Proposed Studies on the Seasonal Distribution, Movement and Variation in Fishing Success for Albacore in the New Zealand Region

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1. Introduction

Two fisheries for albacore *Thunnus alalunga* exist within the New Zealand EEZ. The domestic surface troll fishery lands up to 3,000 tonnes during the January to April season. There are about 200 boats in this fishery, with most fishing concentrated along the west coast of the South Island north of Fiordland. Smaller catches are made off the east coast of the North Island. Foreign licensed longline vessels also catch significant quantities of albacore. These vessels target for albacore and other tuna (bigeye and southern bluefin tuna) north of 37°S while further south albacore is a common by-catch. The catch of albacore, by fishery, is compared with that of other tunas in Table 1 for New Zealand waters. Descriptions of these fisheries can be found in Murray *et al.* (1984) and Murray and Ross (1985).

The longline fishery operating in New Zealand waters is part of a South Pacific-wide fishery dominated by Korean and Taiwanese flag vessels based in Pago Pago, American Samoa. This albacore longline fishery has operated since the early 1950's with an average annual catch of 37,000 tonnes (Wetherall and Yong, 1984). This South Pacific-wide fishery is currently operating at MSY and is not considered to be capable of further expansion (Wetherall and Yong, 1984). The New Zealand component is insignificant (less than 3% of the total).

The New Zealand domestic fishery is the only surface troll fishery currently fishing the South Pacific albacore stock and several factors suggest that this fishery, unlike the longline fishery, may be capable of considerable expansion. New Zealand lies downstream from the albacore spawning grounds in the Coral Sea and Fiji Plateau (Nishikawa *et al.*, 1985) and appropriate sea surface temperatures for catching albacore are within range of New Zealand fishing vessels for most of the year (see figure 1). In addition the difference in size between troll caught and longline caught albacore (Laurs and Dotson, 1983) suggests that the present troll fishery is based on a portion of the stock not specifically included in the determination of Wetherall and Yong's (1984) MSY estimate. Since troll caught fish appear to be younger we can reasonably expect that this portion of the stock may be larger than that caught by longliners. Without knowing considerably more about albacore migration, seasonal variation in fishing success by method, movement of fish between surface and longline fisheries, and the distribution of albacore temporally, spatially and in relation to oceanographic features we will be unable to assess the potential for expansion of the New Zealand surface fishery.

It seems probable that the present catch of albacore in the South Pacific can be increased by further developing surface fisheries (Anon, 1984). New Zealand currently has the largest surface fishery exploiting the South Pacific stock and is ideally situated to intercept migrating fish. The present Westland based surface fishery has variable landings (see Table 1) and appears to be good only in warm years. The variability between years, short seasons and the potential for high effort in a restricted area (100-200 vessels between the 100m and 200m isobaths north of Jackson Bay and south of Cape Foulwind) suggests that the greatest potential for increased landings is through extending the season to fish albacore migrating into and away from the fishery. A second possibility for expansion is through locating oceanographic features that concentrate albacore but are not presently fished. The Tasman Front, Subtropical Convergence and localized upwelling areas are all areas which at times have the potential to concentrate albacore.

Determining when and where albacore are vulnerable to a surface fishery centered on New Zealand provides a broad framework within which to formulate testable hypotheses about distribution and fishing success. The results of such research not only have application in New Zealand and the South Pacific but are also relevant to other epipelagic oceanic species. The purpose of this proposal is to identify hypotheses which are testable and tractable within the Fisheries Research Division (FRD) or in cooperation with specific interested parties. A second purpose is to outline methods for evaluating these hypotheses.

Given the broad geographic distribution of the albacore stock and the interest expressed by overseas researchers we expect that major portions of the research outlined here will be further developed and conducted as joint cooperative projects. To date scientists from several laboratories have expressed interest in cooperative programmes on South Pacific albacore. We therefore expect opportunities for cooperation and exchange with the Honolulu and La Jolla laboratories of the U.S. National Marine Fisheries Service (NMFS/SWFC), the Noumea laboratory of la Office de la Recherche Scientifique et Technique Otre-Mer (ORSTOM), the South Pacific Commission (SPC), the Graduate School of Oceanography of the University of Rhode Island (URI/GSO) and others.

2. Studies on Movement and Migration

There are several data sources which will permit us to make inferences about albacore movement in the New Zealand region. Catch rates of albacore on research cruises, catches by FRD staff incidental to other programmes, analysis of fishing returns in the domestic fishery and logbooks in foreign longline fisheries, all provide abundance indices which can be used to infer geographic and seasonal patterns of abundance. The primary use for these data will be discussed in a separate section. Questions of interest which can not be answered with these data include:

1. Does a zero catch imply a) absence of fish, b) fish are not vulnerable to gear, or c) fish are too scarce to be detected at the level of effort?

2. Are the fish caught in New Zealand waters part of a migrant or "resident" stock?

3. Where do albacore go after passing through the New Zealand fisheries?

4. Is there an exchange of fish between domestic and longline fisheries in New Zealand and elsewhere.

The question of absence or low vulnerability may not be completely resolved but can be compensated for using different fishing methods and acoustic information during each survey. Alternative sampling methods (e.g., deep trolling, vertical and surface longlines) are being developed. The frequent presence of a distinct acoustic signal while catching albacore (Iwasa et al., 1982) and the presence of a large air bladder in albacore suggest that it may be possible to detect albacore with echo sounders when fishing activity or fish abundance are low. Mid-water handlining techniques (Hinds, 1984) may provide a means of identifying acoustic signals produced by albacore. The remaining questions are best suited to mark-recapture experiments.

