken by purse seiners, but significant catches are also made by baitboats and longliners. Fish between about 40 and 170 cm in length are retained, but smaller yellowfin, of low commercial value, are often discarded. With the increased use of FADs the proportion of small yellowfin in the catch has increased. The population of yellowfin in the Atlantic is considered to consist of a single intermingling stock. The fish spawn in equatorial regions of the central Atlantic. Most of the young migrate east to the nursery grounds, where they stay until they are about 65 to 85 cm in length, and then most migrate to the western Atlantic, many returning to the eastern Atlantic fishing grounds at about 110 cm. In the late 1960s catches of yellowfin increased as fleets of purse seine vessels increased their activities in the eastern Atlantic. Catches rose steadily until about 1984, but declined thereafter for a few years due to vessels moving to the Indian Ocean (Figure 5). After 1989, effort in the Atlantic increased again. The peak catch of yellowfin, about 185 000 tonnes, was taken during 1990, but since then catches have been decreasing. The 2000 catch was about 140 000 tonnes. Most of the catch is taken in the eastern Atlantic, with about 20 to 30 000 tonnes coming from the western Atlantic.

Recent analysis for the yellowfin population completed by scientists of ICCAT's Standing Committee on Research and Statistics (SCRS), suggests that the stock is capable of supporting yields of about 150 000 tonnes on a sustained basis (ICCAT, 1999). Since catches had been near that level in recent years, it was concluded that the population was fully exploited, and that any increase in fishing mortality would lead to overfishing and reduced catches. The scientists also cautioned that if fishing effort was being underestimated because of changes in efficiency, then the stock was probably being over-exploited. They also noted that if catches of small fish increased, then the potential yield would probably decrease due to a reduction in the yield per recruit. In 1973, ICCAT instituted controls on the catch of yellowfin of less than 3.2 kg, but these have been ineffective in keeping catches of these small fish down; in fact, they have been increasing. However, action was taken by ICCAT to close certain areas of the Atlantic to fishing on floating objects for the period November to January, in an effort to protect small fish. Further recommendations have been made to set limits on the catch of yellowfin.

2.2.3 Bigeye

Bigeye tuna are very similar to yellowfin in appearance, and fishermen and processors often confuse the two species. Bigeye are distributed throughout most of the world's oceans, but they occur mostly in waters below the thermocline. Among their unique adaptations to life at greater depth is a layer of subcutaneous fat, which insulates them from the cold. This fat makes them very valuable in the *sashimi* market, and has made them the target of subsurface longline fisheries. In the mid 1970s, with the introduction of deep longlines, world catches of bigeye began to increase, reaching about 250 000 tonnes by the mid 1980s (Figure 2), and remained at about that level until the early 1990s, when purse-seine vessels began to utilize FADs for capturing small bigeye for canning. By 2000 the overall catch of bigeye reached about 475 000 tonnes, with much of this increased catch being attributable to the use of FADs.

Pacific Ocean

In the Pacific Ocean annual catches of bigeye have fluctuated between about 100 and 165 000 tonnes prior to 1999. During 1999 and 2000 catches were 173 and 208 000 tonnes respectively (Figure 3); about 50% of this is taken in the eastern Pacific (east of 150°W). With the exception of an increase during 1999, there has been no observable trend in bigeye production in either the eastern or western Pacific, but the size composition of the catch has changed greatly in recent years.

As mentioned above, bigeye tuna are creatures of the deep: they spend most of their time in waters below the thermocline, where they are vulnerable to deep-fishing longline gear. Until recently this form of fishing was the principal method of capturing bigeye. However, during the late 1980s new methods were developed for capturing bigeye with purse-seine nets, which involve using FADs, sophisticated sonar, and deeper nets: the fish are attracted to the FADs, identified at depth by the sonar, encircled with the nets, and captured. The bigeye caught with this method are generally small, averaging about 8 kg, whereas the average for the longline fishery is about 55 to 60 kg. Surprisingly, in late 1999 and during 2000 the purse-seine fishery in the EPO captured mostly large bigeye, averaging about 19 kg. This unusual situation was most likely attributable to a series of large recruitments followed by poor recruitment during the last couple of years (Watters and Maunder, 2001).

With this new method, annual purse-seine catches of bigeye in the eastern Pacific have increased from about 2 000 tonnes in the late 1980s to a high of about 70 000 tonnes in 2000. These increasing surface catches of bigeye contributed to the decline in longline catches (heavy exploitation by longline gear may have also contributed to this decline), which went from an average of about 90 000 tonnes during the 1980s to less than 35 000 tonnes in recent years. Moreover, the total catch data tell only part of the story: since the market value of large longline-caught bigeye is far greater than that of the small bigeye caught with purse seines, the economic effect is enormous. Studies indicate that if purse-seine catches continue at current levels, longline catches will decrease even further (IATTC, 2001). These studies also suggest that, depending on the natural mortality rate of bigeye, total production from the two methods of fishing could very well decline after an initial increase. The same patterns of fishing seem to be prevailing in the western Pacific as well.

Studies based on longline data only, indicate that bigeye in the Pacific Ocean are capable of supporting catches of between about 115 to 150 000 tonnes annually. Because longline catches have been near, and in some cases above, this level in recent years, concern has been expressed that future increases in fishing effort on bigeye would result in overexploitation of the species. Adding to this concern is the increase in the catches of bigeye by purse-seine vessels. This concern over bigeye led the IATTC to adopt conservation measures designed to restrict fishing on floating objects of all types, including FADs during part of the fishing year. These measures are designed to limit the catch of small bigeye, because almost all the surface catch of that species is caught on floating objects, but it will also affect the catch of skipjack and small yellowfin. Such measures were first implemented in 1999.

Although the biological relationship between bigeye taken in the eastern and western Pacific is not known, it seems clear that in both regions there is a need to view developments in the fisheries with caution. In both areas longline catches appear to be declining, and will probably continue to do so as long as surface catches continue at current levels. There is some evidence that the combined catches of longline and purse-seine vessels in the Pacific Ocean may not be sustainable.

Indian Ocean

Prior to 1985, longline vessels were responsible for nearly all the catch of bigeye tuna in the Indian Ocean. Longline catches increased each year until 1985, when surface vessels began to catch more bigeye. After 1985 longline catches levelled off at between about 40 and 60 000 tonnes per year, while surface catches increased, reaching more than 30 000 tonnes by 1997. The status of the bigeye stock in the Indian Ocean is unclear. The relationship among bigeye from different parts of the Indian Ocean is unknown, so for the purposes of stock analysis scientists have assumed that there is a single stock. The most current stock analysis for bigeye in the Indian Ocean has concentrated on fitting the production model to historical catch and effort data (Anganuzzi, Stobberup and Webb, 1996). The conclusions vary, depending on the form of the model used and the data series applied, but the average maximum sustainable yield (AMSY) was estimated by one model to be between about 32 and

45 000 tonnes and by another to be between about 52 and 60 000 tonnes. Since catches have been well over 50 000 tonnes for many years, and during the last three years have averaged about 100 000 tonnes (Figure 4), the lower estimates seem unrealistic. If the higher estimates are correct, then the fishery is currently harvesting bigeye in excess of the AMSY; however, because of the increasing use of FADs in the surface fishery, and the consequent increase in catches of small bigeye, resulting in a shifting vector of age-specific fishing mortality, these estimates are also probably unreliable. Given the similarity of the situation in the Indian Ocean to that in the Pacific, and the results of the stock assessment studies for the latter area, any increases in the surface catch of small bigeye in the Indian Ocean should be viewed with caution, as they will almost certainly reduce longline catches, and could result in a decrease in the total catch. As is the case in other oceans, consideration is being given to limiting the use of FADs in the Indian Ocean by setting season and area closures.

Atlantic Ocean

Although information is limited, the stock of bigeye in the Atlantic is considered to be a single intermingling unit. Prior to 1970, most bigeye tuna taken commercially in the Atlantic Ocean were caught by longline or pole-and-line vessels, but since then the use of purse seines has increased, and by 1993 nearly 30% of the catch of bigeye was taken with this gear. Total catches rose steadily from 1950 to 1985, when they peaked at about 75 000 tonnes, remaining there until 1990 (Figure 5). Since 1992 catches increased, averaging about 120 000 tonnes annually. The increases since 1990 have been due to greater longline fishing effort and increased use of FADs by purse-seine vessels, the latter resulting in increased catches of small fish.

Estimates made by SCRS of AMSY obtained from production models indicate that under optimum conditions the population of bigeye in the Atlantic can sustain catches of between 80 and 95 000 tonnes per year. These analyses indicate that the bigeye stock in the Atlantic is over-exploited, and that at current levels of fishing effort catch levels will decline in the future (ICCAT, 1999). Age-structured models generally corroborate the results of the production models, and indicate that if the fishery on FADs continues to catch large quantities of small fish, the result will be growth overfishing and a decrease in catches. If catches of small fish could be reduced, the total catch would increase. In this regard, ICCAT instituted a minimum size limit of 3.2 kg for bigeye a number of years ago, but it has not been effective, since in recent years about 55% of the bigeye captured in the Atlantic have been below that size. According to SCRS scientists, strict enforcement of the minimum size limit would lead to a 35% increase in the catch, and they have called for a catch limit less than the estimated AMSY and for limitations on fishing for bigeye with FADs.

This concern over the heavy exploitation of small bigeye (and skipjack and yellowfin, as well) in the FAD fishery is not limited to scientists: French and Spanish vessel owners voluntarily imposed their own restrictions on the use of FADs in the eastern Atlantic. Since this initiative by the industry, the governments have also taken action to limit catches by restricting fishing with floating objects during a three-month period in 1999 and prohibiting the use of tender vessels, which maintain, repair, and replace the FADs, as necessary. Governments have also taken action to limit the entry of vessels greater than 24 meters in overall length into the fishery for bigeye.

2.2.4 Albacore

Albacore has the distinction of being the tuna that lead to the development of the present-day world market for canned tuna. Early marketing slogans in the United States, where the first canning of albacore took place, emphasized its white flesh, comparing it to chicken ("almost like chicken", "Chicken of the Sea", and "Breast of Chicken"). Demand for the product grew rapidly, which led to the development of the canned light-meat market for yellowfin and skipjack. Because of the high demand for its white flesh, and the fact that supplies of raw material are limited, never exceeding 260 000 tonnes, canned albacore has always fetched a premium price. Albacore is a temperate species, concentrated mainly in the cooler temperate and subtropical waters of the world's oceans, but undertake extensive migrations, seeking optimum conditions for feeding and reproduction. Surface fishing with hooks and lines in temperate and subtropical regions accounts for most of the catch of younger fish, while longline fisheries in more tropical waters capture the older fish. Purse-seining accounts for only a very small portion of the total albacore catch. Because of the wide distribution and highly-migratory characteristics of this species, levels of catch vary a great deal from year to year: annual catches have ranged from 170 and 255 000 tonnes over the last 25 years, with an average of about 200 000 tonnes (Figure 2). Catches show no trends, up or down, but both 1999 and 2000 showed increases catches in all oceans.

Pacific Ocean

In the Pacific there is a northern stock of albacore that occurs between the equator and about 40°N, from Japan to North America, and a southern stock that is found between 15° and 40°S, from off Chile to around New Zealand. Total catches for these two stocks have fluctuated between 90 and 150 000 tonnes during the last 20 years, with no visible upward or downward trend (Figure 3). On average, about 60% of the catch comes from the northern stock. Most of the albacore harvested commercially in the Pacific Ocean are captured by surface trolling gear and by longlines.

Scientific studies have indicated that the northern stock was possibly overexploited during the mid 1980s but, due to natural fluctuations in abundance, it is currently above the level of abundance necessary to sustain the AMSY (Sakagawa and Hsu, 2000). Based on past experience, it does not seem likely that there will be sustained increases in catch, but rather that environmental variability will play an important role in future production.

Firm conclusions regarding the status of the southern stock are difficult. On the one hand, studies based on tagging data and age-structured models suggest low exploitation rates, whereas production models suggest that the stock is fully exploited and incapable of sustaining increased catches. The former studies are considered more reliable, so it is probable that the stock is not overexploited.

In general, it appears that catches of albacore from the Pacific Ocean will continue to show a great deal of variability in the future.

Indian Ocean

Between 1970 and 1985 the annual average catch of albacore from the Indian Ocean was about 15 000 tonnes (Figure 4). With the introduction of large pelagic gillnets in 1985 catches increased to nearly 30 000 tonnes, where they remained until this form of fishing was banned on the high seas in the early 1990s. Catches subsequently declined to as low as 17 000 tonnes; they increased in 1999 to about 40 000 tonnes. Scientific studies of the effect of fishing on the albacore of this region have been very limited, and it is uncertain whether the stock is fully exploited at recent levels of fishing effort, or whether increasing effort will result in sustained increased catches.

Atlantic Ocean

Total catches of albacore from the Atlantic show no trends, varying between about 60 and 80 000 tonnes per year over the last three decades (Figure 5). The information available is limited, but the population is considered to consist of three independent stocks, one in the North Atlantic, one in the South Atlantic, and one in the Mediterranean Sea.

In the North Atlantic various gears are used to exploit the stock, including longlines, pole-and-line gear, trolling gear, gillnets, and paired trawls. Most of the longline catch is taken in the central-western north Atlantic, while much of the surface catch occurs around the Bay of Biscay. Overall catches have generally been declining since the early 1950s, when they were about 65 000 tonnes per year, due mostly to decreases in longline and trolling effort, although pole-and-line and gillnet effort has been increasing. Recent catches from this northern stock have varied between about 30 and 40 000 tonnes per year. Although reliable estimates of potential sustainable yields are not available, it is generally considered that the northern stock is probably fully exploited, and that increased fishing effort would not result in sustained increased catches. Concern has also been expressed over the observed declines in the biomass of spawning fish, thought to be at about 16 to 20% of its pre-exploitation level. These concerns have led to the conclusion by scientists working cooperatively under the auspices of ICCAT that the fishing mortality of the northern stock needs to be limited to current levels (ICCAT, 1999). Based on this scientific advice, the member governments of ICCAT have agreed to limit the number of vessels fishing northern albacore to 1993/1995 levels.

The southern stock of albacore is harvested mostly off West Africa by longline and pole-and-line vessels. The stock was first exploited on a commercial scale during the early 1950s; catches had risen to about 30 000 tonnes per year by 1985, and generally remained somewhat above that level until 1994. Since 1994 the catches have averaged nearly 30 000 tonnes per year. The AMSY for the stock, estimated with production models, is about 30 000 tonnes, but for nine of the past twelve years the catch has exceeded this level. The current biomass is thought to be above that which would produce the AMSY, and fishing effort below the level needed to harvest the AMSY. In short, the population does not appear to be overfished, but, because of the great uncertainty in the estimates of fishing mortality and biomass, fishing effort should not be increased (ICCAT, 1999). The governments of ICCAT agreed to set a catch quota for 1999 equivalent to the current replacement yield of 28 200 tonnes.

No conclusive assessments have been made for the Mediterranean stock.

2.2.5 Bluefin

There are two species of bluefin tuna, southern bluefin, found throughout the temperate waters of the southern hemisphere, and northern bluefin, found in the north Pacific and the north Atlantic (Some taxonomists consider that the northern bluefin of the Atlantic and the

Pacific are separate species). They are a slow-growing and long-lived species, with some individuals reaching more than 25 years of age. In terms of tonnage landed, bluefin is the least important of the principal market species of tuna; however, these low tonnages belie the commercial importance of the species. Because of their large size, and the colour, texture, and high fat content of their flesh, they are the most sought-after species for sashimi, and command a higher price than any other species of tuna. Southern bluefin spawn in the eastern Indian Ocean, and as they grow they migrate through Australian coastal waters to the high seas, where they are found in the southern parts of all three oceans. In the Pacific Ocean northern bluefin spawn in restricted areas off Formosa and southern Japan, and in the Sea of Japan; some of them migrate across the Pacific to off North America, and then return to the spawning grounds in the west as they approach sexual maturity. A few individuals make southerly migrations to areas below the equator in the western Pacific. In the Atlantic northern bluefin occur in most waters north of the equator and in the Caribbean and Mediterranean Seas. Spawning occurs in the Mediterranean Sea and the Gulf of Mexico. World catches of the two species combined have declined from over 100 000 tonnes during the 1960s to less than 65 000 tonnes in recent years.

Pacific Northern Bluefin

In the northwestern Pacific, around Japan, northern bluefin are taken throughout much of the year by a variety of gears, including purse seines, trolling gear, longlines, fixed traps, and pole-and-line gear. In the eastern Pacific purse-seine vessels take almost all of the catch, mostly in nearshore waters off northern Baja California, with some lesser catches off southern California. During the 1960s catches averaged about 25 000 tonnes per year, about 40% from the eastern Pacific and the rest from around Japan; during the 1970s they averaged about 20 000 tonnes, but varied a great deal from year to year (Figure 6). During the 1980s effort directed at bluefin declined, resulting in a reduction in catches: during that decade annual catches averaged about 14 000 tonnes. The portion of bluefin that migrate to the eastern Pacific is highly variable, and reduction in that migration may also have had something to do with the reduced catches of bluefin in the eastern Pacific. If fishing in the eastern Pacific is resumed at pre-1980 levels catches could be increased, perhaps to former levels. However, much of the current catch consists of small fish, and if these could be protected until they reached a larger size, total production of bluefin from the Pacific could increase.

Atlantic Northern Bluefin

Bluefin tuna are distributed widely throughout the Atlantic Ocean. Historically they were taken in the western Atlantic as far north as Nova Scotia and as far south as southern Brazil. In the eastern Atlantic they were taken off Norway in the north and as far south as North Africa and throughout the Mediterranean Sea. For management purposes, the population has been divided into an eastern and western stock, with the stock boundary approximately equidistant from the two continents. There is some mixing between the two stocks, however, and some scientists think that the bluefin of the Atlantic Ocean and Mediterranean Sea should be considered as a single stock for management purposes (National Research Council, 1994).

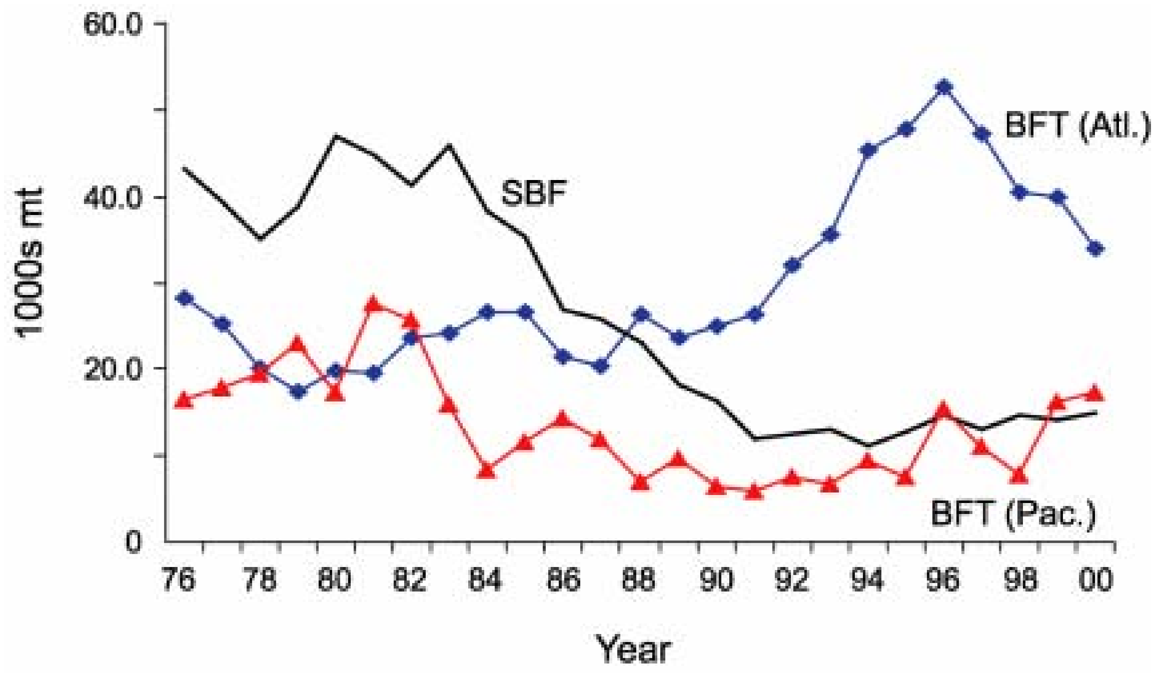

Figure 6. Trends in the world catch of bluefin tunas

Between 1950 and 1970 the total annual catches from the entire Atlantic ranged between 30 and 35 000 tonnes. Catches declined to about half that level during the early 1970s, and then increased to the 1994-1996 level of about 48 000 tonnes (Figure 6). By 2000 catches decreased to less than 35 000 tonnes. Judging from these trends, it would seem reasonable to assume that the fishery for bluefin in the Atlantic is healthy and capable of sustaining the current levels of catch. However, examination of more detailed information leads to the opposite conclusion.

