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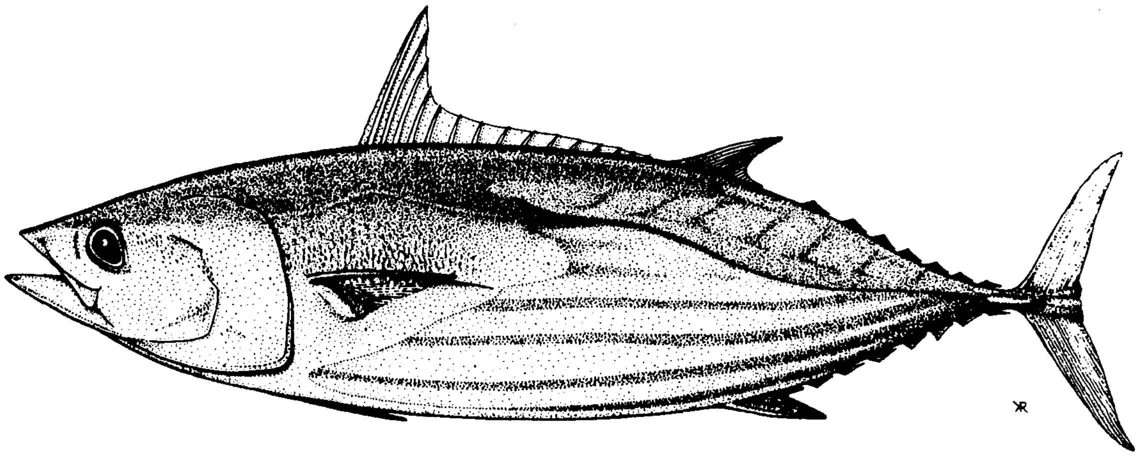
AN ASSESSMENT OF THE SKIPJACK AND BAITFISH RESOURCES OF THE REPUBLIC OF VANUATU



Skipjack Survey and Assessment Programme
Final Country Report No. 9

South Pacific Commission
Noumea, New Caledonia
August 1983

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PREFACE

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

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

Officials of the Ministry of External Affairs of Vanuatu and of the former administrations of France and the United Kingdom assisted the Skipjack Programme in many aspects of the survey in the waters of Vanuatu. Since the survey, Jim Crossland, Director of Fisheries, Vanuatu Ministry of Land and Natural Resources, has provided valuable information.

Tuna Programme
South Pacific Commission

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AN ASSESSMENT OF THE SKIPJACK AND BAITFISH RESOURCES OF THE REPUBLIC OF VANUATU

1.0 INTRODUCTION

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

Tagging and survey operations in the central and western Pacific carried out by the Skipjack Programme between October 1977 and August 1980 totalled 847 days, 14 of which were spent in the waters of Vanuatu. The total study area included all of the countries and territories in the area of the South Pacific Commission and also the waters of northern New Zealand and eastern Australia (Figure A, inside front cover).

The survey of the waters of Vanuatu commenced on 5 December 1977. Since earlier surveys (Anon 1972; Anon 1973) had inferred that the baitfish resource was limited, initial work of the Programme concentrated on exploratory baitfishing. The survey vessel departed for New Caledonia on 12 December 1977 after night baitfishing catches proved to be insufficient to support tuna fishing activities. It returned to Vanuatu on 20 January 1978 carrying bait from New Caledonia and resumed activities for five additional days. Further survey work in Vanuatu by the Skipjack Programme was not planned because of the baitfish situation. However, one day, 31 March 1980, was spent between Matthew and Hunter Islands[1] while in transit between New Zealand and Fiji. This report summarises survey results and gives assessments of the skipjack and baitfish resources of Vanuatu and relates these assessments to those of the region as a whole.

1.1 Background to the Tuna Fishery

Vanuatu is an archipelago composed of a double chain of about 80 islands located between 12 and 23 degrees south latitude and 166 and 173 degrees east longitude. The country has a land mass of 13,480 square kilometres with a 200-mile zone of 848,404 square kilometres (Tuna Programme, unpublished data). The islands, mostly of volcanic origin, lack

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[1] Matthew and Hunter Islands, which lie to the south of Vanuatu and to the east of New Caledonia, are claimed by both Vanuatu and France. The South Pacific Commission stresses that its interpretation of oceanic zones or international boundaries are for scientific purposes only and should not in any way prejudice the claims of any country to areas of the region in which we work. As there are two claims to Matthew and Hunter Islands, reports on the activities of the Skipjack Programme in the approximative 200-mile zone around these islands have been included in the reports for both Vanuatu and New Caledonia.

extensive barrier reefs and lagoons. Coral formations occur principally on fringing reefs, from which there is an abrupt transition to deep water. The waters around the archipelago are tropical oligotrophic and sectors of high productivity are restricted to the estuaries of rivers and to zones of turbulence around the land masses (Grandperrin 1977).

The only large-scale commercial fishing activity has been the operation since 1957 of the South Pacific Fishing Company (SPFC), a transhipping company for frozen tuna and billfish. The major shareholder in the company is Mitsui and Company (Tokyo); the Government of Vanuatu holds a nine per cent share. Annual sales of transhipped fish, primarily to the United States and Japan, averaged 877 million Vatu per year (US$9 million) between 1976 and 1981 (Anon 1982). This company has its freezer facilities at Palekula on Espiritu Santo and receives catches from Taiwanese vessels fishing mainly between 8°S and 35°S in the Tasman and Coral Seas (Bour, Kulbicki and Marsac 1982). Landings increased from 3,930 tonnes in 1959 to a high of 15,600 tonnes in 1972. Since this time landings have fluctuated but shown a decrease in recent years to 4,345 tonnes in 1981 (Bour, Kulbicki and Marsac 1982).

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 (1982b). The 192-tonne *Hatsutori Maru No.1* was used during the survey of Vanuatu in December 1977 and January 1978. The waters of Matthew and Hunter Islands were briefly surveyed on 31 March 1980 with the 254-tonne *Hatsutori Maru No.5*.

The *Hatsutori Maru No.1* was operated with at least three Skipjack Programme scientists, nine Japanese officers and twelve Fijian crew. For the *Hatsutori Maru No.5*, an additional three Fijian crew were employed. Appendix A lists scientists, observers and crew who were on board during the survey in the waters of Vanuatu.

2.2 Fishing, Tagging and Biological Sampling

Both vessels used by the Skipjack Programme were commercial live-bait pole-and-line fishing vessels and the basic strategy of approaching and chumming schools normally employed by these vessels was not changed. As in the case of commercial vessels, 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 *No.5* was less 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 would decrease the fishing power of the research vessel. 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, under an agreement between the Programme and the vessel's owners. From comparison of survey and commercial catches at this time, it was estimated that the fishing power of the Hatsutori Maru under survey conditions such as in Vanuatu was 28.8 per cent of its fishing power during commercial fishing (Kearney 1978).

Since tagging was the primary research tool, attempts to tag large numbers of skipjack and, secondarily, yellowfin (*Thunnus albacares*) usually dominated the fishing strategy. The tagging techniques and alterations to commercial fishing procedures have been described in detail by Kearney and 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 stomach content. 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) describes 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 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. There were insufficient catches in March 1980 in the vicinity of Matthew and Hunter Islands for parasite sampling.

2.3 Baitfishing

Most baitfishing activity was carried out at night using bait attraction lights and a "bouki-ami" net. In some countries, beach seining during daylight hours supplemented night catches. Beach seining was not attempted by the Skipjack Programme in the waters of Vanuatu. Details of both techniques and all modifications employed by the Skipjack Programme are given in Hallier, Kearney and Gillett (1982).

2.4 Data Compilation and Analysis

Five separate logbooks formed the basis 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 by Kleiber and 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 was approached from several viewpoints. Studies of the migration of tagged skipjack, using analytic techniques described in Skipjack Programme (1981b), 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 (1981f) and Argue, Hallier and Williams (MS). Evaluation of population structuring across the whole of the western and central Pacific has centred on a comparison of the tagging results with the blood genetics work (Anon 1980, 1981; Skipjack Programme 1981c). Occurrence and distribution of skipjack parasites have also been evaluated (Lester 1981).

3.0 SUMMARY OF FIELD ACTIVITIES

Figure 1 shows the area surveyed for tuna and baitfish during the first visit. At that time the waters around the islands of Espiritu Santo, Malekula, Efate, the Maskelynes, Epi and Ambrym were surveyed. The waters between Matthew and Hunter Islands were surveyed in March 1980.

Baitfishing activities are summarised in Table 1. Five hauls were made during the first visit. Bait was carried to Vanuatu from New Caledonia during the first visit and to Matthew and Hunter Islands from New Zealand during the second visit.

Skipjack fishing activities, including sightings, tagging and catches are summarised in Table 2. Overall, an average of nine hours per day was spent searching and fishing, excluding days when no time was spent either searching or fishing.

A total of 4,163 kg of skipjack, 1,028 kg of yellowfin and 46 kg of other tuna was caught, or 5,237 kg in all. This gives an average catch of 873 kg per day for those days on which bait was carried and time was spent fishing.

Of the 1,254 skipjack tagged in Vanuatu between December 1977 and January 1978, 30 were double tagged. As of 1 March 1983, none of the double-tagged skipjack and only seven of the single-tagged fish have been recovered, two within and five outside Vanuatu's 200-mile zone. The Programme scientists tagged an additional 25 skipjack in March 1980, none of which has been recovered.

A summary of numbers of fish sampled for biological data is given in Table 3. The size distribution of skipjack tagged (Figure 2) shows a range of 35-78 cm. The average length was 50.4 cm, the same as the Skipjack Programme's overall average. Maturity data are summarised in Figure 3, skipjack diet items in Table 4, and the incidence of tuna juveniles in the stomachs of sampled skipjack and yellowfin in Table 5. Blood samples were taken from 73 skipjack from a school near the western tip of Ambrym on 21 January 1978.

