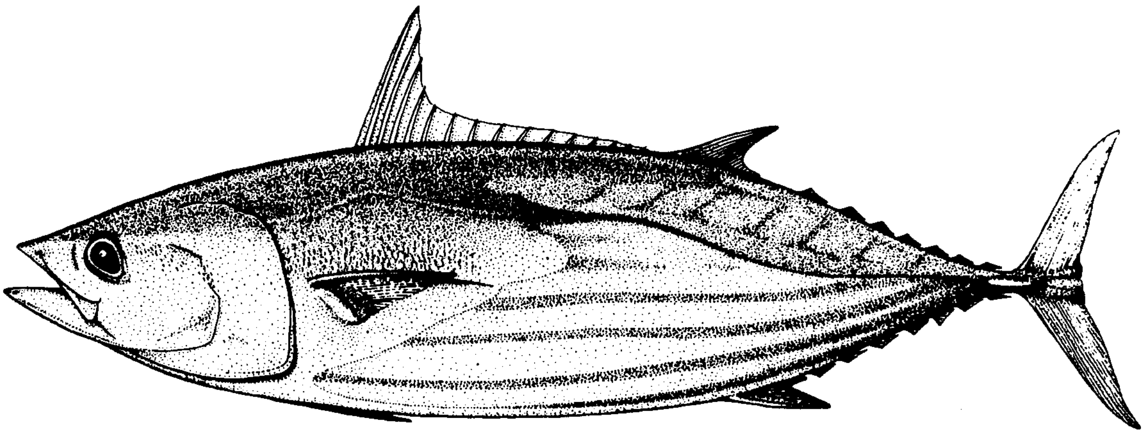
SPC A

AN ASSESSMENT OF THE SKIPJACK AND BAITFISH RESOURCES OF NAURU



Skipjack Survey and Assessment Programme
Final Country Report No. 13

South Pacific Commission
Noumea, New Caledonia
April 1984

AN ASSESSMENT OF THE SKIPJACK AND BAITFISH RESOURCES OF NAURU

Skipjack Survey and Assessment Programme
Final Country Report No.13

South Pacific Commission
Noumea, New Caledonia
April 1984

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.

The Skipjack Programme has been succeeded by the Tuna and Billfish 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 Skipjack Programme's investigation of yellowfin tuna resources of the region, is continuing under the Tuna Programme. Reports have been prepared in a final country report series for each of the countries and territories for which the South Pacific Commission works. 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, L.S. Hammond, 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 Programme is grateful for the assistance of the Department of External Affairs and the Department of Island Development and Industry in facilitating the survey of Nauru waters.

Tuna Programme
South Pacific Commission

For bibliographic purposes this document should be cited as follows:

Tuna Programme (1984). An assessment of the skipjack and baitfish resources of Nauru. Skipjack Survey and Assessment Programme Final Country Report No.13, South Pacific Commission, Noumea, New Caledonia.

CONTENTS

		Page
PREFACE		iii
LIST OF TABLES		vi
LIST OF FIGURES		vii
1.0	INTRODUCTION	1
	1.1 Previous Research and Fisheries Development	1
2.0	METHODS	2
	2.1 Vessels and Crew	2
	2.2 Baitfishing	2
	2.3 Fishing, Tagging and Biological Sampling	2
	2.4 Data Compilation and Analysis	3
3.0	SUMMARY OF FIELD ACTIVITIES	4
4.0	RESULTS AND DISCUSSION	4
	4.1 Baitfish Availability	4
	4.2 Skipjack Fishing	4
	4.3 Skipjack Population Biology	7
	4.3.1 Maturity and recruitment	7
	4.3.2 Diet	8
	4.3.3 Growth	8
	4.3.4 Population structure	11
	4.4 Tag Recapture Data	14
	4.4.1 International migrations	14
	4.4.2 Resource assessment	14
	4.4.3 Fishery interactions	17
5.0	CONCLUSIONS	21
REFERENCES		22
APPENDICES		
A.	Scientists and crew on board the research vessel	27
B.	Abbreviations used for countries and territories in the central and western Pacific	29

LIST OF TABLES

Table		Page
1	Summary of daily field activities in the waters of Nauru	6
2	Summary of length increments for skipjack tagged by the Skipjack Programme in various countries and territories in the Skipjack Programme study area	10
3	Standardised increments of length for fish 50 cm long at release and at liberty for 90 days	11
4	Summary of skipjack release and recovery data for the entire Skipjack Programme, as of 10 October 1983	19
5	Coefficients of interaction between fisheries operating in various countries and territories in the South Pacific Commission region	20

LIST OF FIGURES

Figure		Page
A	The area of the South Pacific Commission	Inside front cover
B	Straight line representations of movements of skipjack tagged by the Skipjack Programme and subsequently recovered	Inside back cover
1	Area surveyed for skipjack by the Skipjack Programme in the waters of Nauru	5
2	Distribution of female skipjack by maturity stage for samples from the entire Skipjack Programme study area	7
3	Average gonad indices, by month, for female skipjack sampled by the Skipjack Programme from tropical waters south of the Equator	9
4	Skipjack serum esterase gene frequency for 163 samples versus the longitude of the sample location	13
5	Numbers of skipjack tag recoveries, by distance travelled and time-at-large, for the entire Skipjack Programme data set	15
6	Numbers of skipjack tag recoveries versus months at large, for the entire Skipjack Programme data set	16

AN ASSESSMENT OF THE SKIPJACK AND BAITFISH RESOURCES OF NAURU

1.0 INTRODUCTION

The Skipjack Survey and Assessment Programme was created in response to rapid expansion of surface fisheries for skipjack (*Katsuwonus pelamis*) during the 1970s in the waters of the central and western Pacific. 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 skipjack 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 throughout the region and sound management of the resource.

The Skipjack Programme carried out 847 days of tagging and survey operations in the central and western Pacific between October 1977 and August 1980. The total study area included all of the countries and territories in the area of the South Pacific Commission and also New Zealand and Australia (Figure A, inside front cover). The Programme surveyed the waters of Nauru between 12 and 15 July 1980 (Kearney & Hallier 1980); this report assesses skipjack and baitfish resources of Nauru on the basis of results of this survey and others conducted in the Programme's study area.

1.1 Previous Research and Fisheries Development

Traditionally, Nauruans caught surface tunas by trolling pearl-shell lures or by deep handlining (Anell 1955; Petit-Skinner 1981), but these activities, along with most other forms of fishing, have declined markedly in recent years. Most Nauruans now fish only occasionally to meet personal needs. However, there is some subsistence fishing by other Pacific Islanders presently resident on Nauru.

Surveys in 1971-1974 by the Japan Marine Fishery Resource Research Center (Anon. 1972; Kikawa 1977) concluded that the lack of baitfish around Nauru precluded the development of a locally based pole-and-line fishery to exploit the apparently abundant surface tuna resource. However, the Japanese distant-water pole-and-line fleet, which utilises live bait transported from Japan, has fished successfully in waters now included in Nauru's Exclusive Economic Zone. Almost 25,000 tonnes of tuna (97% skipjack) were taken between 1972 and 1978, at an average rate of 6.5 tonnes per boat per day (Skipjack Programme 1980). Longlining has also been conducted by Japanese, Korean and Taiwanese vessels (Skipjack Programme 1981a; Klawe 1978). Combined catches by these vessels ranged from 948 to 2,799 tonnes of tuna annually between 1972 and 1976 (Klawe 1978), but only 10 tonnes of this were skipjack.

There has been some exploratory purse-seining in Nauruan waters by United States vessels. In March 1978 the *Jeanette C* made two sets, catching a total of 83 tonnes of tuna, of which 54 tonnes were skipjack (Souter & Broadhead 1978). The *Island Princess* made an unsuccessful set in August 1979 (Souter & Salomons 1980). Nauru's 311,117 square kilometre Exclusive Economic Zone (Sevele & Bollard 1979) lies to the east of the main areas of present activity of the Japanese purse-seine fleet, and between the major areas of United States purse-seining activity, so may be expected to provide suitable conditions for purse-seining.

The Nauru Fishing Corporation was established by the Government of Nauru in 1976, and reportedly built a freezing plant and a katsuobushi plant in 1977 (Kent 1980) to service future tuna fishing ventures. There is no information available on the operations of these plants. Two purse-seiners from the eastern Pacific were purchased by the Nauru Fishing Corporation in 1980, but have yet to establish successful fishing operations (M. Depaune pers. comm.).

2.0 METHODS

2.1 Vessels and Crew

Two Japanese commercial fishing vessels, the Hatsutori Maru No.1 and the Hatsutori Maru No.5, were chartered at different times by the Skipjack Programme from Hokoku Marine Products Company Limited, Tokyo, Japan. Details of both vessels are given in Kearney (1982). The 254-tonne Hatsutori Maru No.5 was used during the survey of Nauru in July 1980.

The Hatsutori Maru No.5 was operated with at least three Skipjack Programme scientists, nine Japanese officers and fifteen Fijian crew. Scientists and crew who were on board during the survey in the waters of Nauru are listed in Appendix A.