For the western stock, catches were at their maximum (10 to 20 000 tonnes per year) during the early 1960s, after which, in the face of increasing fishing effort, they declined to around 3 to 7 000 tonnes per year. Because of these declining catches and a declining biomass, in 1982 ICCAT implemented catch limits, and annual quotas of between 2 and 3 000 tonnes have been in effect since. Current assessments suggest that catches of 2,500 tonnes would be sustainable for the western Atlantic, but at that level of exploitation the biomass of the stock, which is considered to be at a very low level, would not change. In order to ensure any increase at all in biomass the quotas would have to be set lower than current levels of catch, and to increase biomass to AMSY levels within 20 years they would have to be reduced to 500 tonnes per year.

For the eastern stock (which includes the Mediterranean Sea), catches fluctuated around 20 000 tonnes during the early 1960s, hovered around 10 000 tonnes until the mid-1970s, and then increased steadily until 1996, when they reached more than 46 000 tonnes. Since then they have declined. Until 1974 about 70% of the catch came from the eastern Atlantic, but then the catches in that area began to decline while those in the Mediterranean increased, and now comprise the major share of the catch. SCRS scientists have conducted extensive studies of the status of the bluefin stock in the eastern Atlantic, and they have estimated that current catch levels are not sustainable, but that a catch of about 25 000 tonnes per year would halt the decline of the biomass. Catch quotas of 32,000 and 29,500 tonnes were set for 1999 and 2000, respectively. Other conservation measures have been agreed to in the past, but they have not been effective. For example, a minimum size limit of 6.4 kg (with a 15% tolerance) was approved several years ago, but in recent years over 40% of the catch has consisted of fish smaller than this limit. There is grave concern over the status of the bluefin stocks in the Atlantic. Because the eastern stock is so much larger than the western stock, even with low rates of mixing the effects of overfishing in the east could adversely impact the success of the conservation programme in the west (Deriso and Bayliff, 1991 and ICCAT, 1999).

Southern Bluefin

As mentioned above, southern bluefin spawn in the eastern Indian Ocean, and as they grow they migrate through Australian coastal waters to the high seas. Catches have declined considerably over the last decade, from nearly 50 000 to about 15 000 tonnes (Figure 6). The decline is due to overexploitation of younger fish, and possibly a decline in recruitment attributable to a reduced spawning stock; some scientists have suggested that recruitment is in danger of falling to critically low levels unless the spawning biomass is increased substantially while others believe that recruitment is independent of stock size for the range of stock sizes observed in the fishery (Deriso and Bayliff, 1991). Catch limits have been placed on the harvest of southern bluefin by the Commission for the Conservation of Southern Bluefin Tuna (CCSBFT). Australia, Japan, and New Zealand, the principal nations involved in the management of the fishery for southern bluefin, have had catch limits placed on the harvest of this species throughout its range, although there is some dispute as to the status of the stock and what those limits should be. The current annual catch quota is about 12 000 tonnes, but about 17 000 tonnes are actually being taken, the excess mostly by nations other than the three mentioned above. The quota was set to allow the population to recover, but there is some disagreement on whether the level is low enough to ensure an increase in abundance.

3 LOOKING AHEAD

3.1 Production

3.1.1 Yellowfin and skipjack

In general, the outlook for world production of skipjack and yellowfin tuna is mixed. For yellowfin, most of the fisheries, with the possible exception of the eastern Indian Ocean, are probably fully exploited. For skipjack, catches can on the average possibly be increased in the Pacific, but probably not much, if any, in the Atlantic and Indian Oceans

In the eastern Atlantic the catches by the surface fleets targeting yellowfin and skipjack have reached the upper sustainable limit of yellowfin and probably are near that limit for skipjack. This tendency became obvious in the early 1980s, and caused many purse-seine vessels from the Atlantic to transfer their operations to the western Indian Ocean (ICCAT, 1999).

Although the scientific assessments of the stocks in the western Indian Ocean are much less conclusive than those for the Atlantic, it appears that the surface catches of yellowfin and skipjack are at or near the maximum that the stocks can support. The potential for increased production of these two species in the eastern Indian Ocean is unknown (Anganuzzi, Stobberup, and Webb, 1996). Currently, the surface catch in that region is low compared to that of the western Indian Ocean, but it is not known how much, if any, catches can be increased.

In the eastern Pacific Ocean the stock of yellowfin tuna is fully exploited, but the skipjack stock could possibly sustain increased average catches (IATTC, 2001). However, increasing the catch of skipjack could lead to overfishing of yellowfin and bigeye, since small yellowfin and bigeye are often caught together with skipjack, especially on FADs.

In the western Pacific some increase in catch may be possible. This region supports the largest tuna fishery in the world, producing about 60% of the world's skipjack and 35% of the world's yellowfin. Analyses conducted by scientists of the SPC, based mostly on data from tagging experiments, suggest that the skipjack stocks of the region can support an increase in catch. However, for this increase to become reality the stocks of currently underexploited skipjack must be identified, there must be a demand for the raw material, and they must be vulnerable to fishing gear. Similar tagging studies of yellowfin tuna suggested that catches of that species could possibly be increased over current levels. However, the declining catch rates in the longline fishery and increased catches of small yellowfin in the purse-seine fishery on FADs suggest that any increases in fishing effort on yellowfin in the western tropical Pacific should be viewed with caution, and may not lead to sustained increases in catch. Increasing fishing effort may lead to increased catches of skipjack but, since in the western Pacific, as in the eastern Pacific, skipjack are often caught together with small yellowfin and bigeye, the problem lies in ensuring that the increase is in catches of skipjack only, and not those of yellowfin and bigeye (Hampton, Lewis and Williams, 2000).

3.1.2 Bigeye

Assessments and management of bigeye tuna present special problems. Due to the fact that they inhabit the deeper layers of the ocean, catches of bigeye have historically been taken mostly by longline vessels. With the expansion of purse-seine fishing throughout the world's oceans, and the stabilization of production from 1990 to 1997, surface fleets have developed the use of FADs to capture skipjack, and previously unavailable bigeye. Whereas longline vessels capture large bigeye near the optimum size for maximizing the yield per recruit, purse-seine vessels generally catch small bigeye well below that size. In all the major tuna-fishing regions of the world purse-seine catches of bigeye are increasing, while longline catches are generally decreasing. However, it is uncertain whether total catch will increase. The natural mortality rate of bigeye is believed to be lower than that of yellowfin. (Natural mortality almost certainly varies with age, with younger fish having higher rates than older ones, but good estimates of age-specific mortality are not currently available.) If the natural mortality rate of bigeye is as low as 0.4, as it was for some time believed to be, then the current expansion of catch in the surface fisheries cannot be sustained, and overall catches of bigeye will decline. However, if the mortality rate of bigeye is similar to that of yellowfin, then total catches of bigeye can be increased. In either case, longline catches of bigeye will decline. From an economic point of view the effect would be enormous, since the value of the large bigeye caught by longliners and destined for the *sashimi* market is far greater than that of the smaller fish caught by purse seiners and destined for the canned fish market (Deriso, Bayliff and Webb, 1998).

Because of these uncertainties regarding the biology of bigeye, it is difficult to know with any degree of confidence whether catches of bigeye can be expected to rise or fall in the future. If purse-seine fishing effort for small bigeye is allowed to increase further, it may be possible to estimate the natural mortality rate more accurately and determine what the potential production might be. If increased effort results in increased sustained catches, then 0.4 is most likely an underestimate of natural mortality; however, if total catches decrease, this would confirm this lower mortality rate.

3.1.3 Albacore

Of the six stocks of albacore harvested commercially, at least one is considered to be overexploited, three are considered to be fully exploited, and the status of the remaining two is uncertain. Judging from the lack of a trend in the world production of albacore over the last 25 years, and the high degree of interannual variability in the catch, it does not seem likely that increased levels of fishing effort would result in significant increases in catch. Continued fluctuations in catch, associated with a changing environment, will likely be the norm for the future.

3.1.4 Bluefin

Of all the principal market species of tuna, bluefin have suffered the most from the ravages of heavy exploitation, for two main reasons: their longevity, and their exceptionally high value in the *sashimi* market.

Most seriously overexploited is southern bluefin. Production is now about half of what it should be under a proper management regime. To return population abundance to former levels will require, at a minimum, a long-term commitment to keep catches at the currently low levels, or more likely at even lower levels. Judging from the difficulties scientists responsible for the assessment of the southern bluefin stock are having in agreeing on their assessments, it is possible that the current conservation programme could be weakened. If that were to occur, this already heavily depleted stock could be further affected (Deriso and Bayliff, 1991).

Even though total catches of northern bluefin from the Atlantic and Mediterranean are still at high levels, the stocks in both the east and west are considered to be overexploited. Without effective management in the eastern Atlantic and Mediterranean, many analysts consider that overall catches will decline.

Annual catches of northern bluefin in the Pacific have fluctuated between about 15 and 30 000 tonnes over the last several decades. During the last decade catches have declined, but this may be due in part to the decrease in fishing effort in the eastern Pacific. Studies show that if catches of small bluefin taken in the troll fishery of the northwestern Pacific could be reduced, overall production could be increased on a sustained basis as a result of increased yield per recruit.

Judging from current trends in these fisheries for bluefin, and the difficulties in implementing effective management measures, it is possible that world catches of bluefin will not increase, but rather decline.

Because of increasing demand, declining production, and the high price of bluefin, a number of attempts have been made to rear the species in a controlled environment. Bluefin ranching, which involves capturing wild bluefin, holding them in anchored pens, and growing and fattening them for the *sashimi* market, is being developed in various regions of the world, including Japan, where the methods were originally developed, Australia, Morocco, Spain, Croatia, and Mexico. This industry is expected to grow, but output in the foreseeable future will never match or replace production from the wild. Because of the lower value of skipjack and yellowfin, and the high potential cost of artificially rearing them, mariculture does not seem an economically viable alternative in the near future, particularly with respect to the canned fish market.

3.1.5 All species

In view of all the above, it seems likely that the combined world production of yellowfin, bigeye, albacore, and bluefin will not change very much in the future from what it has been during the past few years. Annual production of those species has averaged slightly more than 1.8 million tonnes over the last several years, and will probably stay near that level in the future. Skipjack, however, has shown a significant increase in production, going from about 400 000 tonnes in 1970 to an average of slightly more than 1.9 million tonnes since 1998, although fluctuations in the catches of skipjack due to natural causes will continue in the future, as they have done in the past. Catches of all of these species could move in either direction in the future however, depending on a number of factors.

On the one hand, if more purse-seine vessels enter the fishery in the western Pacific, either through new construction or transfer from other areas, and if the scientists estimates of population abundance are correct, and if these vessels are able to realize the potential increases in catch that the skipjack stock in that region may be able to support, then world tuna catch might increase by as much as 10 to 15%. On the other hand, there is a real possibility that, unless effective management controls are implemented for presently fully-exploited tuna resources, overfishing of those species could occur and world catches decline. These two possibilities are not mutually exclusive. Newly-directed fishing effort in the Pacific could increase the catch of skipjack in that ocean, while overfishing could reduce the catches in other areas.

3.2 Adequacy of Catch Statistics

Complete and timely information on the catches of tunas is fundamental to the monitoring and assessment of the stocks. This information is also essential for many other purposes of a more political, economic, or management nature, *e.g.* compliance with regulations, evaluating supply and demand in the market place, and forecasting tax revenues. The history of data acquisition has been one of progressive improvement, but there is a great deal of room for more improvement. The most complete set of data on world tuna catches is compiled by FAO. The FAO data are from information that is provided to them by governments and international fisheries organizations. The data are not complete in many cases, because some governments and/or international organizations do not collect complete nor timely data, so FAO must make estimates of catches for which no data are available. Neither is the data timely; the FAO reports usually appear with a two-year time lag.

The question then arises: if the data needs improvement, how can that be accomplished? One possible way is to use more effectively the international bodies with responsibility for the management of tuna. Whereas only a few years ago there where many ocean regions where important tuna fisheries existed, but where there were no regional fisheries bodies, there are now regional tuna bodies covering all areas of tuna fishing except for the western Pacific

(Although not Article 64 type tuna bodies, the FFA and SPC do collect data for parts of the western Pacific). The establishment of a regional tuna organization in that area is near completion. Each of these bodies has various degrees of responsibility for the collection and/or compilation of tuna statistics. The degree to which they do this varies. At one extreme, some of these organizations are mandated to directly collect, archive, and distribute such data, while at the other extreme, others are mandated to be a central repository where such information can be received from member governments. The detail and quality of the data varies, as do these specific responsibilities. Perhaps by giving them more specific responsibilities for the collection of data the organizations could work more closely with both the tuna fleets and the governments in giving them technical and financial assistance in creating national data collection centers.

Because the data and the means of collecting them are the same in nearly all tuna fishing areas, it would be efficient and beneficial to coordinate and standardize the data collection among the regional bodies. This coordination could be accomplished in two ways. One way would be to request the FAO to act as the coordinating agent. The other way would be for the bodies themselves to create a coordinating committee, comprised of representatives of each of the regional bodies. In addition to improving the quality of the data, such an approach could lead to the establishment of a system for estimating the world catch of tuna on a real time basis. Most major tuna processing companies, vessel owner organizations, and other industry organizations have information on the catches of the vessels while still at sea. These estimates are made on a daily or weekly basis. It is possible that the regional bodies could collect this sort of information. In fact, one regional tuna body, the Inter-American Tropical Tuna Commission (IATTC), has collected such data for many years and publishes a weekly report of the catches of tuna in the eastern Pacific Ocean. The report has a wide distribution and is well known. It is used for a variety of purposes by governments and industry, and by the IATTC to insure compliance with its conservation programmes for tuna. Because of the fundamental importance of reliable, timely, and accurate statistics of tuna catch on a global, as well as regional, basis, a high priority should be set on the establishment of ways and means for collecting such data. In March of 2000, the FAO in conjunction with regional tuna bodies held an “Expert Consultation on Implications of the Precautionary Approach for Tuna Biological and Technological Research” in Phuket, Thailand. In the report of that meeting (FAO, 2001) it was noted that current data collection programmes for tuna do not provide complete and accurate sets of data for determining the status of the stocks of tuna. A number of recommendations are made for improving data collection and the reader is referred to the report of the Expert Consultation for the details of the recommendations.

4 THE TUNA FISHING VESSELS OF THE WORLD

Since the advent of the human race, every type of device imaginable has been used to capture tuna, from spears or harpoons, to dynamite. Probably the first commercial harvests of tuna were made using hand hauled nets and fish traps. These first commercial captures of tuna probably took place in the Mediterranean Sea. The Phoenicians used fish traps more than three millenia ago to capture bluefin tuna, which they traded throughout their empire. Though such traps are still used to harvest tuna in the Mediterranean Sea, and Japan too, nearly all of the present-day harvest of tuna is made from fishing vessels. The vessels represent a variety of gear types and sizes.

4.1 Gear Types

4.1.1 Purse Seines

Purse-seine nets are set vertically in the water, with floats attached to the upper edge, while along the lower edge is a chain, for weight, and a series of rings, through which the pursing cable passes. Purse-seine nets can be as long as 1.5 km and more than 150 m deep. On sighting a school of tuna, a large skiff with the end of the net attached is released from the stern of the fishing vessel. The vessel encircles the school with the net. The cable is hauled aboard the vessel, causing the bottom of the net to close, and the fish are trapped inside the pursed net. Most of the net is then pulled aboard the vessel, confining the fish in a “sack,” from which they are transferred to the deck of the vessel. Tuna purse-seiners vary in length between about 30 to 115 meters, and can pack on board up to 4 000 tonnes of frozen fish. However, most high-seas tuna seiners average about 70 to 80 meters in length and can carry about 1 000 to 1 500 tonnes of frozen tuna. Such vessels can fish throughout the oceans of the world, and make trips that last up to several months before returning to port. Many carry helicopters to improve their efficiency in finding and catching fish.

Purse seiners target mostly yellowfin tuna and skipjack, and on a world scale account for roughly 60% of all the tuna landed. In recent years the purse-seine catch of bigeye tuna has been increasing rapidly, mostly due to the increased use of FADs.

4.1.2 Longlines

This type of gear involves the use of a mainline which can be more than 100 km in length and from which as many as 3 000 branch lines, each with a baited hook, are dangled in the water column. The mainline is kept afloat by a series of buoys attached at intervals. It can take up to 8 hours to set the net and 12 to retrieve it. The gear is passive, in that it captures whatever fish happen to take the bait. One set of the net can capture several species of tunas, plus other types of fish, particularly swordfish and marlins. The gear fishes mostly at depths between 100 and 150 meters, where temperatures are cool and the largest tuna are most often encountered. These large tunas, especially bigeye and bluefin, fetch very high prices in the *sashimi* markets of Japan. The majority of large longline vessels target bigeye tuna. The smaller longline vessels use shorter mainlines and fewer hooks than do the larger vessels. They operate mostly in nearshore waters, whereas the larger vessels fish throughout the world. These larger vessels are often supplied by tender vessels, and can stay at sea for extended periods. The largest longline fleets are those of Japan, followed by those of Taiwan, Province of China and Republic of Korea.

In terms of tonnage of tuna captured, longlining captures about 14% of the world catch of tunas.

4.1.3 Pole and Line

Pole-and-line fishing, which was developed in several separate regions of the world, involves use of a hook and line attached to the end of a pole, improving both leverage and reach. This general method of fishing has been used for centuries in the South Pacific, Japan, and the Maldives. However, what could be called modern pole and line fishing developed during the early twentieth century. At that time the Japanese developed larger pole-and-line vessels capable of travelling to any ocean where tuna occurred in fishable quantities. The vessels, which carry live bait in tanks of circulating seawater, can freeze their catches and stay at sea for three or four months. In some cases, when bait from cooler waters is carried into tropical areas in pursuit of tuna, the water in the bait tank is refrigerated in order to maintain a temperature similar to that of the water where the bait was captured thereby increasing the survival of the baitfish.