4.0 RESULTS AND DISCUSSION

4.1 Baitfish Availability

The bouki-ami can be a very effective method of catching live bait for pole-and-line fishing; however, for best results this net must be operated in waters of suitable depth, protected from excessive wind, current and

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

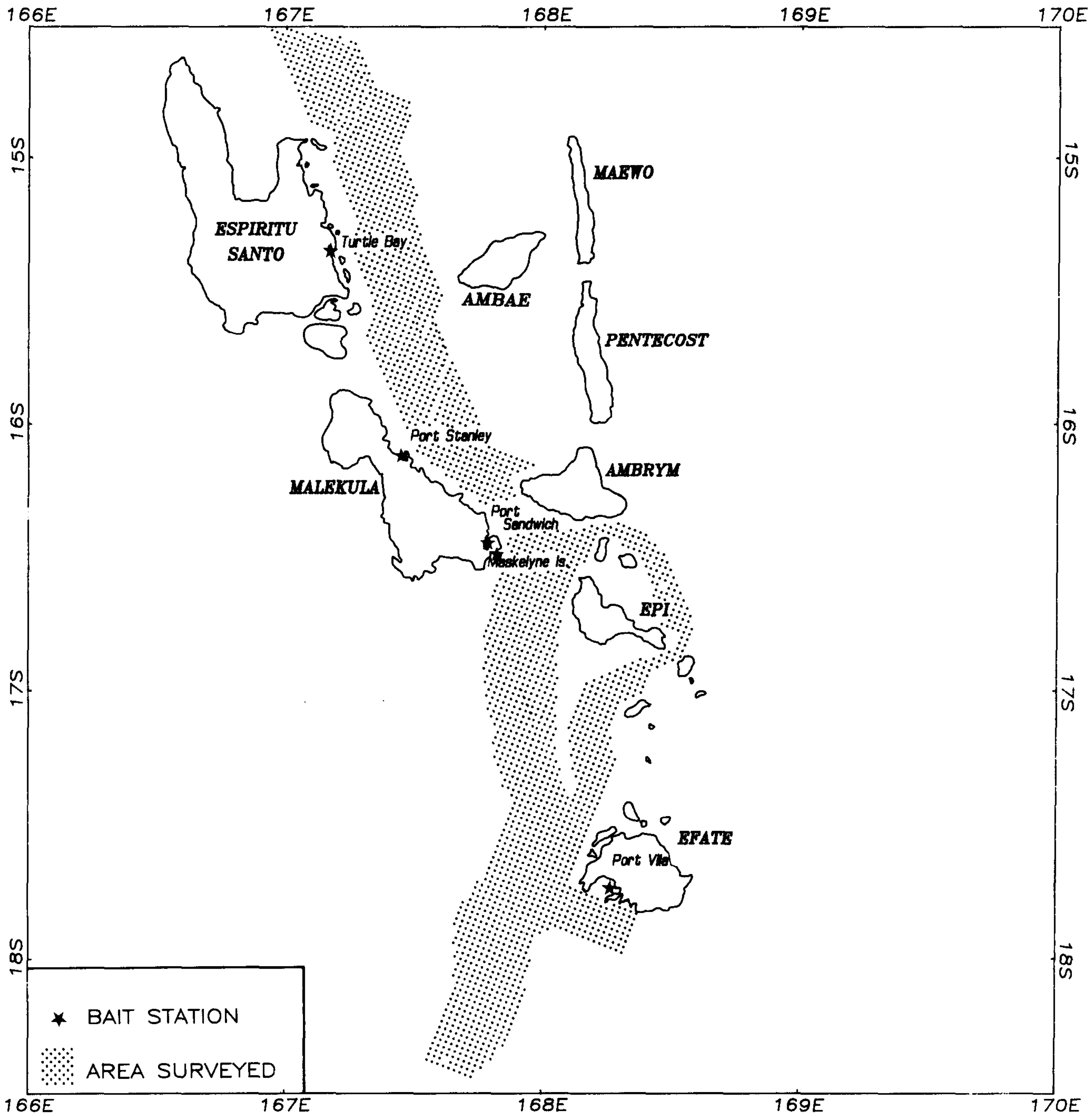

TABLE 1. SUMMARY OF BAITFISHING ACTIVITIES IN THE WATERS OF VANUATU

Anchorage	Time of Hauls	Number of Hauls	Dominant Species	Est. Av. Catch per Haul (kg)	Mean Length (mm)	Other Common Species
Turtle Bay						
Espiritu Santo			Herklotsichthys punctatus *	6	99	Benthosoma fibulatum
15°20'S	Night	1	Stolephorus devisi	5	68	Pterocaesio diagramma
167°10'E			Apogon(Rhabdamia) cypselurus	2	27	Selar crumenophthalmus
Port Stanley						
Malekula			Spratelloides delicatulus	18	37	Apogon(Rhabdamia) cypselurus
16°06'S	Night	3	Hypoatherina ovalaua	10	41	Decapterus macrosoma
167°26'E			Herklotsichthys punctatus	4	49	Priacanthus sp.
Port Sandwich						
Malekula			Stolephorus indicus	44	105	Spratelloides delicatulus
16°25'S	Night	1	Pterocaesio pisang	3		Xiphasia setifer
167°46'E			Pterocaesio sp.	3		Archamia lineolata

* Several revisions of specific names used in a previous Skipjack Programme report on Vanuatu have been maintained. The most notable changes in nomenclature have been :

Herklotsichthys punctatus to Herklotsichthys quadrimaculatus
Pranesus pinguis to Atherinomorus lacunosa

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

Date	General Area	Principal Activity	Bait Carried (kg)	Hours Fishing and Sighting	Schools Sighted (numbers)					Fish Tagged (numbers)			Fish Caught (kg)		Total Catch (kg)
					SJ	YF	S+Y	OT	UN	SJ	YF	OT	SJ	YF	
05/12/77	N Vanuatu	Steaming	0	12	0	0	0	0	0	-	-	-	-	-	-
06/12/77	Santo	In Port	0	0	-	-	-	-	-	-	-	-	-	-	-
07/12/77	Port Stanley	Steaming	0	5	2	0	0	0	1	0	0	0	3	0	3
08/12/77	Malekula Is - Efate Is	Fishing	50	6	3	0	2	0	0	51	0	0	258	7	265
09/12/77	Vila	In Port	0	0	-	-	-	-	-	-	-	-	-	-	-
10/12/77	Vila - Lamap	Steaming	0	10	1	0	0	0	5	-	-	-	-	-	-
11/12/77	Maskelyne Is	Fishing	60	4	1	0	0	0	0	0	0	0	5	0	7
12/12/77	Malekula Is - Efate Is	Steaming	0	0	-	-	-	-	-	-	-	-	-	-	-
20/01/78	Efate Is - Malekula Is	Fishing	444	12	5	0	0	0	2	171	0	0	1028	0	1028
21/01/78	Epi Is	Fishing	270	12	3	0	1	0	0	755	225	0	2166	830	3012
22/01/78	Ambrym Is	Fishing	120	12	4	0	2	1	3	277	23	0	626	92	746
23/01/78	E Vanuatu	Steaming	0	4	0	0	0	0	1	-	-	-	-	-	-
24/01/78	E Vanuatu	Steaming	0	0	-	-	-	-	-	-	-	-	-	-	-
31/03/80	Matthew and Hunter Is	Fishing	125	12	1	0	1	0	4	25	27	0	77	99	176
TOTALS				89	20	0	6	1	16	1279	275	0	4163	1028	5237

TABLE 3. SUMMARY OF NUMBERS OF FISH SAMPLED FOR BIOLOGICAL DATA FROM THE WATERS OF VANUATU

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*	275	131	157	91	134
Yellowfin *Thunnus albacares*	67	22	22	17	17
Mackerel Tuna *Euthynnus affinis*	4	4	4	4	4
Frigate Tuna *Auxis thazard*	7	7	7	7	7
TOTALS	353	164	190	119	162

TABLE 4. STOMACH CONTENTS OF SKIPJACK SAMPLED BY THE SKIPJACK PROGRAMME FROM THE WATERS OF VANUATU

Item No.	Diet Item Fish and Invertebrates	Number of Stomachs	Percentage Occurrence
1	Chum from *Hatsutori Maru*	56	61.54
2	Fish remains (not chum)	42	46.15
3	Squid (Cephalopoda)	33	36.26
4	Tuna juvenile (Scombridae)	20	21.98
5	Acanthuridae	14	15.38
6	Alima stage (Stomatopoda)	12	13.19
7	Empty stomach	11	12.09
8	Chaetodontidae	8	8.79
9	Unidentified fish	7	7.69
10	*Decapterus* sp. (Carangidae)	6	6.59
11	Gempylidae	6	6.59
12	*Stolephorus buccaneeri* (Engraulidae)	5	5.49
13	Aluteridae	4	4.40
14	Euphausiid (Euphausiacea)	4	4.40
15	Carid shrimp (Decapoda)	4	4.40
16	Balistidae	3	3.30
17	Penaeid shrimp (Decapoda)	2	2.20
18	Pteropoda (Gasteropoda)	2	2.20
19	Megalopa stage (Decapoda)	2	2.20
20	Holocentridae	1	1.10
21	Bramidae	1	1.10
22	Stomatopoda	1	1.10
23	Priacanthidae	1	1.10
24	Caesiodidae	1	1.10
25	Exocoetidae	1	1.10
26	Billfish juvenile (Istiophoridae)	1	1.10
27	Trichiuridae	1	1.10
28	Tetrodontidae	1	1.10
29	Anthiidae	1	1.10
30	Fistulariidae	1	1.10
31	Siganidae	1	1.10
32	Bothidae	1	1.10
33	*Ranzania* sp. (Molidae)	1	1.10
34	Ostraciidae	1	1.10
	Total Stomachs Examined	91	

FIGURE 2. LENGTH FREQUENCY DISTRIBUTION FOR TAGGED SKIPJACK FROM VANUATU (upper graph) AND FOR THE TOTAL SKIPJACK PROGRAMME STUDY AREA (lower graph). N is the sample size.

