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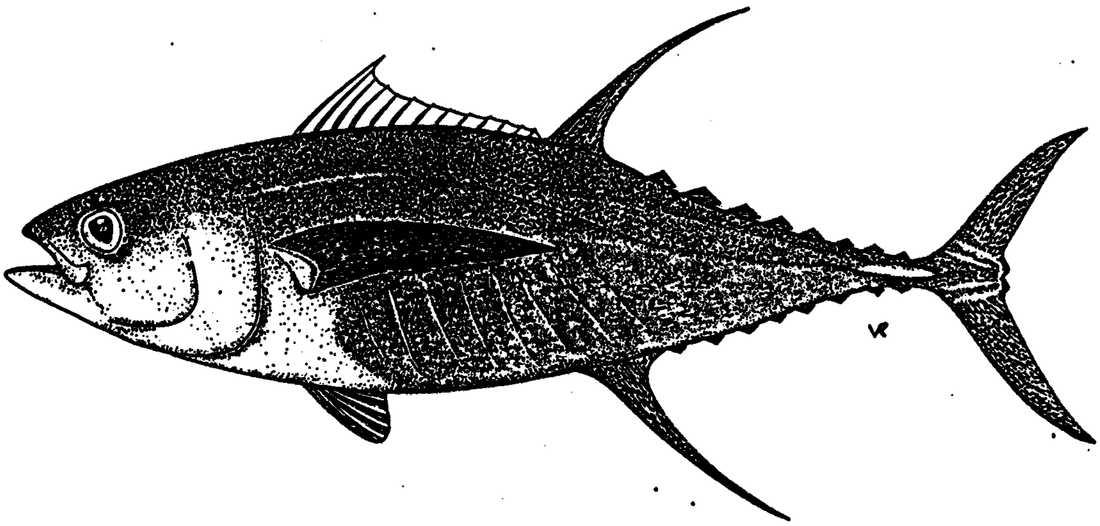
STOCK STATUS OF YELLOWFIN IN THE WESTERN TROPICAL PACIFIC



Tuna and Billfish Assessment Programme
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1. INTRODUCTION

Yellowfin tuna has a long history of exploitation in the Western Tropical Pacific (WTP), first as a by-catch species in the Japanese pole-and-line fishery, and since the early 1950s, as a targeted species in the longline fishery. In the late 1970s, Japanese purse seiners began to move into the area, followed by US, Korean and Taiwanese seiners. Recently, purse seining has also been carried out by locally-based vessels in the Solomon Islands. In addition to the activities of distant-water fishing nations (DWFNs) and locally-based fleets, large catches of yellowfin and other tuna and tuna-like species have occurred for many years in the waters of Philippines and Indonesia, both by industrial fleets and artisanal fishermen. While these areas are not normally thought of as part of the Pacific Islands region, it is almost certain that the tuna stocks of the WTP, particularly of the mobile species such as yellowfin, bigeye and skipjack, are continuous over the area from the Philippines and eastern Indonesia through at least Micronesia and Melanesia. This large diversity of fisheries and their distribution in numerous EEZ and high seas areas has made the task of compiling reliable catch statistics particularly difficult and would make the implementation of management measures, should they prove to be necessary, an even more challenging task.

The continuous expansion of the purse seine fishery since its inception in the WTP has raised some concerns over its impact on the yellowfin resource and the valuable longline fishery that it supports. Because of the lack of necessary fishery data and biological information on yellowfin in the WTP, it has not been possible to carry out a detailed stock assessment that would indicate appropriate levels of catch or effort for the major gear types in operation. This matter is receiving the attention of the Tuna and Billfish Assessment Programme (TBAP), firstly in negotiations with DWFNs and Southeast Asian countries regarding provision of the required fishery data to the Standing Committee on Tuna and Billfish, and secondly in the elucidation of the biological characteristics of yellowfin through the Regional Tuna Tagging Project (RTTP). In view of the increasing concerns among member governments regarding recent developments in the purse seine fishery, the TBAP has attempted, through this paper, to provide the best currently available information regarding the total catch of yellowfin in the WTP, the status of the stock, interaction between the surface and longline fisheries and the implications for management. This information is necessarily preliminary because of the existing gaps in fisheries data coverage, and because much new biological data will become available over the next two to four years through the RTTP.

