SOUTH PACIFIC COMMISSION

REPORT

Ad Hoc Meeting of Scientists to Discuss Skipjack Fisheries Developments and Research Requirements

A Meeting hosted by the South Pacific Commission (SPC) and sponsored by the International Center for Living Aquatic Resources Management (ICLARM), with the assistance of the Food and Agriculture Organization of the United Nations (FAO) and the Inter-American Tropical Tuna Commission (I-ATTC).

Noumea, New Caledonia, 6 - 10 December 1976

Noumea, New Caledonia
December 1976

1. Introduction

1.1. Background

The rapid expansion in skipjack (Katsuwonus pelamis) catches in recent years has greatly increased the research required to enable adequate assessment and evaluation of this, economically the most significant, tuna species. In recognition of the need to identify any shortcomings in the present approach and to define new areas in which skipjack research could be most productive the South Pacific Commission (SPC), International Center for Living Aquatic Resources Management (ICLARM), Food and Agriculture Organization of the United Nations (FAO) and Inter-American Tropical Tuna Commission (I-ATTC) cooperated to hold an Ad Hoc Meeting of Scientists to Discuss Skipjack Fisheries Developments and Research Requirements. The Meeting was held at the South Pacific Commission, Noumea, from 6th to 10th December 1976.

Participants were officially welcomed by the Secretary-General of the South Pacific Commission, Dr E. Macu Salato.

J. Joseph was elected Chairman and J.A. Gulland Rapporteur. Chairmen for the individual sessions on major research topics (agenda items 3.1 - 3.8) were accepted as proposed by the Convener (R.E. Kearney) and were 3.1, J.A. Gulland; 3.2, R.S. Shomura; 3.3, R.C. Francis; 3.4, G.D. Sharp; 3.5, R.E. Kearney; 3.6, A. Fonteneau; 3.7, R.C. Francis; 3.8, A.D. Lewis.

1.2. Agenda

1. Election of Chairman and Rapporteur

2. The state of stock assessment of skipjack based on current knowledge

3. Topics of major individual significance to skipjack research

   3.1 Population identification and migration
   3.2 Growth
   3.3 Mortality
   3.4 Life history
   3.5 Physiology, behaviour and the environment
   3.6 Density
   3.7 Models
   3.8 Statistics

4. Suggestions for future research

5. Adoption of report

2. Resource Assessment

During the past decade there has been a major expansion in the skipjack fisheries of the Pacific. A rough summary of the statistics, which were in many cases merely guesses of total catch based on information available during the meeting, is given in Table 1.

Table 1: Summary of catches (thousand tonnes) of skipjack in the Pacific

	1970	1971	1972	1973	1974	1975	1976
Papua New Guinea	2	17	12	27	40	15	26
Solomon Islands	0	5	8	6	10	7	17
Japan Southern Waters	53	79	80	107	145-196	(133)	(160-200)
Palau	8	2	2	3	5	7	6
Philippines	0	1	21	27	17	(18)	(20)
Indonesia					(10)	(10)	(10)
Total Area 71	63	104	123	170	227-278	190	239-279
Japan Home Islands (Area 61)	151	99	156	201	128	(117)	(100-140)
Total West Pacific (Areas 61, 71)	214	203	279	371	355-406	307	379
New Zealand (Area 81)	-	-	-	-	-	1	5
Tahiti	1	1	1	1	1	1	1
Hawaii	3	6	5	5	3	3	4
E. P. Ocean	56	105	33	45	79	116	130
Total Areas 77, 87	60	112	39	51	83	120	137
TOTAL PACIFIC	274	315	318	422	438-489	428	521

Note: ( ) Based on available statistics up to 1974, and estimations by the group for 1975 and 1976.

This shows that the total Pacific catch has about doubled since 1970, to slightly over a half million tons in 1976. The increase has been most striking in the western central Pacific (FAO statistical area 71, Fig. 1), which includes the Japanese southern (distant water) fishery, and the fisheries of Papua New Guinea and the Solomon Islands. In this area the catches have increased approximately four-fold, whereas the catches in the Japanese home waters and in the eastern Pacific have fluctuated without any very marked trend.

There are a number of series of data of catch per unit effort that can be examined as possible measures of the changes in relative abundance of skipjack in the western Pacific. These are summarized in Table 2.

Table 2: Catches per unit effort in some western Pacific skipjack fisheries

	1970	1971	1972	1973	1974	1975	1976
Papua New Guinea (a)	4.8	4.2	2.7	3.7	4.4	2.7	5.1
Solomon Islands (a)		5.7	2.3	3.2	4.7		
Palau (b)	91	20	30	38	50	64	50
Japanese southern fishery (a)	5.26	5.83		6.43			

Note: (a) tonnes per boat per day
(b) tonnes per boat per month

All data are based on the catch per day (at sea, or fishing) of baitboats, and are subject to the possible errors discussed in Section 3.5. In particular, they are likely to be subject to saturation due to the limited capacity of the gear for handling large catches, so that the figures of c.p.u.e. are likely to underestimate the year-to-year changes in the density of fishing on the grounds, particularly at high catch rates. Also, no corrections have been possible for differences in efficiency among gear or for changes in the average fishing power of the vessels in the fleet.

All the measures of catch per unit effort, with the exception of the Japanese southern fishery, show considerable fluctuations, which are typical also of skipjack fisheries elsewhere (eastern Pacific and Atlantic). The longest series of data on the western Pacific - those of the Japanese home fishery - show year-to-year differences of up to three times (see background document 3). There is also some evidence, especially in local fisheries, that there may be longer periods of fluctuations, such that a few years of good catches will be followed by some years of considerably lower catches. These variations are important in deciding on future fishery policy, e.g. concerning investment in new vessels, since future catches can be quite different from estimates made on one or two years' data.

The meeting discussed at some length whether these fluctuations in catch rates were due to real or apparent changes in the abundance of skipjack. The fluctuations are often similar over wide areas, which suggests that some large-scale environmental phenomena are responsible. The general feeling of the meeting was that fluctuations in catch per unit effort reflected real changes in the abundance of skipjack, but the changes in c.p.u.e. were not necessarily proportional to the changes in abundance.

While the general magnitude of the catch rate in any given skipjack fishery in a given year is largely determined by environmental factors, this does not preclude the possibility that the precise levels of the catch rates are also being affected by the fishing effort.

Since no stock or population is unlimited, increased fishing must at some point or points begin to significantly affect the local abundance of the stock, or the catch rates. These need not necessarily occur at the same point. For example, the catch rate may fall before the abundance is affected, due to interference between vessels. Also, if the fishery is operating on the fringe of a large population, a local reduction in stock abundance may be insignificant in relation to the abundance of the entire population. It should be stressed that moderate reductions in catch rate or in the abundance of a stock or population are not in themselves proof that the stock or population has become fully exploited, or is in any sense "over-fished".

For the long-established Japanese home-water fishery, some evidence (see background document 3) suggests that current levels of fishing have reduced the catch rates. This is supported by the fact that the Japanese skipjack fishermen have found it necessary to extend their operations southwards.

In the more southern waters the total catches up to about 1970 were not of sufficient magnitude that they would have been expected to have had any detectable effect on the stocks. Given the high degree of natural variation, the recent period of increasing catches has been so short that the effects of fishing would only be detectable if they were extremely severe. It is clear, e.g. from the high value of catch per unit effort in Papua New Guinea and the Solomon Islands in 1976, that this is not the case and that, up to the present, fishing has not detectably reduced the abundance of the stock.

