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FISHERIES AND STOCKS OF YELLOWFIN TUNA IN THE PACIFIC AND INDIAN OCEANS - STATUS AND REVIEW OF ASSESSMENT METHODS

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SUMMARY

Yellowfin tuna, *Thunnus albacares*, is found in tropical and subtropical waters of the major oceans. It is a species with a relatively short life span (maximum of about 6-7 years), grows rapidly to a moderate size (maximum of about 190 cm long) and forms large schools in regions of the oceans where forage is abundant.

Fisheries have developed in regions where yellowfin tuna are found in large concentrations. The total world catch was 905,000 MT in 1989 and has increased by 25 percent over the past five years. This growth is largely due to expansion of purse seine fishing in all regions, but particularly in the western Indian Ocean. Currently, the Pacific Ocean contributes about 66 percent of the total catch, the Atlantic Ocean, 17 percent, and the Indian Ocean, 17 percent. The catch is used primarily in high-value markets, such as for canned tuna and "sashimi".

Assessment methods used to determine the condition of the stocks basically rely on fisheries data rather than research survey data. The methods include production model and cohort analysis. In this paper, we review these methods as well as information on the fisheries for yellowfin tuna in the Pacific and Indian Oceans, and the condition of the stocks.

RESUME

L'albacore *(Thunnus albacares)* se trouve dans les eaux tropicales et subtropicales des principaux océans. Il s'agit d'une espèce à la longévité relativement réduite (6-7 ans maximum), qui atteint rapidement une taille modérée (190 cm de longueur maximum) et qui forme des bancs importants dans les zones océaniques où abondent ses aliments.

Des pêcheries se sont développées dans les régions où se trouvent de fortes concentrations d'albacore. La prise mondiale totale était de 905.000 TM en 1989; elle s'est accrue de 25 % depuis cinq ans. Cette augmentation est due en grande partie à l'expansion de la pêche à la senne dans toutes les régions, et particulièrement dans l'ouest de l'océan Indien. A l'heure actuelle, le Pacifique donne environ 66 % de la prise totale, l'Atlantique 17 % et l'océan Indien 17 %. La prise est destinée en majeure partie à un marché à prix élevés, tel que la mise en conserve et le "sashimi".

Les méthodes d'évaluation utilisées pour déterminer l'état des stocks dépendent fondamentalement des données de la pêcherie, plutôt que des données obtenues par prospection. Les mèthodes comprennent le modèle de production et l'analyse des cohortes. Dans le présent document, nous passons en revue ces méthodes, ainsi que l'information sur la pêche d'albacore dans les océans Pacifique et Indien, et l'état des stocks.

RESUMEN

El rabil, *Thunnus albacares*, se encuentra en aguas tropicales y subtropicales de los principales océanos. Su ciclo vital es relativamente corto (máximo 6 ó 7 años), crece con rapidez hasta un tamaño medio (máximo de unos 190 cm) y forma grandes cardúmenes en zonas del océano donde el alimento es abundante.

Las pesquerías se han establecido allí donde el rabil se encuentra en grandes concentraciones. En 1989 la captura mundial totalizó 905.000 t y a lo largo de los últimos cinco años ha experimentado un aumento del 25 por ciento, que se debe en gran parte a la expansión de la pesca con cerco en todas las regiones, pero sobre todo al oeste del Indico. Actualmente, el Pacífico contribuye con el 66 por ciento de la captura total, el Atlántico con el 17 por ciento y el Indico con el 17 por ciento. El pescado obtenido se destina a los mercados caros, como el de atún enlatado y el "sashimi".

Los métodos de evaluación empleados para determinar la condición de los stocks se basan principalmente en los datos de pesquerías más que en datos de encuestas de investigación. Estos métodos incluyen el modelo de producción y el análisis de cohortes. Este documento presenta los métodos mencionados, información sobre las pesquerías de rabil en los océanos Pacífico e Indico y trata sobre la condición de los stocks.

INTRODUCTION

Over the past 15 yrs, there have been unprecedented changes in the fisheries for yellowfin tuna, *Thunnus albacares*. Among the changes were a completely new purse seine fishery developed first in the central-western Pacific (CWP) and then in the western Indian Ocean (WIO). The eastern tropical Atlantic fishery was reduced substantially in size. The eastern tropical Pacific (ETP) fishery declined and recovered to produce a record catch of 288,000 mt of yellowfin tuna in 1989. These changes and others contributed to an increase in the world catch of yellowfin tuna by 77%, from 511,000 mt in 1975 to 905,000 mt in 1989. In 1989, 66% of the yellowfin tuna catch came from the Pacific Ocean, 17% from the Atlantic Ocean and 17% from the Indian Ocean. The catch was worth more than US $1.0 billion, exvessel.

In this document, changes in the major yellowfin fisheries in the Pacific and Indian Oceans are reviewed and the forces responsible for the changes identified. We also review methods that have so far been used to assess the condition of the stocks and we provide recommendations for improvements.

SOURCES OF DATA

Data (catch, catch rate and number of vessels) on the fisheries and information on the stocks of yellowfin tuna of the Pacific and Indian Oceans are contained in scattered documents, published and unpublished, and of varied reliability. We reviewed available publications and evaluated the data in them by cross checking and comparison. Only data and information that appeared reasonable and consistent with information on the fisheries were tabulated and used in this report.

The principal sources of data are as follows:

■ Total catch by ocean and year. FAO's "Yearbook of fishery statistics, catches and landings" series was our source for total catches by oceans. This is a readily available source of comprehensive fishery data, but is not necessarily the most accurate. Missing in the yearbooks are catches by recreational fishermen, as well as accurate statistics on subsistence and artisanal fisheries. The yellowfin tuna statistics also include other species, particularly catches of bigeye tuna, *T. obesus*, which are regularly mixed and reported as yellowfin by some agencies. Nevertheless, the FAO yearbooks account for most of the world catches and provide a good overview of global production.

■ Indian Ocean fishery. The Seychelles Fishing Authority's "Seychelles tuna bulletin" (1990) and the Indo-Pacific Tuna Development and Management Programme report (IPTP 1990) were the main sources of data for the yellowfin tuna fishery in the WIO. These sources provide a comprehensive data set on the major fishery of the Indian Ocean.

■ Eastern tropical Pacific fishery. The Inter-American Tropical Tuna Commission (IATTC) regularly publishes data on the ETP yellowfin tuna fishery in annual, quarterly and background reports. We used these reports as well as unpublished sources for data on the ETP fishery.

■ Central-western Pacific fishery. There is no good, single data set for this fishery. The statistics are undergoing review and revision as new information is uncovered and as officials make data in their files available to scientists. Currently, the most comprehensive statistics on catches for the fishery is SPC (1990a). This data set is clearly different from

that reported by FAO (Figure 1). One or both of these data sets will no doubt undergo revision in the coming years as the differences are sorted out. For our purposes, we used the SPC data set for the CWP fishery.

Because we were not able to locate a single source for total number of boats operating in the CWP fishery, we estimated the number by using a variety of sources. We concentrated on the purse seine segment of the fishery and only vessels in the Japanese, Korean, Taiwan and U.S. fleets. Our main sources were Watanabe (1983), Iizuka and Watanabe (1983) and trade journals for data on the Japanese fleet; Coan (1990) for data on the U.S. fleet; and trade journals and confidential unpublished reports for data on Taiwan and Korean fleets. For early years of the fishery, our estimates are for the entire fishery; for more recent years, they probably represent approximately 85% of the entire international fleet.

PACIFIC OCEAN FISHERIES

Although yellowfin tuna is found in a wide band across the Pacific Ocean bound by about 35° N and 40° S Lat. (Cole 1980), the principal fisheries for this species are concentrated in a more narrow range, 20° N to 20° S and in two fairly distinct regions, ETP and CWP (Figures 2 and 3). In each region, the surface (Figure 2) and longline (Figure 3) fisheries overlap. The regions are separated at about 145° W long., but this demarkation line shifts with season and with changes in large-scale oceanographic conditions, such as the El Niño (Mysak 1986). In some years, the line can be obscured as some catches are made in the zone of separation to bridge the regions. Nevertheless, in most years there is a clear separation of particularly the surface fisheries. This separation has largely been used as the basis for considering the fisheries in the two regions as separate management units supported by separate yellowfin tuna stocks (Suzuki et al. 1978).

The total yellowfin tuna catch in the Pacific was relatively stable at about 375,000 mt during 1975 to 1983 (Figure 4). It then increased sharply to 600,000 mt in 1987 and remained at that level through 1989. During the 1975-83 period of stability, production from the ETP was downward, reaching a low level in 1983; whereas production from the CWP was upward, surpassing the ETP catch in 1980. Since 1983, production from the ETP recovered and dominated the Pacific catch again, while the CWP catch continued at a high level. Both these trends contributed to the sharp increase in total catch from the Pacific since 1983. Currently, the fisheries in the two regions contribute about equal amounts to the total Pacific catch.

