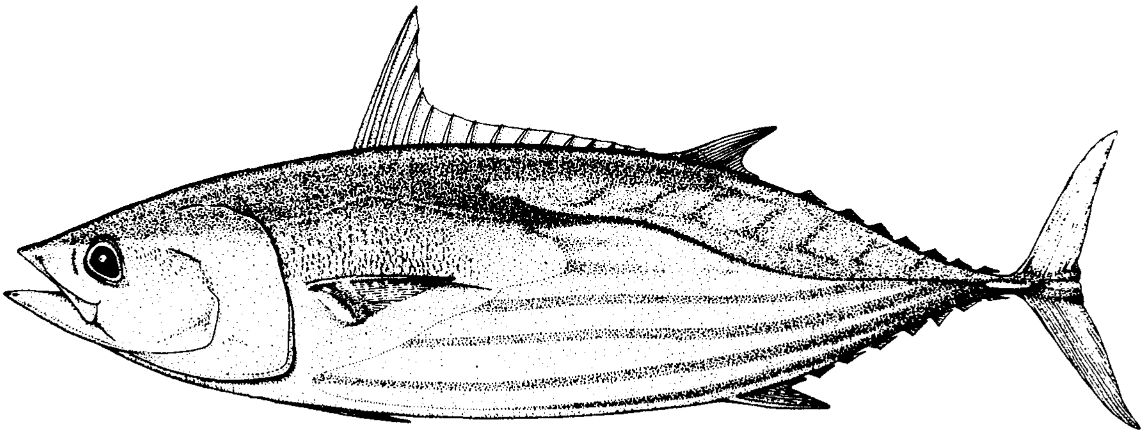
AN ASSESSMENT OF THE SKIPJACK AND BAITFISH RESOURCES OF FIJI

R.E. Kearney



Skipjack Survey and Assessment Programme
Final Country Report No. 1

South Pacific Commission
Noumea, New Caledonia

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PREFACE

The Skipjack Survey and Assessment Programme, which commenced in August 1977 and concluded in September 1981, was an externally funded part of the work programme of the South Pacific Commission. The governments of Australia, France, Japan, New Zealand, United Kingdom and the United States of America provided funding for the Programme.

The Programme worked in the waters of all of the countries and territories within the area of the South Pacific Commission and in New Zealand and Australia. This report is one of a series covering the assessment of the skipjack and baitfish resources of each country. Interim reports detailing the field results for each country have previously been published by the South Pacific Commission in a Preliminary Country Report series.

As the fieldwork and analysis phases of the Skipjack Programme have only recently been completed, many reports resulting from the Programme have not yet been published. Many are at present in draft form and therefore constant reference is given to reports in manuscript (MS). All information so referenced is available from the South Pacific Commission.

Even though the Programme investigated the yellowfin tuna resources of the region, detailed discussion on this species is not included. It will be presented later in the results of the Tuna and Billfish Assessment Programme which succeeded the Skipjack Programme as of October 1, 1981.

The staff of the Skipjack and Tuna Programmes 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.D. Gillett, J.-P. Hallier, P. Kleiber, T.A. Lawson, W.A. Smith and M.J. Williams; Research Assistants, Susan Van Lopik and Veronica van Kouwen; and Programme Secretary, Carol Moulin. Most staff were involved to some extent in the fieldwork from which this report resulted and/or in the analysis of the data and preparation of the manuscript.

The Skipjack Programme is indebted to many people in Fiji who helped make the fieldwork both successful and enjoyable and who also provided additional data and information used in the preparation of this report. Special thanks are due to Dr Peter Hunt, Ratu Tui Cavuilati and Dr Tony Lewis.

Tuna Programme
South Pacific Commission

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AN ASSESSMENT OF THE SKIPJACK AND BAITFISH RESOURCES OF FIJI

1. INTRODUCTION

Tuna fishing and processing of the catch are major industries in Fiji. With a combined value of more than 15 million Fijian dollars per annum they rank third behind sugar and tourism. The greater part of the revenue generated in Fiji from commercial tuna fisheries has historically come from the canning of catches from foreign longline vessels. However, skipjack (*Katsuwonus pelamis*) catches by locally based vessels have increased substantially in recent years and the expanding industry is the focus of intense Government interest.

Commercial exploitation of tuna by pole-and-line fishing was first attempted in Fiji in 1948 by an American operated company, South Seas Marine Products. However, following the lack of success of this venture, it was not until the early 1970s, after the development of sizeable skipjack fisheries in Papua New Guinea and Solomon Islands, that further attempts were seriously contemplated in Fiji. In 1974, a survey of the tuna and baitfish resources of Fiji confirmed the occurrence of sizeable skipjack concentrations, at least on a seasonal basis, and indicated some resources of potential live bait species (Anon 1974). Commercial exploitation of skipjack commenced in 1976 and a total of 625 tonnes was landed in that year. The total effort and catch increased through the 1978/79 season (September 1978-August 1979), when seven vessels operated and landed 3,292 tonnes. The 1979/80 season was a poor one and caused apprehension in Fiji about the future of the fishery. This apprehension was short-lived as 1980/81 catches soared above those of earlier seasons.

In the late 1970s research programmes on the commercial tuna and baitfish species were initiated in Fiji by the Ministry of Agriculture and Fisheries and the University of the South Pacific. However, as these research programmes were in their infancy at the time of the first visit by the Skipjack Programme research vessel in late January 1978, little was known of the magnitude of the resources, or of the biology and behaviour of the species being exploited. Prior to the commencement of the Skipjack Programme, nothing was known of the interaction between the Fijian skipjack fishery and those in the waters of Fiji's neighbours or beyond. In view of the significance of the skipjack fishery to Fiji, the importance of quickly evaluating these interactions and of basing future management on a sound understanding of the resource was appreciated. The apparent low abundance of both skipjack and baitfish in the 1979/80 season, and concern over possible repetition of these poor catches, endorsed the urgency for research and assessment.

This report presents the results of the Skipjack Survey and Assessment Programme in the waters of Fiji and considers the implications of these findings for skipjack and baitfish fisheries development. It covers two visits of Skipjack Programme research vessels to Fiji. The first was divided into two parts, 26 January to 18 February and 28 March to 10 April 1978, which bracketed a period of commercial fishing by the chartered vessel; the second visit was from 1 April to 8 May 1980.

2. RESEARCH PLAN AND SCHEDULE

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

The Programme's field activities spanned almost three years, from October 1977 to August 1980 inclusive, and incorporated visits to all of the countries in the area of the South Pacific Commission and also New Zealand and Australia. Eight hundred and forty-seven days of chartered vessel time were spent in the region and 26 countries and territories were visited. Seventy-eight days were spent in the waters of Fiji in 1978 and 1980. Summaries of research activities on skipjack and baitfish in Fijian waters are given in Tables 1 and 2 respectively. The areas surveyed and the baitfishing locations are shown in Figure 1.

3. VESSEL AND CREW

Two Japanese commercial skipjack live bait and pole vessels were chartered separately by the Skipjack Programme. The *Hatsutori Maru No.1*, of 192 gross tonnes, was used for the first visit, and the *Hatsutori Maru No.5*, of 254 gross tonnes, for the second. Both vessels were chartered from a commercial fishing company, Hokoku Marine Products Company Limited, Tokyo, Japan, and were slightly modified to accommodate the requirements of fisheries research work. Details of both vessels are given in Kearney (1982).

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. Observers from the Ministry of Agriculture and Fisheries of Fiji were on board for varying times throughout the survey. Lists of all personnel and details of the times scientists and observers spent on board are given in Appendix A.

4. METHODS

For tunas, visual scanning and exploratory fishing were the primary survey techniques. Tagging and biological sampling, including blood and parasite studies, were the basic tools used to assist with the assessment of skipjack and yellowfin tuna (*Thunnus albacares*) resources. Analysis of results from these studies, together with all available catch and effort data, constitute the basis for assessment of the resources of skipjack and other tunas.

Baitfish resources were surveyed by exploratory fishing, predominantly at night. Assessments of the baitfish resources were based on these results: catch and effort figures from the commercial fleet, estimates of the magnitude of suitable baitfish habitat, and knowledge of the utility of the common species as skipjack bait.

TABLE 1

SUMMARY OF DAILY FIELD ACTIVITIES IN THE WATERS OF FIJI

Date, area, main activity, bait carried (kg), hours fished, schools sighted, numbers of skipjack, yellowfin, and other species tagged, catch (kg) of skipjack and yellowfin, and catch (kg) of all species combined are shown. 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.

