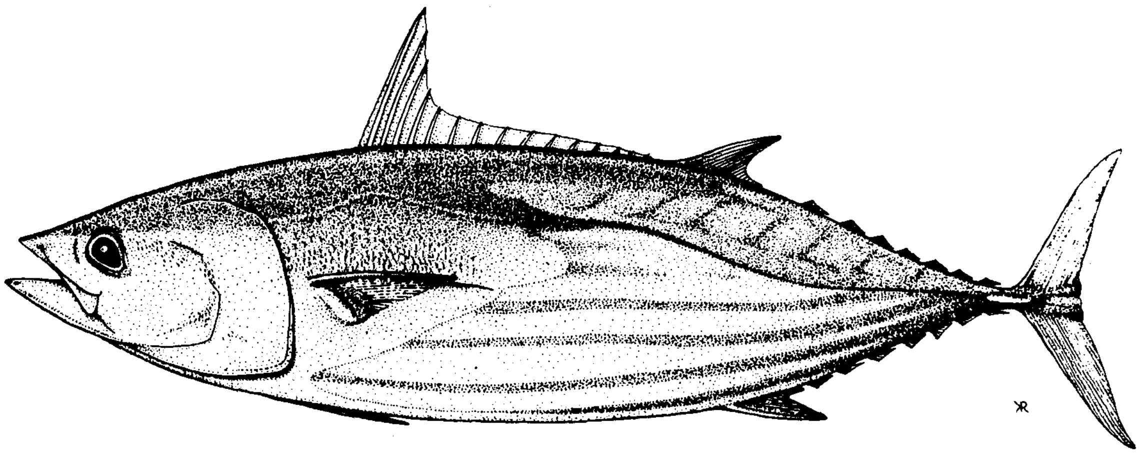
AN ASSESSMENT OF THE SKIPJACK AND BAITFISH RESOURCES OF TOKELAU



Skipjack Survey and Assessment Programme
Final Country Report No. 10

South Pacific Commission
Noumea, New Caledonia
September 1983

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PREFACE

The Skipjack Survey and Assessment Programme was an externally funded part of the work programme of the South Pacific Commission. Governments which have provided funding for the Programme were Australia, France, Japan, New Zealand, United Kingdom and the United States of America, and the generosity of these governments is gratefully acknowledged.

The Skipjack Programme has been succeeded by the Tuna and Billfish Assessment Programme which is receiving funding from Australia, France, New Zealand and the United States of America. The Tuna Programme is designed to improve understanding of the status of the stocks of commercially important tuna and billfish species in the region. Publication of final results from the Skipjack Programme, including results from the Programme's investigation of yellowfin tuna resources of the region, is continuing under the Tuna Programme. Reports for each of the countries and territories for which the South Pacific Commission works have been prepared in a final country report series. Most of these reports have been co-operative efforts involving all members of the Tuna Programme staff in some way.

The staff of the Tuna Programme at the time of preparation of this report comprised the Programme Co-ordinator, R.E. Kearney, Research Scientists, A.W. Argue, C.P. Ellway, R.S. Farman, R.D. Gillett, P. Kleiber, J.R. Sibert, W.A. Smith and M.J. Williams; Research Assistants, Susan Van Lopik and Veronica van Kouwen; and Programme Secretary, Carol Moulin.

The Skipjack Programme is grateful for the assistance provided by the people of Tokelau, especially the residents of Atafu and Fakaofo Atolls. The Director of the Department of Agriculture and Fisheries, Semu Uili, was extremely helpful throughout the entire survey and during the subsequent period of data analysis.

Tuna Programme
South Pacific Commission

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AN ASSESSMENT OF THE SKIPJACK AND BAITFISH RESOURCES OF TOKELAU

1.0 INTRODUCTION

The Skipjack Survey and Assessment Programme was created in response to rapid expansion of surface fisheries for skipjack (*Katsuwonus pelamis*) in the waters of the central and western Pacific during the 1970s. The objectives of the Skipjack Programme were to survey the skipjack and baitfish resources within the area of the South Pacific Commission, and to assess the status of the stocks and the degree of interaction between fisheries for skipjack within the Commission region and beyond. These assessments provide a basis for rational development of skipjack fisheries and sound management of the resource.

Tagging and survey operations in the central and western Pacific carried out by the Skipjack Programme between October 1977 and August 1980 totalled 847 days. The study area included all of the countries and territories in the area of the South Pacific Commission and also the waters of northern New Zealand and eastern Australia (Figure A, inside front cover). Five days, 19-23 November 1978, were spent in the waters of Tokelau. Preliminary results of this survey were reported by Kearney and Gillett (1979).

This report presents final analyses of the work of the Skipjack Programme in Tokelau. This information, together with available data on fishing activities in Tokelau and results from adjacent areas where the Skipjack Programme carried out research, is used to assess the skipjack and baitfish resources of Tokelau.

1.1 Description of the Fishery

Around the islands of Tokelau fishing for skipjack is still carried out using traditional Polynesian methods. Although modern trolling gear has been introduced during recent years, the local Tokelau skipjack fishery could be considered, along with those of some of the isolated atolls in the Caroline Islands, as the most traditional in the South Pacific Commission (SPC) area. MacGregor (1937) and Keen (1976) have described the Polynesian fishing techniques used in Tokelau. Important characteristics of the fishery include lengthy training of potential fishermen, the use of pearl-shell lures, and the division of the catch among the community.

Changes have occurred in the Tokelau fishery in recent years. Most notably, many canoes are now powered with outboard motors and motorised skiffs have been introduced. Crossland and Grandperrin (1979) estimated that there were 244 private fishing craft in Tokelau in 1979, about half of which were classified as "open motor boats", and the remainder as large or small canoes. Although fishery statistics are not collected, the skipjack catch is thought to be about 18 tonnes per year (Semu Uili, Tokelau Department of Agriculture and Fisheries, personal communication).

In the 290,000 square kilometres (Anon 1981a) of the 200-mile exclusive economic zone of Tokelau, skipjack catches have occasionally been made by Japanese long-range pole-and-line vessels using live bait transported from Japan. These vessels recorded annual catches in the waters of Tokelau of 10 to 1,705 tonnes of skipjack from 1975 to 1978 (Skipjack Programme 1980). During this period their average tuna catch per fishing day was high, 9.8 tonnes, and was exclusively skipjack. Due to the distance from Japan, Tokelau has usually been on the extremity of the normal fishing area for pole-and-line vessels. However, a recent publication (Tanaka 1981) shows that a significant portion of the Japanese distant-water catch in the month of September 1980 came from the general Tokelau area. No other nation has pole-and-line vessels operating in Tokelau, although Fijian pole-and-line vessels have recently fished in the adjacent Tuvalu and Kiribati zones during the off-season in Fiji.

Asian longliners catch small quantities of skipjack in Tokelau when fishing primarily for the larger tunas and billfish (Table 1). The catch of these species by longliners totalled 1,034 and 450 tonnes in 1975 and 1976 respectively, the two years for which complete data are available.

TABLE 1. LONGLINE CATCH IN TOKELAU, 1973 TO 1976. These data are from Klawe (1978).

Year	Nationality of Longline Vessel	Skipjack Catch (tonnes)	Total Reported Tuna and Billfish Catch (tonnes)
1973*	Japan	<0.01	5
	Taiwan	-	759
1974*	Japan	-	-
	Taiwan	-	25
1975	Japan	-	8
	Korea	2.8	574
	Taiwan	-	452
1976	Japan	<0.01	1
	Korea	0.6	339
	Taiwan	0.4	110

* No Korean data available for these years.

1.2 Previous Surveys

Little formal fisheries research has been carried out in Tokelau. From 1950 to 1961, during the Pacific Oceanic Fisheries Investigations (POFI), the United States Bureau of Commercial Fisheries made 177 research cruises in the Pacific to explore the distribution and abundance of tuna and other fishes. Forty-seven hours of these expeditions were spent in the general area of Tokelau searching for schools of surface tuna; none were observed (Waldron 1964).

In September and October of 1958, the South Pacific Commission fisheries officer made a "general survey of fisheries" of this country (Van Pel 1958). Another South Pacific Commission fisheries officer visited Tokelau in 1971. During three-and-a-half days in Tokelau this officer learned that fishermen were very concerned that Japanese fishing operations were adversely affecting local skipjack and yellowfin catches (Hinds 1971).

The Tokelau Government established a department of Agriculture and Fisheries in 1978. In the same year the Regional Fisheries Co-ordinator of the United Nations Development Programme made a tour of Tokelau during which observations were made on the possibility of capturing baitfish and on the seasonality of surface tunas (Harry Sperling, personal communication).

Purse-seining has not yet been attempted in the waters of Tokelau. Some years ago exploratory purse-seining by American vessels took place in the nearby Phoenix and Line Islands (Anon undated; Murphy and Niska 1953; Murphy and Ikehara 1955). In 1950 and 1951, the purse-seining vessel John R. Manning spotted 75 tuna schools in the Phoenix and Line Islands to the north and east of Tokelau, but was able to set on only eight of them, and only two of the sets were successful (Murphy and Niska 1953). The Sea Treasure, a 1,170 ton purse-seiner, undertook exploratory fishing in the Line Islands in 1974 and made one unsuccessful set (Anon undated). Results from recent purse-seining in the waters of Western Samoa, Fiji and Wallis and Futuna (A. Gonsalves, American Tuna Boat Owners Association, personal communication) once available, will be relevant and useful for Tokelau.

2.0 METHODS

2.1 Vessel and Crew

A Japanese commercial fishing vessel, the Hatsutori Maru No.1 of 192 gross tonnes (Kearney 1982a), chartered from Hokoku Marine Products Ltd. of Tokyo, Japan, was used for the survey of Tokelau. It was operated with three Skipjack Programme scientists, nine Japanese officers, and twelve Fijian crew. The Director of Agriculture and Fisheries of Tokelau was aboard the Hatsutori Maru for the Tokelau survey and for a portion of the preceding survey cruise in the Marshall Islands. Local residents were encouraged to participate in the fishing activities and provided assistance in capturing baitfish. Appendix A lists scientists, observers and crew on board the research vessel while it was in the waters of Tokelau.

2.2 Research Plan and Summary of Activities in Tokelau

Visual scanning and exploratory fishing for tunas and baitfish were the primary survey techniques. Tagging and biological sampling, including skipjack blood and parasite sampling, were the basic tools for the evaluation of skipjack resources. During 30 months of fieldwork the Programme tagged and released over 150,000 tunas, including 140,443 skipjack. Comparison of results from other areas visited by the Skipjack Programme in the central and western Pacific with those obtained in Tokelau and in nearby countries formed the basis for resource assessment.

Five days were spent in the waters of Tokelau during which the research vessel steamed approximately 840 nautical miles. The waters adjacent to Atafu, Nukunonu, and Fakaofo were surveyed for surface tuna and short visits were made to Atafu and Fakaofo to investigate baitfishing possibilities (Figure 1). Table 2 summarises the daily activities of the Skipjack Programme in the waters of Tokelau. Sixty-four skipjack and one rainbow runner (*Elagatis bipinnulatus*) were tagged; to date, only one of the tagged skipjack has been recovered. Tagged skipjack averaged 49.2 cm fork length, slightly smaller than the average of 50.4 cm for all skipjack tagged during the Programme (Figure 2).