Eastern Tropical Pacific

The ETP fishery is foremost in world production of yellowfin tuna. It is mainly a purse seine fishery (Figure 5) that targets both skipjack, *Katsuwonus pelamis*, and yellowfin tuna, but with yellowfin as the preferred and dominant species. The fishery operates year-round and with no strong seasonality to the catch (Figure 6). In the past 20 yrs, the fishery has undergone a series of major changes and no doubt, it will experience more in the future.

From about 1970 to 1980, the fishery was in an expansion phase and led by the dominant U.S. purse seine fleet; the fishing area expanded, the quota management system accommodated the expansion, and a large number of purse seine vessels were added (Figure 5). The catch increased for a period, then decreased as the biomass was overfished. By the late 1970s, yield-per-recruit was well below optimum, and the catch rate of yellowfin tuna was declining steadily (Figure 7). Some vessels were unable to maintain profitability and left the fishery. Many more (mostly U.S. vessels) left in the following years as the catch rate slid further to a record low with the 1982-83 El Niño event that made fish less available to the purse seiners. In addition, the U.S. tuna processing sector underwent a major restructuring that included wholesale selling of U.S. purse seiners to non-U.S. investors (Sakagawa in press). This resulted in a sharp reduction in vessels in the ETP fishery (Figure 5) and a shift to Mexican-flag seiners dominating the fishery. Many of the departing vessels relocated to the CWP fishery. The El Niño event largely marked the end of the expansion phase in the ETP fishery.

Since 1982-83, the reduced fishing effort together with exceptionally high recruitment to the stock and fishermen concentrating on catching large yellowfin (>90 cm; Figure 8) have contributed to a recovery of both the yellowfin tuna stock and fishery (IATTC 1989). Record high catches have been produced annually since 1985 (average 280,500 mt), and the stock is in good condition.

By concentrating on catching large sizes of yellowfin, however, the fishery has aggravated an incidental catch problem. The problem is with dolphins (mainly *Stenella* spp.). In the ETP, dolphins and large yellowfin tuna are often found together, and purse seine fishermen use this behavior for locating and catching the yellowfin tuna. In 1989, purse seine fishermen produced about 70% of their ETP yellowfin tuna catch from tuna-dolphin associated schools (Sakagawa in press). Unfortunately, this form of fishing results in dolphins being killed in the process and is being severely criticized by environmental groups.

The U.S. government has responded to this environmental concern. Since 1974, it has imposed stringent fishing regulations on the U.S. fleet to reduce the kill (Sakagawa in press). Also, U.S. processors voluntarily pledged in 1990 to no longer purchase tunas caught with dolphins. These measures have produced significant results in reducing the incidental dolphin mortality by U.S. vessels (Figure 9). However, the total kill for the fishery still remains high. While the U.S. fleet has made gains other fleets, mainly Mexican and Venezuelan, have not and have increased their fishing on tuna-dolphin schools. The total annual kill by the fishery is estimated to be about 100,000 animals. Non-U.S. vessels are responsible for most of this kill and eventually will be responsible for all of it as the U.S. fleet withdraws from fishing tuna-dolphin schools.

Central-Western Pacific

The CWP fishery is more complex than the ETP fishery. The significant difference is in number of major fishery components and degree of dependence on yellowfin tuna. In the ETP fishery, purse seine is by far the dominant gear, accounting for virtually the entire ETP yellowfin catch. In the CWP fishery, purse seine is only one of several (ringnet, longline and handline) gears that contribute significant amounts to the total CWP yellowfin catch. The contributions are quite variable from one year to another probably because the gears do not target exclusively on yellowfin tuna. Purse seiners, for example, concentrate on catching skipjack but take large amounts of yellowfin tuna when favorable oceanographic conditions make yellowfin available. The purse seine contribution varies from about 30% to 50% of the CWP yellowfin catch (Figure 10). The longline gear targets mainly bigeye tuna and secondarily yellowfin tuna, and contributes about 10-15% of the total catch. Both these components of the fishery are reviewed in this section.

The longline fishery contributes a small fraction of the CWP yellowfin tuna catch, but has been of long standing interest because it was once the dominant fishery and has contributed the longest time series of statistics for the region. A description of developments in this fishery can be found in Sakagawa et al. (1987), Suzuki (1988) and Suzuki et al. (1989).

The longline fishery was once organized for catching yellowfin tuna and albacore, *T. alalunga*, for the canned tuna market. In the 1970s and early 1980s, it underwent significant changes that directed production away from this market and towards supplying the Japanese sashimi market (Sakagawa et al. 1987). This move resulted in modernization of the longline fleets, including new construction and up-grading of the preservation equipment to super-cold freezing capability, and modification of fishing strategy with deep longlining. Bigeye tuna, emerged as the preferred tropical tuna species for this fishery. Yellowfin tuna, however, continued to be important for some segments of the Japanese and Korean fleets and more recently, for some segments of the Taiwan fleet as well.

The catch rate of yellowfin tuna for the CWP longline fishery has been analyzed in detail by several investigators, most recently by Suzuki et al. (1989). The analysis includes adjustments for changes over time in depth of gear (related to target species), area fished, and time of fishing. A major factor, environmental changes such as depth of the thermocline with and without an El Niño, has not yet been accounted for in the analysis. Nonetheless, their results indicate high and relatively stable catch rates during 1952-60, followed by a downward trend until 1972. The trend was upward between 1972-78 and then sharply downward since 1978 (Figure 12).

The CWP purse seine fishery is a more recent development than the longline fishery. This fishery targets mainly skipjack tuna but takes yellowfin tuna as well, particularly in mixed-species schools. This fishery was developed in the 1970s by the Japanese and U.S. purse seine fleets, but with different approaches. The Japanese concentrated on refining techniques to fish log-associated schools. The U.S., on the other hand, concentrated on developing techniques to fish the fast-moving, free-swimming schools. Both were successful, and their successes led to the rapid buildup of fishing in the region during the 1980s which is continuing (Figure 10).

The trend in purse seine catch of yellowfin tuna from the CWP was sharply upwards between 1980 and 1987 (Figure 10). It has fallen since then but to a moderate level of 75,000 mt in 1988. The fishery operates in all months, but yellowfin appears to be more readily availability during June through November (Figure 6) and most of the fish are less than 80 cm FL (Figure 11). Fish smaller than 80 cm FL are generally caught in log-associated schools, and a range of large and small-sized fish are generally caught in free-swimming schools.

There has not yet been a comprehensive analysis of catch rates of yellowfin tuna for the CWP purse seine fishery. Data from the Japanese fleet have been analyzed by Suzuki et al. (1989) and SPC (1990a). A clear picture of trends, however, has not emerged (Figure 7). Further analytical work is needed, and should include the merging of data from other purse seine fleets operating in the region and accounting for gradual improvements in fishing power of the fleets. This is especially needed because the Japanese fleet operates in a more restrictive area (Suzuki 1988) than the other purse seine fleets and relies on log-associated schools more heavily than the U.S. fleet.

The island nations of the CWP are concerned that the yellowfin tuna stock is being adversely affected by the current purse seine fishing effort in the region. Their concern centers on questions such as "Is purse seine fishing reducing the opportunity of the island coastal fisheries in catching yellowfin tuna, and is purse seine fishing resulting in excessive mortality on small yellowfin tuna?"

INDIAN OCEAN FISHERIES

Although the Indian Ocean is a smaller ocean than the Pacific, the principal fisheries for yellowfin are concentrated in the same narrow band, 20° N to 20° S lat., as in the Pacific. The longline fishery operates throughout this band, artisanal fisheries are scattered at the margins, and there is only one major purse seine fishery, located in the western region (Figure 13).

The Indian Ocean catch of yellowfin tuna was fairly flat at about 40,000 mt in the 1970s (Figure 14). This catch was produced largely by the longline fishery. Purse seine fishing for yellowfin tuna developed in the early 1980s in the western region (Stéquert and Marsac 1986), and the catch increased sharply, reaching 179,000 mt in 1988. It has retreated from this high level since then, but is still at a high level. Virtually all of this increase has come from the western region of the ocean where the purse seine fishery is centered. The recent decline in catch has coastal nations concerned that the stock has been overfished. Because this purse seine fishery is by far the major yellowfin tuna fishery in the Indian Ocean, it is the focus of this section.

The purse seine fishery accounts for more than 65% of the total annual catch of yellowfin tuna from the WIO (Figure 15). The fishery is quite seasonal, geared to the monsoon season of the region. It is also closely linked to the fishery in the eastern tropical Atlantic as purse seiners freely move between the two fisheries depending on fishing conditions. Highest availability of yellowfin tuna is generally during January through April (Figure 6), but could also be high in November and December in some years (Lablache 1990). During this season, the fishery is primarily within the Seychelles EEZ and targeting free-swimming schools of yellowfin tuna. During May through about July, the fishery is concentrated in the Mozambique Channel and is mainly targeting skipjack tuna. From August through October, the fishery is centered east of Somalia and northwest of Seychelles targeting on log schools with mixed tuna species.