To date albacore have been tagged as part of four different programmes in New Zealand, all since 1972. No known recaptures have been made. A summary of these programmes is presented in Table 2. Three problems common to these tagging exercises may explain the lack of returns, 1) a small number of fish tagged relative to probable stock size, 2) low fishing effort on all but the largest size class of fish with most tagged fish being small, and 3) poor advertising and overseas return addresses for tags. The practicality of conducting tagging experiments on South Pacific albacore has not been adequately evaluated but is ultimately dependant on the tag return rate. This implies that fish are properly tagged, advertising is adequate over the likely areas of returns and that sufficient animals can be tagged. The increase in fishing effort, particularly around New Zealand, the development of tagging techniques for troll caught albacore (Laurs et al., 1976) and refinements in tuna tagging generally (Kearney and Gillett, 1982) suggest that studies based on tagging can be successfully carried out. We propose to initiate tagging experiments to identify the pattern of albacore movement and migration in the New Zealand region in relation to ocean circulation. A secondary objective will be to validate check ring periodicity in otoliths and caudal centra.

2.1 Tagging Methods

Tag return rates of 1.8% to 3.6% have been reported for albacore by Laurs et al. (1976) for a series of single tag experiments in the North Pacific. In the South Pacific where fishing effort is less we expect lower return rates. In the first year (1986) we will concentrate tagging to periods before and during the domestic season in areas immediately upstream and downstream of the Westland fishery. The tagging criteria for troll caught fish will be that of Laurs et al. (1976) using the tagging method described by Kearney and Gillett (1982). Initial tagging will be done aboard the GRV Kaharoa in conjunction with Tasman Sea albacore surveys. In 1985 we estimated that between 8% and 10% of commercial troll caught fish were suitable for tagging. We also estimated that the catch rate of the GRV Kaharoa was 50% of the average commercial boat. Despite lower catch rates on research vessels we expect to be able to catch more fish suitable for tagging by fishing short troll lines with a mixture of single barbless and double barbless tuna lures towed at slower than average speed. Preliminary trials suggest that during good weather up to 30% of fish landed on research cruises will be suitable for tagging. Fish will be injected with oxytetracycline and measured before release.

2.2 Tagging Experiments to Study Movement

Our initial hypothesis is that albacore migrate into and move around New Zealand with and in the direction of oceanic and coastal currents. If this hypothesis is true then the migration of albacore to New Zealand might be expected to be associated with the northwest-southeast trending troughs (see figure 2) since oceanic flow is strongly influenced by bathymetry in the Tasman Sea (Heath (1985). These migratory paths might then lead to an accumulation of albacore in two regions of the west coast of New Zealand separated by a broad bathymetric high (the Challenger Plateau). These areas, the North Taranaki Bight and the area south of the Challenger Plateau, are connected by a predominantly northward flowing current.

We can test the hypothesis, of albacore moving with rather than against the direction of flow, using tag returns within a tagging season for releases made in areas north and south of the Challenger Plateau. We would accept our hypothesis if fish tagged north of the Challenger Plateau are not recaptured by vessels operating in the westland fishery. A second condition for accepting our hypothesis would be for all recoveries to be either in the area of release or from other North Island locations downstream from release sites (i.e. northeast coast, Bay of Plenty, or the east coast of New Zealand north of the Chatham Rise). To test the foregoing hypothesis we propose to conduct tagging in the North Taranaki Bight and east Northland coast in November and December 1986. We also propose to conduct tagging in February 1987 along the west coast of the South Island. These periods occur when albacore have been abundant during previous surveys. Tagging will also be conducted opportunistically during the year, on albacore surveys.

2.3 Ancillary Tagging Studies

We expect that a small percentage of tag recoveries will be made by other fisheries in the South Pacific, especially longliners, after fish have been at liberty for several years. Returns from other areas will yield information on the extent of albacore movement and the geographical areas encompassed by the southwest Pacific stock. Returns from other fisheries (longliners, gill netters, trollers, *etc.*) will give estimates of the time lag involved in any fisheries interactions.

We plan to inject most tagged fish with oxytetracycline in order to validate the check ring sequence in otoliths, as has been done for North Pacific albacore by Laurs *et al.* (1985).

All tagging studies will be co-ordinated with other agencies (*e.g.* NMFS/SWFC, etc.).

2.4 Regional Relationships of Albacore Using Parasite Markers

Surface and longline caught albacore are presently considered to be part of a single South Pacific stock (Anon, 1984) which enters New Zealand waters when conditions are favourable. Most albacore caught inshore are 50 to 70 cm in length, but very young fish (< 44 cm) and fish of 80-90 cm are common. In comparison albacore taken by longline are larger than trolled fish.

The relationship between the fish caught off New Zealand and tropical populations has not been established. Similarly movements of albacore around the New Zealand coast, and between surface and longline fisheries have not been investigated.

There are several ways to demonstrate relationships between areas. The first is to use some method of artificially marking the fish and relying on subsequent sightings or recapture to provide evidence as to where the fish go to. Disadvantages include high cost, tag induced mortality, behavioural changes, non-random distribution of tags in the population and the large number of tags required to ensure a significant return.

A second method uses intrinsic markers. These may be morphological characters (for example colour variations); biochemical differences in blood type, protein or enzyme differences; or differences in parasite fauna. Two advantages of intrinsic markers are that by using naturally occurring properties of the fish the trauma of capture and tagging are avoided and the results can be obtained without first mounting an expensive programme to tag large numbers of fish. A major disadvantage is the difficulty in validating such a marker.

The ideal situation is to demonstrate a relationship between fish of different areas using two or more independent techniques. We propose to do this by sampling for parasite markers in conjunction with tagging experiments proposed in earlier segments.

