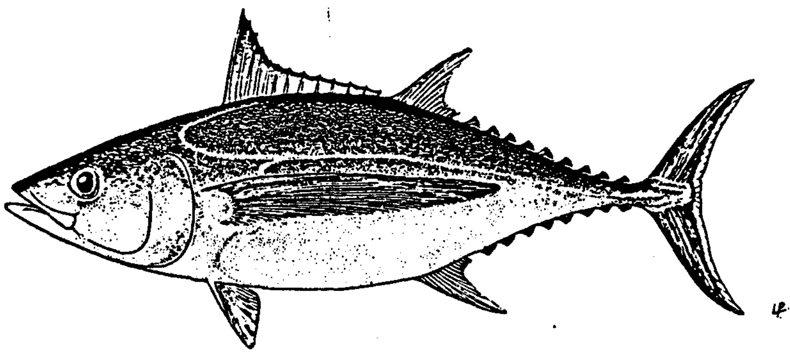
WPS

SOUTH PACIFIC ALBACORE STOCK STRUCTURE: A REVIEW OF AVAILABLE INFORMATION.

A. D. Lewis



Third South Pacific Albacore Research Workshop
Working Paper No. 5

South Pacific Commission
Noumea, New Caledonia
9-12 October 1990

1. INTRODUCTION

Albacore are widely distributed in all three oceans between 40°N and 40°S[1] although abundance is relatively low in equatorial areas. They are captured in often geographically separated surface (trolling, pole and line, driftnet) and longline fisheries, and are known to be capable of extensive movement. Knowledge of their stock structure is thus fundamental to stock assessment and management. The concept of a unit stock is subject to a diversity of definitions in fisheries science, many of which address an underlying genetic basis. It is here defined in functional terms as being 'an appropriate group of fish that can be treated as a homogeneous or independent unit' (Gulland, 1983). This is the case if 'possible differences within the group and interchanges with other groups can be ignored without making conclusions reached ... unacceptable..' It is assumed that members of a unit stock will share the same population parameters.

Questions that arise in defining albacore stock structure, and particularly South Pacific albacore are as follows:-

(a) Are South Pacific[2] albacore a separate stock from North Pacific albacore?

(b) Are South Pacific albacore a separate stock from Indian and Atlantic Ocean albacore?

(c) Do South Pacific albacore constitute a single unit stock?

In delineating stocks, several classes of information are commonly considered (Gulland, 1983)

(i) discontinuities in distribution, as reflected in catches by fishing vessels;

(ii) location of spawning areas (this may enable (genetic) separation of stocks which may otherwise intermingle to some extent);

(iii) differences in population parameters, eg. growth, size structure, mortality;

(iv) differences in measurable hereditary characters or markers, eg. isozyme allele frequencies, mitochondrial DNA sequences, chromosome banding;

(v) tagging data;

(vi) differences in acquired characters, eg. parasites.

Consideration of available information on South Pacific albacore in each of these categories is the primary task of this review. The considerable body of information on Atlantic and to a lesser extent, Indian Ocean albacore is generally not considered.

2. REVIEW OF ALBACORE INFORMATION

2.1 Distribution

Albacore appear to be differentially distributed at various life history stages. Larvae occur generally between 5°-25° latitude (mostly 15-20°); distribution of juveniles (15-50 cm LCF) is less well known;

---

[1] except in the Indian Ocean where the ocean area north of the Equator is relatively small.

[2] South Pacific = south of the Equator

surface concentrations of sub-adults (50-90 cm LCF) occur in temperate waters (30°-40° latitude) and support fisheries in these areas. Distribution of adults is probably the widest, with low relative abundance both in equatorial waters and wide areas of the eastern Pacific, related to temperature limitation (Sund et al., 1981). Catches of adults are made primarily by longline gear, mostly between 10°-30° latitude in the case of the South Pacific, but at higher latitudes in the North Pacific.

Longline data, and particularly Japanese longline data, are the most complete for examining stock structure questions, and in particular question (b), since much longline effort targeting on southern bluefin tuna extends well south of the nominal (40°S) limits of albacore distribution, and is continuous across the Southern Ocean.