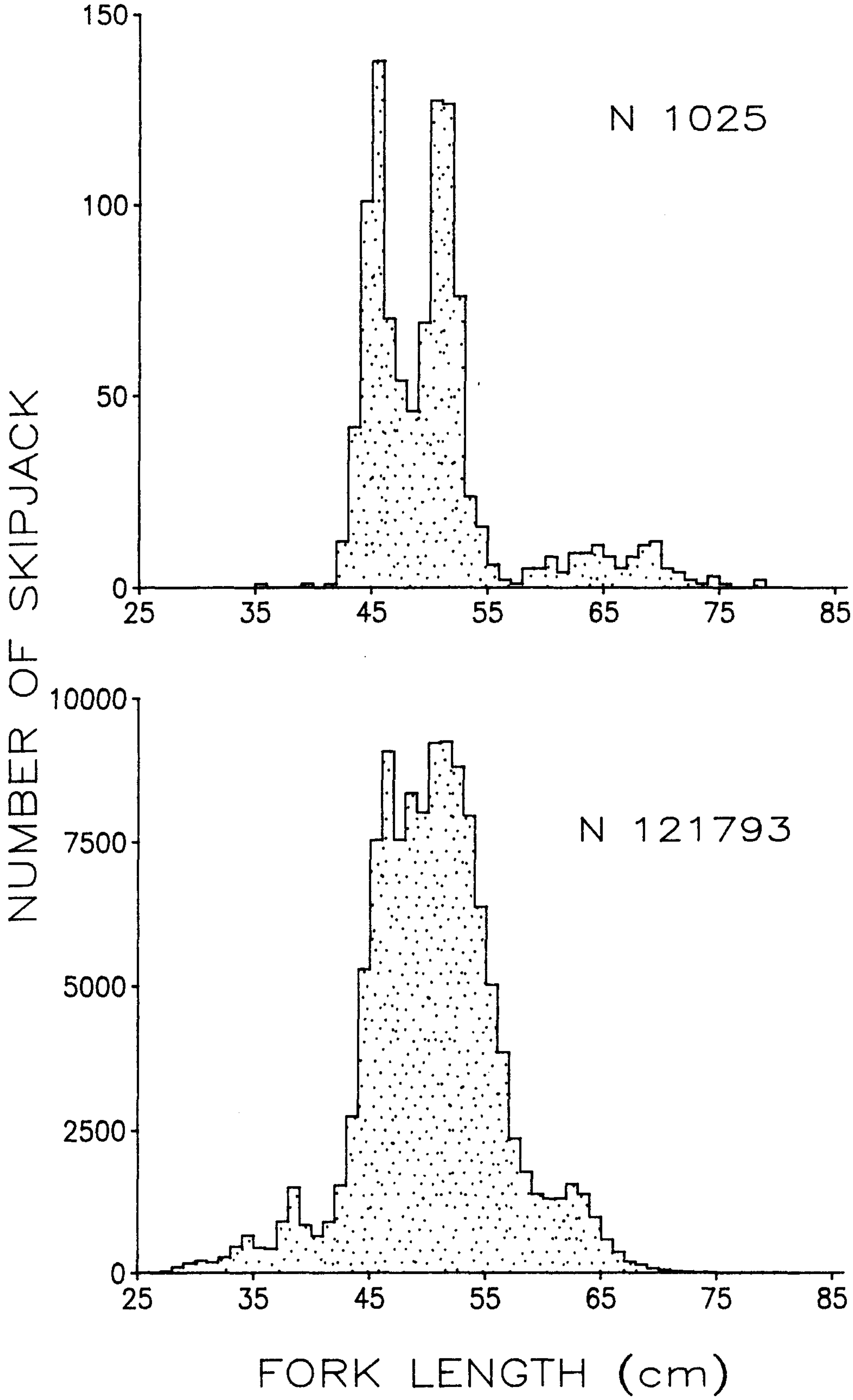

FIGURE 3. DISTRIBUTION OF FEMALE SKIPJACK BY MATURITY STAGE FOR SAMPLES FROM VANUATU (upper graph) AND FOR ALL SKIPJACK SAMPLED FROM TROPICAL WATERS BY THE SKIPJACK PROGRAMME (lower graph). N is the sample size.

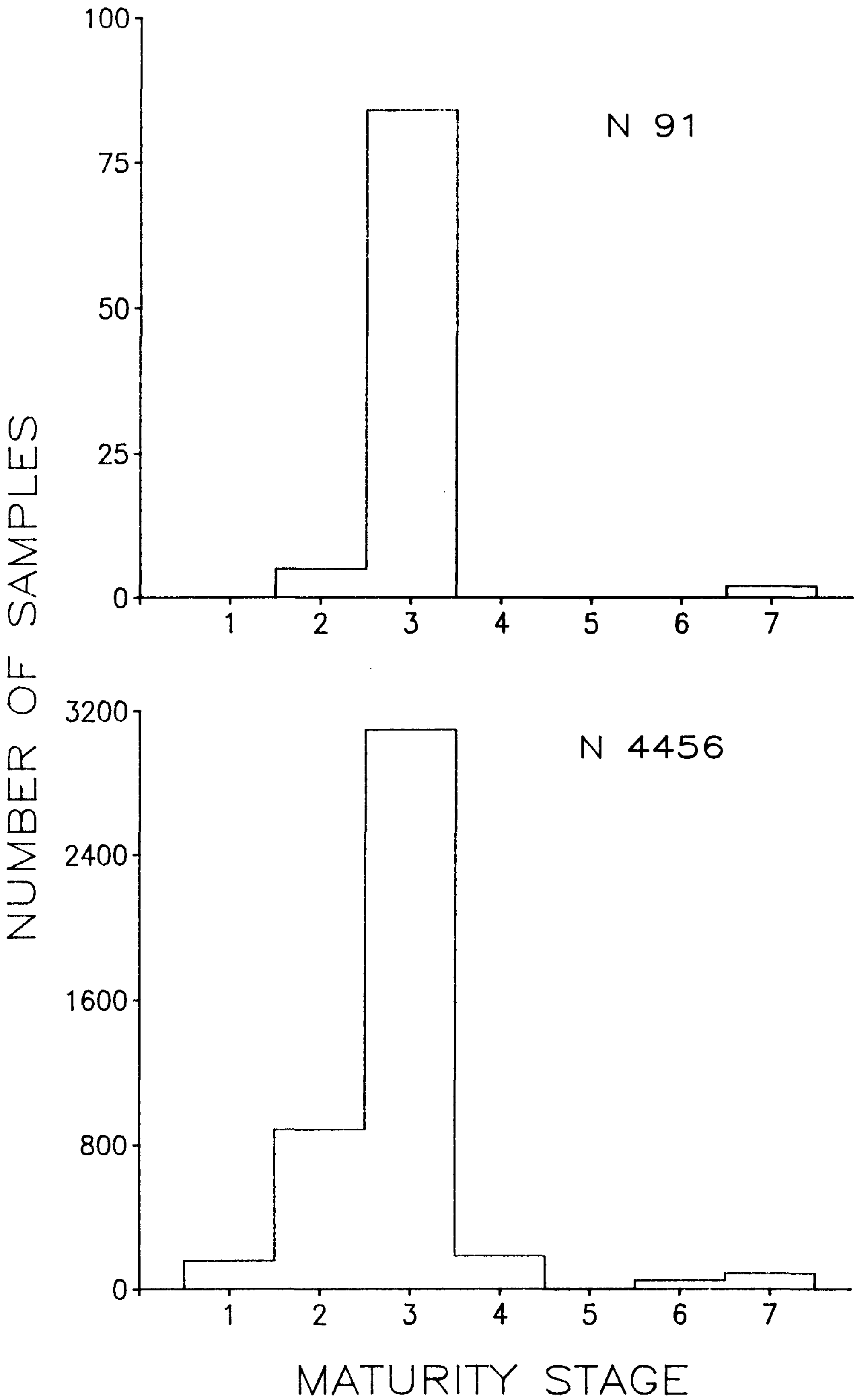

TABLE 5. INCIDENCE OF TUNA JUVENILES IN THE STOMACHS OF TUNA SAMPLED IN THE WATERS OF VANUATU

Predator	Predators Examined	Prey Species (tuna) juveniles)	No. of Prey	Predators with Prey	Prey per 100 Predators	Percentage of Predators with Prey
Skipjack	134	Skipjack	40	12	29.85	8.96
		Yellowfin	3	3	2.24	2.24
		Mackerel Tuna	4	3	2.99	2.24
		Frigate Tuna	69	15	51.49	11.19
		Albacore	1	1	0.75	0.75
Yellowfin	17					
Mackerel Tuna	4					
Frigate Tuna	7					
TOTALS	162		117			

wave action. After close examination of admiralty charts, only the three larger islands of Espiritu Santo, Malekula and Efate appeared to have favourable sites for baitfishing with a bouki-ami. The bouki-ami was set five times during the seven nights when the Hatsutori Maru No.1 baitfished in the waters of Vanuatu. On three other occasions (twice at Port Vila and once at the Maskelyne Islands), the net was not set because baitfish were not evident around bait attraction lights. Details of bait catches and species composition for the three sites surveyed are shown in Table 1.

Bait catches in December totalled 124.5 kg in four hauls, for an average of 31.1 kg per haul. This is similar to the average catch per haul of 30.7 kg for nine hauls executed during the JAMARC surveys (Anon 1972; Anon 1973) but is among the lowest achieved by the Skipjack Programmme in the different countries surveyed (Skipjack Programme 1981e). These catches are insufficient for sustaining commercial fishing activities with a vessel the size of the Hatsutori Maru No.1, considering that 50 kg per fishing day is a normal, average daily requirement (Kearney 1975). The survey was suspended until January when the vessel returned to Vanuatu carrying bait from New Caledonia. One additional haul was then made at Port Stanley, catching 52.5 kg of bait.

Six hundred and forty kilograms of live bait were transported 400 kilometres from Port Bouquet in New Caledonia to Vanuatu. Although this bait, mostly Stolephorus heterolobus and Gymnocaesio gymnopterus, suffered an initial mortality of 40 per cent during the first two days, it was used successfully to chum eight skipjack schools from which 926 skipjack were tagged and released. This experiment demonstrated the feasibility of maintaining and carrying tropical bait species for use in areas where bait are less plentiful. Experiments of this type had been few at the time and this was the first in the waters of Vanuatu.

Sixty bait species caught in bouki-ami hauls in Vanuatu are listed in Table 6 together with their percentage occurrence in the bait hauls and estimated contribution by weight to the total catch. The dominant species by numbers and by weight was the blue sprat, Spratelloides delicatulus, a small fish regarded as excellent skipjack bait. It is easily attracted to lights around which it forms surface aggregations. Stolephorus indicus was the second most abundant species by virtue of its relatively large size. However, this species is extremely delicate and is therefore virtually useless as bait. Two other species, the hardyhead Hypoatherina ovalaua and the sardine Herklotsichthys punctatus[2], also contributed substantially to catches. Only the latter species is regarded as good skipjack bait (Skipjack Programme 1981f).