It is not possible, however, to determine whether or not more moderate reductions in catch rates (e.g. by up to half the values that would have occurred if there had been no fishery), which are typical of fisheries making moderate or full utilization of a resource, are beginning to occur. This important determination must await further study, for which the availability of longer series of data, improved measures of catch per unit effort, better estimation of the stock structure so as to allocate catches from each fishery to the correct subpopulation, and quantitative information of the effect of environmental factors on abundance and availability are likely to be particularly useful. Proposals for relevant studies are given in later sections of this report.

The meeting discussed the possibility of estimating the total catch that could potentially be taken from the whole Pacific. Some estimates of this potential have been published, varying from 500, 000 to 1, 200, 000 tonnes upwards. These estimates were made when the Pacific catch was only 200-300 thousand tonnes. Current catches are approaching the lower estimates, but there are still wide areas in the mid-Pacific in which no significant catches are taken. Even in the western Pacific there are, at least in good years, large unfished areas, though the stocks in these areas may be exploited in other parts of their range. It seems therefore that significant further increase in the Pacific skipjack catches can be taken, particularly from those stocks or subpopulations occurring in the mid and south Pacific.

3. Topics of Major Significance

3.1. Population Identification and Migration

Population identification is essential to the assessment of the interactions between fisheries, and to enable the prediction of the possible effects of exploitation of a fishery in one area on other fisheries.

An attempt was made to define the basic terms relevant to population identification as follows:

(a) Population - all individuals of a species which inhabit a specified region (e.g. all skipjack tuna in the Pacific Ocean).

(b) Subpopulation - a subset of a population which is a self-sustaining genetic unit (e.g. Fujino's (1972) postulated western Pacific skipjack subpopulation).

(c) Stock - the exploitable group of fish existing in a particular area at a particular time (e.g. the group of skipjack tuna exploited by the New Zealand purseseine fishery during the 1975-76 fishing season).

It was pointed out that a stock could contain several subpopulations and that a given subpopulation could consist of part or all of several stocks.

The subpopulation structure of skipjack in the Pacific was discussed at some length. Reports were made of subpopulation hypotheses based on both biochemical genetics and tagging with the following results:

1) The stocks of Pacific skipjack can be divided into at least two (Figure 2) and possibly as many as five (Figure 3) subpopulations based upon examination of existing serum esterase gene frequencies (Figure 4).

2) Clarification of the latter case of 1) may require the examination of new genetic systems (e.g. LAP - four phenotypes, or, TO - six phenotypes) (see Working Paper 7).

3) The degree of genetic heterogeneity in skipjack may be considerable, even to the extent of occurring within single schools.

4) The ranges of different subpopulations overlap and vary in both time and space.

5) Tagging results suggest the existence of two non-mixing units in the eastern Pacific skipjack fishery (one occurring south of 15°N and another north of 15°N) and possibly three partially mixing units in the western Pacific (one which ranges from the Japanese home island fishery south to the equator, a second which ranges from approximately 10°N, south into the Bismarck Sea, and a third which extends south of the Bismarck Sea).

The topic of alternative methods of population identification was discussed. It was reported that concomitant morphometric-genetic studies of the eastern Pacific yellowfin subpopulation structure have indicated a lack of consistent correlation between morphometric and biochemical genetic varieties taken on identical sets of fish. It was recommended (Recommendation No. 1) that morphometric analyses of skipjack not be encouraged.

It was emphasized that in order to maximize the information content of any tagging study, blood sampling and tagging should take place simultaneously.

A discussion took place of where and when additional tagging and sampling for genetic studies would likely be most productive. It was concluded that major emphasis should be given to sampling pre-recruits ($<$ 40 cm) to the major skipjack fisheries of the Pacific. Four stocks of particular interest are those exploited by the New Zealand fishery, the south-eastern Pacific fishery (S of 15°N), the Gilbert Islands fishery and the Philippines. Investigation of the structures of these stocks will require extensive tagging and blood sampling in an area south of the equator, bounded on the west by New Caledonia, south by New Zealand and east by the Marquesas Islands. It was pointed out that a substantial sampling effort will have to be undertaken in areas where, at present, no viable skipjack fisheries exist.

In summary the following recommendations were made:

Recommendation No. 2

In order to further investigate the stock structure of skipjack in the Pacific, a large-scale tagging effort should be undertaken, with substantial sampling effort being undertaken in areas where, at present, no skipjack fisheries exist. This *ad hoc* group of skipjack scientists therefore recommends that the tagging programme being coordinated by the South Pacific Commission be implemented as soon as possible.

Recommendation No. 3

Tagging and genetic sampling should be done simultaneously on the same groups of skipjack.

Recommendation No. 4

Any fishery organizations contemplating genetic sampling should contact Dr Sharp (I-ATTC) or Dr Fujino (Kitasato University) regarding the analysis of those samples.

Recommendation No. 5

Emphasis should be placed on tagging pre-recruits ($<$ 40 cm) to the major skipjack fisheries of the Pacific.

Recommendation No. 6

Sampling for genetic studies directed towards population identification of skipjack should be extended to include larval and juvenile tuna.

3.2. Growth

The study of growth rates and size structure in exploited populations is important to assessment of these populations. The interaction between growth and natural mortality estimates, regardless of their relative magnitudes, affects the estimation of yield and standing stock using age structured models.

The collection of growth data and age structure data can be the best indicator available of the biological effects manifested in a changing fishery or one having already changed from historically normal conditions.

Often the comparison of growth rate and age structure data can be used to hypothesize or corroborate population stratifications. This may account for two potentially important stratifications, age specific movement or migration behaviour, and subpopulation or racial differences (e.g. the growth rate and size distribution appear dramatically different between the western and eastern Pacific skipjack stocks). These comparisons and variations are often our best information about mortality and depletion rates in exploited populations.

The importance of the growth rate estimates strongly indicates a need to validate traditional growth estimation procedures. It is therefore recommended (Recommendation No. 7) that any future working group should arrange for a systematic tabulation and examination of available growth estimates. Tagging and recapture techniques as applied to growth studies can yield highly variable growth estimates, therefore in order to reduce the variations caused by cross population sampling problems (overlap of distinct subpopulations) the sampling for age determination should ideally be coordinated so as to have corresponding genetic data available. This is best accomplished by collecting the materials for these studies simultaneously. There is also a need to examine the effects of size selectivity on the fishery and size-specific vulnerability to fishing effort on the overall growth rate estimates. Potentially severe biases in growth rate estimate will occur if either of these two processes exist and therefore they need to be looked for and, where necessary, compensated for.

The development of better and more direct ageing techniques should be promoted. In particular, techniques for reading the apparent daily rings on otoliths need to be validated, and if found valid should be applied to the Pacific-wide skipjack ageing and growth rate studies. Precautions should be taken to not duplicate effort in the development of the techniques necessary to this work. The goal should be to standardize and automate, if possible, the technique, so as to make it as rigorous and error-free as possible. The search for other direct methods for ageing tunas should be continued.

3.3. Mortalities

The group agreed that, under certain circumstances (e.g. to improve the precision of simulation models) it is desirable to have accurate estimates of mortality (natural and fishing). However, it recognized the difficulties involved. These include:

(i) the accuracy of the estimates, given the available techniques;

(ii) application of the estimates (e.g. the inadvisability of transposing results between areas, etc.);

(iii) the difficulty of separating total mortality components from other factors. It was agreed that the discussion would more realistically be addressed to loss rates from fisheries.

Recognizing these difficulties, the group agreed that other methods apart from those based on tagging and cohort depletion might profitably be considered in skipjack fisheries. Again, the absence of a reliable ageing technique restricts the number of alternatives available. It was felt that knowledge of any changes in the abundance of large skipjack would be valuable, and to this end, recommended (Recommandation No. 8) that nations having longline fisheries which take large skipjack, be encouraged to upgrade and update the data base and make it available on a routine basis.