Date	General Area	Principal Activity	Bait Carried (kg)	Hours Sighting	Schools Sighted					Fish Tagged (numbers)			Fish Caught (kg)		Total Catch (kg)
					SJ	YF	S+Y	OT	UN	SJ	YF	OT	SJ	YF	
25/01/78	Levuka	Steaming	0	9	0	1	0	0	10	0	0	0	0	3	3
26/01/78	Levuka-Suva	Steaming	0	0	-	-	-	-	-	-	-	-	-	-	-
27/01/78	Suva	In port	0	0	-	-	-	-	-	-	-	-	-	-	-
28/01/78	Suva	In port	0	0	-	-	-	-	-	-	-	-	-	-	-
29/01/78	S Viti Levu	Steaming	0	9	0	1	0	0	2	-	-	-	-	-	-
30/01/78	Kandavu Is	Fishing	107	8	4	0	0	0	2	277	0	0	628	0	628
31/01/78	Kandavu Is	Fishing	93	3	3	0	1	0	1	599	24	0	1470	88	1558
01/02/78	Kandavu Is	Fishing	66	12	3	3	1	0	5	37	0	0	104	8	112
02/02/78	Kandavu Is	Fishing	570	12	0	0	1	0	3	343	225	0	933	1004	1940
03/02/78	Kandavu Is	Fishing	278	6	1	2	1	0	4	426	90	1	1087	310	1398
04/02/78	S Viti Levu	Fishing	638	5	0	0	1	0	1	324	30	0	755	89	846
05/02/78	Mbenga Is	Fishing	468	7	2	0	3	0	2	1232	44	0	2660	220	2880
06/02/78	Mbenga Is	Fishing	198	13	4	2	1	0	7	158	0	0	355	3	358
07/02/78	Suva	In port	132	3	2	2	0	0	0	6	0	0	22	0	22
08/02/78	Levuka-Ngau Is	Fishing	90	3	0	0	1	0	1	159	2	0	367	11	377
09/02/78	Koro Sea	Fishing	90	7	2	0	3	0	7	251	16	0	706	78	784
10/02/78	Savu Savu	Fishing	87	11	0	1	1	0	1	501	56	0	1350	268	1629
11/02/78	Vanua Mbalavu Is	Fishing	42	4	2	0	1	0	3	4	0	0	15	0	15
12/02/78	Ringgold Is	Steaming	0	7	0	0	0	0	6	-	-	-	-	-	-
13/02/78	Kia Is	Fishing	144	8	1	1	2	0	2	4	32	0	13	122	134
14/02/78	Kia Is	Fishing	75	6	0	1	0	0	5	0	0	0	0	0	0
15/02/78	Great Sea Reef	Fishing	59	11	0	0	2	1	14	29	7	0	99	18	123
16/02/78	W Yasawa Is	Fishing	98	12	2	2	2	0	3	10	0	0	50	28	77
17/02/78	Nandi-Levuka	Fishing	23	4	1	0	0	0	3	55	0	0	165	0	165
18/02/78	Levuka-Suva	Steaming	0	0	-	-	-	-	-	-	-	-	-	-	-
28/03/78	E Viti Levu	Steaming	0	0	-	-	-	-	-	-	-	-	-	-	-
29/03/78	Ovalau Is	In port	0	0	-	-	-	-	-	-	-	-	-	-	-
30/03/78	S Vanua Levu	Fishing	83	6	2	1	1	0	1	0	0	0	0	0	0
31/03/78	To Lau Group	Fishing	305	12	3	1	1	0	0	2	0	0	18	0	18
01/04/78	Vanua Mbalavu Is	Fishing	30	1	0	0	1	0	0	47	27	0	159	126	284
02/04/78	Vanua Mbalavu Is	Fishing	626	11	9	0	2	0	0	548	1	0	2060	6	2066
03/04/78	Vanua Mbalavu Is	Fishing	906	11	1	0	3	0	3	582	235	0	1817	749	2568
04/04/78	Vanua Mbalavu Is	Fishing	225	3	0	0	2	0	1	309	171	0	1078	649	1728
05/04/78	Vanua Mbalavu Is	Fishing	260	5	1	0	2	0	1	903	16	0	3817	47	3865
06/04/78	Vanua Mbalavu Is	Fishing	300	6	1	0	1	0	0	1642	0	0	6206	0	6206
07/04/78	Suva	In port	0	0	-	-	-	-	-	-	-	-	-	-	-
08/04/78	Suva	Steaming	0	0	-	-	-	-	-	-	-	-	-	-	-
09/04/78	Vanua Mbalavu Is	Steaming	0	0	-	-	-	-	-	-	-	-	-	-	-
10/04/78	E Fiji Is	Baiting	291	0	-	-	-	-	-	-	-	-	-	-	-

Date	General Area	Principal Activity	Bait Carried (kg)	Hours Sighting	Schools Sighted SJ	YF	S+Y	OT	UN	Fish Tagged (numbers) SJ	YF	OT	Fish Caught (kg) SJ	YF	Total Catch (kg)
01/04/80	Conway Reef	Steaming	0	11	0	0	0	0	1	-	-	-	-	-	-
02/04/80	Levuka	Steaming	0	0	-	-	-	-	-	-	-	-	-	-	-
03/04/80	Suva	In port	0	0	-	-	-	-	-	-	-	-	-	-	-
04/04/80	Suva	In port	0	0	-	-	-	-	-	-	-	-	-	-	-
05/04/80	Suva	In port	0	0	-	-	-	-	-	-	-	-	-	-	-
06/04/80	Suva	In port	0	0	-	-	-	-	-	-	-	-	-	-	-
07/04/80	Suva	In port	0	0	-	-	-	-	-	-	-	-	-	-	-
08/04/80	Suva	In port	0	0	-	-	-	-	-	-	-	-	-	-	-
09/04/80	Mbenga Is	Baiting	0	0	-	-	-	-	-	-	-	-	-	-	-
10/04/80	Mbenga Is	Fishing	363	6	1	0	4	0	3	1090	109	0	3655	1057	4712
11/04/80	Mbenga Is	Fishing	531	7	2	0	4	0	1	2130	74	0	6325	380	6733
12/04/80	Mbenga Is	Fishing	390	4	0	0	2	1	0	1000	81	0	3168	437	3605
13/04/80	Mbenga Is	Fishing	461	10	2	0	7	0	1	894	17	0	2818	231	3049
14/04/80	Mbenga Is	Fishing	462	8	4	1	2	0	3	455	30	0	1234	116	1350
15/04/80	Mbenga Is	Fishing	755	10	3	1	3	0	1	597	4	0	1542	20	1562
16/04/80	Coral Coast	Fishing	443	10	4	0	2	0	2	470	1	0	1846	75	1925
17/04/80	Yasawa Is	Fishing	116	4	1	0	1	0	2	106	0	0	380	8	388
18/04/80	Yasawa Is	Fishing	549	9	1	0	3	1	1	353	8	0	1309	51	1370
19/04/80	Great Sea Reef	Fishing	693	9	0	1	1	0	2	1	3	0	4	13	16
20/04/80	Thikombia Is	Fishing	618	4	0	0	1	0	1	1434	400	0	4289	1474	5832
21/04/80	Thikombia Is	Fishing	624	11	0	4	2	0	7	128	59	0	373	199	575
22/04/80	Kia Is	Fishing	627	4	2	0	2	0	1	499	67	1	1657	378	2065
23/04/80	Kia Is	Fishing	483	10	2	1	4	1	4	710	64	0	2153	335	2498
24/04/80	Kia Is	Fishing	312	4	0	1	3	0	1	813	199	0	2435	685	3155
25/04/80	Kia Is	Fishing	371	11	1	1	1	1	1	485	0	0	1885	0	1885
26/04/80	Kia Is	Fishing	714	10	1	2	1	0	1	71	0	0	251	0	251
27/04/80	Thikombia Is	Fishing	572	10	1	1	3	0	2	410	22	0	1229	81	1312
28/04/80	Levuka-Suva	Steaming	0	0	-	-	-	-	-	-	-	-	-	-	-
29/04/80	Suva	In port	0	0	-	-	-	-	-	-	-	-	-	-	-
30/04/80	Suva	In port	0	0	-	-	-	-	-	-	-	-	-	-	-
01/05/80	Suva	In port	0	0	-	-	-	-	-	-	-	-	-	-	-
02/05/80	E Viti Levu	Steaming	0	0	-	-	-	-	-	-	-	-	-	-	-
03/05/80	Yasawa Is	Baiting	0	0	-	-	-	-	-	-	-	-	-	-	-
04/05/80	N Fiji Is	Baiting	384	11	0	0	0	0	0	0	0	0	0	0	0
05/05/80	Rotuma	Fishing	354	3	0	0	0	0	0	0	0	0	0	0	0
06/05/80	Rotuma	Baiting	294	0	-	-	-	-	-	-	-	-	-	-	-
07/05/80	Rotuma	Fishing	264	2	1	2	0	0	0	0	0	0	0	0	0
08/05/80	Rotuma	Fishing	212	9	0	4	0	0	0	0	0	0	0	0	0
09/05/80	SE Rotuma	Fishing	129	3	0	0	0	0	0	0	0	0	0	0	0
TOTALS	Days 78			395	70	37	80	5	123	20094	2114	2	62484	9367	72067
	Fishing 47														
	Baiting 5														
	Steaming 12														
	In port 14														