The use of parasites to delineate stocks for management purposes is a well established technique (McKenzie 1983, Anon 1984, Rhode 1984). Parasites have also been used to give information on host zoogeography (Rhode 1984) and to indicate phylogenetic relationships (Kabata & Ho 1981). Lester et al. (1985) studied school to school variation in skipjack parasites to evaluate how long schools were staying together. Their evidence suggested that New Zealand caught skipjack under 57 cm had recently arrived from the tropics. Aloncle and Delaport (1970, 1974) successfully used the albacore stomach parasite Hirudinella as a biological stock marker in the North Atlantic and also showed that the presence of the nematode Thynnascaris was correlated with the type and quantity of the food in albacore stomachs.

Preliminary analyses (Jones, 1985) suggest that troll caught albacore in New Zealand have a tropical origin and that seasonal and area differences can be detected by parasitological studies. The initial goal of our proposed study is to test these hypotheses.

THE PROGRAMME

Null Hypothesis (1): That there is no parasitological evidence for New Zealand caught albacore having come from tropical waters.

In order to test this hypothesis it will be necessary to show that the parasites in question are not acquired in New Zealand waters, but are of tropical origin.

Null Hypothesis (2): That no statistically significant differences in parasite incidence can be detected in albacore from different areas around New Zealand or between New Zealand and the rest of the South Pacific.

Our ability to test this hypothesis will depend upon demonstrating that differences due to loss or gain of parasites during movements between areas can be detected, and that differences in parasite incidence are not affected by host-age or the physical environment and season.

METHODS

Samples of parasites will be obtained as follows: the head and viscera of up to 10 fish per school will be collected from a maximum of two schools per days trolling on albacore surveys. A school is operationally defined as a discrete burst of continuous fishing activity. Each head will be individually bagged and labelled with the fish length and location. The gut will be injected with formalin prior to freezing to prevent digestion of the stomach contents. Parasites found in these samples will be counted and identified. Analysis of similarities and differences in parasite fauna between areas will be investigated using cannonical multivariate analysis as used by Lester _et al._ (1985). Stomach contents will also be recorded.

3. Catch Rate versus Oceanic Conditions

Research on North Pacific albacore has demonstrated that oceanographic conditions play a major role in the movement and local concentration of albacore. Sea surface temperature has been shown to have a controlling influence on albacore abundance (Blackburn, 1965) with apparent limits of 13.5° C to 25.2° C at all depths of capture (Sund _et al._ 1981). In New Zealand waters the surface fishery appears to be more narrowly determined with nearly all catches over the range of 17.0° C to 19.0° C (Murray _et al._ 1984). Within these temperature ranges frontal structure (Uda, 1973, Laurs and Lynn,1977), upwelling (Pearcy and Mueller, 1970, Laurs _et al._ 1977, Laurs, _et al._ 1984) and water clarity (Murphy, 1959, Laurs, 1983) all concentrate albacore locally and contribute to their vulnerability to fishing gear. In addition to surface oceanographic features, sub-surface features such as thermocline strength and depth of the mixed layer may further explain variation in catch rate but have not been adequately studied in relation to albacore catch rate.

Sund et al. (1981) reviewing the work of Saito (1973) indicate that albacore occur to depths of 380m in the area west of Fiji and were most abundant between 200m and 260m in the vicinity of the thermocline. Beyond these observations, however, little is known of the vertical distribution of albacore. The timing of the New Zealand surface fishery coincides with the season of maximum stratification of the water column. The longline fishery in contrast deploys gear over a wider depth range and catches fish in both winter and summer. It seems probable that part of the apparent seasonal vulnerability of albacore to surface fisheries may be explained by sub-surface features and through a greater understanding of the vertical distribution of albacore.

We propose to characterize seasonal variation in catch rate in both surface and longline fisheries through the analysis of historical data. We further propose to quantify the effects of surface versus sub-surface oceanographic features on catch rate and to describe seasonal changes in vertical distribution of albacore through a series of research cruises. Two research topics will be studied, each with a set of inter-related null hypotheses.

1. Is the pattern of surface and longline fishing for albacore related to oceanographic features with identifiable surface characteristics?

   Hypotheses to Test:

   1.1) The distribution of vessels is random within definable temperature and bathymetric ranges.

   1.2) Fishing activity is concentrated in the vicinity of surface features (e.g., thermal fronts, upwellings, etc.).

   1.3) Fishing activity is concentrated in the vicinity of "successful" fishermen.

2. Is albacore catch rate (estimated on research cruises) related to ocean fronts or thermocline characteristics?

Hypotheses to Test:

2.1) Catch rate is equal at and away from thermal fronts.

2.2) Catch rate is independent of thermocline depth.

2.3) Catch rate is independent of thermocline strength.

2.4) Catch rate is independent of thermocline-front interactions.

The first question is amenable to "nearest neighbor" analysis where daily position and catch is known and can be used to describe the pattern of fleet distribution. Although these data exist for the longline fleets, it is lacking for the domestic fishery. Where fleet distribution is known it will be possible to use CPUE as an index of either abundance or of fishing success and to describe the similarities between vessel aggregations. Using one of the remote sensing products currently available it may also be possible to identify surface oceanographic features with which vessels are associated. Although it is unclear whether existing products will be accurate enough or have an adequate spatial resolution they should at least allow us to stratify CPUE, if vessels are widely scattered, with regard to temperature and bathymetry. The usefulnesses of existing products depends on the scale of the processes (spatial and temporal) and how they are linked to the fishery. Lange _et al._ (1984) for example successfully showed a seasonal component to squid trawl success in relation to the shelf-slope front in the northwestern Atlantic using a commercial remote sensing product. Lasker _et al._ (1981) studying the distribution of anchovy eggs and Laurs _et al._ (1984) studying albacore catch distribution in relation to coastal upwelling had much greater success by combining individual orbital data with coincident fisheries data.