Advances in technology in other fields of biology which might be relevant were foreshadowed. In general, however, because of the lack of knowledge in so many critical areas of skipjack biology (e.g. the spawner/recruit relationship), prospects for obtaining better estimates of mortality do not appear good. It was thus felt that new techniques should be given every encouragement and that ways of estimating population change independent of mortality coefficients be looked at.

It was suggested that predation on skipjack of various sizes by billfish and cannibalism may be important sources of natural mortality which have not previously been examined in any detail. To this end, it was recommended (Recommendation No. 9) that these be investigated. The I-ATTC undertook to examine the question of billfish predation on skipjack.

3.4. Life History

In fisheries science, studies of life history include a variety of subjects but most often concentrate on spawning and reproductive behaviour, larval development and distribution, transition from one stage in life to the next, and migratory patterns.

The opinion was expressed that there is a need to estimate the effects of surface and subsurface fishing on the numbers of individuals that return to the spawning mode if we are to be able to predict survival at different stages of life and at the critical stages in the relationships between spawners and recruits, if any such relationships exist.

If such relationships are to be found, it is important to determine escapement times from one life history stage to another and to identify spawning areas and times as well as the distribution of larvae.

Present knowledge of the distribution of larvae shows that most of those sampled to date occurred in near surface waters, after 60 metres or less, and at temperatures of 24°C or above. They are most abundant in the western and central Pacific to about 150°W, diminishing in occurrence in the eastern Pacific.

Other than these few generalities there is a significant gap in our knowledge of the early life history and the relation of the spawners to the distribution of eggs, larvae and juveniles. We need to be able to improve our ability to locate zones where the early life stages are spent. The sampling problem is substantially one of having to examine the entire water column in search of small skipjack. If the otolith is a record of daily growth, or near daily growth, then the application of the techniques (X-ray spectrometry) developed by Dr John Calaprice (I-ATTC) for elucidation of stock and genetic structure as measured by fine-scale chemical composition in fish tissues, may prove to be invaluable to the location of the thermal zones where small scombrids are found. These techniques have a particular value in that temperature dependent equilibria are measured, which allows one to examine the thermal history of materials which are deposited in a regular time-dependent fashion, such as the otolith growth rings. This may enable us to concentrate sampling in those areas or parts of the water column in which larvae or juveniles are most likely to occur.

Another potential value of these techniques lies in population identification and perhaps even to as fine resolution as that necessary to relate the parent and progeny, given that it is eventually possible to obtain, reasonably consistently, samples of the young life stages of skipjack.

Studies of the distribution of larval tuna in relation to the distribution of mature fish in space and time as evidenced by gonad indices and ova diameter measurements suggests that such studies may be useful in elucidating subpopulations. It was also suggested that examination of the distribution of juveniles might lead to the elucidation of stock structure. This was based on the observation that the distribution of skipjack less than 15 cm correlates well with larval distribution.

3.5. Physiology, Behaviour and the Environment

Skipjack must feed, migrate, obtain oxygen, and dissipate the heat produced in these activities. These requirements determine certain environmental conditions (particularly temperature and oxygen content) which are favourable to skipjack, and which vary according to the size of the animal. There are also differences between stocks/subpopulations according to the manner in which they are adapted/acclimated to different environmental conditions.

The study of physiologically determined tolerance limits in skipjack tunas offers a potentially valuable tool for assessing population variations. The oxygen and temperature sensitivity of each racial component of skipjack may be a distinguishing feature. Overlap in these characteristics to some degree is expected.

The procedures for examining physiological tolerance limits of skipjack are relatively uncomplex and portable to the extent that the required facilities can be used aboard ship. An effort should be made to develop and test shipboard apparatus to be used in the various realms of skipjack exploitation. Evaluation of the feasibility of a Pacific-wide study of temperature and oxygen tolerances of skipjack needs to be made. The primary areas of interest and potential variation from the baseline Hawaiian data would be Papua New Guinea, a warm environment, and New Zealand, the cool habitat extreme. The importance of obtaining data from the available size range of skipjack for each hypothesized stock needs to be emphasized.

The best conditions for catching skipjack in the eastern Pacific occurs when there is a surface layer of water favourable to skipjack sufficiently deep to be attractive to the fish (i.e. not less than about 40 m), but sufficiently shallow that they are kept within range of the gear (i.e. not deeper than about 80 m). For eastern Pacific skipjack and fish with similar requirements, this means that purseseine fishing is most promising where the 20°C isotherm is between 50 and 80 m deep. The limiting concentration of dissolved oxygen of 2.5 ml/L may act as a relatively important barrier to the escapement of skipjack from purseseine gear in a fashion similar to the temperature gradients. These conditions occur, on the average, over relatively wide areas off the American coasts, but elsewhere they are only known to occur in narrow strips at the northern (e.g. off Japan) and southern (e.g. around New Zealand) extremities of the skipjack range (see Working Paper 9).

Development of a cooperative surface and subsurface hydrological survey system on a permanent and ocean-wide basis, employing for example, ships of opportunity equipped with XBT or BT equipment, would be valuable in defining the skipjack habitat.

The scientists working on hydroclimate studies and their application to fisheries need to meet together with fishery scientists to examine available data and to devise the necessary future cooperative studies.

There should be some effort to employ aerial surveys with teledetection gear to study behaviour and availability of schools associated with thermal fronts or other oceanographic structures. For the same reason, fishing vessels should be encouraged to take XBT or thermograph recordings.

A knowledge of the physiological characteristics of skipjack can therefore be of direct value in predicting the best fishing areas either under average conditions or, if up-to-date detailed environmental data are available, within a particular year. This knowledge is also useful in the study of population dynamics. First, the total volume of suitable water determines the relation between average density of fish and their total abundance. Second, the conditions on the fishing ground, and particularly the depth of suitable water, determine the vulnerability of the fish to the gear being used. Together, these two factors help determine the relationship between the observed catches per unit effort and the actual abundance. If they are known, it should be much easier to interpret catch per unit effort data. In particular it may be possible to correct for much of the large year-to-year variations that occur, and which make routine stock assessment studies difficult, and obscure possible effects of fishing on the stock.

3.6. Density

Estimation of relative population density is one of the most important problems to be solved in the assessment of skipjack stock dynamics. Unfortunately skipjack are not randomly distributed over their range (a three dimensional volume of water bounded by the 20°C hyperplane).

The most common measure of stock density is catch per unit of effort, and its relation to density can be written as:

$$U = qkP$$

where U = c.p.u.e.

q = constant of proportionality, related to the fishing power of the gear

P = underlying stock biomass

k = an environmentally related variable which relates the availability of the stock to a particular type of gear.

For skipjack fisheries k appears to be highly variable from year to year, and some understanding of these variations is highly desirable if c.p.u.e. data are to be used to provide useful information or real changes in abundance.

The problem of gear saturation relative to the estimation of stock density was discussed at some length. The basic problem is the nature of non-linearity in the relationship between catch per day's fishing and stock density caused by physical limitations on the rates at which various types of gear can physically accumulate catch. These limits are generally functions of the gear itself and are independent of the amount of fish available for capture at a particular time. It was strongly suggested that this problem be investigated for both purseseiners and baitboats in order to determine its nature in the various skipjack fisheries of the world. In particular it should be examined in cases where both baitboats and purseseiners operate simultaneously (eastern Atlantic, eastern Pacific), in the Papua New Guinea baitboat fishery and in the developing New Zealand purseseine fishery.

