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Biological Perspectives on Future Development of Industrial Tuna Fishing

by
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I. Introduction

The tuna fisheries discussed in this book depend principally on stocks of just two principal species of fish: skipjack (*Katsuwonus pelamis*) and yellowfin tuna (*Thunnus albacares*). Table 1 summarizes tuna fishing data supplied to the South Pacific Commission (SPC) between 1981 and 1985. The importance of these two species is obvious. Yellowfin comprise over 70% of the longline catch and skipjack and yellowfin combined comprise over 95% of the total surface (purse seine and pole-and-line) catch. These two species are caught by the fleets of several nations using three principal gear types: longline, pole-and-line, and purse seine. Yellowfin tuna are caught by all three gear types but predominantly by longline and more recently by purse seine as well. Skipjack are caught by both pole-and-line and purse seine.

The purpose of this chapter is to review available information on the stocks of these two species and on the three fisheries that exploit them in the waters of the Pacific Island states. An attempt will be made to draw some conclusions about their future potential. In the process, certain areas of uncertainty will be exposed and the implications of these uncertainties explored.

This contribution is a synthesis of work by several members of the SPC Tuna and Billfish Assessment Programme. In particular, I would like to thank Richard Farman, Ray Hilborn, James Ianelli and Tom Polacheck for their invaluable input.

II. History and Current Status

Although the various tuna fisheries are discussed elsewhere in this volume by fishing method, some points will be mentioned briefly here in order to set the historical context for interpreting current conditions.

Fishing for tuna in the tropical Pacific is probably as old as human settlement in the region and artisanal tuna fishermen are found today in almost every island community (Gillett 1985a, 1985b). In the first decades of the twentieth century, Japanese fishermen began to extend their activities southward from the home islands, and these early efforts could be considered the beginning of the distant-water fishing era. The most substantial expansion of distant-water fishing began in the late 1940s as Japanese fishing fleets resumed operations after the war. This phase was aided by technological improvements in both bait and catch handling procedures which enabled longer trips and increased carrying capacity (Matsuda and Ouchi 1984).

Expansion of tuna fisheries became explosive in the early 1980s with the introduction of purse seining techniques to the region by Japanese fishermen. Although this method is widely used in other areas of the world, its introduction into the western Pacific depended on modifications to nets and net handling equipment as well as changes in fishing habits. Poor fishing conditions in the eastern Pacific during the 1982-83 El Nino stimulated further expansion as many purse seine vessels moved west.

Table 1: Annual summaries of catch by gear and by species, for the years 1981-1985 as reported to the South Pacific Commission

	1981	1982	1983	1984	1985
Purse seine	(mt)	(mt)	(mt)	(mt)	(mt)
Skipjack	20954	53487	77117	213264	158371
Yellowfin	9522	21706	20386	87638	53432
Other	292	867	860	2482	1455
Total	30768	76060	98363	303384	213258
Pole-and-line	(mt)	(mt)	(mt)	(mt)	(mt)
Skipjack	38385	21075	45775	33014	20612
Yellowfin	303	1160	836	736	981
Other	406	377	311	70	194
Total	39094	22612	46922	33820	21787
Longline	(nos.)	(nos.)	(nos.)	(nos.)	(nos.)
Albacore	123125	178362	125223	263590	196974
Bigeye	211250	272098	188019	322368	420417
Yellowfin	1097512	994871	939996	842178	929241
Billfish	51600	52890	40659	75753	71313
Other	50805	30055	18273	31785	34500
Total	1534292	1528276	1312170	1535674	1652445

Skipjack and yellowfin catch trends in the waters of the Pacific Island states since 1980 are shown in Figure 1 for the three principal gear types. Purse seine catch grew from negligible in 1979 to surpass catches by the other gear types in 1982. In contrast, pole-and-line and longline catches declined slightly or were relatively stable during the same period.

The geographic distribution of skipjack and yellowfin catch for the years 1983 and 1984, the years for which SPC data holdings are most complete, is shown in Figure 2 for each gear. Purse seine yields are greatest in the equatorial region of the western Pacific, ie. in the EEZs of Papua New Guinea, Palau and Federated States of Micronesia. In contrast, both pole-and-line and longline fisheries are more widely dispersed throughout the region. Yields from the longline fishery are greatest in the regions of north and south equatorial current and the equatorial counter current and are relatively uniformly distributed from west to east. Skipjack yields from the pole-and-line fishery are greatest in the region of equatorial counter current and are dispersed more toward the east.