The size composition of yellowfin tuna caught by this fishery is bimodal (Figure 16) and similar to that of the CWP purse seine fishery (Figure 11), but different from that of the ETP purse seine fishery (Figure 8). The smaller modal size, 60 cm FL, is mostly fish caught with logs and mixed with skipjack tuna. Free-swimming schools yield all sizes of fish, but strongly bimodal (Lablache 1990).

Adjustments for the seasonality and searching pattern of the fishery have been made in analyses of the catch rate for this fishery (IPTP 1990). The results show a declining trend in catch rate of yellowfin tuna from 1978 to 1985, a sharp increase between 1986 and 1988 and a decline in 1989 (Figure 7). These results are difficult to interpret because of significant changes in the fishery. Changes such as improved fishing and searching power of the vessels, increased competition, increased use of artificial logs, etc. (IPTP 1990) have occurred. These changes, as well as environmental effects are not part of the adjustments incorporated so far and need to be factored into future analyses. Oceanographic conditions in particular might be the keystone in determining the success or failure of the purse seine fishing season in the WIO (Marsac and Hallier 1990).

ASSESSMENT METHODS

Yellowfin tuna stock assessments in the Pacific and Indian Oceans have concentrated in three regions, the ETP, the CWP, and the WIO. These regions are where industrial-scale fisheries occur rather than where biological subpopulations of yellowfin reside.

Eastern Tropical Pacific

The agency with primary responsibility for monitoring the status of yellowfin tuna stocks in the ETP is the IATTC. Fishery statistics from the ETP tuna fleets have been collected for a number of decades by the IATTC, and ancillary biological observations, otolith, and tagging data have been collected from time to time. Over the years this agency has adopted and pioneered a number of analytical techniques for assessing the status of tuna stocks, including yellowfin, based on the data at its disposal. Assessment of stocks of yellowfin and other tunas in the ETP are published annually (e.g. IATTC 1989).

Estimates of maximum sustainable yield (MSY) of yellowfin and the associated optimum fishing effort level are obtained from a generalized production model analysis developed by the IATTC (Pella and Tomlinson 1969). Classical production model analysis makes the dubious assumption that stocks are in equilibrium with prevailing fishing mortality levels. The IATTC method is free of that assumption.

Time series of yellowfin abundance estimates are calculated in three ways: the catch per effort (CPUE) of a standard vessel class (Figure 7), a general linear model (GLM), and cohort analysis. The GLM method, developed by the IATTC (Punsley 1987), includes a number of co-factors accounting for the effects of, for example, various environmental factors, vessel class composition, and set-type composition on the annual abundance index. The cohort analysis is roughly tuned to the trend in CPUE and gives quarterly biomass estimates of semi-annual cohorts as well as estimates of recruitment to these cohorts.

To conduct cohort analysis the catch must be partitioned into age classes. This is accomplished from the length composition in the catch along with knowledge of size-at-age obtained from otolith studies and from tagging data. A by-product of cohort analysis is the vector of age-specific fishing mortalities which permits the IATTC to conduct classical yield-per-recruit analyses, and thus to report the optimum size at entry into the fishery.

In addition to the traditional assessment objectives above, the degree of interaction between the purse-seine and longline fisheries in the ETP has been assessed by drawing inferences from the time trajectory in the longline catch versus effort plot (Suzuki 1988).

Central-Western Pacific

Yellowfin stock assessments based on longline fishery data in the CWP have been conducted by the National Research Institute of Far Seas Fisheries (NRIFSF). Because the purse-seine fishery in the region has developed only in the last decade, the data collection mechanisms are not as mature nor are the time series as long as for the CWP longline fishery or the surface fishery in the ETP. Joint assessment efforts have been conducted between the NRIFSF and the South Pacific Commission (SPC).

Tsuji (1990) calculated an abundance index series from purse-seine CPUE with an adjusted catch to account for increasing skill in making sets and an adjusted effort to include just searching time using data from the Japanese purse seine fleet. To get a fishery-wide index, CPUEs in individual time and space strata were averaged across strata as is appropriate when the fishery concentrates on areas of higher than average abundance. To demonstrate changes in the tendency to concentrate, an index of concentration was calculated (SPC 1990b) which is the correlation coefficient between CPUE and effort in the strata.

Using longline data, Suzuki et al. (1989) calculated an abundance index with Honma's method and another index series using GLM with season, region, and hook depth as co-factors (Figure 12). The trends were almost identical for the different indices.

Production model analysis of both longline and purse seine catch and effort data was conducted by Suzuki et al. (1989) to estimate MSYs and the associated optimum fishing effort levels for each fishery. The method used was the Fox (1975) equilibrium approximation and the results were inconclusive.

Age composition in the catch of both longline and purse seine fleets has been estimated from the length composition and examined for trends (Suzuki et al. 1989), but apparently no formal cohort analysis has been conducted so far.

Western Indian Ocean

Development of a purse seine fishery in the WIO occurred even later than in the CWP; therefore the time series of data are even shorter. Nevertheless some yellowfin assessment has been attempted. Marsac and Hallier (1990) calculated an abundance index time series from purse seine catch per unit of searching effort. Catch rates in time-area strata with effort above a threshold value were averaged across strata to develop a fishery-wide abundance index (Figure 7). The abundance indices were then used with a generalized production model analysis to estimate MSY. The results were too preliminary for drawing precise conclusions.

FORCES FOR CHANGE

The forces behind the changes in the tuna fisheries of the world are economic, political and social. Understanding of these forces is critical for guiding the use and interpretation of data and information collected from the fisheries for stock assessment purposes. In this section, we provide examples of these forces at work in shaping the yellowfin tuna fisheries.

A good example of the impact of economic and social forces on a tuna fishery is the tuna-dolphin controversy of the ETP. In April 1990, after a long struggle, environmental groups in the U.S. convinced three large tuna processors (Star-Kist Seafoods, Van Camp Seafoods, and Bumble Bee Seafoods) that it would be economically sound and socially responsible to voluntarily stop purchasing and canning yellowfin tuna caught with dolphins. This action precipitated a reshuffling of the participants in the fishery and supplies in the global tuna market. It meant that about 50,000 mt of yellowfin tuna from the ETP fishery that normally are purchased and processed annually by the canners in the U.S. would be sold elsewhere. Also, because most U.S. purse seiners in the ETP fishery depend on tuna-dolphin schools for their production, vessel owners had to make plans to fish elsewhere, fish on other school types, or sell their dolphin-involved catch to non-U.S. processors (Sakagawa in press). This reshuffling is continuing and no doubt when finished, will have affected many fleets and be felt well beyond the ETP fishery.

The impact of these forces on the data series from the ETP fishery is clear, but the significance to stock assessments is not. The fishermen are adjusting and adopting new fishing strategies. Governments are responding with new regulations, including new data reporting requirements. These changes will affect the constancy of the fishery statistics reported from the region to date. Scientists must be alert to documenting the changes and prepared to evaluate the significance of the changes to stock assessment analyses.

In the 1970s, many coastal nations bordering rich tuna fishing areas extended their exclusive economic or fishing zones to 200 mi. In the western Pacific Ocean, where marine resources are virtually the only natural resources availlable to many island nations, this political action of extended zones created virtually a private "lake" with very few places designated international waters for free tuna fishing. The western Pacific island nations banded together in the early 1980s to protect this lake from poachers and to effectively negotiate fees for access to the resource by distant-water fishing nations. They have been relatively successful in negotiating agreements with Japan, the U.S. and others. Through these agreements, the Japanese and U.S. fleets have been limited in size; however, other fleets, such as Taiwan and South Korea, are not and are growing in size - fast becoming as large as the Japanese or U.S. fleets. These fleets are also not as well monitored as the Japanese and U.S. fleets and so far, have not provided comprehensive fishery statistics of their operations. This diminishes the ability of scientists to accurately assess the condition of the CWP tuna stocks. More serious is that continued non-compliance reduces the incentive for others to comply. When fishermen perceive an unfairness in the monitoring system, they have less incentive to cooperate and provide accurate fishery statistics. This perception is building in the CWP fishery and needs to be addressed and corrected.

Finally, although these forces for changes operate at opposition to each other at times, they traditionally tend to encourage expansion of tuna fisheries. The time is fast approaching when expansion will not lead to new and more supplies of yellowfin tuna, but to serious damage to the underlying resource base on which the fisheries depend. As the fleets continue to expand and no new fishing areas are added to accommodate the expanding fishing effort, more effort will be concentrated on existing stocks. Stocks will not be able to sustain the increased effort and will decrease in abundance, driving the fleets to leapfrog from one fishery to another in an attempt to remain profitable. A global crisis will emerge. Practical and new regional fishery management schemes, linked together under a global umbrella, will need to be developed and put into place by interested governments, if the above scenario is to be avoided.