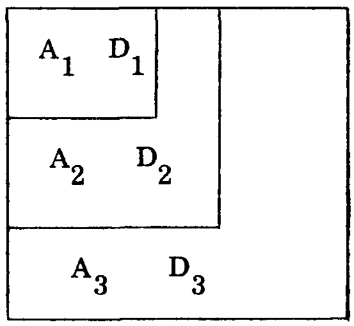
Several measures of stock density were discussed:

1) number of schools encountered per unit of time;

2) average catch per set in a purseseine fishery - it was suggested that the relationship between average school size and total annual skipjack catch be investigated in the eastern Pacific;

3) catch per bucket of bait in a baitboat fishery.

It was pointed out that there is a need to develop estimates of trends in overall western Pacific skipjack abundance. The difficulties in obtaining these estimates are increased by the fact that the area covered by the large Japanese southern water skipjack fleet changes from year to year in relation to skipjack abundance. These can be illustrated diagrammatically as follows, where the Japanese home ports are in the top left-hand corner, and grounds at different distances



from port are represented by three successive zones, of area A_1, A_2, A_3. If the densities in each of these zones, D_1, D_2, D_3 were known, then the total abundance B would be given by the equation

$$B = A_1 D_1 + A_2 D_2 + A_3 D_3 .$$

However, in many years, data are not available from all zones. In years of high abundance the fishery may not extend outside the local zone A_1, whereas in years of low abundance the fishery may extend into the most distant zone, with little or no fishing in the inner zone. In the former case the density in the unfished areas is likely to be as high as in the fished zone, whereas in the latter it may be considerably lower. The extrapolation from fished to unfished areas to produce an estimate of total abundance needs to be done with considerable care.

The problem of estimation of available fishing areas as a function of environmental conditions was discussed. It was pointed out that availability can be an extremely localized phenomenon as fishing tends to be concentrated along physical boundaries and fronts. An example of this is given in figures 5 and 6 which show how the areas fished by the Japanese southern water fleet in August and October 1975 were concentrated along the North Equatorial Convergence Zone (see background document 5).

The problems of aerial spotting were briefly discussed. It was pointed out that aerial survey information is useful for solving specific problems (such as locating fishable schools).

There are obvious difficulties in using sightings from aerial surveys as indices of density, some of which are common to catch per unit effort data, e.g. variation in the proportion of schools that occurs at the surface.

The estimation of the density of eggs and larvae was also discussed. It was pointed out that presently available data are not sufficient to provide accurate estimates of larval density, and that tuna eggs cannot be identified to family, much less to species.

Finally, it was re-emphasized that an analysis of longline catch rates for skipjack may provide the best available estimates of the stock densities of very large skipjack and such an analysis should be carried out (see sections 3.3 and 3.8).

The group recommended (Recommendation No. 10) the promotion and development of programmes to assess aggregation devices as sources of information on density. Studies of aggregation rates need to be carried out in both areas of continuous fishing effort, and, necessarily, in areas of the skipjack habitat with characteristically low, or no fishing activity, so as to perhaps better estimate the overall abundance.

3.7. Models

One of the objectives of modeling in fisheries research is to analytically describe the causes of fluctuations in yield from a stock in order to give advice about development and management.

Traditionally, fishery models have been concerned with the effects of "over-fishing" on fishery resources. In this context it is convenient to distinguish two ways the resource can be affected - "growth-over-fishing" (in which case the manner in which effort is applied across the population age-structure causes subsequent fluctuations in yield) and "recruitment-over-fishing" (in which case fishing has an effect on subsequent recruitment).

It was pointed out that these types of models have proved to be of little use in assessing skipjack fishery dynamics, due to the fact that most skipjack fisheries exhibit large-scale fluctuations which appear to be quite independent of effort. It was further pointed out that modeling will only become a useful tool for the management of skipjack fisheries when the responses of stock dynamics to physical and biological phenomena, independent of fishing effort, are understood and incorporated into the existing models. An example of this is the attempt to relate skipjack catch dynamics in the eastern Pacific to fluctuations in the southern oscillation index which is reported in Working Paper 6.

A second objective to fishery modeling is to give insight into the underlying population structure and mechanisms, and falls under the general heading of structural models. It was pointed out that these types of simulation models have at times been useful for making inferences and testing hypotheses about various exploited tuna stock.

It was recommended (Recommendation No. 11) that if models are to be used for the assessment of skipjack stocks, their assumption be fully understood and investigated before the modeling is attempted. Indiscreet use of modeling is dangerous and misleading and should be avoided.

Finally, it was pointed out that fishery analysts should be extremely careful to define their terms in any publications describing modeling exercises.

3.8. Statistics

The kinds of statistics needed to monitor a fishery range from gross annual figures of catch and value to meet minimal government needs, to detailed fishery and biological statistics required for stock assessment and prediction purposes. In the western Pacific there are some areas from which data on skipjack are lacking or inadequate and in other cases data are not available for analysis on a timely basis. Basically, the problem has been the lack of a centralized mechanism for collecting or discussing these statistics.

The group recognized the far-ranging habits of the skipjack tuna and recognized the existence of two or more subpopulations of this species and expressed the view that the proper monitoring of this resource in the western Pacific can only be logically done on a regional basis. This regional approach was also noted to be applicable for other commercially important tuna species which demonstrate wide-ranging movements.

The group therefore recommended (Recommendation No. 12) that a regional mechanism be established to coordinate the collection, processing and evaluation of all tuna statistics, and that the South Pacific Commission and FAO be asked to assist in implementing this task.

Three important aspects of statistics include the details, precision and timeliness of the data required. The details and precision of the data collected will vary with the fishery and the constraints imposed by the area, e.g. accessibility. For localized fisheries, the total catch by a convenient time unit, e.g. months, should be the minimum statistic required. In this connection, the group recommended (Recommendation No. 13) that all countries fishing in the western Pacific be urged to collect accurate catch statistics even from small-scale tuna fisheries and further recommended (Recommendation No. 14) that all tuna fishing countries collect and process on a timely basis, all statistics necessary for stock assessment.

The standardized statistics needed for stock assessment purposes have not been fully identified for the Pacific; however, the following information requested by ICCAT of its membership should meet the initial basic needs of the western Pacific area.

Task 1: Total annual catch by species and total effort.

Task 2: Catch and effort by month and area (1° or 5° squares) by gear.
Size frequency distribution: by wide areas, quarters and gear.

The group also recommended (Recommendation No. 15) that the ICCAT strategy for data collection be considered for adoption and use in the western Pacific. The group also endorsed the recommendation of the Expert Committee on Tropical Skipjack made at the Tahiti meeting to use a standardized format for the collection of tuna pole and line catch and effort data (see background document 1).

The importance of making the statistics available for evaluation in a timely fashion was highlighted. For example ICCAT requires that all data be reported within six months of the end of the fishing year. The group recognized that Japan, a major tuna fishing country in the western Pacific, is making a major effort to reduce the time lag between data collection and data dissemination, and urged that this effort be continued.

There is a need to identify the kinds of biological statistics that should be collected to further understand the skipjack resources in the western Pacific. The group therefore recommended (Recommendation No. 16) that the Working Party on Skipjack Tuna (see section 4) review this topic and develop a set of biological data requirements for skipjack tuna.

The group considered that size frequency data provided useful biological information, particularly when examining differences between fisheries, or between years, and that these data should be collected. It was stressed that the variability of the size-frequencies of fish in the catches was different in different fisheries. This variability should be studied when determining what intensity of length sampling is desirable, and in developing suitable sampling procedures.