The second question and its attendant null hypotheses lends itself to analysis as an ANOVA or by stepwise multiple linear regression in which effort is variously stratified. Stratification can be by season, fishing method, bathymetry, etc. For the purpose of this study two distinct sampling regimes are imposed by the scale of ocean frontal features we can expect to encounter and our ability to apportion effort before sampling. When fronts are small scale or transitory features they often lack any surface expression. In these situations we can detect and characterize the front through sub-surface thermistors or CTD casts, usually after sampling them. This is by far the most common situation in New Zealand waters and although we can apportion effort with respect to season, fishing method and bathymetry we must either post-stratify relative to the front or treat particular aspects of the front as independent variables. In cases where fronts are meso-scale features (100-1000 km) like the Tasman Front or sub-tropical convergence, it is possible to apportion effort equally in areas upstream,downstream and within the front after mapping an area with CTD transects. For both small scale and meso-scale features catch rate will be used as a response variable while routine measurements of sea surface temperature, salinity, chlorophyll concentration, depth of the mixed layer and thermocline strength will be used as independent variables. In the cases where the front is small the distance from the front and an estimate of frontal strength will also be used as independent variables.

We have developed a research logbook for the domestic fleet in order to develop a database for describing the distribution of fishing vessels and effort. We further propose to evaluate the usefulness and accuracy of existing remote sensing products for the study of fleet distribution using both the domestic and foreign longline fisheries. If existing remote sensing products are inadequate we will seek to develop a specific high resolution (1 km per pixel) product as part of a cooperative project with other agencies.

4. Ancillary Biological Studies

4.1 Proximate Biochemical Composition of Muscle Tissue

The proximate biochemical analysis of fish (i.e., protein, lipid, moisture and ash content) provides criteria upon which to assess the potential value of a species in human nutrition as well as identifying its potential for product development. An equally important but less frequent application of these data is in the assessment of trophic interactions, environmental relationships and seasonal variation in fish condition.

The proximate biochemical composition of three scombrid fishes from New Zealand waters has been studied by the Applied Biochemistry Division of DSIR ((Vlieg, 1982; Vlieq *et al.*, 1983; Vlieg, 1984). Although these studies were oriented to applications in nutrition and food technology, interesting environmental correlates were suggested in two species. Variation in white muscle oil content appears to be related to the presence of anisakid parasites in *Scomber australasicus* (Vlieg, 1982) though the relationship was not quantified due to insufficient samples. In the case of skipjack tuna, however, Vlieg *et al.* (1983) conclusively demonstrated an inverse relationship between white muscle oil content and sea surface temperature. One inference drawn from these studies is that variation in proximate biochemical composition provides an easily obtainable index of fish condition which may be useful in establishing environmental relationships.

Preliminary analyses of albacore white muscle oil content shows that fish caught at different times of the year vary considerably in oil content. Thus far variation in oil content appears to be size independent for troll caught fish. We propose to investigate the sources of variation in oil content as a function of size, season, parasites, stomach contents and water mass characteristics using analysis of variance and regression techniques. A second result of preliminary work shows that oil content is linearly related to muscle water content. This relationship will speed the processing of large sample sizes and has a direct application to the processors.

4.2 Stomach Contents as an Indicator of Albacore Forage

Studies of albacore stomach contents from fish caught in the New Zealand region have resulted in a diverse list of potential albacore forage (see Table 3). These studies are based on fish caught in late spring and summer by trolling (Roberts, 1974), pole and line (Iwasa *et al.* 1982) and purse seine (Bailey and Habib, 1982) primarily on the continental shelf and slope. Bailey (1983) in the most detailed study to date has analysed stomach contents in relation to fish size and area of capture. His data suggests that forage composition may be a function of albacore size. If this relationship, based on mean prey size, holds for a wide range of oceanic conditions it would suggest that albacore are partially selective in their feeding. An alternative hypothesis would be that the observed relationships are due to size segregation of albacore in water masses which tend to support forage of a particular size range.

We propose to test these hypotheses by establishing the relationship between mean prey size and fish size for ocean areas which can be expected to differ in forage composition. This will involve comparisons between shelf and slope waters, and Subtropical Convergence zone and subtropical surface waters.

4.3 Age Determination Based on Otoliths and Caudal Centra

Age estimation methods for albacore have used several different hard parts with varying degrees of success. Vertebral centra have been tried by Otsu and Uchida (1957) and Bell (1962) without success; negative results were also obtained by Otsu and Uchida (1959) using opercular bones. The use of scales has been investigated and reported as poor (Otsu and Uchida, 1959) to good (Bell, 1962) for determining age. Results using dorsal spines have also ranged from poor (Otsu and Uchida, 1959) to good (González-Garcéz and Fariña-Perez, 198~~7~~3). In none of the foregoing studies have the purported annual bands been validated. This may account for some of the variation in utility ascribed to the various hard parts.

The only banding sequence which has thus far been validated for albacore is that of daily increments on sagittae from fish smaller than 100 cm (Laurs, *et al.*, 1985). The usefulness of albacore otoliths for aging, however, may be limited by the difficulty of reading them. Individual otoliths may take one half day each to count increments, with large fish taking longer (Laurs, personal communication). We feel that in situations where large samples, especially of older fish, are required that an alternative technique would be of considerable use. Recent developments in sectioning and staining hard parts has shown considerable promise in other tuna (Berry, 1978; and Prince *et al.*, 1985) and suggests a reappraisal of earlier approaches may be warranted.