TABLE 2
SUMMARY OF BAITFISHING ACTIVITIES IN THE WATERS OF FIJI

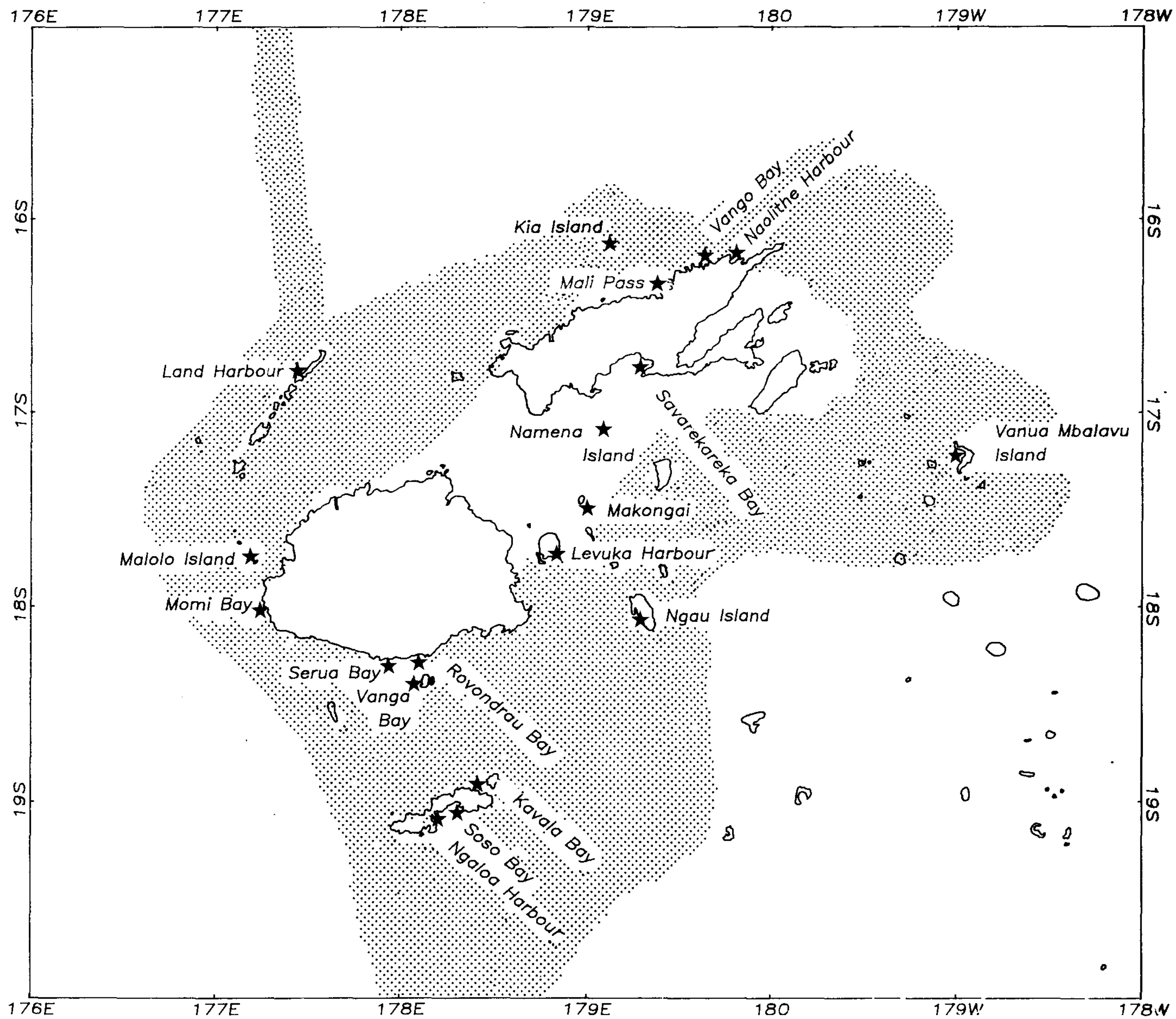
Anchorage	Time of Hauls	Number of Hauls	Dominant Species *	Est. Av. Catch per Haul (kg)	Mean Length (mm)	Other Common Species *
Soso Bay			*Sardinella sirm*	44	91	*Herklotsichthys punctatus*
19°01′S	Night	2	*Bregmaceros* sp.	3	42	Sp. of Exocoetidae
178°17′E			*Scomberoides* sp.	1		Sp. of Cirrhitidae
Kavala Bay			*Thrissina baelama*	23	66	*Dussumieria acuta*
18°58′S	Night	2	*Stolephorus indicus*	9	102	*Pranesus pinguis*
178°25′E			*Hypoatherina ovalaua*	3	48	*Rastrelliger brachysoma*
Kavala Bay			*Spratelloides delicatulus*	24	36	*Priacanthus* sp.
18°58′S	Night	2	*Sardinella sirm*	3		*Sphyraena* sp.
178°24′E			*Hypoatherina ovalaua*	3		*Stolephorus indicus*
Ngaloa Harbour			*Sardinella sirm*	209	88	*Hypoatherina ovalaua*
19°05′S	Night	4	*Rastrelliger brachysoma*	15	88	*Thrissina baelama*
178°11′E			*Rastrelliger kanagurta*	15		*Apogon(Rhabdamia) gracilis*
Vanga Bay			*Spratelloides gracilis*	156	41	*Apogon(Rhabdamia) gracilis*
18°24′S	Night	1	*Spratelloides delicatulus*	50	27	*Gymnocaesio gymnopterus*
178°05′E			*Apogon(Rhabdamia) cypselurus*			*Pterocaesio pisang*
Levuka Harbour			*Spratelloides delicatulus*	5	48	*Scomberomorus commersonii*
17°41′S	Night	1	Sp. of Myctophidae	3	51	*Bregmaceros* sp.
178°50′E			*Scomberoides* sp.			Sp. of Anguillidae (j)
Ngau Is			*Hypoatherina ovalaua*	10	48	*Bregmaceros* sp.
18°02′S	Night	2	*Herklotsichthys punctatus*	10	58	*Sardinella sirm*
179°16′E			*Spratelloides delicatulus*	10	46	*Rastrelliger brachysoma*
Savarekareka Bay			*Rastrelliger brachysoma*	10	50	*Herklotsichthys punctatus*
16°45′S	Night	2	*Hypoatherina ovalaua*	9	44	*Spratelloides delicatulus*
179°21′E			*Stolephorus devisi*	6	40	*Apogon(Rhabdamia) gracilis*
Vanua Mbalavu Is			*Spratelloides delicatulus*	14	45	*Siphamia* sp.
17°13′S	Night	2	*Stolephorus devisi*	7	52	*Herklotsichthys punctatus*
178°58′W			*Bregmaceros* sp.	2	45	*Sardinella sirm*
Vango Bay			*Stolephorus devisi*	69	48	*Herklotsichthys punctatus*
16°13′S	Night	2	*Stolephorus bataviensis*	9	56	*Gazza minuta*
179°33′E			*Stolephorus indicus*	3	54	*Archamia lineolata*
Mali Pass			*Sardinella sirm*	15	73	*Rastrelliger brachysoma*
16°20′S	Night	2	*Hypoatherina ovalaua*	11	55	*Apogon(Rhabdamia) cypselurus*
179°20′E			*Stolephorus indicus*	6	98	*Bregmaceros* sp.
Kia Is			*Spratelloides delicatulus*	18	48	*Apogon(Rhabdamia) cypselurus*
16°13′S	Night	1	*Rastrelliger brachysoma*	12	70	*Sardinella sirm*
179°06′E			*Hypoatherina ovalaua*	12	54	*Herklotsichthys punctatus*
Land Harbour			*Herklotsichthys punctatus*	62	82	*Apogon(Rhabdamia) gracilis*
16°48′S	Night	6	*Spratelloides delicatulus*	59	44	*Hypoatherina ovalaua*
177°27′E			*Sardinella sirm*	55	105	*Stolephorus buccaneeri*
Momi Bay			*Sardinella sirm*	6	81	*Rastrelliger brachysoma*
17°54′S	Night	1	*Herklotsichthys punctatus*	5	66	*Rastrelliger kanagurta*
177°15′E			*Apogon(Rhabdamia) gracilis*	5	37	*Dussumieria acuta*
N Levuka Bay			No Significant Catch			
17°40′S	Night	1				
178°50′E						