The greatest growth in pole-and-line fishing occurred in Southern California in response to a growing demand for tuna following the introduction of tuna canning in the early Twentieth century. It was in this fishery that the "tuna clipper," originated. These pole-and-line vessels were capable of packing up to 600 tonnes of frozen tuna, carrying large quantities of live bait, and staying at sea for many months. Pole-and-line fishing is a two-mode type of fishing. Live bait must first be caught before the tuna, which are most often skipjack and yellowfin, can be captured. The live bait was used to attract the tuna to the vessel where they where caught by pole-and-line gear. If the tuna were feeding well, and the "chummer" could keep the fish along side the vessel, several tonnes could be captured in a short time. Though pole-and-line fishing was at one time the major type of tuna fishing in terms of catch, because of improvements in purse-seine gear and methods it has diminished in importance.

In terms of tonnage of tuna captured, pole-and-line fishing, like longlining, captures about 14% of the world catch.

4.1.4 Trolling

Trolling consists of towing from a vessel, generally less than 20 meters in length, several lines with bait or lures attached. Most troll fisheries target albacore tuna (*Thunnus alalunga*), but several other species are also taken. Trolling accounts for only a very small percentage of the world catch of tunas.

4.1.5 Gillnets

Gillnets consist of a panel of fine, nearly invisible webbing suspended vertically in the water column by a series of floats along the top and a series of weights along the bottom. The fish become entangled when they try to pass through the net. Drift gillnets, which are generally used to capture tunas in the open ocean, consist of a series of individual nets connected together, often-exceeding 100 km in length. Because of the high incidental capture of other species, the use of drift gillnets longer than 2.5 km, was banned on the high seas by the United Nations. Nevertheless, such nets continue to be used inside the juridical waters of several states. Only a small percentage of the world catch of tunas is taken with gillnets.

4.2 Present-day Tuna Fleets

The ability of these different types of vessels to catch fish varies with the type of gear used, and the size of the vessels, and other factors. Their relative differences can be measured in economic and/or biological terms.

With respect to economic terms, a large purse-seine vessel might, on the average, be able to catch 20 tonnes of fish per day fishing (some high-line vessels can average much more than that), all of that is normally destined for canning. During one day of fishing a distant-water longline vessel might catch 2 tonnes of fish much of which is normally sold in the sashimi market, perhaps fetching 10 to 20 times the value per ton of the purse-seine caught fish. The

economic success of fishing for each of the vessel types would, of course, depend on the costs of production, which depend on the cost of capital, amount of fuel used, crew size, etc.
With respect to biological terms, catch is important because it represents mortality of the stock of fish being harvested. Because of their characteristics, such as speed, size, characteristics of the gear deployed, type of fish-finding equipment available (*e.g.* sonar, radar, aircraft), *etc.*, the efficiency (measured in terms of how much fish is caught during a given period of time) may be quite different for two vessels fishing side by side. Estimating this efficiency, or fishing power, and how it changes with time, for the different types of vessels involved in a fishery is essential to the evaluation of the impact of fishing on the stocks of fish being exploited, and therefore to the study of methods to limit fishing capacity.

The FAO definition of fishing capacity, given in the introductory section of this document represents the maximum amount of fish that can be produced by a fully utilized fleet or vessel during a time period, given the size of the stock being fished and the level of fishing technology being employed. The vessel's fishing capacity represents some maximum level of fishing mortality that it can generate. Throughout this study the term "vessel or fleet carrying capacity" is used to represent the capacity of a vessel or fleet to carry fish, and though not equivalent to the FAO definition, this carrying capacity (hold capacity) is assumed to be related to the ability of a vessel to catch fish under normal fishing conditions, and hence to the fishing mortality it can theoretically generate. Also throughout this document when vessel and fleet sizes are being referred to, carrying capacity is used. The two definitions can be equivalent when a fleet of vessels is fully utilized, but for most tuna fisheries, carrying capacity for a fleet of vessels is probably most often less than fishing capacity. Fish carrying capacity is measured for most tuna fishing vessels as the tonnage of fish that can be stored on the vessel when it is fully loaded, or the storage area measured in cubic meters. Of course there is some variability in this, depending on the size of fish being stored. A 1 000-ton vessel can store slightly more than that amount if the fish are small, and slightly less if they are large. Carrying capacity can be calculated for a vessel by examining its history of unloadings, and then taking some average of the maximum amounts unloaded. In the case of volumetric measures the shipyard-rated capacity of the fish holds are used. There is, of course, a correlation between the two measures, and one can be estimated from the other. For example, for the purse seine fleet operating in the eastern Pacific Ocean one cubic meter of storage capacity is equivalent to approximately 0.8 tonnes of carrying capacity, averaged over all sizes of tuna captured. Similar relationships can be defined for net tonnage, gross registered tonnage, displacement tonnage, etc., *versus* carrying capacity. The relationship among these variables is different for different countries, areas, fleets, shipyards etc., depending upon how the variables are defined. It will be essential to standardize the definitions if these relationships for large fleets from a variety of areas and nations are to be defined. In this report, carrying capacity will, in most cases, be used when discussing fleet size.

4.2.1 Purse-seine fleets

As already mentioned purse-seine vessels account for the majority of the commercial landings of tuna, taking about 60% of the nearly 4 million tonnes landed each year. The world fleet of purse-seine vessels consists of a variety of sizes, ranging in carrying capacity to a maximum of about 4 000 tonnes. Smaller vessels with less than about 200 to 250 tonnes capacity, generally fish within one or two days of the coastline, while the large vessels roam throughout the oceans of the world. In terms of the total carrying capacity of the world purse-seine fleet, the majority is comprised of large vessels, and these vessels account for most of the purse-seine catch.

There is no single source from which to obtain a listing of all purse-seine vessels. Most international organizations attempt to keep lists of vessels fishing in their areas, but for many tuna fisheries good records are not maintained.

The most complete data set available is that for the eastern Pacific Ocean, which is maintained by the IATTC. This data set, extending back for about forty years, includes all purse-seine vessels that have captured tuna in the EPO, and characteristics such as length, breadth, gross registered tonnage (GRT), net registered tonnage (NRT), carrying capacity, cubic meters of fish hold capacity, aircraft use, fish-finding electronics, net dimensions, etc. Much of this information is confidential, but in recent years the Commission has been making available to the public a list of the vessels, by name, flag, and fish carrying capacity or cubic meters of hold capacity.

The next most complete listing of vessels, for the western tropical Pacific, is maintained by the Forum Fisheries Agency (FFA) and the Oceanic Fisheries Programme of the Secretariat of the Pacific Community (SPC). The FFA includes in its list all vessels, by flag and size, which are licensed to fish in the waters of the nations belonging to the Agency, which covers much of the region of the western-central tropical Pacific. Although some purse-seine vessels without licences fish in the region, and are not included in the FFA list, the majority are so included. The SPC maintains a similar list of vessels which fish in its convention waters, but this list does not include all of them. In addition to the vessels that have fished in SPC waters, that organization includes some vessels from outside the region, particularly those of the Philippines. There is a great deal of overlap in the FFA and SPC lists, as would be expected, since the geographic areas of responsibility for the two organizations overlap a great deal. Both the FFA and the SPC have recently made their lists available to the public. Beyond the areas of these three international organizations, there or no detailed lists or registers of vessels available from public institutions for the Pacific Ocean in general. Such a lack of available information is important for any studies related to world fleet capacities. Data from industry sources and government reports were used to obtain information for vessels not included in the three lists. All of this information was utilized to estimate the size of the current fleet of large purse seiners operating in the Pacific Ocean. These estimates are shown in Table 1, as number and tonnage of high-seas purse-seine vessels by intervals of 400 tonnes of carrying capacity for the eastern Pacific (EPO) and the western Pacific (WPO). It is believed that these vessels account for at least 95% of the tuna catch from the Pacific Ocean made by purse-seine vessels. Small purse-seine vessels that make their catch mostly near shore make the remaining 5%. In the case of Japan, for example, there are approximately 25 purse seine vessels of about 200 tonnes of carrying capacity each that fish intermittently for tunas around Japan during June to September.

The majority of purse-seine vessels operating in the Indian Ocean fish in the western part of that ocean, and mostly in the region near the Seychelles. The Seychelles Fishing Authority (SFA) has licensed such vessels to fish in its waters since the mid-1980s. Between 1985 and 1995 the SFA maintained and published, on a quarterly basis, lists of purse-seine vessels authorized to fish in its EEZ. During that time the vessels listed in the quarterly reports accounted for most of the catch of tuna made in the Indian Ocean by purse-seine vessels.

Table 1: Estimates for the year 2000 of the numbers and carrying capacities of the world's high-seas tuna purse seine fleet, by 400 ton intervals

Range		ATL	IND	EPO	WPO	Total
<401 (mt)	Vessel #	1	0	52	23	75
	Capacity (mt)	400	0	11 274	6 215	17 889
401-800 (mt)	Vessel #	35	1	31	38	105
	Capacity (mt)	26 265	744	19 802	21 909	68 720
801-1 200 (mt)	Vessel #	10	15	74	156	255
	Capacity (mt)	11 467	16 213	72 867	162 833	263 380
1 201-1600 (mt)	Vessel #	6	9	33	24	72
	Capacity (mt)	8 030	13 204	44 745	33 033	99 012
1 601 – 2000 (mt)	Vessel #	1	9	6	4	20
	Capacity (mt)	1 902	16 343	10 699	6 909	35 653
>2000 (mt)	Vessel #	0	33	9	1	43
	Capacity (mt)	0	80 050	25 558	2 234	107 842
TOTAL	**Vessel #**	**53**	**67**	**204**	**246**	**570**
	Capacity (mt)	**48 064**	**126 554**	**184 945**	**233 133**	**592 696**

A few purse-seine vessels that do not fish in the western Indian Ocean, and therefore are not included in the SFA data, catch small quantities of tuna in the eastern Indian Ocean. Recently the staff of the Indian Ocean Tuna Commission (IOTC) began to collect statistics on the number and characteristics of vessels fishing for tunas in the Indian Ocean, and it has made these statistics available for this study. The IOTC data, along with data from SFA, and supplemented by industry data, were used to estimate the number of high-seas purse-seine vessels fishing in the Indian Ocean (IND) during 2000 (Table 1).

Of the approximately 500,000 tonnes of tuna taken annually in the Atlantic Ocean nearly 45% is reported by ICCAT to be taken by purse seine vessels. Most of the purse seine catch is made in the eastern Atlantic by vessels flying the flags of France or Spain. Though the staff of ICCAT does not at the present time maintain a register or list of purse seine vessels operating in the Atlantic Ocean, it is currently in the process of formulating such a list. The tonnage and number of vessels presented in Table 1 for the Atlantic, by size intervals of 400 tonnes, is therefore comprised of information obtained from a variety of sources, mostly industry, and is not considered to be as complete as that for the other oceans.

The world fleet of high-seas purse-seine vessels currently stands at about 570 vessels. The total carrying capacity of this fleet is estimated to be nearly 600 000 tons, and if it were completely loaded with tuna this would represent nearly 600 000 tonnes of fish. The mean size of a purse-seine vessel is approximately 1 040 tons.

4.2.2 Longline fleets

Longline vessels account for approximately 14% of the world production of tuna. They are not usually referred to in terms of tonnage capacity, but rather as to whether they are distant-water vessels, which are capable of operating in all the world's oceans and staying at sea for extended periods of time, or coastal vessels that normally are smaller and usually fish within the EEZ of the flag state. The former class of vessels accounts for the majority of the longline catch. The various international organizations are in the process of creating databases for the numbers of longline vessels fishing in their areas of competence, but such lists are generally not as far advanced as those for purse-seine vessels. Therefore, not as much detail will be presented for the longline fleets of the world. However, industry organizations, particularly Japan Tuna (*Nikatsuren*), maintain records of longline fleets throughout the world. In a recent document presented at the 2000 Commission Meeting of ICCAT, Document 019, the world fleet of large distant-water longline vessels was listed as follows: Japan, 532 vessels; Chinese Taipei, 600 vessels; Republic of Korea, 198 vessels; and approximately 236 vessels categorized under Illegal, Unregulated and Unreported (IUU) status. These 1 566 longline vessels are most likely an underestimate of the world longline fleet as the list does not include vessels from several nations, nor does it include smaller longline vessels that fish in the more inshore areas, but which land significant quantities of tuna.

4.2.3 Baitboat fleets

Baitboats, like purse-seine vessels are usually classified in terms of fish-carrying capacity. At one time, prior to 1950, baitboats were the dominant type of gear used to capture tuna. Once the modern purse-seine vessels were brought onto the scene in the late 1950s, they quickly overtook baitboats in terms of tonnage of tuna landed on a global basis. As the number of baitboats declined, the proportion of the world catch taken by longliners increased. Currently global catches of longliners and baitboats are almost the same, with baitboats also taking about 14% of the world catch of tunas. In the Pacific and Indian Ocean baitboats account for about 12% of the catch, while in the Atlantic Ocean, baitboats account for about 26% of the catch. In this study no estimate will be made of the number and total capacity of baitboats operating in the world tuna fishery, but because they account for nearly the same amount of catch as do the longline fleets, it is imperative that a concerted effort be made to create a world register of baitboats.

4.2.4 Other fleets

About 12% of the world catch is taken with gear other than purse seine, longline, and pole and line. About one-half of this remaining 12% is taken by trolling vessels that fish for albacore and the rest by a variety of other fishing gears, such as anchored and drifting gillnets, harpoons, and traps. No estimate will be made in this study of the amount of these gears operating in the world tuna fishery.

4.3 Fleet Statistics for the Future

It is obvious from the foregoing discussion that detailed information on the numbers and characteristics of tuna fishing vessels is limited, and not adequate for sophisticated quantitative analyses of fishing capacity on a global scale. It is also obvious that before the problems of global fleet capacity can be addressed in a comprehensive way there must be adequate information on the numbers and kinds of vessels fishing for tunas. The fact that it should be collected has been recognized in many international and national fora, so the only question is how this information can be collected. Most notably, the FAO Agreement to Promote Compliance and the U.N. Agreement on Straddling Fish Stocks and Highly Migratory Fish Stocks call on nations to work together within regional organizations to maintain lists of vessels operating in their areas of competence. Accordingly several of the regional tuna bodies have taken initiatives to create and maintain databases that will include all vessels fishing for tuna in their areas of competence. A world list of tuna fishing vessels and gear must include all types and sizes of vessels used to catch tunas, rather than just large purse- seine and distant-water longline vessels.

Currently, regional tuna bodies cover most waters of the globe where tuna are taken. ICCAT, which has responsibility for the Atlantic Ocean and adjacent seas, has initiated steps to compile a vessel list. The IOTC, which has responsibility for the Indian Ocean, has compiled a list of vessels currently fishing in the Indian Ocean, is working to improve the list and collect historical data on vessels that had previously fished in the area. The SPC, similarly, has compiled a list of vessels fishing in its region, and is working to update that list and compile historical information. The IATTC and FFA maintain databases for vessels that are currently and have previously operated in their respective regions. There are, however, areas that fall outside the jurisdiction of these various bodies, for which data is lacking. Most notably these areas represent parts of the west-central Pacific. The information that is collected by the various organizations is not uniform. Some organizations include detailed data and specifications for individual vessels, but others compile only statistics on the numbers of vessels fishing for tunas. Because the problems of tuna management are quite similar throughout all fisheries and areas, and because the vessels move from region to region, there is a strong need to collect detailed information by individual vessel that is comparable among regional organizations. The type of data that should be collected has been clearly identified in the FAO Agreement to Promote Compliance and by some of the regional tuna bodies, and such lists can serve as useful guidelines for collecting and maintaining a vessel database. The kind of information which would be useful to include in any international registry of tuna fishing vessels to be compiled by the regional tuna bodies includes:

- Name of vessel, former names, and registration number
- Flag of registry and previous flag(s) if applicable
- International radio call sign
- Date and location of construction
- Length, beam, and molded depth
- Gross tonnage
- Fish hold capacity in cubic meters
- Fish-carrying capacity in metric tonnes
- Power of main engine(s)
- Fishing method(s)
- Type of aircraft used in fishing, if applicable
- Name and address of registered owner(s)
- Name and address of manager(s)

In addition to the need to standardize the collection of vessel data, there is an urgent need to compile similar information for areas lying beyond the jurisdictions of the regional bodies. There are several possible means of accomplishing this, but two appear to be most practical. The first would be for the regional bodies to establish an inter-regional council or committee to standardize the collection of data and create a global register of tuna-fishing vessels. This committee or council would need to extend its investigations to include the collection of vessel information from areas outside the geographical areas of responsibility of its members. Because of matters related to jurisdiction and sovereignty, however, it could prove difficult for the regional bodies to collect such data. Therefore, a second possibility might be to call on the FAO to work with the proposed committee or council or to serve as the coordinating mechanism among the regional bodies. This latter approach would ameliorate the problems of jurisdiction and sovereignty that would be associated with the first approach. Both of these approaches are envisioned in the U.N. Stocks Agreement, Annex I, Article 7. It is interesting to note that the secretariats of the regional tuna commissions met in July 1999 at the offices of Eurostat in Luxembourg to consider the need to formulate a mechanism for the collection and exchange of information. Such an initiative could provide a mechanism for collecting and exchanging vessel data.

5 FLEET CAPACITY AND PRODUCTION

After several decades of continued increase in the global landings of tuna, production stabilized in the early 1990s, and remained at about the same average level for 7 years. Landings increased during 1998, and stayed high through 2000, but the increases were due to greater catches of one species, skipjack (Figures 1 and 2). Although there is no comprehensive information on the levels of fishing mortality during those years, studies for some of the important fisheries (Hampton, Lewis and Williams, 2000 and IATTC, 2001) suggest that it increased as a result of increased fleet carrying capacity and increased efficiency of the vessels in the fishery. Ideally, if estimates of fleet size were available for the global tuna fleet over the last several decades, it would be possible to examine in detail the relationship between catch and fishing capacity on a global basis, and to examine the possibility that there was more carrying capacity than needed to make the observed harvests. But, as was discussed above, adequate time series of such data are not available, although an estimate of the size of the current global purse seine fleet is presented

Because a long time series of data on fleet carrying capacity is available only for the eastern Pacific Ocean (EPO), a detailed examination of fleet carrying capacity and tuna production for that area is presented, and it can be used to demonstrate how data for other areas can be examined. Table 2 and Figure 7 show data on purse-seine fleet carrying capacity and the catches of tuna made during 1961 to 2000. The trends presented in Figure 7 show an interesting pattern of fluctuations in fleet carrying capacity and tuna catches that highlight the point raised earlier in this document concerning the need for fleet capacity limitations, particularly with respect to yellowfin. As fleet carrying capacity increases the limited quantity of fish available must be shared with increasingly more vessels, and the catch per vessel decreases. Continued fleet growth eventually results in management action to limit the total catch, but as fleets continue to increase, and catches per vessel continue to decrease, the fishing industry tends to resist controls on the catch and may apply pressure on the various governments to loosen or eliminate those controls. This is the classic situation of a “regulated open access fishery” first defined by Homans and Wilen (1997) and discussed more recently by Gréboval and Munro (1999), *i.e.* a fishery with poorly-defined property rights, coupled with regulations to control the levels of harvest. This scenario is played out fairly clearly in the data presented in Figure 7. In 1966 member governments of the IATTC implemented a conservation programme for yellowfin in the EPO, in the form of an annual total allowable catch. When the catch of yellowfin reached this limit, minus the amounts held in reserve for special allocations, unrestricted fishing for yellowfin in the regulatory area would cease.

During the early years of the programme the conservation measures were very successful from a biological point of view, in that the stock of yellowfin was maintained at a high level of abundance. However, fleet carrying capacity began to increase rapidly as a result of high tuna abundance and correspondingly high catch rates. In 1970 the carrying capacity was about 60 000 tonnes, and the catch of yellowfin was about 150 000 tonnes. The demand for tuna for canning and the prices paid to fishermen were increasing. This stimulated the building of new vessels, and the carrying capacity of the fleet increased to about 160 000 tonnes by 1976, and about 180 000 tonnes by 1981. Prior to 1975 the average weight of fish in the catch was about 12 kg. The catch peaked in 1976, but the fleet continued to grow.