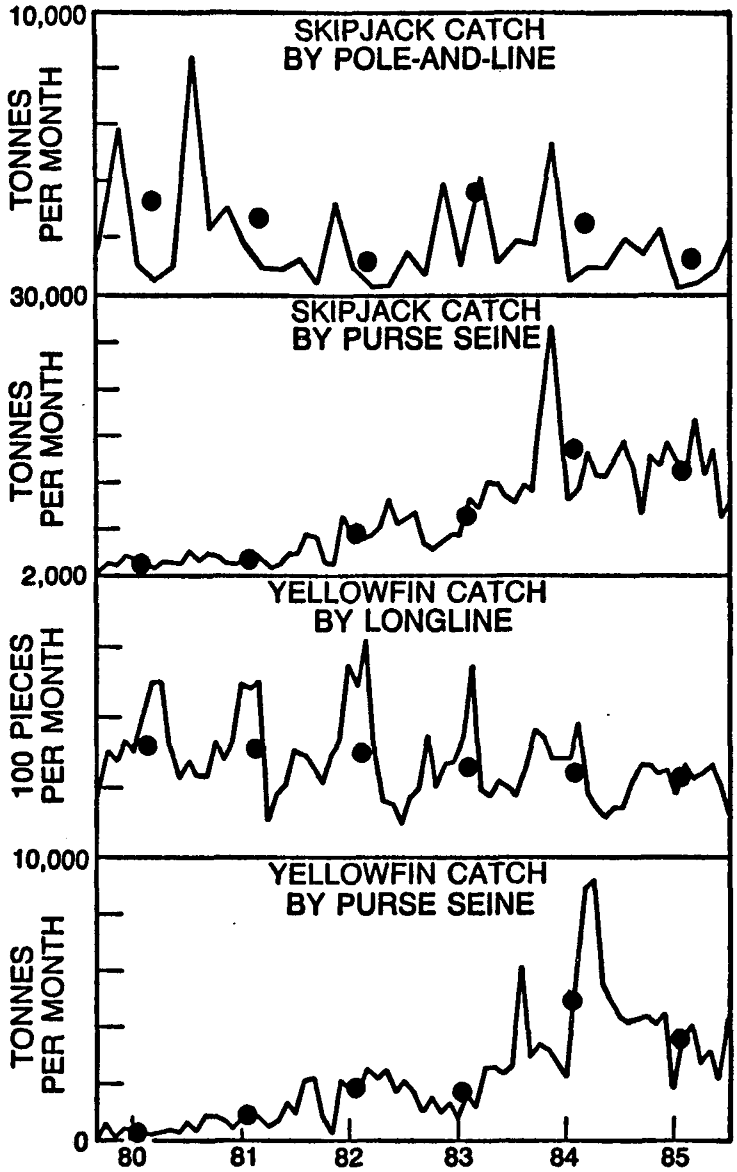

Figure 1. Catch trends by month for each gear type in the western Pacific since 1980. Circles indicate averages for the year.