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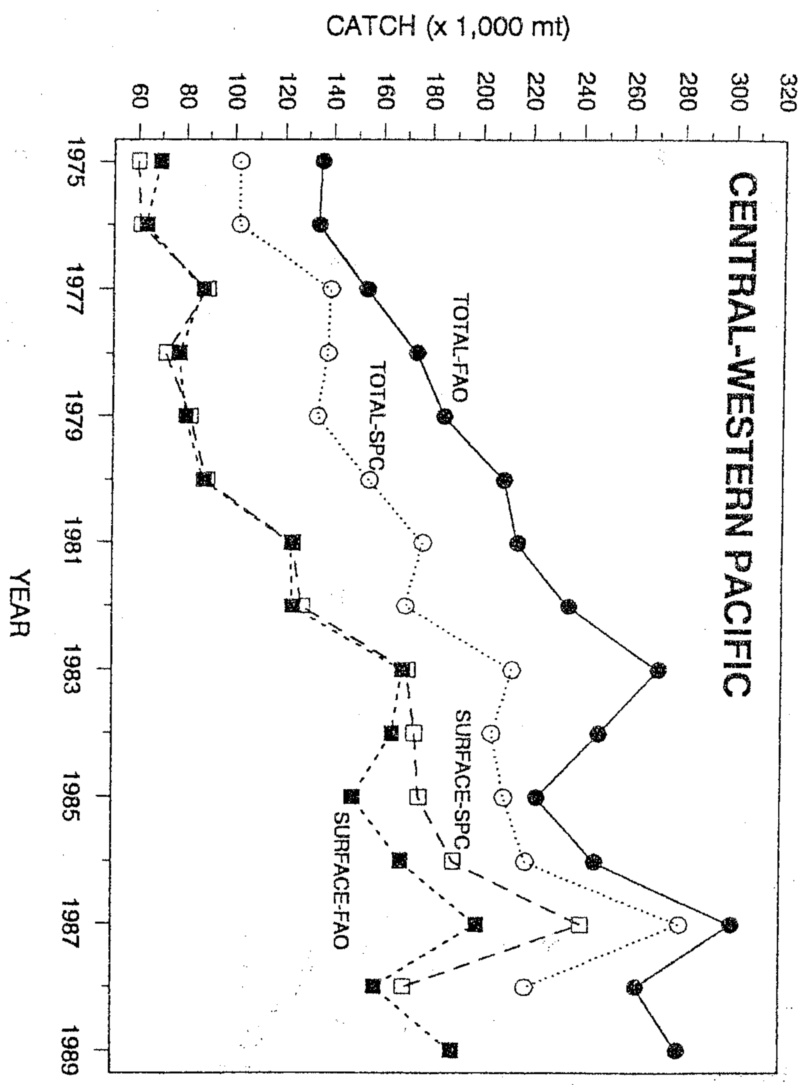


Figure 1. Comparison of yellowfin tuna catch statistics for the central-western Pacific from two sources. SPC statistics are from SPC (1990a). FAO statistics are from FAO, "Yearbook of fishery statistics, catches and landings" series and include catches in FAO area 71 and the western part only of area 77. Surface refers to catches by all gears other than longlines.

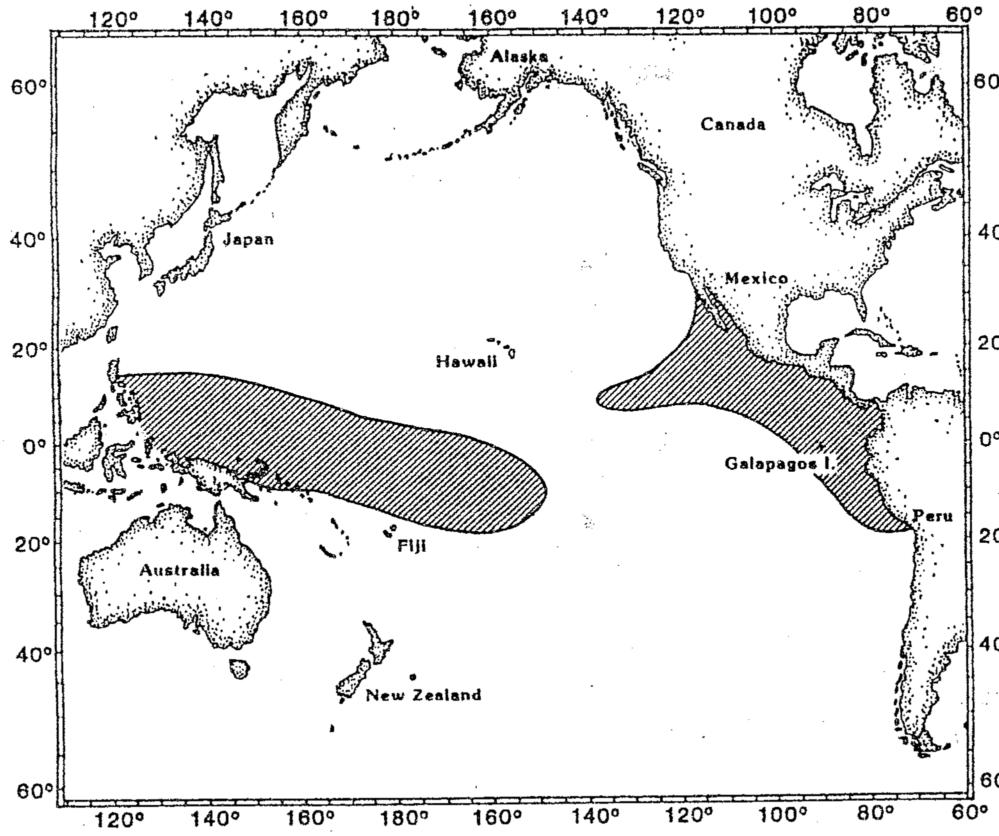


Figure 2. Location of the major fishing areas for yellowfin tuna by surface fisheries in the Pacific Ocean.

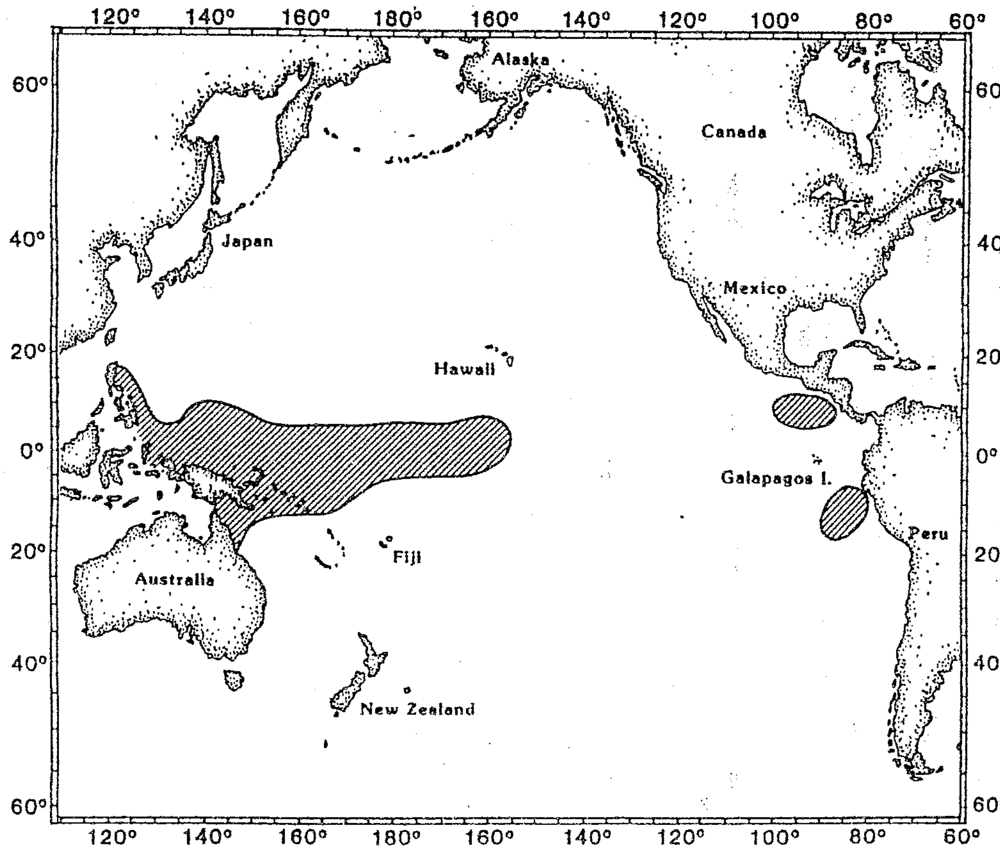


Figure 3. Location of the major fishing areas for yellowfin tuna by longline fisheries in the Pacific Ocean. (Data from Suzuki (1988))

