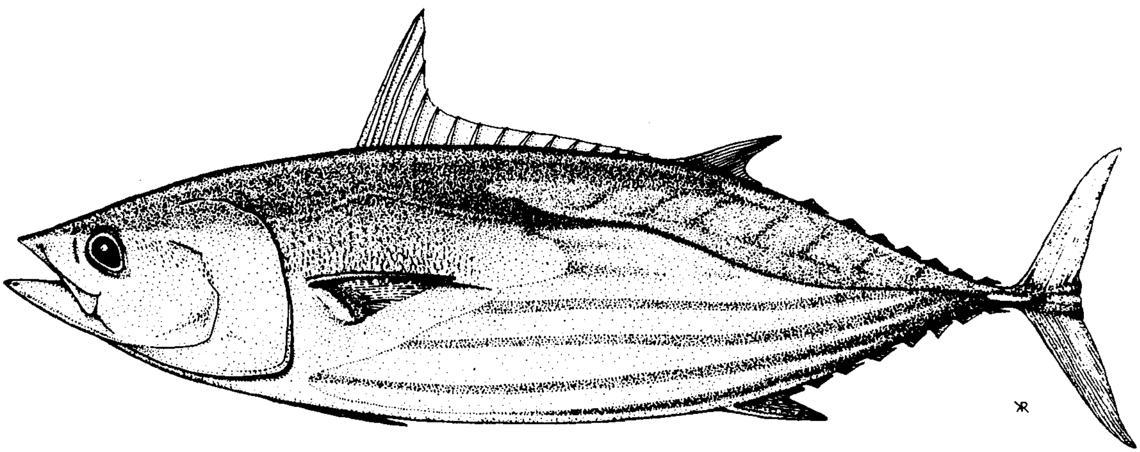
SPC

AN ASSESSMENT OF THE SKIPJACK AND BAITFISH RESOURCES OF TUVALU

C.P. Ellway, R.S. Farman, A.W. Argue
and R.E. Kearney



Skipjack Survey and Assessment Programme
Final Country Report No. 8

South Pacific Commission
Noumea, New Caledonia
August 1983

AN ASSESSMENT OF THE SKIPJACK AND BAITFISH RESOURCES OF TUVALU

C.P. Ellway, R.S. Farman, A.W. Argue
and R.E. Kearney

Skipjack Survey and Assessment Programme
Final Country Report No.8

South Pacific Commission
Noumea, New Caledonia
August 1983

PREFACE

The Skipjack Survey and Assessment Programme was an externally funded part of the work programme of the South Pacific Commission. Governments which 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 is continuing under the Tuna Programme. Papers referred to as manuscripts in this final country report will be released over the duration of the Tuna Programme.

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 indebted to officers of the Ministry of Commerce and Natural Resources in Tuvalu, in particular, Elisala Pita, Chief Fisheries Officer, for assisting staff of the Programme in many aspects of the Tuvalu surveys.

Tuna Programme
South Pacific Commission

CONTENTS

LIST OF TABLES

LIST OF FIGURES

AN ASSESSMENT OF THE SKIPJACK AND BAITFISH RESOURCES OF TUVALU

1.0 INTRODUCTION

Skipjack tuna (*Katsuwonis pelamis*) represent a major natural resource for Pacific island countries. Tuvalu is interested in increasing its returns from this resource through further development of local fisheries and licensing of foreign fishing vessels. Reliable resource assessments are essential for rational management of all skipjack fisheries, and obtaining data for these assessments throughout the central and western Pacific was the primary function of the Skipjack Programme.

This report presents the final results of work by the Skipjack Programme in the waters of Tuvalu, compares them to the results from the Skipjack Programme for the entire study area and to those of other surveys in Tuvalu, and considers their implications for the development of tuna fisheries in Tuvalu.

1.1 Background to the Fishery

Traditionally, tuna fishing in Tuvalu has been conducted from large canoes trolling a few miles offshore, using pearl-shell lures. In more recent years motorised skiffs have superseded canoes in Funafuti. Tuna fishing occurs all year round; however, best catches occur during June and July (M. Batty, personal communication). Fish average 2-3 kg in weight and catches normally range between 25 and 250 kg per vessel day (Anon 1976). In 1978, the tuna catch in Tuvalu was estimated to be as high as a few hundred tonnes (M. Batty, personal communication) and formed a major proportion of the total Tuvalu fish catch. The demand for fresh fish in Tuvalu exceeds the supply, which fluctuates irregularly. Fish caught by local fishermen are usually sold on the beach or in the village (Zann undated), but there are plans for a central fish market and a cold storage facility (Anon 1979).

By far the largest catches from the waters of Tuvalu are taken by foreign fishing vessels. Longline catches of tuna and billfish by Japan, Taiwan and Korea averaged approximately 2,000 tonnes in 1975 and 1976 (Klawe 1978), the two years for which complete statistics were available to the Programme. Pole-and-line statistics for the period 1972 to 1978 show that Japanese long-range pole-and-line vessels have taken about 1,000 tonnes of skipjack annually, excluding the high 1976 catch of 7,500 tonnes (Skipjack Programme 1980a). Tuvalu is on the southern extremity of the area fished by Japanese vessels, and is fished only when pole-and-line fishing in northern areas, closer to Japan, is poor. Therefore previous catches by Japanese vessels are not indicative of the potential pole-and-line catch from Tuvalu waters.

Since Tuvalu declared its 200-mile fishing zone (1 January 1979), fishery access agreements allowing foreign vessels to fish in Tuvalu have been negotiated with Korea and Taiwan. The licensing of 137 Korean longliners in 1980 generated revenue of US$84,000, and in 1981 the revenue from licensing 115 Korean longliners was US$92,000. In 1981 Tuvalu negotiated an access fee with Taiwan of US$84,000 for 100 boats (Forum Fisheries Agency, unpublished data).

Research into the potential for development of a skipjack fishery in Tuvalu dates from 1970 when a United Nations Development Programme/Food and Agricultural Organization, South Pacific Tuna Mission noted the absence of information on bait availability (UNDP/FAO 1969). In 1976, consultants suggested that there was limited potential for a pole-and-line fishery because of the low abundance of live bait (Anon 1976). In 1978, Travis (1978) considered the scope for establishing an artisanal skipjack fishery in Tuvalu. The first attempts to assess the skipjack resource were made by the Skipjack Programme during surveys in the waters of Tuvalu in June/July 1978 and July 1980. Preliminary results of the 1978 survey are presented and discussed in Kearney, Hallier and Kleiber (1978). In 1980, the Fiji-based Ika Corporation carried out exploratory bait and skipjack fishing with two 80-tonne pole-and-line boats under a Fishery Permit Agreement (Anon 1980a). In 1982, Tuvalu received the 173-tonne pole-and-line vessel _Te Tautai_ as a gift from the Japanese Government (McQuarrie 1982). This vessel has since fished for surface tunas in the waters of Fiji.

2.0 METHODS

The objectives of the Skipjack Programme were to survey the skipjack and baitfish resources of the countries within the area of the South Pacific Commission and to assist with the assessment of the status of the stocks and the degree of interaction between individual fisheries within the region and beyond (Anon 1975). These assessments provide a basis for the rational development of skipjack fisheries throughout the region and for sound management of the resource.

2.1 Research Schedule

The Programme's fieldwork spanned almost three years, from October 1977 to August 1980, and incorporated visits to all the countries and territories in the area of the South Pacific Commission, as well as Australia and New Zealand (Figure A, inside front cover). Chartered vessel time spent in the region totalled 847 days, and 25 countries and territories were visited. Nineteen days were spent in the waters of Tuvalu, from 25 June to 4 July 1978, and from 30 June to 8 July 1980.

2.2 Vessel and Crew

The Skipjack Programme conducted each survey using live-bait pole-and-line vessels. In 1978, the Programme chartered the _Hatsutori Maru No.1_ of 192 gross tonnes, and in 1980, the _Hatsutori Maru No.5_ of 254 gross tonnes, from a commercial fishing company, Hokoku Marine Products Company Limited, Tokyo, Japan. Minor modifications were made to the vessels to accommodate the requirements of fisheries research. Kearney (1982) provided details of both vessels.

The _Hatsutori Maru No.1_ operated with at least three Skipjack Programme scientists, nine Japanese officers and nine to twelve Fijian crew. The _Hatsutori Maru No.5_ employed three additional Fijian crew. Representatives from the Tuvalu Fisheries Department participated in the survey, and were on board for varying periods of time. Appendix A provides a complete list of scientists, crew and observers on board the vessels during surveys in Tuvalu.

The _Hatsutori Maru No.1_ and _No.5_ carried fewer crew members than under commercial fishing conditions and the skipjack capture rate was necessarily reduced to facilitate tagging operations. Moreover, several crew members were required to assist scientists in the tagging operations, further reducing the effective number of fishermen. Relative fishing power of the Hatsutori Maru No.1 was calibrated in Fiji by comparing survey catches with those of the commercial fleet at the same time, and also by comparing the performance of the Hatsutori Maru No.1 under survey conditions to its performance under commercial conditions with the same captain and expanded crew. A conversion factor of 3.47 was subsequently applied to survey catches of the Hatsutori Maru No.1 to enable comparison with catches of commercial vessels (Kearney 1978). It was assumed that a similar factor was applicable to the survey catches of the Hatsutori Maru No.5.

2.3 Skipjack Fishing and Tagging

The basic fishing strategy was to approach and chum the tuna schools that were sighted. Fishing methods were the same as those used by both vessels when fishing commercially. As when fishing commercially, minor variations in technique were tried from day to day depending on the behaviour of skipjack schools and the quantity and quality of live bait carried. Skipjack and yellowfin were poled into cradles designed specifically for tagging. Tagging techniques and alterations to normal fishing procedures are described in detail in Kearney and Gillett (1982).

2.4 Biological Sampling

A log of all fish schools sighted throughout the survey was maintained. In it were recorded the species composition of each school, the presence of associated objects or fauna, the number of schools chummed each day and the biting response of each school. Specimens of all tuna and other species which were poled or trolled, but not tagged and released, were analysed routinely for information on length, weight, sex, gonad weight, stage of maturity, and stomach contents. Stomach contents were identified as accurately as possible under prevailing conditions on deck, and any items resembling tuna juveniles were retained in preservative and periodically forwarded to Noumea, New Caledonia, for identification to species. Argue (1982) gives details of the methods used for collection of biological data.

Blood samples for subsequent genetic analysis were collected from skipjack according to the methods described by Fujino (1966) and Sharp (1969) and were frozen and packed on dry ice for airfreighting to the Australian National University, Canberra, Australia, where they were electrophoretically analysed (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

Assessments of the baitfish resources were based on Skipjack Programme catch and effort figures, catches by Ika Corporation vessels operating in Tuvalu, estimates of the extent of suitable baitfish habitat, and knowledge of the usefulness, as skipjack bait, of the species commonly found in the areas surveyed.

A Japanese "bouki-ami" net, set at night around bait attraction lights, was used by the Programme for baitfishing. Procedures were similar to those used by commercial vessels operating in the tropical western Pacific waters, but were modified where necessary to meet the Programme's special requirements. Beach seining during daylight was available as an alternative bait catching technique, but was not used in Tuvalu. Details of both techniques and all modifications employed are given in Hallier, Kearney and Gillett (1982). Special attention was paid to increasing the survival of delicate tropical bait species encountered in Tuvalu by careful handling of bait on board the vessel using modifications of techniques discussed by Smith (1977).

2.6 Data Compilation and Analysis

Five separate logbook systems formed the basis for compiling data accumulated during the fieldwork outlined in Sections 2.3, 2.4 and 2.5. Data from these shipboard logs were entered into the Programme's Hewlett Packard Series 1000 computer system in Noumea. Data entry and processing techniques are discussed by Kleiber and Maynard (1982).

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), have formed the basis of investigations of movement patterns and fishery interactions. Evaluation of the magnitude of the skipjack resource and its dynamics based on tagging data have 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 for juvenile abundance, in Argue, Conand and Whyman (1983). Procedures used to compare fishing effectiveness between different baitfish families are described in Skipjack Programme (1980b, 1981b). 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 1980b, 1981; Skipjack Programme 1981c). Occurrence and distribution of skipjack parasites have also been evaluated (Lester 1981).