2.2 Baitfishing

Baitfishing carried out by the Programme usually employed a "bouki-ami" net set at night around bait attraction lights. In some countries beach seining during daylight was used as an alternative bait catching technique. Details of both techniques and all modifications employed by the Skipjack Programme are given in Hallier, Kearney & Gillett (1982). In Nauru only visual inspections around bait attraction lights at night were made, since there were no situations in which the research vessel could be anchored and the bouki-ami net deployed. Only small numbers of baitfish were attracted to the underwater lights.

2.3 Fishing, Tagging and Biological Sampling

Both vessels used by the Skipjack Programme were designed for commercial live-bait, pole-and-line fishing, and the basic strategy of approaching and chumming schools normally employed by such vessels was not changed. As with commercial fishing, minor variations in technique were tried from day to day depending upon the behaviour of skipjack schools and the quantity and quality of live bait carried.

The number of crew on the Hatsutori Maru No.1 and Hatsutori Maru No.5 was fewer than either of these vessels carry when fishing commercially. The effective number of fishermen was further reduced because at least one crew member was required to assist each scientist in the tagging procedures. Moreover, the need to pole tuna accurately into the tagging cradles reduced the speed of individual fishermen. Clearly, these factors decreased the fishing power of the vessels under research conditions. During the first survey in the waters of Fiji (26 January to 10 April 1978), the Hatsutori Maru No.1 fished commercially for approximately one month, as part of the charter agreement between the Programme and the vessel's owner. From comparison of survey and commercial catches at this time, it was estimated that the fishing power of the Hatsutori Maru No.1 under survey conditions, such as in Nauru, was 29 per cent of its fishing power during commercial fishing (Kearney 1978). It was assumed that the same conversion ratio of 3.47 applied to the Hatsutori Maru No.5.

Since tagging was the primary research tool, attempts to tag large numbers of skipjack usually dominated the fishing strategy. The tagging techniques and alterations to commercial fishing procedures have been described in detail by Kearney & Gillett (1982).

Specimens of tuna and other pelagic species which were poled or trolled, but not tagged and released, were routinely analysed. Data collected included length, weight, sex, gonad weight, stage of sexual maturity, and a record of stomach contents. In addition, a log was maintained of all fish schools sighted throughout the Programme. Where possible the species composition of each school was determined. Records were kept of the chumming response and catch by species from each school. Argue (1982) described methods used for the collection of these data.

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

Beginning in December 1979, body cavities of skipjack captured on board the Programme's vessels were examined for the presence of macro-parasites. 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.

2.4 Data Compilation and Analysis

Five separate logbooks were used for compiling data accumulated during the fieldwork outlined in Sections 2.2 and 2.3. The techniques used to enter data from these logs into computer files and to process data are discussed in Kleiber & Maynard (1982). Electrophoretic data from blood samples and parasite identifications from skipjack viscera were also coded and entered into computer files. Data processing was carried out on the Programme's Hewlett Packard 1000 computer in Noumea.

Assessment of the skipjack resource and possible interactions among skipjack fisheries required several different approaches. Records of the migration of tagged skipjack formed the basis of investigation of movement patterns and fishery interactions using analytic techniques described in Skipjack Programme (1981c) and Kleiber, Sibert & Hammond (ms.). Evaluation of the magnitude of the skipjack resource and its dynamics, based on tag recapture data, were described by Kleiber, Argue & Kearney (1983). Methods employed in biological studies of growth are described in Lawson, Kearney & Sibert (ms.) and Sibert, Kearney & Lawson (1983), and of juvenile abundance, in Argue, Conand & Whyman (1983). Procedures used to compare fishing effectiveness between different baitfish families are described in Argue, Williams & Hallier (ms.). Evaluation of population structuring across the whole of the western and central Pacific was based on a comparison of the tagging results with blood genetics analyses (Anon. 1980, 1981; Skipjack Programme 1981b) and analyses of the occurrence and distribution of skipjack parasites (Lester, Barnes & Habib ms.).

3.0 SUMMARY OF FIELD ACTIVITIES

The area surveyed for tuna and baitfish while in the waters of Nauru is shown in Figure 1 and a summary of the field activities is presented in Table 1.

Four days were spent in Nauru's waters in mid 1980. The Programme spent 33 hours searching and fishing for tuna. Since no live bait was available for pole-and-line fishing, only trolling was attempted, resulting in the capture of one skipjack, which was not tagged.

The reproductive condition and stomach contents of this fish were noted. It was a female, 51 cm long, close to the average size of 50.4 cm recorded by the Programme during the entire study. No blood or parasite samples were taken.

4.0 RESULTS AND DISCUSSION

4.1 Baitfish Availability

There is virtually no habitat suitable for baitfish around the island of Nauru, because of the absence of a back-reef lagoon or shallow, protected embayments with fresh-water runoff. Only small populations of baitfish can be expected to occur. This has been corroborated by earlier surveys which failed to reveal adequate concentrations of bait necessary to the operation of a large pole-and-line vessel (Anon. 1972; Kikawa 1977). Apart from a few schools of scad (*Selar* sp.), no baitfish species were sighted by the Skipjack Programme in Nauruan waters and no baitfishing was attempted.

The use of wild or cultured bait from adjacent countries was considered by the Programme for its Nauru surveys. However, baitfish catches in Tuvalu, the country surveyed prior to the Nauru visit, proved to be insufficient (Ellway et al. 1983). An attempt to obtain cultured live bait from Kiribati was unsuccessful because of a labour dispute there.

4.2 Skipjack Fishing

During the four-day survey of Nauru waters, 44 schools were sighted, at an average rate of 1.33 schools per hour spent searching or fishing. This is much higher than the sighting rate of the overall Programme (0.75 schools/hour). Furthermore, 41 of the schools were sighted during the 19.5 hours in which the vessel was within 50 nautical miles of Nauru, at an average of 2.1 schools per hour. Only five of the schools were identified to species (Table 1); three of these contained skipjack. As there was no pole-and-line fishing, it is not possible to determine what the catch rate would have been. However, the Japanese pole-and-line fleet averaged 6.5 tonnes per boat per day between 1972 and 1978 (Skipjack Programme 1980), compared with an average catch by these vessels of 5.5 tonnes per boat per day elsewhere in the South Pacific Commission region during the same period (Tuna Programme unpublished data). Thus, skipjack may be considered to be more than normally abundant in Nauruan waters.