It was noted that the annual catch of some fisheries for skipjack tuna was relatively small, e.g. Tahiti and Hawaii, and thus their catches are not significant when compiling statistics of the total catch from the whole Pacific. However, there are many instances in which detailed catch and effort data or other information from small fisheries provide valuable leads to events of wide and general interest, e.g. concerning trends in abundance or the relationship between availability and environmental conditions. In this connection the group noted that information from fisheries on large skipjack tuna, e.g. the Tahitian and Hawaiian fisheries and the longline fishery, were likely to be particularly valuable in providing some insight into the possible impact of the fisheries on small skipjack on the overall mortality rates. The catch rates in these fisheries should be monitored on a continuing basis.

4. Arrangements for Further Research

The group believes that during its meeting it made considerable progress towards understanding the skipjack stocks of the western Pacific, though perhaps less than was hoped, and certainly less than would be needed to give adequate scientific advice and predictions regarding the skipjack stocks and the fisheries on them. If such progress as has been achieved is not to be wasted it is essential that arrangements are made for the scientific work to be continued and properly coordinated.

Though questions still remain concerning the population structure of the skipjack in the western Pacific, and their migrations, it is clear that individual fish move over considerable distances, and that there is likely to be significant interaction between different fisheries. A considerable number of countries catch skipjack in the western Pacific, some at long distances from their home ports, and most of them carry out some scientific research. Without prejudice to any permanent regional arrangements that might be made in the future for skipjack research and management (which may or may not be carried out under the same arrangements) it is most important that some arrangements are made now for the continuing coordination of the research and related activities of all these countries. A particularly important aspect concerns statistics (see Section 3.8).

At present no single regional grouping includes all countries with interests in the western Pacific skipjack. For example, the South Pacific Commission has an ongoing programme on skipjack and has an Expert Committee on Tropical Skipjack, but several major fishing countries are not members of the South Pacific Commission, and there is significant movement of skipjack into and out of the area in which the Commission works. On the other hand the Indo-Pacific Fisheries Council does not include among its present members Island countries and territories. This problem was recognized by IPFC in passing the following resolution in Colombo in October 1976, setting up a special working group on western Pacific skipjack.

> "Recognizing the rapid expansion of the fisheries on skipjack in the southwest Pacific and the urgent need for scientific advice so that timely and appropriate decisions on management and development can be taken, the Special Committee on Management of Indo-Pacific Tuna recommends to IPFC to establish a subsidiary scientific body or group on western Pacific skipjack, with the following terms of reference:
>
> In cooperation with the countries of the Central and western Pacific, and appropriate regional organizations, to promote and coordinate those scientific research activities which will lead to a better understanding of the skipjack resources of the Western Pacific, and which will enable proposals to be made for management and rational utilization of these resources, which can be implemented at the appropriate national or regional level.
>
> In particular the group should endeavour to
>
> 1) facilitate the better identification of separate skipjack stock or stocks in the region by (a) an intensive tagging experiment, (b) genetic studies, and (c) other relevant studies;
>
> 2) investigate the feasibility of a workshop on skipjack catch and effort data no later than two years hence."

The present *ad hoc* meeting therefore recommends (Recommendation No. 17) to the South Pacific Commission that it seriously consider the suggestion for active cooperation, and that it should consult with FAO/IPFC at the technical level so as to enable the proposed group, suitably widened in scope and membership, to undertake the necessary scientific consultation, at least until more permanent arrangements are made.

5. Summary Recommendations

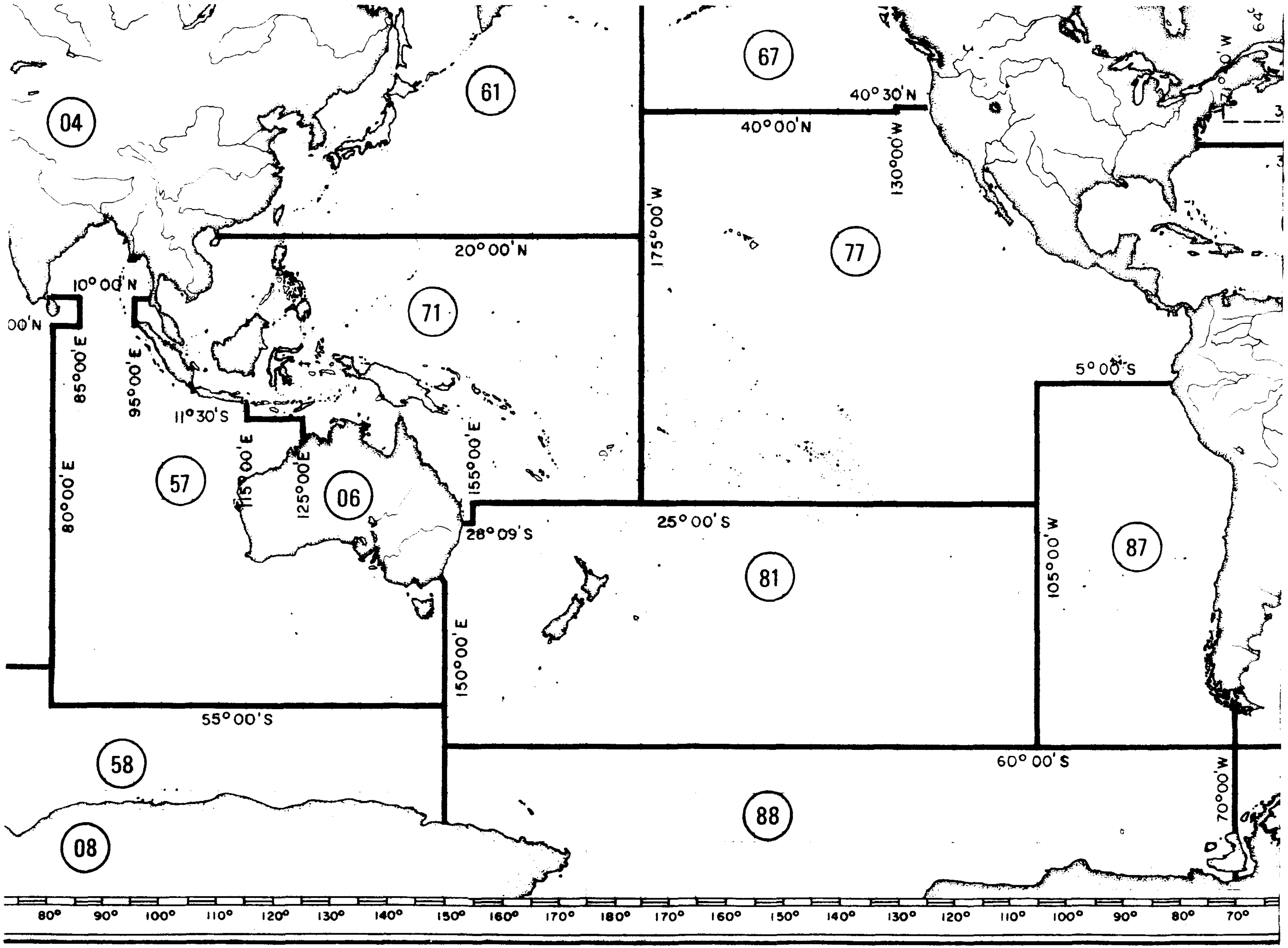
During its discussions the meeting identified a large number of different research activities that needed attention. The reason for these activities, and the details of the proposals are set out in the previous sections, but the meeting also made the following broad general recommendations to all those concerned with western Pacific skipjack.

(a) High priority should be given to the proposed Skipjack Survey and Assessment (tagging) Programme being coordinated by the South Pacific Commission (see Recommendation No. 2).