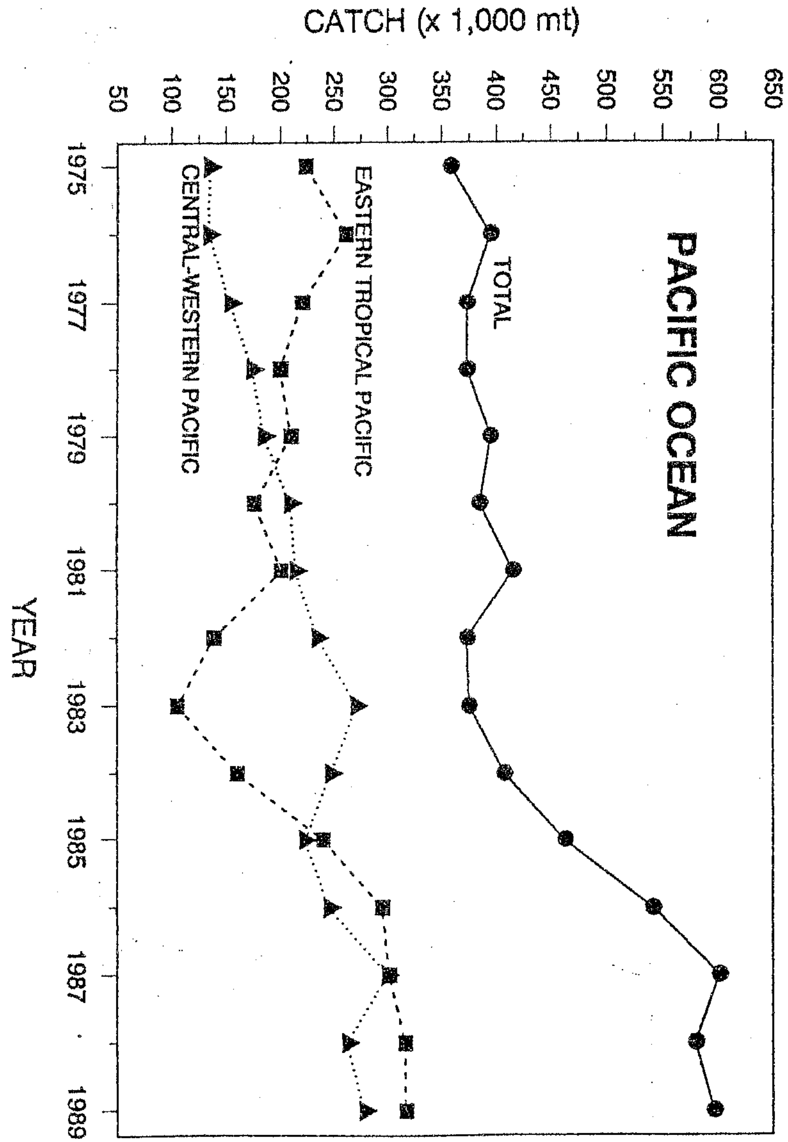


Figure 4. Catch of yellowfin tuna from the Pacific Ocean by ETP and CWP regions.

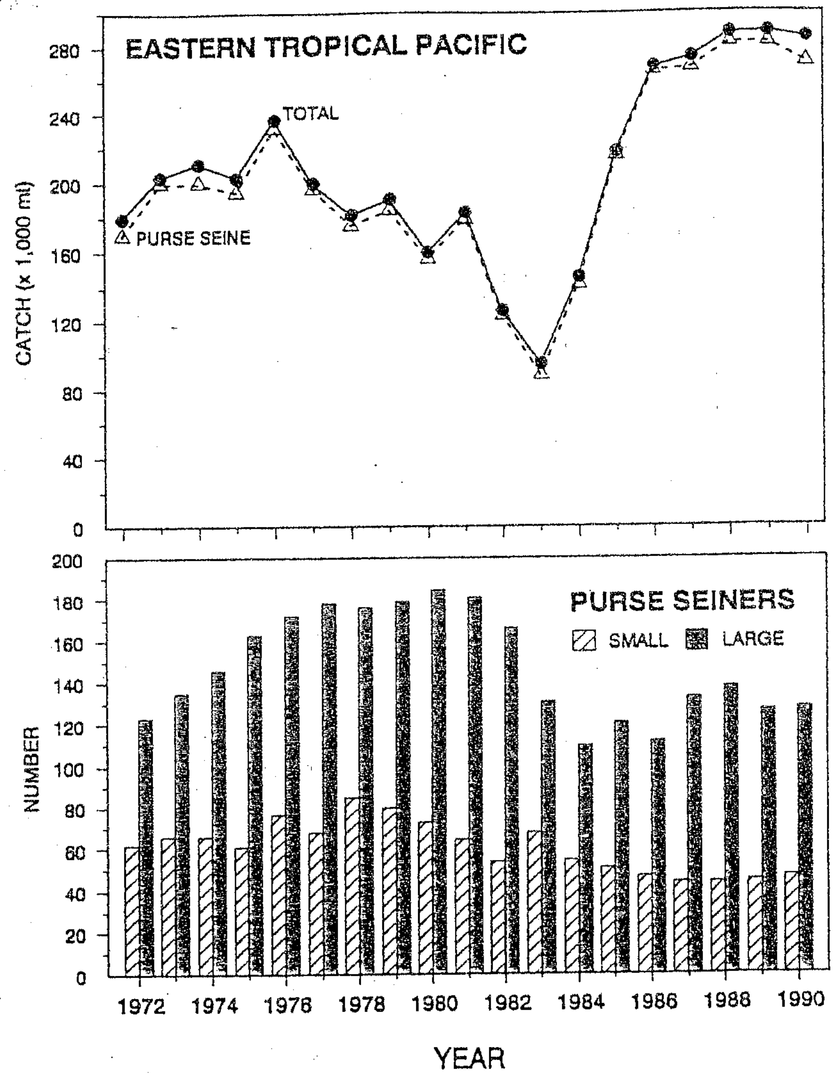


Figure 5. Catch of yellowfin tuna and number of purse seiners participating in the ETP fishery. Number of purse seiners include all vessels making one or more landings during the year. Vessels are grouped by carrying capacity: small, <270 mt; large, ≥270 mt. (Data from IATTC annual reports)

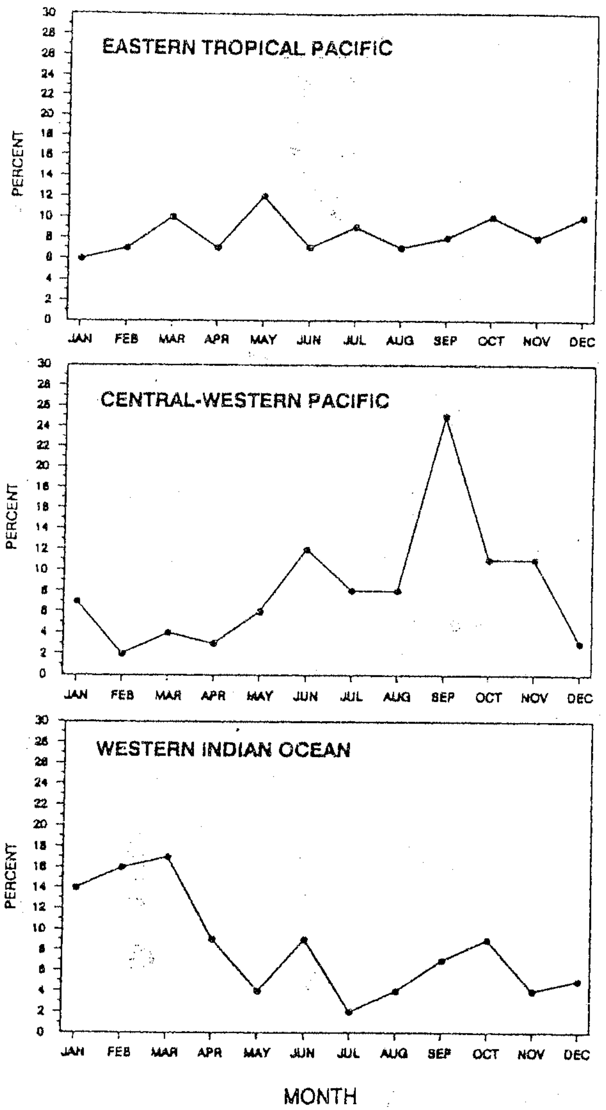


Figure 6. Percentage of total yellowfin tuna caught by month for purse seiners during the 1989 fishing season in the Pacific and Indian Oceans. (Data from IATTC (personal communication) for ETP; Coan (1990) for CWP; Seychelles Fishing Authority (1990) for WIO)