As the fleet grew and competition for the fish increased, many vessels increasingly began to target small fish by fishing on schools associated with floating objects, such as logs and marine debris (In fact, a California law prohibiting the landing of fish less than 7.5 pounds was repealed at this time at the behest of the tuna processing industry). These small fish had previously not been heavily fished. Between 1977 and 1983 the size of fish in the catch decreased by one half, to about 6 kg. This decrease in average size reduced the yield per recruit and the total potential yield of the yellowfin population in the EPO. The lower yield from the fishery and the increased fleet size resulted in the closure to unrestricted fishing coming progressively earlier each year. It also resulted in lower annual catches and earnings per vessel. Because of the dire economic situation facing the vessels, many vessel owners pressured their governments to ease the conservation regulations. Because of these pressures, by 1978 it became impossible for the governments to reach agreement to close the fishery in time to stay within the recommended catch limits, and by 1980 the conservation programme had failed completely. By 1982 the catch had declined by more than half, to the low levels of the mid-1960s, when the conservation programme was first implemented, even though during the early l980s fishing effort was the highest it had ever been. Because of the poor catches in the eastern Pacific vessels began to leave the EPO for newly developed fishing grounds in the western Pacific. Others stayed in port because catch rates were so low, due to lower abundance coupled with a very strong El Niño event that made yellowfin less available to the fishery, so it was not profitable for them to go fishing. From 1983 to 1985, fishing effort stayed low and, the yellowfin stock recovered to considerably higher levels of abundance.

After 1985 vessels began to return from the western Pacific to fish for yellowfin tuna in the EPO, and many of the vessels that had been inactive resumed fishing. Fishing success was very good, the yellowfin catch reaching the highest levels in the history of the fishery during 1986 through 1996; the fleet during that period averaged about 110 000 tonnes of capacity, much less than its previous peak. The size of fish in the catch was large, averaging more than 12 kg, because most of the fishing was done on schools of large tuna associated with dolphins. Because of the good fishing, and apparently high profits, the fleet began to grow through new construction, reactivation of vessels, and transfers from other fisheries. Fleet carrying capacity continues to grow and is currently about 180 000 tonnes. Because of concern over dolphins, increasingly more fishing effort has been applied to non-dolphin schools of fish, particularly fish associated with floating objects, thus decreasing the average size of fish in the catch and possibly the yield per recruit of yellowfin. Most of this non-dolphin associated fishing is done on man-made fish-aggregating devices (FADs). The situation is similar to that during the mid to late 1970s with respect to yellowfin tuna. Even though there are restrictions on the fishery, the fleet continues to grow. This situation has caused concern among the governments of the region over the possibility of repeating the detrimental overfishing and economic events of that earlier period caused by too large a fleet. This concern has resulted in steps to limit fishing capacity in the region.

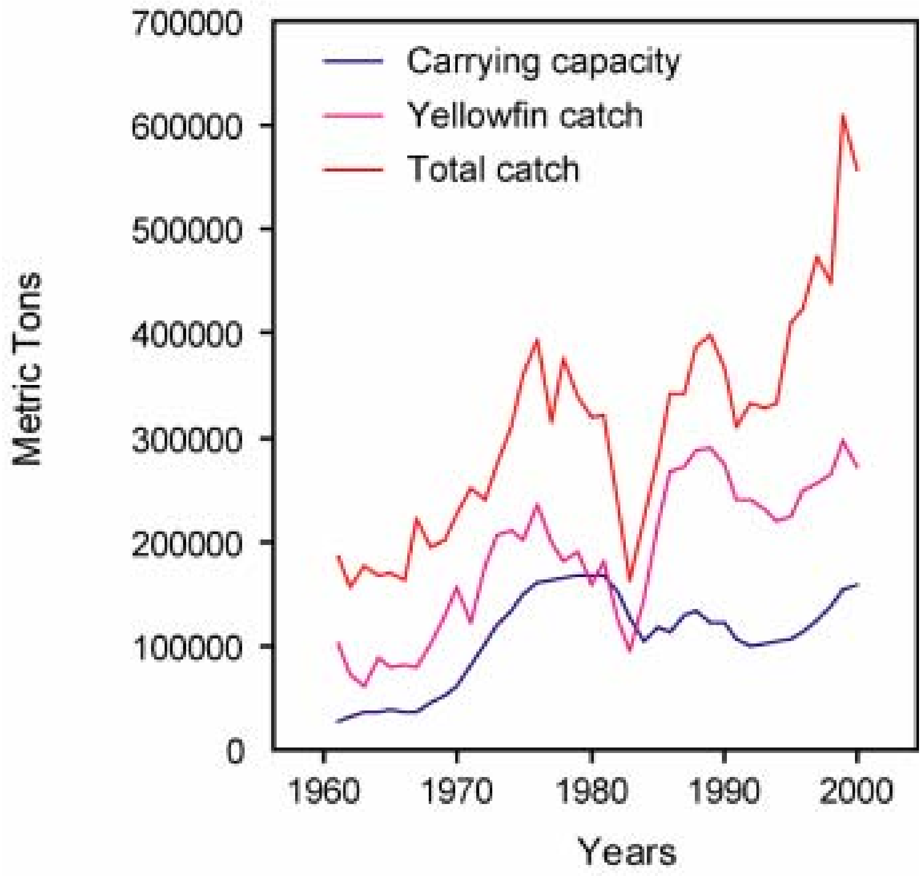

Figure 7. Trends in the catch of yellowfin tuna, yellowfin, skijack and bigeyecombined, and carrying capacity of purse-seine vessels in the eastern Pacific Ocean

There is, however, one major difference between the situation in the 1970s and early 1980s and the present situation. As explained earlier, fishing on floating objects captures mostly skipjack tuna, with much lesser amounts of small bigeye and yellowfin. Because of opposition to fishing for tuna associated with dolphins, most of the new fishing capacity has concentrated on fishing on FADs, which has substantially increased the catch of skipjack. From 1986 to 1991 skipjack catches averaged about 65 000 tonnes. The catches of this species began to increase when floating-object fishing started to expand in 1992, and by 1999 it had reached an all time high of nearly 270 000 tonnes. It has already been pointed out that the stock of skipjack in the EPO is not fully exploited and can probably sustain increased yields, while yellowfin and bigeye are fully exploited and subject to catch restrictions. The problem is reverting once again to that of a regulated open-access fishery: if the fleet is allowed to continue to increase because of potentially greater skipjack catches, the maintenance of the yellowfin and bigeye conservation programmes will be placed in jeopardy. This same scenario is playing itself out in other fisheries, notably those of the Atlantic and Indian Oceans.

In addition to the conservation problems brought about by having a fishing capacity greater than needed to harvest the available catch (excess capacity), serious economic problems are also created (Bertignac *et al*, 2001 and 1998). Although it is not the object of this paper to discuss economic problems in the tuna fisheries, the subject is mentioned because it will ultimately affect the success of any tuna management programmes entered into by the nations involved in these matters. The expansion of FAD fishing that was just described for the eastern Pacific is a worldwide phenomenon. World catches of skipjack reached the highest level in the history of the fishery during 1998 (Figure 2). The western Pacific fishery alone produced more than 200 000 tonnes in excess of what it had been producing in previous years. Skipjack catches during 1997 and 1998 were at record highs in the EPO, and the other ocean areas also produced high catches of skipjack. Production of skipjack during 1999 was high again, with that of the EPO reaching an all-time high. The pattern of concentrating fishing effort on FADs and high catches of skipjack prevailed once again during 2000. Coupled with these increased catches of skipjack, nearly all of which is destined for canning, has been a sharp drop in price paid to the vessels. From the beginning of 1998, to the end of that year, the ex-vessel price of skipjack dropped by nearly half. Price continued to decline during 1999, 2000, and early 2001 reaching its lowest level in more than 30 years. Many vessels are fishing at below operating costs and accumulating debt. Some vessels have been de-activated, and others are directing more effort to fishing for yellowfin, because of the slightly higher price. This pressure on yellowfin and bigeye too, creates conservation problems for species that are already heavily exploited, and exacerbates the economic problems caused by the high production of skipjack. Skipjack is a species that has shown great year-to-year variability in catch. This variability appears to be independent of the effects of fishing, and is most likely attributable to changing environmental features that alter abundance. Although the tendency has been towards increasing trends in catch of skipjack, there will continue to be a high level of year-to-year variability in these catches.

It seems obvious that any solutions to the problem of excess capacity will have to ultimately deal with the sort of economic problems mentioned above if there is to be a long-term, rational solution to the problem of excess capacity. Even though there are a number of economic studies dealing with this issue (Morrison, 1985, Squires 1987, Fare, Grosskopf and Kokkelenberg, 1989, Segerson and Squires 1990 and 1993, and Berndt and Fuss, 1989), just how they will be dealt with is a bit uncertain, since the problem of "overcapitalization in fisheries is in fact considerably more complex than that encountered in standard industrial organization economics" (Gréboval and Munro, 1999), and to get governments to focus on the economic problems related to overcapitalization has proven to be very difficult, at best.

The definitions developed by the FAO working groups on capacity have been primarily technical definitions, not economic ones. There is an urgent need to develop such economic definitions as well as quantitative approaches to evaluate overcapitalization and excess capacity in world tuna fisheries. In fact, the FAO meeting on fishing capacity held in Mexico City in 1999 attempted to deal with the issue of overcapitalization, but ended up dealing with the issue of overcapacity in terms of optimal fleet sizes for harvesting target catch levels (TCL), and examined a number of quantitative approaches that could be applied to the problem of determining whether excess capacity exists in certain tuna fisheries. The group concluded that two techniques, *Peak-to-Peak* and *Data Envelopment Analysis*, should be applied to a variety of case studies in order to evaluate more fully their benefits and limitations. Because of the availability of a time series of data on fleet carrying capacity and catch, and in keeping with the recommendation of the working group in Mexico City, data for the eastern Pacific tuna fishery have been analyzed by the Data Envelopment Analysis (DEA) approach. The DEA approach was chosen over the Peak to Peak, because the former utilizes more information on the fishery including biological and environmental data and provides more detailed results with which to examine the capacity problem, whereas the latter is more parsimonious with respect to both the data used and the results. Data Envelopment Analysis is also theoretically consistent with economics, whereas Peak-to-Peak is more *ad hoc* in nature.

Table 2: Carrying capacity of purse-seine vessels, catch of yellowfin, and total catch of yellowfin, skipjack, bigeye and bluefin taken by purse-seine vessels in the Eastern Pacific Ocean, 1961-2001 (mt tonnes)

Year	Capacity	Yellowfin	TOTAL
1961	27 250	102 643	184 996
1962	31 163	71 452	156 210
1963	36 550	62 028	176 717
1964	36 631	88 650	167 456
1965	38 728	78 898	168 961
1966	36 304	80 611	164 082
1967	36 650	79 959	222 075
1968	46 012	102 016	194 293
1969	51 807	128 858	201 323
1970	61 246	155 626	226 185
1971	80 668	122 839	250 643
1972	102 022	177 128	240 793
1973	119 735	205 253	274 139
1974	133 449	210 364	309 620
1975	148 667	202 142	360 274
1976	160 197	236 327	394 275
1977	162 294	198 816	314 327
1978	164 252	180 534	377 005
1979	167 016	189 674	340 094
1980	167 855	159 425	319 800
1981	167 862	181 813	322 177
1982	152 270	125 084	235 888
1983	127 640	94 256	163 741
1984	103 929	145 061	222 947
1985	117 738	216 992	280 394
1986	112 606	268 274	341 208
1987	130 240	272 247	342 285
1988	133 819	288 074	388 279
1989	121 277	289 375	398 340
1990	123 220	273 329	367 934
1991	106 365	239 121	309 799
1992	99 971	239 849	333 408
1993	101 434	232 071	329 394
1994	104 411	219 223	333 528
1995	106 019	223 776	409 050
1996	113 396	250 076	423 559
1997	125 319	256 676	473 778
1998	137 946	264 426	448 152
1999	154 454	295 773	610 400
2000	158 000	272 000	557 000
2001	185 000	350 000	540 000

5.1 Data Envelopment Analysis of the Eastern Pacific Tuna Fishery

The Data Envelopment Analysis (DEA) approach is a linear programming technique, which utilizes a variety of inputs, developed by economists to consider the issue of inefficiency of business enterprises. The methodology has been adapted to fisheries to examine the issue of overcapacity. Kirkley and Squires (1999b) applied this methodology, using the approach of Fare, Grosskop and Kokkelenberg (1989), and Fare, Grosskop and Lovell (1994) to the fishery for mid-Atlantic sea scallop, *Placopecten magellanicus*. The methodology can be applied to fisheries for which various levels of data are available. The 1999 FAO Mexico City meeting on Fishing Capacity, discussed the application of this technique at four different levels of data availability: Level 1 – total landings and number of vessels; Level 2 – data on vessel sizes and time spent fishing, plus Level-1 data; Level 3 – catch by species, size structure and vessel type, CPUE, effort, and price, plus Level-2 data; Level 4 – biomass estimates, cost and earnings data, efficiency estimates, plus Level–3 data.

5.1.1 Data used

The data used for the analysis of the EPO purse-seine fishery was between Level 3 and Level 4. A time series of data, grouped by vessel size classes, was analysed for 1971 through 2000. Seven size classes, based on metric tonnes of carrying capacity, were used: Class 1 (1-181), Class 2 (182-363), Class 3 (364-726), Class 4 (727-1088), Class 5 (1089-1451), Class 6 (1452-1814) and Class 7 (>1814). Classes 1 and 2 have the lowest catchability coefficients (q) among the seven groups. Classes 3-7 have similar catchability coefficients, but because of size their economic efficiency varies considerably. Catch data, expressed in metric tonnes, were available by years for each of the major species, skipjack, yellowfin, and bigeye, taken in the fishery. Effort for each year was expressed in days fishing; days spent at sea running to and from the fishing grounds, drifting, or not actively fishing were not included in the estimates of days fishing. Catch and effort data computed from individual vessel logbook information, were provided by Dr. Michael Hinton of the IATTC. Biomass estimates of yellowfin and bigeye were provided by Mr. Patrick Tomlinson of the IATTC. Biomass estimates for skipjack were not available. Sea-surface temperature data for the EPO were from Dr. Gary D. Sharp (http://faculty.csumb.edu/SharpGary/world/).

5.1.2 Empirical results

Because individual vessel data were unavailable, the analysis used aggregate data to estimate fishing capacity; therefore it was not possible to examine variation among vessels. Fishing capacity, discussed earlier in this paper, is the maximum amount of fish that can be caught by the purse-seine fleet over a period of time, when fully utilizing its variable inputs under normal operating conditions, given the biomass of the stock being fished, the environmental characteristics of the area fished (temperature in this case), and harvesting technology. The estimates of fishing capacity from the linear model are based on the highest observed catches in a year, and take into account yearly changes in stock biomass and sea-surface temperature. There were two separate outputs from the analysis, one for yellowfin only and the other for yellowfin, bigeye and skipjack combined.

The DEA estimates of fishing capacity are shown in Figure 8 with the observed annual catches of yellowfin tuna and the carrying capacity (hold capacity) of the fleet summed over all size classes. The estimated fishing capacity was relatively low during the early 1970s, climbed rapidly to a peak in 1976, and then declined to a low during 1983; it rose again to a second peak in 1986 and stayed relatively high until the end of the time series. In every year of the series the estimated fishing capacity is well in excess of the observed carrying capacity of the fleet. For the combined fleet, capacity utilization (CU) is less than 1 in every year, indicating that carrying capacity of the purse-seine fleet operating in the EPO is underutilized with respect to yellowfin tuna. The extent of underutilization is not proportional to the values of CU, since the biological average maximum sustainable yield (AMSY) for yellowfin in the EPO is much less than the estimated fishing capacity. The AMSY for yellowfin in the EPO appears to be somewhere around 300 000 tonnes, while the estimate of fishing capacity for yellowfin is above 400 000 tonnes in 25 out of 30 years. If the model used to compute fishing capacity incorporated a function describing sustainable fishing, including the AMSY, into the analysis this would have acted as a constraint on the upper limit of the estimates. Regardless of the apparent overestimation of fishing capacity, it is clear that if the vessels in the fishery were utilized more fully, carrying capacity in the EPO purse-seine tuna fishery could be substantially reduced without reducing the corresponding catch.

The second analysis examined fishing capacity for all species combined. The results are shown in Figure 9. Once again, estimated fishing capacity exceeds observed catch by a large margin in every year. The ratio of observed catch over fishing capacity is shown in Figure 10. CU is also less than one in every year. It would appear once again that fishing capacity is overestimated because the estimation was done without constraining the potential catch of yellowfin and bigeye by their respective yield curves. The results are further confounded by the fact that a sustainable yield curve has not been estimated for skipjack in the EPO. However, the same conclusion drawn for the yellowfin analysis regarding too much carrying capacity in the EPO tuna fleet can be drawn for the combined-species results.