Examination of catch and effort statistics for the years 1976-1980[3] inclusive (Fisheries Agency of Japan, 1978-1982) reveals the following consistent patterns in albacore longline hooking rates by quarter (Fig. 1, data for 1980, provides a representative illustration):

- low albacore catches off south-west Australia and south-east Australia in the first quarter (January-March), with negligible catches across the Great Australian Bight;
- moderate albacore catches continuously across the Great Australian Bight in the second quarter (April-June);
- negligible albacore catches across the Great Australian Bight during the third and fourth quarters.

Particularly as albacore is not the target species, and catch rates therefore probably underestimate abundance, it is concluded that there is evidence for potential interchange of albacore between the South Indian and South Pacific Oceans, particularly during the second quarter. Anecdotal information on surface sightings of sub-adults in South Australian waters is also available (K. Williams, J. Hampton, pers. comm.);

These data can also be used to examine Indian Ocean/Atlantic Ocean distribution:

- south of the Cape of Good Hope (35°S), catches of albacore are made in every quarter.

It is therefore concluded there is no barrier to free interchange of albacore between Indian and South Atlantic Oceans. Morita (1977), in a much more detailed study examining a large series of length frequency data as well as catch/effort data, reached a similar conclusion.

The southwards extension of the South American continent to 56°S acts as an effective barrier to direct albacore interchange between the Pacific and Atlantic Oceans.

The Japanese longline data are also useful to examine albacore catches in equatorial areas, and thus question (a). Virtually no albacore catches are made between 5°N and 5°S in the Pacific Ocean (albacore in the Indian Ocean do not occur north of the Equator). This fact, combined with the existence of discrete non-overlapping North Hemisphere/South Hemisphere spawning grounds (and spawning seasons), clear discontinuities in larval distribution and the absence of sub-adults in equatorial surface waters, support the conventional belief that North and South Pacific albacore constitute separate unit stocks. There are, however, occasional longline catches made on the Equator (Wetherall, Riggs and Yong, 1979). It should also be noted in passing that the pattern of longline effort differs quite markedly between the two hemispheres.

---

[3] Publication of these data has been discontinued since that time.