FIGURE 1. SURVEY AREA AND BAITFISHING LOCALITIES FOR THE SKIPJACK PROGRAMME SURVEY IN THE WATERS OF TOKELAU

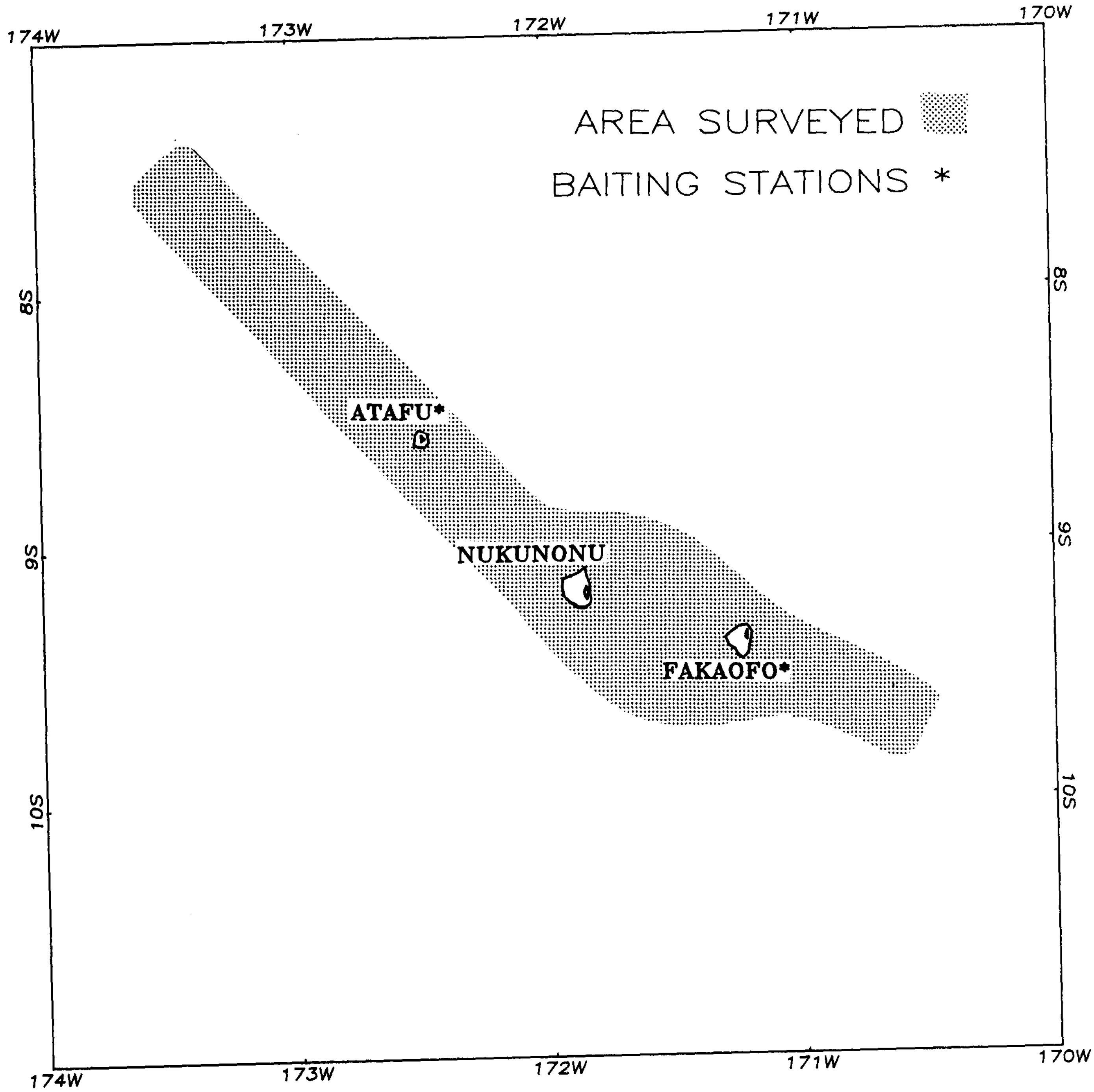
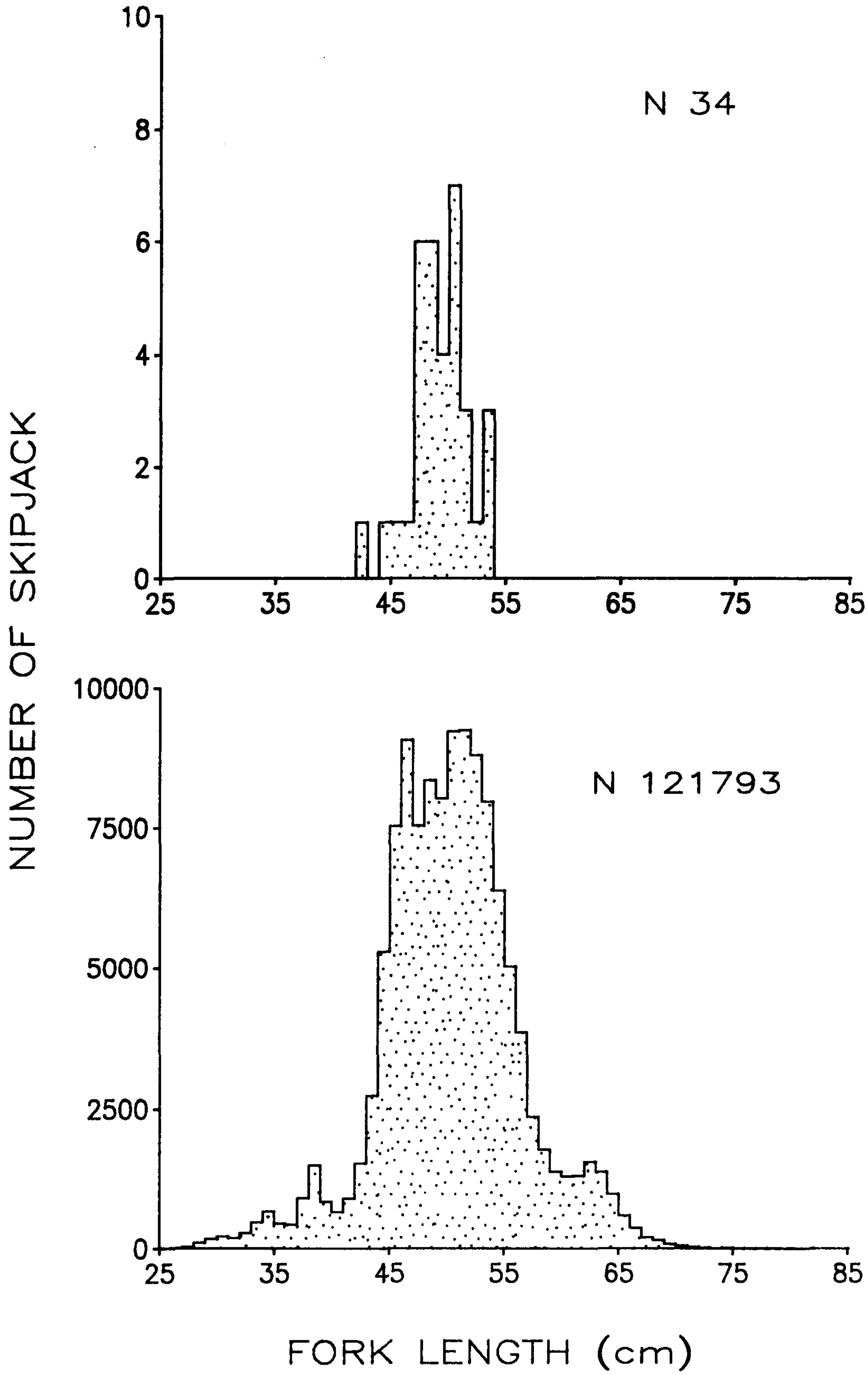


TABLE 2. SUMMARY OF DAILY FIELD ACTIVITIES IN THE WATERS OF TOKELAU. Schools sighted are given by species: SJ = skipjack or skipjack with other species except yellowfin, YF = yellowfin or yellowfin with other species except skipjack, S+Y = skipjack with yellowfin or skipjack with yellowfin and other species, OT = other species without skipjack or yellowfin, UN = unidentified, but most likely schools with tuna.

Date	General Area	Principal Activity	Bait Carried (kg)	Hours Fishing and Sighting	Schools Sighted (numbers)					Fish Tagged (numbers)			Fish Caught (kg)		Total Catch (kg)
					SJ	YF	S+Y	OT	UN	SJ	YF	OT	SJ	YF	
19/11/78	NW of Tokelau	Baiting	0	9	0	0	0	0	13	-	-	-	-	-	-
20/11/78	Atafu	Baiting	0	7	1	0	0	0	16	-	-	-	-	-	-
21/11/78	Fakaofo	Baiting	26	5	0	0	0	0	16	0	0	0	0	0	0
22/11/78	Fakaofo	Fishing	41	5	2	0	3	0	2	64	0	1	229	6	239
23/11/78	Nukunono-Fakaofo	Steaming	0	9	0	0	0	0	18	-	-	-	-	-	-
TOTALS				35	3	0	3	0	65	64	0	1	229	6	239

FIGURE 2. LENGTH FREQUENCY DISTRIBUTIONS FOR TAGGED SKIPJACK FROM TOKELAU (upper graph) AND FOR THE TOTAL SKIPJACK PROGRAMME STUDY AREA (lower graph)



2.3 Skipjack Fishing and Tagging

The Skipjack Programme used a Japanese commercial live-bait pole-and-line vessel, and its basic strategy for spotting, approaching and chumming tuna schools was not changed. As in commercial fishing, minor variations in technique were tried from day to day depending upon the behaviour of skipjack schools. The number of crew on the Hatsutori Maru No.1 was less than this vessel would carry under commercial fishing conditions. As at least one crew member was required to assist each scientist in the tagging procedures, the effective number of fishermen was further reduced. Furthermore, the need to pole skipjack accurately into the tagging cradles reduced the speed of the individual fishermen. In 1978, during the Skipjack Programme's survey in the waters of Fiji, the relative fishing power of the Hatsutori Maru No.1 was calibrated by comparing its catches with those of the commercial fleet operating in the same area, and also by comparing the performance of the vessel under survey conditions to its performance in the one-month period during which it fished under commercial conditions with the same captain and enlarged crew. It was determined that to convert the quantity of catch made during the survey to the probable commercial catch, a factor of 3.47 was required (Kearney 1978).

As tagging was a primary tuna research tool, attempts to tag large numbers of fish often dominated the fishing strategy; at other times, purely exploratory fishing was the primary concern. The tagging technique and alterations to normal fishing procedures have been described in detail in Kearney and Gillett (1982).

2.4 Biological Sampling

Specimens of tuna and other pelagic species which were poled or trolled, but not tagged and released, were routinely analysed. Information collected included length, weight, sex, gonad weight and gonad maturity. In addition, stomach contents were identified as accurately as possible under prevailing conditions on deck; any items resembling tuna juveniles were retained in preservative and periodically sent to Noumea for identification to species. A record of all fish schools sighted throughout the survey was maintained. Where possible, the species composition of each school was determined and records were kept of schools chummed and the biting response of each. Argue (1982) details methods for biological sampling and tuna school observations.

In several countries blood samples for subsequent genetic analysis were collected using methods described by Fujino (1966) and Sharp (1969). Blood samples were frozen, packed on dry ice, and air freighted to the Australian National University, Canberra, Australia, where they were electrophoretically analysed according to the methods described by Richardson (1983).

Beginning in December 1979, body cavities of skipjack were examined for the presence of macro-parasites, and complete sets of gills and viscera were taken from five fish from each school (up to a maximum of three schools per day), frozen, and subsequently air freighted to the University of Queensland, St Lucia, Australia, for detailed examination for the presence of parasites.