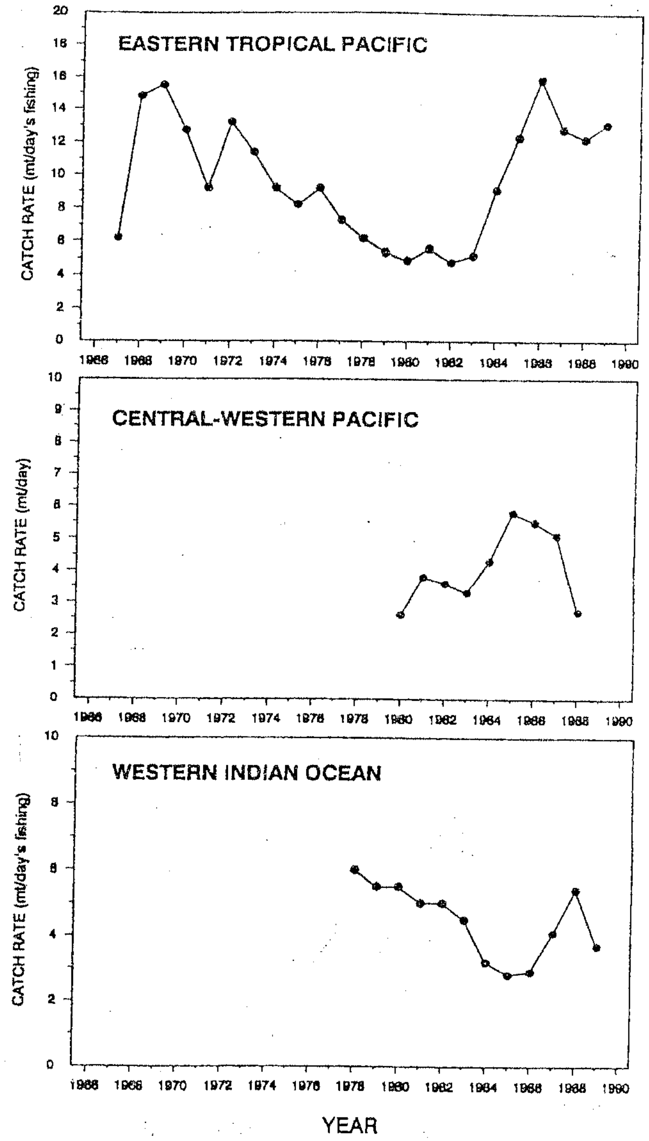


Figure 7. Standardized catch rates for the major purse seine fisheries of the Pacific and Indian Oceans. (Data from IATTC (1990) for ETP; SPC (1990a) for CWP; IPTP (1990) for WIO)

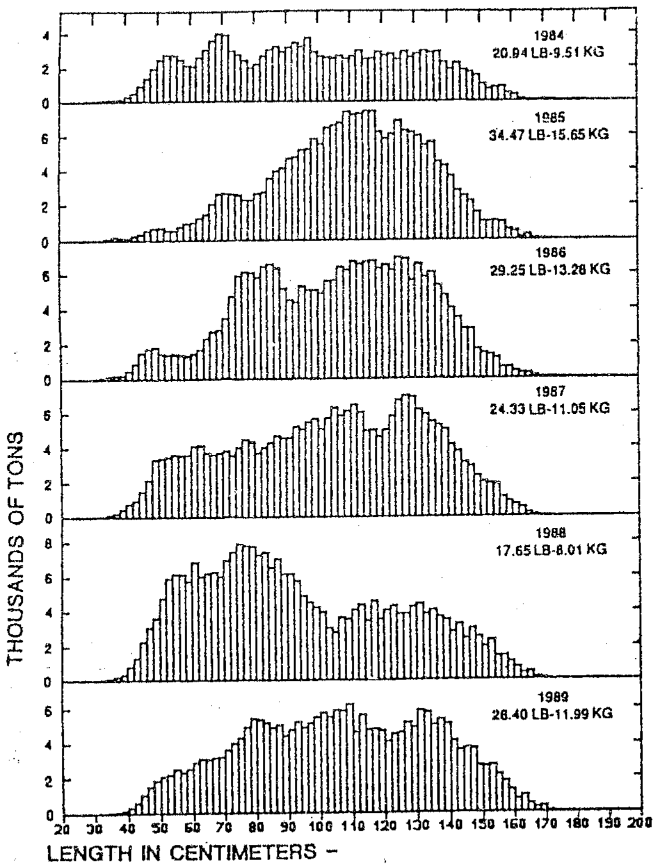


Figure 8. Size composition of yellowfin tuna caught in the ETP fishery in 1984-89. Average size of fish by year is shown. (Figure from IATTC (1990))

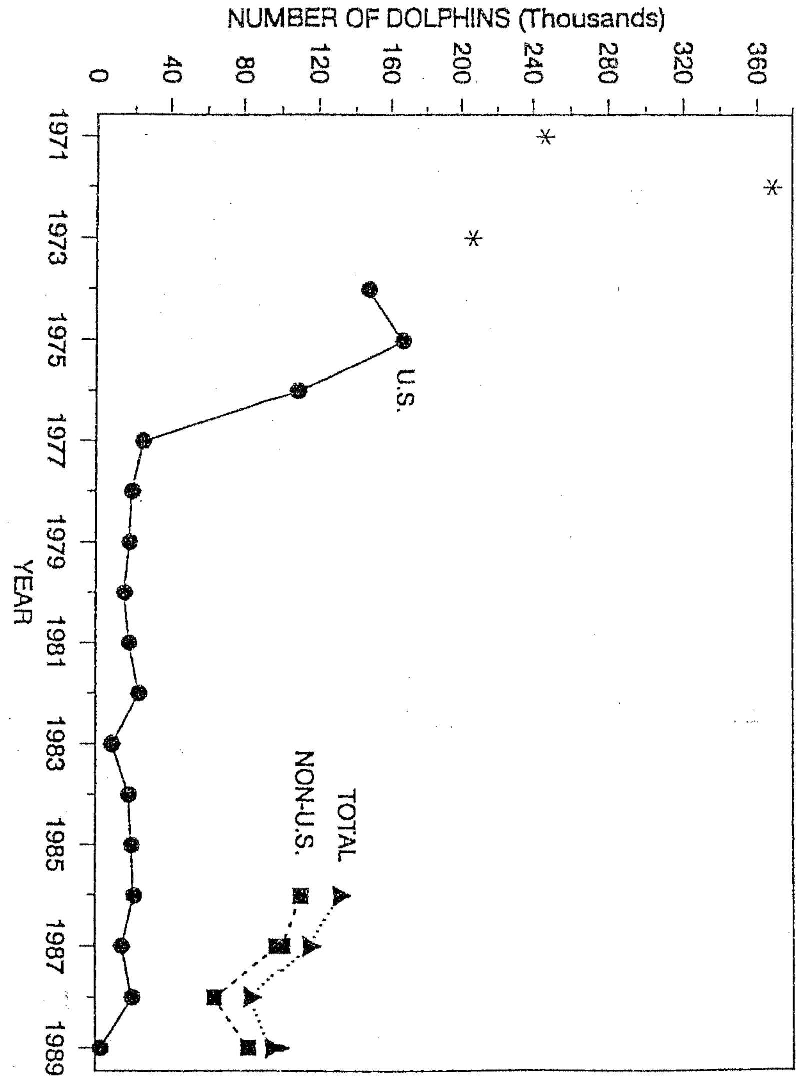
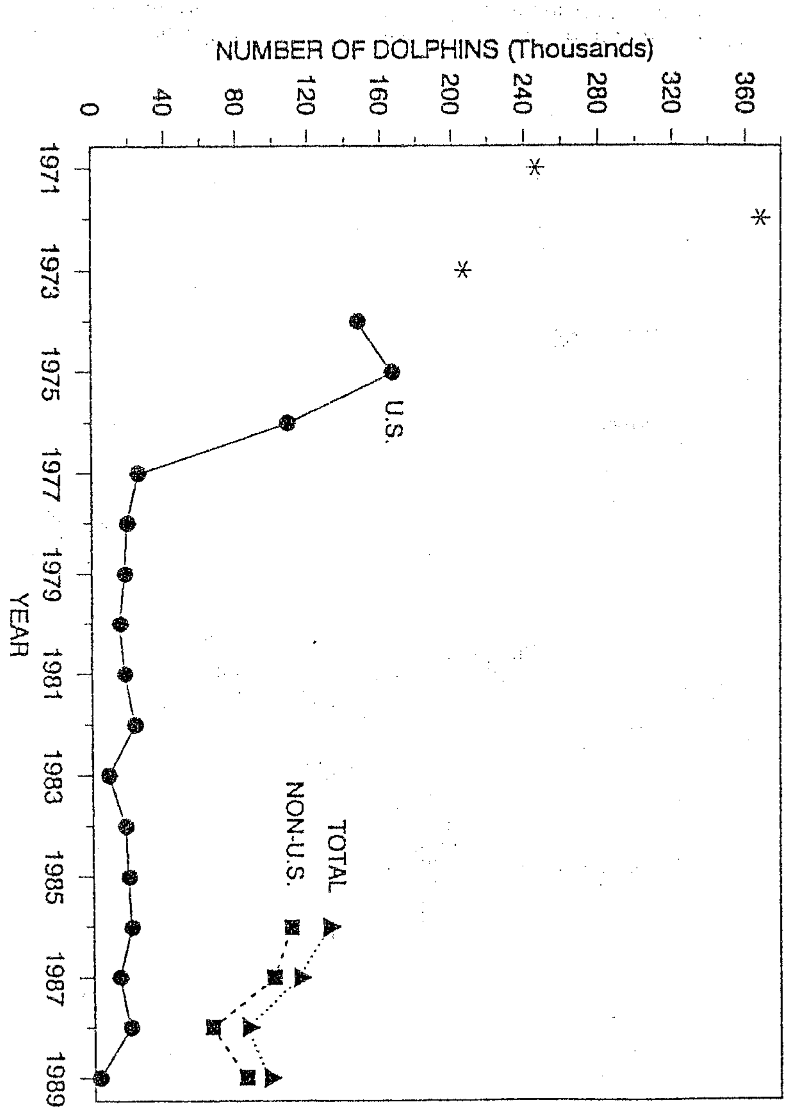