Anchorage	Time of Hauls	Number of Hauls	Dominant Species *	Est. Av. Catch per Haul (kg)	Mean Length (mm)	Other Common Species *
Makongai 17°26′S 178°58′E	Night	2	Sardinella sirm Spratelloides gracilis Spratelloides delicatulus	30 5 4	162 56	Apogon(Rhabdamia) gracilis Pranesus pinguis Caesio coerulaureus
Namena Is 17°06′S 179°07′E	Night	2	Sardinella sirm Spratelloides gracilis Spratelloides delicatulus	134 4 4	137 55 57	Gymnocaesio gymnopterus Apogon(Rhabdamia) gracilis Stolephorus devisi
Vanua Mbalavu Is 17°12′S 178°58′W	Day	1	No Significant Catch			
Vanua Mbalavu Is 17°11′S 179°01′W	Night	2	Sardinella sirm Spratelloides delicatulus Apogon(Rhabdamia) gracilis	111 111 63	121 52 42	Spratelloides gracilis Pterocaesio pisang Dussumieria acuta
Vanua Mbalavu Is 17°09′S 179°02′W	Night	6	Spratelloides delicatulus Apogon(Rhabdamia) gracilis Sardinella sirm	194 58 3	50 47	Stolephorus devisi Decapterus macrosoma Pterocaesio diagramma
Rovondrau Bay 18°16′S 178°06′E	Night	2	Stolephorus indicus Thrissina baelama Herklotsichthys punctatus	91 45 22	91 69 69	Sardinella sirm Hypoatherina ovalaua Pranesus pinguis
Serua Bay 18°16′S 177°57′E	Night	8	Sardinella sirm Stolephorus indicus Thrissina baelama	78 76 57	99 95 72	Herklotsichthys punctatus Alepes sp. Spratelloides delicatulus
Serua Bay 18°16′S 177°56′E	Night	3	Sardinella sirm Herklotsichthys punctatus Spratelloides delicatulus	146 54 44	101 82 44	Stolephorus indicus Thrissina baelama Hypoatherina ovalaua
Malolo Is 17°46′S 177°13′E	Night	1	Herklotsichthys punctatus Sardinella sirm Spratelloides delicatulus	38 27 15	70 100 41	Hypoatherina ovalaua Stolephorus devisi Alepes sp.
Noalithe Harbour 16°10′S 179°52′E	Night	1	Sardinella sirm Sardinella leiogaster Herklotsichthys punctatus	390 126 38	76 94 79	Hypoatherina ovalaua Stolephorus buccaneeri Spratelloides delicatulus
Vorovoro Is 16°20′S 179°19′E	Night	2	Stolephorus indicus Herklotsichthys punctatus Stolephorus devisi	199 78 70	74 76 60	Hypoatherina ovalaua Pranesus pinguis Apogon(Rhabdamia) gracilis
Kia Is 16°14′S 179°06′E	Night	5	Sardinella sirm Hypoatherina ovalaua Stolephorus heterolobus	68 49 40	134 54 59	Apogon(Rhabdamia) cypselurus Apogon(Rhabdamia) gracilis Stolephorus buccaneeri
Kia Is 16°13′S 179°05′E	Night	3	Sardinella sirm Stolephorus heterolobus Herklotsichthys punctatus	127 15 10	139 59 98	Hypoatherina ovalaua Apogon(Rhabdamia) gracilis Spratelloides delicatulus
Foviung Efau 12°29′S 177°02′E	Night	3	No Significant Catch			

* Several revisions of specific names used in this report are in progress but for consistency, names used in previous Skipjack Programme reports on Fiji have been maintained. The most notable changes in nomenclature have been:

Herklotsichthys punctatus to Herklotsichthys quadrimaculatus
Pranesus pinguis to Atherinomorus lacunosa

FIGURE 1. THE AREA OF FIJIAN WATERS SURVEYED BY THE SKIPJACK PROGRAMME. Baiting stations are marked ✶.



4.1 Skipjack Fishing, Tagging and Biological Sampling

Both vessels used by the Skipjack Programme were commercial live bait and pole fishing vessels and the basic strategy of approaching and chumming schools normally employed by these vessels was not changed. As for 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 and, as at least one crew member was required to assist each scientist in the tagging procedures, the effective number of fishermen was further reduced. Moreover, the need to pole skipjack accurately into the tagging cradles reduced the speed of individual fishermen. One of the specific aims of the first visit of the Skipjack Programme to Fiji was to calibrate the fishing power of the Hatsutori Maru No 1 against the commercial fleet operating in this area, and against this vessel's own performance in the one-month period during which it fished under commercial conditions with the same captain and a larger crew.

As tagging was a primary tuna research tool, attempts to tag large numbers of fish often dominated the fishing strategy. The tagging techniques and alterations to normal fishing procedures have been described in detail by Gillett and Kearney (1982).

During the second visit to Fiji the opportunity of having a relative high tag recovery rate (proven by the first visit) was taken to conduct a double tagging experiment. The primary objective was to evaluate tag shedding, or slippage, although comparisons of mortality, migration and growth between single and double tagged fish were also to be evaluated. This information, together with the studies on the influence of tag length, fish length, physical condition of the fish, experience of the tagger and position of the tagging cradle, was anticipated to provide an evaluation of the Programme's tagging procedures and to indicate possible improvements for future tagging studies. Methods used in this study have been described in Skipjack Programme 1981a.

Specimens of all tuna and other pelagic species which were poled or trolled, but not tagged and released, were routinely analysed. Data collected included length frequency distributions, length/weight relationships, sex ratios, gonad weights and stages of maturity, and stomach contents. In addition, a log of all fish schools sighted throughout the survey was maintained. Where possible, the species composition of each school was determined and records were kept of schools chummed and the biting response of each. Details of the methods used for all biological sampling are given by Argue (1982).

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

During the second visit to Fiji, skipjack body cavities 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 samples were air freighted to the University of Queensland, St Lucia, Australia, for detailed examination for the presence of parasites.

4.2 Baitfishing

Most baitfishing carried out by the Programme employed a "bouki-ami" net set at night around a bait attraction light. Procedures were similar to those used by commercial vessels operating in this region, but were modified where necessary to meet the Programme's special requirements. 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 by Hallier and Gillett (1982).

4.3 Data Compilation and Processing

Five separate logbook systems formed the basis for compiling data accumulated during the fieldwork outlined in Sections 4.1 and 4.2. Descriptions of these and techniques used in computerising and processing the data are given by Kleiber and Maynard (1982). Data processing was carried out on the Programme's Hewlett Packard 1000 computer. Electrophoretic characteristics of all blood samples collected and analysed at the Australian National University, and parasite identifications on all viscera specimens taken and analysed at Queensland University, were also coded and computerised.

4.4 General Analysis

Assessment of the skipjack stocks and possible interactions between the Fiji fishery and those in other countries were approached from many viewpoints. Intensive studies of the migration of tagged skipjack have formed the basis of investigations on the behaviour of skipjack and the movement of individuals and possibly stocks. Analytical methods for investigating these migratory patterns have been previously described (Skipjack Programme 1981b). Methods employed in other biological studies are described in other sources as listed; mortality (Skipjack Programme 1981b and Kleiber MS), growth (Skipjack Programme 1981c and Lawson and Kearney MS), spawning, feeding and cannibalism (Argue, Conand and Whyman MS). Evaluation of population structuring across the whole of the western and central Pacific centred on a comparison of tagging results with blood genetics work (Anon 1980 and 1981). Occurrence and distribution of skipjack parasites have been given preliminary evaluation (Lester 1981).

An earlier evaluation of the Fijian baitfish fishery was undertaken in 1980 by Skipjack Programme staff at the request of the Fijian Government. This evaluation involved review of the results obtained by the commercial vessels operating in Fiji and comparison of these with the results from the Skipjack Programme. Details of these analyses have previously been published (Ellway and Kearney, 1981).