2.5 Baitfishing

Baitfishing was carried out by the Skipjack Programme in Tokelau using a lampara net and bait attraction light during the night, and a beach seine net during the day. Baiting procedures were, of necessity, different from those used by commercial vessels operating in other parts of the Pacific and from those used by the Skipjack Programme in other parts of the survey area (Hallier, Kearney and Gillett 1982). This was due to the fact that none of the three atolls of Tokelau has an adequate pass in the reef. Even small outboard-powered skiffs frequently have trouble negotiating the reef and narrow man-made channels. Furthermore, these small openings give access to the main islands but not into the lagoon. It was therefore impossible to use the regular "bouki-ami" technique which requires the vessel to be anchored in the lagoon. A description of the specialised baiting procedures for Tokelau appears in Appendix B.

2.6 Data Compilation and Processing

Five separate logbooks were used aboard ship for compiling data gathered during Skipjack Programme fieldwork. Descriptions of the logbooks are given by Kearney (1977), Argue (1982), Kearney and Gillett (1982) and Hallier, Kearney and Gillett (1982). Data from these logs were entered into the Programme's Hewlett Packard 1000 computer system in Noumea. The techniques used in entering and processing the data are discussed by Kleiber and Maynard (1982). Electrophoretic characteristics of all the blood samples collected and analysed at the Australian National University, and parasite identifications of all viscera specimens taken and analysed at Queensland University, were also entered into computer files.

2.7 Data Analysis

Assessment of the skipjack resource and possible interactions among skipjack fisheries was approached from several viewpoints. Studies of the migration of tagged skipjack, using analytic techniques described in Skipjack Programme (1981a), formed the basis of investigations of movement patterns and fishery interactions. Estimation of the magnitude of the skipjack resource and its dynamics based on tagging data has been described by Kleiber, Argue and Kearney (1983). Methods employed in biological studies of growth are described in Lawson and Kearney (MS) and Sibert, Kearney and Lawson (1983), and of juvenile abundance, in Argue, Conand and Whyman (1983). Procedures used to compare fishing effectiveness between different baitfish families are described in Skipjack Programme (1981b) and Argue, Hallier and Williams (MS). Evaluation of population structuring across the whole of the western and central Pacific has centred on a comparison of the tagging results with the blood genetics work (Anon 1980, 1981b; Skipjack Programme 1981c). Occurrence and distribution of skipjack parasites have also been evaluated (Lester 1981).

3.0 RESULTS AND DISCUSSION

3.1 Baitfish Assessment

The Skipjack Programme made five attempts to capture baitfish in Tokelau; one at night and four during the day. The planned steps for night baiting using the lampara net, as outlined in Appendix B, were only completed as far as step 8, due to the failure of lights to attract reasonable quantities of bait. One beach seining attempt was abandoned because the net skiff was swamped while negotiating the small channel at Atafu Island. Table 3 summarises the results of the baitfishing activities. Beach seining produced 40.5 kg of baitfish and night baiting produced 5 kg, giving a total catch of 45.5 kg of baitfish. This is under the estimated minimum amount of bait a pole-and-line vessel would require for one day of fishing (Kearney 1975).

The 45.5 kg of bait was captured with approximately 216 man-hours of effort, or 4.8 man-hours per kg. By comparison, using the bouki-ami technique the Skipjack Programme required an average of only 0.15 man-hours of labour to capture a kilogram of bait in Papua New Guinea in May-June 1979, and 0.09 man-hours/kilogram in Solomon Islands in June 1980. Furthermore, the time spent baitfishing during daylight hours in Tokelau reduced the time available to fish for tuna, whereas in Papua New Guinea and Solomon Islands, baitfishing took place at night.

The most common species of baitfish captured in Tokelau (63% of the catch) was the blue-spot mullet (Valamugil seheli), which is not considered as effective for chumming tuna as the anchovies and sprats usually captured in the countries of the central and western Pacific with established fisheries. Factors responsible for the poor quality of this bait include dark colouration, sluggish activity in the water, and failure to remain close by the vessel after being chummed. The blue sprat, Spratelloides delicatulus, is an effective baitfish species and accounted for approximately one-third of the baitfish catch in Tokelau.

The absence of passes large enough for a standard commercial live-bait vessel to enter Tokelau lagoons seriously limits baitfishing possibilities. Nowhere in the Pacific islands do commercial boats obtain bait by the techniques that the Skipjack Programme, out of necessity, used in Tokelau.

Local fishermen stated that baitfish were not plentiful in the lagoon, but that concentrations at times occurred outside the lagoon close to the reef (Harry Sperling, personal communication). It was assumed that these were the pelagic anchovy, Stolephorus buccaneeri and a rabbitfish (family Siganidae). The Skipjack Programme attempted to catch bait in tropical waters outside a lagoon on only one occasion (Rotuma Island, Fiji), and less than a kilogram of hardyheads (Atherinidae) was caught. Baiting outside lagoons is rarely done by commercial boats in the tropical central and western Pacific.

Other atolls in countries near Tokelau have also produced small or inconsistent live-bait hauls. Funafuti Atoll in Tuvalu yielded large bait catches on the first visit (Kearney, Hallier and Kleiber 1978), but very little on a subsequent visit (Ellway et al. 1983). There was a similar difference in results between the two visits to Penrhyn Atoll (Lawson and Kearney 1982). Baitfishing attempts at Beveridge Reef, near Niue (Kearney and Argue 1980), and at Suwarrow Atoll in the Cook Islands (Lawson and Kearney 1982) were unsuccessful.

At Tarawa in Kiribati and Rangiroa in French Polynesia, the culturing of baitfish has been undertaken to alleviate the problem of bait shortage. To date, neither of these projects has developed into a full-scale commercial venture. Kearney and Rivkin (1981) discuss possible economic constraints on such baitfish projects. However, even if bait culturing eventually proves to be economically feasible in other island countries, the isolation of Tokelau and the absence of a suitable pass in the reef

TABLE 3. SUMMARY OF BAITFISHING ACTIVITIES BY THE SKIPJACK PROGRAMME IN THE WATERS OF TOKELAU

Anchorage	Time of Hauls	Number of Hauls	Dominant Species	Est. Av. Catch per Haul (kg)	Mean Length (mm)	Other Common Species	Comment
Atafu Is. 08°33.0′S 172°31.0′W	Night	1	*Spratelloides delicatulus*	5	50	Sp. of Siganidae Sp. of Acanthuridae	Lampara net
Fakaofo Is. 09°23.5′S 171°15.5′W	Day	1	*Valamugil seheli*	25.5	42	*Liza Vaigiensis*	Beach seine on reef flat
Fakaofo Is. 09°23.0′S 171°15.5′W	Day	2	*Spratelloides delicatulus*	7.5	38		Beach seine in fairly deep water

Explanatory Notes

Anchorage : Recorded positions are truncated to the nearest minute.

Number of Hauls : Number of hauls at the anchorage position. A haul is defined as any time the net was placed in the water.

Dominant Species : Those species that made up at least one per cent of the numbers caught from one or more bait hauls at a particular location, ranked on their weighted proportion of the catch.

Average Catch (species) : The average catch in kilograms per haul is given for the dominant species for each anchorage and gear type. This average catch is the product of the total catch in kilograms for the particular anchorage and gear type and the weighted proportion of the particular species in this catch. The weighted proportion of each species was determined from the numerical proportion in the catch multiplied by the cube of the mean standard length for that species, anchorage and gear type, and by a scaling factor. The scaling factor was chosen so that the sum of weighted proportions would equal the sum of numerical proportions. If the mean standard length was unknown, the numerical proportion was used.

Mean Length : Weighted by numerical abundance when there were multiple hauls at the same location.

pose serious problems for bait culture in that country. Also, the possibility of damage to such a project by severe tropical storms must be considered.

3.2 Fishing Success/Skipjack Abundance

The small catch by the Skipjack Programme in Tokelau by trolling and poling (89 skipjack, 2 yellowfin, and 1 rainbow runner; 239 kg in total) was not considered to be a fair indication of the abundance of tuna at the time of the survey. Obviously, the small amount of bait available placed a major restriction on tuna fishing activities. The blue-spot mullet proved to be poor tuna bait, and only one of the six schools chummed with mullet reacted positively. Later the same day, the only school chummed with blue sprats responded favourably.

As the fishing success in Tokelau strongly reflected baitfish supply and quality, the number of schools sighted is considered more indicative of the abundance of surface schooling tunas than actual catches. During the five days spent in the waters of Tokelau, 71 schools of surface tunas were spotted in 35 hours of searching time, or 2.03 schools per hour. This sighting rate is considerably greater than the average of 0.75 for the entire Skipjack Programme. Table 4 gives the average number of sightings for other areas surveyed by the Skipjack Programme, and it can be seen that the number of schools sighted per hour in Tokelau was amongst the highest for any country or territory surveyed by the Programme. However, the abundance of tuna in Tokelau, as in other areas of the tropical central and western Pacific, could be highly variable. The Japanese pole-and-line statistics for the years 1972 to 1978 (Skipjack Programme 1980) show a five-fold variation in the catch per unit effort in Tokelau during these years. The fishing lore of Tokelau states that the abundance of surface tunas in the shore areas fluctuates from year to year, with one or two outstanding years in every ten (Semu Uili, personal communication). This variation between years is also demonstrated by the different numbers of schools sighted in Tokelau by the United States Bureau of Commercial Fisheries surveys (no schools in 47 hours) and the Skipjack Programme survey (71 schools in 35 hours).

3.3 Fishing Potential

Considering the extremely limited bait resources, Tokelau has restricted scope for deriving benefit, other than for local consumption, from the relatively high abundance of surface tunas observed. The licensing of long-range pole-and-line boats is one option. However, Tokelau is not in an area normally fished by these vessels since it is located a considerable distance from Japan, where most of these vessels are based. Moreover, there has been an overall decline in the size of the Japanese pole-and-line fleet in recent years. Purse-seining is another possibility. Since the late 1970s, a number of innovations in tropical purse-seining have made this fishing technique effective throughout the Pacific. Purse-seining in Tokelau now appears to be technically feasible. Tokelau has the major advantage of being located relatively close to canning and port facilities in American Samoa. However, the huge cost of a seining operation suggests that at least in the short term, the main economic benefits to Tokelau from seining would probably arise from licensing fees from foreign vessels.