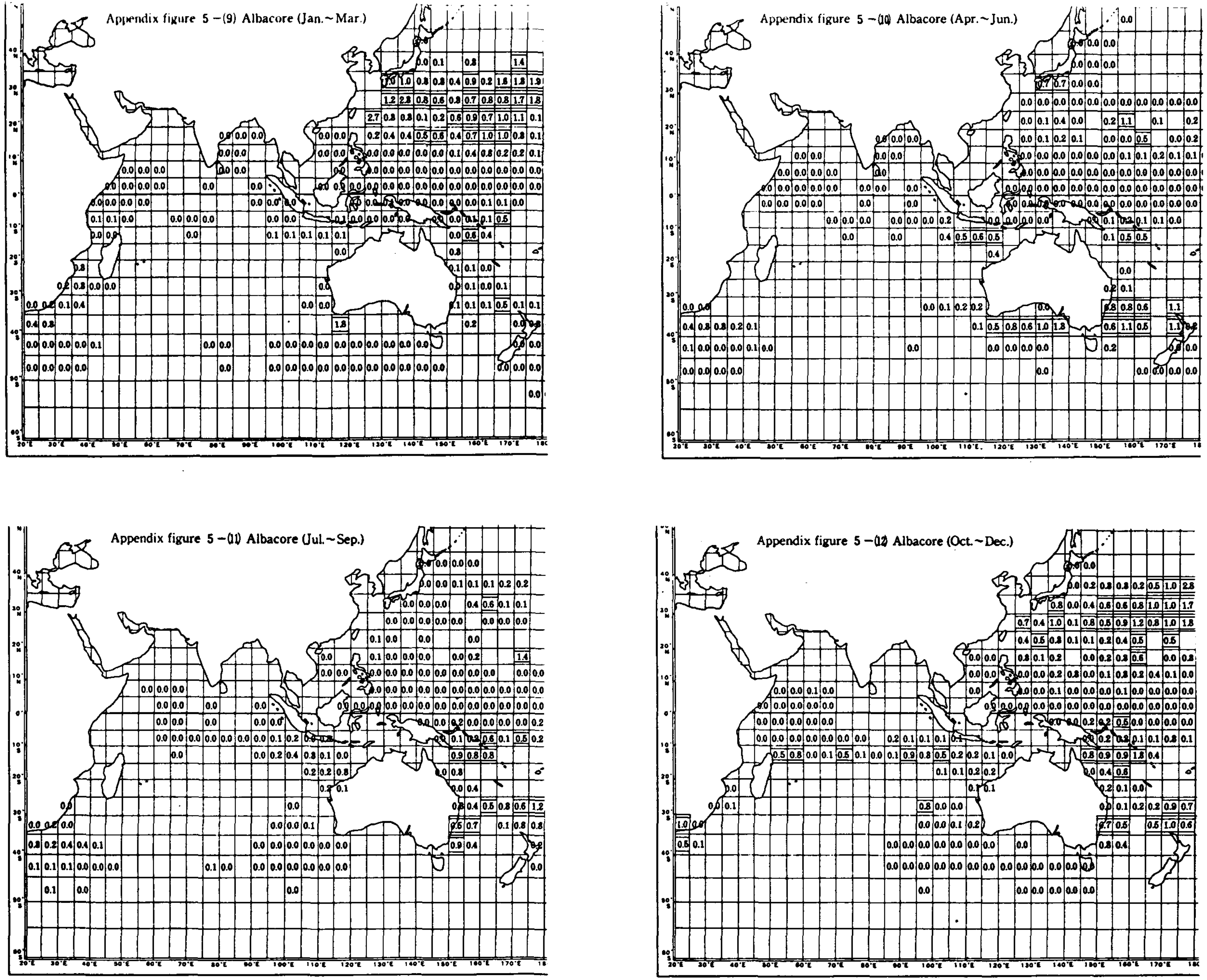


Fig. 1. Catch per effort data (hook rate per 100 hooks) for longliners of Japan, by quarter, 1980. (Figures from JFA, 1982.)

Nakamura (1969) reviewed available information from South Pacific longline fisheries (hook rate, size composition, oceanographic discontinuities) in considering ecological/size segregation in South Pacific albacore, and concluded that segregation by size was much less distinct than in the North Pacific, possibly related to the less clear differentiation of water masses.

2.2 Spawning areas

Spawning areas for albacore have been established on the basis of gonad examination and larval distribution (S. Pacific -Ueyanagi, 1969; Yoshida, 1971; Nishikawa et al., 1985). On these grounds, it has been generally accepted that albacore spawn in summer in sub-tropical Pacific waters centred on 20°N and 20°S. These spawning grounds are thus symmetrically distributed in the two hemispheres, with temporal separation of spawning seasons. (Figure 2)

It has recently been suggested, from growth studies based on daily otolith increments (Wetherall et al., 1989), that spawning of albacore in the South Pacific may be semestral. The larval distribution data are admittedly very incomplete and larvae/juveniles have been collected outside the summer months. (Argue et al., 1983) The geographical separation between Northern and Southern Hemisphere spawning grounds is however not contested, this potentially providing a mechanism for division into genetically distinct hemispheric stocks.

Spawning grounds located at similar latitudes are described for the other oceans. The South Pacific and South Indian Ocean spawning areas which potentially inter-connect are separated by extensive areas of unsuitable larval habitat.

2.3 Population parameters

Few data are available on population parameters, such as growth, and mortality, of South Pacific albacore to enable inter-areal comparisons, although there is considerably more data for North Pacific and more recently, Indian Ocean albacore. Table 1 summarizes von Bertalanfly growth parameters obtained from these studies.

Table 1. Comparison of von Bertalanffy growth parameters for Pacific albacore. (One recent Indian Ocean study is also included.)

Source	L_∞	k	t_0
Western North Pacific 1	104.8	0.431	1.504
North Pacific 1	114.4	0.308	0.818
North Pacific 1	145.3	0.159	-0.056
North Pacific 2	125.0	0.184-0.199	n/a
Eastern North Pacific 1	108.8	0.2247	-2.2728
Western North Pacific 1	145.3	0.150	-0.396
North Pacific 1	118.8	0.250	1.999
South Pacific 3	192.0	0.06	-3.3
Indian Ocean 4	128.1	0.162	0.897