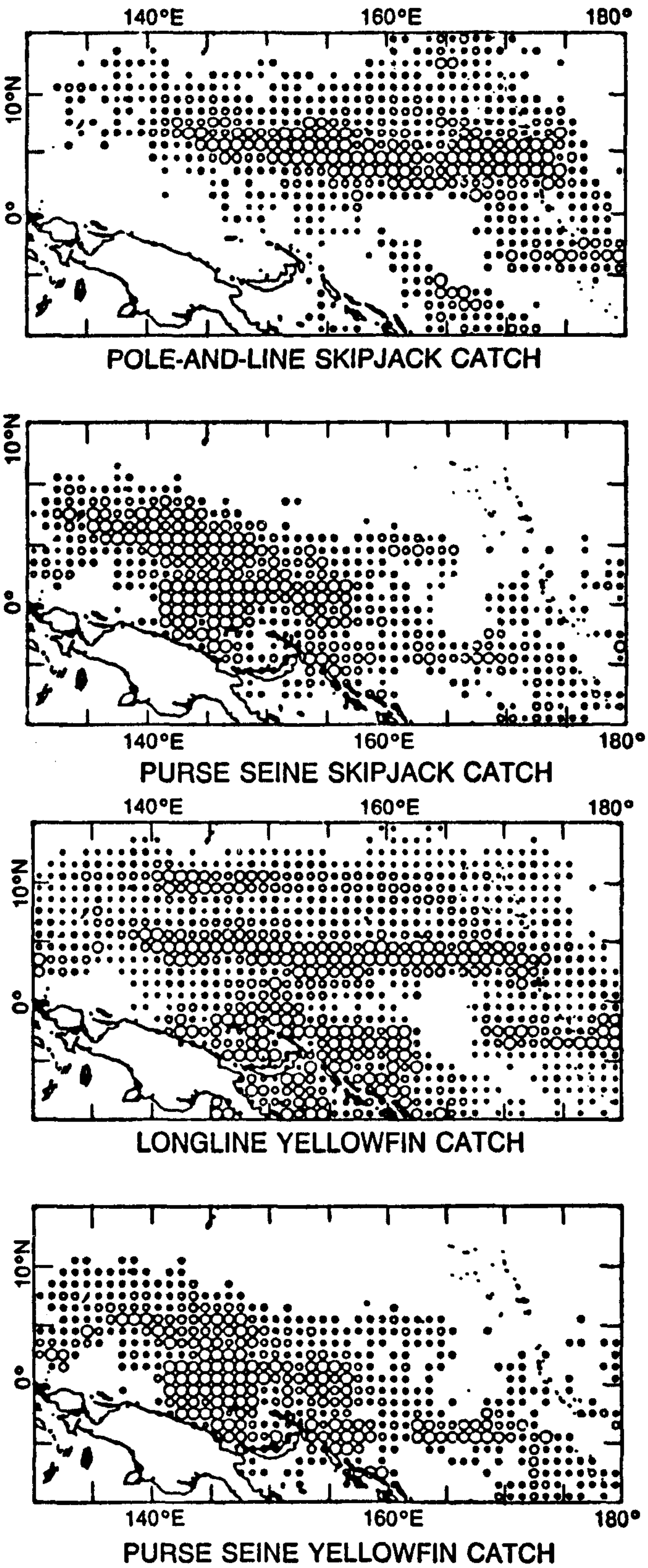

Figure 2. Geographic distribution of catch by gear for the period 1984-85. The size of the circle is proportional to total catch for the period.

Catch per unit of fishing effort is traditionally used as and indicator of stock size by fishery biologists. Figure 3 show the recent trends in both skipjack and yellowfin CPUE for the three fisheries. There are no sharp downward trends that would give an unambiguous indication of overfishing. The downward trend in the longline CPUE is the continuation of a long established decline that can be traced back to the 1960s.