3.0 RESULTS AND DISCUSSION

3.1 Summary of Field Activities

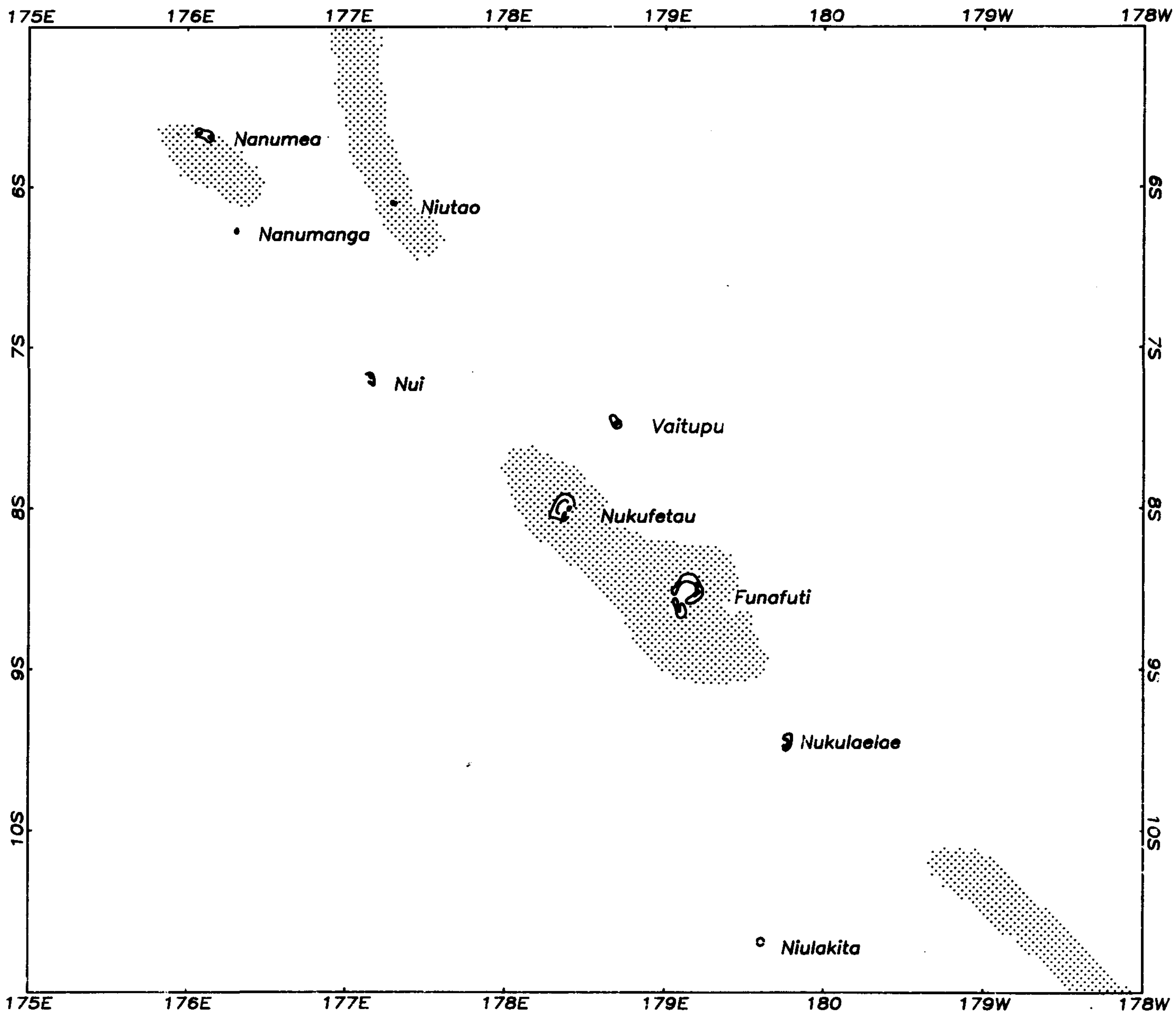
During the two surveys the research vessels spent a total of nineteen days in the waters of Tuvalu. Fifteen days were spent fishing for skipjack, three days baiting, and one day travelling; 11,190 kg of skipjack and 509 kg of yellowfin and other surface tunas were caught (Table 1). On both visits the vessels surveyed the waters around Funafuti, Nukufetau and Niutao, and in 1980 waters around Nanumea were also surveyed (Figure 1). An average of 8.9 hours were spent spotting each day, slightly higher than the Programme's average of 8.6 hours per day.

The vessels fished for bait on 15 occasions at 6 different localities in Funafuti lagoon, and caught a total of 1,504 kg of live bait. In addition, 591 kg of mollies (*Poecilia mexicana*), cultured in American Samoa, were carried for trial fishing during the first visit. A total of 3,039 skipjack and yellowfin were tagged and released (Table 1) and 28

TABLE 1. SUMMARY OF DAILY ACTIVITIES BY THE SKIPJACK PROGRAMME IN THE WATERS OF TUVALU. 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 very likely tuna.

Date	General Area	Principal Activity	Bait Carried (kg)	Hours Fishing and Sighting	Schools Sighted (numbers) SJ	YF	S+Y	OT	UN	Fish Tagged (numbers) SJ	YF	OT	Fish Caught (kg) SJ	YF	Total Catch (kg)
25/06/78	SE of Tuvalu	Fishing	591	12	10	0	2	1	5	988	28	0	3439	80	3523
26/06/78	Funafuti	Fishing	450	3	4	0	1	0	6	64	74	0	195	197	392
27/06/78	Funafuti	Fishing	420	12	7	1	3	0	5	481	19	0	1769	73	1870
28/06/78	Funafuti	Fishing	357	10	5	1	0	0	0	43	1	0	190	6	205
29/06/78	Funafuti	Fishing	522	11	5	1	2	0	3	156	13	0	277	44	357
30/06/78	Nukufetau	Fishing	435	12	0	0	2	1	6	34	0	0	134	4	141
01/07/78	Funafuti	Fishing	333	11	6	0	0	0	2	624	0	0	2416	0	2416
02/07/78	Funafuti	Fishing	236	6	5	0	1	0	0	108	0	0	428	2	430
03/07/78	Funafuti	Fishing	483	7	1	0	0	0	2	0	0	0	5	0	5
04/07/78	Niutao Island	Fishing	404	12	3	0	0	0	4	88	0	0	548	0	548
30/06/80	W of Tuvalu	Steaming	0	0	-	-	-	-	-	-	-	-	-	-	-
01/07/80	Funafuti	Baiting	18	0	-	-	-	-	-	-	-	-	-	-	-
02/07/80	N Funafuti	Fishing	50	7	2	0	0	0	4	3	0	0	17	0	17
03/07/80	Funatuti	Baiting	8	0	-	-	-	-	-	-	-	-	-	-	-
04/07/80	Funafuti	Baiting	8	0	-	-	-	-	-	-	-	-	-	-	-
05/07/80	Funafuti	Fishing	92	7	1	0	0	1	9	24	0	0	143	0	143
06/07/80	Funafuti	Fishing	126	6	2	0	0	2	1	2	0	0	11	0	35
07/07/80	Nukufetau	Fishing	174	8	1	0	0	0	14	2	0	0	15	0	15
08/07/80	Nanumea	Fishing	111	10	3	0	0	0	3	287	0	0	1602	0	1602
TOTALS				134	55	3	11	5	64	2904	135	0	11189	406	11699

FIGURE 1. AREAS SURVEYED BY THE SKIPJACK PROGRAMME IN THE WATERS OF TUVALU



skipjack have since been recovered.

Biological data were collected from 943 fish which were poled on board but not tagged (Table 2). A comparison of length-frequency distributions for sampled skipjack and tagged skipjack shows little difference in size compositions (Figure 2). Different size frequency distributions of skipjack were recorded on the two visits. In 1978, skipjack averaged 51 cm in length while in 1980, the average size was 60 cm and skipjack smaller than 50 cm were absent from the catch. Skipjack caught in Tuvaluan waters by Ika Corporation vessels in May and June 1980 had modal lengths of 61 and 59 cm (Anon undated).

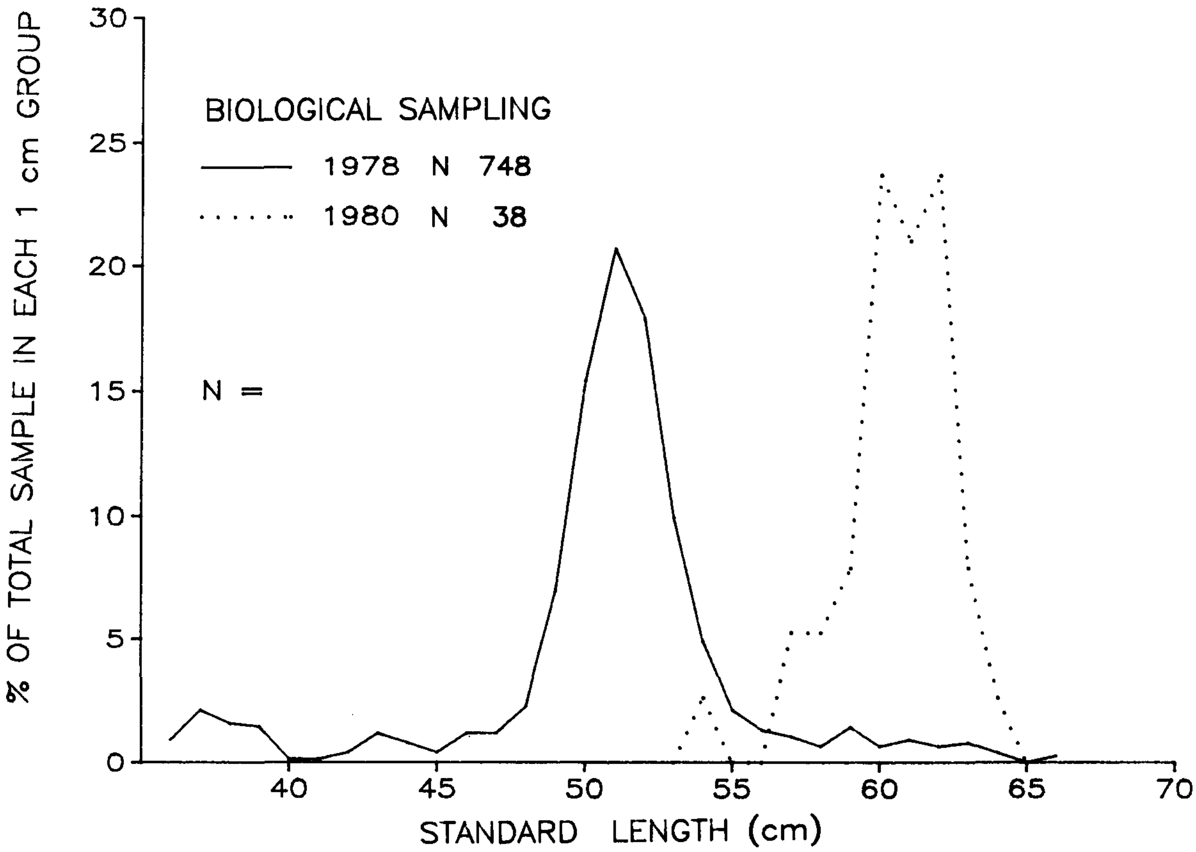
TABLE 2. SUMMARY OF NUMBERS OF FISH SAMPLED FOR BIOLOGICAL DATA FROM THE WATERS OF TUVALU. Results from both Skipjack Programme visits are combined.

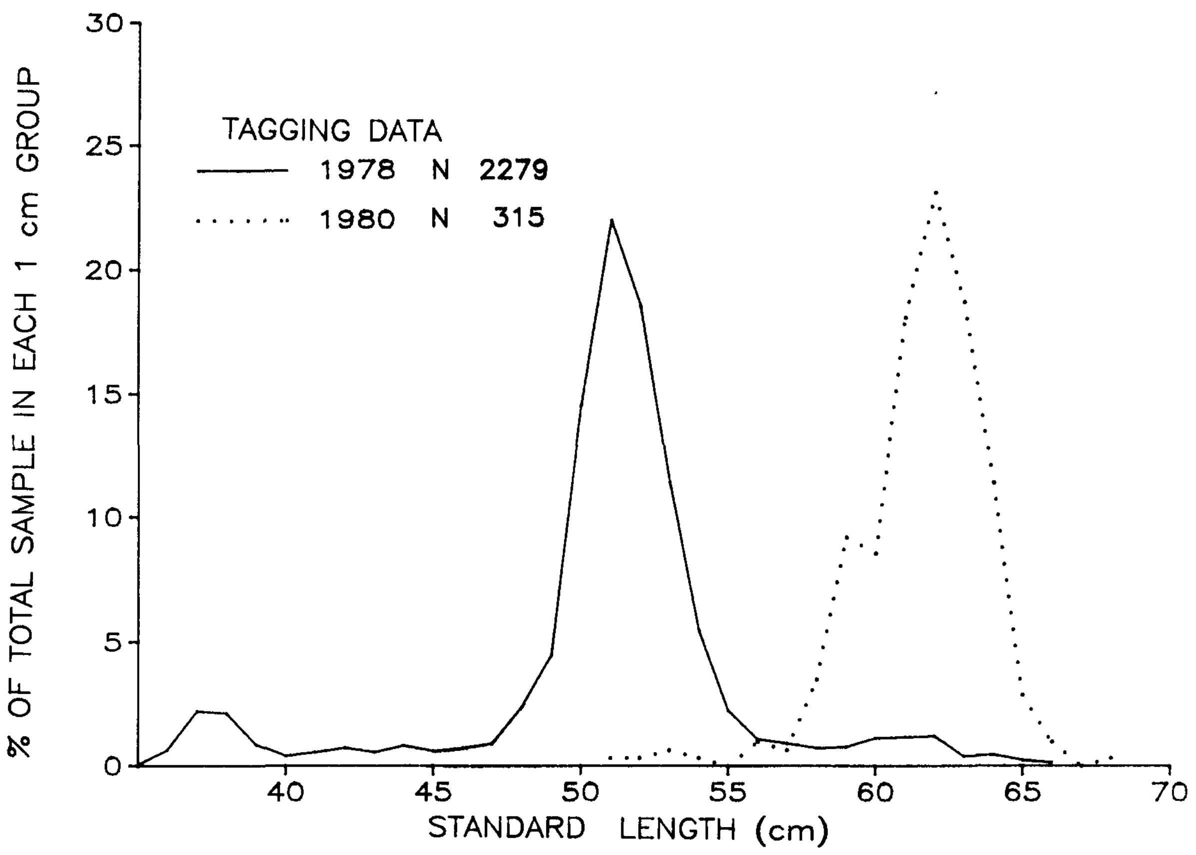
Species	Total No. Measured	Total No. Weighed	Total No. Examined for Sex	Total No. Examined for Stomach Content	Total No. Examined for Tuna Juveniles
Skipjack _Katsuwonus pelamis_	791	378	379	243	379
Yellowfin _Thunnus albacares_	102	74	73	64	71
Mackerel Tuna _Euthynnus affinis_	5	5	5	5	5
Rainbow Runner _Elagatis bipinnulatus_	43	35	35	32	32
Dolphin Fish _Coryphaena hippurus_	1	1	1	1	1
Wahoo _Acanthocybium solandrii_	1	1	1	1	1
TOTALS	943	494	494	346	489

3.2 School Sightings and Fishing Success

High rates of school sightings were achieved during both visits to Tuvalu (0.99 and 1.13 schools per hour for the first and second visits respectively); these are higher than the average of 0.75 schools per hour for the whole area surveyed by the Skipjack Programme. The majority of schools in Tuvalu were found by sighting bird flocks (128 of 138 schools) and most of the remainder were encountered in association with a variety of surface objects such as whales or logs. Eighty-nine (89) per cent of the identified schools sighted contained some skipjack, and 19 per cent of schools contained some yellowfin. Over both visits, 46 per cent of schools responded positively to chumming with live bait, very similar to the Programme's overall average of 47 per cent.

FIGURE 2. SIZE FREQUENCY DISTRIBUTION FOR SAMPLED (upper graph) AND TAGGED (lower graph) SKIPJACK IN 1978 AND 1980. N is the sample size.





The average daily catch, corrected for the effect of research operations on catch efficiency using a factor of 3.47 (Kearney 1978), varied markedly between the two visits (Table 3). During the first visit the average daily catch was 3.4 tonnes, identical to that for the entire Programme area. During the second visit the average daily catch was only 1.3 tonnes.