1 Foreman (1980)
2 Laurs and Wetherall (1981)
3 Murray and Bailey (1989)
4 Huang et al. (1990)

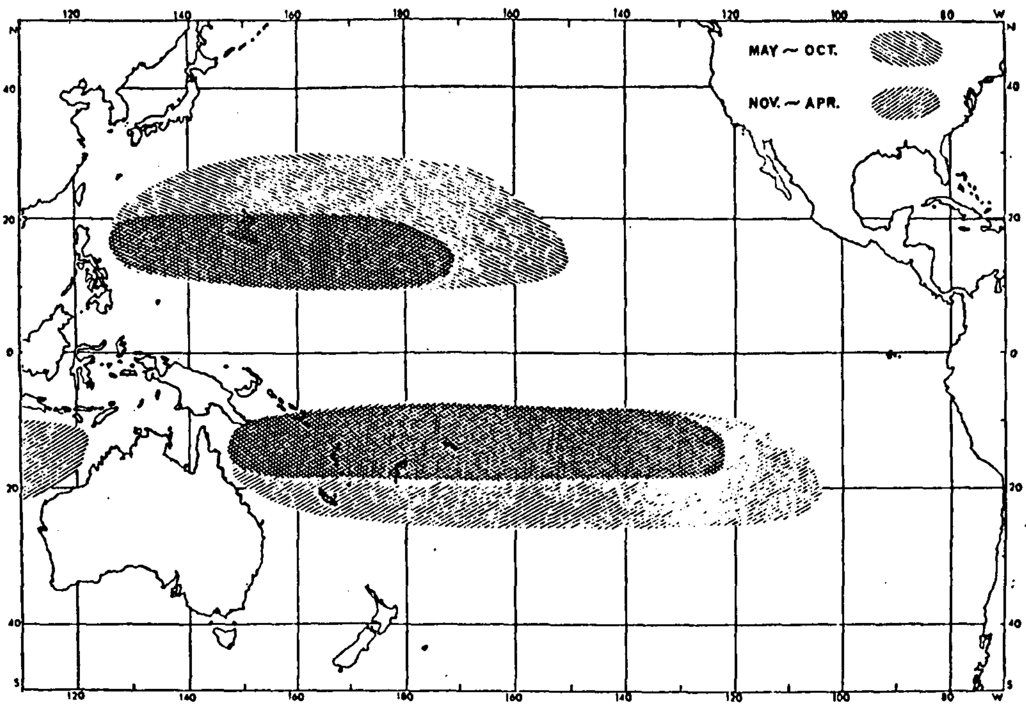


FIGURE 2. Distribution of albacore larvae in the Pacific Ocean (from Ueyanagi, 1969). The spawning areas are coincidental with larval distribution.

The limited South Pacific growth data show some incompatibility with data from daily otolith increments (Wetherall et al., 1989) suggesting higher growth rates than those from the small amount of tag return data, a preliminary study using caudal vertebrae (Murray and Bailey, 1989) and most North Pacific estimates. A companion paper examines this question using available length-frequency data for South Pacific albacore. (Hampton, Fournier and Sibert, WP.1)

Laurs and Wetherall (1981) used tagging data to demonstrate different growth rates in two groups of North Pacific albacore which were consistent with differences in length frequency distributions. The two groups also exhibited different migration patterns. In the South Pacific, knowledge of population parameters is not sufficient to be able to contribute to understanding stock structure.

2.4 Measurable hereditary characters

It can be reasonably assumed that unit stocks should be separable in most cases on the basis of differences in genetically determined characters. If such genetic differences can be demonstrated for units separated on other criteria (eg. geographic discontinuity in distribution), the units can be assumed to constitute distinct stocks. The converse is however not necessarily valid, a point not well understood, as Graves and Dizon (1989) point out.

Most work with albacore genetic characters has involved North Pacific albacore, seeking ultimately to determine differences between the two groups of albacore described earlier. Graves and Dizon (1989) examined in the first instance, mitochondrial DNA from the South Atlantic (Capetown, South Africa) and the North Pacific (San Diego, USA). No restriction sites were found which could distinguish Atlantic from Pacific albacore. Whilst this result does not preclude the possible of genetic differentiation in other unexamined characters, the authors concluded that the two groups of fish had either been separated for a short period of time in evolutionary terms or there was sufficient gene flow to prevent differentiation. (The rate required is small indeed.) On the basis that inter-oceanic differences could not be demonstrated, no intra-oceanic (i.e. S. vs. N. Pacific) comparisons were undertaken.