2. ESTIMATES OF TOTAL CATCH

Yellowfin are caught in the WTP by purse seine, pole-and-line and longline fleets of DWFN and Pacific Island countries, by ringnet, purse seine and handline in the Philippines, and by pole-and-line in eastern Indonesia. Estimates of yellowfin catch by these fisheries are shown in Table 1 and the various sources of statistics noted.

The pole-and-line fisheries in the Pacific Islands region are directed primarily at skipjack and catch relatively little yellowfin, although good catches of small fish (less than 60 cm) have been recorded at various times, particularly in the Papua New Guinea fishery in the late 1970s. The yellowfin pole-and-line catch has varied in the range 4,000-13,000 mt over the past ten years.

The catch of yellowfin[1] by the major purse seine fleets expanded rapidly during the early 1980s to reach 80,000 mt by 1983. After a period of stability the catch again increased in the late 1980s, with a record 145,000 mt estimated for 1987 when the *El Nino* event of 1986-87 is thought to have increased the vulnerability of yellowfin to purse seining in the WTP. In a similar fashion, unfavourable environmental conditions in 1988 (the *La Nina* or anti-*El Nino*) are thought to have been responsible for the lower purse seine catch in that year. Data for 1989 are incomplete at this stage, but suggest an increase in catch from the 1988 level. There are few historical data available on the size composition of yellowfin caught by purse seiners. Recent sampling of US purse seiners suggests that most fish are less than 80 cm, although sets on free-swimming schools often yield catches of large fish up to 150 cm.

The catch of yellowfin by longliners increased during the 1970s and declined during the 1980s, although some increase was seen in 1987-1988. Catch per unit effort (CPUE) data for the Japanese fleet indicate that the catch in 1989 was similar to or slightly less than that in 1988. Longline-caught yellowfin are generally greater than 80 cm, with most fish 90-140 cm (Suzuki 1988).

Large catches of yellowfin in Philippines and Indonesia were first recorded in the mid-1970s, although the magnitude of catches prior to this time is not clear from the available statistics. The combined catch of the two countries was around 50,000-75,000 mt during the latter half of the 1970s, and increased in the 1980s. The combined catch in recent years has exceeded 90,000 mt. Small yellowfin, many as small as 20 cm, dominate the catch in both countries, with both the purse seine and ringnet fisheries in Philippines and the pole-and-line fishery in Indonesia being based on FADs moored in coastal waters. Handlining of large (100-150 cm) yellowfin also takes place in Philippines.

3. TRENDS IN ABUNDANCE INFERRED FROM CPUE

Some indication of the status of the yellowfin stock can be obtained by examining the time series of CPUE from the various fisheries. Figure 1 gives the time series of CPUE for Japanese purse seiners fishing in the WTP and an abundance index that is corrected for changes in the spatial and temporal distribution of the fishery. In principal, the latter should provide a more

[1] Catch statistics for purse seine and pole-and-line caught yellowfin are likely to contain a small and possibly variable proportion of bigeye tuna, as these species are neither separated on log sheet records nor in landing statistics. In the first twelve months after implementation of the Multilateral Treaty on Fisheries, port sampling of US purse seiners in Pago Pago indicated that 28% of the catch in number recorded as yellowfin was in fact bigeye. This percentage has not been calculated by weight, but would be substantially less than 28% because of the small size of the bigeye sampled relative to the yellowfin.

accurate indication of apparent abundance than raw CPUE. In fact, the time series are very similar and suggest stable or increasing apparent abundance up to 1987 followed by a sharp decrease in 1988. Recent data show that CPUE recovered in 1989. It should be emphasised that these time series are indicators of *apparent* abundance, i.e. the abundance of that portion of the stock that was available to purse seining in the area of operation of the fishery. In particular, no allowance has been made here for the effect of variations in environmental factors that are known to affect the success of purse seine fishing, although such a study is currently in progress. Preliminary results of this study suggest that the high apparent abundance in 1986 and 1987 was at least partly due to the *El Nino* event at that time, which probably increased the vulnerability of yellowfin to purse seining in the WTP because of the reduced depth of the mixed layer[2]. Similarly, it is likely that the much lower apparent abundance in 1988 was due to the *La Nina* (anti-*El Nino*) event in that year, which, on average, resulted in a deeper mixed layer in the WTP in 1988.