The difference in daily catch rate between the two surveys may be due to a number of factors. Shortage of natural bait curtailed fishing activity on all five fishing days of the second survey and prevented fishing on three other days. As a result, only 7.6 hours/day were spent skipjack fishing in 1980, compared with 9.6 hours/day during the 1978 visit (Table 1). Even though tuna sightings and chumming success were high during the second visit, the natural occurrence of large quantities of alternative prey, the pelagic anchovy *Stolephorus buccanneeri*, as confirmed by examinations of stomach contents, may have contributed to the short biting response of most schools and hence to poor catches. From the single school for which a prolonged biting response was encountered, the shortage of bait limited the number of fish caught.

School sightings and catches reported by vessels of the Ika Corporation in July 1980 provide a comparison with the survey data (Table 3). The average daily catch rate of the two commercial Ika vessels was 3.4 tonnes for the same month. This catch rate was more than double the 1.3 tonnes estimated from Skipjack Programme results. It may be a better representation of the actual fishing conditions during the period of the second survey than the catch rate reported by the research vessel, since the research vessel was hindered by a shortage of bait. Generally, a higher number of schools were reported per day by the Skipjack Programme than by the Ika Corporation vessels. This may have been due to the Programme's recording of all schools sighted, or perhaps to increased spotting capability from the larger Skipjack Programme vessel. Ika Corporation vessels reported variable average daily catch rates between May and October 1980 (0.1 to 6.0 tonnes), with July producing the best daily average (Table 3).

Catches by Japanese long-range pole-and-line vessels between 1972 and 1978 averaged 8.1 tonnes per day in the waters of Tuvalu (Skipjack Programme 1980a), much higher than daily catch rates by Ika and research vessels. Highest daily catch rates for Japanese vessels occurred between August and December.

3.3 Biological Observations

Many aspects of skipjack population biology were considered by the Skipjack Programme, including mortality, production, migration, recruitment, sexual maturity, ecology of juveniles, feeding, growth, population structure and parasite infestations.

3.3.1 Maturity and recruitment

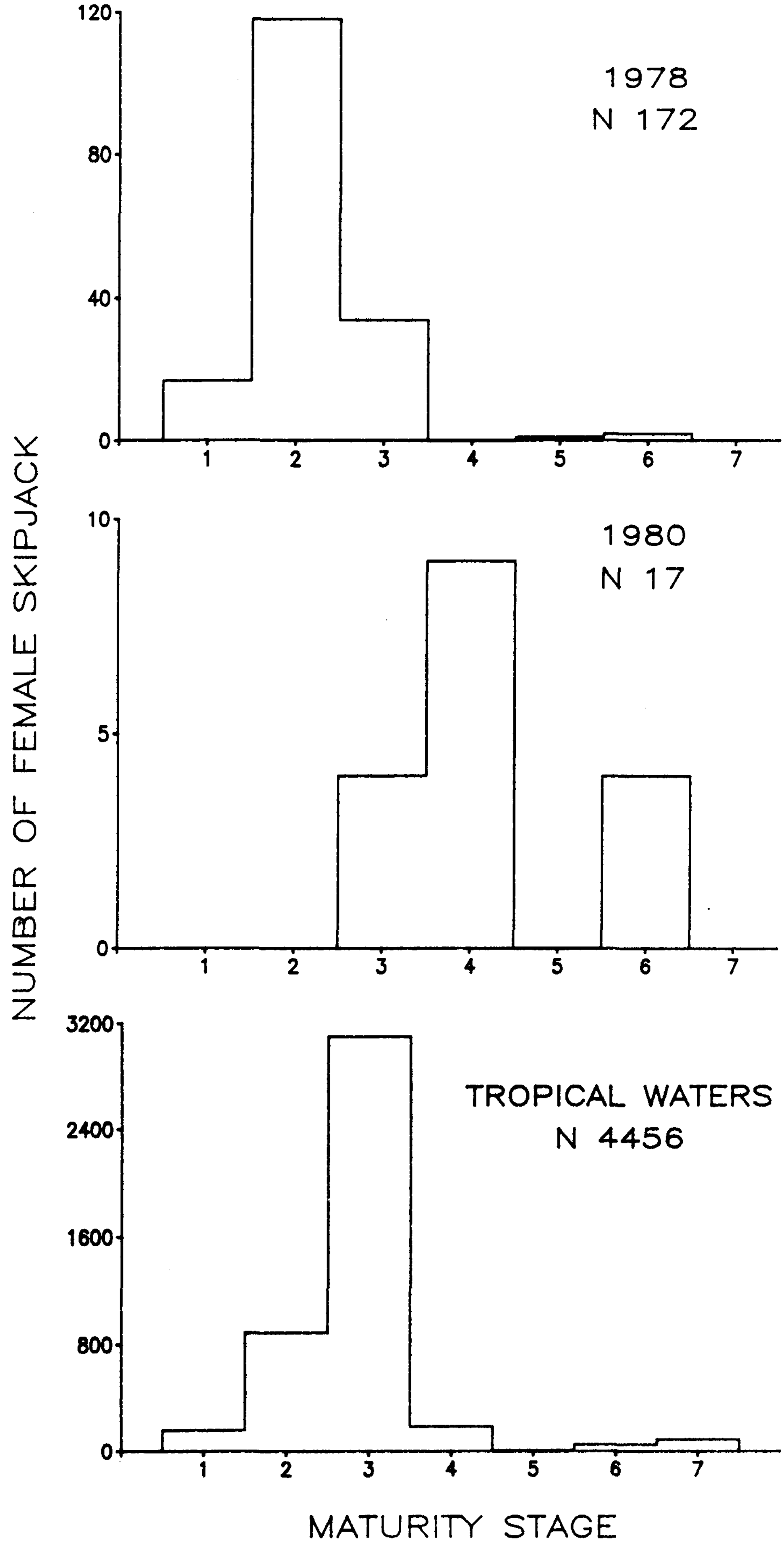
Female skipjack gonads were classified into seven maturity categories, representing a progression of reproductive stages from immature (stage 1) to post spawning (stages 6 and 7). Maturing gonads were classified as stages 2 and 3 and mature gonads as stage 4. Ripe females were classified as stage 5. The frequency of different female maturity stages among Tuvalu skipjack is compared with the frequency of female maturity stages for all countries visited by the Skipjack Programme (Figure 3). It can be seen

TABLE 3. SUMMARY OF SCHOOL SIGHTINGS, CHUMMING SUCCESS AND TUNA CATCH FOR SKIPJACK PROGRAMME AND IKA CORPORATION SURVEYS IN THE WATERS OF TUVALU. Catches for the Ika Corporation survey (Anon 1980a) are those for the waters of Tuvalu only.

	Vessel	Tuna Schools Sighted	Days Spent Fishing	Schools Sighted (per day)	Schools Sighted (per hour)	No. of Schools Chummed	Chumming Success (%)	Tuna Catch Rate (tonnes/day)
SKIPJACK PROGRAMME								
June/July 1978	HM No.1	95	10	9.5	0.99	64	43.7	3.43*
July 1980	HM No.5	43	5	8.6	1.13	14	57.1	1.25*
IKA CORPORATION								
May 1980	HM No.3	13	3	4.3		5		2.93
June 1980	HM No.2	75	21	3.5		29		1.46
	HM No.3	65	16	4.1		32		1.36
July 1980	HM No.2	45	13	3.5		16		0.87
	HM No.3	34	5	6.8		30		5.98
August 1980	HM No.2	36	7	5.1		11		2.1
	HM No.3	23	4	5.7		11		1.58
September 1980	HM No.2	41	9	4.5		15		2.07
	HM No.3	98	16	6.1		64		3.29
October 1980	HM No.2	19	8	2.4		9		0.16
	HM No.3	25	10	2.5		12		0.12

* Figures are extrapolated to theoretical commercial catches using a factor of 3.47 (Kearney 1978).

FIGURE 3. FREQUENCY DISTRIBUTIONS OF FEMALE SKIPJACK BY MATURITY STAGE IN TUVALU IN 1978 (upper graph), IN TUVALU IN 1980 (middle graph), AND FOR ALL FEMALE SKIPJACK SAMPLED FROM TROPICAL WATERS BY THE SKIPJACK PROGRAMME (lower graph). N is the sample size.



that most fish sampled in the tropical central and western Pacific had stage 3 gonads while in Tuvalu, stage 2 predominated in females sampled in the first visit and stage 4 during the second visit. This was consistent with a difference in size distribution, since fish caught in Tuvalu in 1980 were larger. Mean length of female skipjack at different maturity stages in Tuvalu waters is shown in Table 4.

TABLE 4. MEAN LENGTHS OF FEMALE SKIPJACK AT DIFFERENT MATURITY STAGES IN THE WATERS OF TUVALU

	June/July 1978			July 1980		
Maturity Stage	Mean Fork Length (cm)	Standard Deviation	Number Sampled	Mean Fork Length (cm)	Standard Deviation	Number Sampled
1	39.2	2.1	17	-	-	0
2	51.9	3.2	118	-	-	0
3	54.0	4.6	34	60.9	1.2	4
4	-	-	0	60.4	1.6	9
5	50.5	-	1	-	-	0
6	53.5	1.4	2	59.9	1.7	4
7	-	-	0	-	-	0

The average gonad index[1] for female skipjack in Tuvalu was low in 1978 (11.7), which is in accord with their smaller size and earlier maturity stage. In 1980, a higher female gonad index of 36.4 was observed, which is consistent with their larger size and later maturity. In both years, gonad indices were similar to low average values that are common to skipjack from tropical waters south of the Equator from April through August (Argue, Conand and Whyman 1983). Only two ripe females were caught during the entire Skipjack Programme and one of these was caught in Tuvalu. The low incidence of ripe females does not necessarily imply that there are few ripe females in the area. It could perhaps result from: a poor biting response by spawning fish; spawning fish may not be common at the surface; or the last stages of development may occur at night. Presence of stage 4 and 5 female skipjack suggests that at least some skipjack spawning occurs in the waters of Tuvalu during the cooler months.

The incidence of juveniles in the stomachs of predators is considered a measure of relative abundance of juveniles, as well as an indication of nearby spawning. During two visits to Tuvalu, the examination of 489 fish stomachs, including those of 379 skipjack, revealed only 5 skipjack juveniles in the stomachs of 4 adult skipjack; all juveniles were from the first visit. The incidence of 1.32 skipjack juveniles per 100 skipjack predators (Table 5) was within the range of zero to four juveniles per 100 stomachs found in countries to the northwest of Tuvalu in the region of the

---

1 Gonad index=10^7(gonad weight gm/(fish length mm)^3).
High index values, particularly over 50, are associated with skipjack whose gonads have a high percentage of eggs that are ready to be spawned (Raju 1964).

north equatorial counter current. It is much lower than the 25 to 50 juveniles per 100 stomachs found in Vanuatu, Wallis and Futuna and the Marquesas Islands.

TABLE 5. INCIDENCE OF TUNA JUVENILES IN STOMACHS OF SKIPJACK AND OTHER SPECIES SAMPLED IN THE WATERS OF TUVALU

Predator	Predators Examined	Prey Species (tuna juveniles)	No. of Prey	Predators with Prey	Prey per 100 Predators	Percentage of Predators with Prey
Skipjack	379	Skipjack	5	4	1.32	1.06
Yellowfin	71					
Rainbow Runner	32					
Mackerel Tuna	5					
Dolphin Fish	1					
Wahoo	1					
TOTALS	489		5			

The relatively low incidence of juveniles in the stomachs of predators observed in Tuvalu may have resulted from the time of the visits (June and July), since juveniles are generally more abundant from October to March south of the equator (Argue, Conand and Whyman 1983). However, as virtually nothing is known about movements of juvenile skipjack, the extent to which local spawning contributes to recruitment in Tuvalu and elsewhere cannot be established.

3.3.2 Diet

Stomach contents were examined for food items other than skipjack juveniles. The results are listed in detail in Appendix B and summarised in Table 6. The data for the two visits have been combined as they show few differences in major items eaten or in their relative occurrence. Apart from chum, the five types of food found most commonly in stomachs of skipjack in Tuvalu were fish remains, squid, holocentrids, acanthurids and unidentified juvenile fish. The variety of food items in the diet (39 in skipjack from Tuvalu) is consistent with the supposition that skipjack are highly opportunistic feeders.

TABLE 6. PERCENTAGE OCCURRENCE OF MAJOR FOOD ITEMS IN STOMACHS OF SKIPJACK SAMPLED IN THE WATERS OF TUVALU

Total No. of Stomachs Examined	243
Percentage of Stomachs Containing Food	87.7
Food Item (% occurrence)	
Chum	56.4
Fish remains (not chum)	44.0
Squid (Cephalopoda)	30.5
Holocentridae	17.7
Acanthuridae	16.5
Juvenile fish	16.1

The proportions of major items in the stomachs of Tuvalu skipjack do not differ markedly from those recorded for all skipjack examined in tropical Pacific countries during the three years of the Skipjack Programme survey (Tuna Programme, unpublished data). Continuing analyses by the Tuna Programme suggest that the composition of skipjack diet may be influenced by such factors as time of day and distance from land.

3.3.3 Skipjack growth

Insufficient returns of fish tagged in Tuvalu waters were available to permit analysis of skipjack growth. However, growth rates have been estimated from tag return data for a number of neighbouring Pacific island countries (Lawson and Kearney MS; Sibert, Kearney and Lawson 1983). The estimated growth data for Fiji, Kiribati, Papua New Guinea and the Solomon Islands from Lawson and Kearney (MS) are shown in Table 7. It can be seen that growth rates vary considerably among areas, with smaller fish from Fiji growing comparatively faster than those from other countries, and larger fish from Solomon Islands and Kiribati growing more slowly. Sibert, Kearney and Lawson (1983) obtained similar results using more exacting statistical procedures. Geographical variations in growth rate make it unwise to infer growth rates in Tuvalu from these estimates.

TABLE 7. ESTIMATES OF SKIPJACK GROWTH RATES FOR SEVERAL COUNTRIES IN THE SPC REGION, BY SIZE AT RELEASE AND TIME-AT-LARGE. Average growth rates with standard errors greater than 3 cm or for samples of less than six skipjack are considered unreliable, and are given in brackets (Lawson and Kearney MS).