FIGURE 1. AREA SURVEYED FOR SKIPJACK BY THE SKIPJACK PROGRAMME IN THE WATERS OF NAURU

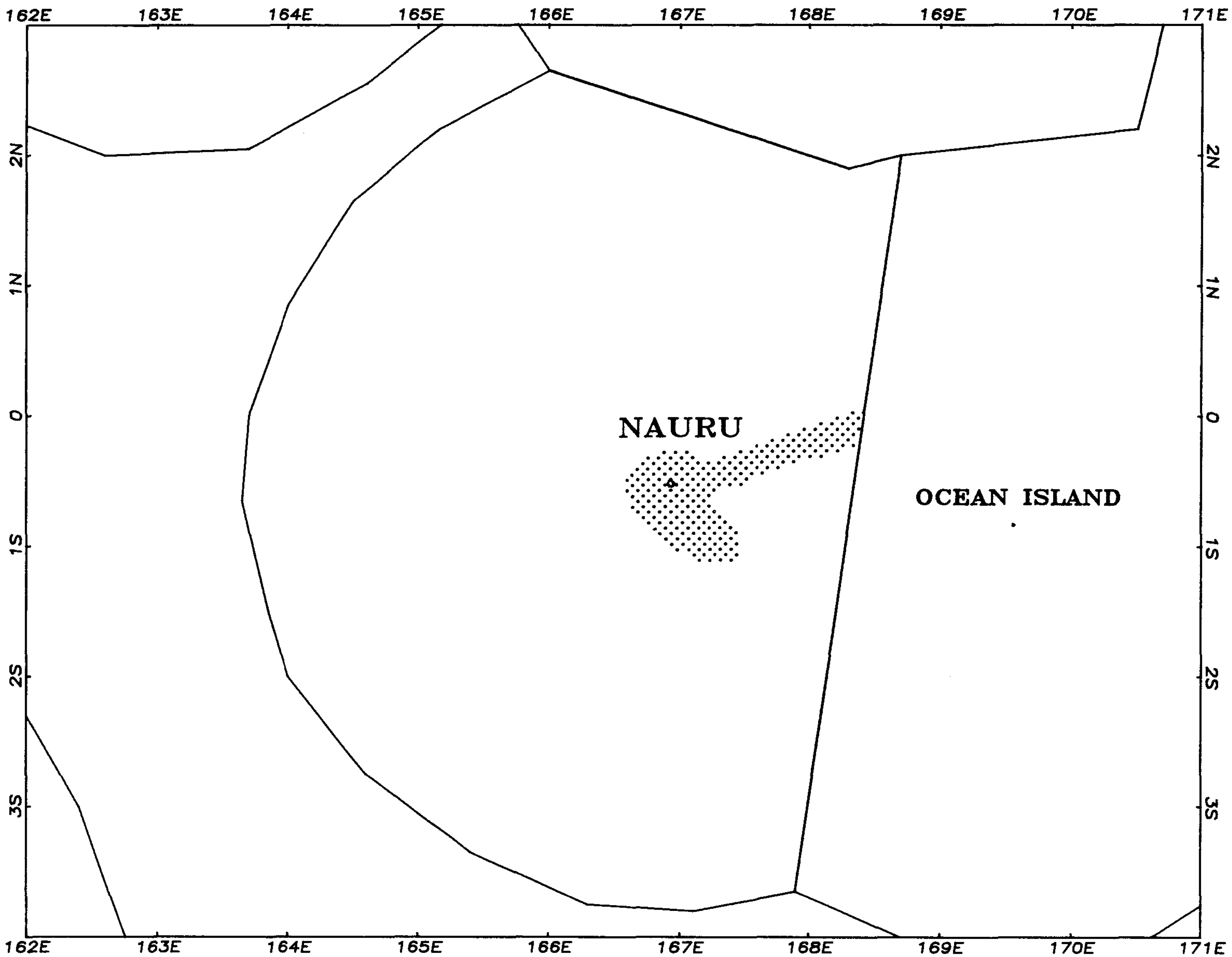


TABLE 1. SUMMARY OF DAILY FIELD ACTIVITIES IN THE WATERS OF NAURU. Schools sighted are identified by species: SJ = skipjack or skipjack with other species except yellowfin, YF = yellowfin or yellowfin with other species except skipjack, S+Y = skipjack with yellowfin or skipjack with yellowfin and other species, OT = other species without skipjack or yellowfin, UN = unidentified.

Date	General Area	Principal Activity	Bait Carried (kg)	Hours Searching or Fishing*	Schools Sighted (numbers)					Fish Tagged (numbers)			Fish Caught		Total Catch (kg)
					SJ	YF	S+Y	OT	UN	SJ	YF	OT	SJ	YF	
12/07/80	E Nauru	Fishing*	0	9	1	0	0	0	5	-	-	-	-	-	-
13/07/80	Nauru	Fishing*	0	10	1	1	0	0	19	-	-	-	-	-	-
14/07/80	Nauru	Fishing*	0	6	1	0	0	1	15	0	0	0	1	0	3
15/07/80	N Nauru	Fishing*	0	8	0	0	0	0	0	-	-	-	-	-	-
TOTALS	Days 4			33	3	1	0	1	39	0	0	0	1	0	3

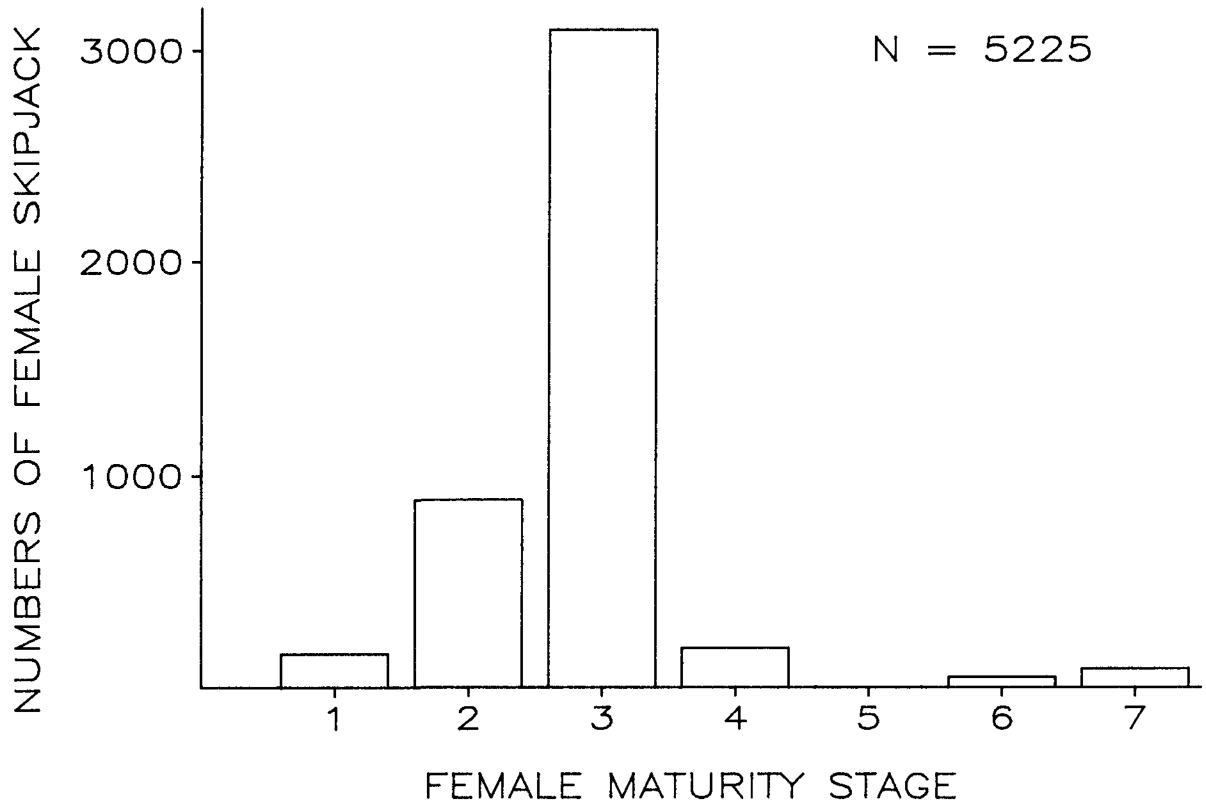
* = All fishing was done by trolling.

4.3 Skipjack Population Biology

4.3.1 Maturity and recruitment

Figure 2 presents female skipjack maturity data for all Skipjack Programme samples from tropical central and western Pacific waters. Seven stages of gonad maturity were recognised using criteria in Argue (1982), representing a progression of reproductive condition from immature (stage 1) to post-spawning (stages 6 and 7). Maturing gonads were classified as stages 2 and 3, mature gonads as stage 4 and ripe gonads as stage 5. Only one female was sampled in Nauru and was stage 3, which is the dominant stage in most of the Programme's samples.

FIGURE 2. DISTRIBUTION OF FEMALE SKIPJACK BY MATURITY STAGE FOR SAMPLES FROM THE ENTIRE SKIPJACK PROGRAMME STUDY AREA



Seasonal changes in female gonad index[1] for all Skipjack Programme samples from tropical waters suggest that skipjack spawning is most

---

1 Gonad index=10^7(gonad weight gm/(fish length mm)^3) (Schaefer and Orange 1956). 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).

frequent south of the Equator during spring-summer months (October to March) (Figure 3). This trend is very similar to that presented by Naganuma (1979) for samples collected from a wide area of the tropical south Pacific, and by Lewis (1981) for samples from the Papua New Guinea fishery, just a few degrees south of the Equator. The single female sampled from Nauru in 1980 had a gonad index value of 73.5, higher than the July average for skipjack of a similar size from the total Programme sample (Figure 3).

A further index of spawning activity is the incidence of skipjack juveniles observed in the stomachs of predators. An average of 200 skipjack juveniles per 100 skipjack predator stomachs was observed in Nauru during the survey in 1980 (i.e. 2 juvenile skipjack found in the single stomach sampled). This value, the highest observed during the entire Programme, is undoubtedly an artifact resulting from the very small sample size, but the presence of juveniles suggests that skipjack breeding does occur in Nauruan waters. Argue et al. (1983) presented detailed analyses of the tuna juvenile data, taking into account size-selective predation by adults, time of day, distance from land and sampling season. Skipjack juveniles occurred most frequently in the stomachs of skipjack between October and March in the Programme's samples from tropical waters south of the Equator, which is roughly the period of maximum skipjack gonad development in these waters. The data also indicate that during the 1977 to 1980 survey period, abundance of juvenile skipjack within the study area was highest in two areas, one roughly bounded by Solomon Islands, Papua New Guinea and Vanuatu, and the other including the Marquesas and Tuamotu Islands. As virtually nothing is known about the movements of juvenile skipjack, the relative contributions of spawning in these areas or in local waters to recruitment in Nauru cannot be established.