5. SUMMARY OF FIELD ACTIVITIES

Thirty-nine days were spent in Fijian waters during each of the two visits for a total of 78 days. Of these 78 days, 47 were spent skipjack fishing, 5 baiting, 12 travelling and 14 in port (Table 1); baiting was carried out on 43 nights (Table 2). The number of days spent in port was above the overall average of 4.1 days per month for the Skipjack Programme because Fiji was home for most of the crew, so holidays were accumulated while working in other countries, and taken in Fiji.

A total 22,210 skipjack and other tunas were tagged in Fijian waters (Table 1) and 3,107 others were sampled as part of the investigation of the biology of skipjack and other tunas (Table 3).

TABLE 3
SUMMARY OF NUMBERS OF FISH SAMPLED FOR BIOLOGICAL DATA

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_	2359	1127	1158	426	928
Yellowfin _Thunnus albacares_	731	304	284	161	267
Mackerel Tuna _Euthynnus affinis_	2	0	0	0	0
Frigate Tuna _Auxis thazard_	11	7	7	7	7
Dolphin Fish _Coryphaena hippurus_	2	2	2	2	2
Double Lined Mackerel _Grammatorcynus bicarinatus_	2	2	2	2	2
Totals	3107	1442	1453	598	1206

During the early part of the first survey, the _Hatsutori Maru No.1_ operated in the same general area as the commercial Fijian fleet. The resulting catches were compared to those of the commercial vessels and to those of the _Hatsutori Maru No.1_, when it fished commercially, to derive a figure of 0.288 for the relative fishing power of the vessel under survey conditions (Kearney 1978). Subsequent survey catches in Fiji and other countries were then corrected on the basis of this fishing power conversion factor to approximate catch rates under commercial operation.

During the first visit, the need to calibrate the fishing power of the Hatsutori Maru No.1 necessitated that the vessel operate predominantly in the same area as the commercial fleet; consequently, survey of new areas was restricted. During this visit, 185 schools of tuna and associated species were sighted in 215 hours of searching, at an average of 0.86 schools per hour. This is slightly more than the average of 0.77 schools per hour for all of the countries visited by the Skipjack Programme. Fifty per cent of the schools chummed responded positively, which is slightly higher than the long-term average of 46.7 per cent. During this first visit, 9,425 skipjack and yellowfin tuna were tagged. Preliminary discussion of these and other results from the first cruise are given by Kearney (1978).

During the second visit, a major objective of the Programme was to evaluate tagging procedures by the implementation of a double tagging experiment. In order to maximise tag returns, and thereby facilitate the evaluation of tag slippage rates, most fishing was done in the same general area as the commercial fleet. Consequently, the value of this cruise, from a survey viewpoint, was also restricted. However, the comparisons of our fishing results during the second visit with those of the commercial fleet operating in the same area proved invaluable, particularly considering the large differences in the catch rates for both skipjack and baitfish between the Programme's vessel and the commercial fleet (see Section 6.1).

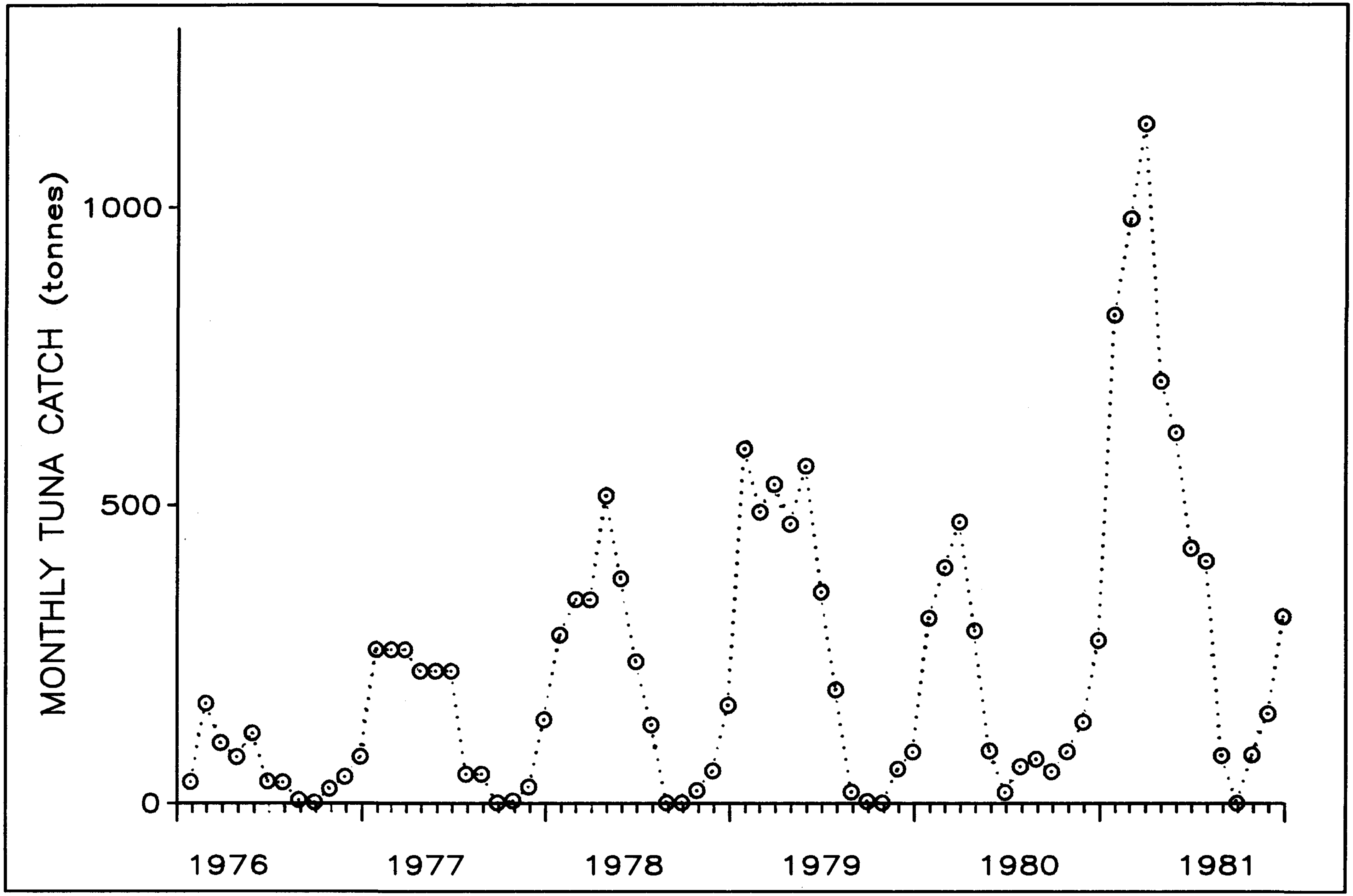
April 1980 was a poor month for the skipjack fishery in Fiji (Figure 2). Even so, 12,785 skipjack and other tunas were tagged and released during the second visit, all of them in April. Almost half of the fish released were double tagged. The crew of the Hatsutori Maru No.5 sighted 130 surface schools of tuna in 180 hours searching, at an average of 0.72 schools per hour. Fifty-five per cent of the schools chummed responded positively.

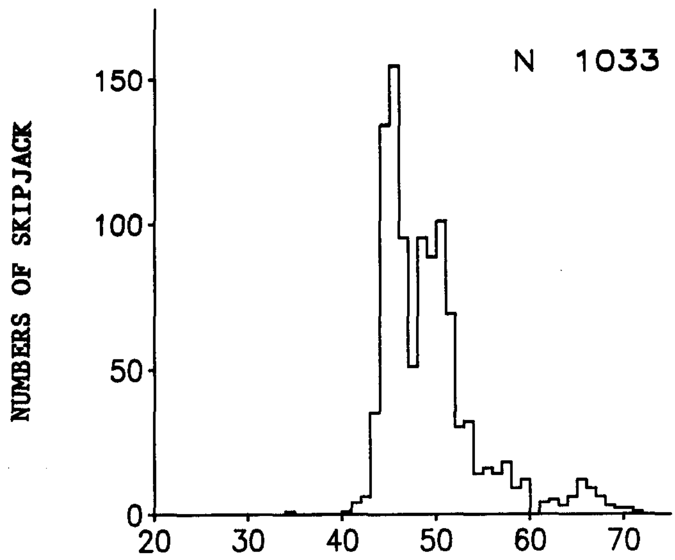
A feature of surface schools of skipjack during both surveys was the wide range of sizes of individuals within schools (Figures 3a and 3b). During the second survey, schools often comprised skipjack from 40-55 cm with no distinct size mode.