The prospects for day baiting or night baiting in areas shallower than those fished with the bouki-ami could not be evaluated at the time of the 1977/1978 Skipjack Programme survey (Kearney, Lewis and Hallier 1978). During January and February 1982, 85 beaches were surveyed by the Vanuatu Fisheries Department. A beach seine was used during the day on five beaches and a lampara net was used around bait attraction lights at night on twelve beaches. At the request of the Vanuatu Fisheries Department, one scientist from the Tuna Programme assisted in these operations. The results of this survey, combined with those of additional trials conducted

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2 The taxonomic nomenclature for this species has been changed from Herklotsichthys punctatus to Herklotsichthys quadrimaculatus.

TABLE 6. BAIT SPECIES, PERCENTAGE OF BOUKI-AMI HAULS CONTAINING A PARTICULAR SPECIES, AND ESTIMATED TOTAL CATCH, FOR THE SKIPJACK PROGRAMME SURVEY IN THE WATERS OF VANUATU

Species	Percentage Occurrence	Estimated Catch (kg)
Spratelloides delicatulus	100	54
Stolephorus indicus	20	44
Hypoatherina ovalaua	80	28
Herklotsichthys punctatus *	100	15
Stolephorus devisi	40	4
Apogon(Rhabdamia) cypselurus	80	3
Pterocaesio pisang	20	3
Pterocaesio sp.	20	3
Sardinella sirm	100	0
Selar crumenophthalmus	100	0
Sp. of Anguillidae (j)	80	0
Sp. of Siganidae	80	0
Sp. of Acanthuridae	80	0
Scomberoides sp.	80	0
Decapterus macrosoma	80	0
Sp. of Sphyraenidae	80	0
Pranesus pinguis	60	0
Sardinella clupeoides	60	0
Sp. of Chaetodontidae	60	0
Sp. of Holocentridae	60	0
Sp. of Mullidae	60	0
Priacanthus sp.	60	0
Bregmaceros sp.	60	0
Sp. of Crustacea	60	0
Sp. of Syngnathidae	60	0
Sp. of Balistidae	60	0
Fistularia sp.	60	0
Megalaspis cordyla	40	0
Spratelloides gracilis	40	0
Sp. of Squid	40	0
Archamia lineolata	40	0
Caranx sexfasciatus	40	0
Gazza minuta	40	0
Grammatorcynus bicarinatus	40	0
Archamia zosterophora	40	0
Sp. of Synodontidae	40	0
Selar boops	40	0
Sp. of Apogonidae	40	0
Apogon fraenatus	40	0
Sp. of Bothidae	40	0
Sp. of Caesiodidae	40	0
Sp. of Pomacentridae	20	0
Sp. of Priacanthidae	20	0
Caranx sp.	20	0
Benthosema fibulatum	20	0
Pterocaesio diagramma	20	0
Stolephorus bataviensis	20	0
Plotosus anguillaris	20	0
Leiognathus elongatus	20	0
Sp. of Myctophidae	20	0
Sp. of Aluteridae	20	0
Xiphasia setifer	20	0
Dussumieria sp.	20	0
Stomatopod larvae	20	0
Sp. of Paralepidae	20	0
Decapterus sp.	20	0
Sp. of Crustacea (j)	20	0
Pseudamia polystigma	20	0
Sp. of Lutjanidae	20	0
Sp. of Octopus	20	0

* Several revisions of specific names used in a previous Skipjack Programme report on Vanuatu have been maintained. The most notable changes in nomenclature have been :

Herklotsichthys punctatus to *Herklotsichthys quadrimaculatus*
Pranesus pinguis to *Atherinomorus lacunosa*

by the Fisheries Department between March and June 1982, gave an average catch of 29 kg for nine sets of the beach seine and 39.2 kg for 14 sets of the lampara net (Grandperrin et al. 1982a).

The average beach seine catch obtained by the Fisheries Department survey compares favourably with those of the Skipjack Programme in other countries (Skipjack Programme 1981e). The average lampara net catch seems comparatively good but includes one very large, 364 kg haul. Furthermore, this haul consisted mainly of Herklotsichthys punctatus, a species which has been shown to undergo significant natural fluctuations in abundance, as noted in Vanuatu by Grandperrin et al. (1982b), in the Marshall Islands by Hida and Uchiyama (1977), and in Kiribati by Kleiber and Kearney (1983). In Palau, there was a marked decline in abundance of this species in apparent response to fishing pressure (Johannes 1981). Its ability to support regular catches is therefore questionable. The average lampara net catch without that haul is reduced to 14.2 kg for 13 hauls, much less than averages with either the bouki-ami or the beach seine in Vanuatu.

During a joint SPFC-Fisheries Department baitfish survey in March 1982 Japanese baitfish experts estimated potential bait catches of two and five tonnes per haul in Hog Harbour and Turtle Bay (Espiritu Santo) respectively (Blackburn 1982). However, actual night baitfishing trials in September of that year failed to confirm these estimates, suggesting that the estimates were unduly optimistic and/or were affected by the seasonality of the resource (Grandperrin et al. 1982b).

Although no baitfishing was carried out near Matthew and Hunter Islands, the bait resources of these two islands are considered to be negligible since both islands have a complete lack of suitable bait habitat.

4.2 Skipjack Fishing

Of the total of 14 days spent in Vanuatu, only 6 were spent with bait on board. Therefore skipjack catch results are based on a relatively short time spent actually fishing.

The average catch of 873 kg per day achieved by the Programme vessel represents an estimated equivalent commercial catch rate of 3.03 tonnes per day, using a conversion factor of 3.47 (Kearney 1978). This is about 11 per cent less than the average catch per day over the entire duration of the Programme. This overall catch rate is perhaps misleading as it includes days when the fishing potential was reduced due to the low amount of bait carried, and includes one day spent in an entirely different area during the second visit. If only the fishing results around Efate, Malekula, Epi and Ambrym islands, when bait was plentiful, are used, then the average catch increases to 5.5 tonnes per day. This falls between the 3 tonnes per day caught by the Japanese fleet fishing in the same area and the 6.2 tonnes per day caught by that same fleet fishing in the northern, northwestern and western Pacific areas of Vanuatu between 1974 and 1979 (Skipjack Programme 1980).

A total of 43 schools were sighted during the 10 days spent searching or fishing, for an average of 0.48 schools sighted per hour. This is well below the Programme's overall average of 0.75 schools per hour. Species could be identified for 63 per cent of all schools sighted in Vanuatu. Of these, 74 per cent had skipjack and 22 per cent had both skipjack and yellowfin.

Generalising from a survey limited to a few days fishing in areas concentrated around the main islands is tenuous. The relatively high estimate of potential commercial catch (5.5 tonnes per day) for days on which bait was carried should not be extrapolated to an annual expectation, especially since these results were obtained during mid-summer, a period of possible above-average abundance.

4.3 Skipjack Population Biology

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

4.3.1 Maturity and juvenile recruitment

Figure 3 presents female skipjack maturity data for Vanuatu (upper graph) and for all Skipjack Programme samples from tropical central and western Pacific waters (lower graph). In both graphs maturing skipjack (stage 3) dominate, as they do in most samples from pole-and-line catches in the tropical western Pacific. Presence of skipjack females with recovering gonads (stage 7) in Vanuatu in December 1977 and January 1978 implies that at least some skipjack spawning took place during this survey period.

Seasonal change in female gonad index[3] for all Skipjack Programme samples from tropical waters suggests that skipjack spawning is most intense south of the Equator between October and March (Figure 4). This trend is very similar to the trend presented by Naganuma (1979) for samples collected from a wide area of the tropical south Pacific, and to that presented by Lewis (1981) for samples from the Papua New Guinea fishery, just a few degrees south of the Equator. Skipjack sampled from Vanuatu in December 1977 and January 1978 had high gonad index values (42.7 for 40-49.9 cm skipjack and 58.0 for 50-59.9 cm skipjack), similar to overall averages in Figure 4 for these skipjack sizes and months. Three skipjack sampled from Hunter Island on 31 March 1980 had gonad indices less than 20, similar to overall averages for March and April. These results suggest that skipjack spawning in the waters of Vanuatu exhibits seasonal periodicity similar to that observed in the larger data set from the entire study area.

Another index of spawning activity is the incidence of skipjack juveniles observed in the stomachs of predators. An average of 29.9 skipjack juveniles per 100 skipjack predator stomachs was observed in Vanuatu (Table 5). This is one of the highest levels observed in the Programme study area. Argue, Conand and Whyman (1983) present more detailed analyses of the tuna juvenile data, taking into account size selective predation by adults, time of day, distance from land and season that adults were sampled. They hypothesise 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