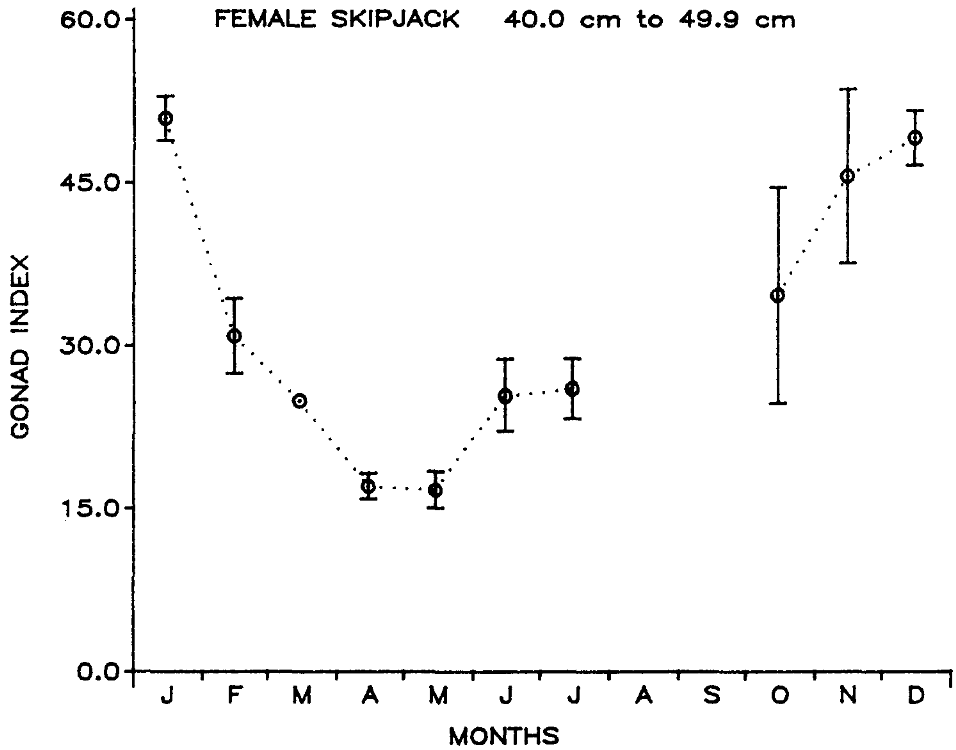
4.3.2 Diet

The one skipjack sampled in Nauru contained only skipjack juveniles in its stomach. Almost all samples taken by the Skipjack Programme throughout the tropical central and western Pacific contained a wide variety of diet items (e.g. Tuna Programme 1984), indicating that skipjack are opportunistic feeders. Nevertheless, fish appear consistently to be the most important component of the diet of skipjack.

4.3.3 Growth

The growth of skipjack, as in other tunas, is a function of size. Larger fish increase in length more slowly than smaller fish (Joseph & Calkins 1969). Therefore, when a tagged 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 2 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 different. Similarly, the effects of size-at-release can be seen by noting the difference in growth increments

FIGURE 3. AVERAGE GONAD INDICES (± two standard errors), BY MONTH, FOR FEMALE SKIPJACK SAMPLED BY THE SKIPJACK PROGRAMME FROM TROPICAL WATERS SOUTH OF THE EQUATOR. Standard errors omitted for one small (<5) sample (top graph, March); other sample sizes were at least 8 and most exceeded 100. No samples for August and September.



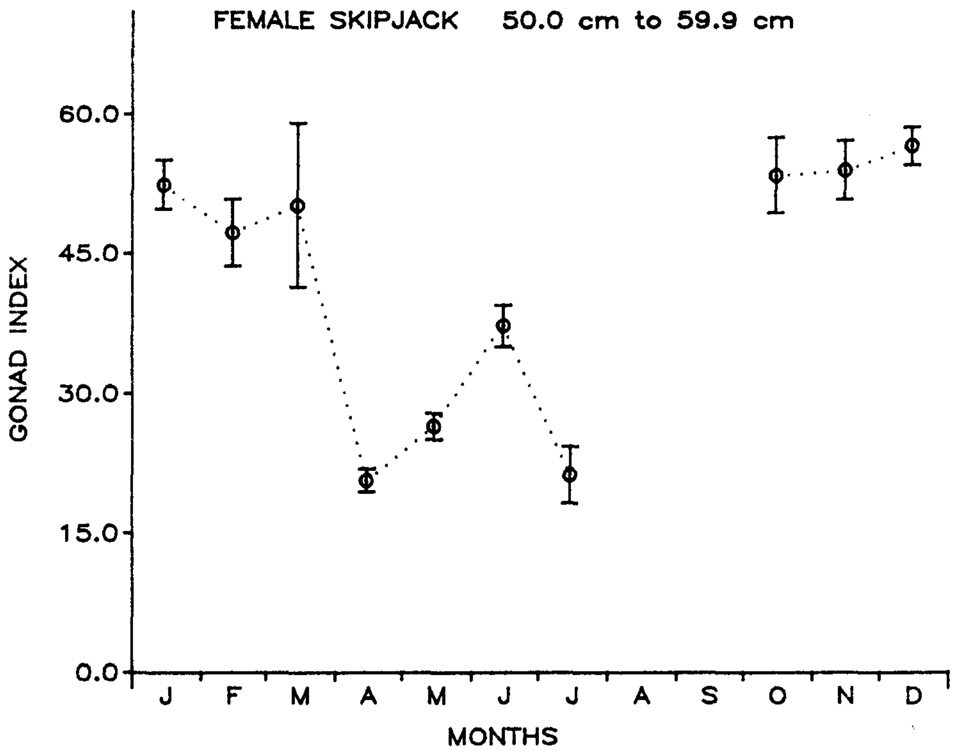


TABLE 2. SUMMARY OF LENGTH INCREMENTS FOR SKIPJACK TAGGED BY THE SKIPJACK PROGRAMME IN VARIOUS COUNTRIES AND TERRITORIES IN THE SKIPJACK PROGRAMME STUDY AREA. Fish were at large for periods between 10 and 365 days. Country abbreviations are explained in Appendix B.

	RECAPTURES WITHIN COUNTRY OF RELEASE						RECAPTURES OUTSIDE COUNTRY OF RELEASE					
Country and Visit	Sample Size	Mean Size at Release	Mean Size at Recapture	Mean Days at Liberty	Increment Mean	Increment Standard Deviation	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	0.65	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 (see Kearney, Lewis & Smith 1972; Lewis, Smith & Kearney 1974).

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 different. Growth increments were in most instances quite small, and the proportion of fish which did not show any measurable growth was high (40.1%). There are several possible 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 et al. 1983). Standardised growth increments are presented in Table 3. Growth varied considerably from country to country, and differed significantly between visits to a country and between fish recovered inside and outside of the country of release (Sibert et al. 1983). Thus, skipjack growth seems to be highly variable in time and space. The growth observed in tagged skipjack is a function of where and when the fish were tagged, and where they were recovered. It may be closely coupled to environmental conditions such as temperature and other oceanographic variables that are thought to regulate the abundance of food.

TABLE 3. STANDARDISED INCREMENTS (cm) OF LENGTH FOR FISH 50 CM LONG AT RELEASE AND AT LIBERTY FOR 90 DAYS. The 95 per cent confidence interval of each increment is given in parentheses. Country abbreviations are explained in Appendix B.

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

It is not possible to assess growth of skipjack in Nauru waters since no fish were tagged there.

4.3.4 Population structure

There is movement of some skipjack adults over much of the western and central Pacific (Figure B, inside back cover), suggesting that genetic exchange is possible among all parts of the Programme's study area. However, detailed examination of tag recapture data (Section 4.4.1) and preliminary analyses of fishery interactions (Section 4.4.3) indicate that the actual level of exchange of skipjack, at least of the size caught by pole-and-line gear, may be quite low. Analyses of the genetic variation in skipjack throughout the central and western Pacific were undertaken by the Skipjack Programme to provide additional information on migration, population structure and, ultimately, potential interactions between fisheries.

Results from electrophoretic analysis 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 Pacific between approximately 120°E and 130°W (Figure 4). There was considerable variation in individual esterase gene frequency values along this gradient, although the cause of this variability was unclear (Anon. 1981).