(b) Arrangements should be made for coordinating skipjack research, encompassing all countries with interests in the fisheries in the region. For the immediate future, pending more permanent arrangements, this could be done through a working party sponsored jointly by SPC and IPFC (see Recommendation No. 17).

(c) This working party should give early attention to the collection and compilation, on a regional basis, of catch and effort statistics, and of such environmental data as are likely to assist in the interpretation and analysis of the statistical data (see Sections 3.5. and 3.8.).

Figure 1. The demarcation of FAO statistical areas in the Pacific Ocean



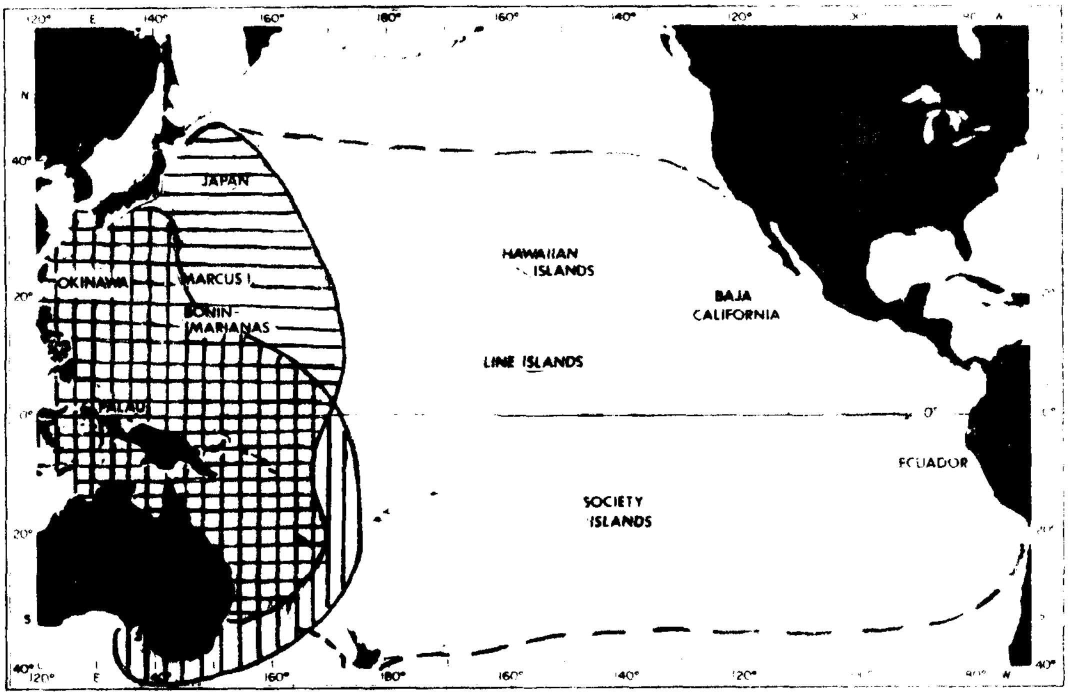


Figure 2. Proposed ranges of the western Pacific subpopulation (horizontally hatched area for summer and vertically hatched for winter of the northern hemisphere) and the central-eastern Pacific subpopulation(s), (unhatched circum-equatorial area), (See Fujino, 1972, Fig.4 for detail).

Figure 3. Postulated subpopulations of skipjack in the Pacific Ocean (see Working Paper No.9)