Graves and Laurs (1981) had earlier conducted electrophoretic analysis of albacore tissue to detect genetic variability at various enzyme loci. Such variability can be used to establish allelic frequency differences between stocks or genetic units. Forty-six loci were screened initially in 5 tissues, but scored in eye tissue, with only 3 of these loci weakly polymorphic. A fourth (GPI-A) was highly polymorphic and hence useful for population studies. A low overall heterozygosity of 0.017 was recorded.

The present author, in a comparative study of electrophoretic variation in 21 Indo-Australian scombrid species, using liver tissue, obtained rather different results from a sample of 22 South Pacific albacore (Lewis, 1981). Of the 27 loci examined, four were highly polymorphic (ADA, GDA (not screened in North Pacific material), PGM-2 (presumed screened but not recorded as polymorphic) and GPI (as in North Pacific). There was additionally another moderately polymorphic locus (SORDH - monomorphic in North Pacific)). A moderately high overall heterozygosity value of 0.102 was obtained, this value exceeded only by wahoo in the species array studied. Additionally, a polymorphic serum esterase was detected in blood samples with an allele not found in a larger North Pacific sample analyzed earlier by Fujino (1970).

These apparently significant differences would seem worthy of further investigation in considering North and South Pacific stock differences. Further, the presence of at least four highly polymorphic and relatively stable loci in South Pacific material would lend itself to investigation of any proposed differentiation within the South Pacific area.

Ratty et. al., (1986) carried out chromosomal analysis (C-banding) on North Pacific albacore, skipjack and yellowfin, as a prelude to evaluating genetic heterogeneity in North Pacific albacore. The study provided useful information on speciation processes within the Thunnini, with the authors concluding that further C-banding and possibly G-banding could prove useful for detecting differentiation in albacore populations. This appears not to have been taken further.

The author is unaware of morphometric or meristic approaches to stock differentiation in albacore.

2.5 Tagging

A large amount of tagging in the North Pacific over many years has elucidated details of the quite complex patterns of movement (eg. Otsu and Uchida, 1963), these involving regular trans-oceanic migration. Recent data (Laurs and Lyn, 1977) have suggested the existence of two groups of albacore in the North Pacific (see earlier). No recaptures of albacore have been recorded in the South Pacific, despite the large number of North Pacific releases, and relatively intensive longline effort in the South Pacific.

Albacore tagging in the South Pacific has been carried out under the auspices of SPAR, since 1986, by NMFS, ORSTOM and NZ MAFFish, and by a gamefish tagging programme in eastern Australia. The releases by time/area strata are listed in Table 2. Of these nearly 7,000 SPAR releases, only 7 recaptures have been recorded to date. Details of these recaptures are given in Table 3 and Figure 3. Albacore have also been tagged in eastern Australia in a game fishing tagging programme. (NSW Fisheries Research Institute, pers. comm.), to produce over 1900 releases for 5 recaptures. The relatively small number of returns to date does not allow realistic consideration of stock structure.

We are unaware of any tag releases of albacore in the Indian Ocean.

2.6 Acquired characters (other than tags)

One attempt has been made to deduce albacore movements in the South Pacific from parasite data, particularly didymozoid trematodes (Jones, 1989). This study speculated that there is a general easterly movement of juvenile albacore from New Zealand along the Sub-Tropical Convergence Zone, with adult fish moving north to spawn and returning again after spawning.

3. DISCUSSION

3.1 South Pacific - North Pacific albacore

There seems no reason to challenge the general belief that hemispheric stocks exist in the Pacific, on the basis of the general discontinuity in distribution at the Equator, the geographically separate spawning grounds, likely temporally separate spawning seasons, and the lack of tag returns in the South Pacific from a large number of North Pacific tag releases.

There may be sufficient interchange between the two hemispheres, based on occasional longline capture of adults in the Equator, to minimize genetic differentiation through gene flow. For management purposes, the stocks can be regarded as functionally distinct, according to the present definition.

The possible differences suggested by the electrophoretic analysis may be worth pursuing, if only as a preliminary to a detailed electrophoretic study of intra-South Pacific genetic variation.

3.2 South Pacific - Indian Ocean albacore

Despite the clear potential for limited interchange of albacore between the two areas in the second quarter, based on longline data, stocks can probably be regarded as functionally distinct.