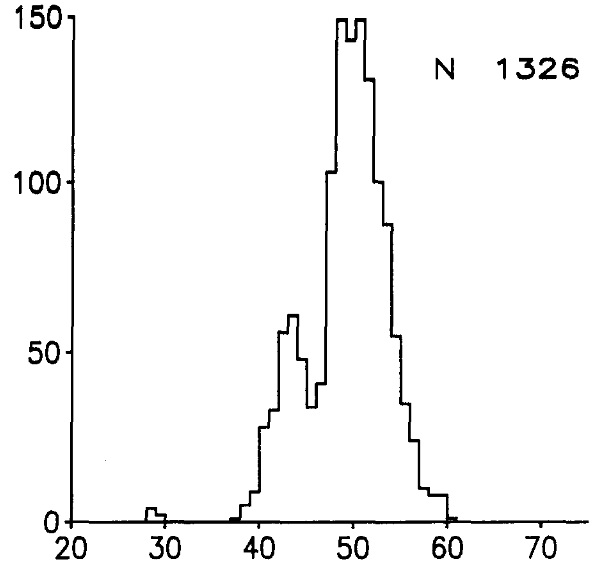
During both visits the large percentage of yellowfin tuna was noteworthy. In the first survey, 21 per cent of all schools fished contained some yellowfin, and during the second survey this figure increased to 39 per cent. Approximately 10 per cent of the fish tagged on both occasions were yellowfin.

During, and immediately following, the first visit in 1978, tag recoveries were promptly reported by most fishermen. Unfortunately, during the following fishing season (1978/79), the system for recovering tags from fish recaptured in Fiji lapsed temporarily. As a result, only 57 tags were returned from Fiji in 1979. Of these, 46 were returned by one person and were accompanied by inadequate recovery data. The data accompanying these 46 tags were such as to suggest that the pattern of recoveries reported for Fiji for 1979 should be regarded as questionable at best. Little weight has been placed on these data in subsequent analyses. Fortunately, by April 1980 the system for tag recoveries within Fiji had been completely overhauled and was again operating efficiently. Unfortunately, the problems with the tag recovery system in 1979 made it impossible to compare the tag recovery patterns from the two sets of releases. Skipjack migration, mortality and fishery interaction results presented therefore relate only to the relatively poor 1979/1980 season.

FIGURE 2. FLUCTUATIONS IN MONTHLY TUNA CATCHES BY THE FIJIAN POLE-AND-LINE FLEET, 1976-1981



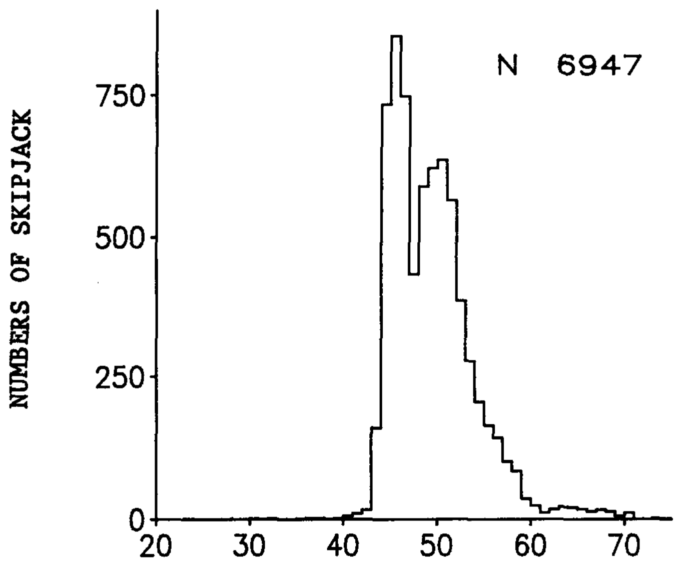


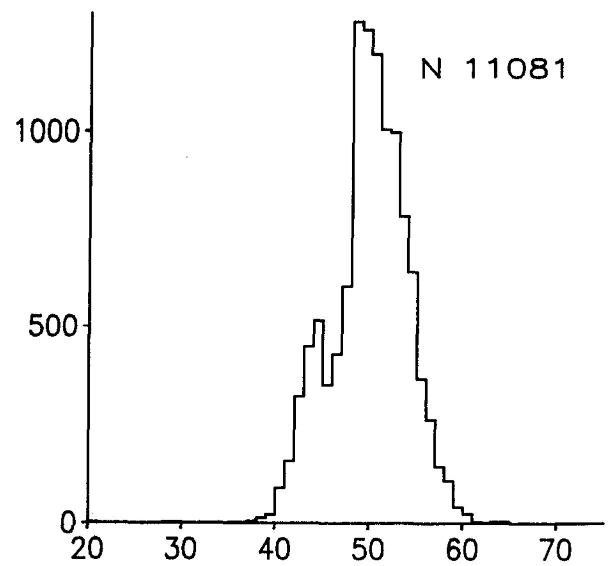


FORK LENGTH IN CENTIMETRES

FIGURE 3a. SIZE FREQUENCY DISTRIBUTION OF SKIPJACK SAMPLED FOR BIOLOGICAL INFORMATION DURING THE FIRST VISIT (JANUARY-APRIL 1978) TO FIJI

FIGURE 3b. SIZE FREQUENCY DISTRIBUTION OF SKIPJACK SAMPLED FOR BIOLOGICAL INFORMATION DURING THE SECOND VISIT (APRIL-MAY 1980) TO FIJI





FORK LENGTH IN CENTIMETRES

FIGURE 3c. SIZE FREQUENCY DISTRIBUTION OF SKIPJACK TAGGED DURING THE FIRST VISIT (JANUARY-APRIL 1978) TO FIJI

FIGURE 3d. SIZE FREQUENCY DISTRIBUTION OF SKIPJACK TAGGED DURING THE SECOND VISIT (APRIL-MAY 1980) TO FIJI

A total of 29 different baitfishing localities were surveyed during the two visits to Fiji. Seventy-two bait hauls were made for a total catch of 12,820 kg of bait to give an average of 178 kg per haul (Table 2). Much of this baitfishing was carried out in areas normally exploited by the commercial fleets and, while these results are of limited survey value, they enabled comparison of the performance of the chartered vessel with the commercial fleet as part of the overall assessment of the Fijian baitfish fishery (Ellway and Kearney, 1981). In addition, efforts by Skipjack Programme scientists helped overcome problems of identification of the baitfish species exploited by the commercial fleet.

6. RESULTS AND DISCUSSION

At the time of the first visit by the Programme to Fiji it was assumed that the results would be of only limited exploratory value in a country with an established pole-and-line fishery. The main value was anticipated to result from the improved assessment of baitfish and skipjack resources. Consequently, discussion in this report is concentrated on those aspects of the results which relate directly to assessment of the resources.

Of the Skipjack Programme work in Fiji, the only part that was primarily survey in nature was the visit to Rotuma, between 5 May and 9 May 1980. Unfortunately, bad weather restricted the value of this survey, as it was almost impossible to fish. Nonetheless, a few very large schools of skipjack and yellowfin tuna were observed, and scientists and crew on board the research vessel considered that, given good weather, substantial catches would have been made.

6.1 Skipjack Fishing

It was fortuitous that the visits to Fiji in 1978 and 1980 were carried out during a period of fluctuation in the Fiji skipjack pole-and-line fishery. This fishery had been expanding rapidly from 1976 to 1980, particularly during the 1979/80 season, but the poor 1980/81 season dampened the hopes, at least temporarily, for continued expansion. Results from one good (1977/78) and one bad (1979/80) season provide insight into the differences between the skipjack stocks in these two periods. In addition, the comparison of results from the chartered vessels with those of the commercial fleet operating in the same area proved invaluable; the results from the first year's (1978) work enabled calibration of the efficiency of the Programme's vessel, while those from the second year (1980) provided an independent assessment of the apparently poor 1979/80 season.

In 1978, the survey was divided into two parts which bracketed a period of commercial fishing by the Hatsutori Maru No.1. During this commercial activity the vessel and crew were approximately as efficient as the average vessel in the fleet, catches being slightly higher than the fleet average (Table 4).