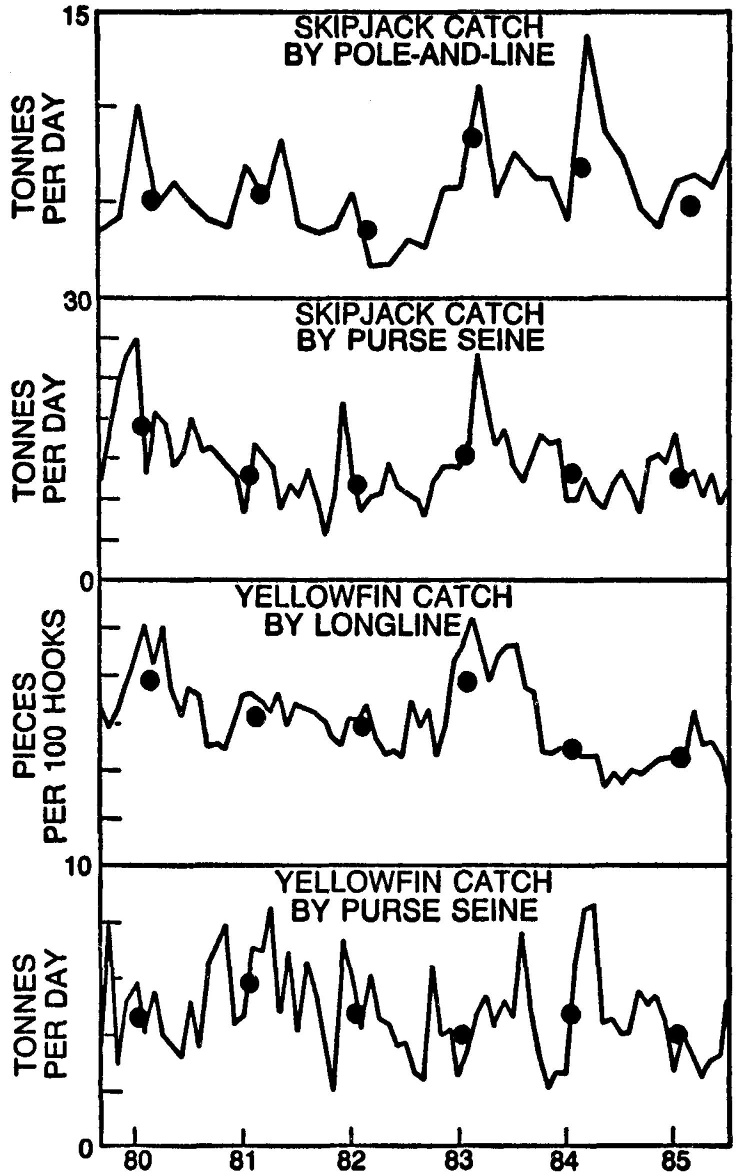

Figure 3. Trends in catch per unit of effort by month for each gear type in the western Pacific since 1980. Circles indicate averages for the year.

A second major change accompanied the expansion of the purse seine fishery - the dependence of flotsam. Tuna schools are often found in association with something else. In the eastern Pacific, there is a strong association between tuna schools and pods of certain species of dolphins. This association is exploited by fishermen who hunt for aggregations of dolphins and surround them with their nets in order to catch the associated tuna school. In the western Pacific, the association between dolphins and tuna has not been demonstrated. Instead, tuna schools are found in association with floating logs and other debris. Fishermen hunt for logs rather than for dolphins and often make a single set each day just before dawn.

Dependency on flotsam in the western Pacific is extreme. Few sets are made on freely swimming schools and the proportion of the total catch from freely swimming schools is therefore small (Figures 4). The dependency is so great that individual logs are marked with lights and radio beacons so that they can be found and vessels often make repeated sets on the same individual log. Some vessels have taken up the practice of launching artificial flotsam, or payaos, to compensate for the paucity of logs, also a common practice in the Atlantic Ocean (Bard *et al* 1985).

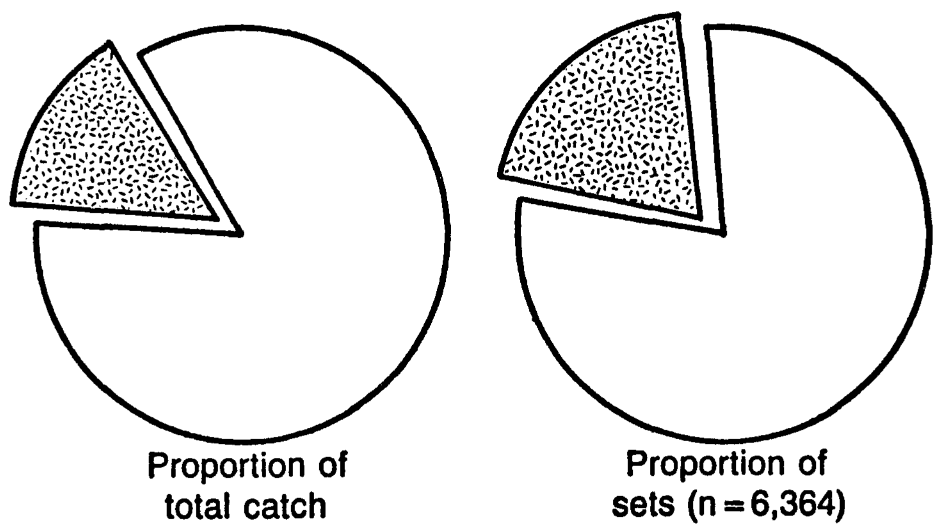

Figure 4. Proportion of catch and set by set type for Japanese purse seine vessels in 1985. Shaded segments indicate sets on freely swimming schools; unshaded segments indicate sets on schools associated with debris.

III. Issues and Uncertainties

A. Interaction between fisheries

'Fisheries interaction' is a convenient term used to refer to problems associated with multiple fisheries operating on different scales with different gear types and exploiting widely dispersed stocks and highly mobile fish. Some potential problems are impacts of purse seining on both longline and pole-and-line fisheries for yellowfin and skipjack, of harvests in one area on harvests in another, and of industrial fishing on artisanal fishing.