TABLE 4. RESUME OF SIGHTINGS OF SURFACE TUNA SCHOOLS BY THE SKIPJACK PROGRAMME

Country/Territory	Visit	Number of Schools Sighted per Hour: Skipjack	Yellowfin	Skipjack+ Yellowfin	Others+ Unidentified	Total Schools	Positive Response to Chumming (%)
Papua New Guinea	(1)	0.19	0.29	0.04	0.10	0.62	42.62
	(2)	0.15	0.06	0.10	0.50	0.81	43.96
Solomon Islands	(1)	0.15	0.09	0.06	0.16	0.46	41.10
	(2)	0.09	0.01	0	0.65	0.75	54.92
Vanuatu		0.30	0	0.07	0.21	0.58	66.67
New Caledonia		0.46	0.02	0.03	0.22	0.73	49.61
Fiji	(1)	0.22	0.07	0.11	0.45	0.85	50.00
	(2)	0.16	0.12	0.20	0.31	0.79	55.86
Tonga	(1)	0.14	0	0.08	0.27	0.49	50.00
	(2)	0.22	0.14	0	0.04	0.40	34.78
Wallis and Futuna	(1)	0.37	0.01	0.02	0.47	0.87	70.00
	(2)	0.09	0.12	0.05	0.39	0.65	43.48
Western Samoa	(1)	0.38	0.02	0.04	1.71	2.15	60.00
	(2)	0.29	0.18	0	0.35	0.82	41.67
American Samoa	(1)	0.19	0	0	0.81	1.00	16.67
	(2)	0.27	0.18	0	0.27	0.72	60.00
Tuvalu	(1)	0.40	0.01	0.06	0.63	1.10	43.55
	(2)	0.22	0	0	0.96	1.18	57.14
Kiribati	(1)	0.48	0.03	0.03	0.70	1.24	55.93
	(2)	0.22	0.02	0.03	0.76	1.03	56.52
Trust Territory	(1)	0.05	0.02	0.03	0.34	0.44	24.24
of the Pacific	(2)	0.09	0.02	0.03	0.42	0.56	30.43
Islands	(3)	0.15	0.06	0.05	0.68	0.94	48.15
Tokelau		0.09	0	0.09	1.86	2.03	42.86
Cook Islands	(1)	0.17	0	0.02	0.78	0.97	37.50
	(2)	0.12	0.10	0	0.42	0.64	11.11
French Polynesia	(1)	0.22	0.02	0.03	0.49	0.76	52.83
	(2)	0.43	0.03	0.06	0.33	0.85	59.90
New Zealand	(1)	0.32	0	0	0.28	0.60	42.59
	(2)	0.48	0.01	0	0.11	0.60	9.09
Australia		0.35	0.02	0.05	0.17	0.59	45.73
Pitcairn Island		0	0.08	0.20	0.28	0.55	46.15
Niue		0.17	0.11	0.06	0.74	1.08	40.00
Norfolk Island		0.07	0.02	0.05	0.18	0.32	50.00
Nauru		0.09	0.03	0	1.15	1.27	0
TOTAL SURVEY		0.22	0.05	0.07	0.41	0.75	46.67

Note: (1), (2) and (3) specify first, second and third visits, respectively, to an area.

3.4 Biological Observations on Skipjack

A summary of the biological data collected in Tokelau and referred to in this section appears in Table 5.

3.4.1 Stomach contents

An important aspect of the Skipjack Programme was investigation of skipjack feeding behaviour and spawning activity, through examination of stomach contents. Table 6 lists the items found in the 11 skipjack stomachs examined by the Skipjack Programme in Tokelau. Although the sample size was small, the stomach contents were typical of samples from tropical waters. The wide range of fish and invertebrates found was consistent with the opportunistic feeding behaviour of skipjack.

The number of tuna juveniles per 100 predator stomachs is considered an indicator of the relative abundance of tuna juveniles in a particular area. Although tuna juveniles were not detected from stomachs of 24 skipjack and 2 yellowfin examined in Tokelau, this was probably due to the small sample size and not the absence of tuna juveniles in the area. In other areas near Tokelau where it was possible to examine many more stomachs, tuna juveniles were found. Skipjack sampled in the Cook Islands to the east of Tokelau had 5.9 skipjack juveniles per 100 stomachs (Lawson and Kearney 1982), and skipjack sampled in Tuvalu to the west of Tokelau had 1.3 skipjack juveniles per 100 stomachs (Ellway et al. 1983). Argue, Conand and Whyman (1983) discuss the results of a region-wide study of predation on juvenile skipjack. They suggest that Tokelau is in an area where juvenile skipjack are not particularly abundant, and that juvenile abundance is highest at the approximate longitudinal extremes of the Programme's study area.

3.4.2 Sexual maturity

States of gonad maturity among female skipjack were classified into seven categories, representing a progression of reproductive condition from immature (stage 1) to post-spawning (stages 6 and 7). Maturing gonads are classified as stages 2 and 3, and mature gonads as stage 4. Ripe females are classified as stage 5. The frequency distribution of different female maturity stages among the skipjack surveyed in Tokelau (Figure 3, upper graph) is compared with that for all countries in tropical waters visited by the Skipjack Programme (Figure 3, lower graph). It can be seen that the occurrence of maturity stages two and three in Tokelau is similar to that for the whole study area (stage 3 gonads dominated the sample, followed by stage 2 gonads). The absence of ripe females (stage 5) in the Tokelau sample is to be expected, given the small number of skipjack sampled in Tokelau and the fact that only two running ripe females were found in the whole area surveyed by the Skipjack Programme. The low incidence of ripe females does not necessarily imply that they are not present in the waters of Tokelau or the total survey area. Possible explanations include a failure of spawners to respond to chum, a lack of surface schooling behaviour by spawners, and a rapid transition to spawning condition at night.

3.5 Growth

The growth of skipjack, as in other tunas, is a function of size. The growth of larger fish, as measured by the rate of change in length, is slower than for smaller fish (Skipjack Programme 1981d). When a tagged

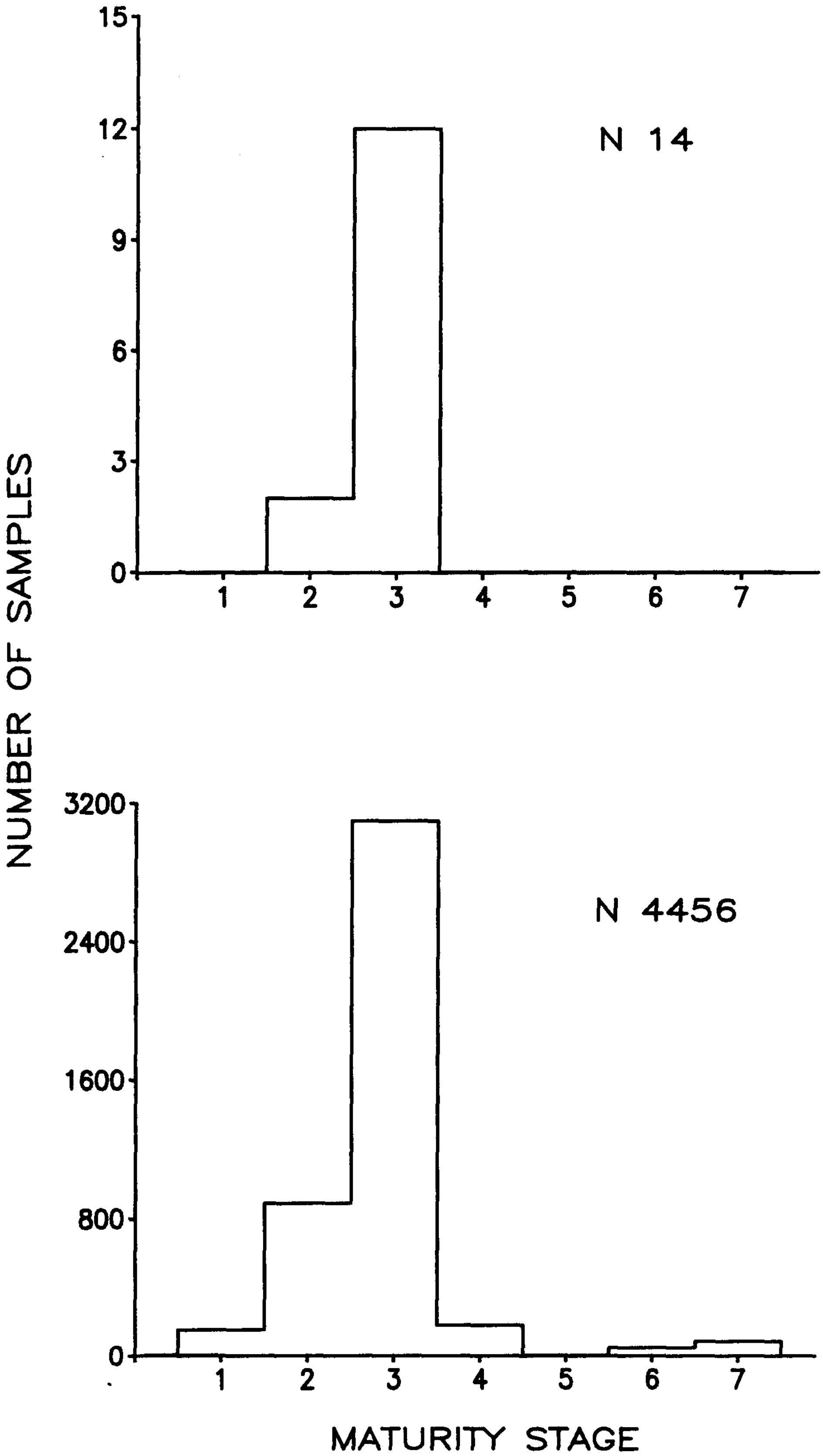
TABLE 5. SUMMARY OF NUMBERS OF FISH SAMPLED FOR BIOLOGICAL DATA FROM THE WATERS OF TOKELAU

Species	Total No. Measured	Total No. Weighed	Total No. Examined for Sex	Total No. Examined for Stomach Content	Total No. Examined for Tuna Juveniles
Skipjack *Katsuwonus pelamis*	24	24	24	11	24
Yellowfin *Thunnus albacares*	2	2	2	2	2
TOTALS	26	26	26	13	26

TABLE 6. STOMACH CONTENTS OF SKIPJACK SAMPLED FROM THE WATERS OF TOKELAU

Item No.	Diet Item Fish and Invertebrates	Number of Stomachs	Percentage Occurrence
1	Fish remains (not chum)	8	72.73
2	Alima stage (Stomatopoda)	7	63.64
3	Megalopa stage (Decapoda)	6	54.55
4	Chum from *Hatsutori Maru*	5	45.45
5	Scaridae	4	36.36
6	Chaetodontidae	3	27.27
7	Holocentridae	3	27.27
8	Acanthuridae	3	27.27
9	Carangidae	3	27.27
10	Synodontidae	3	27.27
11	Squid (Cephalopoda)	3	27.27
12	Balistidae	2	18.18
13	Tetrodontidae	1	9.09
14	Ostraciidae	1	9.09
15	Gempylidae	1	9.09
16	Diodontidae	1	9.09
17	Blue goatfish (Mullidae)	1	9.09
18	Aluteridae	1	9.09
	Total Stomachs Examined	11	

FIGURE 3. DISTRIBUTION OF FEMALE SKIPJACK MATURITY STAGES FOR THE SURVEY OF TOKELAU (upper graph) AND FOR ALL TROPICAL WATERS SURVEYED BY THE SKIPJACK PROGRAMME (lower graph)



fish is recovered, its increase in size depends on not only the length of time it was at liberty, but also its size when released. For a given time at liberty, a small fish will have a greater increase in length than a larger fish. These considerations complicate the evaluation of growth by the analysis of tagging data. Table 7 presents a summary of size and growth information for skipjack tagged and released in the study area, for each size class for which there were adequate data. Mean size at release varied from 41 cm to 55 cm; time at liberty varied from less than a day to over 300; growth increments varied from -0.3 cm to over 12 cm. The effects of time at liberty can be seen by noting the difference in growth increments calculated from tag release and recovery data generated by the two visits to Fiji (FIJ1 and FIJ2) where the fish were released at approximately the same size, but the mean times at liberty were quite different. Similarly, the effects of size at release can be seen by noting the difference in growth increments between the first visit to Kiribati (KIR1) and the second visit to Papua New Guinea (PNG2) where the fish were at liberty for approximately the same period of time, but the mean sizes at release were quite different. On the whole, growth increments were quite small and the percentage of fish which did not show any measurable growth was quite high (40.1%). There are several reasons for this apparent lack of growth. Firstly, the time at liberty may have been too short for much growth to have occurred. Secondly, skipjack may be near their maximum size when tagged and released. Thirdly, skipjack may have encountered conditions unfavourable for growth. Fourthly, errors in length measurement at both release and recovery may have obscured what little growth there was.