Table 2. Albacore tagging in the South Pacific 1986-1990

1. Releases in New Zealand waters

R.V. Kaharoa	Nov-Dec 1986	West Coast North Island (Reef Pt to North Taranaki Bight)	138
	Feb 1987	East Coast North Island (Madden Banks)	178
	Jan 1988	" " " " " " "	211
	Feb 1988	West Coast North Island (North Taranaki Bight)	370
	Feb-Mar 1988	Chatham Rise	45
	Jan-Feb 1989	West Coast South Island	855
	April 1989	South East Coast North Island	56
	Jan-Feb 1990	West Coast South Island	815
Commercial trollers (2)	Jan-Feb 1987	West Coast South Island (Westport to Hokitika)	70
(1)	Feb 1988	East Coast North Island (Cape Runaway)	19
			2757

2. Releases in Australian waters

NSW Fisheries Research Institute Gamefish Tagging Programme	1981-89	NSW Coast	1691
	1989-90	NSW Coast	210est
			1901app.

3. Releases in the central South Pacific

R.V. Townsend Cromwell	Feb 1986	37° - 40°S, 153° - 146°W	21
	Jan-Feb 1987	36° - 40°S, 165° - 149°W	425
R.V. Coriolis	Feb-Mar 1987	38° - 41°S, 138° - 127°W	190
Commercial trollers	Feb-Mar 1986	38° - 41°S, 155° - 140°W	702
	Jan-Apr 1987	36° - 40°S, 155° - 145°W	456
	Dec 1987 - Apr 1988	38° - 40°S, 165° - 155°W	757
	1988-89		1499
	1989-90		?
			4050 +

NOTES:

(i) The Hatsumori Maru tagged and released 3 albacore in New Zealand waters and 16 in Australian waters while under charter to SPC in 1979.

(ii) The JAMARC R.V. Kaio Maru tagged 301 albacore in New Zealand waters from 1981 to 1982.

(iii) New Zealand MAF tagged 1200 albacore in New Zealand waters from 1972 to 1975.

(iv) CSIRO tagged 65 albacore in NSW waters from 1960-63 and 38 in S. Australian waters in 1984 as part of its SBT tagging programme.

Table 3. Recaptures of tagged albacore in the South Pacific

	Release Information				Recapture Information (see Fig. 3)						
	Date	Lat.	Long.	Size (cm)	Date	Lat.	Long.	Size (cm)	Days free	Minimum distance moved (n mile)	Vessel
a	28 Feb 1986	40°32'S	150°36'W	72	14 Jul 1988	26°02'S	167°28'W	88	868	1205	Asian longliners
b	9 Mar 1986	40°20'S	145°50'W	78	16 Apr 1987	38°23'S	133°45'W	86	404	570	"
c	30 Jan 1987	37°42'S	153°37'W	80	6 Jun 1988	32°38'S	153°41'W	92	494	300	"
d	27 Feb 1987	40°39'S	177°00'E	76	13 Aug 1987	30°40'S	171°45'E	80	199	730	"
e	28 Feb 1987	39°43'S	151°04'W	64	27 Apr 1987	38°23'S	145°38'W	?	59	260	"
f	25 Feb 1987	40°21'S	177°11'E	80	18 Aug 1989	42°15'S	170°05'E	96.5			New Zealand troller
g	1 Feb 1988	38°24'S	173°00'E	61	26 Dec 1988	38°47'S	158°33'E	?			Japanese drifnet
h-l	Australian recaptures from NSW releases; all within 400 km of release point. Full data not available										

NOTE:

Release type

d, f, g = NZ releases in EEZ
a, b, c, e = US releases in SCTZ
h, i, j, k, l = NSW State Fisheries Gamefish Tagging Programme.