Prior to the 1980s, the major fleets operated in a way that minimized interactions between them. Pole-and-line fleets exploited surface dwelling skipjack schools. Longline fleets exploited deeper dwelling mature populations of yellowfin. Pole-and-line fleets typically operated in different areas than longline fleets. The introduction of large-scale purse seining removed these tidy separations. Catches by purse seiners typically contain a mixture of both skipjack and small yellowfin. There are important areas of overlap between the purse seine fishery and both longline and pole-and-line fisheries as shown in Figure 5.

Interaction between fisheries has many aspects and these have been discussed previously by Lenarz and Zweifel (1979), Sibert (1984) and Hilborn (1985b). Because of the large number of vessels, wide geographic area, and high valued product the longline fishery merits special attention. Thus interaction between purse seine and longline fisheries for yellowfin arguably has the greatest potential for adverse impact.

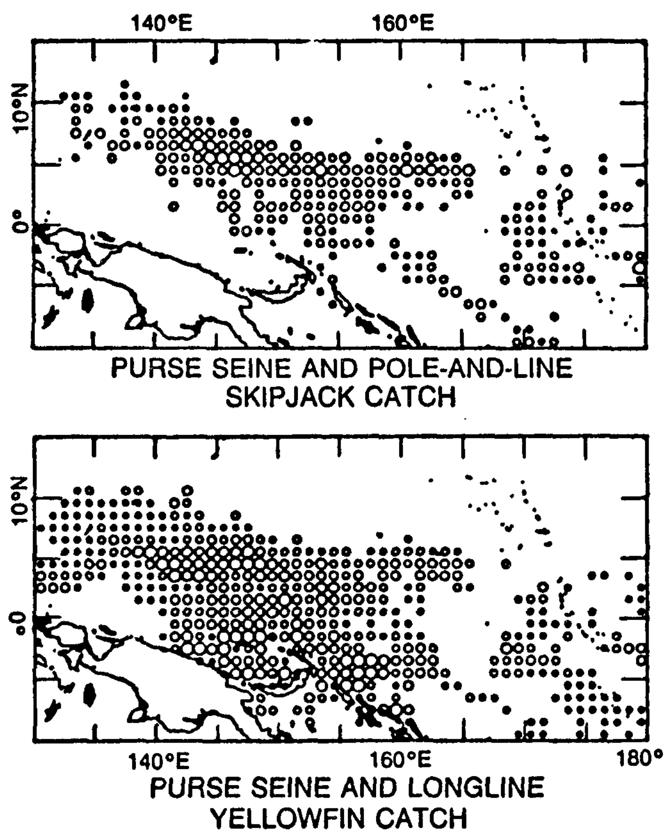

Figure 5. Geographic distribution of overlap in catch by gear for the period 1984-85. The size of the circle is proportional extent of catch by both fleets.

There are broad geographic areas of overlap between longline and purse seine fisheries (Figure 5). The average size of purse seine-caught yellowfin is much lower (approximately 5 kg) than that of longline-caught fish (approximately 25 kg). These size differences are naturally a reflection of a difference in age and the concern over interaction is based on the simple biological assumption that some proportion of young fish vulnerable to the purse seine fleet grow to an age vulnerable to longline fishing.

Knowledge of growth, mortality, intensity of fishing, vulnerability to fishing, recruitment of individuals to vulnerable stocks, and exchange between stocks vulnerable to the different gears would enable biologists to predict the extent of interaction. Unfortunately, none of this information is available for yellowfin stocks in the western tropical Pacific. Nevertheless, calculations can be made based on information from other parts of the world and making some simple assumptions about exchange and recruitment (Hilborn 1985a).

Figure 6 shows the results of such calculations based on the simplest possible assumptions about exchange and recruitment, namely that fish caught by the two fisheries are from a single uniformly mixed stock and that recruitment to the stock is not affected by fishing. Panel A of Figure 6 gives the calculated yield from the surface fishery in kilograms of fish per individual recruited to the stock as in relation to both surface and longline fishing intensities. Surface yield increases in proportion to surface fishing intensity and is only affected by the longline fishery at very high levels of surface fishing intensity.