Corrections for the effects of size at release and time at liberty on the observed growth increment were calculated using analysis of covariance and a linearised version of the von Bertalanffy growth equation. The corrections have been used to calculate a standard growth increment for an arbitrary size at release and time at liberty (Sibert, Kearney and Lawson 1983). Standardised growth increments are presented in Table 8. It can be seen that the amount of growth varied considerably from country to country. Further analysis shows that growth increments also differed significantly between visits to a country and between fish recovered inside and outside of the country of release (Sibert, Kearney and Lawson 1983). Skipjack growth is therefore seen to be highly variable in time and space. The observed growth in tagged skipjack is a function of where the fish were tagged, when they were tagged, and where they were recovered. Thus, growth of skipjack may be closely coupled to environmental conditions such as temperature and other oceanographic variables that are thought to regulate the abundance of food.

Growth of skipjack from Tokelau could not be examined due to insufficient tag returns from releases in Tokelau.

3.6 Recruitment

For Tokelau, the lack of sufficient tag recoveries and adequate data on the occurrence of skipjack juveniles and spawners severely restricts a study of skipjack recruitment to the fishery. The recovery in Tokelau of a skipjack tagged in New Zealand waters indicates that some fish are recruited to the Tokelau fishery from as far away as 1,745 nautical miles. Figure 3 showed that female skipjack with stage 3 gonads were found in Tokelau waters, which suggests that spawning may take place in, or close to Tokelau. Whether such spawning contributes significantly to local recruitment is unknown.

TABLE 7. SUMMARY OF SKIPJACK GROWTH INCREMENTS BY VISIT FOR FISH AT LIBERTY FROM 10 TO 365 DAYS. Appendix D explains country abbreviations.

	RECAPTURES WITHIN COUNTRY OF RELEASE						RECAPTURES OUTSIDE COUNTRY OF RELEASE					
Country and Visit	N Sample Size	Mean Size at Release	Mean Size at Recapture	Mean Days at Liberty	Increment Mean	Increment Standard Deviation	N Sample Size	Mean Size at Release	Mean Size at Recapture	Mean Days at Liberty	Increment Mean	Increment Standard Deviation
FIJ1	431	48.0	48.6	23.9	.65	2.29	3	51.3	55.3	68.7	4.00	2.65
FIJ2	208	51.2	55.3	108.7	4.09	5.34	9	51.7	61.3	237.8	9.67	11.86
KIR1	279	48.4	49.8	56.0	1.43	2.18	15	51.0	55.2	137.3	4.20	3.43
MAQ2	26	48.3	48.0	18.9	-0.27	1.31	3	48.0	60.0	273.7	12.00	3.00
PAL1	0						14	59.0	63.1	113.6	4.14	4.59
PAL3	14	40.8	47.8	85.3	7.00	5.55	143	40.6	49.3	171.0	8.71	6.49
PNG0 *	290	54.6	56.4	87.6	1.78	2.46	16	53.4	57.6	229.7	4.25	3.86
PNG2	609	54.6	55.2	51.5	0.63	3.17	37	51.5	56.8	197.8	5.32	4.58
PON1	7	53.9	57.7	84.7	3.86	2.67	12	53.9	57.6	152.4	3.67	3.37
PON3	13	51.4	57.2	168.0	5.77	2.31	43	55.4	59.9	186.0	4.47	4.30
SOL1	38	51.8	54.3	192.5	2.45	4.28	2	52.5	57.5	199.0	5.00	0.00
TRK1	1	50.0	56.0	121.0	6.00	-	10	49.7	56.7	152.6	7.00	2.79
TRK2	1	53.0	54.0	21.0	1.00	-	6	53.5	60.0	186.2	6.50	4.04
VAN1	1	52.0	52.0	0.0	0.00	-	3	50.7	57.3	261.0	6.67	2.89
WAL1	0						22	53.0	54.4	198.5	1.36	2.77
WAL2	0						7	52.9	57.1	242.7	4.29	5.22
WAL1+WAL2	0						29	53.0	55.0	209.2	2.07	3.63
ZEA1	213	45.8	46.4	37.9	0.64	2.30	11	47.5	54.2	305.7	6.64	3.41
ZEA2	1	54.0	54.0	76.0	0.00	-	3	50.3	57.7	323.7	7.33	4.51

* Results for skipjack tagged and released in Papua New Guinea from 1972 to 1974.

TABLE 8. CALCULATED GROWTH INCREMENTS (cm) FOR FISH RECAPTURED WITHIN COUNTRY OF RELEASE. Calculations for fish 50 cm in length at release and at liberty for 90 days. The 95% confidence interval of each increment given in parentheses. See Sibert, Kearney and Lawson (1983) for details. See Appendix D for abbreviations.

Country	Increment	Visits Included
FIJ	4.5 (±1.2)	FIJ1, FIJ2
KIR	1.4 (±1.2)	KIR1
PAL	8.5 (±6.4)	PAL3
PNG	3.6 (±1.9)	PNG2
PON	4.1 (±4.1)	PON3
SOL	2.5 (±1.4)	SOL1
ZEA	1.5 (±5.2)	ZEA1

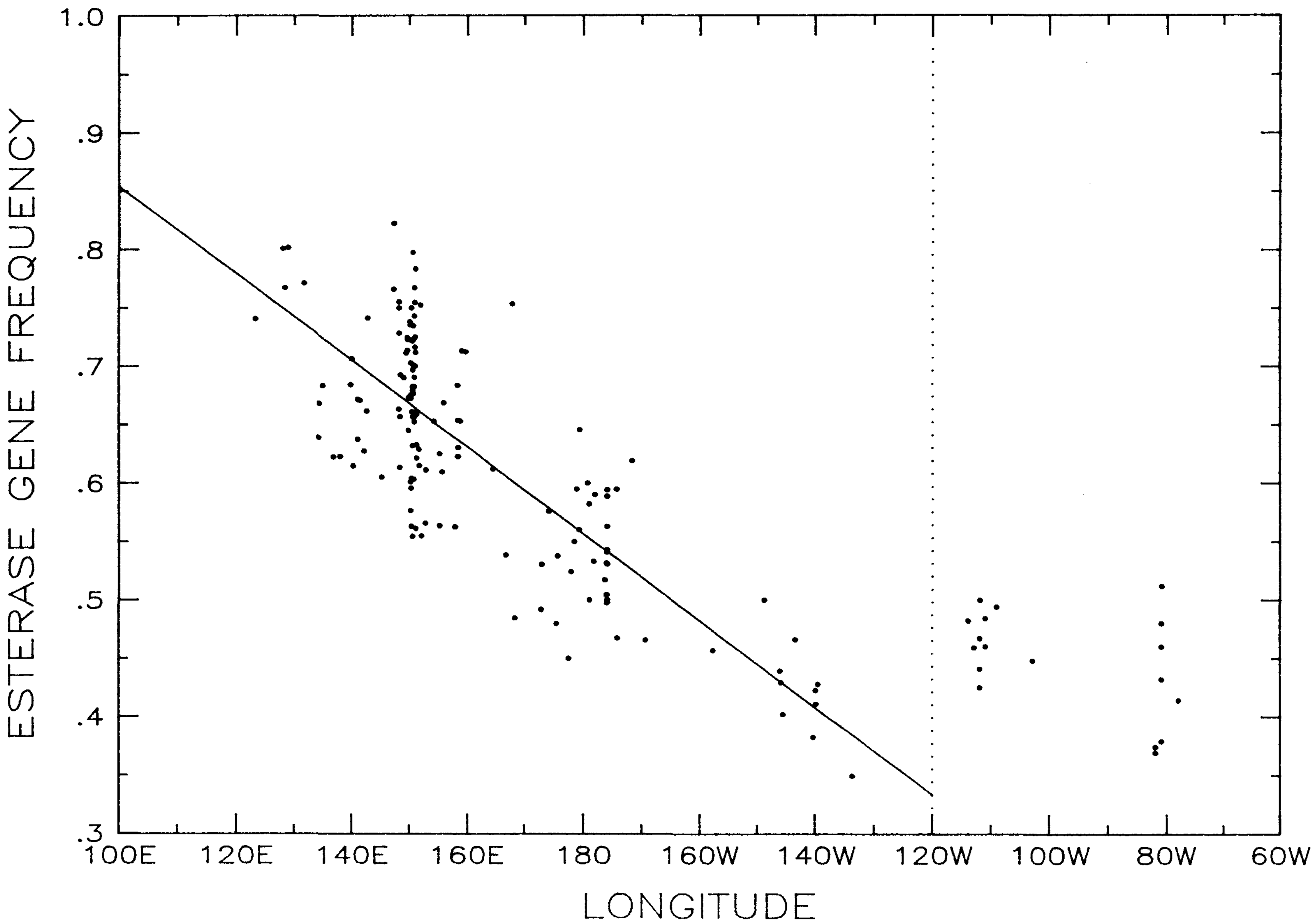
3.7 Population Structure

3.7.1 Blood genetics and tagging

The Skipjack Programme investigated skipjack population structuring by collecting blood samples from individual skipjack schools throughout the area. During the fieldwork, blood samples were obtained from approximately 100 skipjack from each of 58 schools. Large numbers of tags were released in each of these schools. The blood samples were analysed to estimate the gene frequency of several enzymes assumed to be genetic population markers (Anon 1981b). Serum esterase was considered most suitable for detailed consideration. In Figure 4, the gene frequency of serum esterase is plotted against the longitude from which the samples were taken. The figure shows a pronounced gradient in esterase gene frequency across the study area with a flattening of the gradient between French Polynesia and the eastern Pacific.

To assist in the analysis and interpretation of these data, the Skipjack Programme hosted two workshops during which experts in the fields of genetics and population biology met with the Programme's scientists. The results of those workshops appear in Anon (1980, 1981b) and are summarised in Skipjack Programme (1981c). At the workshops the existence of the esterase gradient was considered to be strong evidence that there is some form of population structuring, i.e. Pacific skipjack do not comprise a single panmictic population in which all adults of a single generation have an equal chance of mating. Several population structure models have been proposed for skipjack in the Pacific Ocean (Fujino 1970, 1976; Sharp 1978; Anon 1981b). One model, suggested by the tagging and blood genetics data, is called the clinal population structure model (Anon 1981b). It has the basic premise that the probability of breeding between skipjack is inversely proportional to the distance between them. Acceptance of this model implies that there are no genetically isolated skipjack subpopulations in the study area, separated by geographical boundaries, which is contrary to hypotheses advanced by Fujino (1970, 1976) and Sharp (1978). In Figure B (inside back cover) it can be seen that there is movement of skipjack adults over much of the western and central Pacific, suggesting that genetic exchange is possible among all countries within the Programme's study area.

FIGURE 4. SKIPJACK SERUM ESTERASE GENE FREQUENCY VERSUS LONGITUDE OF THE SAMPLE LOCATION. The regression line was fitted to data for 145 samples to the left of the dotted line; the correlation coefficient was -0.81. Esterase gene frequencies for 18 eastern Pacific samples are shown to the right of the dotted line.