We propose to compare counts of caudal centra stained with alizarin red S, which preliminary work has shown to highlight bands, with counts of daily increments on sagittae using the method of Laurs *et al.* (1985). We also propose to compare these increment counts with counts of external ridges found in the sulcus of sagittae observed with the SEM. In addition we plan to examine otolith sections to determine whether the increment sequence used by Laurs *et al.* (1985) is related to that observed in the sulcus and to validate their technique using tetracycline marked recaptures from tagging experiments.

5. Literature Cited

Anon. 1975. James Cook surveys albacore resource. Catch '75(4):8.

Anon. 1984. Report on the ad hoc workshop on the stock assessment of tuna in the Indo-Pacific region. UNDP Indo-Pacific Tuna Programme IPTP/84/GEN/6.

Anon. 1984. Distribution and discrimination of stocks. pp 6-7. In Aberdeen Laboratory triennial review of research 1979-81; 74 pp.

Aloncle, H. and F. Delaport. 1970. Populations et activite de *Thunnus alalunga* de atlantique N-E etudies en fonction du parasitisme stomacal. Rev. Trav. Inst. Peches marit. 34(3): 297-300.

__________ 1974. Données nouvelles sur le germon *Thunnus alalunga* Bonnaterre, 1788 dans le nord-est Atlantique. Rev. Trav. Inst. Peches marit. 38: 5-102.

Argue, A.W. and R.E. Kearney. 1983. An assessment of the skipjack and baitfish resources of New Zealand. Skipjack Survey and Assessment Programme Final Country Rept. no. 6, 68 pp.

Bailey, K.N. and G. Habib. 1982. Food of incidental fish species taken in the purse-seine skipjack fishery, 1976-81. FRD Occ. Pub. Data Ser. no. 6, 24 pp.

Bailey, K.N. 1983. Food and feeding habits of fish associated with skipjack tuna in New Zealand. M.Sc. thesis, Victoria Univ., Wellington, N.Z. xii + 206 pp.

Bell, R.R. 1962. Age determination of the Pacific albacore of the California coast. Calif. Fish and Game 48: 39-48.

Berry, F.H. 1978. Vertebral-related studies. p. 337-339. In: J.J. Hunt (ed.). Proceedings of the Atlantic bluefin tuna ageing workshop. Int. Comm. Conserv. Atl. Tunas, Collect. Vol. Sci. Pap. 7(2): 332-348.

Blackburn, M. 1965. Oceanography and the ecology of tunas. Oceanog. Mar. Biol. Ann. Rev. 3:299-322.

González-Garcéz, A, and A.C. Fariña-Perez. 1983. Determining age of young albacore, Thunnus alalunga, using dorsal spines, pp 117-122. In E.D. Prince and L.M. Pulos (ed.). Proceedings of the international workshop on age determination of oceanic pelagic fishes: tunas, billfishes and sharks. U.S. Dep. Comm. NOAA Tech. Rep., NMFS 8.

Heath, R.A. 1985. Large scale influence of the New Zealand seafloor topography on western boundary currents of the South Pacific Ocean. Austr. J. Mar. Freshw. Res. 36: 1-14.

Hinds, V. 1984. Tuna fishing: handlining in midwater. FishDex 28.

Ichikawa, W. 1981. Report of the albacore survey by the R.V. Kaio Maru no. 52 in New Zealand waters, 1981. JAMARC Rept. 20, 117 pp.

Iwasa, K., G. Habib and G.I.T. Clement. 1982. Report of the albacore survey by the R.V. Kaio Maru no. 52 in New Zealand waters, 1982. JAMARC Rept. 18, 150 pp.

Kabata, Z. and Ju-Shey Ho. 1981. The origin and dispersal of Hake (genus Merluccius; Pisces; Teleostei) as indicated by its copepod parasites. Mar. biol. ann. rev., 19: 381-404.

Kearney, R.E. and R.D. Gillett. 1982. Methods used by the skipjack survey and assessment programme for tagging skipjack and other tuna. Tuna & Billfish Assessment Programme Tech. Rept. 7:19-43.

Lange, A.M.T., M.C. Ingham and C.A. Price. 1984. Distribution of maturing Illex illecebrosus relative to the shelf-slope water front of the northeastern United States. NAFO SCR/IX/109 Ser. No. N906, 17 pp.

Lasker, R., J. Pelaez and R.M. Laurs. 1981. The use of satellite infrared imagery for describing ocean processes in relation to spawning of the northern anchovy (Engraulis mordax). Remote Sensing of the Environ. 11:439-453.

Laurs, R.M. 1983. The North Pacific albacore - an important visitor to California Current water. CalCOFI Rept. 24:99-106.

Laurs, R.M. and R.C. Dotson. 1983. Exploratory longline fishing for albacore tuna in eastern North Pacific waters during November - December 1982. NOAA/NMFS/SWFC Admin. Rept. LJ-83-05, 71 pp.

Laurs, R.M., P.C. Fielder and D.R. Montgomery. 1984. Albacore catch distributions relative to environmental features observed from satellites. Deep-Sea Res. 31:1085-1099.

Laurs, R.M., W.H. Lenarz and R.N. Nishimoto. 1976. Estimates of rates of tag shedding by North Pacific albacore, Thunnus alalunga. Fish. Bull. 74:675-678.

Laurs, R.M. and R.J. Lynn. 1977. Seasonal migration of North Pacific albacore, Thunnus alalunga, into North American coastal waters: distribution, relative abundance, and association with transition zone waters. Fish. Bull. 75:795-822.

Laurs, R.M., R. Nishimoto and J.A. Wetherall. 1985. Frequency of increment formation on sagittae of North Pacific albacore (Thunnus alalunga). Can. J. Fish. Aquat. Sci. 42: 1552-1555.