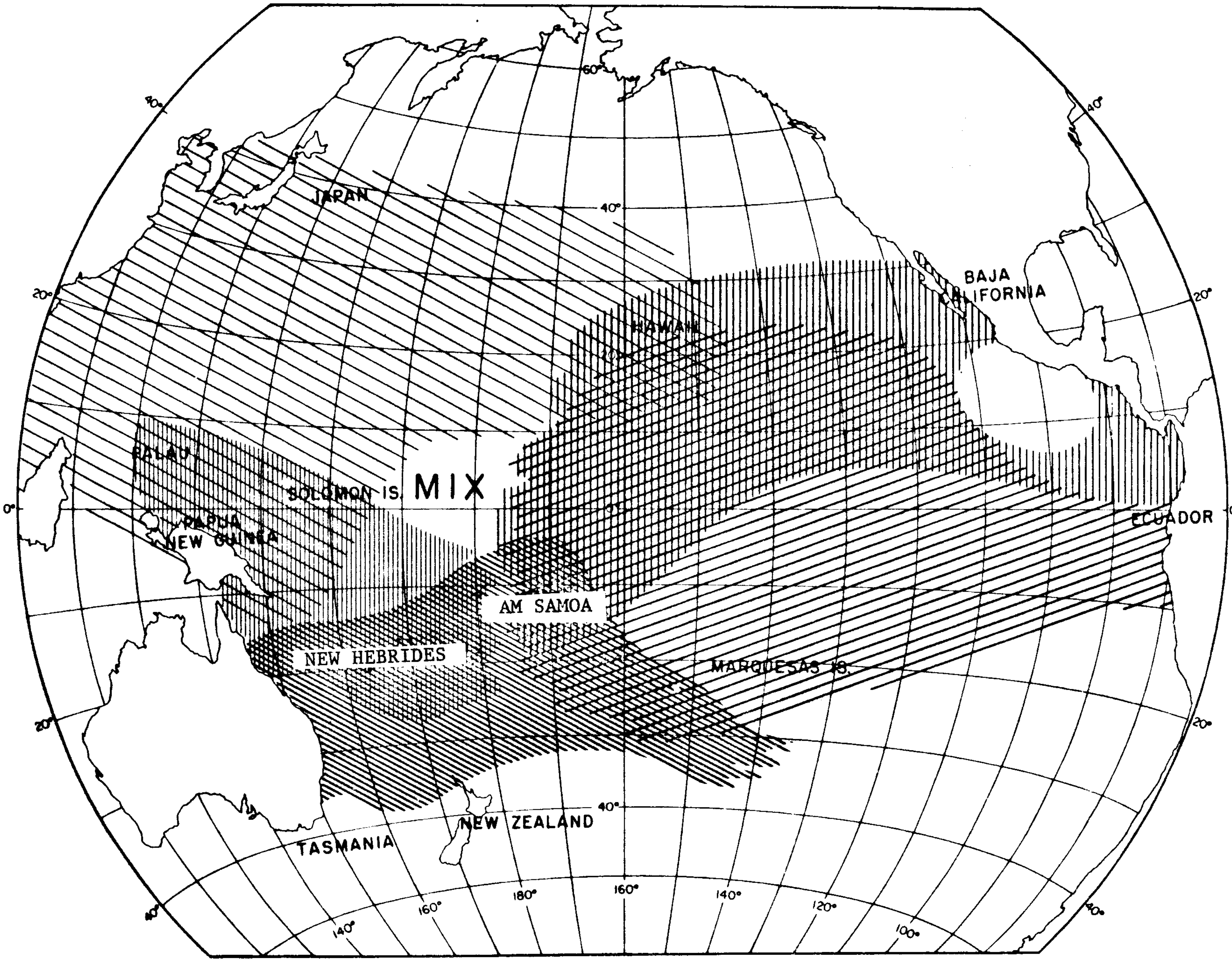


Figure 4. Frequency distribution of samples from Fujino and Sharp with N>80

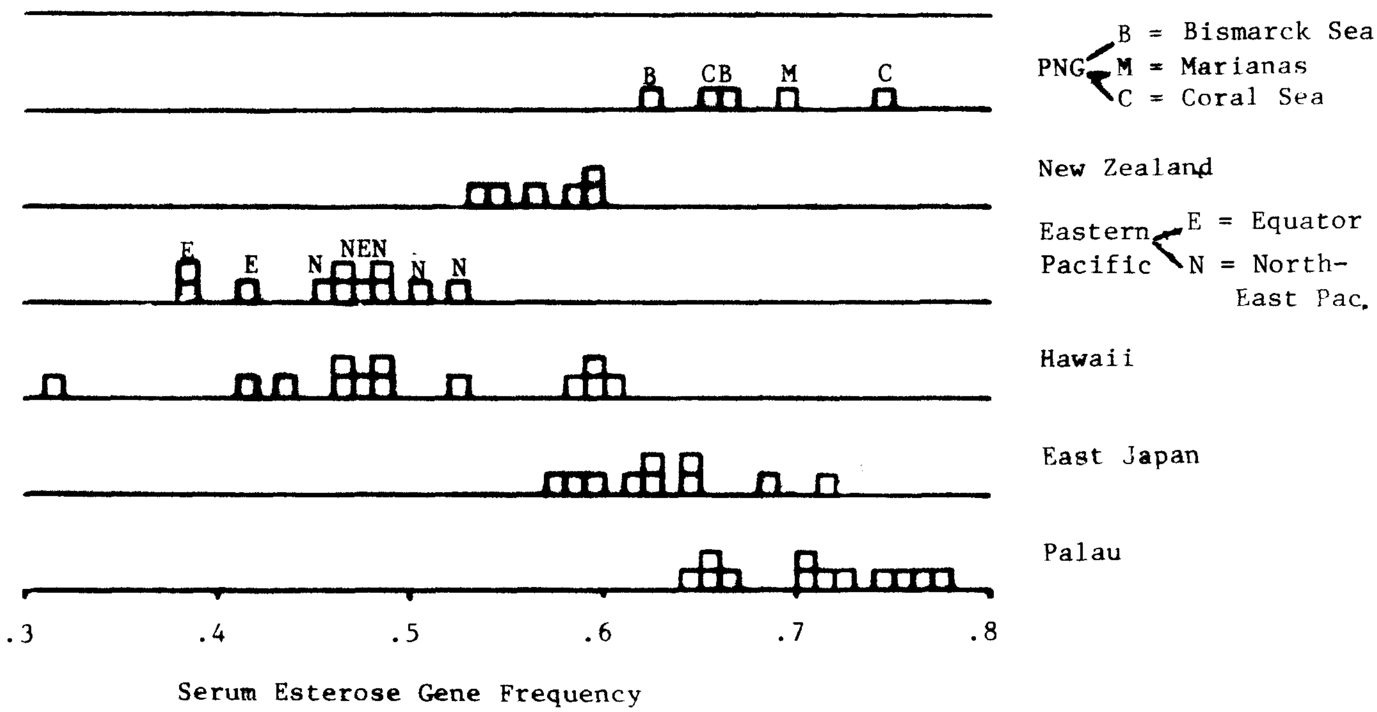


Figure 5. Positions of catches by the Japanese southern water skipjack fleet in August 1975 (see background document 5).

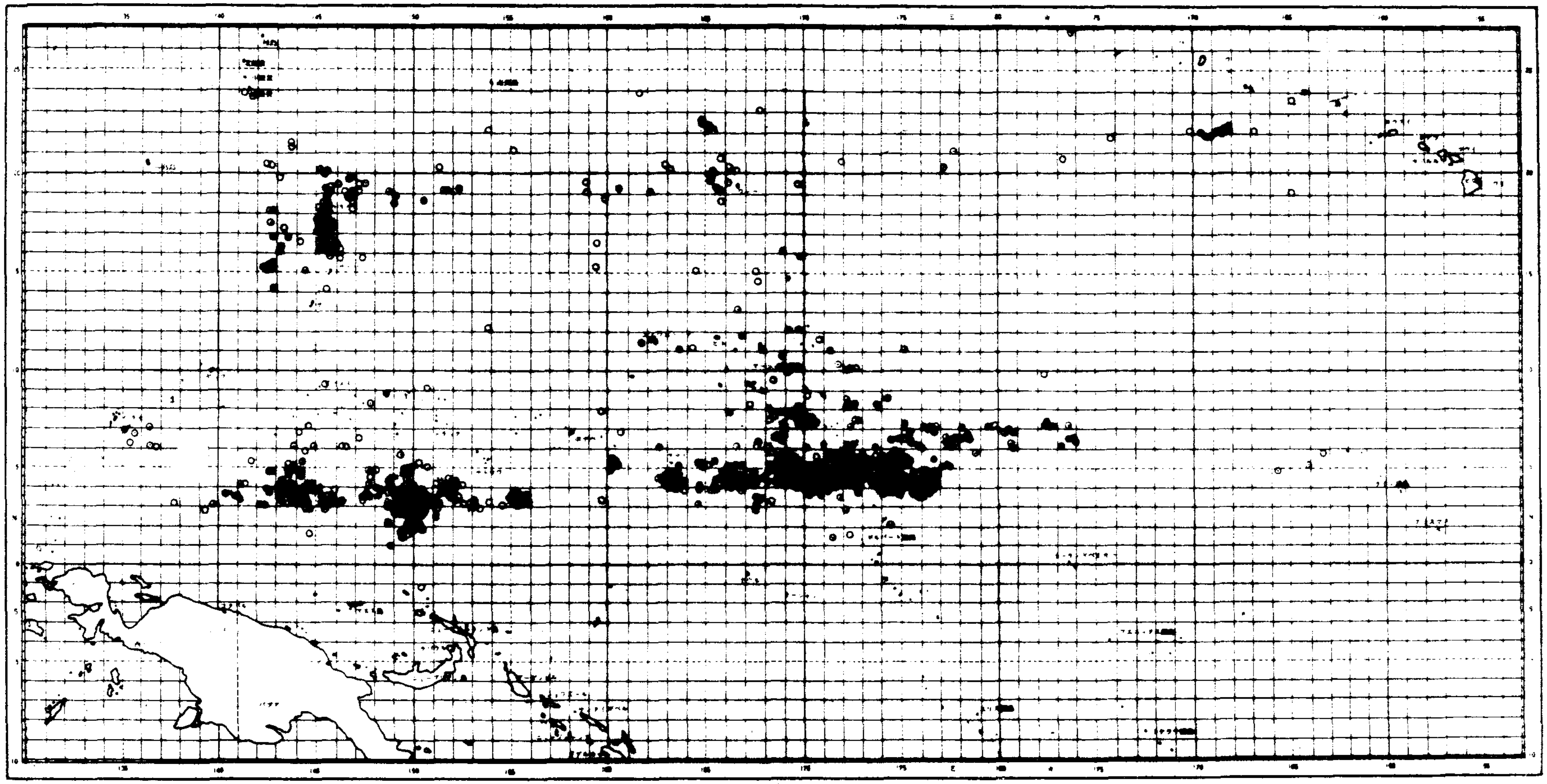
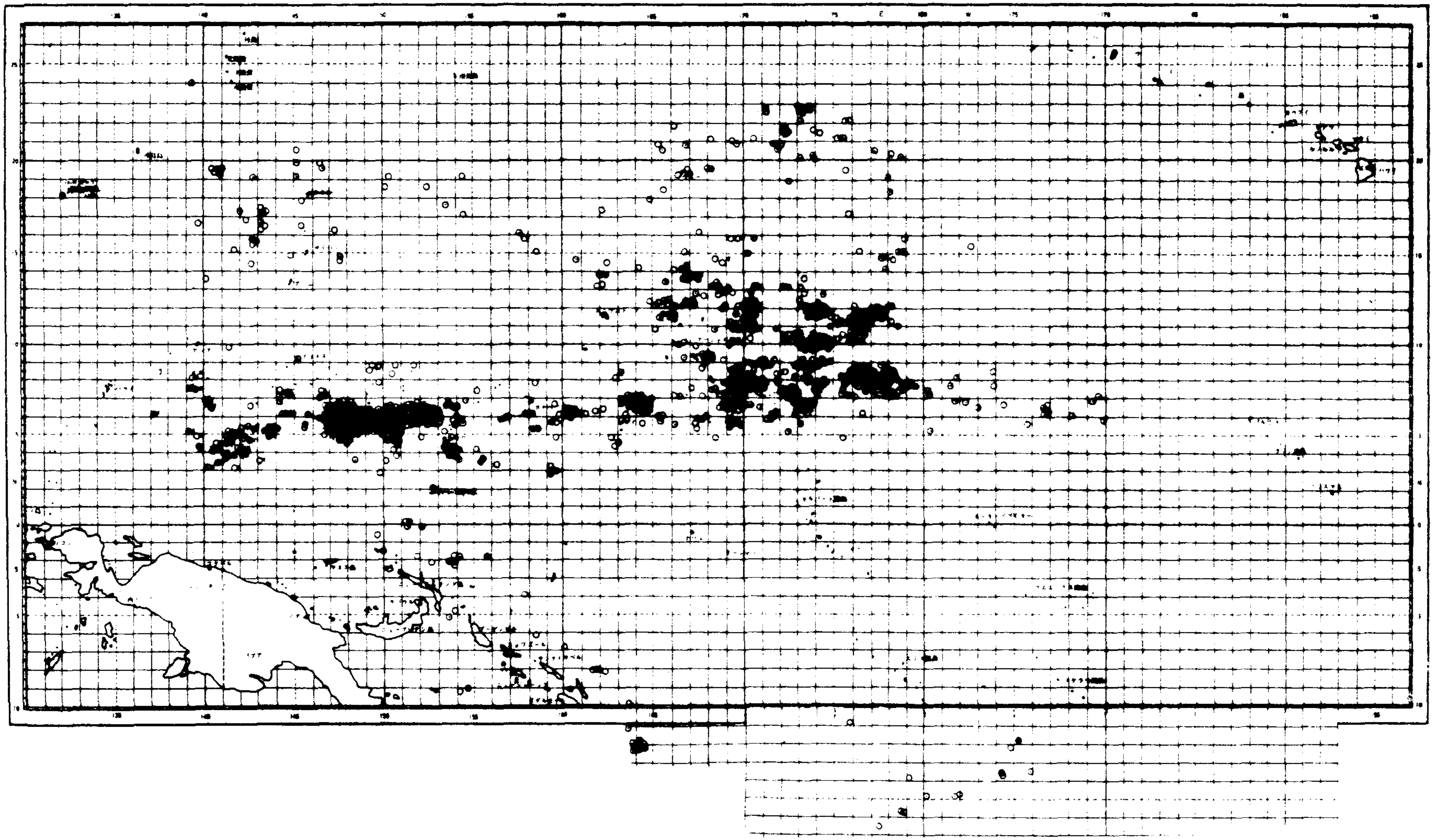