Panel B of Figure 6 gives the yield from the longline fishery. Longline yield increases in proportion to longline fishing intensity but is strongly affected by surface fishing at relativel low levels. Panel C of Figure 6 gives the combined yield in kilograms from both fisheries and shows clearly that, in terms of kilograms of fish, a mixture of surface and longline fishing is justified.

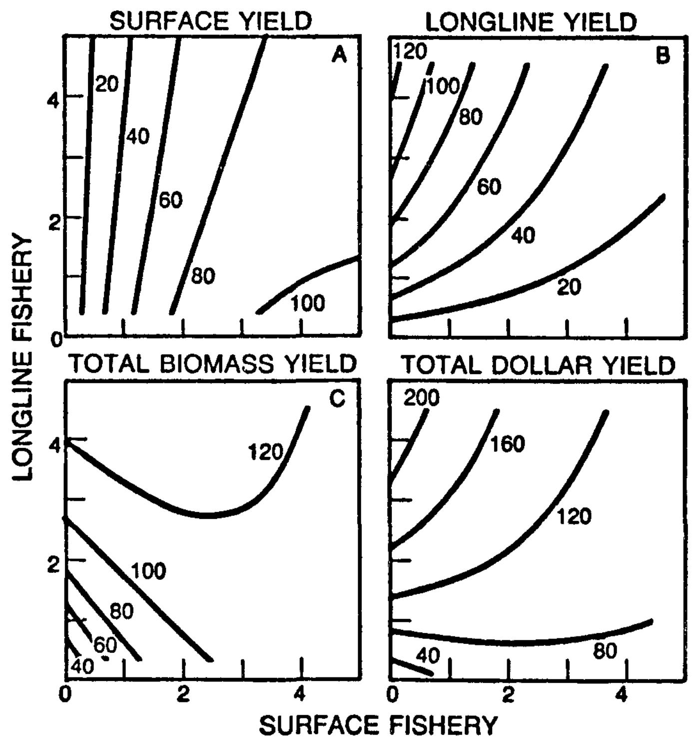

Figure 6. Theoretical yield of combined fisheries at different levels of fishing intensity.

Since the price per kilogram of longline-caught fish sashimi for the sashimi market is much greater than that of purse seine-caught fish for the cannery market, there are important economic consequences. Panel D of Figure 6 illustrates the total yield in dollars from the fishery. At very low levels of longline fishing, economic yield can be increased slightly by introducing surface fishing. However, at higher levels of longline fishing, the surface fishery actually decreases total economic yield.

The obvious question is where are current fisheries on these surfaces? The honest answer is that we don't know because there is insufficient data on yellowfin stocks from the western Pacific. The question deserves an answer, however, and on the basis of not being able to detect impacts as severe as predicted at high levels of fishing intensity, it can be concluded tentatively that current fisheries are operating at around two or less on these figures. In other words, current fisheries, both surface and longline, are harvesting a small proportion of the stocks. Purse seine activity is having little impact on the longline fishery, but increases in purse seine effort should be monitored carefully.

There are obvious uncertainties in these calculations and the appearance of the yield curves depends greatly on assumptions about stock mixing and recruitment. Nevertheless, the general conclusions are unchanged: although total biomass yield may be increased by combining both harvest methods, economic yield is greatest when surface fishing intensity is low. This conclusion reaches beyond simple biological assessments but clearly indicates the importance of the interplay between biological and economic processes. The implications for a manager depend on his point of view, ie. whether he owns purse seiners, owns longliners or is attempting to maximize benefits from his EEZ.

B. Effects of flotsam

This dependency on flotsam is a relatively recent development and tied conceptually to the use of moored fish aggregation devices (FADs). There has not been sufficient experience with this fishing practice on which to build an understanding of the implications for tuna stocks. What little information there is suggests caution. One of the advantages of flotsam and FADs from the standpoint of the fishermen is that they reduce search time and hence costs to such an extent that the economic structure of the fishery is altered. Flotsam and FADs make it possible to harvest fish at a much lower margin. It is therefore economically possible for fishermen to continue fishing overexploited stocks and cause further serious depletion (Floyd and Pauly 1984).