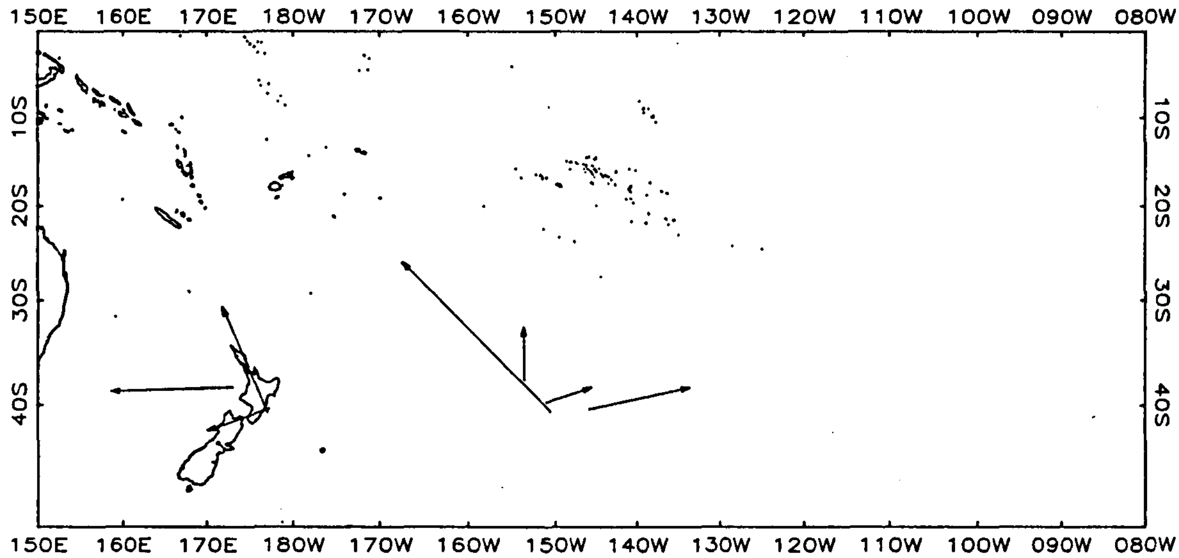


Fig. 3. Movements of tagged albacore in the South Pacific (1986-1988)

Indian Ocean and South Atlantic stocks would however seem to be subject to greater interchange. By extension, the absence of mitochondrial DNA differences between South Atlantic and North Pacific albacore is not altogether surprising.

3.3 South Pacific albacore

There is presently insufficient information from tagging data, population parameters and other characters (hereditable or acquired) to consider whether or not South Pacific albacore constitute a single homogeneous stock from a management viewpoint. Data available in most cases is rudimentary and considerably more basic research is required.

There has been some speculation as to the origins of sub-adult albacore caught in the Tasman Sea and those along the Sub-Tropical Convergence Zone (Murray and Bailey, 1986; Laurs, pers. comm.), based on the very limited tagging data and the parasite study.

If so, this would suggest a situation possibly analogous to that described for the North Pacific, with two groups of fish showing very little interchange (Laurs, 1979) - a 'northern sub-stock', making trans-Pacific migrations and resulting in regular movement between the U.S. surface fishery north of 40°N, and the Japanese surface and longline fisheries; and a 'Southern sub-stock', showing movement only between the U.S. surface fishery south of 40°N, and the longline fishery east of 180° i.e. not trans-Pacific.

The analogy is probably not appropriate, given the quite different oceanographic structure of the North and South Pacific Oceans. There is no feature in the South Pacific corresponding to the Transition Zone off the U.S. west coast, so important to concentrating albacore migrating from the central Pacific and indeed albacore appear in general to be not abundant in the eastern South Pacific (E of 90°W). No commercial fishery exists off the South American coast, even though a minor one has operated off Chile in some years (see Foreman, 1981) and sub-adult albacore do occur at the surface as far east as Easter Island (109°W). The expanding troll fishery along the STCZ now operates as far east as 120°W.

Longline effort, as noted earlier, is also distributed quite differently in the North and South Pacific.

Tagging work planned for the future may add to our understanding of South Pacific albacore stock structure although results to date, at least in terms of recovery rates, have not been encouraging. There is scope for electrophoretic investigation, given the apparent availability of suitable genetic markers. As such data become available, combined with steadily accumulating length-frequency data from the newly developed (in most cases) surface fisheries, a re-examination of historical longline catch/effort and size data may become worthwhile.

At the present time, it would seem appropriate to regard South Pacific albacore as a functional unit stock, with the majority of the standing biomass occurring west of 100°W.

BIBLIOGRAPHY

ARGUE, A.W, F. CONAND, and D. WHYMAN (1983). Spatial and temporal distribution of juvenile tunas from stomachs of tunas caught by pole-and-line gear in the central and western Pacific Ocean. South Pacific Commission, Tuna and Billfish Assessment Programme, Technical Report No. 9, 47pp.

FISHERIES AGENCY OF JAPAN, 1978-1982. Annual report of effort and catch statistics by area on Japanese tuna longline fishery, 1976-1980.