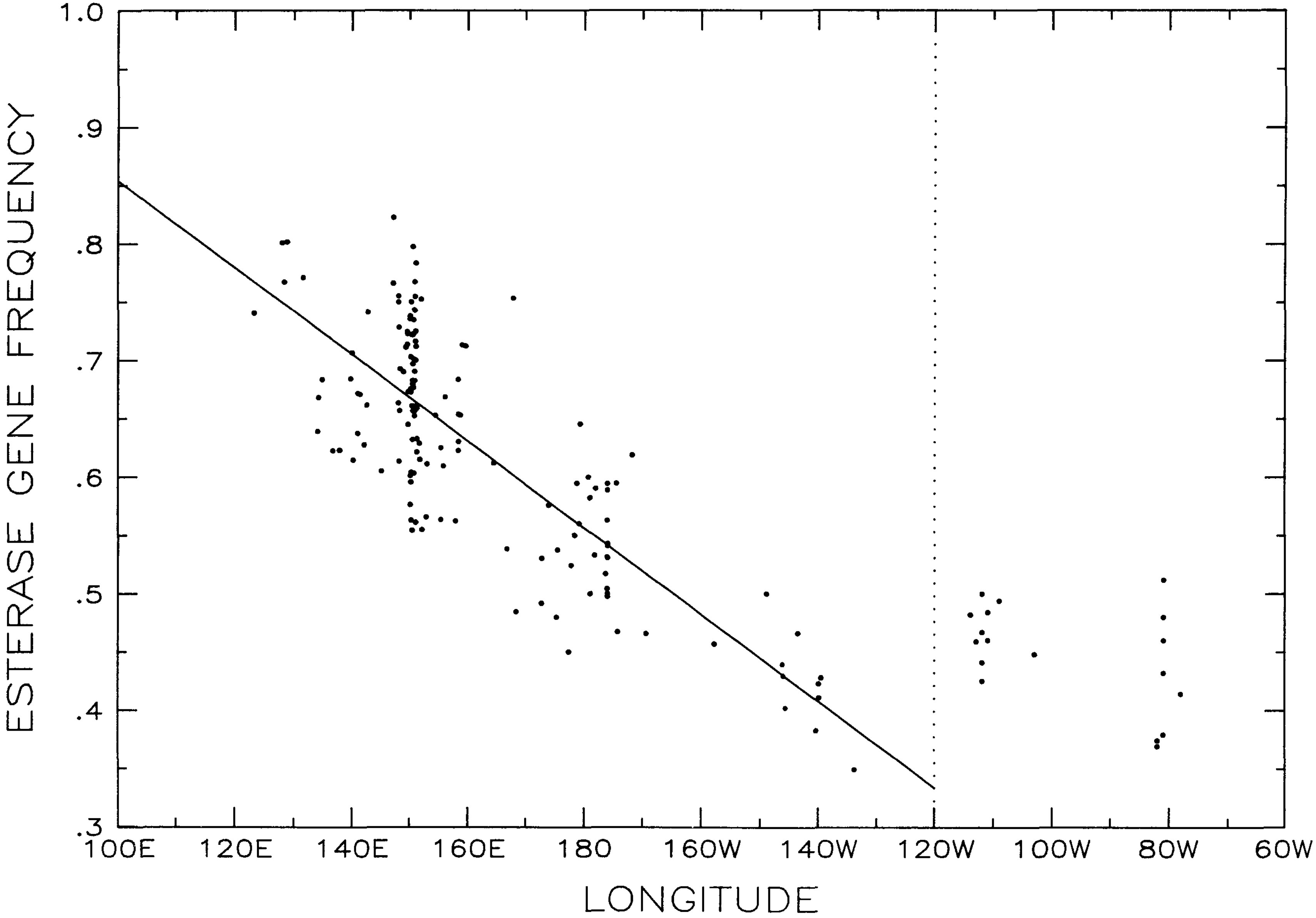
Several models of population structure of skipjack in the Pacific Ocean have been proposed (Fujino 1972, 1976; Sharp 1978; Anon. 1981). One of these models, suggested by the Programme's tagging and blood genetics data, is called the clinal population structure model (Anon. 1981). It has the basic premise that the probability that any two skipjack will ever breed is at any instant 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 (1972, 1976) and Sharp (1978).

The gradient in esterase gene frequency is consistent with several possible distributions of skipjack spawning, one being a relatively even distribution of spawning in tropical waters across the study area. Alternatively, it may be considered a product 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 (east of 130°W) and those from French Polynesia suggests that skipjack from these areas may have the same genetic origin and thus could collectively represent the group at one extreme. The geographic pattern of occurrence of skipjack juveniles in predator stomachs (Section 4.3.1) tentatively supports the latter view of skipjack spawning.

Parasite samples were taken over a wide range of tropical waters and from subtropical and temperate waters of Norfolk Island and New Zealand, but not from Nauru. A multivariate analysis presented by Lester et al. (ms.) showed that the parasite faunas from widely separated tropical areas were similar, and that skipjack caught in New Zealand carried many tropical parasites. The parasite studies did not improve definition of skipjack population structure, nor offer a means of clarifying fishery interactions.

After two workshops hosted by the Skipjack Programme to examine the question of skipjack population structure, it was concluded (Anon. 1980, 1981) that it is difficult to choose between the various population structure hypotheses, due to limitations of the extant blood genetics, tagging and ancillary data. However, the genetics data supported the conclusions that there should be minimal short-term interactions between fisheries at the extremes of the Programme's study area, and that interaction should increase as the distance between fisheries decreases.

FIGURE 4. SKIPJACK SERUM ESTERASE GENE FREQUENCY FOR 163 SAMPLES VERSUS THE LONGITUDE OF THE SAMPLE LOCATION. Each point is the average of approximately 100 specimens sampled from a single school on the same day.



4.4 Tag Recapture Data

The Skipjack Programme did not tag any skipjack in Nauru and there were only four recoveries in Nauruan waters of skipjack tagged elsewhere. These fish came from Fiji, the Gilbert Group of Kiribati, Marshall Islands and Tuvalu. Thus, migration patterns and size, dynamics, and interactions of the stock cannot be assessed for skipjack from Nauru. The results of the overall Programme will therefore be used as a basis for discussion and specific aspects relevant to the assessment of Nauru's resources will be emphasised.

4.4.1 International migrations

Figure B presents a selection of Skipjack Programme tag returns plotted as straight line trajectories between tagging and recovery location. Returns were selected by plotting no more than one example of a migration in each direction between any pair of ten degree squares and no more than two examples of a migration wholly within any ten degree square. The impression from this figure is one of considerable mixing of skipjack, with little evidence of barriers to movement of skipjack within the study area. The lack of apparent movement beyond the area surveyed reflects poor chances for recovery as a result of low fishing effort and environmental barriers to migration at the latitudinal extremes (skipjack are seldom encountered polewards of 40 degrees latitude or in waters less than 16°C).

The overall impression of many wide-ranging international migrations depicted by Figure B does not accurately reflect the average over all the tag recoveries. The figure overemphasises long-distance, relatively rare migrations, due to the procedure used to select recoveries for the figure. The majority (86%) of tag recoveries were made less than 250 nautical miles from their release site and within 180 days of tagging (Figure 5). Long-distance migrations are prevalent only within the group of skipjack that were at large for more than 180 days.

4.4.2 Resource assessment

The Programme's tag recapture data provide a basis for assessing the magnitude of the skipjack resource and its resilience to fishing pressure. A model formulated by Kleiber et al. (1983) was used to analyse tag attrition rates (the frequency of tag returns as a function of time) to derive estimates of various parameters of skipjack stock dynamics. Separate analyses were performed for the whole study area covered by the Programme and for the 200-mile zones of Papua New Guinea, Solomon Islands, the Gilbert Group of Kiribati, Fiji, New Zealand, and the Society Islands of French Polynesia, for each of which there were sufficient tag recapture statistics, as well as data on either catch or effort by fishing fleets. Figure 6 shows the numbers of tag returns for the whole Skipjack Programme study area versus the numbers of months these tags were at large after release. The straight line in the figure depicts the average number of tag recoveries one would predict per month from fitting the mathematical model of Kleiber et al. (1983) to the catch and tag return data.

The data points (stars) in Figure 6 deviate little from the line predicting the average number of tag returns per month. The instantaneous rate of decrease of tag returns estimated from the fitting procedure is called the tag attrition rate, which results from natural and fishing mortality, changes in vulnerability, and emigration. An additional component, presumably small, includes both the continual shedding of tags

FIGURE 5. NUMBERS OF SKIPJACK TAG RECOVERIES, BY DISTANCE TRAVELLED AND TIME-AT-LARGE, FOR THE ENTIRE SKIPJACK PROGRAMME DATA SET. Data are for tag returns received by 10 October 1983. Recaptures for 103 fish which travelled more than 1,500 nautical miles are included in the sample sizes, but are not shown in the figure.