Laurs, R.M. and J.A. Wetherall. 1981. Growth rates of North Pacific albacore, Thunnus alalunga, based on tag returns. Fish. Bull. 79:293-302.

Laurs, R.M., H.S.H. Yuen and J.H. Johnson. 1977. Small-scale movements of albacore, Thunnus alalunga, in relation to ocean features as indicated by ultrasonic tracking and oceanographic sampling. Fish. Bull. 75:347-355.

Lester, R.J.G., A. Barnes and G. Habib (1985) Parasites of skipjack tuna; fishery implications. Fish. Bull. 83: 343-356.

MacKenzie, K. 1983. Parasites as biological tags in fish population studies. Adv. Appl. Biol. 7: 251-331.

Murphy, G.I. 1959. Effect of water clarity on albacore catches. Limnol. & Oceanog. 4:86-93.

Murray, T., P. Swanson and C. Carey. 1984. Tuna resources and tuna research in New Zealand. FRD Internal Rept. 9, 6 pp.

Murray, T. and A. Ross. 1985. Status of tuna resources and tuna research in New Zealand - 1985. SPC/Fisheries 17/WP. 25, 8 pp.

Nishikawa, Y., M. Honma, S. Ueyanagi and S. Kikawa. 1985. Average distribution of larvae of oceanic species of scombroid fishes, 1956 - 1981. Far Seas Fish. Res. Lab. S series 12, 99 pp.

Otsu, T. and R.N. Uchida. 1957. Age determination of albacore by the vertebral method. Proc. Indo-Pacific Fish. Coun. 7(II-III): 49-52.

__________________ 1959. Study of age determination by hard parts of albacore from central North Pacific and Hawaiian waters. Fish Bull. 59(150) 353-363.

Pearcy, W.G. and J.L. Mueller. 1970. Upwelling, Columbia River plume and albacore tuna. Proc. 6th Intern. Sympos. Remote Sensing of the Environ. 2:1101-1113.

Prince, E.D., D.W. Lee and J.C. Javech. 1985. Internal zonations in sections of vertebrae from Atlantic bluefin tuna, Thunnus thynnus, and their potential use in age determination. Can. J. Fish. Aquat. Sci. 42: 938-946.

Rhode, K. 1984. Zoogeography of marine parasites. Helgolander Meeresunters. 37: 35-52.

Roberts, P.E. 1974a. Albacore off the north-west coast of New Zealand, February 1972. N.Z. J. Mar. & Freshw. Res. 8:455-472.

Roberts, P.E. 1974b. Selective feeding by albacore and skipjack tuna in the New Zealand region in spring. Proc. Indo-Pacific Fish. Council 15(III): 461-469.

Sund, P.N., M. Blackburn and F. Williams. 1981. Tunas and their environment in the Pacific Ocean: a review. Oceanog. Mar. Biol. Ann. Rev. 19:443-512.

Uda, M. 1973. Pulsative fluctuation of oceanic fronts in association with the tuna fishing grounds and fisheries. J. Fac. Mar. Sci. Tech., Tokai Univ. 7:245-265.

Vlieg, P. 1982. Compositional analysis of jack mackerel and blue mackerel. N.Z. J. Sci. 25: 229-232.

_________ 1984. Proximate composition of New Zealand slender tuna Allothunnus fallai. N.Z. J. Sci. 27: 435-438.

_________, G. Habib and G.I.T. Clement. 1983. Proximate composition of skipjack tuna Katsuwonus pelamis from New Zealand and New Caledonian waters. N.Z. J. Sci. 26: 243-250.

Wetherall, J.A. and M.Y.Y. Yong. 1984. Assessment of the South Pacific albacore stock based on changes in catch rates of Taiwanese longliners and estimates of total annual yield from 1964 through 1982. NOAA/NMFS/SWFC Admin. Rept. H-84-11, 7 pp

TABLE 1: Summary of tuna catches in New Zealand in tonnes ("0" = no catch, "-" = no information).

	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984
Albacore											
domestic	898	646	25	621	1686	814	817	1622	1535	710	2527
longline	-	-	-	-	-	-	215	744	841	882	919
Bigeye											
domestic	0	0	0	0	0	0	0	0	0	0	0
longline	-	-	-	-	-	-	238	453	652	442	527
Yellowfin											
domestic	1	1	1	1	1	1	1	1	2	0	2
longline	-	-	-	-	-	-	11	100	90	31	58
Southern Bluefin											
domestic	4	0	0	5	10	5	130	173	208	112	96
longline	-	-	-	-	-	-	6605	5074	2754	1618	1491
Northern Bluefin											
domestic	-	-	-	-	-	-	-	-	-	-	-
longline	-	-	-	-	-	-	2	5	99	62	41
Butterfly											
domestic	0	0	0	0	0	0	0	0	0	0	0
longline	-	-	-	-	-	-	67	40	54	70	59
Skipjack											
domestic	659	1159	291	1657	2841	3129	2717	3221	3723	3911	3865
joint venture	-	324	4443	5889	6395	5903	7609	3903	1507	4222	0
Total Tuna											
domestic	1562	1806	317	2284	4538	3949	3665	5017	5468	4733	6490
others	-	324	4443	5889	6395	5903	14747	10319	5997	7327	3095

TABLE 2: Summary of albacore tagging in New Zealand waters.