Technological advances in purse seining that might result in an increase in CPUE (and hence apparent abundance) over time have not been specifically accounted for in Figure 1. In particular, the increasing proficiency in the capture of free-swimming schools (as opposed to schools aggregated under logs, FADs or other attractors) could have been partly responsible for the increasing trend in CPUE to 1987. However, the effect of technological advance has probably been minimised to some extent in Figure 1 by only considering data from the Japanese fleet, which has operated predominantly 500 GRT purse seiners since the beginning of the fishery. Analyses of the data that specifically account for technological advance are in progress.

The time series of yellowfin CPUE for the Japanese longline fleet in the WTP is shown in Figure 2. Only Japanese data have been used because of the long time series available and the relatively good coverage of the Japanese fleet in the WTP on the Regional Tuna Fisheries Database. Also, changes in CPUE due to changes in fleet composition are avoided. The data show that CPUE has been variable, but distinctive trends are visible in the time series. From 1962 to 1975 there was a clear downwards trend in CPUE. Between 1975 and 1978 there was almost a doubling of CPUE, and these higher levels persisted until about 1983 after which CPUE decreased to about the level it had been in the mid-1970s. CPUE has been essentially constant since 1984. A similar pattern was observed by Suzuki *et al.* (1989) for CPUE corrected for geographical and temporal changes in the fishery.

The interpretation of these trends is complicated by the possible influences of environmental variation. To address one aspect of this, a study is planned to investigate the correlation between catch rates of various species and the water temperature in which hooks fished. The change in setting technique from shallow to deep sets (SPC 1988) could also have affected longline CPUE. Up until 1983, most Japanese longlining in the WTP was a mixture of deep

2 The mixed layer is the upper layer of the ocean that is of fairly constant temperature due to the mixing effects of wave and wind action. Below the mixed layer is the thermocline, a zone in which temperature falls rapidly with increasing depth. When the thermocline is closer to the surface, the purse seine net hangs into the colder water, which effectively cuts off the escape route for small yellowfin, as they are normally restricted for physiological reasons to the warmer waters of the mixed layer.

and shallow sets, with the deep sets more likely to catch bigeye and the shallow sets more likely to catch yellowfin (although both set types do catch both species). From 1984 onwards, the proportion of shallow sets was much reduced, which may have had a negative impact on yellowfin CPUE.

In spite of these difficulties, some interpretation of the trends is possible, particularly in relation to the estimates of total catch by gear type given in Table 1. During the period 1962-1975, virtually no purse seining occurred in the WTP, while the catches by pole-and-line vessels were small. Similarly, available statistics suggest that yellowfin catches in Philippines and Indonesia prior to 1974 were relatively small. This then indicates that the clear downwards trend in Japanese longline CPUE during the 1962-1975 period was due to a decline in yellowfin abundance resulting from longline fishing alone. This is a common feature of tuna longline fisheries that results from "fishing down" of the adult portion of the virgin stock.

The sudden increase in CPUE in 1976-1978 is difficult to explain. A succession of strong year classes could have produced this effect, and its persistence over several years provides some support for this explanation. It is worth noting that such a phenomenon has been well documented in the Eastern Tropical Pacific yellowfin purse seine fishery (IATTC 1988).

The fall in catch rates between 1978 and 1984 probably reflects a decline in the abundance of yellowfin available to the longline fishery. It is not possible to say conclusively at this time what was responsible for this decline, although there are several possibilities. First, the increase in the catch of small fish by the purse seine fishery in the period 1980-1983 could have reduced recruitment into the longline fishery, although the 1-3 year age difference between yellowfin vulnerable to the purse seine and longline fisheries (Suzuki 1988) might have been more reasonably expected to produce a decline in longline CPUE in the late rather than early 1980s. Second, the expanding catches of small yellowfin in Philippines and Indonesia in the late 1970s could have produced the decline in longline CPUE, however it is probable that their effect would be blurred by the greater age difference between the fish and the geographical separation of the fisheries. Third, the longline fishery itself may have been primarily responsible for the reduction in yellowfin abundance simply by fishing down a stock that had been previously boosted by a succession of strong year classes. More information on yellowfin movement, natural mortality and growth in the WTP is required before good population dynamics models can be developed to distinguish between these different possibilities.