Area of Release	Size at Release (cm)	Days at Large	Sample Size	Growth Rate (cm/yr)	Standard Deviation (cm)
Fiji	40-49	31-180	38	17.23	14.89
Fiji	50-59	31-180	12	(11.95)	20.79
Fiji	40-49	181-450	20	16.6	3.91
Fiji	50-59	181-450	10	7.01	6.10
Kiribati (Gilbert Is)	40-49	31-180	180	9.46	9.96
Kiribati (Gilbert Is)	50-59	31-180	39	1.42	12.78
Kiribati (Gilbert Is)	40-49	181-450	1	(5.43)	-
Kiribati (Gilbert Is)	50-59	181-450	0	-	-
Papua New Guinea	40-49	31-180	16	(20.85)	14.47
Papua New Guinea	50-59	31-180	292	5.40	11.75
Papua New Guinea	40-49	181-450	3	(19.38)	7.70
Papua New Guinea	50-59	181-450	15	8.23	2.45
Solomon Islands	40-49	31-180	87	12.72	11.23
Solomon Islands	50-59	31-180	42	5.75	18.43
Solomon Islands	40-49	181-450	77	11.37	7.90
Solomon Islands	50-59	181-450	50	4.08	6.35

Geographic and temporal variability in skipjack growth is thought to reflect variation in environmental conditions, but as yet, neither the degree of environmental heterogeneity nor the precise effects of the environment on skipjack growth are well understood.

3.3.4 Population structure

Some skipjack adults travel long distances over much of the western and central Pacific (Figure B, inside back cover), suggesting that genetic exchange is possible between all countries within the study area. Results from electrophoretic analyses of skipjack blood samples show a gradient in esterase gene frequency, a genetic marker used to infer population structure, from west to east across the tropical Pacific between approximately 120°E and 120°W (Figure 4). The similarity between eastern Pacific esterase gene frequencies (to right of the dotted line in Figure 4) and those from French Polynesia suggests that eastern Pacific skipjack have similar genetic origins to skipjack in French Polynesia.

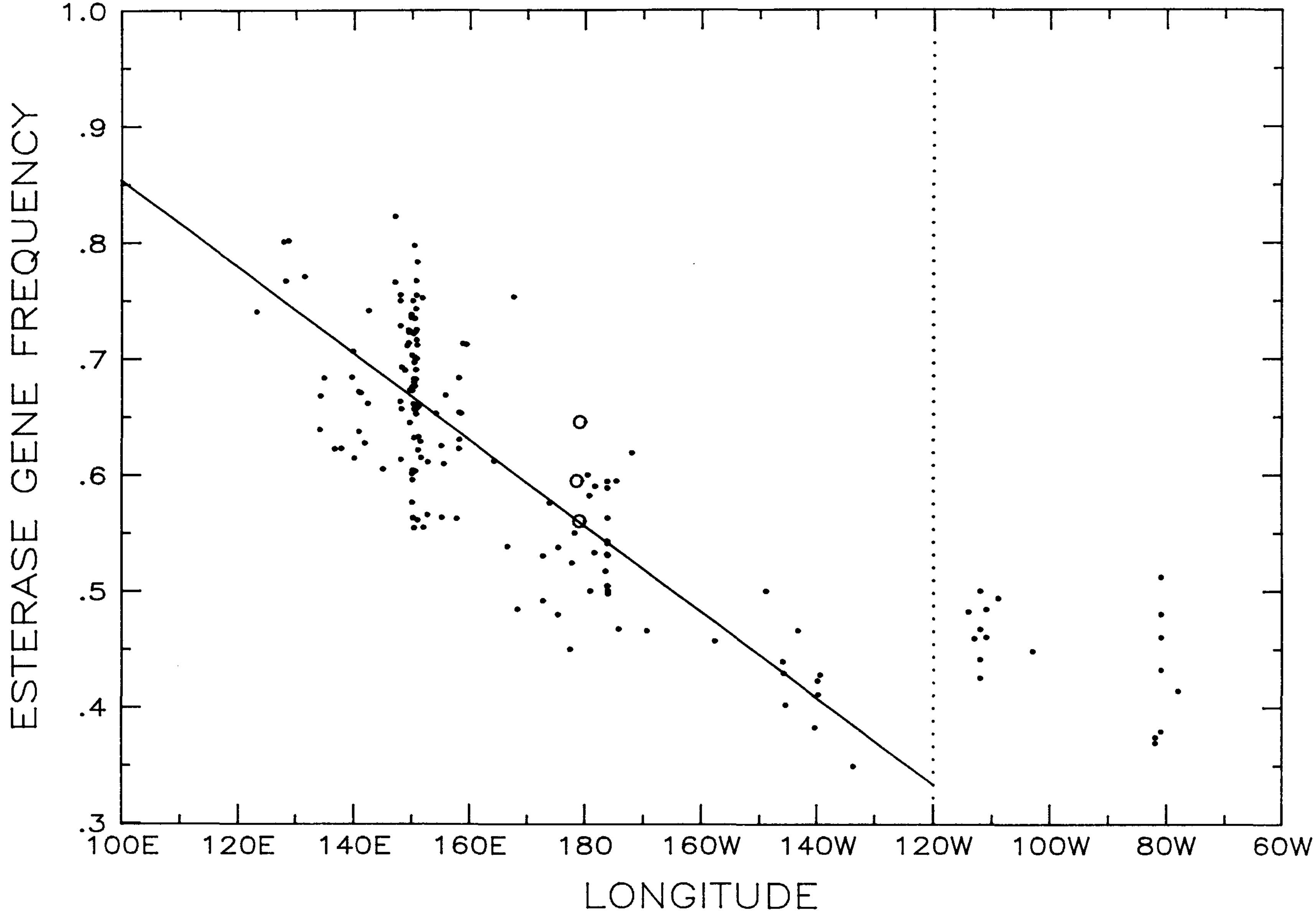
The esterase gene frequencies for the three samples taken in the waters of Tuvalu are somewhat above the regression line in Figure 4, which depicts the average gene frequency one would expect at any particular longitude between 120°E and 120°W, but were within the 95 per cent prediction limits for the regression line. There was considerable variation in individual esterase gene frequency values at many points along this average line, so the variation in the Tuvalu samples is not unusual. The cause of this variability was unclear (Anon 1981).

Several population structure models are consistent with the tagging and blood genetics data (Anon 1980b, 1981). Each includes an isolation by distance component such that the degree of genetic similarity between skipjack decreases in proportion to the distance between them. One model, called the clinal population structure model, implies that, contrary to previous suggestions (Fujino 1970, 1976; Sharp 1978), there are no genetically isolated skipjack subpopulations in the study area separated by stable geographical barriers.

The gradient in esterase gene frequency is consistent with several distributions of skipjack spawning, one being a relatively even distribution of skipjack spawning in tropical waters across the study area. Alternatively, one could view the gradient as a region of "overlap" of skipjack from two or more centres of higher spawner density at the approximate extremes of the study area or beyond. Relative abundance of skipjack juveniles 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 two SPC workshops on skipjack population structure, it was concluded (Anon 1981) that, because of limitations of the available blood genetics, tagging and ancillary data, it is difficult to choose between the different models. 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 decrease as the distance between fisheries increases.

FIGURE 4. SKIPJACK SERUM ESTERASE GENE FREQUENCY FOR 163 SAMPLES FROM INDIVIDUAL SKIPJACK SCHOOLS, VERSUS LONGITUDE OF THE SAMPLE LOCATION. The circles represent esterase gene frequencies for samples from Tuvalu. The regression line on the left of the dotted line includes 145 samples collected between Palau and the Marquesas Islands (correlation coefficient -0.81). Esterase gene frequencies for 18 eastern Pacific samples are shown to the right of the dotted line.



Parasite samples were taken over a wide range of tropical waters, including those of Tuvalu during the second survey, and also from subtropical waters of New Zealand and Norfolk Island. Preliminary results from a multivariate analysis presented by Lester (1981) show that the parasite faunas of widely separated tropical areas are quite similar, and that skipjack caught in New Zealand carried many tropical parasites. Analyses of parasite data are continuing; however, preliminary results do not suggest a way of clarifying fishery interactions in tropical waters based on parasite fauna, nor is it likely that definition of skipjack population structure will be greatly improved by further analysis of the existing parasite data.

3.4 Skipjack Resource Assessment

There are several approaches to evaluation of the skipjack resource. One approach is to examine the relationship between catch and various levels of fishing effort, when such data are available over a period of years. Since there is little information on fishing by the Japanese distant-water pole-and-line fleet prior to 1972 for the waters of countries and territories of the region, and recent catches by this fleet are not yet available, this approach was not attempted. Instead, the approach relied primarily on analysis of tag release and recapture data to examine migration of skipjack, to estimate magnitude and resilience of the skipjack resource to fishing pressure, and to estimate fishery interactions.

3.4.1 Skipjack migration

Of the 2,904 skipjack tagged in Tuvalu waters, 28 were subsequently recaptured (Table 8). Nineteen skipjack were recovered from the waters of other countries and territories (Figure 5), mainly the Marshall Islands. Seven were recovered from international waters and two were recovered in Tuvalu waters. Eighty-nine (89) per cent of the 2,904 skipjack were released during the 1978 visit, and 86 per cent of the subsequently recaptured skipjack were tagged during this same period. The recapture rate for fish tagged in Tuvalu (28 of 2,904) was one per cent, which is less than the 4.4 per cent for the entire Programme. This is undoubtedly due to the absence, at the time of tagging, of a fishery for skipjack in Tuvalu waters close to the tagging area.

The low level of local exploitation also probably resulted in a higher proportion of fish being recaptured in distant rather than local waters. Table 9 shows that of the recoveries from fish tagged in Tuvalu, 77 per cent were at liberty for more than 99 days and 96 per cent had travelled more than 200 miles. This is quite different from the recapture profile for the entire Programme where 75 per cent of recaptures were taken within 99 days and only 17 per cent travelled more than 200 miles. Further discussion of general migrations is given in Skipjack Programme (1981a).

The limited information available from so few recaptures can be used to derive only very general conclusions about movement of fish tagged in Tuvalu. Movement of fish out of Tuvalu waters appears to be predominantly north and west (Figure 5). Since the number of recaptures is influenced by the amount of fishing effort, this apparent movement may only reflect the deployment of distant-water fishing fleets. The lack of accurate statistics on fishing effort near Tuvalu obviates any assessment of skipjack movements in waters surrounding Tuvalu.

TABLE 8. RECOVERIES OF TAGGED SKIPJACK RELEASED IN TUVALU BY THE SKIPJACK PROGRAMME. Releases are listed for each month in which skipjack were tagged in the waters of Tuvalu. Recoveries are enumerated for each country in which they occurred, and for each month in which they were taken. Abbreviations for recovery areas are explained in Appendix E.

Year and Month of Release	Number of Releases	Month of Recovery	Recovery Area															
			TUV	FIJ	GIL	HAW	HOW	INT	KOS	MAS	NAU	PAM	PHO	PNG	SOL	WES	YAP	TOTAL
78/06	1766	78/07	1															1
		78/08														1		1
		79/02		1														1
		79/07													1			1
		79/10												1				1
		79/11										1			1			2
		80/01								1								1
		80/07						1										1
78/07	820	78/09	1															1
		78/10			1			2					1					4
		78/11					1	1										2
		78/12							1									1
		79/02			1						1							2
		79/10						1										1
		79/11						1										1
		80/02								1								1
		80/03															1	1
		80/05				1												1
80/07	318	80/09						1										1
		80/11								1								1
		81/02		1						1								2
	Total Recoveries in Each Area		2	2	2	1	1	7	1	4	1	1	1	1	2	1	1	28

FIGURE 5. MIGRATION ARROWS FOR RECOVERIES OF SKIPJACK TAGGED IN TUVALU AND RECOVERED OUTSIDE TUVALU. Tick marks represent intervals of 30 days between release and recapture dates.

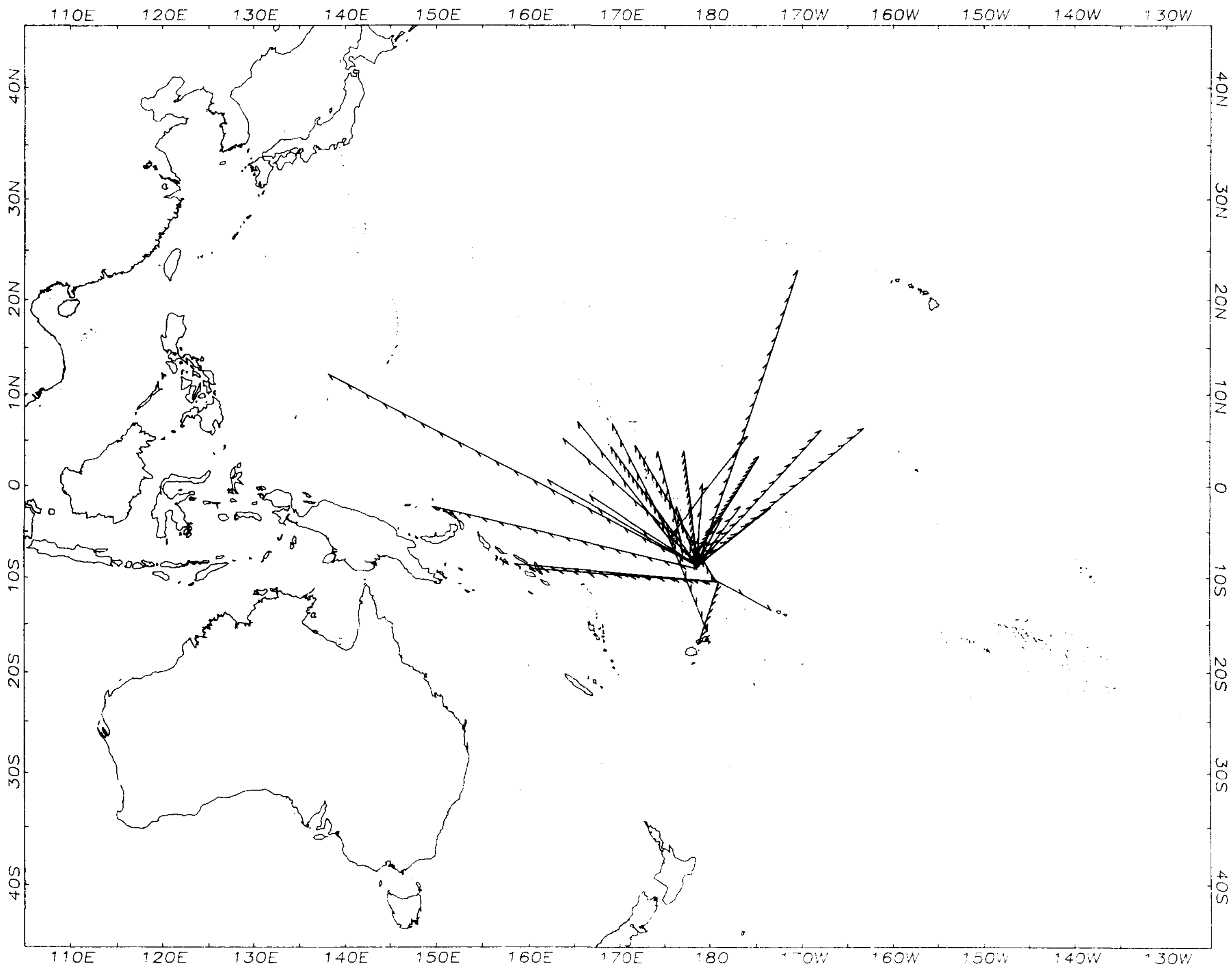


TABLE 9. NUMBERS OF SKIPJACK RECOVERIES BY TIME-AT-LARGE AND DISTANCE TRAVELLED FOR SKIPJACK RELEASED IN THE TOTAL STUDY AREA AND IN THE WATERS OF TUVALU. Recoveries for which date of recovery was not precisely known have been omitted.