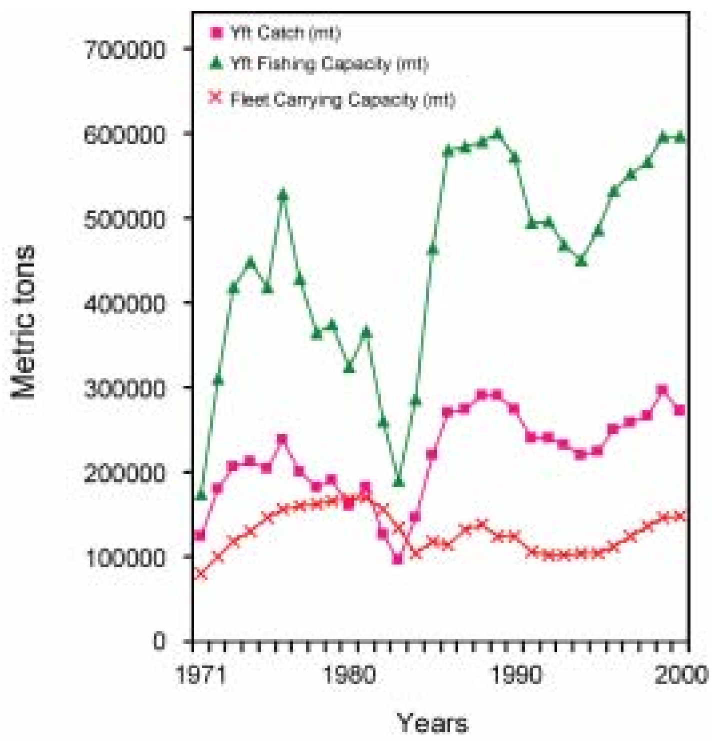

Figure 8. DEA estimated fishing capacity for yellowfin tuna, catch of yellowfin tuna, and carrying capacity of purse-seine vessels in the eastern Pacific Ocean

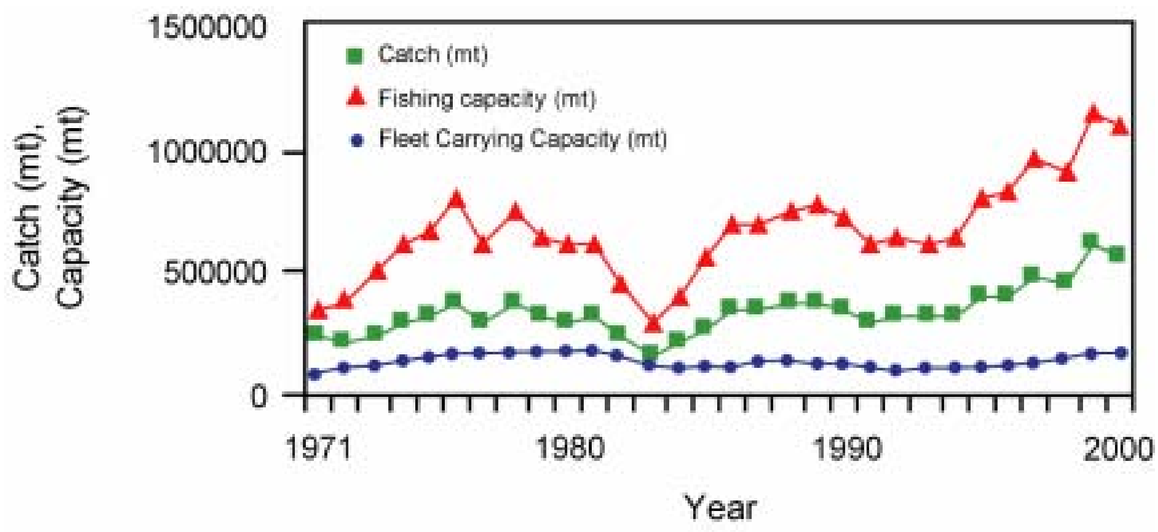

Figure 9. DEA estimated fishing capacity for the combined catch of yellowfin, bigeye and skipjack tunas, combined catch of yellowfin, skipjack and bigeye, and carrying capacity of purse-seine vessels in the eastern Pacific Ocean

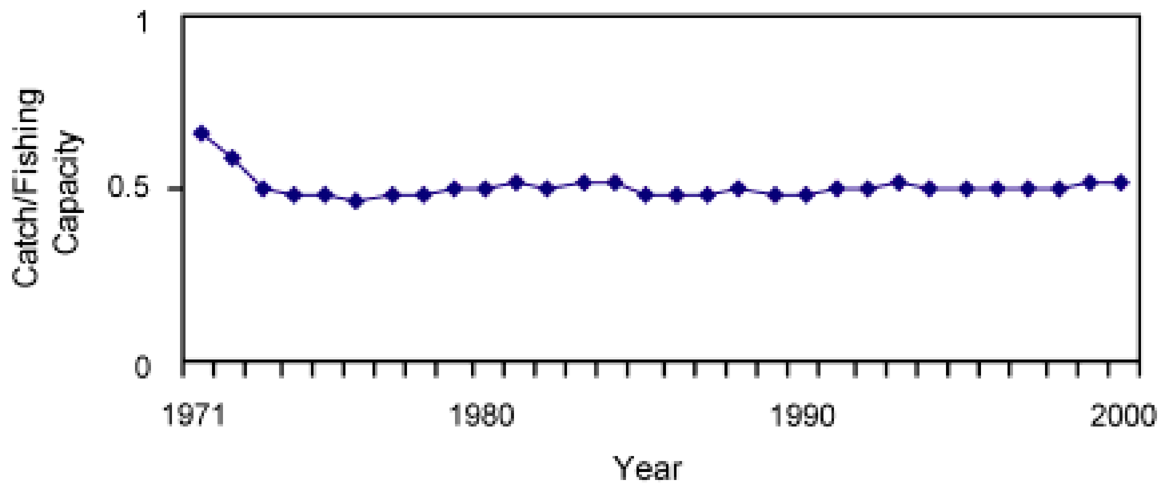

Figure 10. The ratio of total annual catch of tunas to DEA estimated fishing capacity for purse-seine vessels in the eastern Pacific Ocean

Examination of CU by vessel classes provides an opportunity to determine whether all size vessels are underutilized in the fishery. The CUs for the seven vessel classes are:

Vessel Size Class	CU
1	1.000
2	1.000
3	1.000
4	0.287
5	0.553
6	1.000
7	1.000

On one hand, the estimated CUs for Classes 1, 2, 3, 6, and 7 are equal to one (1), indicating that these vessel classes are fishing at full capacity and no matter how their fishing strategy might be altered, they cannot be expected to produce more tuna than they are currently producing. On the other hand, Classes 4, and 5, have estimated CUs of less than one (1), indicating that they are not fishing at full capacity. In fact, vessel Classes 4 and 5 are the major sources of excess capacity, as reflected in Figures 8 and 9. The source of this excess seems to derive from the number of days fishing. To be fully utilized Classes 4 and 5 would have to increase substantially the number of days they fish during the year.

The conclusion that can be drawn from this DEA is that there are too many purse-seine vessels operating in the tuna fishery of the EPO, and that the carrying capacity of the fleet can be substantially reduced without a corresponding reduction in catch. However, because no upper limit on the estimation of fishing capacity was introduced by the inclusion of a yield curve for yellowfin and bigeye, it is difficult to provide a realistic estimate of just how much the fleet can be reduced.

These results demonstrate the need for further analysis, using data for individual vessels, so that more detailed information concerning the variation among vessels can be evaluated, and the incorporation of information on yield curves for the species being harvested so that the estimates of fishing capacity do not go unrestrained. It would appear that owing to the fact purse-seine vessels may fish in both the EPO and WPO during a single year, future analyses should be done on a Pacific-wide basis.

5.2 Looking at the Global Picture

With the exception of the above DEA for the EPO there are no other published quantitative analyses addressing the issue of capacity in other tuna fisheries. Certainly the present analysis is very limited in scope and does not provide very detailed nor comprehensive results, but it does however, demonstrate that fishing capacity in the tuna purse-seine fishery of the EPO is most likely not fully utilized, and it further demonstrates that the DEA approach provides a useful tool for examining the issue of fishing capacity in tuna fisheries. Although there has been no quantitative analysis conducted for the other fisheries, inferences can be drawn for the other fisheries by comparing their fishing success with the results of the DEA for the EPO purse-seine fleet. For example, if the catch of tunas per ton of carrying capacity of purse-seine vessels for each of the fisheries (EPO, WPO, IND, ATL) is compared with the ratio of fishing capacity estimated by DEA for the EPO (which represents the maximum catch the EPO fleet can make when fully utilized) to the capacity ton of purse-seine vessels, an indication can be gained of whether the fleets of areas other than the EPO are fully utilized. In every comparison the catch per capacity ton is much less than the EPO estimate of fishing capacity per ton of carrying capacity. Catch rates for the various fisheries ranged between 2.5 and 4.0 tonnes of tuna per ton of carrying capacity while the ratio of estimated fishing capacity to carrying capacity was near 8.0. These numbers tend to suggest that, like the fleet in the EPO, the fleets in the other regions are not fully utilized, indicating that the catch of tuna in those areas could be taken be a smaller fleet than currently exists.

6 CAPACITY LIMITATION EXPERIENCES IN TUNA FISHERIES

There are few, if any, cases in international tuna fisheries for which measures to limit fleet capacity have been successfully implemented, even though there have been expressions of concern about growing fleet capacity by industry, nations and international fisheries organizations. The IATTC and ICCAT have begun the process of attempting to implement measures to control fishing capacity of all or some of the tuna fleets operating in their respective convention waters.

6.1 International Fisheries Organization Initiatives

In the case of ICCAT, two resolutions to limit fleet size have been approved: 1) Parties, non-parties, and fishing entities fishing for northern albacore agreed that from 1999 onward, they would limit the fishing capacity of their vessels (*i.e.* number of vessels) to the amount corresponding to that of the vessels that operated in the 1993-1995 period. They agreed also to submit a list of vessels that operated under their flags in the northern albacore fishery during 1993-1995, and each year thereafter. The primary purpose of submitting these lists was to ensure compliance with the agreement. 2) A similar agreement, but for bigeye, and based on 1991 and 1992 vessel numbers, limiting the number of fishing vessels in excess of 24 meters in length, applies throughout the Convention waters of ICCAT. As is the case for albacore, each nation must submit a list of vessels and a basis for the list, in order to ensure compliance with the agreement. Although the limitation applies to the number of vessels these numbers are to be associated with a limitation of Gross Registered Tonnage in order not to increase total fishing capacity. The member governments of ICCAT also passed a resolution in 1999, endorsing the FAO International Plan of Action for the Management of Fishing Capacity.

In 1998, the members of IATTC agreed to limit the carrying capacity of purse-seine vessels operating in the EPO during 1999. Each of 13 nations with purse-seine vessels fishing in the region for tunas was assigned a carrying capacity limit. The limit established for each state took into account various factors, including the catches of national fleets during the 1985-1998 period, the amount of catch historically taken within the zones where each state exercises sovereignty or national jurisdiction, the landings of tuna in each nation, the contribution of each state to the IATTC conservation programme, including the reduction of dolphin mortality, and other factors. The agreement also acknowledged and affirmed the rights of several states without vessels currently fishing in the EPO, but with a longstanding and significant interest in the EPO tuna fishery, to develop their own tuna fishing industries. The limits for 1999 that were assigned to each state are shown in Table 3. With the exception of that for Costa Rica, all country quotas listed in the table were approximately equivalent to the actual fleets operating during 1998.

Costa Rica was assigned a limit on the basis of its coastal adjacency, the tuna processing facilities located in Costa Rica, its long involvement in the conservation programmes for tunas in the EPO, its contributions as a founding member of the IATTC, and its intention to acquire a fleet of tuna vessels. Since the passage of the IATTC resolution, Guatemala, exercising "its legitimate rights under international law" declared a carrying capacity quota of about 10 000 tonnes. This capacity was filled by vessels that transferred their registries from the country whose flag they were flying prior to registry in Guatemala. Once the resolution to limit carrying capacity was approved by the member governments of IATTC, several coastal and non-coastal states without tuna fleets began negotiations within the Commission to have capacity limitation quotas assigned to them and other member states of the organization with small quota limitations sought to have them increased to allow their fleets to grow.

Scientists at the IATTC have stated that a total fleet carrying capacity of about 130 000 tonnes would be adequate to harvest the current catch levels in the area. (The DEA results support this statement). At the time the 1998 resolution was approved, the fleet carrying capacity was about 138 000 tonnes. The resolution set a carrying capacity limit of 158 837 tonnes, which included allowances for some increases. The fleet carrying capacity in the eastern Pacific is currently near 180 000 tonnes, and there are indications that more vessels will be coming into the fishery, resulting in an even higher carrying capacity. The problem facing the Commission is how to stop fleet growth over the short term and reduce fleet size over the long term. Though initially some agreement was reached to limit fleet size, this agreement was for 1999 only, and the governments were unable to extend the resolution to 2000 or beyond (65th Meeting of IATTC, October 4–11, 1999, Background Paper 1).

The CCSBFT, which has responsibility for southern bluefin tuna, sets annual catch limits that are partitioned among the three contracting governments, Australia, Japan, and New Zealand. The governments of these states can, if they choose, limit the numbers of their vessels that participate in the fishery.

Table 3: Fleet limits set by IATTC for the 1999 fishing year (IATCC, 1998)

Carrying Capacity (mt)	
Belize	1 877
Colombia	6 608
Costa Rica	6 000
Ecuador	32 203
El Salvador	1 700
Honduras	499
Mexico	49 500
Nicaragua	2 000
Panama	3 500
Spain	7 885
United States	8 969
Vanuatu	12 121
Venezuela	25 975

In the case of IOTC, there are no measures to limit carrying capacity, but its members have recognized that such measures are necessary, and have undertaken "to adopt concerted actions to limit the fishing capacity of the fleet of large-scale vessels fishing for tropical tunas in the IOTC area of competence". As a first step the Scientific Committee of IOTC was asked to make recommendations on the best estimate of the optimum capacity of the fishing fleet, which will permit the sustainable exploitation of tropical tunas; they noted, however, that due to lack of technical information they were unable to make such recommendations.

6.2 National Initiatives

Prior to any international efforts to limit fleet carrying capacity in tuna fisheries, there had been efforts by some states to limit capacity or number of fishing vessels within their own national fleets. Most notably, Japan, during the 1960s and 1970s, limited the number of high-seas longline vessels allowed to fish for tuna under its flag. This was done because a growing fleet of Japanese longline vessels was reducing the catches per vessel and consequent per-vessel earnings. The programme was not very successful because the excess capacity transferred from Japan to other countries and because new vessels were constructed for nations other than Japan (Keen, 1973). This, in a large way, is how the Taiwanese and Korean longline fleets got their start.

6.3 Industry Initiatives

6.3.1 The longline industry

The problem of too much longline capacity is once again a serious one confronting not only the Japanese tuna-fishing industry, but those of other nations as well. Because of the high prices paid for *sashimi*- grade fish in the Japanese market and the increasing demand for raw material, the longline fleets of several countries have grown rapidly, and these fleets are targeting the Japanese market. Added to this is the fact that increased FAD fishing by purse-seine vessels worldwide has reduced the availability of fish to the longline fishery, which in some cases had already been reduced by too much longline effort. This increased FAD fishing has caused concern over the health of the stocks of tuna and other types of fish supporting the longline fisheries of Japan, and has apparently created economic hardship for the longline fleets of Japan and other nations. Considering these facts, and in keeping with the FAO Plan of Action for the Management of Fishing Capacity, the Japanese longline industry has undertaken action to reduce the size of its large-scale tuna longline fleet by about 20%. It has also enlisted the cooperation of other nations, notably Taiwan, Province of China, with large-scale longline fleets to reduce the size of their fleets correspondingly. Japan has already targeted about 130 vessels for removal from the fishery. Taiwan, Province of China has agreed to limit its fleet to 600 vessels, and will require that Taiwanese owned vessels that are now under flags of convenience fly the Taiwanese flag. In order to keep within the 600-vessel limit, some of these recalled vessels would be scrapped. The owners of vessels removed from the fishery, in both Japan and Taiwan, Province of China, will be compensated for their vessels. This time the Japanese are more likely to be successful because the primary target for *sashimi* grade longline-caught fish is the Japanese market, and the nations which do not cooperate in the programme to reduce longline fishing capacity could lose access to that market. An organization made up of industry representatives, the Organization for Promotion of Responsible Tuna Fisheries (OPRTF), has been established to track tuna coming into the Japanese market to ensure that it is from cooperating nations, and to assist in the reimbursement of Japanese and Taiwanese fishermen for the costs of implementation of the programme. Other longline fishing nations are considering adhering to this organization and cooperating in the programmes to reduce fleet size.

6.3.2 The purse-seine industry

A similar industry initiative by the purse-seine vessel owners of the world was undertaken in late 2000 and early 2001. The initiative was to limit the production of skipjack tuna taken by purse-seine vessels, and was motivated by plummeting raw material prices caused by excess fleet capacity and consequent overproduction of tuna. An industry organization, the World Tuna Purse Seine Organization (WPTO), was created, and it is working to resolve the problems of excess fishing capacity and tuna production. A more detailed discussion of the WPTO and its objectives and programmes will be presented later in this report.

Efforts to limit the capacity of tuna fleets have not been very successful so far, on either an international or national level, but the current industry programme to reduce longline fleets, and the initiative of purse seine vessel owners to limit fishing effort, are promising and can set an interesting precedent for formulating action plans to resolve the capacity problems facing tuna fisheries. Examining these experiences, and their successes and failures, provides insight into the important issues that must be resolved, and that will be discussed below respecting the implementation of successful programmes. The crux of the problem in these international fisheries seems to be centered on the issue of allocation of catch (fleets) among participants, i.e., who gets what share of what is available.

7 THE REALITIES OF LIMITING FLEET SIZE

It has been made clear throughout this document that great concern has been expressed by nations, and international organizations over the size of the world's tuna fleets. The problem of excess capacity in the fishery of the EPO was discussed at some length. The severe economic situation caused by excess capacity during the late 1970s gave clear evidence of how conservation programmes can fail as a result of too much fishing capacity. Just how an appropriate level of fishing capacity can be defined and measured is not an easy task. The DEA results presented earlier in this report, did not give a clear picture of the level of excess capacity currently existing in the EPO fishery. This was due in part to the unprecedented high catches of skipjack made during 1999 and 2000. Likewise, the data were not available to examine trends in fleet size, using these sorts of analyses, for fleets in other oceans. Even though there is little irrefutable, quantitative data showing that overcapacity in tuna fisheries exist, other than for the EPO, and, if it does, by how much, most governments with tuna fleets (and their scientific advisors) believe that there is too much capacity and are initiating action in the different regional tuna bodies to do something about it. The member governments of the IATTC, and the other countries with fleets fishing in the eastern Pacific, have initiated action to limit the capacity of the fleets fishing in the EPO.

Most of the other international tuna bodies have called attention to the need to control the growth in tuna fleet capacity, and, indeed, some have also expressed the need to reduce the existing capacity. There have been some limited attempts to do this, but so far these have not been very effective. (Apparently the most effective action taken has been that of the longline industry, rather than governments or regional tuna bodies.) Heretofore, the problem of too much fishing capacity, fishing effort, or fishing mortality has been addressed mostly through the application of catch quotas, closed areas and seasons, gear restrictions, etc. Some management schemes for tuna employ all of these methods, and more, to control fishing mortality for a single species. This sort of micro-management is often confusing, complex, and difficult for fishermen to comply with, not to mention the heavy implicit and explicit costs of management, and is not always effective in achieving the desired conservation objectives. Such management approaches can frequently end up reducing vessel efficiency and productivity per vessel. As pointed out earlier in this document, these sorts of events cause conservation programmes to fail. Setting capacity limits would mitigate many of these problems, but could introduce others, such as how to increase the catch of underexploited species while protecting overexploited species, determining optimum fleet size, allocating fleet capacity among participants, measuring and monitoring vessel efficiency, accommodating the desires of states without fleets to acquire them, etc. All of these issues, and others, must be considered in any attempt to effectively control capacity.

7.1 Controlling Catch

The problem of allowing catches of underexploited skipjack to increase, while limiting the catch of fully-exploited yellowfin and bigeye in a mixed-species fishery (Squires 1994), was described earlier in this paper, but how such a situation could be handled under a limited entry programme was not. There are two obvious approaches. One approach might be to limit the fleet to a size capable of generating the amount of fishing effort needed to take the allowable catch of yellowfin and bigeye over the period of a year. In this case the full potential of the skipjack catch might not be realized, but in an economic sense this could be beneficial to the vessel owners and to the nations under whose flag these vessels fish (but perhaps not to consumers). For example, as has already been noted, in recent years, because of the record high catches of skipjack as a result of increased fleet size and FAD fishing, prices paid for raw tuna dipped to the lowest levels they have been in 30 years. If skipjack catches were to decrease, prices would likely increase. Otherwise, for prices to increase in face of increased skipjack production, demand would have to outstrip the increasing supply of skipjack, or catches of the other tuna species would have to decrease proportionately. This approach of limiting fishing capacity to that necessary to take the available yellowfin while foregoing some potential for increase in skipjack, catch could be employed effectively in the EPO, Atlantic, and Indian Ocean purse-seine fisheries, but not very well in the western Pacific fishery, where skipjack makes up about 75% of the total tuna catch made by purse-seine vessels. Another approach might be to allow the fleet to increase to a size capable of taking the full potential of the skipjack resource. In this case the fleet would be larger than needed to harvest the other species of tuna, *i.e.*, there could be excess capacity relative to yellowfin and bigeye. Catch quotas would have to be placed on the other species to prevent them from being overexploited. Alternatively, gear research might lead to a method to harvest skipjack from around FADs without harvesting the other species. If this were possible, then vessels could continue to fish for skipjack after the catch limits for the other species were filled. (This could be fraught with the economic problems just described.) Currently no such methods exist. However, if fleet size was allowed to grow because of greater potential skipjack catches, leading to excess capacity with regards to yellowfin, it is possible that industry would pressure their governments to lift restrictions on the higher-priced yellowfin, resulting in overfishing of that species.