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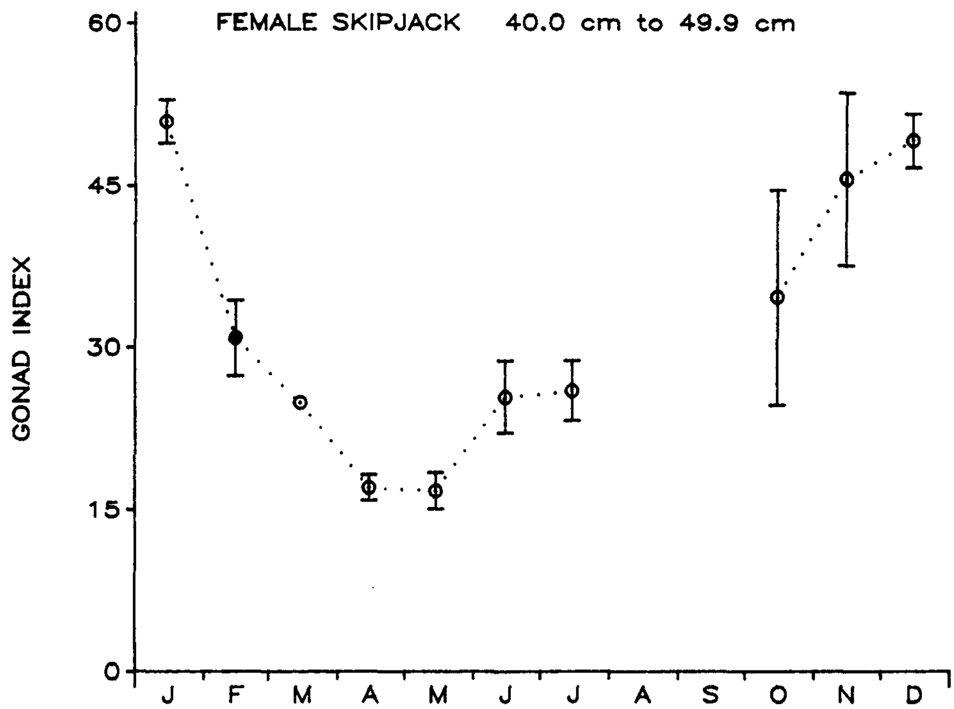
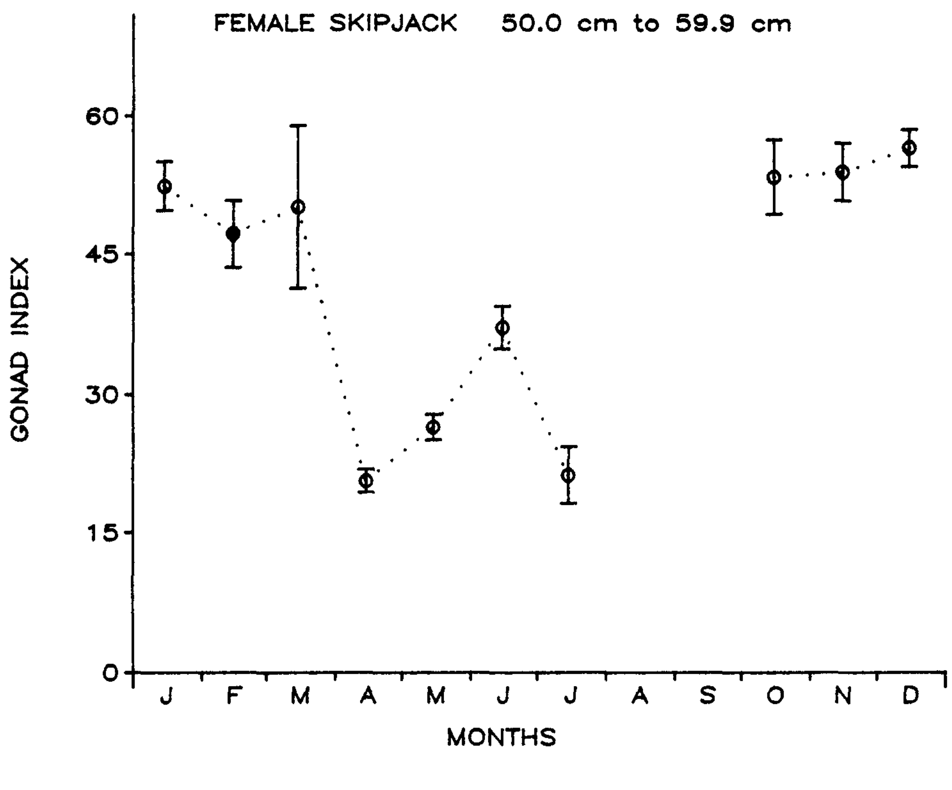
[3] Gonad index=10^7(gonad weight gm/(fish length mm)^3).
High index values, particularly over 50, are associated with skipjack whose gonads have a high percentage of eggs that are ready to be spawned (Raju 1964).

FIGURE 4. AVERAGE FEMALE GONAD INDICES, BY MONTH, FOR SKIPJACK SAMPLED BY THE SKIPJACK PROGRAMME FROM TROPICAL WATERS SOUTH OF THE EQUATOR. Circles denote means and bars denote two standard errors about the means. Standard errors omitted for sample sizes less than 5; most sample sizes exceeded 75. No samples for August and September.





Guinea and Vanuatu, and the other including the Marquesas and Tuamotu Islands. Skipjack juveniles also 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 gonad development in skipjack in these waters. However, as virtually nothing is known about the movements of juvenile skipjack, the extent to which local spawning contributes to recruitment in Vanuatu and elsewhere cannot be established.

4.3.2 Diet

Common diet items of skipjack in Vanuatu, other than chum and fish remains, were squid (Cephalopoda), tuna juveniles (several species in the family Scombridae), surgeon fish (Acanthuridae) and the alima stage of stomapods (Table 4). Each of these items occurred in over ten per cent of stomachs examined; 33 items occurred in at least one skipjack stomach.

The wide variety of diet items observed in skipjack from tropical waters indicates that skipjack are highly opportunistic feeders. Community groups of skipjack prey species are thought to vary across the study area, and identification of groups is the subject of ongoing analyses.

4.3.3 Growth

The growth of skipjack, as in other tunas, is a function of size. Larger fish grow more slowly than smaller fish (Skipjack Programme 1981d). When a tagged fish is recovered, its size will depend on not only the length of time it was at liberty, but also its size when it was released. For a given time at liberty, a small fish will have a greater increase in length than a larger fish. These considerations complicate the evaluation of growth by the analysis of tagging data. Table 7 presents a summary of size and growth information for skipjack tagged and released in the study area, for each size class for which there were adequate data. Size at release varies from 41 cm to 55 cm; time at liberty varies from less than a day to over 300; growth increments vary from -0.3 cm to over 12 cm. The effects of time at liberty can be seen by noting the difference in growth increments between the two visits to Fiji (FIJ1 and FIJ2) where the fish were released at approximately the same size, but the mean times at liberty were quite different. Similarly, the effects of size at release can be seen by noting the difference in growth increments between the first visit to Kiribati (KIR1) and the second visit to Papua New Guinea (PNG2) where the fish were at liberty for approximately the same period of time, but the mean sizes at release were quite different. On the whole, growth increments are quite small and the overall percentage of fish which did not show any measurable growth is quite high (40.1%). There are several reasons for this apparent lack of growth. First, 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, they may encounter conditions unfavourable for growth. Fourthly, errors in length measurement at both release and recovery may obscure what little growth there is.

It is possible to calculate corrections for the effects of size at release and time at liberty on the observed growth increment. These calculations were carried out using analysis of covariance and a linearised version of the von Bertalanffy growth equation. The corrections can be used to calculate a standard growth increment for an arbitrary size at release and time at liberty (Sibert, Kearney and Lawson 1983).

TABLE 7. SUMMARY OF SKIPJACK GROWTH INCREMENTS BY VISIT FOR FISH AT LIBERTY FROM 10 TO 365 DAYS. For explanation of country abbreviations see 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
VAN1 **	1	52.0	52.0	0.0	0.00	-	5	48.6	58.6	361.5	10.00	6.12
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
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.

** Second entry for visit VAN1 includes fish at liberty up to 730 days.

Standardised growth increments are presented in Table 8. It can be seen that the amount of growth can be expected to vary considerably from country to country. Further analysis shows that growth increments also differ significantly between visits to a country and also between fish recovered inside and outside of the country of release (Sibert, Kearney and Lawson 1983). Skipjack growth is seen to be highly variable in time and space. The observed growth in tagged skipjack is a function of where the fish were tagged, the year in which they were tagged, and where they were recovered. Thus, growth of skipjack may be closely coupled to environmental conditions such as temperature and other oceanographic variables that regulate the abundance of food.

TABLE 8. CALCULATED GROWTH INCREMENTS FOR FISH RECAPTURED WITHIN COUNTRY OF RELEASE. Calculations for fish 50 cm in length at release and at liberty for 90 days. The 95% confidence interval of each increment given in parentheses. See Sibert, Kearney and Lawson (1983) for details. For explanation of country abbreviations see 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 generalise about growth of skipjack that reside in Vanuatu since only two fish were tagged and recaptured in Vanuatu, with one recaptured on the day it was released.

4.3.4 Population structure

4.3.4.1 Blood genetics and tagging

There is movement of some skipjack adults over much of the western and central Pacific (Figure B, inside back cover), and such movement suggests that genetic exchange is possible among all countries within the Programme's study area. On the other hand, fishery interaction analyses completed to date suggest that the actual level of exchange, for skipjack of the size caught by pole-and-line gear, is low among at least the locally based pole-and-line fisheries in tropical waters (Argue and Kearney 1982, 1983; Kearney 1982a; Kleiber and Kearney 1983).

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 120°W (Figure 5). The esterase gene frequency for the sample taken in the waters of Vanuatu was 0.75, just outside the 95 per cent prediction limits for the regression line, a result to be expected for five per cent of the samples. There was considerable variation in individual esterase gene frequency values along this average line, 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 1970, 1976; Anon 1981). One of these models, suggested by the tagging and blood genetics data, is called the clinal population structure model (Anon 1981). It has the basic premise that the probability of breeding between skipjack is inversely proportional to the distance between them. Acceptance of this model implies that there are no genetically isolated skipjack subpopulations in the study area, separated by stable geographical boundaries, which is contrary to hypotheses advanced by Fujino (1970, 1976) and Sharp (1978).

The gradient in esterase gene frequency is consistent with more than one possible distribution of skipjack spawning, one being a relatively even distribution of skipjack spawning in tropical waters across the study area. Alternatively, one could view the gradient as the result of "overlap" of skipjack from two or more centres of higher spawner density at the approximate extremes of the study area or beyond. The similarity between eastern Pacific esterase gene frequencies (to the right of the dotted line in Figure 5) and those from French Polynesia suggests that eastern Pacific skipjack have the same genetic origin as skipjack in French Polynesia and thus could collectively represent the group at one extreme. Occurrence of skipjack juveniles (Argue, Conand and Whyman 1983) also appeared highest at the longitudinal extremes of the Programme study area, including the waters of Vanuatu, thus lending some support to the latter view of the distribution of skipjack spawning.