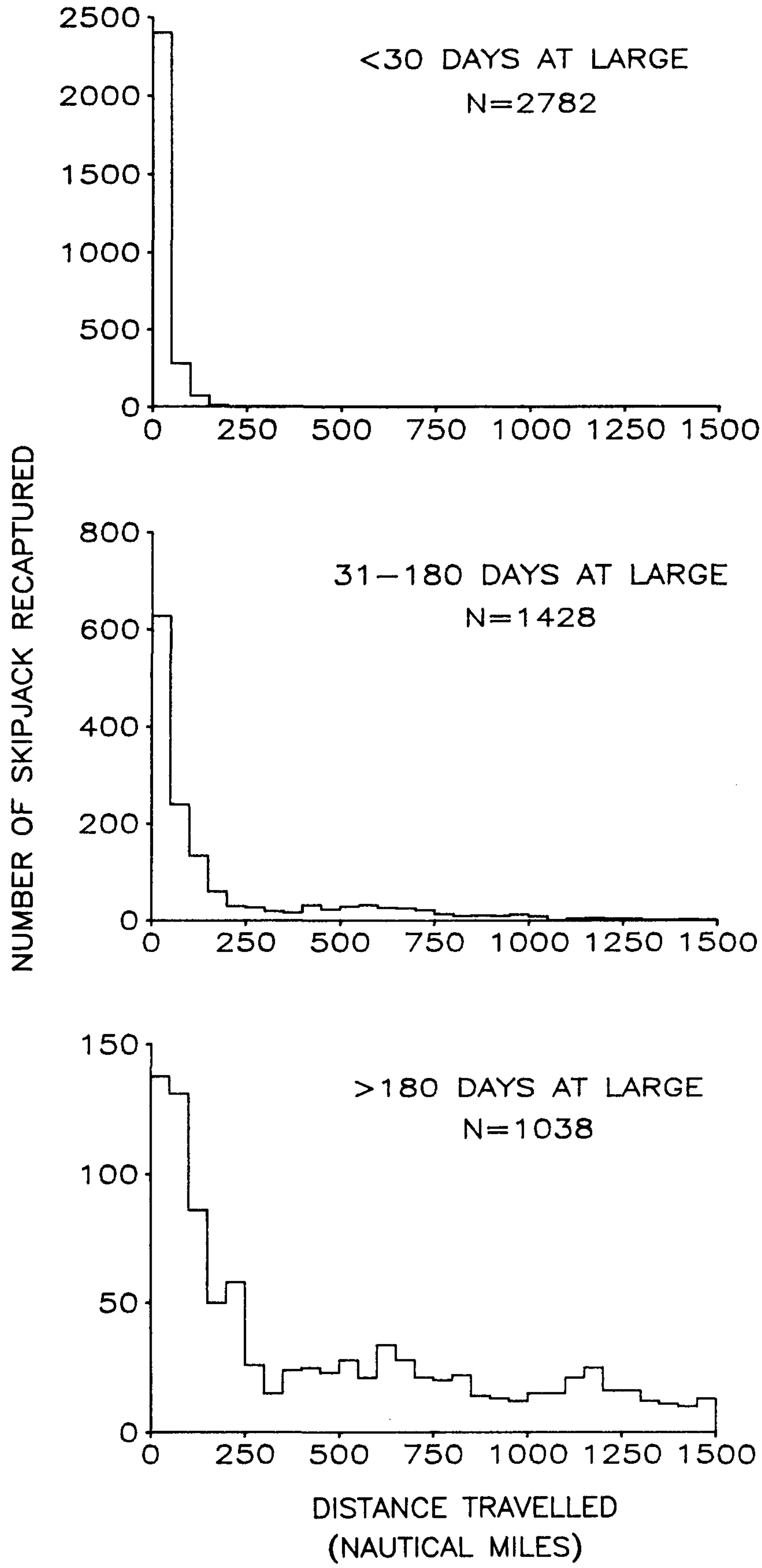
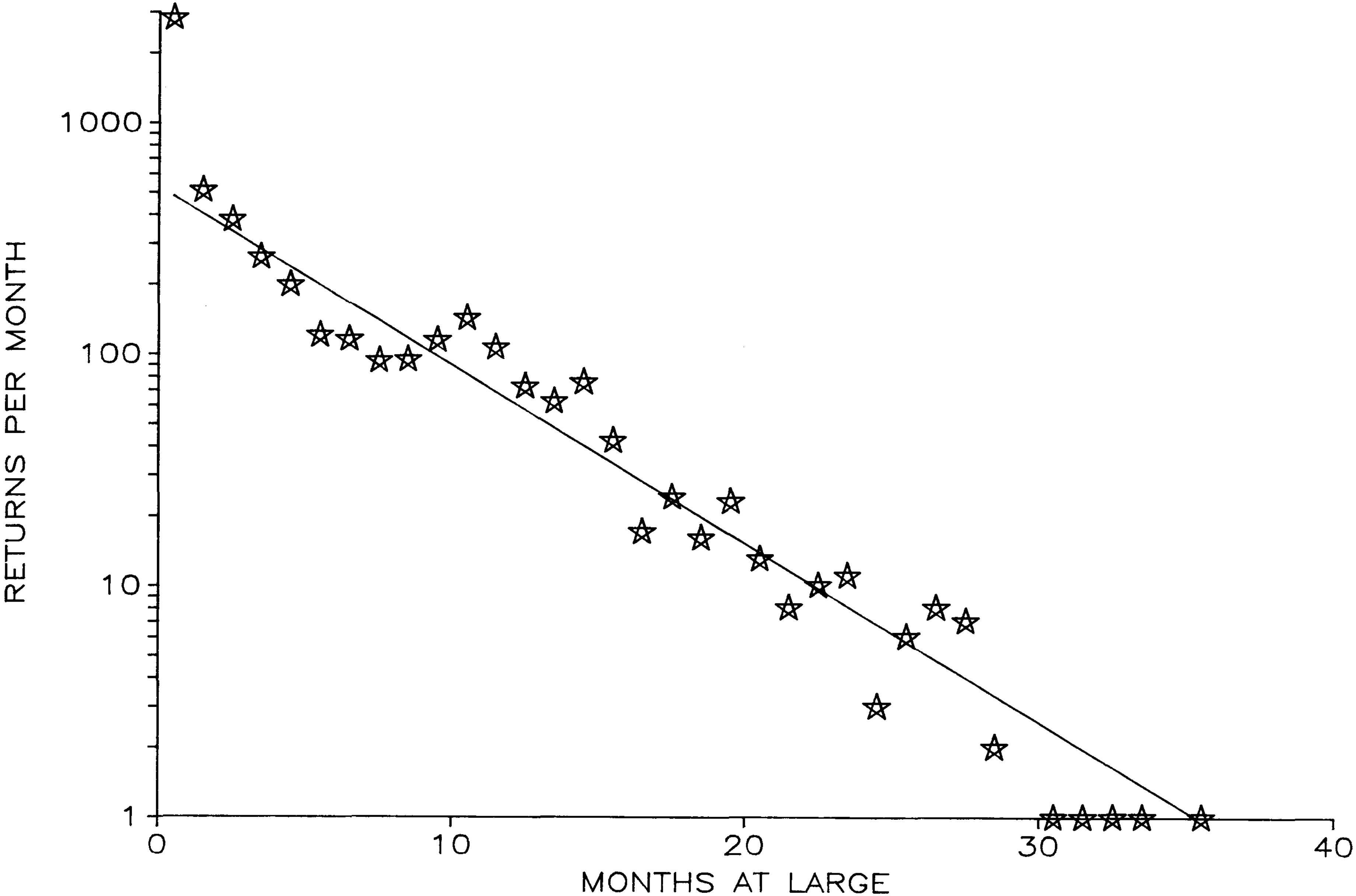


FIGURE 6. NUMBERS OF SKIPJACK TAG RECOVERIES VERSUS MONTHS AT LARGE, FOR THE ENTIRE SKIPJACK PROGRAMME DATA SET. The Y axis has a logarithmic scale.



and continual mortality from the effects of tagging. The estimate of attrition rate was 0.17 per month (Kleiber et al. 1983), which is similar to the rate of 0.23 estimated for skipjack stocks from the north eastern tropical Pacific (Joseph & Calkins 1969). Thus, after six months at large, close to 70 per cent of the tag releases by the Skipjack Programme were unavailable for recapture, for one or another of the reasons above, and after a year this had increased to 90 per cent. Assuming steady-state conditions in the stock, these fish were replaced by new recruits through reproduction, growth and immigration.

The model also provided estimates of several other parameters of the skipjack stock, but in doing so a correction factor was applied to account for non-return of recaptured tags, return of tags without sufficient or accurate recapture data, and loss of tags immediately after application through shedding or mortality. In the entire study area, the population size or "standing stock" which was vulnerable to surface fisheries was estimated to be approximately three million tonnes during the 1977 to 1981 study period (95% confidence range of 2.5 million to 3.7 million tonnes). Average monthly catch, 19,000 tonnes, divided by population size provided an estimate of average monthly fishing mortality of 0.006, which is a small proportion of the monthly attrition rate. Other losses, through natural death, emigration and decreased vulnerability to fishing are difficult to partition, but because the study area was vast and covered much of the area of skipjack distribution in central and western Pacific waters, it has been assumed that emigration is the smallest of the three.

The product of standing stock and monthly attrition rate provides an estimate of monthly "throughput" - the biomass (tonnes) of skipjack recruited to the standing stock each month. It is assumed for the duration of the tagging experiment to be matched by an equal amount leaving each month (i.e. steady-state conditions prevail). From Skipjack Programme data, throughput was estimated to be 0.46-0.59 million tonnes per month. Average monthly loss due to catch represents approximately four per cent of the estimated monthly throughput. Hence, there appears to be potential for greatly increased catches from the region as a whole before recruitment would be affected (Kleiber et al. 1983). The experience with much more mature skipjack fisheries off the coast of Japan and in the eastern Pacific, where there has been no relationship between catch per unit effort and effort over a period of 20 or more years (Joseph & Calkins 1969; Kearney 1979), supports this view.

4.4.3 Fishery interactions

With increasing fishing activity and changing gear technology, catches from the area served by the South Pacific Commission have grown remarkably in recent years, leading inevitably to greater interaction between fisheries (Kearney 1983). These may occur, for example, between various types of fishery within a particular country (e.g. artisanal *vs* industrial), between fisheries based on different gear types (e.g. purse-seine *vs* longline for yellowfin) or between fisheries operating in different countries. The data of the Skipjack Programme provide a measure of the last type of interaction.