		Total Study Area		Tuvalu	
Days at Large	Distance Travelled (miles)	Number of Fish	Proportion of Recaptures (%)	Number of Fish	Proportion of Recaptures (%)
0-50	<200	3416	64.0	1	3.8
	>200	22	0.4	0	0
50-99	<200	472	8.8	0	0
	>200	116	2.2	5	19.2
>99	<200	549	10.3	0	0
	>200	764	14.3	20	77.0
TOTALS		5339		26	

Evidence of skipjack migration into Tuvalu waters was obtained by the recovery, in Tuvalu waters, of a small number of fish that had been tagged elsewhere (Figure 6): six from Fiji, one from Wallis and Futuna, and one from New Zealand. Although two large batches of tags (in Solomon Islands and the Gilbert Group of Kiribati) were released well within range (two skipjack tagged in Tuvalu reached Solomon Islands), none of these fish was recovered in Tuvalu (Table 10). The lack of local exploitation seems the most likely reason, but migratory patterns influenced by ocean conditions prevailing during the tagging period, coupled with high natural mortality during the lengthy migration, may have contributed to this observation. The migration of skipjack into Tuvalu waters may vary seasonally, but the degree of this variability cannot be estimated using the limited release and recapture data available.

3.4.2 Skipjack population parameters

Tagging data provide information on parameters necessary for assessment of magnitude of the skipjack resource and its resilience to fishing pressure. In any country's waters, the population of skipjack (defined as the standing stock of fish that are vulnerable to the fishery) is expected to be subjected to losses through emigration, natural mortality, exploitation and reduced vulnerability through growth. It is possible to estimate these losses for the total study area from the decreasing number of tag recaptures over time.

A tag recapture and attrition model (Kleiber, Argue and Kearney 1983) was fitted by a non-linear least squares regression technique (Conway, Glass and Wilcox 1970), to the observed aggregate monthly tag returns and corresponding estimated skipjack catches (19,000 tonnes per month) from all gears in the study area during the period tags were at large. The model took account of immediate and longer term tag losses from the tagged

FIGURE 6. MIGRATION ARROWS FOR RECOVERIES OF SKIPJACK IN TUVALU THAT WERE TAGGED OUTSIDE TUVALU. Tick marks denote intervals of 30 days.

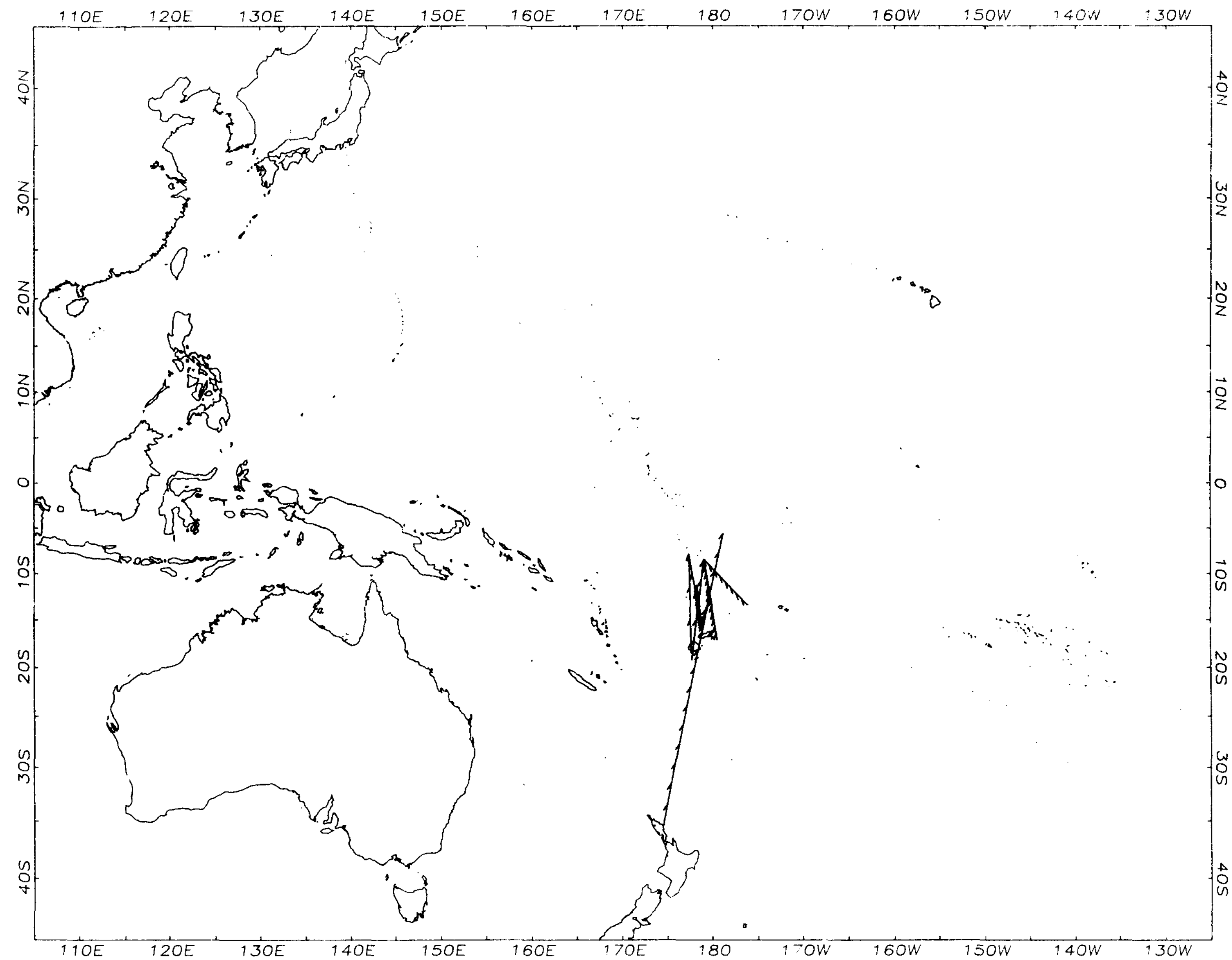


TABLE 10. SKIPJACK TAG RELEASE/TAG RECOVERY MATRIX FOR ALL TAG RELEASES AND FOR ALL TAG RECOVERIES RECEIVED BY THE PROGRAMME AS OF 16 DECEMBER 1982. Releases and recoveries are arrayed by tagging or recovery location, usually a country or territory except in cases where small geographical divisions were more informative; abbreviations are explained in Appendix E. 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
16065	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	4	107	5	7	32	1058	94	3	54	605	2	13	71	25	10	5	1	68	41	52	1022	6176

population through tag shedding and mortality due to tagging. Similarly, it accounted for information lost through non-return of tags and the return of tags without useable recapture information. The monthly tag returns and predicted tag return from the fitted model are plotted in Figure 7. The returns are aggregated into month-at-large categories, so the plot represents the distribution of returns over time rather than the actual number of tags returned in any calendar month. Because a constant monthly catch rate was assumed, the logarithmic plot of the theoretical tag return rate is a straight line.

It has been proposed that to allow for sufficient time for tagged fish to mix adequately in the study area, only recaptures after one month of release be considered (Skipjack Programme 1981a). In this case, the best fitting slope (0.17 month^{-1}) represents the attrition rate, or the proportion of the population that is lost per unit time. If these losses are offset by recruitment, meaning that the population is at steady state, the attrition rate represents the population turnover rate, or the proportion of the population being replaced in that area per unit time.

Throughput, calculated as population times turnover rate, is thought to be the most appropriate measure of the magnitude of the skipjack resource because it is a rate against which catch can best be compared (throughput is equivalent to recruitment under steady state conditions). A high throughput relative to catch is evidence, though not proof, that fishing pressure is having slight impact on the fish stocks; the population size alone gives limited indication of the amount of harvesting which the population can support without becoming depleted. The harvest ratio is the ratio of monthly catch to throughput.

Estimated values and confidence intervals for turnover, throughput, population size and harvest ratio for the Skipjack Programme study area are given in Table 11. Results show a relatively large skipjack population, of the order of three million tonnes, which is turning over rapidly. In comparison, the harvest ratio is small (0.037) illustrating potential for increased catches. The resource of skipjack in the waters of Tuvalu is obviously only a small part of the population in the whole region; however, the lack of sufficient data prevents similar calculation of its magnitude.

3.4.3 Fishery interactions

Where sufficient numbers of tagged fish have been recaptured in neighbouring fisheries, it has been possible to estimate the degree of fishery interaction. Prerequisites for this analysis are that each country has a substantial fishery and that catch information is also available. Interaction is defined as the percentage of recruitment (throughput) in the destination country which arises from immigrants from the donor country. Only four pairs of countries or areas have these prerequisites, thereby permitting quantitative estimates of interaction. These are Papua New Guinea-Solomon Islands, Fiji-New Zealand, New Zealand-Western Samoa and New Zealand-Society Islands. The results of calculations of interaction are given in Table 12. For the most part, interactions between these coastal state fisheries are minimal. Interaction is expected to increase as adjacent fisheries expand. Interaction is also thought to be much higher between coastal state fisheries and distant-water fisheries operating throughout the region. Unfortunately, the lack of catch and effort statistics from the distant-water fleets, principally Japanese pole-and-line, Japanese purse-seine and United States purse-seine fleets, has prevented accurate evaluation of these interactions.

FIGURE 7. AGGREGATE TAG ATTRITION. Stars are the observed tag returns for skipjack tagged throughout the total study area, recovered anywhere, and with precise date of recovery information, excluding recoveries by the Skipjack Programme. The line is the theoretical tag return rate based on the best fit of the tag attrition model to the data.

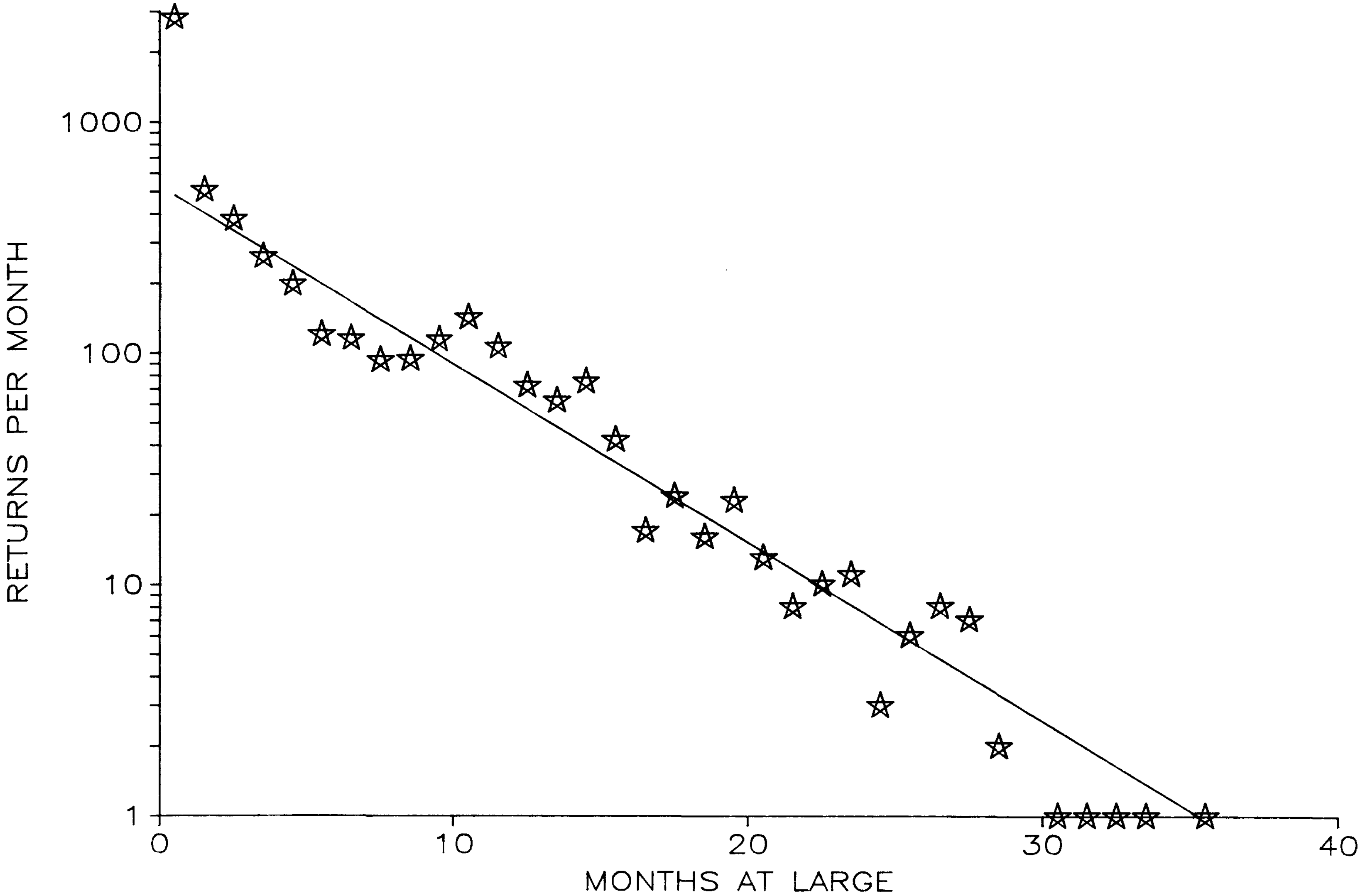


TABLE 11. SKIPJACK POPULATION PARAMETER ESTIMATES AND 95 PER CENT CONFIDENCE LIMITS, DERIVED FROM THE AGGREGATE DATA SET FOR THE TOTAL STUDY AREA. Results from Kleiber, Argue and Kearney (1983).