FOREMAN, T. (1980) Synopsis of biological data on the albacore tuna, *Thunnus alalunga* (Bonnaterre, 1788) in the Pacific Ocean. I-ATTC, La Jolla, California.

FUJINO, K. (1979) Immunological and biochemical genetics of tunas. Trans. Am. Fish. Soc. 99 (1): 152-178.

GRAVES, J.E and A.E. DIZON. (1989) Mitochondrial DNA sequence similarity of Atlantic and Pacific albacore tuna *(Thunnus alalunga)*. Can. J. Fish. Aquat. Sci. 46: 870-873.

GRAVES, J. and R.M. LAURS. (1981) An electrophoretic investigation of protein variability in the north Pacific albacore. NOAA SWFC Admin. Rept. LJ-81-22.

GULLAND, J.A. (1983). Fish stock assessment: a manual of basic methods. (FAO/Wiley Series on Food and Agriculture, Vol. 1.) A Wiley Interscience Publication.

HUANG, C.S., C.L. WU, C.L. KUO and W.C. SU (1990). Age and growth of the Indian Ocean Albacore, *Thunnus alalunga*, by scales. IPTP TWS/90/53.

JONES, J.B. (1989). Movements of albacore tuna *(Thunnus alalunga)* in the South Pacific: evidence from parasites. Paper prepared for the 2nd SPAR Workshop, Fiji, 1989.

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. Fishery Bulletin 75 (4): 795-822.

LAURS, R.M. and J.A. WETHERALL (1981). Growth rates of North Pacific albacore, *Thunnus alalunga*, based on tag returns. Fishery Bulletin 79 (2): 293-302.

LEWIS, A.D. (1981) Population genetics, ecology and systematics of Indo-Australian scombrid fishes, with particular reference to skipjack tuna *(Katsuwonus pelamis)*. Unpublished Ph.D thesis, ANU, Canberra.

MORITA, S. (1977) On the relationship between the albacore stocks of the South Atlantic and Indian Oceans. ICCAT SCRS/77/85, p.232-237.

MURRAY, T. and K. BAILEY (1986). Results from recent albacore research cruises. Catch 13 (11): 17-18.

MURRAY, T. and K. BAILEY (1989). Preliminary report on age determination of South Pacific albacore using caudal vertebrae. Paper prepared for 2nd SPAR Workshop, Fiji, 1989.

NAKAMURA, H. (1969) Tuna distribution and migration. Fishing News (Books) Ltd., London: 76pp.

NISHIKAWA, Y.M. HONMA, S. UEYANAGI and S. KIKAWA (1985). Average distribution of larvae of oceanic species of scombroid fishes, 1956-1981. Far Seas Fisheries Research Laboratory, Contribution No. 236.

RATTY, F.J., Y.C. SONG and R.M. LAURS (1986). Chromisomal analysis of albacore, *Thunnus alalunga,* and yellowfin, *Thunnus albacares,* and skipjack, *Katsuwonus pelamis,* tuna. Fishery Bulletin 84 (2): 469-476.

SUND, P.N., M. BLACKBURN and F. WILLIAMS (1980). Tuna and their environment in the Pacific Ocean: Mar. Biol. Ann. Rev., 19: 443-512.

UEYANAGI, S. (1969b) Observations on the distribution of tuna larvae in the Indo-Pacific Ocean with emphasis on the delineation of the spawning areas of albacore, *Thunnus alalunga*. Far Seas Fish. Res. Lab., Bull., 2: 177-256.

WETHERALL, J.A., F.V. RIGGS and M.Y.Y. YONG (1979). Assessment of South Pacific albacore stock. U.S. Nat. Mar. Fish. Serv., Southwest Fish. Center, Admin. Rep. H-79-6: 17pp.

WETHERALL, J.A., R.N. NISHIMOTO and M.Y.Y. YONG (1989). Age and growth of South Pacific albacore determined from daily otolith increments. Paper prepared for 2nd SPAR Workshop, Fiji, 1989.

YOSHIDA, H.O. (1971) Distribution, apparent abundance, and length composition of juvenile albacore, *Thunnus alalunga*, in the South Pacific Ocean. U.S. Nat. Mar. Fish. Serv., Fish. Bull., 69 (4): 821-827.