Tag recapture data enable assessment of interaction only within one generation of fish. However, within-generation assessments are most appropriate for skipjack, since the absence of any relationship between catch per unit effort and effort, even within intense fisheries (Joseph & Calkins 1969; Kearney 1979), suggests that between-generation interactions are not significant. Within-generation interactions between fisheries may be construed in various ways, such as the change in catch in one fishery resulting from catches in another, or the fraction of recruitment in a fishery attributable to migration from another fishery. The methods developed by the Skipjack Programme measure interaction in the latter way, that is, as a function of throughput.

A parameter, the "immigration coefficient" I, was derived to express interaction as the percentage of the throughput in a "receiver" country which could be ascribed to migration from another, "donor" country (Kleiber et al. ms.). An earlier version of I expressed interaction as the contribution of migrants to standing stock of the receiver country (Skipjack Programme 1981c). The present coefficent is computed from the number of tag releases in the donor country and the number of recoveries of those tags in the receiver country, together with various parameters of the two stocks, estimated by the tag attrition model of Kleiber et al. (1983). Two values of I exist for any pair of fisheries, one for each of the directions in which interaction may occur. It should be remembered that, as with the parameters derived from the tag attrition model, the immigration coefficient measures only the interaction between particular fisheries operating in defined areas. It does not provide a measure of migration of fish from all parts of a country's fishery zone to the whole fishery zone of another country, and is therefore a minimum estimate of interaction.

Table 4 summarises the recoveries from skipjack released throughout the total study area, by country/territory of release and recovery and offers a simple index of the degree of interaction between fisheries. However, this form of presentation takes no account of tag recovery effort, that is, the catch from which the tags were recovered. Reliable catch data are necessary for quantifying the interactions. These were available to the Programme for some locally based fisheries during the period tags were at large, but not for catches between 1979 and 1982 by the large United States and Japanese distant-water purse-seine fisheries and the Japanese distant-water pole-and-line fishery. These fisheries operate in much of the western Pacific and over the period of tag recoveries they accounted for a significant percentage (~20%) of Skipjack Programme tag returns. Until the Programme receives catch data from these fisheries, accurate estimates of interaction between distant-water and locally based fisheries cannot be made.

With the available data, the Skipjack Programme has calculated coefficients of interaction in at least one direction for as many pairs of countries and territories in the South Pacific Commission region as possible. A selection of the results is shown in Table 5. Most coefficients are small, with over half of them less than two per cent, but they span a wide range, from less than 0.1 per cent for movements from Kiribati to the Federated States of Micronesia to 37 per cent for movements from the Federated States of Micronesia to the Marshall Islands. Most of those omitted from the selection in Table 5 were also very low, from 0.1 to 1.0 per cent (e.g. Argue & Kearney 1982; Tuna Programme 1984). Thus, with very few exceptions, interactions at the time of tagging were quite low, at least between the particular fisheries listed in Table 5. Developments in these areas since then may have already altered the levels of interaction. It should also be noted that these results apply only to skipjack of the size tagged by the Programme (mostly >45cm). Skipjack smaller than this could very well move large distances and contribute significantly to interactions between stocks in the fished areas.

TABLE 4. SUMMARY OF SKIPJACK RELEASE AND RECOVERY DATA FOR THE ENTIRE SKIPJACK PROGRAMME, AS OF 10 OCTOBER 1983. 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 B. 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	1948	1					5								1							4				1			2			6		1	2	2		3	1977
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						108		6		77	9			2			23							31		366
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	113			1			13							10		215
2651	QLD		3																									2		25			1			2						33
48	SCK																																									
1725	SOC																												36													36
6221	SOL			1	1				1	2																16				526												547
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	1999	405	1	1	38	41	192	11	34	1	42	9	73	1	4	1	1	4	111	5	7	32	1058	149	3	54	606	2	13	71	25	10	5	1	68	41	52	1022	6235

TABLE 5. COEFFICIENTS OF INTERACTION BETWEEN FISHERIES OPERATING IN VARIOUS COUNTRIES AND TERRITORIES IN THE SOUTH PACIFIC COMMISSION REGION (from Kleiber, Sibert & Hammond ms.). See Appendix B for abbreviations for countries and territories. The numerals following country codes indicate tag release data sets from separate visits to the same country.

Donor Country	Receiver Country									
	PNG[c]	SOL[c]	PAL[c]	FSM[d]	MAS[d]	MAR[d]	FIJ[c]	ZEA[e]	WES[f]	SOC[c]
PNG	-	2.6	0.8	1.4	0.5					
SOL 77	1.1	-								
SOL 80	3.7	-								
PAL 78			-	8.6	2.2					
PAL 80	1.6	0.4	-	3.5	1.3	0.7				
FSM	0.7	0.9		-	37.0	10.8				
MAS					-					
MAR				17.4		-				
FIJ 78							-	0.6[a]		
FIJ 80							-			
ZEA							6.5	-	2.1[b]	3.6
KIR[c]				<0.1	0.1					

a assuming β_r=0.76 and T_d=7300

b assuming β_r=0.76

c local pole-and-line fishery

d Japanese pole-and-line fishery

c local purse-seine fishery

f local artisanal and subsistence fishery

Fishery interactions increase as the distance between fisheries decreases. If fisheries in neighbouring countries expand their areas of operation to include waters adjacent to common borderlines, the degree of interaction may increase. Furthermore, if different gear types were to operate in the same area, such as purse-seine and pole-and-line fleets working in the same or nearby fishing grounds of a country, then the degree of interaction would be much higher than present figures indicate. Since there is evidence of migration of skipjack to Nauru from several adjacent countries there exists the possibility of interactions between fisheries in the future. At the present low levels of exploitation, there probably are only very small interactions between fisheries operating in Nauruan waters and those operating elsewhere.

5.0 CONCLUSIONS

The rate at which schools of surface tuna were sighted by the Skipjack Programme indicates that skipjack are likely to be very abundant in Nauruan waters, at least in the middle of the year. Catch statistics from Japanese live-bait, pole-and-line vessels and from exploratory purse-seining by American vessels confirm this view, and suggest that good catches may be made in most months of the year. As little fishing and no tagging was done in the waters of Nauru by the Skipjack Programme, due to the unavailability of bait, there are no additional data which would enable the size of the skipjack resource, or its dynamics, to be evaluated. However, the resource assessments made by the Skipjack Programme for its entire study area in the central and western Pacific may be used to infer that the skipjack resource in Nauruan waters is large, since Nauru's EEZ occupies a central location in the study area. Turnover should be similar to that calculated for the region as a whole.

The absence of any significant baitfish resource in Nauru precludes exploitation of skipjack by locally based live-bait, pole-and-line fishing. A small-scale fishery could perhaps be developed using techniques not dependent on live bait, such as trolling or poling with pearl-shell lures. Any such fishery would benefit from the deployment of fish aggregation devices, as has been done in countries such as Niue and Western Samoa. Purse-seining, which is by many criteria a very efficient means of harvesting surface tuna, is likely to offer the best prospect for future development of a large-scale, commercial fishery; however, considerable variability in the abundance of skipjack could make it difficult to operate a purse-seine fishery based solely on exploitation of Nauru's EEZ.

The Programme demonstrated that migration of skipjack occurs from adjacent fishing zones into the EEZ of Nauru, and undoubtedly there is also movement from Nauruan waters to other areas. Therefore, there exists the possibility of significant interaction with fisheries elsewhere in the central and western Pacific for any skipjack fishery which might be developed in Nauru's waters. Tagging studies could be useful in monitoring such interactions.

REFERENCES

ANELL, B. (1955). Contribution to the history of fishing in the southern seas. Studia Ethnographica Upsaliensia No.9, xix + 249 pp.

ANON. (1972). Summary report on live bait fishes for skipjack pole-and-line fishing in the waters of Nauru in 1971. Japan Marine Fishery Resource Research Center, Tokyo, Japan, 4 pp., mimeo.

ANON. (1980). 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, 22 pp.

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, v + 39 pp.

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. pp. 45-69, 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.

ARGUE, A.W., F. CONAND & 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, vii + 47 pp.

ARGUE, A.W. & 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, x + 73 pp.

ARGUE, A.W., M.J. WILLIAMS & J.-P. HALLIER (ms.). Fishing performance of some natural and cultured baitfish used by pole-and-line vessels to fish in the central and western Pacific Ocean. Tuna and Billfish Assessment Programme Technical Report, South Pacific Commission, Noumea, New Caledonia.

ELLWAY, C.P., R.S. FARMAN, A.W. ARGUE & R.E. KEARNEY (1983). An assessment of the skipjack and baitfish resources of Tuvalu. Skipjack Survey and Assessment Programme Final Country Report No.8, South Pacific Commission, Noumea, New Caledonia, vii + 47 pp.

FUJINO, K. (1966). Instructions on collecting blood and serum samples from tuna fishes. FAO Fisheries Circular No.26, Food and Agriculture Organization of the United Nations, Rome, Italy, 5 pp.