A striking feature of the performance of the Hatsutori Maru No.5 during the 1980 visit was its outstanding catch rate when compared to the commercial fleet. From Table 4 it can be seen that, even under the survey and tagging conditions that prevailed throughout this visit, the Hatsutori Maru No.5 outfished all but one of the boats of the Fiji commercial fleet. When a conversion to commercial fishing is made, based on previous estimates of the relative fishing power of the Hatsutori Maru No.1, the Hatsutori Maru No.5 would have taken 139.5 tonnes. This is 71 per cent of the total taken by the commercial Fijian fleet of eight vessels, or more than three times as much as that taken by any one vessel during the same period. While it is possible that the exact conversion rate determined for the Hatsutori Maru No.1 may not be applicable to the No.5, there is no doubt that some considerable raising factor is necessary. The vessel's performance completely overshadowed those of the commercial fleet during this month. The relatively good catches by the Hatsutori Maru No.5 also suggest that skipjack and baitfish were not as scarce during this period as the low catches recorded by the commercial fleet would suggest (Ellway and Kearney 1981).

TABLE 4

COMPARISON OF BAITFISH AND SKIPJACK CATCHES OF THE SKIPJACK PROGRAMME CHARTERED VESSELS WITH SIMILAR VESSELS IN THE FIJIAN FLEET DURING EACH OF THE THREE SURVEY PERIODS

Note that catches by Programme vessels were accurately measured whereas those by the commercial fleet were estimated from declared catches in buckets and an average content per bucket of 1.8 kg of bait. (Data from Fisheries Division, Ministry of Agriculture and Fisheries, Fiji, and Skipjack Survey and Assessment Programme, South Pacific Commission.)

VESSEL		Average Bait Catch (kg) per Night Fished	Average Skipjack Catch (tonnes) per Day Fished
PERIOD: February 1 - 21,1978			
Hatsutori Maru No.2		152.5	3.65
Hatsutori Maru No.5		151.2	4.53
Hatsutori Maru No.6		154.4	4.66
Hatsutori Maru No.1	(SPC)	149.4	0.72* (2.72**)
PERIOD: March 28 - April 10,1978			
Hatsutori Maru No.2		129.3	5.23
Hatsutori Maru No.5		204.0	4.47
Hatsutori Maru No.6		135.9	5.48
Hatsutori Maru No.1	(SPC)	311.3	2.33* (8.10**)
PERIOD: April 9 - 27, 1980			
Hatsutori Maru No.2		58.7	2.21
Hatsutori Maru No.3		33.2	2.45
Hatsutori Maru No.7		51.5	1.69
Hatsutori Maru No.5	(SPC)	354.0	2.31* (8.02**)

* Survey catches including tagged fish.
** Raised estimate of commercial catch (survey catch x 3.47). (See Section 5.)

6.2 Evaluation of the Resource

Of a total of 140,443 skipjack tagged in the whole of the western and central Pacific, 20,094 were tagged and released in Fijian waters. The differences between size frequency distributions of fish tagged in Fiji (Figures 3c and 3d) and those taken in the commercial fishery (Anon undated, Fiji Ministry of Agriculture and Fisheries, unpublished data) were slight and it has been assumed that the fish tagged were representative of the exploited population.

TABLE 5
RELEASE AND RECAPTURE SUMMARY FOR ALL TAGGED SKIPJACK RELEASED IN FIJI AND RECOVERED INTERNATIONALLY

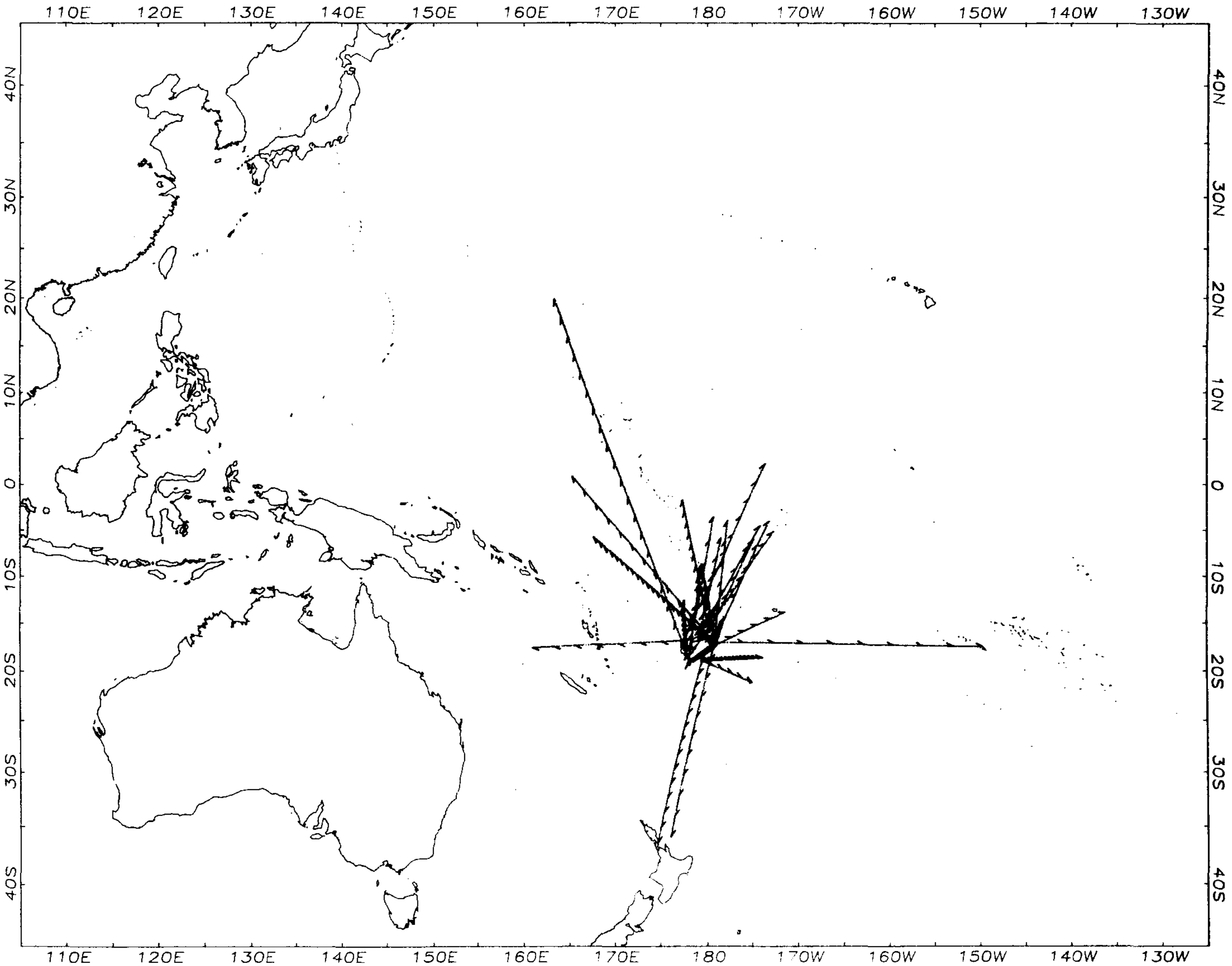
Releases are listed for each month in which skipjack were tagged. Recaptures are enumerated for each country in which they occurred and for each month in which they were taken. For explanation of country abbreviations see Appendix C.

Year and Month of Release	Number of Releases	Month of Recapture		Country of Recapture											
				CAL	GIL	INT	NAU	PHO	SOC	TON	TUV	WAK	WAL	WES	ZEA
7801	876														
		Unknown	7												
7802	3539	7807								1	1				
		7902									1				
		7903													1
		7905								1					
		7910										1			
		Unknown	22												
7803	2														
7804	4031	7808												1	
		7809				1		1							
		7811													1
		7901							1						1
		7902												1	
		7904					1								
		8002				1									
		8005											1		
		Unknown	31												
8004	11646	8007									1				
		8008									1				
		8009						2							
		8010				1					1				
		8011		1											
		8102				2		1							
		8104			1								1		
		8107									1				
		Unknown	23												
Country Recapture Totals				1	1	5	1	4	1	2	6	1	2	2	3

6.2.1 Skipjack migration

Fish tagged in Fiji were recovered internationally in French Polynesia, Kiribati, Nauru, New Caledonia, New Zealand, Tonga, Tuvalu, Wake Island, and Western Samoa (Table 5, Figure 4). These, together with the recovery in Fiji

FIGURE 4. STRAIGHT LINE REPRESENTATIONS OF THE MOVEMENTS OF SKIPJACK TAGGED IN FIJI AND RECOVERED IN OTHER COUNTRIES. Movements plotted have been selected to show no more than two examples between any pair of ten degree squares, one in each direction, and no more than one example of movement wholly within any ten degree square. Tick marks on the arrows represent 30-day periods between release and recapture.



of skipjack tagged in Australia, Norfolk Island, Solomon Islands, Tuvalu, Wallis and Futuna, and New Zealand, clearly show international exchange within the resources exploited in the Fijian fishery (Table 6, Figure 6). In addition, skipjack tagged in Fiji may well have gone to many countries without being recaptured, and, had skipjack been tagged in other seasons or years, recoveries may well have come from different areas. Furthermore, skipjack tagged in some countries and recovered in others may well have passed through Fijian waters without being recaptured. For example, skipjack tagged in south-eastern Australia and recovered in French Polynesia and fish from New Zealand recovered in Kiribati could well have passed through Fijian waters en route.