	Estimate	Confidence Interval
Attrition (Turnover) per month	0.17	(0.15 - 0.20)
Throughput (tonnes per month)	520,000	(460,000 - 590,000)
Population Size (10^6 tonnes)	3.0	(2.5 - 3.7)
Harvest Ratio	0.037	(0.032 - 0.042)

TABLE 12. SUMMARY OF FISHERY INTERACTION RESULTS BETWEEN SIX REGIONAL FISHERIES. Results from Argue and Kearney (1982).

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%
Fiji	New Zealand	8800 (1980-1981)	<1%
New Zealand	Western Samoa	700 (1976-1978)	14%
New Zealand	French Polynesia (Society Islands)	1500 (1978-1980)	9%

Although there are inadequate data to evaluate interaction between local fisheries in Tuvalu waters and local fisheries in other coastal states, this interaction is assumed to be low. However, it is possible that the much larger and closer purse-seine and pole-and-line fisheries of extra-regional nations could well be significantly reducing the abundance of skipjack in Tuvalu waters.

3.5 Bait Availability

A major aim of the Skipjack Programme was to determine the baitfishing potential of the countries and territories in the study area. Before the Programme's research vessels visited each country, examination of coastal charts enabled general estimation of the size of the likely baitfishing areas. There are nine atolls in Tuvalu, but only one of these, Funafuti, has a sufficiently deep lagoon with adequate entrances to permit baitfishing by vessels of the size used in this survey. The survey was therefore restricted to this one lagoon. Baitfishing effort and catch by the vessels *Hatsutori Maru No.1* and *No.5* in 1978 and 1980 respectively are shown in Table 13.

As a large amount of cultured bait (mollies) was carried by the survey vessel during the first visit, the need to catch natural bait was reduced, and only two nights were spent baiting. Catches of 182 kg and 279 kg of natural bait, mostly the blue sprat (*Spratelloides delicatulus*), were loaded into the baitwells on these nights giving a high result overall when compared with other Skipjack Programme catches in tropical waters. The amount of bait loaded would have been much higher had the vessel had greater baitwell capacity; a surplus of more than 300 kg of bait had to be released alive each night.

The occurrence of a full moon at the time of the second visit hindered baitfishing by reducing the effectiveness of the underwater lights. The average bait catch during the second visit was only 40 kg per haul, again mostly blue sprats. It was not possible to evaluate how much the full moon conditions contributed to these low catches and how much they were the direct result of low abundance. Several different locations in Funafuti lagoon, including some that had earlier been productive for vessels from the Ika Corporation, were fished with poor results. Bait catches improved on successive nights after the full moon, but were still barely adequate for skipjack fishing. Extensive searching during the day for bait on the east side of the lagoon revealed only a few concentrations of small sprats.

Results from the survey by Ika Corporation vessels (Anon 1980a) give a broader indication of bait availability in Tuvalu (Table 14). During commercial fishing, the vessels *Hatsutori Maru No.2* and *No.3* spent 58 nights baiting in Funafuti lagoon from May to October 1980. Catches per vessel averaged 92 kg nightly, but varied from month to month with an apparent decrease in the average catch on a monthly basis. Their average catches in July 1980 are comparable to those obtained by the *Hatsutori Maru No.5*, but are much lower than those of the *Hatsutori Maru No.1* in 1978 at a similar time of the year. Whether the catch decline reflects natural variability in bait biomass, or the effects of fishing is difficult to establish without further data on bait abundance over a longer time scale. However, the decline in catches emphasises the need for caution in planning the exploitation of Tuvalu's limited baitfish resources.

A list of all bait items caught by the Skipjack Programme in Tuvalu and their frequency of occurrence in bouki-ami hauls is given in Table 15.

TABLE 13. SUMMARY OF BAITFISHING EFFORT AND CATCH BY THE SKIPJACK PROGRAMME IN THE WATERS OF TUVALU

Anchorage	Time of Hauls	Number of Hauls	Dominant Species	Est. Av. Catch per Haul (kg)	Mean Length (mm)	Other Common Species
		June/July 1978				
Funafuti Lagoon			*Spratelloides delicatulus*	232	42	*Pranesus pinguis*[1]
08°29'S	Night	2	*Bregmaceros* sp.	5	39	*Archamia lineolata*
179°11'E			*Pterocaesio diagramma*			*Grammatorcynus bicarinatus*
Funafuti Lagoon			*Spratelloides delicatulus*	265	43	*Pseudamia polystigma*
08°30'S	Night	2	*Archamia lineolata*	23	47	*Halichoeres* sp.
179°12'E			*Bregmaceros* sp.			*Grammatorcynus bicarinatus*
		July 1980				
Funafuti Lagoon			*Spratelloides delicatulus*	47	33	Sp. of Holocentridae
08°31'S	Night	3	*Pranesus pinguis*	10	71	*Parapriacanthus* sp.
179°11'E			*Archamia lineolata*	7	35	*Bregmaceros* sp.
Funafuti Lagoon			*Spratelloides delicatulus*	9	29	*Bregmaceros* sp.
08°29'S	Night	3	*Pranesus pinguis*	4	85	*Selar crumenophthalmus*
179°12'E			*Archamia lineolata*	1	40	Sp. of Crustacea
Funafuti Lagoon			*Pranesus pinguis*	2	88	*Selar crumenophthalmus*
08°29'S	Night	1	*Spratelloides delicatulus*	2	44	Sp. of Mullidae
179°10'E			*Bregmaceros* sp.			Sp. of Holocentridae
Funafuti Lagoon			*Spratelloides delicatulus*	46	31	Sp. of Mullidae
08°26'S	Night	4	*Pranesus pinguis*	8	60	*Archamia lineolata*
179°10'E			*Bregmaceros* sp.			*Stenatherina panatela*

[1] The taxonomic nomenclature for this species is under review, and a change from *Pranesus pinguis* to *Atherinomorus lacunosa* is anticipated.

Explanatory Notes

Anchorage	: Recorded positions are truncated to the nearest minute. For large bays there may be more than one position tabulated.
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 three 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. Since the average catch per haul is given for only the dominant three species, the total of the three is in general less than the total catch for the anchorage and gear type.
Mean Length	: Weighted by numerical abundance when there were multiple hauls at the same location.
Other Common Species	: The three species which were next in numerical occurrence to the dominant species.

TABLE 14. COMPARISON OF SKIPJACK PROGRAMME AND IKA CORPORATION (Anon 1980a) BAITFISHING RESULTS IN THE WATERS OF TUVALU

		Nights Spent Fishing	Bouki-Ami Hauls	Total Catch (kg)	Average Catch per Haul (kg)	Average Catch per Night (kg)
SKIPJACK PROGRAMME						
June/July 1978	HM No.1	2	4	461	115.3*	230.5
July 1980	HM No.5	7	11	444	40.4	63.4
IKA CORPORATION						
May 1980	HM No.3	3	4	360	90.0	120.0
June 1980	HM No.2	19	29	1947	67.0	102.5
	HM No.3	13	21	1356	64.6	104.3
July 1980	HM No.2	6	11	480	43.6	80.0
	HM No.3	0	0	0	-	-
August 1980	HM No.2	3	4	330	82.5	110.0
	HM No.3	1	2	120	60.0	120.0
September 1980	HM No.2	9	12	495	41.3	55.0
	HM No.3	0	0	0	-	-
October 1980	HM No.2	4	5	240	48.0	60.0
	HM No.3	0	0	0	-	-

* Does not include an estimated 600 kg of live bait released because of insufficient baitwell capacity.

TABLE 15. CATCH AND FREQUENCY OF OCCURRENCE OF BAIT SPECIES IN BOUKI-AMI HAULS IN FUNAFUTI LAGOON. Both Skipjack Programme surveys are combined.

Species	Percentage of Hauls of which Species Occurred	Catch (kg)
Spratelloides delicatulus	100	1338
Pranesus pinguis[1]	67	73
Archamia lineolata	60	65
Bregmaceros sp.	60	9
Pterocaesio diagramma	27	0
Sp. of Mullidae	27	0
Sp. of Crustacea	20	0
Sp. of Holocentridae	20	0
Sp. of Sphyraenidae	13	0
Grammatorcynus bicarinatus	13	0
Scomberoides sp.	13	0
Sp. of Octopus	13	0
Selar crumenophthalmus	13	0
Stenatherina panatela	13	0
Decapterus macrosoma	13	0
Sp. of Chaetodontidae	7	0
Sp. of Acanthuridae	7	0
Halichoeres sp.	7	0
Pseudamia polystigma	7	0
Parapriacanthus sp.	7	0
Sp. of Lethrinidae	7	0
Total Catch		1485

[1] The taxonomic nomenclature for this species is under review, and a change from Pranesus pinguis to Atherinomorus lacunosa is anticipated.

Most abundant was the blue sprat, which accounted for 90 per cent by weight of the bait caught. This species is common in atoll lagoons where it schools close to the surface. Sprats are easily captured when they gather near the surface around bait attraction lights at night. The blue sprat is regarded as excellent bait, although it is difficult to maintain for long periods in baitwells, this being especially true for smaller fish. The common hardyhead, Pranesus pinguis, and cardinalfish, Archamia lineolata, occurred in small quantities and comprised the remainder of the catch. Both species are regarded as relatively hardy bait, although hardyheads are not particularly attractive to tuna (Skipjack Programme 1981b).

The size of sprats varied considerably between the first and second visits. The average sizes per baiting anchorage were 42 and 43 mm in 1978, and between 29 and 44 mm in 1980. During the second visit, scouting for bait during the day revealed large numbers of post-larval and small sprats less than 30 mm in length. Ika Corporation vessels also reported catches of small sprats, primarily during the full moon period (Anon 1980a). From data collected in Papua New Guinea, it has been suggested that reproductive development of the blue sprat commences when the fish is between 35 and 40 mm in length (Lewis, Smith and Kearney 1974). Therefore, the catches in Tuvalu during the second visit were probably of immature fish and representative of recent recruits to the baitfishery. Periodic catches of large numbers of immature sprats in Tuvalu emphasises the concern that fishery-induced depletion of bait resources could occur if juveniles were heavily fished.

A total of 591 kg of mollies (*Poecilia mexicana*), cultured in American Samoa, were transported to Tuvalu for bait effectiveness trials. These were used with varied results in association with natural bait caught in Funafuti lagoon (Bryan 1980; Skipjack Programme 1980b). In general, the mollies exhibited excellent keeping qualities over prolonged periods at high density in bait tanks (Skipjack Programme 1981b). Periodic outbreaks of epidermal infection could be controlled through the administration of antibiotics. However, the advantage of the hardiness of mollies was offset by their reduced attractiveness to tuna; for example, chumming success was lower in 1978 when mollies were used in conjunction with natural bait (Table 3). Kearney and Rivkin (1981) recently reviewed economic aspects of five bait culture projects in the Commission area and suggested a cautious approach to development of new bait culture projects, taking into account both economic and biological criteria.

Searching for bait during the day revealed only a few possible sites suitable for beach seining at the southern end of Funafuti lagoon. However, because of the restricted habitat and the lack of sardine species suitable for exploitation by beach seine gear, it is unlikely that beach seining would provide bait in quantities comparable to that provided using the bouki-ami technique.

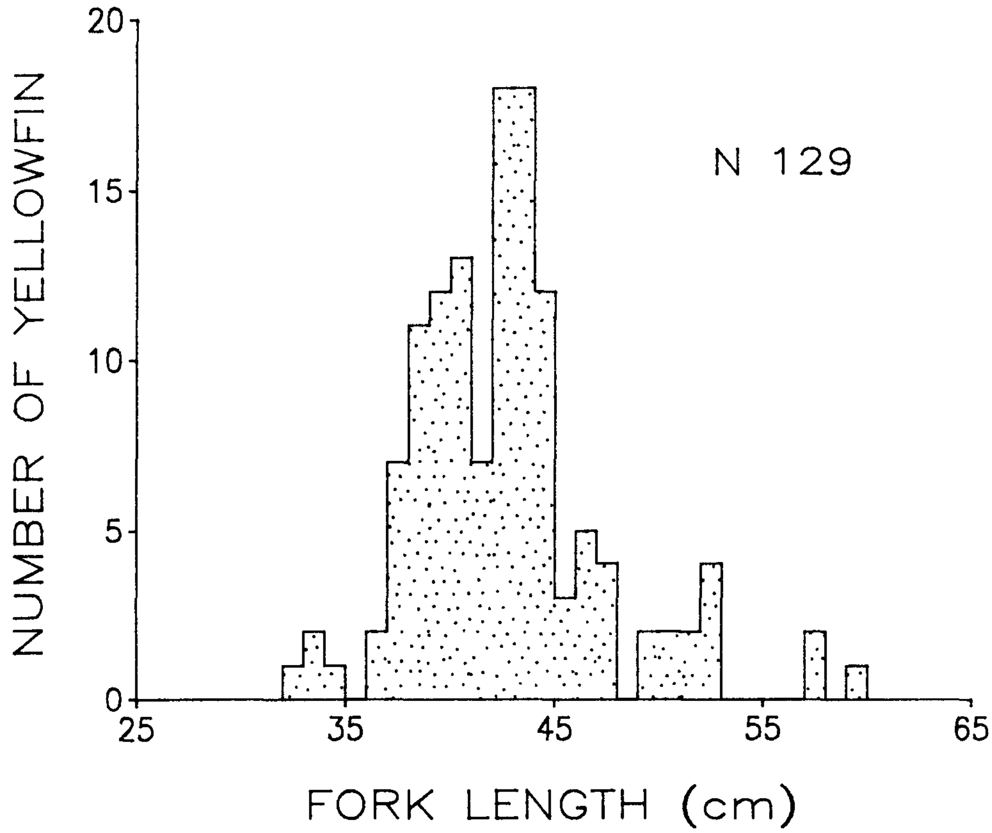
Overall, the survey bait catches illustrate the degree of variability of catches associated with a single species fishery. Continuing low catches and the presence of immature fish in catches indicate a resource with potential for fishery-induced depletion. The bait resource in Funafuti appears capable of supporting a small baitfish fishery for a limited portion of the year.