FUJINO, K. (1972). Range of the skipjack tuna subpopulation in the western Pacific Ocean. pp. 373-384 _in_ Sugawara, K. (ed.), The Kuroshio II, Proceedings of the second symposium on the results of the cooperative study of the Kuroshio and adjacent regions, Tokyo, Japan, September 28-October 1, 1970. Saikon Publishing Company, Tokyo, Japan.

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

HALLIER, J.-P., R.E. KEARNEY & R.D. GILLETT (1982). Baitfishing methods used by the Skipjack Survey and Assessment Programme and recommendations on baitfishing techniques for the tropical Pacific. pp. 71-107, _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.

JOSEPH, J. & T.P. CALKINS (1969). Population dynamics of the skipjack tuna (_Katsuwonus pelamis_) of the eastern Pacific Ocean. _Inter-American Tropical Tuna Commission Bulletin_ 13:1-273.

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, 13 pp.

KEARNEY, R.E. (1979). An overview of recent changes in the fisheries for highly migratory species in the western Pacific Ocean and projections for future developments. _SPEC(79)17_. South Pacific Bureau for Economic Co-operation, Suva, Fiji, ii + 96 pp.

KEARNEY, R.E. (1982). Development and implementation of the Skipjack Survey and Assessment Programme. pp. 1-17 _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.

KEARNEY, R.E. (1983). _Assessment of the skipjack and baitfish resources in the central and western tropical Pacific Ocean : a summary of the Skipjack Survey and Assessment Programme_. South Pacific Commission, Noumea, New Caledonia, iii + 37 pp.

KEARNEY, R.E. & R.D. GILLETT (1982). Methods used by the Skipjack Survey and Assessment Programme for tagging skipjack and other tuna. pp. 19-43, _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.

KEARNEY, R.E. & J.P. HALLIER (1980). Interim report of the activities of the Skipjack Survey and Assessment Programme in the waters of Nauru

(12-15 July 1980). Skipjack Survey and Assessment Programme Preliminary Country Report No.25, South Pacific Commission, Noumea, New Caledonia, 5 pp.

KEARNEY, R.E., A.D. LEWIS & B.R. SMITH (1972). Cruise Report Tagula 71-1, survey of skipjack tuna and bait resources in Papua New Guinea waters. Research Bulletin No.8, Department of Agriculture, Stock and Fisheries, Port Moresby, Papua New Guinea, ix + 145 pp.

KENT, G. (1980). The politics of Pacific island fisheries. Westview Press, Boulder, Colorado, U.S.A., ix + 191 pp.

KIKAWA, S. (1977). Japanese skipjack tuna, Katsuwonus pelamis, baitfish surveys in the western and southwestern Pacific Ocean. pp. 81-88 in Shomura, R.S. (ed.), Collection of tuna baitfish papers. National Oceanic and Atmospheric Administration Technical Report National Marine Fisheries Circular 408, Department of Commerce, Washington, U.S.A.

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. Occasional Paper No.10, South Pacific Commission, Noumea, New Caledonia, 41 pp.

KLEIBER, P., A.W. ARGUE & 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, vi + 38 pp.

KLEIBER, P. & C.A. MAYNARD (1982). Data processing procedures of the Skipjack Survey and Assessment Programme. pp. 109-122, 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.

KLEIBER, P., J.R. SIBERT & L.S. HAMMOND (ms.). A parameter for estimating interaction between fisheries for skipjack tuna (Katsuwonus pelamis) in the western Pacific. Tuna and Billfish Programme Technical Report, South Pacific Commission, Noumea, New Caledonia.

LAWSON, T.A., R.E. KEARNEY & J.R. SIBERT (ms.). Estimates of length measurement errors for tagged skipjack (Katsuwonus pelamis) from the central and western Pacific Ocean. Tuna and Billfish Assessment Programme Technical Report, South Pacific Commission, Noumea, New Caledonia.

LESTER, R.J.G., A. BARNES & G. HABIB (ms.). Parasites of skipjack tuna : fishery implications. Parasitology Department, University of Queensland, Brisbane, Australia.

LEWIS, A.D. (1981). Population genetics, ecology and systematics of Indo-Australian scombrid fishes, with particular reference to skipjack tuna (Katsuwonus pelamis). Unpublished Ph.D. thesis, Australian National University, Canberra, Australia, ix + 314 pp.

LEWIS, A.D., B.R. SMITH & R.E. KEARNEY (1974). Studies on tunas and baitfish in Papua New Guinea waters - II. Research Bulletin No.11, Department of Agriculture, Stock and Fisheries, Port Moresby, Papua New Guinea, vii + 111 pp.

NAGANUMA, A. (1979). On spawning activities of skipjack tuna in the western Pacific Ocean. Bulletin of the Tohoku Regional Fisheries Research Laboratory 40:1-13.

PETIT-SKINNER, S. (1981). The Nauruans. McDuff Press, San Francisco, U.S.A., 292 pp.

RAJU, G. (1964). Studies on the spawning of the oceanic skipjack Katsuwonus pelamis (Linnaeus) in Minicoy waters. Proceedings of the Symposium on Scombroid Fishes, Part 2:744-768. Marine Biological Association of India, Mandapam Camp, India.

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.

SCHAEFER, M.B. & C.J. ORANGE (1956). Studies of the sexual development and spawning of yellowfin tuna (Neothunnus macropterus) and skipjack (Katsuwonus pelamis) in three areas of the eastern tropical Pacific Ocean, by examination of gonads. Inter-American Tropical Tuna Commission Bulletin 1:281-349.

SEVELE, F.V. & A. BOLLARD (1979). South Pacific economies : statistical summary. Occasional Paper No.15, South Pacific Commission, Noumea, New Caledonia.

SHARP, G.D. (1969). Electrophoretic study of tuna hemoglobins. Comparative Biochemistry and Physiology 31:749-755.

SHARP, G.D. (1978). Behavioural and physiological properties of tunas and their effects on vulnerability to fishing gear. pp. 397-449, in Sharp, G.D. and A.E. Dizon (eds), The physiological ecology of tunas. Academic Press, New York, U.S.A.

SIBERT, J.R., R.E. KEARNEY & 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, vii + 43 pp.

SKIPJACK PROGRAMME (1980). 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, iii + 91 pp.

SKIPJACK PROGRAMME (1981a). Fishing effort and catch by the longline fleets of Japan (1962-77) and Taiwan (1967-77) within 200 miles of the countries in the area of the South Pacific Commission. Skipjack Survey and Assessment Programme Technical Report No.3, South Pacific Commission, Noumea, New Caledonia, 249 pp.

SKIPJACK PROGRAMME (1981b). An appraisal of the genetic analysis of skipjack blood samples. Working Paper No.10, Thirteenth Regional Technical Meeting on Fisheries, 24-28 August 1981, Noumea, New Caledonia, South Pacific Commission, Noumea, New Caledonia.

SKIPJACK PROGRAMME (1981c). Skipjack migration, mortality and fishery interactions. Working Paper No.9, Thirteenth Regional Technical Meeting on Fisheries, 24-28 August 1981, Noumea, New Caledonia, South Pacific Commission, Noumea, New Caledonia, 35 pp.

SOUTER, D. & G. BROADHEAD (1978). Purse-seine fishing for yellowfin and skipjack in the southern waters of the central and western Pacific: Jeanette C charter. Technical Bulletin No.2, Pacific Tuna Development Foundation, Honolulu, Hawaii, U.S.A., 77 pp.

SOUTER, D. & T. SALOMONS (1980). Tuna purse seining: Island Princess cruise report, June-October 1979. Report from Living Marine Resources Inc. to the Pacific Tuna Development Foundation, Honolulu, Hawaii, U.S.A., 37 pp., mimeo.

TUNA PROGRAMME (1984). An assessment of the skipjack and baitfish resources of Papua New Guinea. Skipjack Survey and Assessment Programme Final Country Report No.12, South Pacific Commission, Noumea, New Caledonia, x + 91 pp.

APPENDIX A. SCIENTISTS AND CREW ON BOARD THE RESEARCH VESSEL

South Pacific Commission Scientists

Jean-Pierre Hallier	12-15 July 1980
James Ianelli	12-15 July 1980
A.W. Argue	12-13 July 1980
Charles Ellway	14-15 July 1980
Timothy Lawson	14-15 July 1980

Japanese Crew

Mitsutoyo Kaneda, Captain
Tsunetaka Ono
Mikio Yamashita
Yashikazu Oikawa
Seima Kobayashi
Kenji Arima
Yukio Sasaya
Koji Wakasaki
Yoshihiro Kondoh

Fijian Crew

Eroni Marawa
Kitione Naivaurerega
Samuela Ue
Samuela Delana
Josua Raguru
Eroni Dolodai
Metuisela Koroi
Luke Kaidrukiya
Aminiasi Kuruyawa
Jovesa Buarua
Sovita Lequeta
Tuimasi Tuilekutu
Jona Ravasakula
Lui Andrews

APPENDIX B. ABBREVIATIONS USED FOR COUNTRIES AND TERRITORIES IN THE CENTRAL AND WESTERN PACIFIC

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