Tagging Agency	Dates	Agency Receiving Tags	No. Tagged	Reference
N.Z. Ministry of Agriculture & Fisheries	Feb. 1972-Jan. 1975	CSIRO, Australia	1200	Roberts (1974a), Anon (1975)
South Pacific Commission	March 1979	SPC, New Caledonia	3	Argue & Kearney (1983)
Japan Marine Fisheries Resources Research Center and N.Z. Ministry of Agriculture and Fisheries	Jan-Feb 1981 Jan-Feb 1982	JAMARC, Japan	265 36	Ichikawa (1981) Iwasa, *et al.* (1982)

TABLE 3: Albacore forage items in New Zealand waters identified from stomach contents by Roberts (unpublished), Iwasa *et al.* (1982), Bailey and Habib (1982), Bailey (1983).

Coelenterates
- unid. siphonophores

Crustacea
- unid. copepods
- Stomatopods
  - *Squilla* sp
- Hyperiid Amphipods
  - *Parathemisto gaudichaudii*
  - *Phronima sedentaria*
  - *Phrosina semilunata*
  - *Brachyscelus crusculum*
  - *B. rapacoides*
  - *Hemityphus rapax*
  - *Vibilia* sp.
- Euphausids
  - *Euphausia similis*
  - *E. spinifera*
  - *E. superba*
  - *Nematoscelis megalops*
  - *Nyctiphanes australis*
  - *Pseudoeuphausia latifrons*
  - *Stylocheiron maximum*
  - *S.* sp.
  - *Thysanoessa gregaria*
  - *Thysanopoda acutifrons*
  - *T. aequilis*
- Natants
  - *Acanthephyra* sp.
  - *Chlorotocus novaezealandiae*
  - *Pasiphaea notosivado*
  - *Sergestes arcticus*
  - *S. armatus*
- Reptants
  - *Ibacus alticrenatus* (phyllosoma)
  - *Jasus* sp. (phyllosoma)
  - *Munida gregaria*
  - *Nectocarcinus* sp. (?)
  - *Ovalipes catharus* (megalopa)
  - *Plagusia chubrus* (megalopa)

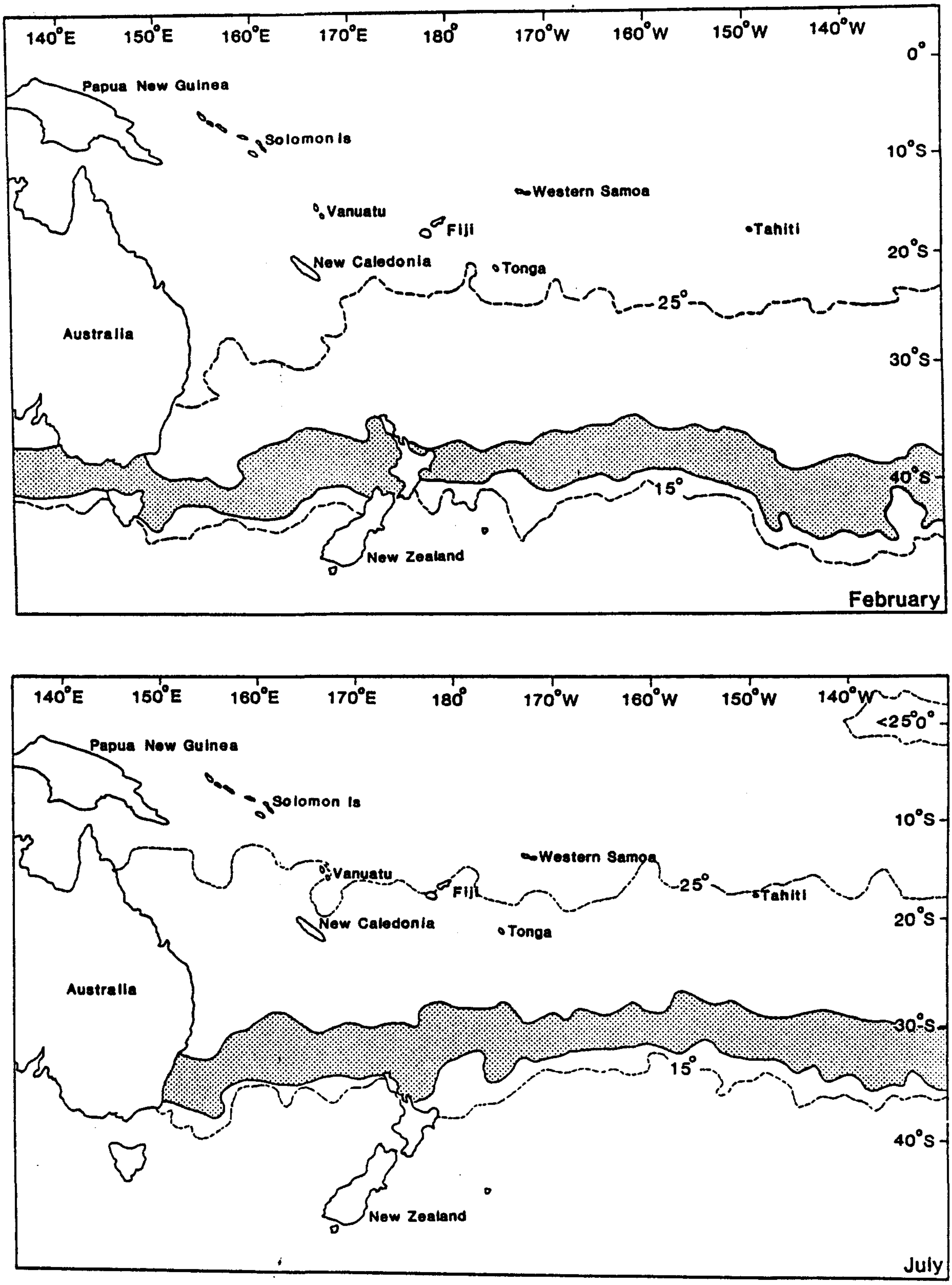
Molluscs
- unid. pteropods
- Cephalopods
  - *Argonauta* sp.
  - *Bathyteuthis abyssicola* (?)
  - *Heteroteuthis* sp.
  - *Histioteuthis* sp.
  - *Iridioteuthis maoria*
  - *Lycoteuthis* sp.
  - *Moroteuthis* sp.
  - *Neoteuthis* sp. (?)
  - *Nototodarus sloani*
  - *Octopoteuthis* sp.
  - *Octopus* sp.