Figure 6. Positions of catches by the Japanese southern water skipjack fleet in October 1975 (see background document 5).



LIST OF PARTICIPANTS

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LIST OF WORKING PAPERS

South Pacific Skipjack - Data Needs.	J.A. Gulland	WP. 1
South Pacific Skipjack - Population Models.	J.A. Gulland	WP. 2
The Skipjack Fisheries of the Indian Ocean.	R.E. Kearney & W.L. Klawe	WP. 3
The Relevance of Data Collected in Papua New Guinea to Skipjack Population Studies in the Western Pacific.	A.D. Lewis	WP. 4
Some Hypotheses on the Skipjack Resources of the Pacific Ocean.	R.E. Kearney	WP. 5
Skipjack in the Eastern Pacific.	E.D. Forsbergth & R.C. Francis	WP. 6
Stock Identification of Skipjack Tuna.	K. Fujino	WP. 7
Distribution and Abundance of Skipjack Tuna Larvae.	W. Matsumoto*	WP. 8
Physiology and Environmental Restrictions on Skipjack Tuna.	G.D. Sharp	WP. 9
Age and Growth of Skipjack Tuna, Katsuwonus pelamis, Yellowfin Tuna, Thunnus albacares, and Albacore, Thunnus alalunga, as Indicated by Daily Growth Increments on Sagittae.	J.H. Uchiyama* & P.J. Struhsaker*	WP.10
Larval Distribution and Indications of Spawning Areas of Skipjack Tuna in the Pacific Ocean.	S. Ueyanagi	WP.11
Skipjack Tuna - Some Thoughts, Views and Speculations.	R.S. Shomura	WP.12

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Working Papers were presented as unpublished manuscripts or drafts and requests for copies should be directed to the authors.

LIST OF BACKGROUND DOCUMENTS

Document	Author	Previous Publication	Number
Report of the First Meeting of the Expert Committee on Tropical Skipjack. Papeete, Tahiti, 25 February - 1 March 1974.	Anon.	SPC, Noumea, New Caledonia	1
Subpopulation Identification of Skipjack Tuna Specimens from the Southwestern Pacific Ocean.	K. Fujino	Bull. Jap. Soc. Scient. Fish (1976) 42 (11):1229-1235	2
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Rapport du Groupe de travail sur le listao atlantique. Dakar, 22-27 mars 1976.	Anon.	(I. S. R. A.) ORSTOM	4
Perspectives de développement de la pêcherie de thons dans le Sud Pacifique.	J.C. Le Guen, J.R. Donguy and C. Henin	To be published in "La Pêche Maritime"	5
An Estimation of Papua New Guinea's Tuna Fisheries Potential.	R. E. Kearney	Manuscript in preparation	6
Results of Tagging Conducted by the Far Seas Fisheries Research Laboratory.	Anon	Unpublished data	7
Extracts from "Distribution and Migration of Skipjack Tuna in the North Pacific Area."	K. Kasahara	Manuscript in preparation	8
Hypothetical Habitat of Skipjack Tuna Based on Temperature and Oxygen Requirements.	Barkley, R.A., W.H. Neill, and R.M. Gooding	Manuscript in preparation	9
Results of Tagging Conducted by Tohoku Fisheries Research Laboratory.	Anon. (Tohoku Fisheries Research Laboratory)	Unpublished data	10

Document	Author	Previous Publication	Number
Selected Skipjack Statistics from the Pacific.	Anon.	Unpublished, Preliminary Figures	11
The Biology, Ecology and Resource of the Skipjack Tuna (Katsuwonus pelamis).	W. A. Matsumoto and R. A. Skillman	Southwest Fisheries Center, Admin. Report No. 12H, 1975	12
A Regional Approach to Fisheries Management in the South Pacific Commission Area.	R. E. Kearney	Background Paper South Pacific Forum, Oct. 1976	13
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Behavioral and Physiological Properties of Tunas and their Effects on Vulnerability to Fishing Gear.	G. D. Sharp	Manuscript in preparation	15
A Report of the Fourth Joint Meeting of the IPFC Special Committee on Management of Indo-Pacific Tuna and the IOFC Committee on Management of Indian Ocean Tuna.	Anon.	IPFC/76/9 November 1976	16
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Biology of Skipjack in New Zealand Waters.	C. M. Vooren	Unpublished manuscript	19

Requests for copies of background documents should be directed to the source of previous publication or the author concerned.