7.2 The World Tuna Fleet

There are now four Article 64 type regional tuna organizations, and soon there will be five. Each of these four organizations has instituted conservation controls of one form or another because of heavy exploitation of the resources falling within its responsibility, and each has expressed the need to limit fleet capacity. Because many of the vessels that fish tuna move from the jurisdiction of one body to those of others, it would be ideal to set a limit on size for the global fleet. However, it is probably not practical to attempt to set such limits at the outset, because each of the regional bodies sets different forms of conservation controls based on its understanding of the dynamics of the fisheries for which it is responsible. It would make more sense at the outset to approach the setting of capacity limits on a regional basis, relying on each regional body to determine how this could best be achieved. However, it will be necessary, because of the tendency for tuna vessels to move from fishery to fishery, and from ocean to ocean, that the various regional bodies work closely together, exchanging information and ideas, to ensure their activities are coordinated and complementary to each other's programmes. Such coordination is extremely important with respect not only to the vessels that move from fishery to fishery, but also to the resources that inhabit the waters of more than one organization, particularly if total fleet capacity is to be determined on the basis of the total allowable catch of a species or group of species. Two approaches for coordinating the efforts of the regional bodies have already been mentioned.

Although the subject of this document is the limitation of fishing capacity, such capacity limitations are fundamentally based on catch. For example, when the size of a fleet is limited by either carrying capacity or numbers of vessels, assuming no changes in vessel efficiency nor in the number of days fished, the level of harvest for that fleet is also fixed, falling within a range determined by natural fluctuations in the abundance, availability, and/or vulnerability of the stock of fish being fished. A prerequisite to setting reasonable capacity limits is a determination of total allowable catch levels. Once these catch levels are determined, efficiency changes notwithstanding, capacity levels can be fixed accordingly. For most multinational tuna fisheries, as soon as limitations in fleet size are fixed, efficiency changes notwithstanding, catches will correspondingly be fixed.

The distribution of vessels among flags will determine, to a large extent the distribution of catch among the nations representing those flags. The issue then becomes one of allocation, that is who gets what share of the available resource. This issue of allocation is at the heart of nearly all fisheries controversy, and in multinational fisheries there has been little success in resolving it. If a resolution to this sort of problem is to be found, there must first be a series of criteria defined, and agreed to by nations, for partitioning the catch or in this case the allowable fleet capacity, among participants. This would include not only the nations currently having vessels operating in the fishery, but also other states with the desire or intention of entering the fishery to be controlled. The problem of new entrants into a controlled fishery is as contentious a problem as allocation of the catch or fleet size is among the nations already participating in the fishery. This problem was recognized nearly 25 years ago by Joseph and Greenough (1978) when they wrote:

As fleets increase beyond the capability of the tuna stocks to fill their holds, disputes over who should get what share of the available harvest could intensify to the point where they become so dominant in everyone's mind that finding solutions to other important problems becomes impossible. To prevent this from happening, there is a strong need to limit the number of tuna vessels being built. Though most agree that such a need exists, it will be extremely difficult to control fleet size because of conflicting interests among nations.

There has been little progress in developing fleet limitations and catch allocations for tuna fisheries since this statement was made. There are a few exceptions, however: (1) The total catch of southern bluefin tuna has been partitioned among three nations, Australia, Japan, and New Zealand, that have historically accounted for nearly all of the catch of that species, or in whose waters the species is fished. However, there are new entrants in the fishery, and these have not been allocated quotas, which has caused the catch limitations set by the CCSBFT to be exceeded. This, coupled with increasingly more intense disputes among the original three nations over the levels of allocation, place the continuation of the conservation programme in jeopardy. (2) For the Atlantic tuna fishery, ICCAT has adopted catch allocations for swordfish and northern bluefin tuna. The allocations were based mostly on historical catch records, and once again the lack of a clear set of criteria for making allocations has lead to disputes and disagreements among the Parties. (3) Capacity limits have been allocated for only one tuna fishery, that of the eastern Pacific Ocean. However, this programme has not been very successful so far. After reaching agreement to allocate the fleet capacity limitation for 1999, the nations of the region failed to continue the agreement for 2000. On a more positive note, the recent action taken by the tuna longline industry to reduce and limit fleet size bears close watching, and may offer hope that something meaningful can be accomplished in other tuna fisheries. The initiative of WTPO is also encouraging from this respect as well. The common thread leading to the difficulties encountered in the efforts of the regional organizations to limit capacity has been the lack of a set of realistic criteria for making acceptable allocations for the present participants in the fishery and for new entrants. Defining these criteria is a necessary prerequisite to resolving the capacity issue.

7.3 Possible Criteria for Allocating Fleet Capacity Limitations

Both the IATTC and ICCAT have dealt extensively with the issue of defining a set of criteria, which could be used as a basis for making allocations. For the IATTC the allocations would be for fleet capacity limits, whereas for ICCAT they would deal with catch allocations. Regardless of the objective, catch or capacity, the issues are very much the same, and the results determine to a high degree the levels of catch that could be taken by the respective fleets.

The IATTC has held three meetings of a working group that deals with the issue of allocation of the fleet capacity limits, the first in September 1998, the second in October 1999, and the third in July/August 2000. ICCAT held two such meetings as well, the first in the summer of 1999, and the second in the spring of 2000. Although none of these meetings ended in an agreement as to specific criteria to use for determining allocations, they did identify a number of criteria, which might be considered. Some of these criteria are:

- Interests, fishing patterns, and fishing practices of parties to the regional organization and other participants in the fisheries governed by the regional body;
- Contributions of parties and participants to conservation and management of the stocks, including control mechanisms and compliance with regional management recommendations, to the collection and provision of accurate data, and to the conduct of scientific research on the stocks;
- The needs of coastal states whose economies are overwhelmingly dependent on the exploitation of living marine resources, particularly resources falling within the responsibilities of the regional body;
- The economic importance of the fishery to the state in terms of fleet sizes, catches and landings, and processing facilities;
- The importance of ensuring equitable fishing opportunities for all members;
- The interests of developing states from the region in whose areas of national jurisdiction the stocks occur;
- Historical catches taken by parties and participants, both on the high seas and in the EEZs of the nations bordering the convention waters;

- Interests of artisanal, subsistence, and small-scale fisheries;
- The need to minimize economic dislocation in states whose fishing vessels have habitually fished in the zone;
- The respective dependence of the coastal states and the states fishing on the high seas on the stocks concerned;
- Dependence on the fishery for direct domestic consumption;
- Fishing traditions;
- The status of fish stocks relative to AMSY and the existing level of fishing effort in the fishery.

This list of criteria is broad and all encompassing. It reflects the interests, desires, and aspirations of all states, but is so broad that to attempt to include all of these criteria in any scheme to allocate fleet capacity, or catch, would spell certain doom for an agreement. Obviously, these various points should be kept in mind by states while formulating allocation schemes, but to quantify parameters based on “interests,” “desires,” “needs,” etc., would be difficult, if not impossible, to achieve.

Data for some of these criteria, such as current and historical fleet capacity, current and historical catch, and current and historical shore-side processing facilities and infrastructure, and also demographics and economic data, is readily available, and parameters for these can be easily quantified in any allocation formula that might be developed. However, weighting of each of these criteria will be the result of negotiation among governments, and at present there is little concrete guidance from international law for doing this. Another difficult problem is how to handle the desires of nations that currently do not have fleets fishing in the region, but that wish to enter the fishery. For most of the tuna fisheries being considered in this study, there are fleets that are larger than needed to harvest the allowable catch. The problem is how to reduce these fleets, not how to increase them. Therefore if new vessels flagged under previously non-fishing nations are to enter the fishery, then either fleets of other nations will have to be removed from the fishery, or the fleet capacity in the fishery will grow even larger. This problem of new entrants will not be easy to resolve. Article 116 of the United Nations Convention on the Law of the Sea speaks of the rights of states to participate in fisheries on the high seas, and many would interpret that to mean that a fishery cannot be closed to new entrants. At the same time, Articles 117, 118, and 119 speak about the obligations and responsibilities of states respecting the conservation of these living resources, and calls on them to cooperate with other states and appropriate regional bodies, to manage and conserve the resources. However, Article 119 goes on to say that there shall be no discrimination in form or fact against the fishermen of any state. Just how to address this conundrum is perplexing, but it very likely will have to involve some aspect of assigning property rights in the fishery, and may require revisiting some of these articles in the Law of the Sea Convention, and also the instruments creating the regional tuna bodies.

8 THE ESSENTIAL AND INITIAL STEPS

As has been discussed throughout this document, there are a number of complex and difficult issues that require resolution before there can be a realistic expectation that a workable scheme to limit fleet capacity can be achieved. Some of these have already been mentioned, but only briefly. They are further discussed in the paragraphs that follow.

8.1 The Resource Base

It is obvious that some knowledge about the amount of fish available for harvest is a necessary prerequisite to setting realistic capacity limitations. As noted in Kirkley and Squires (1999a), excess capacity in fisheries should be defined relative to a biological reference point pertaining to sustainable resource use. To set the desired target capacity, a target resource stock size, or target catch, must first be specified. This implies that fundamental information relative to the productivity of the stock be available. This fundamental information would ideally include estimates of the AMSY, the average potential production that could be sustained at various levels of fishing effort or fishing mortality, and the ability to monitor changes in these estimates of potential productivity as a result of natural or anthropogenic changes. It is important to determine this for each of the species in the fishery, so as to evaluate which are fully exploited, which are overexploited, and which are capable of sustaining increased yields. The current situation in which most of the stocks of tuna are fully exploited, while in some regions skipjack tuna is capable of sustained increases in yield, is an example of the complicating factors in trying to set optimal limits on fleet capacity. If capacity limitations are set on the basis of skipjack productivity, there might well be overexploitation of yellowfin and bigeye, as explained earlier. Unless a means of harvesting skipjack without capturing yellowfin and or bigeye is developed, the difficult decision as to whether to forego increased production of skipjack to protect the other species will have to be made.

Of course the objective of most of the scientific programmes of regional fisheries bodies is to provide this kind of information, but the degree to which it is available differs considerably among the organizations. This is particularly the case when considering the various species of tunas harvested in a single fishery. Knowledge about abundance and potential production is better for some species than for others in the same fishery. When good information is available it might be a fairly straightforward task to determine target catch levels, thereby providing the requisite information needed to adequately assess target fishing capacity for the fishery in question. When such information is not available, or is inadequate, then it is essential that the first priority would be to initiate programmes to acquire the information. In the meantime, there is still an international obligation to consider action, failing adequate data. The Precautionary Approach, which has been codified in several recent international instruments, states that the lack of scientific information should not be a reason not to take management action, so in many cases some action will have to be taken, even though information is lacking on the exact effect of that action.

8.2 Fleet Statistics

It is also obvious that before any realistic attempts can be made to define fleet limits, it is essential that information about the size and characteristics of the fleet that is currently operating be available. In most tuna fisheries, a variety of fishing gears is used to take the total harvest. In some, such as that in the eastern Pacific, one type of gear is dominant. In this case, purse-seine vessels account for about 90% of the total catch, or nearly 100% of skipjack, 95% of yellowfin, and 50% of bigeye, while longliners account for most of the remainder. Pole-and-line vessels take about 1% of the catch from the EPO. Therefore, limiting the fleet size of purse-seine vessels alone could be an effective means of controlling capacity, and would require only information on this gear type. However, from a political or "fairness" point of view it probably would be necessary over the long term, to set capacity limits for all gear types.

For the western Pacific, the largest tuna fishery in the world, purse seiners take about 70% of the total catch of tuna, while longliners and baitboats account for slightly more than 12% each. In the Indian Ocean, purse-seine vessels account for about 41% of the total catch, longliners about 21%, baitboats about 13%, gillnets about 15%, and miscellaneous gears take about 10%. In the Atlantic Ocean tuna fishery, as in the Indian Ocean, no single gear type accounts for an overwhelming majority of the catch; purse seiners capture about 44%, baitboats about 27%, and longliners about 17% of the catch. Certainly for the Atlantic and Indian Ocean fisheries, any effective means of controlling fleet capacity would have to include limits on all major gear types, and therefore information on all of these would be required.

Under ideal conditions, information extending back for several years, on the number of vessels operating in the fisheries, by gear type, size characteristics, and relative fishing power would be needed, along with corresponding catch information on a per-trip basis. For most tuna fisheries this level of detail is not available, but for purse-seine fleets data on the numbers and carrying capacities of vessels are available. This limited information on the number of purse-seine vessels currently operating in the various fisheries could be used to set preliminary or provisional capacity limits for purse-seine fleets, allowing time to improve the purse-seine vessel data base and the capacity limitation programmes, and to collect data for the other gear types in anticipation of instituting controls on these other gear types.

Once capacity limits are set, it will become imperative that the management body be able to monitor changes in efficiency of those vessels fishing under the capacity limits. Experience tells us that when limits are placed on fishermen with respect to the type of gear that they can employ, or how long they can fish, there is a tendency for them to apply their ingenuity to improving their ability to catch fish with that gear, or increase the catch they can take during the time they are permitted to fish ("capital stuffing, Wilen 1985 and 1989). For example if the number of vessels, or capacity of vessels permitted to participate in a fishery is limited, the catch per vessel, or per carrying-capacity ton, has a tendency to increase through time as a result of technological developments by the industry, assuming of course that the stock is not being overfished. Therefore it becomes of great importance to monitor these changes in efficiency, and to be able to adjust the total capacity limits accordingly, as otherwise a fleet capacity set to harvest a certain level of catch, would, through increased efficiency, take more than that amount without a change in carrying capacity. (Of course, as defined by economists (Squires, 1994), capacity expands through "productivity growth" since potential maximum catch increases). The result would be exceeding the target catch, and possibly overfishing the stock, with possible economic disruption of the industry. Similar problems related to relative efficiency among vessels can arise when limits are set on the basis of fleet capacity. For example, say country A has a fleet of 10 vessels of 1 200-tonnes of capacity each, and by agreement it is limited to that capacity. Assume that a 600-ton vessel and a 1 200-ton vessel have the same fishing power and spend, on the average, the same number of days at sea fishing during a year (which is, in fact, the case in some tuna fisheries). Under a restriction on the size of its fleet, economic considerations not withstanding, country A may decide to replace its 10 large vessels with 20 vessels of 600 tons each, thereby theoretically doubling its fishing power. Such a situation would defeat the objective of limiting fishing mortality by limiting fishing capacity. Measuring efficiency changes is a difficult technical problem, but high priority should be assigned to that task in any capacity limitation programme.

8.3 Optimum Fleet Size

If the type of information on catch and fleets discussed above is available, it can be used to determine the size and composition of the fleet (optimum fleet carrying capacity or target fishing capacity as defined by FAO) needed to harvest a predetermined level of catch, or total allowable catch (TAC). To determine the optimum fleet capacity, or target fishing capacity, the management institution will need to determine what the TAC should be, for example the best estimate of AMSY, or some catch level less than AMSY in an attempt to improve economic rents, or some level greater than AMSY to maximize such things as employment of fishermen and shipyard workers. This, of course, assumes a fishery can be in "equilibrium" at various levels of population abundance, at, above or below the level of AMSY. It also assumes that keeping a population below the AMSY level is an acceptable alternative to the currently-held opinion, expressed in a number of international instruments, that populations should be maintained at or above the MSY level. In most of the tuna fisheries this task will be complicated by the fact that several species are taken by a single vessel. There are few tuna fisheries that are truly species-specific, the troll fishery for albacore perhaps being a notable exception. Most vessels tend to "fish for dollars", and capture whatever species of tuna is available to them. They seldom catch a single species during a trip or over a year, although they may concentrate in areas where the catch of one species is normally higher than those of the others. For many of the tuna fisheries fleet sizes will have to be established on the basis of combined-species TACs, which may limit the amount of catch from one species, most notably skipjack, to much less than the stock might be capable of yielding on a sustained basis, in order to protect the more heavily-exploited species, or to limit overall supplies in an attempt to increase ex-vessel prices. Once this level is determined, the ability of the fleet to take that harvest needs to be evaluated. If the fleet is fully utilized and cannot harvest the TAC, then there is room to expand capacity, if it is underutilized relative to the TAC, then there is overcapacity. Kirkley and Squires (1999b) discuss this matter in terms of capacity utilization (CU), that is, the proportion of available capacity that is utilized, which is usually defined as the ratio of actual output to some measure of capacity output such as defined by DEA.

The assessments of the tuna stocks being exploited, their current levels of abundance and their ability to sustain catches at a certain level, are mostly matters of a biological or technical nature, and should not be the object of negotiation, or a source of great controversy among the Parties. However, determining the size to which the fleet should be limited is a much more difficult problem, and the subject of negotiation among the Parties. Once this limit is decided, then setting into motion a programme to actually limit fleet capacity is yet another matter, one that is more subjective, open to negotiation among the Parties, and much more difficult to resolve. It involves the issue of allocation, that is how to apportion the limited fleet capacity among the Parties: coastal states with vessels currently fishing in the area, coastal states without vessels in the area, but with aspirations to acquire vessels, distant-water fishing nations (DWFNs) with vessels in the area, and DWFNs without vessels in the area, but desiring to acquire such fleets.

8.4 Fleet Capacity Limits

For many tuna fisheries, especially if skipjack is excluded, CU is believed to be less than one, indicating an excess capacity problem. Therefore the issue is not one of just limiting capacity, but one of reducing the current capacity to the optimum level. Before there can be meaningful discussions as to how to reduce fishing capacity, an approach to allocating capacity among participants must be developed. There are a number of ways that this can be accomplished, with the simplest being a "default" scheme, which implies allocating capacity limits among the participants in the fishery solely on the basis of the current distribution of fleet. This means that the fleet would remain at its current size and distribution by flag. Obviously it would be difficult to reach a consensus on such a scheme. Those states with small or no fleets would be in opposition, while those with currently large fleets would be in favor of such a scheme. To resolve such issues, a scheme that allocates fleet capacity to nations, allows for reducing fleet size to the optimum, addresses the issue of new entrants into the fishery, and allows national fleets to increase or decrease within the overall limits would have to be developed.

Probably the most important first step in developing such a scheme will be to define a set of criteria that can be used to determine allocations. The various criteria that have been discussed by different fisheries bodies dealing with tunas have been listed earlier. Two among this list that are considered to be defining criteria, are historic participation in the fishery and coastal adjacency to the resource; however, the others will probably not be ignored in any negotiations to select criteria. Respecting historic participation, over the last several decades most tuna fleets have been owned and operated by fully-developed countries. For years, more than 85% of the world catch of tuna was taken by Japan, USA, France, Spain, and Taiwan, Province of China. Recently this trend has been changing. The Philippines, Indonesia, Ecuador, Mexico, and other coastal states, particularly less-developed nations, have been increasing their participation in world tuna fisheries. On a global basis, probably about 65% of all tuna taken is captured within 200 miles of shore. Most of this is within the EEZs of developing coastal states, and is taken by DWFNs.

How should these facts weigh in determining allocation formulae? Should the fact that a nation has a long history of tuna fishing be an important consideration in determining whether it should be allowed to continue to fish in the future at that same level? Considering the highly migratory nature of tunas, should the fact that a coastal state happens to have tuna spending part of their life in its EEZ provide any special privileges or rights to that state regarding preferential harvesting of the resource while it is in the EEZ, or when it leaves the EEZ? Given that most fishery resources, including tuna, are fully, or overexploited, should this be a reason to question the right of every nation to exploit the resources of the high seas? Perhaps Article 116 of LOS should be revisited respecting the rights of all states to have their nationals engage in fishing on the high seas. What benefits should accrue to nations that have invested political and fiscal resources to conserving tuna resources? Should a developing nation that has not previously been involved in tuna fishing be given preferences for fleet development over nations that have been previously involved and have expended capital and exercised political will in the conservation of those resources? Should preference be given to nations with a "genuine interest" in the fishery in question? And what, in fact, constitutes a genuine interest? Must there be a certain number of the nationals of that state employed in the fisheries, or a certain level of capital investment that has derived from nationally-owned and -capitalized enterprises. If there are vessels flagged under a state, but no shore-side infrastructure or investment in tuna fishing (a flag of convenience) does this constitute a "genuine interest"? These are the kinds of questions that must be grappled with during the development of set of criteria that can be used to define an allocation scheme. It is unclear as to whether the treaties of some international bodies allow them to deal with issues of allocation and economics. If there is doubt about their legal authority to do this, then their treaties must be amended to permit such dealings.