The gradient in esterase gene frequency is consistent with more than one possible distribution of skipjack spawning, one being a relatively even distribution of skipjack spawning in tropical waters across the study area. Alternatively, the gradient may be viewed as a result of "overlap" of skipjack from two or more centres of higher spawner density at the approximate extremes of the study area or beyond. The similarity between eastern Pacific esterase gene frequencies (to the right of the dotted line in Figure 4) and those from French Polynesia suggests that eastern Pacific skipjack have the same genetic origin as skipjack in French Polynesia and thus could collectively represent the group at one extreme. Occurrence of skipjack juveniles (Section 3.4.2) also appeared highest at the longitudinal extremes of the Programme study area (Argue, Conand and Whyman 1983), thus lending some support to the latter view of the distribution of skipjack spawning.

After the workshops it was concluded that, due to limitations of the extant blood genetics, tagging and ancillary data, it is difficult to choose between the various population structure hypotheses (Anon 1981b; Skipjack Programme 1981c). However, the genetics data supported the conclusions that there should be minimum short-term interactions between fisheries at the extremes of the Programme's study area, and that the potential for interactions should increase as the distance between fisheries decreases.

3.7.2 The occurrence of parasites

Parasite samples were taken over a wide range of tropical waters, and from subtropical waters of New Zealand and Norfolk Island. Results from a multivariate analysis presented by Lester (1981) showed that the parasite fauna of tropical samples from widely separated areas were quite similar, and that skipjack caught in New Zealand carried many tropical parasites. Analyses of parasite data are continuing; however, results to date do not offer a means of clarifying fishery interactions in tropical waters through parasite fauna, nor is it likely that definition of skipjack population structure will be greatly improved by further analysis of the existing parasite data.

3.8 Skipjack Migration

Figure B (inside back cover) is a straight line migration map summarising Skipjack Programme data for the entire survey area. Only a portion of all tag returns is illustrated (two arrows in each direction between any pair of 10 degree squares). Table 9 shows the number of fish tagged in each country or territory and recaptured in other countries or territories. Figure 5 shows that most recoveries occurred within one month of tagging and close to the point of release, although there is a tendency for at least a portion of the tagged population to migrate, and this proportion increases with more time-at-large.

Two tagged skipjack were recaptured in Tokelau waters. One had been tagged a month earlier in Tokelau and the other almost two years earlier in New Zealand. Table 10 gives details of the dates and areas of release and recapture for these two fish. Little can be learned about skipjack migration from the recapture of two tagged fish. Some fish may move into Tokelau from temperate waters and some fish probably remain for periods longer than a month.

TABLE 9. SKIPJACK TAG RELEASE/TAG RECOVERY MATRIX FOR ALL TAG RELEASES AND FOR ALL TAG RECOVERIES RECEIVED BY THE PROGRAMME AS OF 16 DECEMBER 1982. Releases and recoveries are arrayed by tagging or recovery location, usually a country or territory except in cases where smaller geographical divisions were more informative; abbreviations are explained in Appendix D. Not included in the table are returns for which the country or area was unknown.

COUNTRY OF RECAPTURE

NUMBER OF RELEASES BY COUNTRY

		AMS	CAL	FIJ	GIL	GUM	HAW	HOW	IND	INT	JAP	KOS	LIN	MAQ	MAR	MAS	MTS	NAU	NCK	NOR	NSW	PAL	PAM	PHL	PHO	PNG	PON	QLD	SOC	SOL	TOK	TON	TRK	TUA	TUV	VAN	WAK	WAL	WES	YAP	ZEA	TOT
775	AMS	3																																					1			4
10219	CAL		18		1					2					1											2	2			10			1									37
20094	FIJ		1	1949	1					5								1							4				1			2			6		1	2	2		3	1978
174	GAM																																									
4569	GIL	1			385			24		32		1	1			14		1					2		1		1															463
108	JAP				1				2	3	7				1	1																										15
297	KOS									3						2																										5
20282	MAQ				1			1		4				42											1				1													50
195	MAR									2	1				2		1										1						2									9
327	MAS									2						1		1																								4
1229	NCK																		1																							1
91	NIU																																									
1113	NOR		2	1																										1												4
4322	NSW	1	6	2						1											2								1	8									1		9	31
7233	PAL				3				28	69		3			1	6						104		6		77	9			2			23							31		362
367	PHO				1																																					1
59	PIT																																									
8550	PNG				1	1		5	7	18		1				7						2	2			958	3	1		26			11							3		1046
5518	PON				1			2		17	2	23			1	30								1		1	58			1			13							10		160
2651	QLD		3																									2		25			1			2						33
48	SCK																																									
1725	SOC																												36													36
6221	SOL			1	1				1	2																16				525												546
64	TOK																														1											1
1969	TON																								1				1			10							1			13
1054	TRK									4		5				5											19						16							2		51
5528	TUA																												5					25								30
2904	TUV			2	2		1	1		7		1				4		1					1		1	1				2					2				1	1		28
1254	VAN																									1				4						2						7
18065	WAL		1	14	5			5		11						3									24	2			3				1		1			66	11		6	153
1926	WES	1																											1	1									19		1	23
778	YAP				2				3	7	1				3							1					1						3							5		26
12734	ZEA		5	31						3										1	2								5		1	1			1	1			5		1003	1059
140443	TOT	6	36	2000	405	1	1	38	41	192	11	34	1	42	9	73	1	4	1	1	4	107	5	7	32	1058	94	3	54	605	2	13	71	25	10	5	1	68	41	52	1022	6176

FIGURE 5. NUMBERS OF SKIPJACK TAG RECOVERIES BY DISTANCE TRAVELLED AND TIME-AT-LARGE FOR THE TOTAL SKIPJACK PROGRAMME DATA SET. Data are for tag returns received by 4 November 1982. Recaptures for 96 fish, which travelled more than 1,500 nautical miles, are included in the sample sizes, but are not shown in the figure.

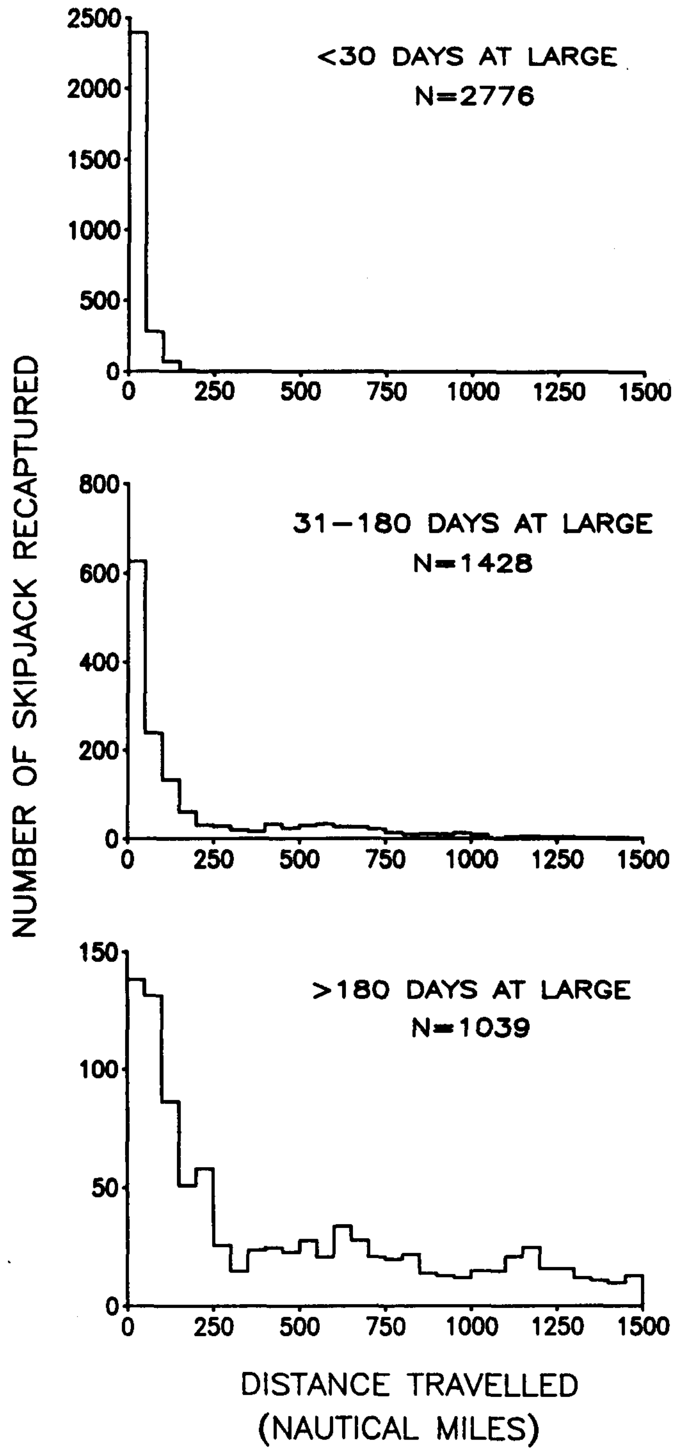


TABLE 10. MIGRATION DATA FOR TAGGED SKIPJACK RECOVERED IN TOKELAU

Tag No.		Date	Latitude	Longitude	Size	Country
SF03077	release data:	78/11/22	09deg 23'S	171deg 17'W	49.1cm	TOK
	recapture data:	78/12/22	09deg 23'S	171deg 23'W	40.6cm*	TOK
At large for 30 days. Distance = 5.9 naut. miles in direction 270.deg. true.						
SH08459	release data:	79/03/06	35deg 51'S	175deg 30'E	46.5cm	ZEA
	recapture data:	80/11/04	09deg 23'S	171deg 13'W	67.9cm	TOK
At large for 609 days. Distance = 1745.8 naut. miles in direction 28.deg. true.						

* Measurement error.