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

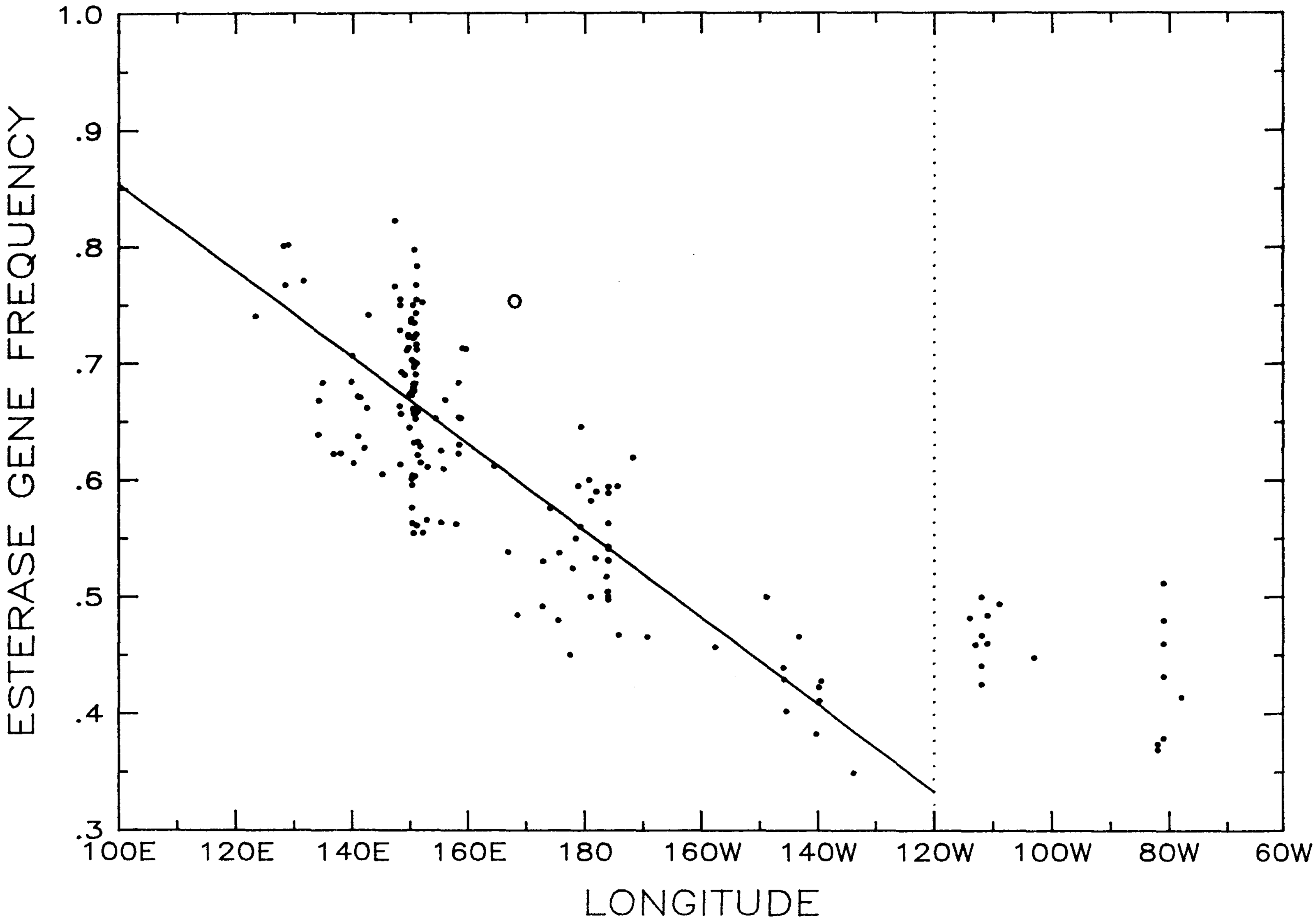
4.3.4.2 The occurrence of parasites

Parasite samples were taken over a wide range of tropical waters, 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 tropical samples from widely separated 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.

4.4 Resource Assessment from Tagging Data

Of the 1,254 tags released in Vanuatu between December 1977 and

FIGURE 5. SKIPJACK SERUM ESTERASE GENE FREQUENCY FOR 163 SAMPLES FROM INDIVIDUAL SKIPJACK SCHOOLS, VERSUS LONGITUDE OF THE SAMPLE LOCATION. The circle represents the esterase gene frequency for the sample from Vanuatu. 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.



January 1978, 7 have been returned. None of the 25 tags released in March 1980 have been recovered. Of the 7 Vanuatu releases that were recovered, 2 were from the Programme's tagging vessel (one on the day it was released and the other after 44 days at liberty). The other 5 were recovered in Solomon Islands (4) and Papua New Guinea (1) after 8 to 22 months. Three fish tagged in other countries were recovered in Vanuatu by Japanese pole-and-line vessels. One fish (out of a total of 12,734) released in New Zealand waters was recovered in Vanuatu after being at liberty for 12 months. Two fish (out of a total of 2,651) released in Queensland waters were recovered in Vanuatu after being at liberty for 10 months. The low number of returns of tagged fish released in Vanuatu, and also of recaptures in Vanuatu waters, is to be expected because of the long distance to larger fisheries and the small skipjack catches in Vanuatu. Tag and release data for these tagged fish are presented in Table 9.

The following three sections highlight general results from the Skipjack Programme's releases of tagged skipjack. In particular, results are given which bear on stock assessment and fishery interaction within the region and which are therefore relevant to Vanuatu.

4.4.1 International migrations

Figure B (inside back cover) presents a selection of Skipjack Programme tag returns plotted as straight line arrows 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 one example of a migration wholly within any ten degree square. The impression from this figure is one of considerable mixing of skipjack. Clearly there are few barriers to movement of some 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 where water temperatures are less than 16°C).

It should be noted, however, that the overall impression of many wide-ranging international migrations depicted by Figure B does not accurately reflect the average case for all the tag recoveries. This figure overemphasises long-distance, relatively rare migrations, due to the procedure used to select recoveries for the figure. In fact, the vast majority (86 %) of tag recoveries were made less than 250 nautical miles from their release site and within 180 days of tagging (Figure 6). Long-distance migrations are prevalent only within the group of skipjack that were at large for more than 180 days (lowest graph in Figure 6). The implication then is that few skipjack of the size that were tagged are available for long enough to be recovered at great distances from their release site.

As mentioned above, a small number of tagged fish were shown to have migrated either into or out of Vanuatu. These migrations are shown schematically in Figure 7. There is a suggestion of an appreciable degree of international movement in these data; however, the recovery effort was too low to permit a rigorous analysis. Fishery interactions throughout the study area are discussed in terms of their relevance to Vanuatu in Section 4.4.3.

TABLE 9. DETAILS OF ALL RECOVERED SKIPJACK TAGS RELEASED IN VANUATU AND ALL SKIPJACK TAGS RECOVERED IN VANUATU BUT RELEASED ELSEWHERE

TAG NO.		DATE	LATITUDE	LONGITUDE	SIZE	COUNTRY
AY04271	release data:	77/12/08	16deg 15'S	167deg 46'E	50.6cm	VAN1
	recapture data:	78/01/21	16deg 15'S	167deg 51'E	48.8cm	VAN
At large for 44 days.		Distance = 4.8 naut. miles in direction 90.deg. true.				
A09340	release data:	78/01/21	16deg 45'S	167deg 56'E	50.0cm	VAN1
	recapture data:	78/10/08	07deg 45'S	157deg 00'E	55.0cm	SOL
At large for 260 days.		Distance = 837.6 naut. miles in direction 309.deg. true.				
A09760	release data:	78/01/21	16deg 15'S	167deg 51'E	50.0cm	VAN1
	recapture data:	78/10/02	09deg 00'S	159deg 00'E	60.0cm	SOL
At large for 254 days.		Distance = 676.2 naut. miles in direction 309.deg. true.				
B00119	release data:	78/01/21	16deg 15'S	167deg 51'E	52.0cm	VAN1
	recapture data:	78/10/17	09deg 00'S	160deg 45'E	57.0cm	SOL
At large for 269 days.		Distance = 601.5 naut. miles in direction 315.deg. true.				
B00322	release data:	78/01/21	16deg 15'S	167deg 51'E	52.0cm	VAN1
	recapture data:	78/01/21	16deg 15'S	167deg 51'E	51.6cm	VAN
At large for 0 days.		Distance = 0.0 naut. miles in direction 0.deg. true.				
B01080	release data:	78/01/21	16deg 15'S	167deg 51'E	47.0cm	VAN1
	recapture data:	79/11/15	09deg 00'S	159deg 20'E	57.0cm	SOL
At large for 663 days.		Distance = 661.4 naut. miles in direction 310.deg. true.				
B00405	release data:	78/01/22	16deg 22'S	167deg 57'E	44.0cm	VAN1
	recapture data:	79/10/16	02deg 07'S	150deg 49'E	64.0cm	PNG
At large for 632 days.		Distance = 1324.6 naut. miles in direction 308.deg. true.				
K32870	release data:	79/05/02	17deg 36'S	148deg 09'E	58.0cm	QLD1
	recapture data:	80/03/18	16deg 16'S	164deg 31'E	70.0cm	VAN
At large for 321 days.		Distance = 942.5 naut. miles in direction 88.deg. true.				
K34121	release data:	79/05/03	16deg 22'S	150deg 12'E	48.0cm	QLD1
	recapture data:	81/02/26	13deg 27'S	165deg 54'E	67.0cm	VAN
At large for 665 days.		Distance = 926.7 naut. miles in direction 81.deg. true.				
K03054	release data:	79/03/13	37deg 38'S	176deg 33'E	52.0cm	ZEA1
	recapture data:	80/03/18	16deg 21'S	164deg 31'E	71.0cm	VAN
At large for 371 days.		Distance = 1426.8 naut. miles in direction 330.deg. true.				

FIGURE 6. NUMBERS OF SKIPJACK TAG RECOVERIES BY DISTANCE TRAVELLED AND TIME-AT-LARGE FOR THE TOTAL SKIPJACK PROGRAMME DATA SET. Data are for tag returns received by 4 November 1982. Recaptures for 96 fish, which travelled more than 1,500 nautical miles, are included in the sample sizes, but not shown in the figure.