4. CURRENT STATUS OF THE STOCK

The most recent appraisal of yellowfin stock status in the WTP was carried out by Suzuki *et al.* (1989), who concluded on the basis of fisheries data up to 1986 that a total catch of about 210,000 mt was sustainable. This conclusion was based on the fact that recent longline CPUE was similar to the level of the mid-1970s, indicating a similar adult abundance. Also, longline CPUE since 1984 was constant while total catches in excess of 200,000 mt were taken.

Furthermore, analyses of yellowfin age composition in the Japanese purse seine and longline fisheries and in the Philippines payao fishery showed no consistent trends but much year-to-year variation. In particular, average size of yellowfin captured by Japanese longliners has remained reasonably constant in recent years. If recruitment to the longline fishery had been affected by prior exploitation of younger fish by the surface fisheries, an increase in the average size of longline-caught yellowfin would be expected. Similarly, average size of yellowfin caught by US purse seiners is highly variable but shows no consistent trend (Figure 3).

Based on the available data, both prior to and since 1986, this review supports the conclusion reached by Suzuki *et al.* (1989). It appears that longline CPUE has remained constant up to 1989, and that the fall in purse seine CPUE in 1988 was probably environmentally induced. There is no evidence that yellowfin is currently over-exploited in the WTP.

As a note of caution, however, it should be recognised that the large total catch in 1987, due primarily to a large increase in the purse seine catch, may not be sustainable and may have a negative effect on longline CPUE during 1990-1991. The future response of longline CPUE to the 1987 catch will provide valuable information on resource productivity and possible long-term yields.

5. SURFACE FISHERY - LONGLINE FISHERY INTERACTION

Some discussion has already taken place regarding the possible large-scale effects of surface fisheries on longline CPUE. Even where no such large-scale effects are apparent, there still remains the possibility that more local, small-scale interactions could exist that might be of interest to member governments. The potential for small-scale interactions, say at the 5° square and month level, depends basically on the rate of mixing both horizontally and vertically in the area of the fisheries. If horizontal mixing is rapid, stocks in small areas will be quickly replenished after heavy exploitation by fish from surrounding areas, which would reduce the potential for small-scale interaction. On the other hand, if vertical mixing is rapid, large removals by purse seiners from the surface population will quickly be passed on to the sub-surface population available to longlining.

There are few data on horizontal movement rates that would enable predictions of small-scale interaction to be made. However, empirical analyses by Polacheck (1988) were not able to detect any small-scale interaction suggesting that either horizontal mixing is rapid or vertical mixing is slow. In respect of the latter, various sonic tracking studies have demonstrated the ability of yellowfin to undertake rapid and substantial vertical movements. However, in general, vertical stratification of yellowfin by size and spawning behaviour may be the mechanisms that determine the extent of vertical mixing. The fact that smaller yellowfin tend to be found in surface schools, and hence vulnerable to purse seining, and that larger yellowfin tend to be located deeper in the water, suggests that mixing is gradual and related to growth. However, adult yellowfin in free-swimming schools are often caught by purse seiners, and there is evidence that vertical exchange of adult fish is influenced by spawning activity. Studies have suggested that spawning activity of yellowfin in the WTP increases during the third and fourth quarters (Suzuki 1988), and this corresponds to a period of increase in the apparent abundance of free-swimming schools (as indicated by CPUE) (SPC 1988). Also, the higher incidence of large yellowfin that are in spawning condition in purse seine catches as opposed to longline catches indicates that surface schooling may be associated with spawning (Hisada 1973). The most direct effect of purse seining on the longline fishery would therefore result from fishing free schools of adult yellowfin, however because of the possible seasonal nature of vertical exchange and/or rapid horizontal mixing, localised effects on longline CPUE may not occur.

A detailed assessment of both large- and small-scale interaction between purse seine and longline gears will be possible at the completion of the RTTP.

6. IMPLICATIONS FOR MANAGEMENT

The major conclusion reached in this review of yellowfin stock status in the WTP is that the fishery should be regarded as fully exploited at the typical level of catch taken since 1983, i.e. around 200,000-220,000 mt per year. Without critical biological information in the process of being collected by the RTTP, it cannot be concluded with any certainty whether or not larger catches can be sustained. However, with the prospect of further substantial increases in purse seine effort over the coming years, and the demonstrated capacity of purse seiners to take advantage of favourable environmental conditions to achieve substantially larger catches (as occurred in 1987), management of the fishery for biological reasons may become necessary.