Figure 9. Estimated incidental kill of dolphins by the tuna purse seine fishery of the ETP. Estimates for 1971-73 are less precise than for later years when more rigorous sampling procedures were used. (Figure from Sakagawa (in press))



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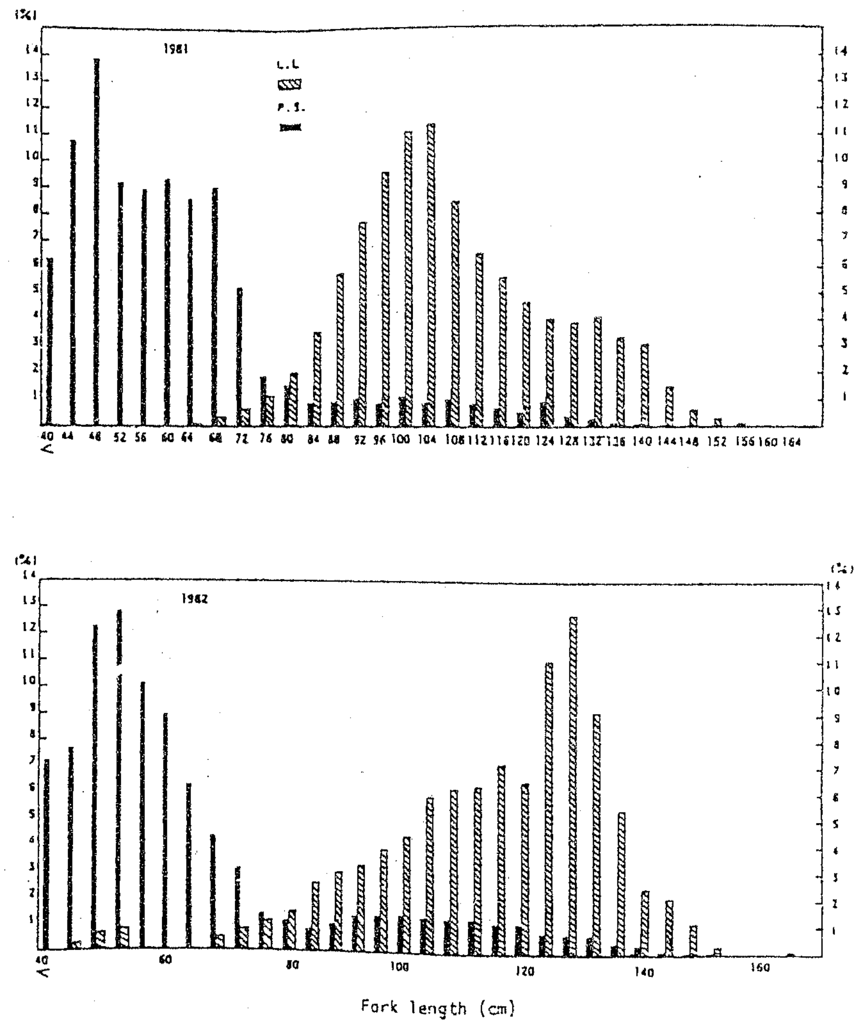

Figure 11. Size composition of yellowfin tuna caught in the CWP fishery by purse seiners (P.S.) and longliners (L.L.) in 1981 and 1982. (Figure from Suzuki (1988))

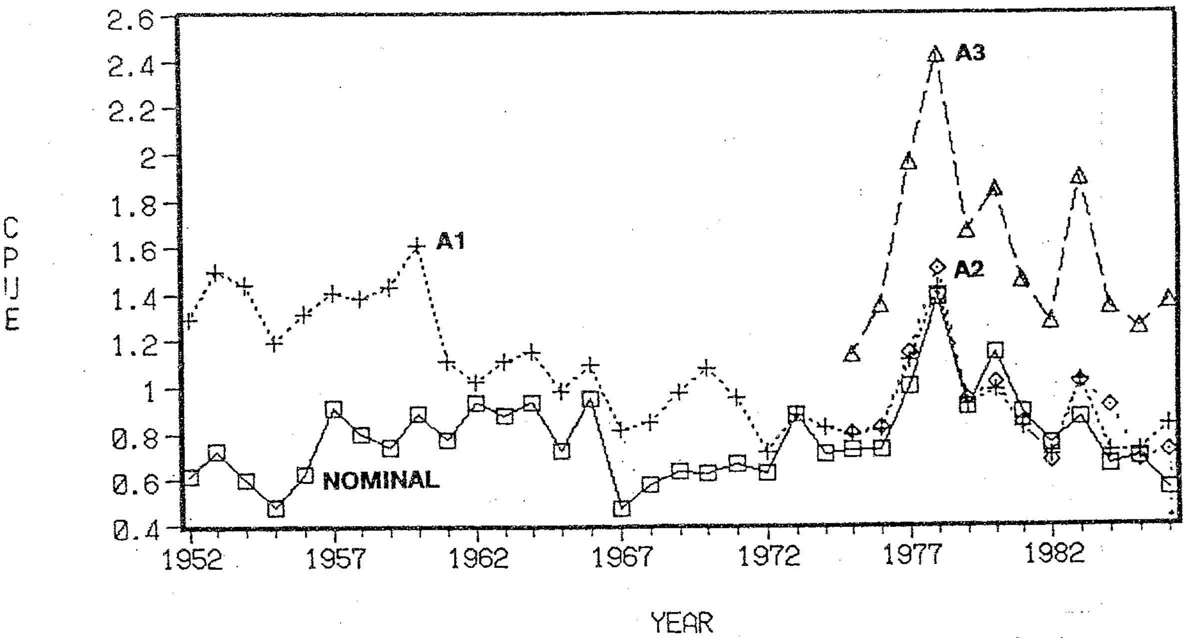

Figure 12. Comparison of four standardized catch rates of yellowfin tuna computed from Japanese longline data. "Nominal" is with no adjustments to the data. A1 is standardization with the "Honma" method. A2 is standardization for deep and regular longlining and with the Honma method. A3 is standardization for deep and regular longlining and with the general linear model technique. (Figure from Suzuki et al. (1989))

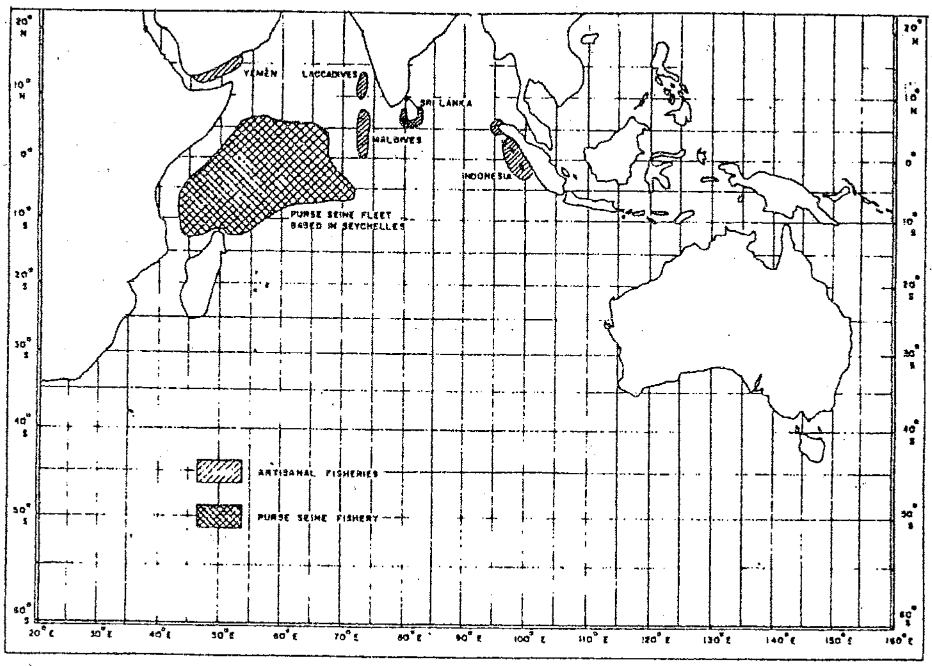

Figure 13. Location of the major fishing areas for yellowfin tuna by artisanal and purse seine gears in the Indian Ocean. (Figure from IPTP (1985))