Sepioloidea pacifica
Spirula spirula
Todarodes filippovae
unid. cranchiid
unid. sepiolid

Salps
Salpa sp.

Teleosts
Aldrichetta forsteri
Allomycterus jaculiferus
Argyropelecus sp.
Brama brama
Chauliodus sloani
Cubiceps caeruleus
Decapterus koheru
Engraulis australis
Emmelicthys nitidus
Hippocampus sp.
Idiacanthus sp.
Lepidopus caudatus
Lestidiops pacificum
Macrorhamphosus gracilis
Maurolicus muelleri
myctophids
Hygophum hygomi
Symbolophorus boops
Lampanyctodes hectoris
Lampanyctus alatus australis
Ceratoscopelus townsendi
Oreosoma atlanticum
Plagiogeneion rubiginosus
Rexea solandri
Sardinops neopilchardus
Scomber australasicus
Scomberesox saurus
Stomias boa boa
Thyrsites atun
Trachurus declivis

Figure 1: The distribution of 17 - 19°C water (stipled area) in summer and winter months of 1982 in the southwest Pacific based on mid-month GOSSTCOMP portrayls for February and July.



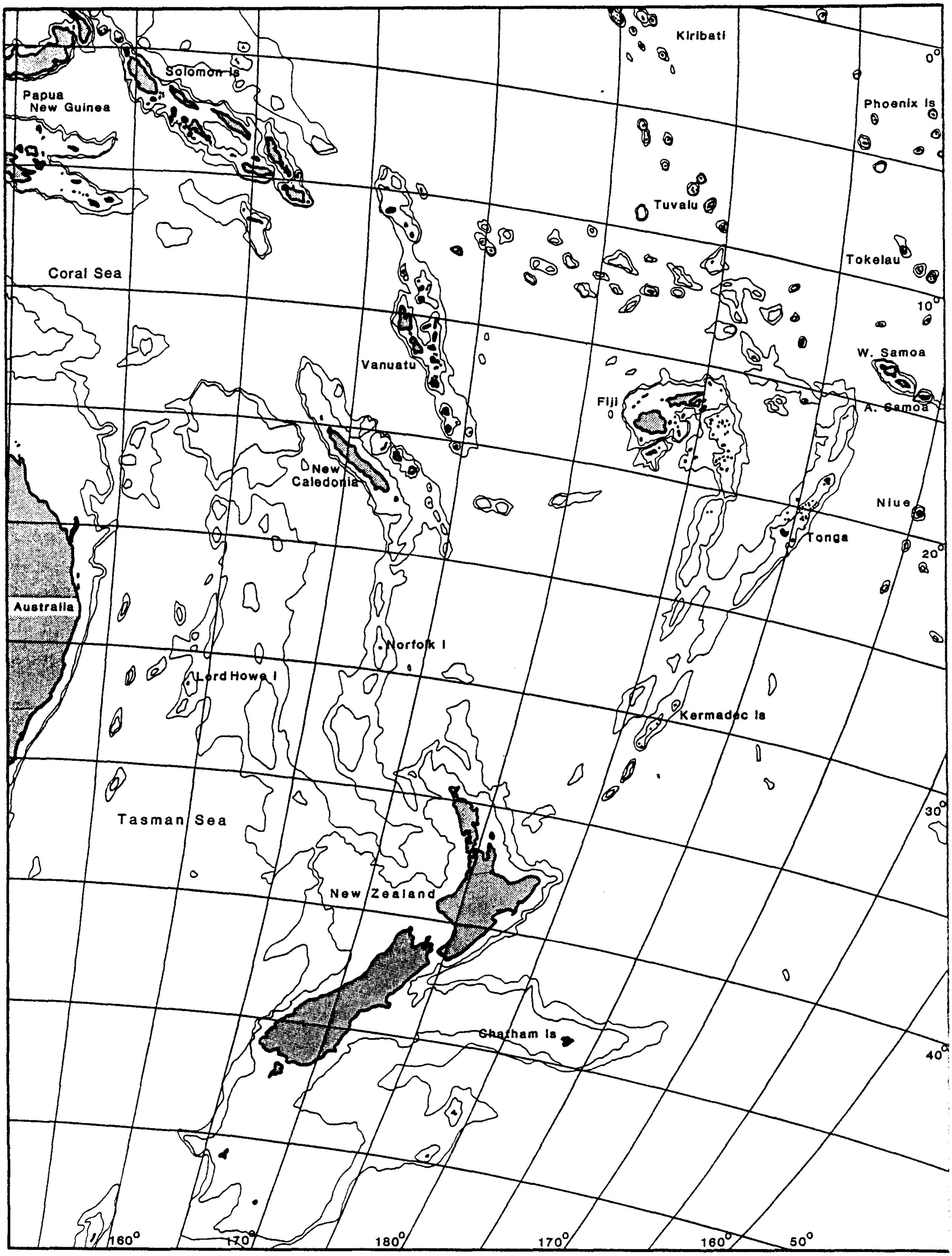


Figure 2: The southwestern Pacific Ocean
(Depth contours are 1000 and 2000m.Scale 1:15 000 000)