Another complication is the possibility of complete decoupling of the fisheries scientist's most useful index of stock size, catch per unit of effort, from the stock. In the case of a purse seine fishery operating on freely floating flotsam, such as logs, catch per set merely indicates the size of the aggregation around the log at the time the catch was made; catch per day fished merely indicates the abundance of logs (assuming a different log each day). Neither of these indicators carries any information on the larger stock of fish from which the flotsam attracts schools.

Some useful calculations are possible, however, if sufficiently detailed data are available. When vessels make repeated sets around the same object, it is possible to calculate the recruitment rate to the object and the size of the larger population from which recruitment occurs (Hallier 1985; Ianelli 1986). While neither of these calculations truly measure the stock as a whole, they provide useful tools for small-scale management. Also, the collection of size information from free-floating flotsam fisheries will provide an important warning if stocks begin to be overexploited.

C. High variability in yellowfin CPUE

Another way to look at the information in Figure 3 is to examine catch in relation to the amount of fishing effort applied as shown in Figure 7. In a fully exploited stock, these figures show a humped form with lower yields at higher efforts. The contrast between the plots for skipjack and yellowfin is striking. The month to month changes in skipjack catch are generally in proportion to month to month changes in effort (ie. along the diagonal). Month to month changes in yellowfin catch on the other hand are often not in proportion to effort (ie. vertical). The dramatic between-month drops in catch at constant effort would lead to the absurd conclusion that catches of a few thousand tonnes result in a halving of the population if one holds the assumption that CPUE is proportional to stock size. Nevertheless, annual catch is proportional to the average effort and there is no indication of low catch at higher efforts - indications that the stock is not seriously depleted.

The causes of this variability are unknown but there are several related possibilities. The dependence of flotsam may have decoupled CPUE from stock size as mentioned above. Under some conditions, seine vessels operated in a coordinated fashion so that small areas may be subjected to unusually intense fishing effort. As a consequence, the yellowfin stock in a small area may be depleted in a localized and transitory manner. Either of these possibilities could account for the variations seen in Figure 7, and it is possible that this variability is the first signal that yellowfin stocks are being affected by exploitation.

D. Data reporting

The fundamental data of fisheries science are times series of catch and effort. These fundamental data, often augmented by auxiliary information such as size distributions of fish caught, relationships between age and length, tag recapture results, and geographic distribution of catch, are used to calculate potential yields from fisheries. Ultimately most of the data are obtained from the fishery itself. How to accomplish the flow of data from fishermen to resource analysts and managers is an eternal problem in fisheries.

Data for analysis of western tropical Pacific tuna fisheries come from two basic sources. First is the historical fisheries data published by various distant-water fishing nations (Fisheries Agency of Japan 1962...1980a, 1962...1980b; Fisheries Research and Development Agency 1980...1985; Tuna Research Center 1973...1983). The practice of publishing fisheries data was discontinued in the late 1970s by some DWFNs. The second source of data is the information supplied by fishermen in compliance with licensing requirements of the Pacific Island states.