Once an allocation scheme is agreed on there will be two additional components of this scheme that must be decided before a workable programme to limit capacity can become a reality. The first component would be to decide whether, after allocating the fleet capacity limits among nations already in the fishery, to allow fleets of nations not previously in the fishery to enter it, and, if such an allowance were made, how it would be implemented. Obviously, it can be assumed that there is already enough, or too much, capacity in the fishery in question, or the subject of fleet limitation would not be under discussion. Therefore, it would not be realistic to expect that any nation that wished to enter the tuna fishery could do so. The same sorts of criteria used to make the initial allocations of capacity would have to be developed to determine which new entrant nations would qualify. Also, where would these quota limitations for new capacity come from? Would there be a reserve for new entrants set aside that is taken from the overall capacity quota, or would there be assigned property rights that could be traded among players? The second component would be to determine if and how changes in national allocations could be made. Tuna fishing is a very dynamic business. Vessels move from fishery to fishery, are bought and sold on a regular basis, and enter and exit fisheries as economics and politics dictate. Once capacity is limited and allocated among players it would not remain static. As overall efficiency of vessels increased (or decreased) adjustments in capacity limits would have to be made. A vessel owner with vessels under the capacity limit of country A might wish to increase the number of vessels owned. How could new capacity quota be acquired? Would the government under whose jurisdiction the vessels fished need to negotiate additional capacity quota, or would individual property rights be assigned in the fishery-- rights that can be traded or transferred, or should the allocation criteria be renegotiated periodically as conditions in the fishery changed? These dynamic characteristics of the tuna fisheries would have to be accounted for in any capacity limitation programmes that might be developed.

Returning to the matter of reducing fleet capacity, this would have to be dealt with as capacity limitation schemes are developed. For most fisheries there is probably already too much capacity, so any schemes developed to reduce capacity would have to start with fleets that are too large. Once a reduction programme was initiated, capacity could then be reduced through attrition, without replacement, through some sort of a buyback scheme, or through some other mechanism. If an attrition scheme is used, it would probably have to be one in which an “attrition target” would be included in each country allocation that was proportional to the allocation. There has been a great deal of skepticism shown over the usefulness of buyback schemes. In fact, the FAO Working Group was generally negative about such schemes, indicating that even though they result in an immediate reduction in capacity, they encourage further investment in capacity. They also can act as an incentive to increased efficiency, resulting in increased fishing power, or capacity. However, given that changes in vessel efficiency (productivity growth) are monitored and accounted for, buyback schemes could be an effective means of handling some of the dynamic demands of tuna fishing. Although it may be too early to tell, the scheme developed by the Japanese fishing industry for the world longline fleets may provide a useful example that can be used for other tuna fisheries.

8.5 Enforcement

Once a capacity limitation scheme is implemented, then for it to remain effective there must be some assurances that the parties follow the rules laid down within the scheme. This will entail monitoring the numbers and capacity of all vessels included in the scheme. Likewise, some way of monitoring the entry into the area of vessels that are not part of the scheme would be needed. This would be a difficult task and would involve surveillance by member states of the agreement, by vessels operating within the programme, and cooperation with other regional tuna bodies. It may also involve requiring every tuna vessel desiring to fish on the high seas to be equipped with a GPS, which would allow the position of the vessel to be monitored by a regulatory body. To ensure compliance, a standardized series of sanctions will need to be implemented by the nations of the agreement. These could include port state controls and economic sanctions taken on the recommendations of the organization and applied against nations that diminish through their actions the effectiveness of the capacity limitation or conservation programme. In some cases this would require protocols to the instruments creating these tuna bodies, which would allow them to establish compliance committees and to generally treat the matter of enforcement.

Along these same lines, it would be important to institute mechanisms for exchanging information on the various fleets and their activities among the different tuna bodies. When capacity limitations are instituted in one region, there will be a "slop-over" effect of vessels from the restricted area migrating to fish in areas where there are no restrictions. It would be essential that such information be exchanged among the regional bodies. If there were no provisions within the instruments creating these bodies to enter into such cooperative arrangements, then they would have to be added.

These are some of the important issues that nations will need to address if long-term solutions to solving the problems of too much fishing capacity are to be successfully resolved. This will require the acquisition of much information, the cooperation of nations, the political will to find solutions to the difficult issues defined above, and international institutions to provide the necessary technical and logistic support. Obviously, it is highly unlikely that all of these issues would be resolved before a scheme could be implemented to limit fishing capacity. It would be necessary to create provisional and/or transitional schemes that could operate on limited information, but which could be modified and improved as additional information became available.

9 SOME POSSIBLE OPTIONS FOR LIMITING FLEET CAPACITY

Several methods have been used to control the harvest of fish. These methods fall into two general categories, input controls and output controls. Input controls are concerned with the manner in which fishing is accomplished, and include such measures as limiting the fishing mortality by limiting the length of the fishing season or the fishing capacity in terms of numbers, sizes, and types of vessels and fishing gear used, closing areas, or taxing the fishermen's right to fish. Output controls are concerned with results of fishing, and attempt to control the amounts and characteristics of the fish that are harvested. These include such measures as catch quotas, size limits on individual fish caught and or landed, and quotas on bycatch species. Nearly all the management measures for fisheries have been discussed in a special report of the Organization for Economic Cooperation and Development (1996), and reviewed by Gréboval and Munro (1999). Both of these works are referred to in the discussions below.

Most of the measures that have been developed to conserve marine resources have been fraught with problems. For example input controls, such as limiting the length of the fishing season or the number of fishing vessels generally results in fishermen adjusting their fishing practices, or the performance of their vessels, to improve efficiency in order to increase their share of the available catch. Likewise, output controls, such as global catch quotas, result in fishermen "racing" to take as large a share of the quota as they can before the quota is reached. The result is shorter and shorter seasons, which creates economic dislocation in the industry. Additionally, there is a biological down side to this "racing" as well. By cramming the allowable catch into a shorter and shorter time period, non-equilibrium fishing can result in overfishing of the population, because the allowable yield in most cases would have been determined prior to the setting of catch limits on the basis of a fishery that operated over an entire year. Also, different substocks might be vulnerable at different times of the year, and with a short season some substocks could be overfished and others underfished. These same problems could exist in fisheries in which the length of the fishing season is limited. Fishermen would race to get in as many fishing days as possible, leaving repairs and maintenance until the season was closed. The allowable number of fishing days would be expended in shorter and shorter time periods. Setting minimum size limits that effectively increase yield per recruit in tuna fisheries can be particularly difficult to achieve because most schools of tunas contain at least some small fish, and these nearly all die before they can be returned to the sea. The result has been a tendency for management to introduce additional regulations to control these inadequacies. In some fisheries the amount of regulation has become so complex that it is difficult for the fishermen to understand them, much less abide by them, and for the management agencies to enforce them. Setting a limit on the size of the fleet allowed to operate in a fishery would go a long way toward reducing the complexity of management. This is part of the reason, economic considerations notwithstanding, that nearly all of the regional tuna bodies, and also the industry in some tuna fisheries, have called for controls on the number of vessels allowed to operate in the worlds tuna fisheries. However, as has been made clear throughout this paper, the task of finding a workable mechanism to achieve effective fleet limitation is a daunting one. Some possible approaches are discussed in the following sections.

9.1 The Status Quo

Obviously, the simplest option would be to do nothing about fleet capacity, but to continue to manage the tuna fisheries as they are now being managed. As just mentioned, this has entailed the application of a multitude of measures to control the catches of various tuna species. In the Atlantic the restrictions include limits on the total amounts of bluefin, swordfish, and albacore that can be harvested, restrictions on the use of FADs, closed areas and closed seasons for some species, minimum size limits for many species, including some imposed on one species to protect small fish of another species when the two are taken together, and vessel size limitations. In the eastern Pacific there is a catch quota on yellowfin tuna, restrictions on fishing on floating objects in certain time and area strata, closed areas for yellowfin fishing, controls on fishing tuna in association with marine mammals that involve mortality quotas, prohibitions against discarding bycatch, gear restrictions, reporting requirements, and a variety of other measures. If the status quo regarding fleet capacity is maintained, then it can be expected that there will be increasingly more complex restrictions implemented in efforts to protect tunas from overexploitaiton. Layer upon layer of regulations makes it difficult for fishermen to understand them, much less to comply with them. Under this "death by a thousand cuts" approach, the task of enforcement would be formidable, and it would be difficult, if not impossible, for any regional body or nation to enforce them effectively. Market forces would determine whether fleets grow or decline, and the rates of fleet growth would be adjusted by subsidies for new vessels to enter the fisheries dependent upon the interests of governments to support their fisheries and/or their boat-building industries. There will be ups and downs in production as a result of natural factors such as the occurrence of El Niño events, and these will be exacerbated by the tendency of too much fishing capacity, resulting in overexploitation of the resources. Examples of this were given earlier for the fishery in the EPO. Because maintaining the present situation will inevitably lead to overfishing, political chaos, and economic waste in the tuna fisheries of the world, all of the regional tuna bodies have expressed their desire to adopt measures to limit the size of tuna fleets fishing within their treaty waters. Therefore, the option of status quo, is not a viable one if nations are to exercise their responsibilities regarding the stewardship of the tuna resources for which they are responsible.

9.2 A Moratorium on Fleet Growth

An approach frequently raised among nations during discussions to limit fleet capacity is the possibility of setting a moratorium on fleet growth, *i.e.*, to allow no new vessels into the fishery, except to replace those lost through sinking or attrition due to old age. This of course works fine for those nations with well-established tuna fleets, but it would not address the problem of how nations without fleets could acquire them, or how nations with small fleets could expand them. It therefore seems likely that unless a moratorium was accompanied with some sort of scheme for handling new entrants into the fisheries, it would be doomed to failure. Nevertheless, there have been recent expressions of interest, mostly from the industry, to implement a moratorium on fleet growth. Most notably the World Tuna Purse Seine Organization (WTPO) has called for a moratorium on the construction of purse-seine vessels. The members of that organization, all tuna purse-seine owners, have agreed that there is too much purse-seine capacity and that action should be taken very soon to stop the growth of the purse-seine fleet. Such a move would be beneficial in that it would allow time to develop a more comprehensive capacity limitation programme for purse-seine vessels before damage could be done to the tuna resources. A moratorium could also serve a useful purpose with respect to other gear types, such as baitboats and gill-nets, which take much smaller portions of the total tuna catch. Once a capacity limitation programme for purse seiners was placed into effect, a moratorium on baitboats and other vessel types could be implemented. This would allow time to collect the necessary information and data necessary to develop a comprehensive limitation programme for those other gear types, and would ensure that no detrimental effects caused by unrestricted fishing of these other gear types would occur.

9.3 An Industry Programme

The situation regarding excess longline fishing capacity became so severe that the fishing industry itself undertook measures to reduce the size of the international fleet of longliners that fish for tunas on a global basis. The details of these measures have been reviewed earlier in this report. Similarly, as mentioned earlier, there has been an initiative by the purse-seine vessel owners of the world to limit the amount of fishing effort generated by these vessels on a global scale, and to limit the number of purse seine vessels permitted to fish for tuna. Although this initiative was motivated in a major way by falling ex-vessel prices paid for tuna, the growing size of the world purse-seine fleet was also an important factor in the owners' decisions to take action. In a meeting held in Manila, Philippines, on November 30–December 1, 2000, tuna purse-seine boat owners from many different nations cited the need to manage the global fishing fleet in order to prevent overfishing of the tuna stocks, the rise in the catches of skipjack, resulting in an oversupply of raw material, and creating large inventories of frozen skipjack and canned tuna, as reasons to take action to limit fishing activity. The boat owners agreed to undertake measures to reduce the amount of time their vessels spent fishing. For some fleets this entailed a halt to fishing for 30 days, within 60 days of the adjournment of the meeting, for others a reduction in fishing effort of 20% during the same period, and for still others, extending turnaround time between trips to several weeks. They also called for a moratorium on the building of new purse-seine vessels for fishing tuna, except to replace existing vessels, in which case the replacement vessel would be of an equivalent size to the retired vessel, and the retired vessel would be decommissioned. Finally, they agreed to create an international purse-seine owners' organization to monitor the provisions of their agreement.

A second meeting of the purse seine organisation was held in Guayaquil, Ecuador, on March 1–2, 2001. At this meeting the boat owners signed an agreement creating the WTPO, which would become effective upon ratification by the signatories to the agreement. The WTPO, has as its purposes the promotion of responsible and sustainable fishing in order to maintain a balance between the tuna resources and their exploitation in a rational and economic manner, the fostering of scientific research related to tuna purse seining and product development, and the development strategies to promote world demand for tuna. At the second meeting it was agreed to extend the provisions from the Manila meeting through June 2001, at which time a third meeting would be convened in Guayaquil to consider further action. Not all purse-seine vessel owners were represented at the meetings. The reasons that so many boat owners did not attend are not clear; perhaps in some cases it had to do with fears that their governments might view this as an attempt to influence prices, rather than an attempt to conserve the resources, and that they would be sanctioned for contravening domestic trade laws. In total, the fleets that were not in attendance represented nearly one-half of the world's purse-seine fleet, and for any agreement to be successful their participation would be required. However, the fact that these initiatives to limit purse-seine fishing effort and capacity were taken by the attendees at the Guayaquil meeting, signifies a major step toward a general industry recognition that there is a problem of too much fishing capacity in the world's tuna fleets. This initiative should be recognized by the governments with jurisdiction over the vessels in the agreement and be nurtured, encouraged, and developed. It is a major first step in developing a "mind set" within the tuna industry that controls on fleet capacity are needed. Obviously for an approach such as this to be successful participation by the owners of nearly all of the purse-seine vessels of the world would be necessary.

There is no international legal basis nor mandate for an industry coalition such as the WTPO to control the size and behavior of an international tuna fleet, but if a majority of the vessels were involved, it could be successful. There is, however, already a precedent as set by the longline industry. This precedent could help smooth the way for any action to be taken by the WTPO. These actions to be taken by the coalition and the boat owners would, of course, be voluntary. Each owner of a boat currently fishing, and also prospective new entrants, would hopefully view the actions taken to cap or reduce fleet size as beneficial to their own interests. The boat owners' organization would have to accomplish a number of tasks. These would include, *inter alia*, determining the optimum fleet capacity and the development of methods to maintain the fleet at that size. If the fleet were to be reduced, mechanisms for doing that would be needed. Also, the important problem of how to handle new entrants would need resolution. How could this be done without assigning property rights to the resource? Obviously it would have to be done through cooperation among current and prospective fleet owners, and voluntary agreement to follow the recommendations of the organization. One approach would be for the organization to set up a funding scheme to buy and retire vessels in order to reach the optimum fleet size, and to buy and retire other vessels to allow the entry of new entrants that would qualify under a predetermined set of criteria. Although such a scheme would seem at first sight to be a far step from reality, it would, in fact, be quite similar to the scheme developed by the Organization for Promotion of Responsible Tuna Fisheries (OPRTF), which was created by the tuna longline fishing industry. OPRTF has established a fund from industry and government sources with which to buy and retire excess longline capacity. Like OPRTF, a purse-seine owner's organization would need to acquire funding to carryout its functions and to buy and retire vessels. Such funding could come from vessel assessments and contributions from governments.

It has already been demonstrated by the action taken in Manila and Guayaquil that there is a mind set in the international tuna industry to undertake such a scheme, and it could be implemented rather quickly. The timing for such an undertaking would seem to be propitious, because ex-vessel price being paid for tuna reached a low ebb as a result of high production of skipjack tuna. A fleet capacity cap or reduction might serve to bring supplies into balance with demand, in which case the long-term outlook for ex-vessel price would likely improve. If such a scheme were implemented, it would provide the opportunity, and the time, for governments to develop a more comprehensive programme, if one were needed.

At first glance the reaction to such a proposal would be that an industry organization would have no legal right to attempt to control fleet size, by denying a sovereign state the right to enter a fishery, or by capping or reducing the size of the fleet of a sovereign state. That reaction would be correct; they have no legal right to take such actions. However, they do have the right to undertake joint, voluntary action to protect the resource upon which their livelihood depends. Likewise, with respect to vessel assessments, there is nothing to prevent a group of boat owners from taxing themselves for the common good, in fact, it is done all the time. With respect to new entrants, obviously a boat owners' organization cannot prevent a sovereign state from bringing new vessels into a fishery, but it can work with the prospective new boat owners to demonstrate that before investing in a new vessel, working within an organization dedicated to the well-being of the industry in general can improve its chances of insuring sound conservation of the resource, not to mention improving there opportunity to be economically successful.

9.4 Intergovernmental Regional Programmes

Probably the most straightforward approach to setting capacity limitations would be for each of the regional tuna bodies to formulate and administer limitation programmes for its area of responsibility. The problems facing each of the bodies would be essentially the same, too many players, including those in the game, those wanting a bigger share of the game, and those not yet in the game, but wanting to get in.

The first step for the regional body would be to determine the optimum fleet capacity for its region. This would, as was shown earlier, depend heavily on scientific advice regarding the potential of the stock(s) to sustain catches at given levels of fishing effort, and would be adjusted according to the objectives of the regional body regarding the desired levels of harvest. For example the body might wish to harvest something less than the maximum that the combined stocks could sustain, particularly with regard to the problems associated with unexpectedly high skipjack production in recent years due to the expansion of FAD fishing. Ideally this would be done for each type of fishing gear, but attempting to do this for all fleets at the outset would be cumbersome and difficult to achieve. Because purse-seine vessels account for the overwhelming majority of the world catch of tuna, and the longline industry has already undertaken a programme to reduce its fishing capacity by 20%, a programme to control just purse seiners could prove effective, except possibly in the Atlantic Ocean. If the purse-seine programme was successful, it could be expanded to include other gear types, such as baitboats and gillnets, which take much smaller proportions of the total catch. Pending a comprehensive capacity limitation programme for baitboats and gillnets, like that for purse-seine vessels, a moratorium might be applied to the expansion of these latter vessels.

Once a target capacity was identified, the next step would be to find a way for the fleet to stay within that capacity, if it did not already exceed it, or a way to reduce the capacity if the fleet currently exceeded that target. One way that has been used in some fisheries to attempt to control fleet size has been to call upon nations to maintain their fleets at certain levels, or to not allow the fishing effort generated by their vessels to increase over certain designated levels. The objective of keeping fleet size or fishing effort at certain non-quantified levels is perhaps too subjective, and too open to interpretation by the parties so it would be very difficult to ensure compliance. In most instances such approaches have not worked very well.