Presumably, the objectives of a management regime would be to ensure the biological viability of the yellowfin population and to maintain an acceptable mix of gear types that take account of a variety of biological, economic and social issues. With this in mind, there are two characteristics of the fishery that have major implications for management of yellowfin in the WTP.

First, the fishery covers a diverse range of gear types and fishing nations. An effective management regime must include all significant fisheries exploiting yellowfin in the WTP. In particular, Philippines and Indonesia need to be included in any such arrangement, because of the large catch of their combined fisheries and the small size of fish that are targeted. Management of the DWFN purse seine fishery alone, for example, would not necessarily satisfy the biological objectives of management because it comprises only part of the fishery-induced effect on the reproductive potential of the population.

Second, yellowfin is not the only target species in any of the major tuna fisheries of the WTP. In the DWFN purse seine and Philippine/Indonesian fisheries, skipjack is the principal target species. In the longline fishery, bigeye are often targeted because of their higher price on the Japanese sashimi market. Any regulation of yellowfin catch may therefore have a negative impact on the catch of other species. In the case of skipjack, which is almost certainly under-exploited and capable of withstanding increased catches, the resulting loss of existing or potential revenue for some member countries may be considerable. This requires that any management arrangement take account of the catches of other species when determining the appropriate combination of gear types.

7. SUMMARY

(i) Yellowfin are caught in the WTP by purse seine, pole-and-line and longline fleets of DWFN and Pacific Island countries, by ringnet, purse seine and handline in the Philippines, and by pole-and-line in eastern Indonesia. In recent years, the total catch has been about 200,000-220,000 mt, although the catch in 1987 was about 280,000 mt due to favourable conditions for purse seine fishing.

(ii) The CPUE trend in the purse seine fishery has generally been increasing, except for a sharp drop in 1988 thought to be due to unfavourable environmental conditions. CPUE recovered to around previous levels in 1989. In the longline fishery, CPUE decreased steadily from 1962 to 1975, probably because of declining adult yellowfin abundance resulting from the activities of the longline fishery itself. Longline CPUE doubled between 1975 and 1978, possibly as a result of a succession of strong year classes, then declined to its mid-1970s level by 1984. The reasons for this last decline are not clear, and could be due to large surface catches in the Philippine/Indonesian fishery and the DWFN purse seine fishery and/or the activities of the longline fishery itself. Longline CPUE has been constant since 1984.

(iii) This review supports the conclusion of Suzuki *et al.* (1989) that the fishery is likely to be fully exploited and total catches of the order of 200,000 mt should be sustainable. However, more fisheries data and biological information are required to ascertain long-term potential yields more accurately and to determine alternative, biologically acceptable combinations of catch by the different gear types.

(iv) The empirical evidence for a large-scale effect of the surface fisheries on the longline fishery is presently inconclusive. Similarly, small-scale effects have not been detected, possibly indicating rapid horizontal mixing at this scale and/or slow exchange between surface and sub-surface stocks. More information on both large-scale and small-scale interaction will be provided by the Regional Tuna Tagging Project.

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TABLE 1 Estimates of total yellowfin tuna catches (mt x 10^3) for the Western Tropical Pacific.

Year	Purse seine	Pole-and-line	Longline	Indonesia/ Philippines	Total
1971	0	0	22	0	22
1972	0	0	24	0	24
1973	0	1	29	15	45
1974	0	1	30	52	83
1975	2	2	34	64	102
1976	0	9	41	52	102
1977	7	8	50	74	139
1978	7	7	66	58	138
1979	11	7	52	64	134
1980	10	13	66	66	155
1981	35	11	53	78	177
1982	44	8	42	76	170
1983	81	8	42	82	213
1984	80	9	31	85	205
1985	70	12	34	94	210
1986	91	5	29	94	219
1987	145	5	39	91	280
1988	75	4	49	91	219

Notes:

1. Purse seine consists of catches by vessels of US, Japan, Taiwan, Korea and Solomon Islands. Catches were estimated by TBAP staff using the Regional Tuna Fisheries Database, FAO Yearbook statistics and Suzuki *et al.* (1989).