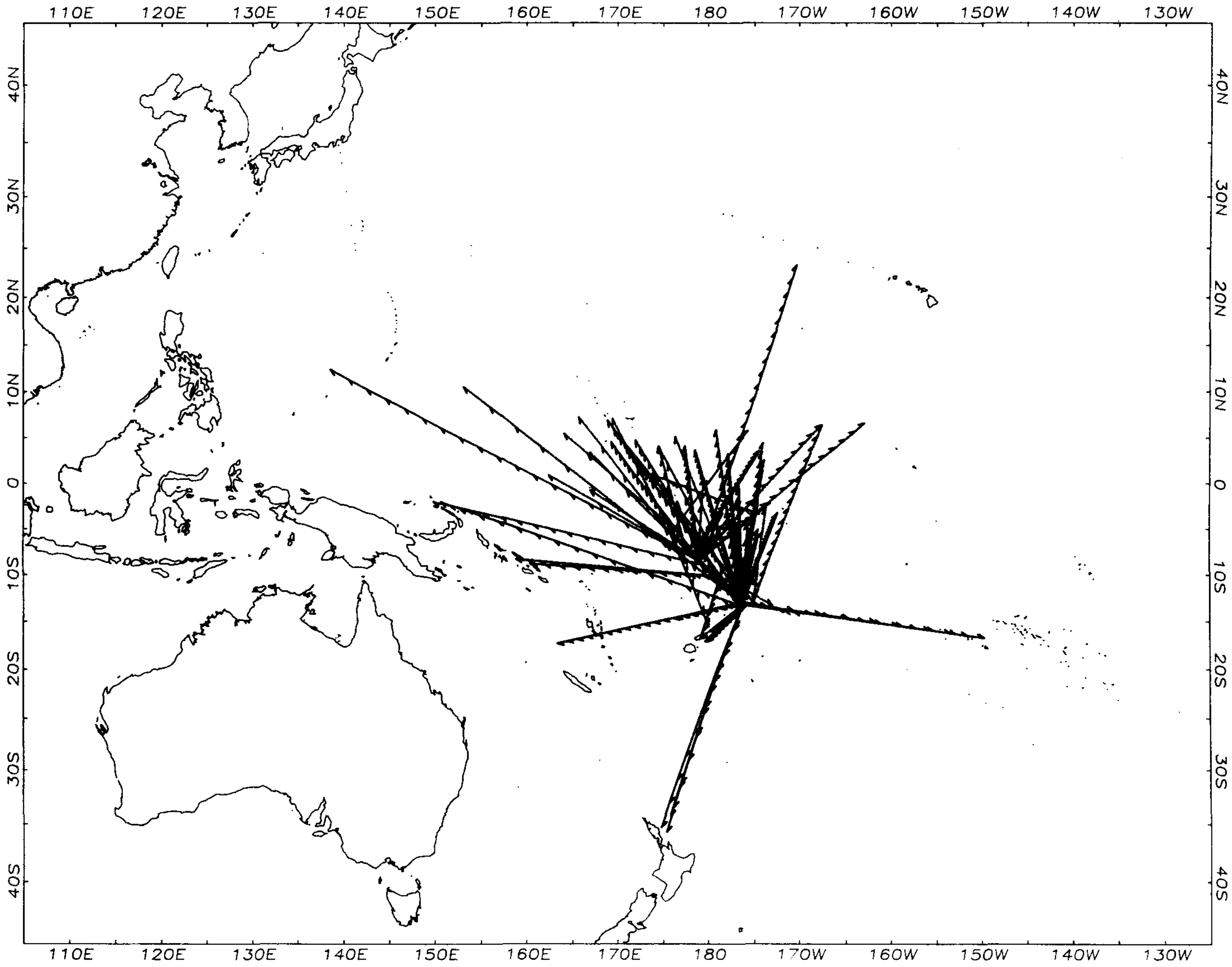
The 200-mile exclusive economic zone of Tokelau is surrounded by the 200-mile zones of Tuvalu, Wallis and Futuna, Western Samoa, American Samoa, the Cook Islands, and the Phoenix group of Kiribati. As the Skipjack Programme was able to tag 23,266 skipjack in these areas, 210 of which were subsequently recaptured, an examination of these tag recapture data (Appendix C) can be informative of skipjack movements in Tokelau. The relevant straight-line migration trajectories are shown in Figure 6. The tag returns indicate that there is at least some interchange between areas as far east as the Society Islands of French Polynesia, as far west as Yap in the Federated States of Micronesia, as far north as Hawaii, and as far south as New Zealand.

The limited fishing activity for skipjack in the waters of Tokelau and the lack of data for fisheries in the zones surrounding Tokelau contribute to the difficulty of studying skipjack movements and thus determining migratory patterns in this area. The unavailability of recent catch information (1979 to 1982) for the Japanese long-range pole-and-line fleet and the Japanese and United States long-range purse-seine fleets is particularly limiting. The pattern of tag recoveries in Figure 6 shows that most skipjack were recovered to the north and northwest, a reflection, in part, of large fisheries in this direction. Little fishing takes place to the east and southeast, so the four recoveries in French Polynesia, from a very small fishery, become more significant in terms of fish movement, but how much more significant cannot be determined without complete catch and effort data.

3.9 Fishery Interactions

Using catch statistics and tag recoveries, several measures of fishery interactions are possible: the change in catch in one fishery resulting from increased catches in other fisheries, within a generation or between generations; the fraction of recruitment (or standing stock) that arises from immigration from neighbouring fished areas; the change in yield per recruit resulting from different fishing strategies. The absence of any demonstrable relationship between catch per unit effort and effort for established skipjack fisheries suggested that between-generation fishery interactions were negligible for fisheries in the western and central Pacific. Therefore evaluation of interactions within one generation was considered more urgent.

FIGURE 6. MIGRATION ARROWS FOR 80 OF 210 RECOVERIES OF SKIPJACK TAGGED IN THE WATERS OF TOKELAU, TUVALU, WALLIS AND FUTUNA, WESTERN SAMOA, AMERICAN SAMOA, COOK ISLANDS, AND THE PHOENIX GROUP OF KIRIBATI. Tag movements have been selected to show no more than two examples between any pair of five degree squares. Each tick mark on the arrows represents 30 days at large.



The initial approach followed by the Skipjack Programme was to use tagging data plus available catch statistics to estimate coefficients of migration between particular fisheries (Skipjack Programme 1981a). The product of population size in the donor fishery and migration coefficient gave an estimate of the tonnes of skipjack migrating between fishing areas. Comparison of these estimates with estimates of population size in the recipient country, or in the donor country, illustrated stock interactions within one skipjack generation, since they measured the fraction of the standing stock that migrated to or from a particular area. Results demonstrated a generally low level of stock interaction for existing locally based fisheries.

A more appropriate expression of interaction is the percentage of recruitment in the destination country that is due to immigration from the donor country (Tuna Programme, manuscript in preparation). This estimate of interaction is independent of the correction factor applied to account for non-return of recaptured tags, return of tags with insufficient or inaccurate recapture data, and loss of tags immediately after application through slippage or mortality, assuming that the correction factor is the same in the donor and destination countries.

There are four pairs of countries and territories in the Skipjack Programme study area for which estimates of interaction due to skipjack movement have been measured (Table 11). These are Papua New Guinea - Solomon Islands, New Zealand - Fiji, New Zealand - Society Islands, and New Zealand - Western Samoa. As shown in column four of the table, skipjack immigrants from the fished area in a particular donor country were generally a small fraction (<10%) of recruitment (throughput) in the destination country's fished area, which implies that interactions amongst fisheries in these countries are generally minor. It should be noted that this situation applies only to skipjack of the size tagged by the Programme (most were between 40 and 60 cm). Skipjack smaller than this range could very well move large distances and contribute significantly to interactions between stocks in the fished areas. However, as fisheries of the SPC region are not yet exploiting fish less than 40 cm to any great degree, it can be reasonably assumed that fishery interactions resulting from movement of small fish are presently negligible.

TABLE 11. SUMMARY OF FISHERY INTERACTION RESULTS BETWEEN SIX REGIONAL FISHERIES. Table from Argue and Kearney (1982b).

Donor Country	Destination Country	Average Annual Destination Country Catch in tonnes (years)	Range of Estimates of Percentage of Destination Country Throughput from Donor Country Migrants
Solomon Islands	Papua New Guinea	38400 (1978,1979)	1% to 5%
Papua New Guinea	Solomon Islands	22100 (1979-1981)	2%
New Zealand	Fiji	3800 (1979-1981)	8% to 12%
New Zealand	Western Samoa	700 (1976-1978)	14%
New Zealand	French Polynesia (Society Islands)	1500 (1978-1980)	9%
Fiji	New Zealand	8800 (1980-1981)	<1%

It has been pointed out that fishery interactions increase as the distance between fisheries decreases. Thus if fisheries in neighbouring countries were to expand their areas of operation to include waters adjacent to their common borderlines, the degree of interaction could be expected to increase. Furthermore, if substantial fisheries were to develop in overlapping areas, such as purse-seine and pole-and-line fleets operating in the same waters within a country, then the degree of interaction would be much higher than that among locally based fisheries which at present are all relatively isolated. Interactions affecting the skipjack resource in the waters of Tokelau can be expected to increase as fisheries in the waters of countries and territories surrounding Tokelau expand.

There is potential interaction between the fishery in Tokelau and those in several other countries; however, tag data and catch statistics were insufficient for quantifying interactions between these fisheries.

3.10 Skipjack Population Dynamics

Some analyses of skipjack mortality based on the whole of the Programme's data set have been completed (Skipjack Programme 1981a; Kleiber, Argue and Kearney 1983). These studies examined the Skipjack Programme's tag release and recovery data in aggregate. Figure 7 shows the number of tag returns received per month at liberty plotted against time at large, exclusive of returns with imprecise date of recapture and recaptures by the Programme's tagging vessel. The values plotted represent the returns per month which would have resulted had all the tags been released on the same day. The tag returns per month decline with time at an approximately constant rate on a logarithmic scale. The initial, high value on the left of Figure 7 probably occurred because of insufficient time during the first month for the tagged fish to become mixed with the total population.

One of the major reasons for tagging tuna was to enable estimates to be made of various parameters of population dynamics which are crucial in assessing the magnitude of the skipjack resource and its resilience to fishing pressure. The parameters considered here are: (1) the population, which is the standing stock of fish which are vulnerable to the fishery; (2) the attrition rate, which in steady state conditions is the population turnover rate, or in other words, the proportion of the population cycling through the area in a period of time due to immigration, emigration, local productivity and mortality; (3) the throughput (population size times the turnover rate), which is the tonnes of fish cycling through the area per unit time; and (4) the exploitation rate, which is the proportion of the population which is harvested. Of the four parameters, throughput is the best measure of the magnitude of the skipjack resource because it is a rate against which catch (also a rate) can be compared. A high throughput relative to catch is evidence (though not proof) that fishing is having little impact on the population. The population size alone gives very little indication of the harvest rate that the population can support without becoming depleted.

In order to obtain parameter estimates and confidence ranges for the estimates, a tag recapture and attrition model (Kleiber, Argue and Kearney 1983) was fitted by an iterative regression technique (Conway, Glass and Wilcox 1970) to the recovery data in Figure 7. The best fitting values for these parameters, and their 95 per cent confidence limits are given in Table 12. These values have been adjusted using the correction factor described in Section 3.9.

FIGURE 7. NUMBERS OF SKIPJACK TAG RECOVERIES VERSUS MONTHS AT LARGE. The Y axis is in logarithmic scale.