3.6 Yellowfin Tuna Biology and Tagging Results

Yellowfin tuna accounted for four per cent of the total tuna catch taken by the Programme in the waters of Tuvalu (Table 1). Nineteen per cent of all schools sighted in Tuvalu contained some yellowfin. During the second visit none of the schools encountered contained any yellowfin.

The length frequency distribution of yellowfin tagged during the first visit is shown in Figure 8. Yellowfin averaged 42.7 cm fork length, about 8 cm smaller than tagged skipjack. All yellowfin sampled were immature and sex could seldom be determined. The diet of yellowfin in Tuvalu was different from that of skipjack in that a much higher crustacean component was present in the form of three items: alima stage of stomatopods, crustacean remains and amphipods (Appendix C). One hundred and thirty-five yellowfin were tagged in Tuvalu, but to date none has been recovered. This is not surprising in view of the small number of releases and the relatively light fishing effort in the immediate area of tagging. Evaluation of yellowfin resources is being carried out under the Commission's Tuna and Billfish Assessment Programme which succeeded the Skipjack Programme.

FIGURE 8. LENGTH FREQUENCY DISTRIBUTION FOR YELLOWFIN TAGGED IN 1978 IN TUVALU. N is the sample size.



4.0 CONCLUSIONS

4.1 Skipjack Resources

Catch and sighting results from Skipjack Programme surveys suggest that skipjack were in reasonable abundance in the waters of Tuvalu during the June/July survey periods in 1978 and 1980. Available statistics for Japanese distant-water pole-and-line vessels show that in some years, high average daily catches, in excess of eight tonnes per day, have been taken between August and December. Further survey work in Tuvalu during the June to October period would appear to merit consideration, as this would provide more information on seasonal variability in skipjack and baitfish resources.

The lack of a substantial skipjack fishery in Tuvalu waters at the time of the survey, and the absence of catch statistics after 1978 for distant-water vessels fishing in Tuvalu, prevented estimation of many skipjack population parameters for Tuvalu. In other areas of the western Pacific where detailed catch statistics were available, it was found that levels of exploitation within locally based fisheries were well below the turnover rates of the stocks. This, coupled with the very low level of fishing effort by local fishermen, leaves little doubt that the skipjack resource in Tuvalu could yield catches much higher than existing levels.

Tagging and recovery data, blood genetics studies, and analyses of parasite distributions suggest that even though there is evidence of population structuring, there are no permanent barriers to the movement of skipjack in the western and central Pacific. Tagging has shown that skipjack from Tuvalu travel to many countries in the region, although distinct patterns in migration were not readily apparent. Few fish were recaptured in the waters of Tuvalu due to the low level of local fishing effort. These fish came from countries to the south, namely Fiji, Wallis and Futuna, and New Zealand. Interactions between locally based fisheries in nearby areas of the equatorial Pacific have been shown to be minimal at present, and a similar low level of interaction between Tuvalu and these locally based fisheries is assumed. Due to the international nature of the skipjack resource, however, increases in fishing effort both locally and in other countries, particularly those neighbouring Tuvalu, could amplify current levels of interaction. The potential for increased catches of skipjack in the waters of Tuvalu may well be reduced by expansion of neighbouring fisheries, and accordingly close attention should be paid to recent increases in purse-seine fishing activity.

4.2 Baitfish Resources

The visits of the *Hatsutori Maru No.1* and *No.5* to Tuvalu enabled the baitfish resources to be surveyed using fishing techniques similar to those used extensively in tropical waters by commercial pole-and-line boats. Baitfishing was restricted to Funafuti lagoon, the only baitfishing ground accessible to vessels of the size used in these surveys; Nukufetau atoll offers some potential for smaller vessels but could not be surveyed by the Skipjack Programme. Although there was little difficulty in capturing sufficient bait during the first visit in June/July 1978, in July 1980 bait appeared to be less plentiful and was of small size. The Ika Corporation vessels from Fiji also made poor catches in July 1980.

The baitfish catch in Funafuti was dominated by a single species, the blue sprat, which appears to undergo major fluctuations in recruitment and population size. This, coupled with the limited area of the Funafuti lagoon, suggests that the total abundance of sprats is not great. Thus, in the absence of a diversity of other bait species, large fluctuations can be expected in the bait catch, indicating a bait resource with little capacity for supporting a skipjack fishery.

Alternative baiting techniques are unlikely to provide quantities of bait comparable to those taken by "bouki-ami" net, but might provide sufficient bait to supplement bouki-ami catches. Alternative sources of bait, such as aquaculture, cannot be recommended at this time.

Overall, the limited availability of bait in Tuvalu waters will probably remain an obstacle to the maintenance of a locally based pole-and-line fishery; although it is possible that one vessel, fishing for only part of the year, could capture sufficient bait for economical operation.

REFERENCES

ANON (undated). Annual Report 1980. Fisheries Division, Ministry of Agriculture and Fisheries, Suva, Fiji.

ANON (1975). A proposal for a skipjack survey and assessment programme in the central and western equatorial Pacific Ocean. Expert Committee on Tropical Skipjack (16-17 October 1975), South Pacific Commission, Noumea, New Caledonia.

ANON (1976). A preliminary investigation into the fisheries potential of Tuvalu. Volume II, Fisheries Development Limited, London.

ANON (1979). Country Statement - Tuvalu. Regional Technical Meeting on Fisheries 1979, 11 : Working Paper No.3, South Pacific Commission, Noumea, New Caledonia.

ANON (1980a). Reports on skipjack fishing in the Tuvaluan waters. Ika Corporation, Suva, Fiji.

ANON (1980b). Review of preliminary results from genetic analysis of skipjack blood samples collected by the Skipjack Survey and Assessment Programme. Skipjack Survey and Assessment Programme Technical Report No.1, South Pacific Commission, Noumea, New Caledonia.

ANON (1981). Report of the second Skipjack Survey and Assessment Programme workshop to review results from genetic analysis of skipjack blood samples. Skipjack Survey and Assessment Programme Technical Report No.6, South Pacific Commission, Noumea, New Caledonia.

ARGUE, A.W. (1982). Methods used by the Skipjack Survey and Assessment Programme for collecting biological, tuna school and ancillary data from a pole-and-line fishing vessel. In Kearney, R.E. (Ed.). Methods used by the South Pacific Commission for the survey and assessment of skipjack and baitfish resources. Tuna and Billfish Assessment Programme Technical Report No.7, South Pacific Commission, Noumea, New Caledonia. pp 45-69.

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

ARGUE, A.W. and R.E. KEARNEY (1982). An assessment of the skipjack and baitfish resources of Solomon Islands. Skipjack Survey and Assessment Programme Final Country Report No.3, South Pacific Commission, Noumea, New Caledonia.

BRYAN, P.G. (1980). The efficiency of mollies, *Poecilla mexicana*, as live bait for pole-and-line skipjack fishing: fishing trials in the tropical central Pacific. Marine Fisheries Review 42:15-24.

CONWAY, G.R., N.R. GLASS and J.C. WILCOX (1970). Fitting nonlinear models to biological data by Marquardts algorithm. Ecology, 51(3):503-507.

FUJINO, K. (1966). Instructions for collecting blood and serum samples from tuna fishes. FAO Circular 26, Food and Agriculture Organization, Rome, Italy.

FUJINO, K. (1970). Skipjack tuna subpopulation identified by genetic characteristics in the western Pacific. In Marr, J.C. (Ed.). The Kuroshio: A symposium on the Japan current. East-West Center Press, Honolulu, 1968. pp 385-393.

FUJINO, K. (1976). Subpopulation identification of skipjack tuna specimens from the southwestern Pacific Ocean. Japanese Society of Scientific Fisheries Bulletin 42(11):1229-1235.

HALLIER, J.-P., R.E. KEARNEY and R.D. GILLETT (1982). Baitfishing methods used by the Skipjack Survey and Assessment Programme and recommendations on baitfishing techniques for the tropical Pacific. In Kearney, R.E. (Ed.). Methods used by the South Pacific Commission for the survey and assessment of skipjack and baitfish resources. Tuna and Billfish Assessment Programme Technical Report No.7, South Pacific Commission, Noumea, New Caledonia. pp 71-107.

KEARNEY, R.E. (1978). Interim report of the activities of the Skipjack Survey and Assessment Programme in the waters of Fiji (26 January-18 February, 28 March-10 April 1978). Skipjack Survey and Assessment Programme Preliminary Country Report No.5, South Pacific Commission, Noumea, New Caledonia.

KEARNEY, R.E. (1982). Development and implementation of the Skipjack Survey and Assessment Programme. In Kearney, R.E. (Ed.). Methods used by the South Pacific Commission for the survey and assessment of skipjack and baitfish resources. Tuna and Billfish Assessment Programme Technical Report No.7, South Pacific Commission, Noumea, New Caledonia. pp 2-17.

KEARNEY, R.E. and R.D. GILLETT (1982). Methods used by the Skipjack Survey and Assessment Programme for tagging skipjack and other tuna. In Kearney, R.E. (Ed.). Methods used by the South Pacific Commission for the survey and assessment of skipjack and baitfish resources. Tuna and Billfish Assessment Programme Technical Report No.7, South Pacific Commission, Noumea, New Caledonia. pp 19-43.

KEARNEY, R.E., J.-P. HALLIER and P. KLEIBER (1978). Interim report of the activities of the Skipjack Survey and Assessment Programme in the waters of Tuvalu (25 June-4 July 1978). Skipjack Survey and Assessment Programme Preliminary Country Report No.10, South Pacific Commission, Noumea, New Caledonia.

KEARNEY, R.E. and M.L. RIVKIN (1981). An examination of the feasibility of baitfish culture for skipjack pole-and-line fishing in the South Pacific Commission area. Skipjack Survey and Assessment Programme Technical Report No.4, South Pacific Commission, Noumea, New Caledonia.

KLAWE, W.L. (1978). Estimates of catches of tunas and billfishes by the Japanese, Korean and Taiwanese longliners from within the 200 mile economic zone of the member countries of the South Pacific Commission. South Pacific Commission Occasional Paper No.10, Noumea, New Caledonia.

KLEIBER, P., A.W. ARGUE and R.E. KEARNEY (1983). Assessment of skipjack (Katsuwonus pelamis) resources in the central and western Pacific by estimating standing stock and components of population turnover from tagging data. Tuna and Billfish Assessment Programme Technical Report No.8, South Pacific Commission, Noumea, New Caledonia.

KLEIBER, P. and C.A. MAYNARD (1982). Data processing procedures of the Skipjack Survey and Assessment Programme. In Kearney, R.E. (Ed.). Methods used by the South Pacific Commission for the survey and assessment of skipjack and baitfish resources. Tuna and Billfish Assessment Programme Technical Report No.7, South Pacific Commission, Noumea, New Caledonia. pp 109-122.

LAWSON, T.A. and R.E. KEARNEY (Manuscript). Estimates of growth rates and length measurement errors for skipjack (Katsuwonus pelamis) from the western Pacific Ocean based on tagging data. Tuna and Billfish Assessment Programme Technical Report, South Pacific Commission, Noumea, New Caledonia.

LESTER, R.J.G. (1981). Preliminary results of observations on the parasites of Pacific skipjack tuna. Regional Technical Meeting on Fisheries 1981, 13 : Background Paper, South Pacific Commission, Noumea, New Caledonia.

LEWIS, A.D., B.R. SMITH and R.E. KEARNEY (1974). Studies on tunas and baitfish in Papua New Guinea waters - II. Department of Agriculture, Stock and Fisheries Research Bulletin 11, Port Moresby, Papua New Guinea.

McQUARRIE, P. (1982). Te Tautai : A gift to Tuvalu from Japan. Pacific Islands Monthly, 53(7).

RAJU, G. (1964). Studies on the spawning of the oceanic skipjack Katsuwonus pelamis (Linnaeus) in Minicoy waters. Proceedings Symposium on Scombroid Fishes, Marine Biological Association of India, Part II:744-768.

RICHARDSON, B.J. (1983). Distribution of protein variation in skipjack tuna (Katsuwonus pelamis) from the central and south-western Pacific. Australian Journal of Marine and Freshwater Research 34:231-251.

SHARP, G.D. (1969). Electrophoretic study of tuna hemoglobins. Comparative Biochemistry and Physiology, 31:249.

SHARP, G.D. (1978). Behavioural and physiological properties of tunas and their effects on vulnerability to fishing gear. In Sharp, G.D. and A.E. Dizon (Eds). The physiological ecology of tunas. Academic Press, New York. pp 397-450.

SIBERT, J.R., R.E. KEARNEY and T.A LAWSON (1983). Variation in growth increments of tagged skipjack (Katsuwonus pelamis). Tuna and Billfish Assessment Programme Technical Report No.10, South Pacific Commission, Noumea, New Caledonia.

SKIPJACK PROGRAMME (1980a). Skipjack fishing effort and catch, 1972-1978, by the Japanese pole-and-line fleet within 200 miles of the countries in the area of the South Pacific Commission. Skipjack Survey and Assessment Programme Technical Report No.2, South Pacific Commission, Noumea, New Caledonia.

SKIPJACK PROGRAMME (1980b). A preliminary comparison of fishing effectiveness between cultured and natural baitfish species used by tuna pole-and-line fishing gear. Regional Technical Meeting on Fisheries 1980, 12 : Working Paper No.17, South Pacific Commission, Noumea, New Caledonia.

SKIPJACK PROGRAMME (1981a). Skipjack migration, mortality and fishery interactions. Regional Technical Meeting on Fisheries 1981, 13 : Working Paper No.9, South Pacific Commission, Noumea, New Caledonia.

SKIPJACK PROGRAMME (1981b). Further observations on fishing performance of baitfish species in the South Pacific Commission area. Regional Technical Meeting on Fisheries 1981, 13 : Working Paper No.13, South Pacific Commission, Noumea, New Caledonia.

SKIPJACK PROGRAMME (1981c). An appraisal of the genetic analysis of skipjack blood samples. Regional Technical Meeting on Fisheries 1981, 13 : Working Paper No.10, South Pacific Commission, Noumea, New Caledonia.