2. Pole-and-line catches for 1971-1986 were taken from Suzuki *et al.* (1989) and include catches by Japan, Fiji, Kiribati, Solomon Islands and Papua New Guinea. Catches for 1987 and 1988 were taken from SPC (1989).

3. Longline consists of catches by vessels of Japan, Taiwan and Korea. Catches for 1971-1986 are taken from Suzuki *et al.* (1989). Catches for 1987-1988 are taken from SPC (1989).

4. Indonesia/Philippines consists of catches by those countries, predominantly by locally-based fleets. The main fishing methods are ringnet, purse seine and handline (Philippines) and pole-and-line (Indonesia). Estimates were taken from Suzuki *et al.* (1989). The 1988 catch is assumed to be the same as the 1987 catch.

FIGURE 1 Trend in Western Pacific yellowfin tuna abundance in the area 10°N-10°S, 130°E-180° indicated by raw Japanese purse seine CPUE and an abundance index that accounts for changes in the temporal and spatial distribution of fishing. Source: Regional Tuna Fisheries Database.

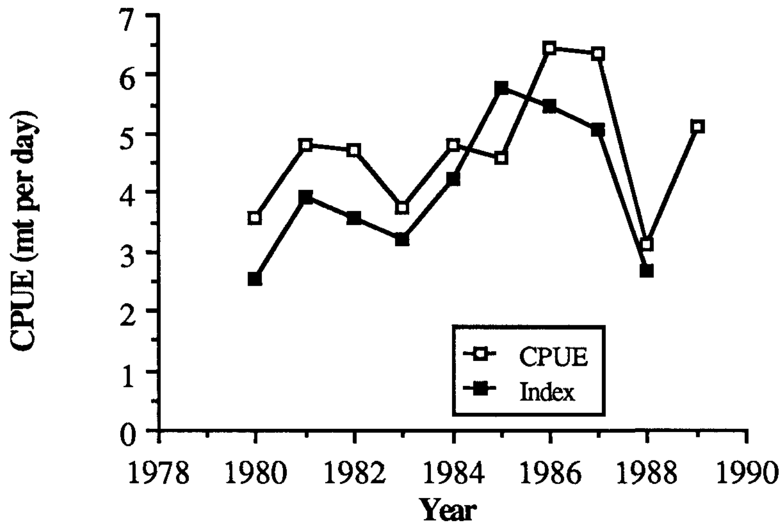

FIGURE 2 Japanese longline CPUE from the area 10°N-10°S, 130°E-180°. Source: 1962-1980 Japan Fishery Agency annual statistics; 1981-1989 Regional Tuna Fisheries Database.

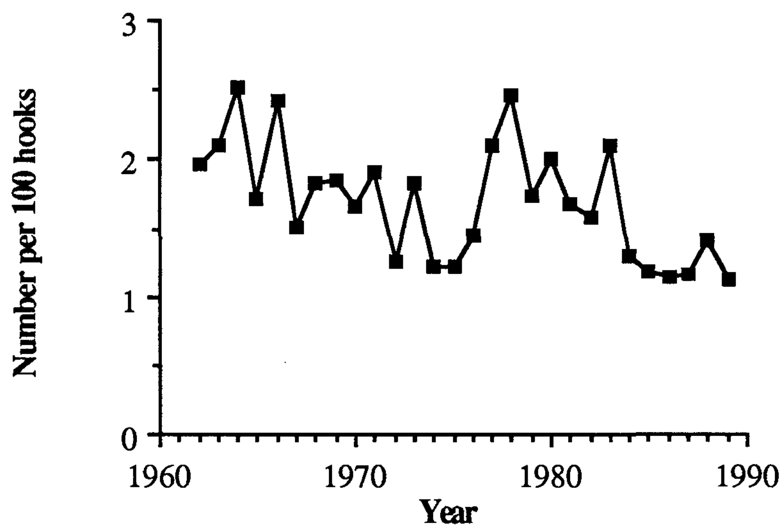

FIGURE 3 **Average size of yellowfin caught by US purse seiners in the WTP and sampled by the National Marine Fisheries Service in Pago Pago. "North" refers to north of the equator and "South" to south of the equator. Source: 1981-1986 Honda *et al.* (1988); 1988 NMFS Tuna Treaty Monitoring Program port sampling data.**