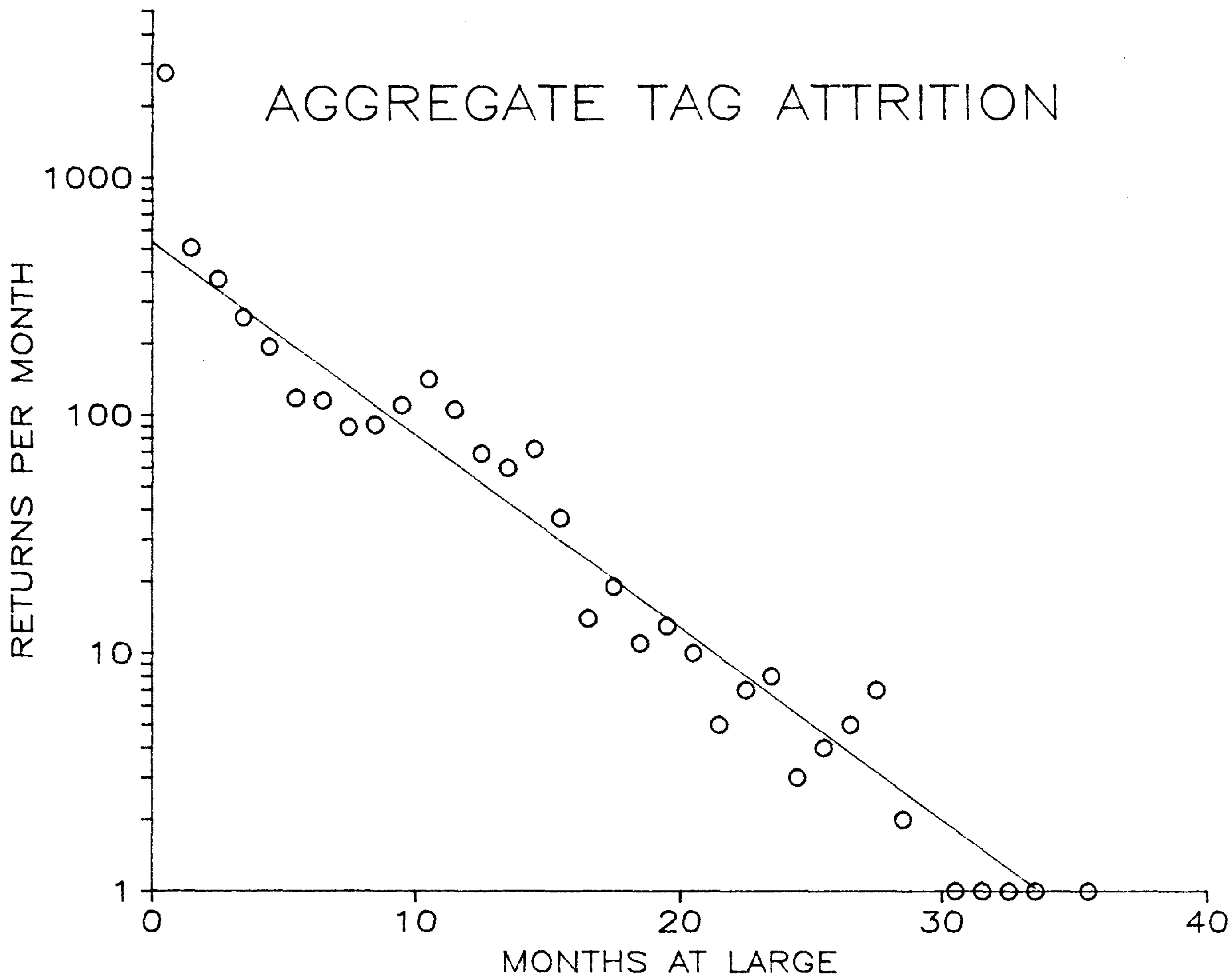


TABLE 12. SKIPJACK POPULATION PARAMETERS AND 95 PER CENT CONFIDENCE LIMITS ESTIMATED FROM AGGREGATE TAG RETURNS. The aggregate data set includes skipjack returns from all releases by the Skipjack Programme. Estimates of population size, throughput and fishing mortality have been corrected for recaptured tags that were not returned or were returned with insufficient data, for mortality due to tagging, and for tag shedding. Results from Kleiber, Argue and Kearney (1983).

	Estimate	Confidence Limits
Attrition (turnover) per month	0.17	(0.15 - 0.20)
Population size (tonnes)	3,000,000	(2,500,000 - 3,700,000)
Throughput (tonnes per month)	520,000	(460,000 - 590,000)
Catch per month	19,000	
Fishing mortality per month	0.0063	(0.0051 - 0.0077)

The average catch for the whole of the study area during the years that the tags were at large, approximately 19,000 tonnes per month, is very low compared to the estimated throughput of 520,000 tonnes per month, implying that current harvest levels are not reducing skipjack stocks. These parameter estimates were derived from aggregate tag recovery rates over the whole of the study area. As such they represent average values for a large region and, where they could be estimated, the values for particular countries and territories varied considerably from these average values.

To apply the model to tag return data from tag releases in the waters of individual countries, it was necessary to have a considerable number of tag recoveries over an extended period of time, and a record of the fishing effort and/or catch. The lack of these data meant that it was not possible to estimate skipjack population parameters for Tokelau. Countries and territories such as Fiji, Solomon Islands, Kiribati, and French Polynesia, where there are local fisheries and where it was possible to make population parameter estimates, appear to have considerable potential for expansion of their fisheries (Kearney 1982b; Argue and Kearney 1982a; Gillett and Kearney 1983; Kleiber and Kearney 1983).

4.0 CONCLUSIONS

The results of the Skipjack Programme survey indicate that the harvestable baitfish resources of Tokelau area are extremely small. It is very unlikely that live-bait tuna fishing with locally captured bait will ever be commercially viable in Tokelau, and there are major obstacles to the culturing of baitfish.

Skipjack have been shown to be quite abundant, at least at certain times, in the waters of Tokelau. Available information suggests that present fisheries in the waters of Tokelau are having a minimal impact on the skipjack population there and that catches could be substantially increased without detrimental effects. However, the overall migration study reveals that skipjack are a truly regional resource and interaction with fisheries in neighbouring countries should be carefully monitored, particularly in light of the rapid expansion of purse-seining in the region. Future, short-term benefits for the people of Tokelau, apart from the continued local consumption of skipjack, could result from the licensing of foreign fishing vessels.

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APPENDIX A. SCIENTISTS, OBSERVERS AND CREW ON BOARD THE RESEARCH VESSEL

South Pacific Commission Scientists

Robert Gillett	19-23 November 1978
Jean-Pierre Hallier	19-23 November 1978
Christopher Thomas	19-23 November 1978

Observers

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Vaopuka Iese)	19-23 November 1978
Temalo Elekana)	"
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APPENDIX B. PLANNED STEPS FOR BAITFISHING IN TOKELAU

The procedure below was only followed to step 8 while using the lampara net at night, due to failure of the lights to attract reasonable quantities of baitfish.

At Fakaofo in Tokelau a similar procedure was attempted. Bait was beach seined during the day inside the lagoon or on the reef flat and then loaded onto the research vessel. Details of the beach seine technique, other than the arduous logistic problems of transporting the gear and catch, noted below, are described in Hallier, Kearney and Gillett (1982).

1. One skiff was taken ashore to determine baiting feasibility while the research vessel drifted offshore.

2. The skiff returned to the vessel and transported seven crew members ashore.

3. One crew member returned to the vessel for a second skiff, loaded the lampara net (beach seine) into one skiff, loaded a 2.5 Kw generator into the other skiff, and transported both skiffs to shore.

4. The generator and lampara net (beach seine) were unloaded onto the landing site.

5. One skiff returned to the vessel for the bait receiver.

6. The generator (200 kg), 2 skiffs (350 kg each), and bait receiver (100 kg) were carried from the landing site to the lagoon.

7. The skiff, with gear and generator, was anchored in 20 metres of water in the lagoon. Underwater (1,500 watt) and overwater (150 watt) lights were used to attract bait.

8. Bait was captured with the lampara net (beach seine), was transferred to the bait receiver, and was towed to the island.

9. The bait was bucketed to the landing site, and then placed into another bait receiver.

10. The crew swam the receiver through the surf zone into the ocean.

11. The receiver was towed by outboard skiff to the research vessel.

12. The bait was loaded onto the research vessel.

13. Tuna fishing commenced.

APPENDIX C. SKIPJACK TAGGING IN AREAS SURROUNDING TOKELAU. For explanation of country abbreviations, see Appendix D.

Release Area	Month/ Year of Release	No. Released	Recapture Area	Month/ Year of Recapture	No. Recaptured
AMS	06/78	74			
AMS	02/80	701	AMS	02/80	3
			WES	04/80	1
NCK	11/78	163			
NCK	12/78	1066	NCK	12/78	1
PHO	12/79	367	KIR	07/80	1
WES	06/78	1767	AMS	01/79	1
			SOL	05/80	1
			WES	06/78	10
			WES	07/78	1
			WES	10/78	2
			WES	11/78	1
			WES	05/79	1
			ZEA	unknown	1
WES	02/80	159	SOC	12/80	1
			WES	02/80	1
			WES	04/80	2
			WES	05/80	1
TUV	06/78	1766	FIJ	02/79	1
			INT	07/80	1
			KIR	10/78	1
			MAS	01/80	1
			PAM	11/79	1
			PNG	10/79	1
			SOL	07/79	1
			SOL	11/79	1
			TUV	07/78	1
			WES	08/78	1
TUV	07/78	820	HAW	05/80	1
			HOW	11/78	1
			INT	10/78	2
			INT	11/78	1
			INT	10/79	1
			INT	11/79	1
			KIR	02/79	1
			KOS	12/78	1
			MAS	02/80	1
			NAU	09/78	1
			PHO	10/78	1
			TUV	09/78	1
			YAP	03/80	1
TUV	07/80	318	FIJ	02/81	1
			INT	09/80	1
			MAS	11/80	1
			MAS	02/81	1

WAL	05/78	13513	CAL	12/79	1
			FIJ	07/78	1
			FIJ	01/79	1
			FIJ	02/79	2
			FIJ	03/79	2
			FIJ	07/79	1
			FIJ	07/80	1
			FIJ	unknown	1
			HOW	08/79	1
			HOW	04/80	1
			HOW	06/80	1
			HOW	07/80	1
			INT	10/78	2
			INT	11/78	1
			INT	10/79	3
			INT	04/80	1
			INT	08/80	1
			INT	02/81	1
			KIR	09/78	2
			KIR	10/78	1
			KIR	02/79	1
			KIR	01/80	1
			MAS	09/78	1
			MAS	11/79	1
			MAS	02/80	1
			PHO	08/78	1
			PHO	09/78	4
			PHO	10/78	15
			PHO	11/78	1
			PHO	09/80	1
			PNG	09/79	1
			PNG	unknown	1
			SOC	02/79	1
			SOC	07/79	1
			SOC	08/79	1
			TRK	03/79	1
			TUV	01/79	1
			WAL	05/78	49
			WES	07/78	4
			WES	08/78	5
			WES	10/78	1
			ZEA	01/79	1
			ZEA	03/79	4
			ZEA	04/79	1
WAL	05/80	2552	FIJ	02/81	4
			FIJ	03/81	1
			INT	10/80	1
			INT	02/81	1
			MAS	02/81	1
			PHO	09/80	1
			PHO	03/81	1
			WAL	05/80	17
			WES	12/80	1
TOTAL		23266			210

APPENDIX D. ABBREVIATIONS FOR COUNTRIES, TERRITORIES AND SUBDIVISIONS THEREOF

AMS - American Samoa
CAL - New Caledonia
COK - Cook Islands
FIJ - Fiji
GAM - Gambier Islands (French Polynesia)
GIL - Gilbert Islands (Kiribati)
GUM - Guam
HAW - Hawaii
HOW - Howland and Baker Islands (U.S. Territory)
IND - Indonesia
INT - International waters
JAP - Japan
JAR - Jarvis (U.S. Territory)
KIR - Kiribati
KOS - Kosrae (Federated States of Micronesia)
LIN - Line Islands (Kiribati)
MAQ - Marquesas Islands (French Polynesia)
MAR - Northern Mariana Islands
MAS - Marshall Islands
MTS - Minami-tori shima (Japan)
NAU - Nauru
NCK - Northern Cook Islands
NIU - Niue
NOR - Norfolk Island
NSW - New South Wales (Australia)
PAL - Palau
PAM - Palmyra (U.S. Territory)
PHL - Philippines
PHO - Phoenix Islands (Kiribati)
PIT - Pitcairn Islands
PNG - Papua New Guinea
POL - French Polynesia
PON - Ponape (Federated States of Micronesia)
QLD - Queensland (Australia)
SCK - Southern Cook Islands
SOC - Society Islands (French Polynesia)
SOL - Solomon Islands
TOK - Tokelau
TON - Tonga
TRK - Truk (Federated States of Micronesia)
TUA - Tuamotu Islands (French Polynesia)
TUV - Tuvalu
VAN - Vanuatu
WAK - Wake Island (U.S. Territory)
WAL - Wallis and Futuna
WES - Western Samoa
YAP - Yap (Federated States of Micronesia)
ZEA - New Zealand