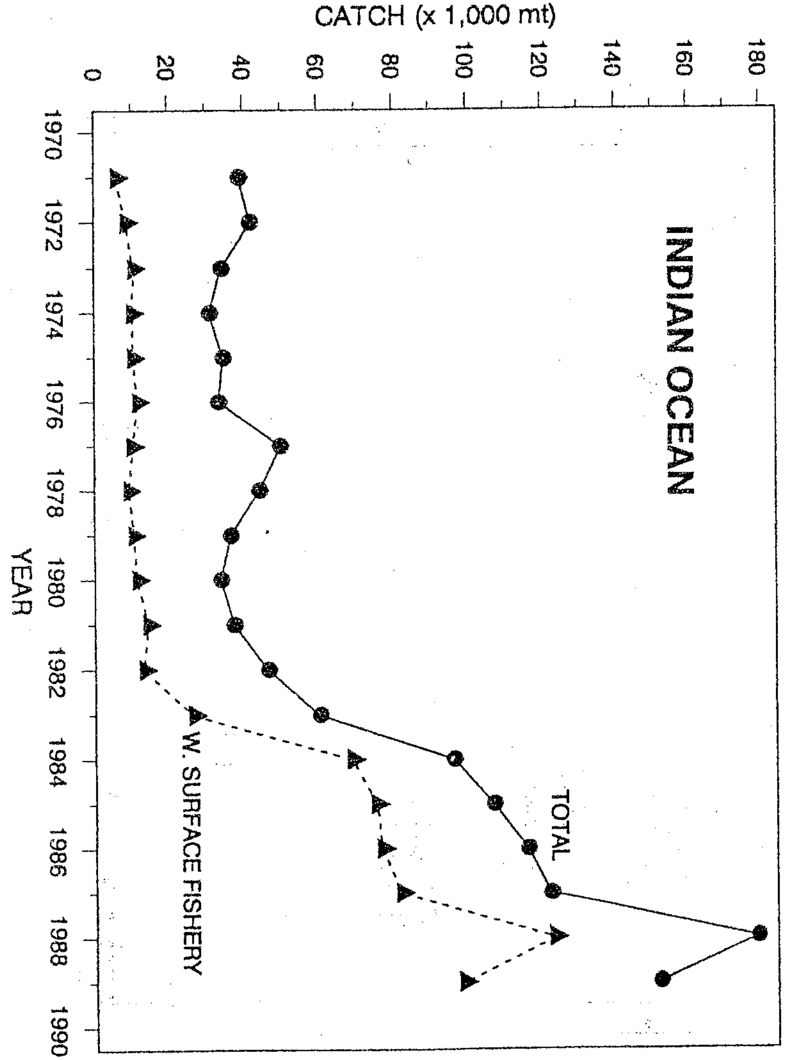

Figure 14. Catch of yellowfin tuna from the Indian Ocean. The largest share is produced by the surface fishery in the western region, east of 95° E long.

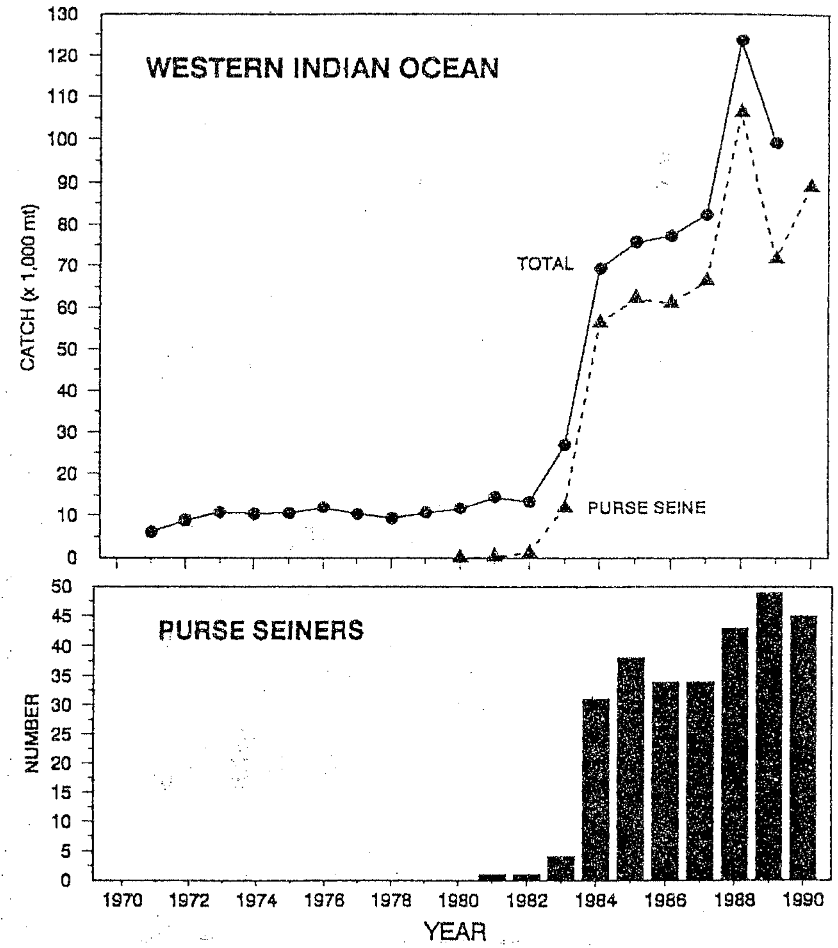

Figure 15. Catch of yellowfin and number of purse seiners participating in the WIO fishery. (Data from IPTP (1990), Lablache (1990), Seychelles Fishing Authority (1990))

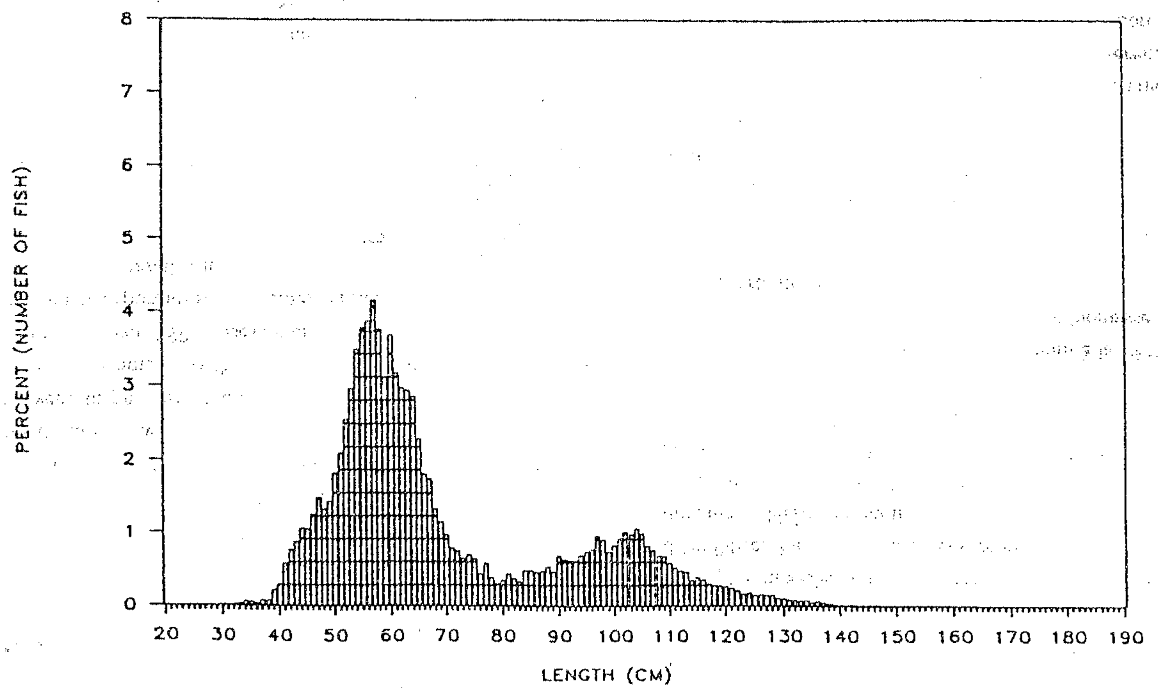

Figure 16. Size composition of yellowfin tuna caught by the purse seine fishery in the WIO.