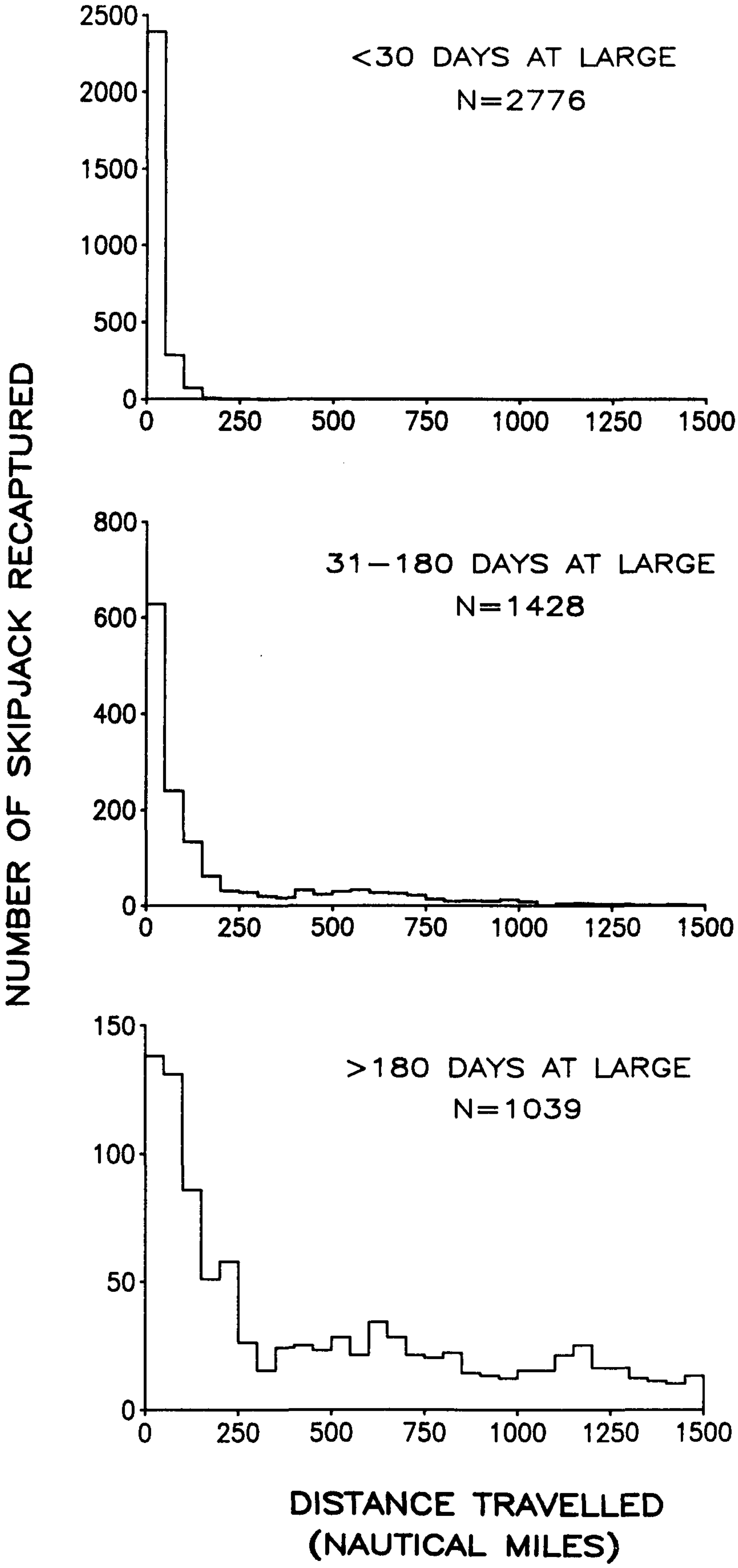
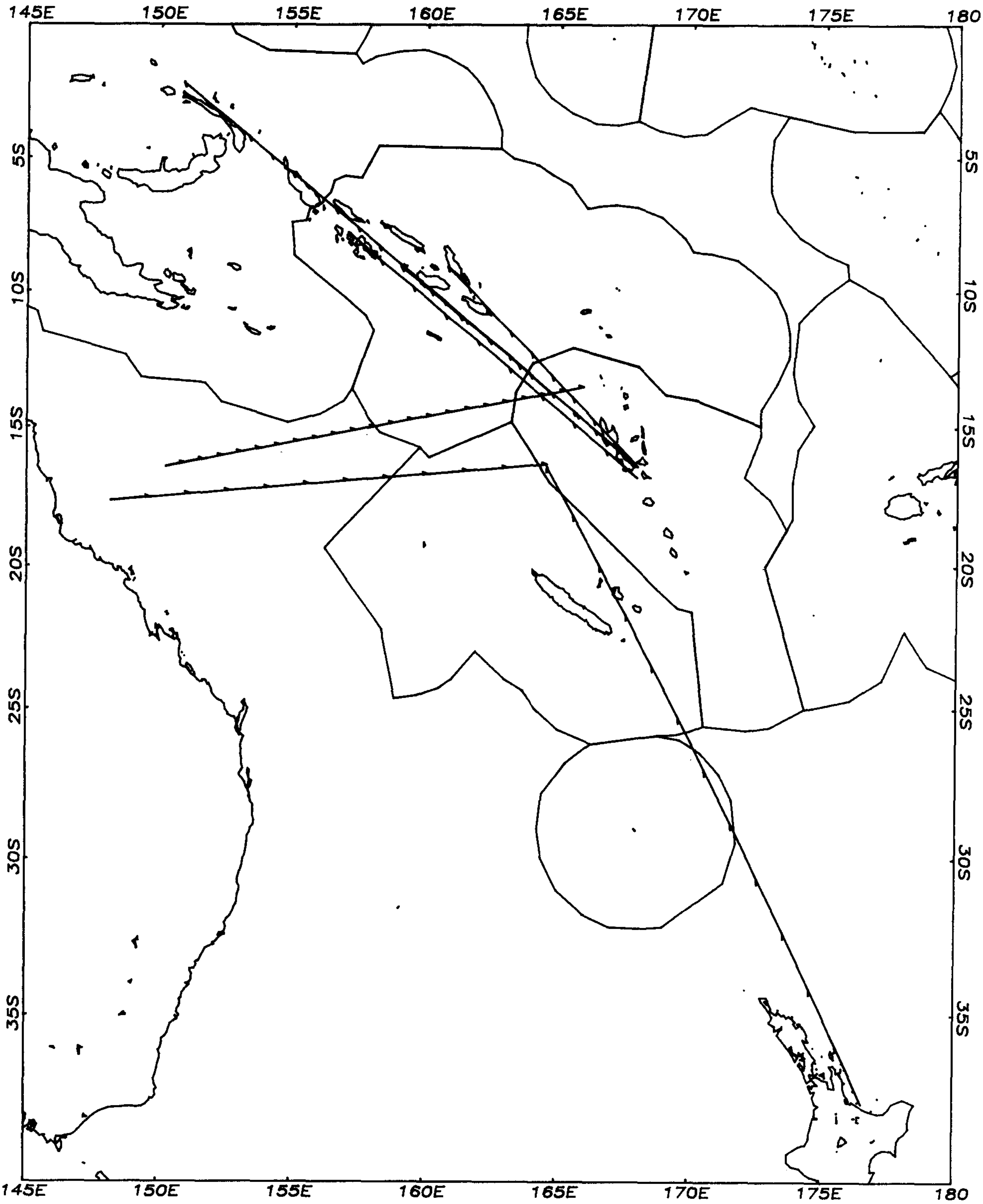


FIGURE 7. MIGRATION ARROWS FOR TAGGED SKIPJACK RELEASED IN VANUATU AND FOR SKIPJACK TAGGED IN AUSTRALIA AND NEW ZEALAND AND RECAPTURED IN VANUATU. No more than one arrow has been drawn between any pair of one degree squares of longitude and latitude. Tick marks indicate intervals of 30 days. In the absence of internationally accepted zones, 200-mile boundaries were estimated by Tuna Programme staff. The boundaries shown below should not prejudice any boundaries that may be derived in the future.



4.4.2 Mortality and production

The distribution of tagging throughout the study areas was such that large numbers of skipjack were tagged in the vicinity of important fisheries with similarly large numbers tagged in waters quite remote from these fisheries. If movement of tagged skipjack away from fished areas is assumed to be balanced by movement back into fished areas, then the decline in numbers of tag recoveries with increasing time-at-large can be assumed to be due to the following factors: death of tagged fish from natural and man-induced causes (e.g. predation, starvation, disease, "old age" and fishing); changes in vulnerability to fishing gears; and, to a lesser extent, emigration away from the study area as a whole, for example, into unfished central Pacific waters. These principles have been discussed by Kleiber, Argue and Kearney (1983) who developed an analytical model for the analysis of tag release and recovery data. Figure 8 shows the numbers of tag returns versus the numbers of months these tags were at large after release. This picture is what would be expected with time if all tags were released simultaneously in the different areas. 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, Argue and Kearney (1983) to the catch and resulting tag returns.

As can be seen from the figure, the actual data points (stars) 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 fishing and natural mortality, changed vulnerability and emigration. An additional component, presumably small, includes both the continual shedding of tags and continual mortality from the effects of tagging (Skipjack Programme 1981a). The estimate of attrition rate was 0.18 per month (Kleiber, Argue and Kearney 1983). 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 reason or another, and after a year this had increased to 90 per cent.

The model also provides an estimate of the population size or standing stock in the study area that is vulnerable to surface fisheries. This was estimated to be approximately three million tonnes during the 1977 to 1981 study period (2.5 million to 3.7 million).[4] Average monthly catch, 19,000 tonnes, divided by population size provides an estimate of average monthly fishing mortality, in this case approximately 0.006, which is a small proportion of the monthly attrition rate. This leaves losses through natural death, decreased vulnerability to fishing, and emigration. It is difficult to partition these last three loss factors, although considering that the study area was vast and covered much of the area of skipjack distribution in tropical waters, it has been assumed that emigration is the smallest of the three.