SMITH, B.R. (1977). Appraisal of the live bait potential and handling characteristics of the common tuna bait species in Papua New Guinea. In Shomura, R.S. (Ed.). Collection of tuna baitfish papers. United States National Marine Fisheries Service Circular 408:95-103.

TRAVIS, W. (1978). Some thoughts on the logical development of artisanal fisheries in Tuvalu. Unpublished manuscript.

UNDP/FAO (1969). South Pacific Tuna Mission 1969 Report. Annexe III, Gilbert and Ellice Islands Colony.

ZANN, L.P. (undated). Tuvalu's artisanal fishing fleet. Effects of energy crisis on small craft and fisheries in the South Pacific: Report 2. Institute of Marine Resources, University of the South Pacific, Suva, Fiji.

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

Scientists

A.W. Argue	1980, June 29 - July 8
Charles Ellway	1978, June 22 - July 4
Jean-Pierre Hallier	1978, June 22 - July 4
" "	1980, June 29 - July 8
James Ianelli	1980, June 29 - July 8
Christopher Thomas	1978, June 22 - July 4

Observers

Patrick Bryan, American Samoa Baitfish Project
J. Hayakawa, Hokoku Marine Products
Takatashi Morita, Hokoku Marine Products
Elisala Pita, Tuvalu Fisheries Division
Sam Rawlings, Tuvalu Fisheries Division
Ioapo Tapu)
Lotonu Taulau) Tuvalu Fishermen
Tupou Teuki)

Vessel Crew

Kenji Arima
Ryoichi Eda
Sakae Hyuga
Mitsutoyo Kaneda, Captain, Hatsutori Maru No.5
Seima Kobayashi
Koshihiro Kondoh*
Yoshio Kosuka
Masahiro Matsumoto, Captain, Hatsutori Maru No.1
Akio Okumura
Yoshikatsu Oikawa*
Tsunetaka Ono
Yukio Sasaya
Kohji Wakasaki*
Mikio Yamashita*

Fishing Crew

Lui Andrews*
Vonitiese Bainamoli
Jovesa Buarua
Mosese Cakau
Samuela Delana*
Lui Diva
Eroni Dolodai
Luke Kaidrokai
Kitione Koroi*
Metuisela Koroi
Aminiasi Kuruyawa
Sovita Lequeta
Jone Manuka
Eroni Marawa*
Joshua Raguru
Jona Ravasakula*
Napolioni Ravitu
Ravaele Tikovakaca
Tuimasi Tuilekutu
Samuela Ue*
Taniela Verekila

* Indicates that he crewed on both visits.

APPENDIX B. DIET ITEMS FOUND IN STOMACHS OF SKIPJACK SAMPLED IN THE WATERS OF TUVALU

Item No.	Diet Item	Number of Stomachs	Percentage Occurrence
	Fish and Invertebrates		
1	Chum from Hatsutori Maru	137	56.38
2	Fish remains (not chum)	107	44.03
3	Squid (Cephalopoda)	74	30.45
4	Holocentridae	43	17.70
5	Acanthuridae	40	16.46
6	Juvenile fish	39	16.05
7	Alima stage (Stomatopoda)	39	16.05
8	Carid shrimp (Decapoda)	32	13.17
9	Empty stomach	30	12.35
10	*Stolephorus buccaneeri* (Engraulidae)	19	7.82
11	Gempylidae	17	7.00
12	Gastropoda	14	5.76
13	Megalopa stage (Decapoda)	14	5.76
14	Siganidae	12	4.94
15	Phyllosoma stage (Decapoda)	10	4.12
16	Heteropoda (Gastropoda)	9	3.70
17	Shrimp (Decapoda)	9	3.70
18	Exocoetidae	8	3.29
19	Paralepidae	8	3.29
20	Unidentified fish	7	2.88
21	Crustacean remains	6	2.47
22	Tuna juvenile (Scombridae)	5	2.06
23	Amphipoda	5	2.06
24	Chaetodontidae	3	1.23
25	Balistidae	3	1.23
26	Blue goatfish (Mullidae)	3	1.23
27	Trash material	2	0.82
28	Nomeidae	2	0.82
29	Mollusca	2	0.82
30	Tunicate (Urochordata)	2	0.82
31	Polychaeta (Annelida)	1	0.41
32	Apogonidae	1	0.41
33	Sternoptychidae	1	0.41
34	Trichiuridae	1	0.41
35	Plastic material	1	0.41
36	Scaridae	1	0.41
37	Anchovy juvenile (Engraulidae)	1	0.41
38	Bramidae	1	0.41
39	*Decapterus* sp. (Carangidae)	1	0.41
40	*Scomberoides* sp. (Carangidae)	1	0.41
	Total Stomachs Examined	243	

APPENDIX C. DIET ITEMS FOUND IN STOMACHS OF YELLOWFIN SAMPLED IN THE WATERS OF TUVALU

Item No.	Diet Item	Number of Stomachs	Percentage Occurrence
	Fish and Invertebrates		
1	Alima stage (Stomatopoda)	42	65.63
2	Chum from Hatsutori Maru	33	51.56
3	Crustacean remains	20	31.25
4	Fish remains (not chum)	17	26.56
5	Amphipoda	17	26.56
6	Squid (Cephalopoda)	14	21.88
7	Acanthuridae	13	20.31
8	Phyllosoma stage (Decapoda)	12	18.75
9	Megalopa stage (Decapoda)	12	18.75
10	Juvenile fish	10	15.63
11	Carid shrimp (Decapoda)	6	9.38
12	Siganidae	4	6.25
13	Gastropoda	4	6.25
14	Holocentridae	3	4.69
15	Chaetodontidae	3	4.69
16	Octopus (Cephalopoda)	2	3.13
17	Zoaea stage (Crustacea)	2	3.13
18	Paralepidae	2	3.13
19	Sternoptychidae	1	1.56
20	Bramidae	1	1.56
21	Nomeidae	1	1.56
22	Shrimp (Decapoda)	1	1.56
23	Aluteridae	1	1.56
24	Echeneidae	1	1.56
25	Empty stomach	1	1.56
26	Heteropoda (Gastropoda)	1	1.56
27	Stolephorus buccaneeri (Engraulidae)	1	1.56
	Total Stomachs Examined	64	

APPENDIX D. RELEASE AND RECAPTURE INFORMATION ON RECOVERIES OF SKIPJACK TAGGED IN THE WATERS OF TUVALU. For explanation of country abbreviations see Appendix E.

TAG NO.		DATE	LATITUDE	LONGITUDE	SIZE	COUNTRY
SK23022	release data:	78/06/30	08deg 42'S	179deg 03'E	51.0cm	TUV1
	recapture data:	78/07/28	08deg 25'S	179deg 00'E	. cm	TUV
At large for 28 days.		Distance = 17.3 naut. miles in direction 350.deg. true.				
SK22936	release data:	78/07/01	08deg 42'S	179deg 10'E	51.0cm	TUV1
	recapture data:	78/09/22	05deg 40'S	176deg 17'E	55.0cm	TUV
At large for 83 days.		Distance = 250.2 naut. miles in direction 316.deg. true.				
SK21163	release data:	78/06/25	10deg 35'S	178deg 33'W	46.0cm	TUV1
	recapture data:	79/02/17	17deg 03'S	179deg 16'E	52.0cm	FIJ
At large for 237 days.		Distance = 408.3 naut. miles in direction 198.deg. true.				
SF01788	release data:	78/06/25	10deg 23'S	178deg 48'W	49.0cm	TUV1
	recapture data:	79/07/19	09deg 00'S	160deg 35'E	56.0cm	SOL
At large for 389 days.		Distance = 1221.9 naut. miles in direction 272.deg. true.				
SK21289	release data:	78/06/25	10deg 23'S	178deg 48'W	51.0cm	TUV1
	recapture data:	79/11/25	08deg 30'S	159deg 00'E	55.0cm	SOL
At large for 518 days.		Distance = 1318.5 naut. miles in direction 273.deg. true.				
SK21534	release data:	78/06/25	10deg 23'S	178deg 48'W	49.0cm	TUV1
	recapture data:	80/01/25	04deg 32'N	172deg 11'E	61.6cm	MAS
At large for 579 days.		Distance = 1044.6 naut. miles in direction 329.deg. true.				
SK22104	release data:	78/06/25	10deg 08'S	179deg 05'W	51.6cm	TUV1
	recapture data:	78/08/14	13deg 30'S	172deg 50'W	50.0cm	WES
At large for 50 days.		Distance = 418.9 naut. miles in direction 119.deg. true.				
SK22203	release data:	78/06/27	08deg 40'S	179deg 13'E	51.0cm	TUV1
	recapture data:	79/11/27	06deg 20'N	162deg 45'W	64.0cm	PAM
At large for 518 days.		Distance = 1404.8 naut. miles in direction 51.deg. true.				
SK22501	release data:	78/06/27	08deg 40'S	179deg 13'E	51.9cm	TUV1
	recapture data:	78/10/04	02deg 00'S	175deg 25'E	51.1cm	KIR
		to	to	to		
		78/10/09	02deg 24'S	178deg 00'E		
SK22715	release data:	78/06/28	08deg 59'S	179deg 04'E	53.0cm	TUV1
	recapture data:	79/10/19	02deg 12'S	149deg 59'E	66.0cm	PNG
At large for 478 days.		Distance = 1782.6 naut. miles in direction 281.deg. true.				
SF00027	release data:	78/06/29	08deg 12'S	178deg 38'E	37.0cm	TUV1
	recapture data:	80/07/13	03deg 20'N	174deg 15'W	64.0cm	INT
At large for 745 days.		Distance = 812.6 naut. miles in direction 32.deg. true.				
SK22735	release data:	78/07/01	08deg 40'S	179deg 06'E	53.5cm	TUV1
	recapture data:	79/10/19	06deg 09'N	167deg 26'W	63.3cm	INT
At large for 475 days.		Distance = 1199.7 naut. miles in direction 43.deg. true.				

SK22753	release data:	78/07/01	08deg 40'S	179deg 06'E	53.5cm	TUV1
	recapture data:	80/03/01	12deg 10'N	138deg 36'E	62.0cm	YAP
At large for 609 days.		Distance = 2719.5 naut. miles in direction 297.deg. true.				
SK23034	release data:	78/07/01	08deg 40'S	179deg 06'E	53.0cm	TUV1
	recapture data:	78/11/11	03deg 32'S	178deg 13'W	46.0cm	INT
At large for 133 days.		Distance = 347.1 naut. miles in direction 28.deg. true.				
SK23046	release data:	78/07/01	08deg 40'S	179deg 06'E	51.0cm	TUV1
	recapture data:	78/10/05	00deg 43'N	162deg 31'E	53.5cm	INT
At large for 96 days.		Distance = 1140.2 naut. miles in direction 299.deg. true.				
SK22799	release data:	78/07/01	08deg 42'S	179deg 10'E	52.0cm	TUV1
	recapture data:	80/02/08	04deg 20'N	169deg 25'E	45.0cm	MAS
At large for 587 days.		Distance = 975.6 naut. miles in direction 323.deg. true.				
SK22992	release data:	78/07/01	08deg 42'S	179deg 10'E	50.0cm	TUV1
	recapture data:	78/10/28	02deg 24'S	173deg 02'W	51.8cm	PHO
At large for 119 days.		Distance = 599.7 naut. miles in direction 51.deg. true.				
SK22996	release data:	78/07/01	08deg 42'S	179deg 10'E	51.0cm	TUV1
	recapture data:	78/11/25	02deg 12'S	176deg 20'W	55.0cm	HOW
At large for 147 days.		Distance = 473.6 naut. miles in direction 35.deg. true.				
SK23148	release data:	78/07/01	08deg 42'S	179deg 10'E	52.0cm	TUV1
	recapture data:	79/11/10	03deg 53'N	177deg 32'E	63.6cm	INT
At large for 497 days.		Distance = 761.3 naut. miles in direction 353.deg. true.				
SK23224	release data:	78/07/01	08deg 42'S	179deg 10'E	54.0cm	TUV1
	recapture data:	80/05/15	23deg 02'N	170deg 04'W	78.0cm	HAW
At large for 684 days.		Distance = 2006.2 naut. miles in direction 18.deg. true.				
SK23330	release data:	78/07/01	08deg 42'S	179deg 10'E	54.0cm	TUV1
	recapture data:	78/09/09	00deg 58'S	167deg 06'E	57.0cm	NAU
At large for 70 days.		Distance = 857.3 naut. miles in direction 302.deg. true.				
SK23531	release data:	78/07/02	08deg 44'S	179deg 03'E	55.0cm	TUV1
	recapture data:	78/10/02	00deg 19'N	179deg 40'E	52.5cm	INT
At large for 92 days.		Distance = 544.2 naut. miles in direction 4.deg. true.				
SK23277	release data:	78/07/04	05deg 57'S	177deg 15'E	61.9cm	TUV1
	recapture data:	79/02/02	03deg 50'N	174deg 40'E	66.5cm	KIR
At large for 213 days.		Distance = 607.1 naut. miles in direction 345.deg. true.				
SK23553	release data:	78/07/04	05deg 57'S	177deg 15'E	60.0cm	TUV1
	recapture data:	78/12/09	05deg 14'N	164deg 15'E	60.0cm	KOS
At large for 158 days.		Distance = 1028.0 naut. miles in direction 310.deg. true.				
1E18112	release data:	80/07/08	05deg 49'S	176deg 15'E	65.0cm	TUV2
	recapture data:	81/02/08	06deg 52'N	169deg 35'E	69.1cm	MAS
At large for 215 days.		Distance = 859.3 naut. miles in direction 332.deg. true.				
1E14882	release data:	80/07/08	05deg 43'S	175deg 58'E	59.0cm	TUV2
	recapture data:	80/09/01	05deg 00'N	175deg 00'W	58.0cm	INT
		to	to	to		
		80/09/10	06deg 00'N	176deg 00'W		

1E14900	release data:	80/07/08	05deg 43'S	175deg 58'E	63.0cm	TUV2
	recapture data:	80/11/01	07deg 03'N	165deg 49'E	65.5cm	MAS

At large for 116 days. Distance = 977.8 naut. miles in direction 321.deg. true.

1E18177	release data:	80/07/08	05deg 43'S	175deg 58'E	62.0cm	TUV2
	recapture data:	81/02/11	15deg 46'S	179deg 47'W	48.0cm	FIJ

At large for 218 days. Distance = 652.8 naut. miles in direction 158.deg. true.

APPENDIX E. 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)
MAH - Matthew and Hunter Islands
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