A more straightforward approach would be to partition the target capacity among the players, including making provisions for prospective players. To do this, a set of criteria, with appropriate weighting factors that could be used to determine the allocations, would have to be identified. The reality of any discussion of these criteria is that the current size of a nation's fleet being considered for limitation would weigh heavily, if for no other reason than that the nations with large fleets would be the most active participants in any negotiations. Coastal adjacency would also be an important consideration, not so much from the perspective of the "legal rights" of a coastal state to an entitled share of the resource that spends time in its EEZ, as from the practical fact that almost half of all the tuna taken on a global basis is taken within 200 miles of the coastline, which means that coastal states control access to a large share of the region in which tuna are fished. There are two important considerations that nations must evaluate in deciding on the importance of this criterion. First, tuna are highly migratory, and spend only part of their time within the coastal zone, the remainder being spent on the high seas. Even without access to the coastal zone, DWFNs could still harvest large quantities of tuna. In fact, some fleets never go into any coastal zones to fish, making all of their harvests on the high seas. Some tuna resources could be overexploited, even if fished only on the high seas. Second, a coastal state should not, on the average, expect that it could harvest the same amount of tuna when fishing both within its coastal zone and on the high seas, as it could if it fished only in its coastal zone. Likewise, historical catch statistics which reflect catches made in coastal zones are normally computed using combined data from vessels flying the flags of many nations operating in those coastal zones, and in most cases it should not be expected that the fleet of a coastal state could harvest the same amount within its zone unless its fleet was equivalent in size to the international fleet that operated in that coastal zone. If the coastal state did build such a fleet and confined its fishing to within its own EEZ, owing to the seasonal nature of the availability of the fish inhabiting the coastal waters, its fleet would be idle much of the time. Therefore, though coastal adjacency will be one of the criteria discussed, the weight it would be given in determining allocations would be mitigated by these aforementioned facts.

Before finalizing the partitioning of capacity among the players, the governments making up the regional body must deal with the issues of nations with small fleets wishing to increase them and nations without fleets wishing to acquire them. This is one of the fundamental issues that is at the core of many fishery management problems. It is an inescapable fact that many of the world's fisheries resources are overexploited, and many more are fully exploited. Demand for fish continues to increase, and along with this increase is the opportunity for entrepreneurs to profit and nations to develop industries.

Fisheries cannot continue to expand, however, as there is a limit to what can be harvested. No longer can the ocean be considered a frontier, where the fish is there for the taking. Since most tuna fisheries are "saturated", which means that is there is adequate fleet to take the allowable harvest, then it is necessary to develop a scheme to allow capacity to transfer among players, including new ones. There are a number of ways in which this problem can be approached.

One would be to allow no new entrants until some portion of the previously-assigned country allocations were returned to the governing body. For example a nation that formerly had a capacity quota might surrender some of its quota because the size of its fleet had become reduced. That unused quota could then be assigned to new entrants, based on a series of criteria determined by the management authority. However, experience shows that the rate at which nations exit the tuna fishery is not high as vessels are long-lived and expensive and owners seek to cover fixed costs and spread fixed costs over catches, so the opportunity for new entrants would be correspondingly low. This would engender great debate and controversy between those already in the fishery and those who want to enter it. It could be argued that even though the resource is highly migratory and in need of management to insure its conservation, the coastal state would have a sovereign right to exploit the resource while in its coastal waters, and therefore could not be excluded from the fishery. It would also be argued that under international law all states have a right to exploit these resources on the high seas. Given existing international law and the disposition of nations regarding sovereign rights to exclude completely states from a fishery, the result would be a failure to reach agreement. However, the world is becoming ever more crowded, and greater and greater demands are placed on its natural resources. Most tuna fisheries are fully exploited, and it should not be expected that the opportunity to fish for tuna would remain open to any state desiring to do so. Entry into tuna fisheries must be controlled if the resources are to be maintained at levels at or near AMSY. However, to provide the legal and political basis to institute effective controls, the concept of open access to the oceans resources, particularly highly-migratory tunas must be re-examined, and in the end some of the opportunities to harvest the oceans resources that have always been considered the right of everyone may need to be modified.

Another approach to solving the problem would be to set aside for new entrants a certain percentage of the capacity quota before allocating it to the parties with fleets currently operating in the fishery. For many fisheries this might require that fleet size be reduced substantially, since in most cases there is excess capacity. Again, a set of criteria would have to be determined for choosing which newly-entering nations or individuals would be assigned capacity quotas. A problem that immediately comes to mind regarding this scheme is what would happen after the reserve was fully utilized. Would allocations be reduced and an additional reserve established? Carried to the extreme, one could imagine a large number of states each with a very small fleet.

Still another approach for establishing a reserve for new entrants would be the introduction of a scheme that would allow the management authority to purchase a quota that had already been allocated and hold it in reserve for new entrants. In this case the management authority would establish a fund, which would be used to buyback capacity quotas that were assigned to individuals or nations, and those purchased capacity quotas would be allocated to new entrants, based on some predetermined set of criteria. As already pointed out, there has been a great deal of controversy over whether buyback schemes can be effective in resolving fisheries management issues. The FAO Working Group on Capacity (FAO, 1998) expressed some reservations about the use of buyback schemes, stating that initially they tend to reduce fishing capacity, but, in the long run, unless other provisions are made, they can be ineffective for controlling fishing mortality. Holland *et al.* (1999), concluded that the potential for buyback programmes to achieve their goals is limited. At a minimum, for buyback schemes to be effective there must be some guarantee that the purchased vessels are permanently removed from the fishery. Gréboval and Munro (1999) discuss examples of where buyback schemes have shown some promise, especially, when coupled with other measures, such as individual vessel quotas. Buyback schemes can also serve in other ways to ensure that capacity limitation programmes are effective. Changing efficiency is a persistent problem attributed to many input control measures. If such changes in efficiency are quantified and monitored, vessel buyback would offer a means of keeping fleet capacity in balance with the target catch, or target fishing mortality. There is however, a strong need to focus research efforts on the efficacy of buy-back schemes for managing tuna fisheries.

Using capacity limits as the sole mechanism for managing a fishery has certain shortcomings. As already pointed out, some of these shortcomings can be overcome by accounting for efficiency changes and adjusting capacity accordingly. Even if these changes could be accurately and timely measured, which is very difficult to do, there would still be a tendency for vessels to increase the fishing mortality, which would be possible if they increased the amount of time they fished during the year. These effects could be mitigated by coupling a catch quota with the capacity limitations. If the catch quota were global in nature, *i.e.*, applying to all elements in the fishery on a first-come-first-served basis, the tendency would be for vessels to "race" to catch as much of the quota as possible before the season to unrestricted fishing ended. The adverse effect on stock productivity of stacking up fishing effort into a shorter period of time could be diminished somewhat by partitioning the year into a series of open and closed fishing periods. However, there would still be a tendency to "race" to catch more fish during these shorter periods of time.

Another alternative would be to assign quotas to individual nations (or to individual vessels). Partitioning the catch quota among nations would offer the opportunity for each nation to develop plans to manage its fishery within the framework of the vessel limits and catch quotas. However, many of the problems associated with global quotas would also exist for national quotas. The problems of partitioning catch quotas among nations would be very similar to those of partitioning capacity limits to nations. A series of criteria would need to be developed for making the allocations. Such catch allocations have been made in many of the world's fisheries, and for tuna. ICCAT has allocated catches for bluefin and swordfish among nations. These allocations have been based mostly on current levels of catch made by the nations fishing in the Atlantic Ocean. Interestingly, ICCAT has not made specific provisions for new entries into the fishery, and *de facto*, has closed the fishery to new entrants and non-participating parties. For southern bluefin tuna the total allowable catch is partitioned among three nations, Australia, Japan, and New Zealand, with long histories in the fishery. These three nations are the only members of the CCSBT. Although states other than these three harvest southern bluefin, they currently cannot be members of the organization, nor do they have catch allocations.

Although there have been several efforts to create country allocations of global catch quotas in the eastern Pacific, these have been unsuccessful. Joseph and Greenough (1978) suggested a partially-allocated quota system. In their scheme the total catch quota would be portioned into two parts, based on historical catches made within the EEZ and on the high seas. Each coastal state with a fishing fleet would be allocated a catch quota equivalent to the average total catch made by all vessels fishing within that coastal state's EEZ. If a coastal state did not have a fishing fleet, its potential share would go into an unallocated pool. The unallocated quota would also include a share of the total quota computed on the basis of average catches taken on the high seas. Country catch allocations could be taken anywhere in the convention area of the regional tuna body, including the EEZs of any coastal state. Fleets of nations without quota allocations would be permitted to fish until the unallocated quota was filled. Coastal state fleets with quota allocations would fish until their quota was filled and then could continue to fish for unallocated quota, so long as that season was open. An interesting aspect of this scheme was the setting of a user's fee or tax that applied to any vessel operating in the fishery. This tax would be used for several things, including as an incentive-adjusting mechanism, but most of it would be returned to coastal states in compensation for the right of all vessels to fish in their EEZs. Such a scheme, if coupled with capacity limits that were partitioned among participants, could provide an option for managing tuna fisheries.

Instead of assigning catch quotas to nations, they could be assigned to an individual producer or vessel. By coupling the individual catch quota with an individual capacity quota, many of the problems associated with national catch and capacity quotas would be eliminated. The tendency for vessels to race to take as much of the allowable quota as possible and the tendency to build increasingly more efficient vessels would be eliminated. If these individual quotas were transferable, more options to improve the fishery would become available. Buyback schemes could be used to reduce overall vessel capacity, and nations wishing to enter the fishery for the first time, or desiring to increase their fleets, could purchase quotas from those already in the fishery. With individual quotas, the decision to offer a vessel for buyback, or to buy a vessel, would be based solely on economic reasons, and would serve to maintain or improve the economic viability of the fishery, whereas if the rights belonged to nations the decisions might be based as much on political reasons as on economic reasons, and these would not necessarily improve the economic viability of the fishery. Davidse (1995), Squires, Kirkley and Tisdell (1995), Squires (1994), Grafton (1996), Squires *et. al.* (1998) and Gréboval and Munro (1999) discuss in some detail the advantages and disadvantages using individual quotas, and they generally conclude it is an important tool for controlling fishing capacity.

Of all the schemes for resolving the problems of tuna management, particularly the problem of excess fishing capacity, that have been discussed here and elsewhere, those that tend to incorporate some form of property rights which allows the recipient of those rights to trade or transfer them to other users seem to offer the greatest opportunity for success. These property rights could take two forms. One would be a right assigned to an individual which would allow a certain vessel capacity, which would in turn result in a probable level of harvest, or an individual catch quota. The other would be to assign the right to a nation or a party to that agreement to limit capacity. In the case of an individual property right, the decision to offer a vessel for buyback would be based on purely economic reasons, and would serve to maintain the economic viability of the fishery. If rights belonged to a nation, the decisions to offer up vessels would be based perhaps as much on social or political reasons as on economic reasons, and these would not necessarily improve the economics of the fishery, nor ensure the conservation of the species. Property rights have been assigned in some fisheries, but these have involved management programmes within a single nation, e.g., those of Australia, New Zealand, and the USA. Some of these programmes have been very successful, and others less so. Property rights have not heretofore been established for any multinational high-seas fishery, with the possible exception of the non-governmental programme described earlier for the longline fishery.

To establish property rights in an international fishery targeting highly-migratory species raises various complex issues regarding states' rights and responsibilities regarding the exploitation and management of these resources. One of the most important of these is the question of whether regional bodies have the authority to assign property rights in an international fishery. None of the conventions of regional tuna bodies, which are currently in effect, include articles dealing with the issue of property rights. Likewise the Law of the Sea Convention does not touch on this issue with respect to fisheries. However, in the broadest sense, one might consider some of the articles in Part XI of that Convention, dealing with THE AREA, as offering some guidance and precedent for dealing with the issue of international fisheries bodies being empowered to assign property rights in tuna fisheries. Article 151 of the Convention mandates the AUTHORITY to take measures to promote the growth, efficiency, and stability of markets for the minerals derived from the AREA. The AUTHORITY is also empowered to issue production authorizations, i.e., a "licence" to exploit the resources of the AREA, or to deny a licence, as appropriate. Of course, the important difference in dealing with the issue of property rights for the resources of the AREA and property rights for tuna resources, is that in the former case the resources are sessile and confined to the areas beyond the jurisdiction of coastal states, while in the later case the resources inhabit areas of the high seas, as well as the EEZs. As was discussed above, just how the matter of coastal states without fleets, but wishing to obtain them, will be dealt with regarding property rights will be a critical matter to resolve. The actual assignment of transferable property rights may offer such a solution, as was discussed above. If the regional tuna bodies are expected to deal with the problems of excess fishing capacity, then they will need to be empowered with the authority to deal with economic and social issues related to the fisheries for which they are responsible, including the authority to assume and assign property rights in the fisheries.

10 CONCLUSIONS AND RECOMMENDATIONS

The world's high seas purse-seine fleet is made up of approximately 570 vessels ranging in size between about 250 and 4 000 tonnes of carrying capacity. The combined total carrying capacity of these vessels is about 600 000 tonnes. The recent catches made by this fleet have been nearly 2 million tonnes annually. This translates to about 3 tonnes of catch per capacity ton per year, or 3 600 tonnes per vessel per year, implying that the average tuna vessel makes about three trips per year (a few well managed, large purse-seine vessels have recorded annual catches in excess of 12 000 tonnes, although these are the exceptions). A modern, well-maintained tuna purse seine vessel can easily make four or five trips per year and still have time for vessel haul-out, repairs, and maintenance. Per vessel production of 3 600 tonnes per year is low and represents a waste of labour and capital, which places in jeopardy the possibilities of putting into place effective conservation and management programmes. In the EPO the purse-seine fleet catches about 3 tonnes of tuna per ton of carrying capacity. The DEA results show a CU substantially less than one. Since the global catch per capacity ton is similar to that of the fleet in the eastern Pacific, it seems possible that the CU for the global fleet is less than one, indicating it is not fully utilized. These figures of low production corroborate the expressions of concern by most of the regional tuna bodies, and by the tuna industry, that the size of the world's tuna fleet is too large, and should be reduced. Though estimates of how much the purse-seine fleet should be reduced have not been given by the industry nor most of the regional bodies, it seems obvious that if the fleet were used more efficiently, the amount of tuna that is currently being harvested could be taken with significantly fewer vessels. In fact, scientists of the IATTC have suggested that the purse-seine fleet that operates in the eastern Pacific Ocean should be reduced by about 15-20%. These expressions of concern make the time propitious for initiation of some schemes of capacity limitation.

The process of devising a scheme for reducing purse-seine fleet capacity, obtaining agreement among the various players on it, and getting it into effect will be a long and arduous one. In the meantime, the world fleet is continuing to grow and the realities of effective management and conservation remain elusive. It is imperative that something be done quickly to reverse this trend. Over the short term, a practical approach would be to place a moratorium on the introduction of all types of new tuna vessels into the fishery. This could perhaps be most readily achieved for purse seine vessels by working with the WTPO. A "grass-roots" approach, emanating from within the industry, could prevent the fleet from growing, thus allowing time for governments and regional bodies to work on schemes to reduce capacity to optimum levels. There would be several factors that the WTPO would have to deal with to set a moratorium on fleet growth. The most important of these factors would be handling the matter of new entrants into the tuna fisheries. An approach that could be used by the WTPO would be for buyers and sellers to agree to purchase vessels only from within the current fleet, or to build only a vessel of a size equivalent to one that is removed from the fleet. In this case removed means scrapped and not transferred to other fisheries or other uses. It is important that governments, industry and regional tuna bodies, work with the WTPO, and other appropriate industry groups to achieve a moratorium as quickly as possible.

The initiatives taken by the longline industry to reduce fishing capacity on a global basis should be applauded by governments. The same governments of all nations with longline fleets should work with the longline industry to formalize the agreements and incorporate them within the framework of the regional tuna bodies. In this way other fleets not currently part of the longline industry coalition would be brought into the capacity limitation programme and the programmes would be strengthened and improved.

Considering the fact that baitboats and gillnets boats account for about 20 to 25% of the total landings of tuna, it is important that some scheme be developed to control the growth of these gear types. However, the urgency is not so compelling as it is for the purse-seine fleet. If controls are placed on purse seiners and longliners, but not on baitboats or gillnetters capital will flow toward the latter. Consideration should be given to working in a timely fashion toward the establishment of a moratorium on the addition of new baitboats and/or gill -netters to current fleets. Once established, a moratorium would allow time to examine alternative mechanisms for placing controls on baitboats and gill-net boats.

There are various actions that would have to be taken by governments and international organizations before a long-term solution to the capacity limitation problem, such as one of those mentioned earlier in this text, could become a reality. Important among these would be ensuring that the proper international legal basis exists for limiting entry into tuna fisheries and assigning property rights to the participants in those fisheries. Protocols to the UN Convention on the Law of the Sea and changes to the instruments establishing the various regional tuna bodies would have to be made. These changes would have to define the rights and obligations of states regarding the utilization of the sea's living resources, and also the authority for international bodies to limit entry and assign property rights. In this respect, the

FAO can act as a catalyst for these changes to the various instruments by convening a series of working groups and/or meetings to define what these changes should entail and how they should be made.

The five regional tuna bodies would benefit from the establishment of some sort of coordinating mechanism to harmonize their efforts to manage the world's tuna fisheries, particularly with respect to limiting fishing capacity. Such a coordinating body, which would need to have some permanency, could be structured as an independent body serving the needs of the regional organizations, or it could be a part of the FAO. In this latter case however, provision would have to be made to allow the participation of governments and/or fishing entities which harvest tuna, but that are not members of the FAO, the United Nations, nor their specialized agencies. There are several functions that the permanent committee would need to carry out, including *inter alia*, coordinating the standardization and collection of catch data and creating and maintaining an international register of tuna fishing vessels.

It is also important to ensure the compliance of nations and vessel operators with the provisions of whatever agreements are made to limit fishing capacity and manage tuna fisheries. Like the permanent coordinating committee mentioned above, a permanent compliance committee, comprised of representatives of all of the regional tuna bodies, would be able to propose various actions to ensure that the terms of any agreements to limit capacity are complied with. An important matter that this committee would need to deal with is the development of international standards for the application of sanctions against nations or individuals whose actions diminish the effectiveness of the various international agreements to limit capacity and manage the tuna resources.

There are three very important technical matters that are in need of immediate research if effective schemes for managing fishing capacity are going to become a reality. The first is the development of quantitative means of monitoring efficiency changes or productivity growth in fishing vessels under management controls, the second has to do with the evaluation of buy-back schemes for multinational tuna fisheries, and the third has to do with the application of quantitative techniques to measuring fishing capacity. A logical approach to evaluate the first two of these research needs would be the establishment of technical working groups. Perhaps this could be established most effectively through the FAO. The third matter could be achieved by a Pacific-wide Data Envelopment Analysis, because data for individual vessels are available in the archives of the IATTC and SPC/FFA. A joint analysis of these data by scientists affiliated with the respective fisheries bodies would provide an excellent opportunity to evaluate fully the applicability of this technique to the world tuna fisheries.

In conclusion, a growing human population, which is expected to reach 10 billion people by the middle of the Twenty first century, is placing increasingly greater demand on the world's natural resources. This is especially true respecting the sea's living marine resources. Tuna resources are no exception to this, and in an effort to meet this growing demand, catches have steadily increased over the last 50 years. Tuna fleets have grown and become so large that many vessels are operating far below economic optima. These conditions make it difficult for governments to ensure the rational exploitation and adequate conservation of the tuna stocks. Bringing new vessels into the tuna fisheries of the world has been unrestricted and been considered everyone's right, and this right is enshrined in international law. It is time to change this policy, and time to limit the number of vessels authorized to fish for tuna. The high seas can no longer be considered a frontier in which its natural resources are there for the taking. The current legal and political basis ensuring the right of every person to fish on the high seas must be re-examined and brought in line with current reality. This will require bold new approaches as to the management of the high-seas resources. The time we have to work on this is limited, and action must be swift if we are to ensure that tuna populations are maintained at levels of abundance that can support maximum yields on a sustained basis, and to guarantee to future generations the option to enjoy the benefits of these resources.

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