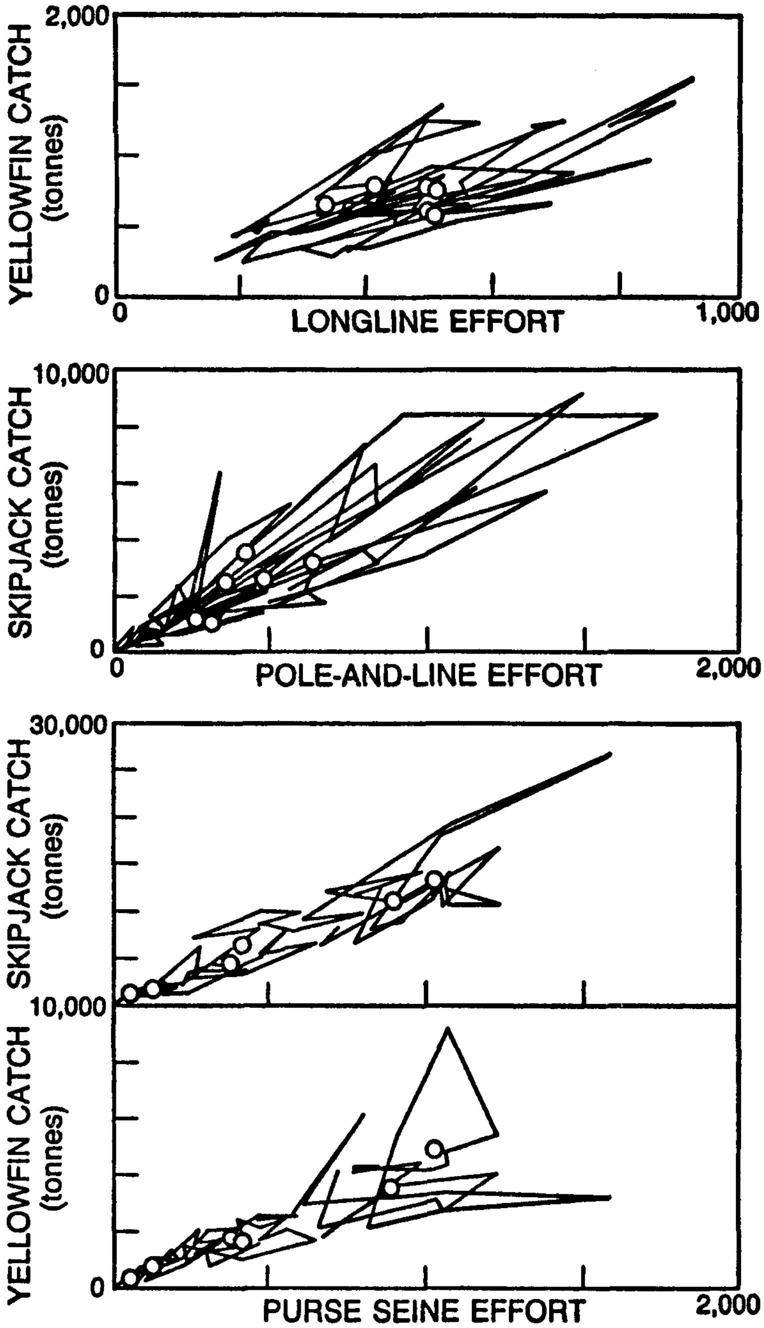

Figure 7. Catch as a function of effort by month since 1980. Circles indicate annual averages.

Evaluations of the current state of the fishery depend extensively on the reliability of data from this second source - the daily record of fishing activity in the region. Unfortunately, there is no compelling reason to believe that these data are either complete or reliable. Calculations of the percentage of catch reported to regional fisheries agencies ranged from less than 40% for pole-and-line fleets to about 90% for some purse seine fleets (Tuna Programme 1986).

Normally a sample size of 40 to 90% of a population would be considered adequate, however, there is some reason to consider that the sample is biased. A large proportion of the non-reported catch may be taken in international waters where reporting is generally not mandatory. Some data, summarized in Table 2, are available, however, which enable comparison between purse seine catches reported without position (presumably from international waters) with catches reported with positions (ie. from within EEZs). It is clear from Table 2 that conditions were quite different for the fishing which accounted for a majority of the catch. The percentage of successful sets was 83% in areas where positions were not reported compared to 69% in other areas. The result is that CPUE, measured as catch per day, was 30% higher in regions where positions were not reported. Thus there is ample reason to conclude that the sample of the fishery on which management decisions are based is badly biased.

Table 2: Summary of purse seine data reported to SPC by U.S. flag vessels for 1984

	With Positions (EEZ)	*Without Positions (international waters)*
Total annual catch	42%	58%
Average catch/day fishing	14.6 tonnes	19.6 tonnes
Set success rate	68.8%	82.9%
Average catch per successful set	29.5 tonnes	30.5 tonnes

IV. Conclusions

Tuna fishing in the tropical western Pacific has a long history with several well-established and successful fishing methods. The recent introduction of purse seining into the region has been accompanied by several uncertainties about how the stocks will be affected and about how to best manage the fishery. The growing aspirations of the Island states of the region to obtain a fair share the the revenues from the pelagic fisheries of their EEZs has added to the uncertainties and has also given a note of urgency to their resolution.

Fundamental facts of tuna biology in this region are simply unknown. The information on which the biologists base their analyses is not only incomplete but also biased. Furthermore, economic and political changes have resulted in less rather than more information flow from the fishermen to the biologists.

In spite of these uncertainties, the prognosis for further expansion of tuna fishing is good. There are few obvious causes for alarm with respect to general levels of exploitation. The uncertainties, intensified by the great importance of this resource to the continued economic development of the countries of the region, argue for caution in the planning of expansion and should provide impetus for more thorough data collection and more extensive research.

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