The product of standing stock (population size) and monthly attrition rate provides an estimate of monthly throughput for the study area. In this context, throughput measures the tonnes of skipjack being recruited to the standing stock each month, which is assumed for the duration of the

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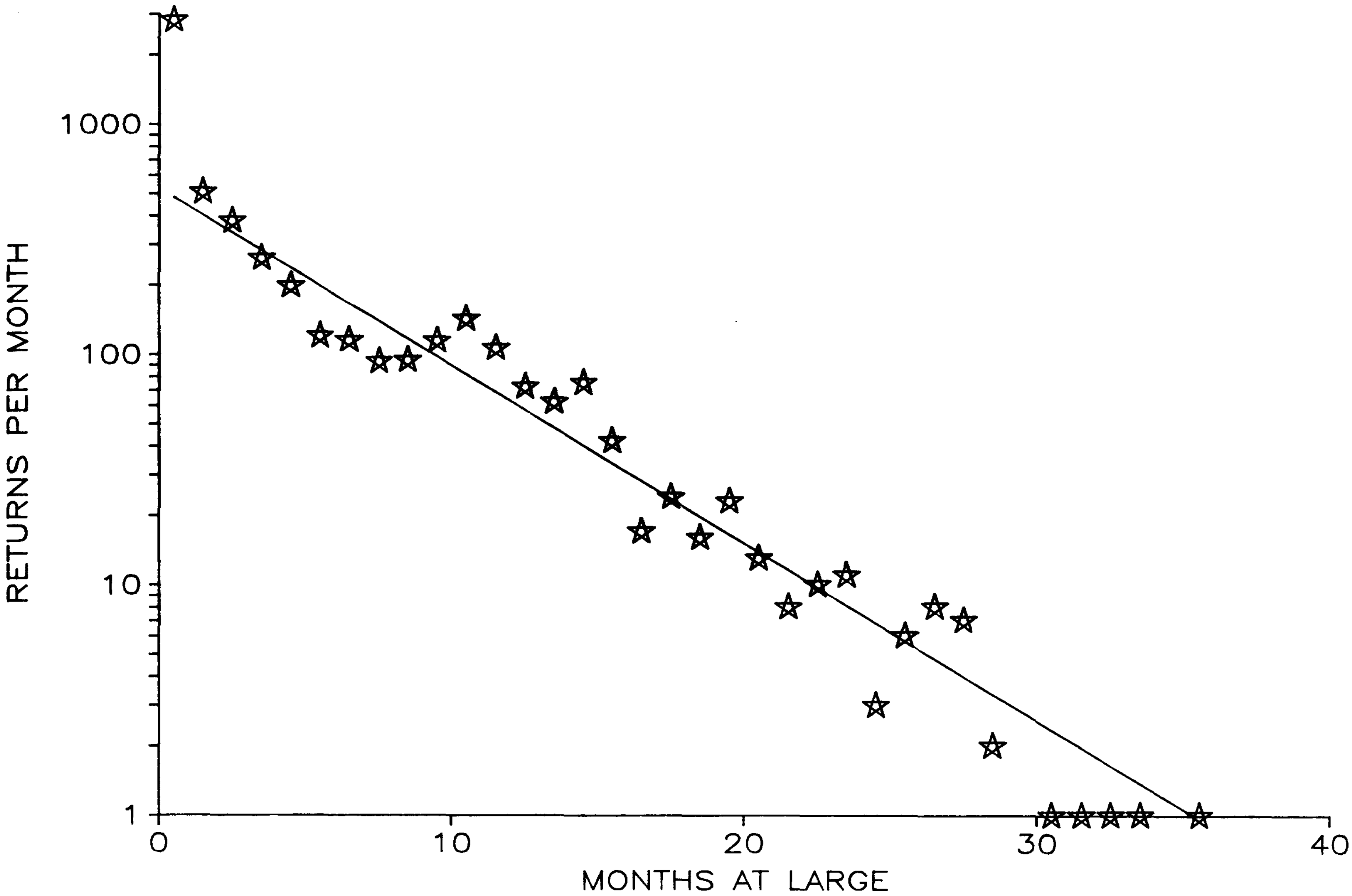
4 The estimates of population size and throughput have been adjusted downwards using a coefficient, p, of <1.0 to account for recaptured tags that were not returned by fishermen or processors, for short-term mortality due to tagging, and for short-term tag slippage.

FIGURE 8. NUMBERS OF SKIPJACK TAG RECOVERIES VERSUS MONTHS AT LARGE



tagging experiment to be matched by an equal amount leaving each month (for reasons noted above). From Skipjack Programme data, recruitment was estimated to fall between 0.4 and 0.6 million tonnes per month. Average monthly loss due to catch represents approximately four per cent of the estimated monthly recruitment. Hence, there would appear to be potential for greatly increased catches from the region as a whole before recruitment would be affected (Kleiber, Argue and Kearney 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, supports this claim (Joseph and Calkins 1969, Kearney 1979).

The resource of skipjack in the waters of Vanuatu is obviously some small fraction of the total standing stock in the study area. Although the data for Vanuatu are insufficient to quantify this fraction or the size of the local skipjack resource, it is safe to say that should the fishery for skipjack increase ten-fold in the waters of Vanuatu, there should be no immediate concern that recruitment would be significantly impaired as a result of this increase. There is, however, cause for concern that any great increase in skipjack fisheries in neighbouring countries, such as the recent build-up in the purse-seine fishery, could have serious detrimental impact on the quantity of skipjack available in Vanuatu.

4.4.3 Fishery interactions

One of the principal reasons for tagging skipjack was to investigate the degree of interaction among skipjack fisheries throughout the western and central Pacific. Table 10 summarises the recoveries from skipjack released throughout the total study area, by country/territory of release and recovery. This form of presentation, however, 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 and these were available to the Programme for the locally based fisheries during the period tags were at large, but not for catches, 1979-1982, by the large and growing United States and Japanese distant-water purse-seine fisheries, nor for any of the catch by 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 monthly catch data from these fisheries, estimates of interaction between distant-water and locally based fisheries cannot be made.

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

The initial approach followed by the Skipjack Programme was to use tagging data plus catch statistics to estimate coefficients of migration between particular fisheries (Skipjack Programme 1981b). The product of

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 B. Not included in the table are returns for which the country or area was unknown. Releases at Hunter Island are included in the Vanuatu total.

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
10194	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												548
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
1279	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	1	4	107	5	7	32	1058	94	3	54	605	2	13	71	25	10	5	1	66	41	52	1022	6176

estimate of the tonnes of skipjack migrating between fishing areas. Comparison of these estimates with estimates of population size in the recipient country, or in the donor country, illustrated stock interactions within one skipjack generation, since they measured the fraction of the standing stock that migrated to or from a particular area. Results demonstrated a generally low level of stock interaction for existing locally based fisheries.

A more appropriate expression of interaction is the percentage of recruitment (throughput) in the destination country that is due to immigration from the donor country (manuscript in preparation). It is independent of p, if p is the same in the donor and destination countries. There were four pairs of countries and territories in the Skipjack Programme study area for which it was possible to obtain quantitative estimates of this interaction (Table 11). These were Papua New Guinea - Solomon Islands, New Zealand - Fiji, New Zealand - Society Islands, and New Zealand - Western Samoa (Argue and Kearney 1982, 1983; Tuna Programme MS; Gillett and Kearney 1983; Kearney 1982a). As shown in Column 4 of the table, skipjack immigrants from the fished area in the donor countries were generally a small fraction of recruitment (throughput) in the destination countries' fished area (less than 10 per cent), which implies that interactions amongst present locally based fisheries in these countries are minor. It should be noted that this situation applies only to skipjack of the size tagged by the Programme (most were between 40 and 60 cm). Skipjack smaller than this could very well move large distances and contribute significantly to interactions between stocks in the fished areas. However, as fisheries in the study area are not yet exploiting fish less than 40 cm to any great degree, it can be reasonably assumed that fishery interactions resulting from movement of these small fish are presently negligible.

TABLE 11. SUMMARY OF FISHERY INTERACTION RESULTS BETWEEN SIX REGIONAL FISHERIES

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

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 would be expected to increase. Furthermore, if different gear types were to operate in the same area, such as purse-seine and pole-and-line fleets operating on the same or nearby fishing grounds of a country, then the degree of interaction would be much higher than that measured amongst present locally based fisheries. The limited tagging data indicate some interchange of fish between Vanuatu and neighbours, thus showing the need to monitor fishery interactions if there is a marked increase in fishing effort close to Vanuatu.

5.0 CONCLUSIONS

5.1 Baitfish Resources

Prior to the survey of the waters of Vanuatu, examination of charts of coastal areas suggested that there were few suitable, large baitfishing areas and that the total baitfish resource would thus be limited. The survey by the Skipjack Programme confirmed this limitation of the baitfish resources vulnerable to exploitation by the bouki-ami technique. Surveys in other areas have shown that species which are available exhibit wide seasonal fluctuations in abundance. The absence in Vanuatu of large quantities of species such as *Stolephorus heterolobus*, *S. devisi* or *Spratelloides gracilis*, which constitute the bulk of baitfish catches in Papua New Guinea and Solomon Islands, certainly detracts from the stability of the baitfish resource.

A recent survey by the Vanuatu Fisheries Department of the day-baiting potential resulted in some reasonable daily catches (Grandperrin *et al.* 1982b), but largely of species which are likely to show marked variability in abundance and rapid decline in abundance in response to fishing pressure. It is therefore concluded that even though some sizeable catches are possible on a seasonal basis, the baitfish resources of Vanuatu are inadequate to support a commercial pole-and-line fleet year-round.

5.2 Skipjack Resources

Largely because of problems with obtaining adequate bait for normal fishing activities, the survey of the skipjack resources of Vanuatu was shorter than anticipated. Because of this, only 1,279 fish were tagged. The lack of a sizeable skipjack fishery meant that few tags were recovered here, further reducing the utility of tag release and recovery data for local resource assessment. Resource evaluation was therefore by necessity dependent on the limited fishing results from the Skipjack Programme and other sources, and comparisons with assessments for other regions of the total study area. Catch rates by the survey vessel were average compared to those in other countries throughout the survey area. Furthermore, as Vanuatu is adjacent to Solomon Islands and Fiji, which both have established fisheries and assessed sizeable resources, there is good reason to assume that the skipjack resource within the Vanuatu 200-mile zone is indeed considerable.

The present level of exploitation of skipjack in the waters of Vanuatu is very low and there is probably negligible interaction from the locally based pole-and-line fisheries in other nearby countries. However, the rapidly expanding purse-seine fishery could be anticipated to interact progressively with local stocks, particularly when purse-seine fishing moves closer to the waters of Vanuatu.

The lack of suitable baitfish resources does restrict the options for local fisheries development. Small-scale skipjack fisheries development could, at least in the short-term, be best directed towards opportunistic exploitation of schools associated with fish aggregation devices. Larger commercial fishing activity might increasingly favour purse-seining, but the licensing of distant-water pole-and-line fleets should not be disregarded, at least in the short-term.

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

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Napolioni Ravitu
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Samuela Ue

APPENDIX B. ABBREVIATIONS FOR COUNTRIES, TERRITORIES AND SUBDIVISIONS THEREOF

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