Recovery, in a large number of countries, of skipjack tagged in Fiji confirms that there is some interchange of common fish stocks over large areas of the central and western Pacific (Figure 4). At first glance, Figures B (inside back cover) and 4 imply that skipjack are extremely migratory, or at least transient. However, evaluation of the proportion of the total skipjack population that is migrating is required before the impact of these apparently numerous international migrations can be evaluated. Only 23 of the 20,094 skipjack tagged in Fiji were recovered in other countries, five more were recovered from international waters. Furthermore, this small number of recoveries was widely spread in both time and space and therefore provides little insight into the general direction of migration of skipjack leaving Fiji. It was, however, surprising, in view of the high level of fishing effort west of 160°E, that no fish tagged in Fiji were recaptured there (a single fish tagged in Western Samoa, east of Fiji, did travel westward of 160°E to Solomon Islands).

Plots of the number of tagged skipjack recaptured against time-at-liberty and distance travelled for all Skipjack Programme tag recoveries show that most skipjack are recaptured after a short time at liberty at a point relatively close to that of release (Figure 5). Fijian tag recoveries follow the same pattern (Table 7), but include an even higher percentage of short-term recoveries. These results suggest that the average skipjack within the size range tagged by the Skipjack Programme (Figures 3c and 3d) which was recaptured did not migrate a large distance. This can be partially explained by high natural mortality (later discussed), by the tendency of many skipjack to remain in the same area for extended periods, and by an exaggeration of the real situation due to the uneven distribution of fishing effort across the Pacific. This latter point is particularly noticeable in the Fijian situation where local fishing is concentrated in a relatively small area. Furthermore, there is no other sizeable skipjack fishery, and hence little likelihood of tag recoveries, within 1,000 miles of the Fijian fishing grounds. Less than 4.9 per cent of total Skipjack Programme tag recoveries were recorded from areas more than 1,000 miles from the point of release; from releases in Fiji, 0.5 per cent of those recovered exceeded the 1,000 mile mark.

The large distances between Fiji and the other Pacific skipjack fisheries and the small number of skipjack tagged in Fiji which were recovered in other countries suggested that few skipjack tagged in other countries would be recovered in Fiji. In fact, there were many such recoveries (51), dominated by 31 from releases in New Zealand to the south-southwest and 14 from Wallis and Futuna to the north northeast (Table 6 and Figure 6). There was, however, only a single recovery in Fiji of a tag

FIGURE 5. NUMBERS OF SKIPJACK TAG RECOVERIES BY DISTANCE TRAVELLED AND TIME-AT-LARGE FOR THE TOTAL SKIPJACK PROGRAMME DATA SET. Data are for tag returns received by November 4, 1981. Recaptures for 96 fish which travelled more than 1,500 nautical miles are included in the sample sizes but not shown in the figure.

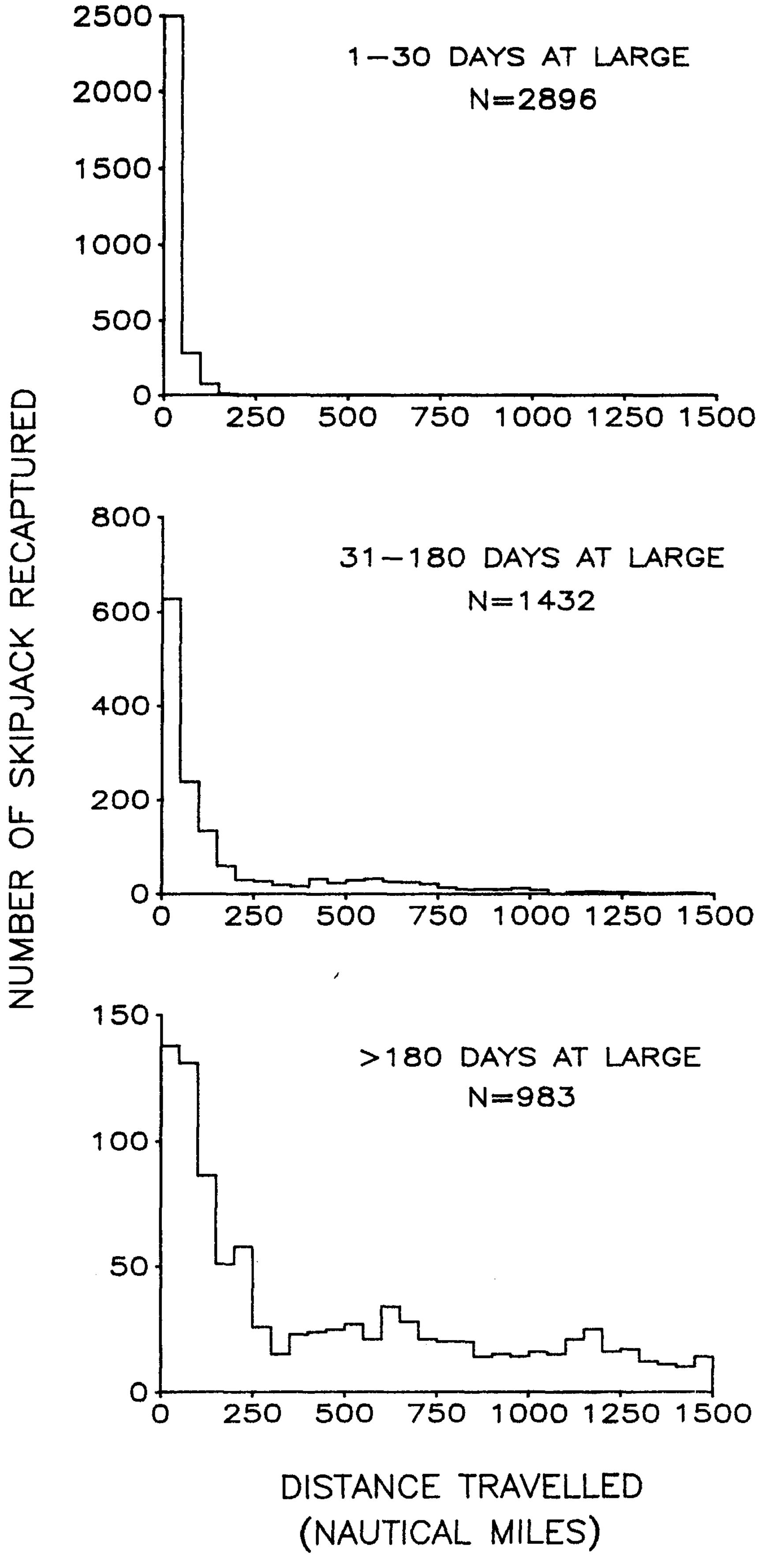


TABLE 6

RELEASE AND RECAPTURE SUMMARY FOR ALL TAGGED SKIPJACK RELEASED BY THE SKIPJACK PROGRAMME

Data for returns up to May 27, 1982. For explanation of country abbreviations see Appendix C.

COUNTRY OF RECAPTURE

NUMBER OF RELEASES BY COUNTRY

		AMS	CAL	FIJ	GIL	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	TOTAL
775	AMS	3																																				1			4
10219	CAL		18		1				2					1											2	2			10			1									37
20094	FIJ		1	1946	1				5								1							4				1			2			6		1	2	2		3	1975
174	GAM																																								
4569	GIL	1			385		24		31		1	1			15		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		1	1																									1												3
4322	NSW	1	6	2					1											2								1	8									1		9	31
7233	PAL				3			29	63		5			1	4						104		5		76	7			2			21							30		350
367	PHO				1																																				1
59	PIT																																								
8550	PNG				1		5	7	18		1				8						2	2			958	3	1		26			12							4		1048
5518	PON				1		2		16	2	23			1	26								1		1	58			1			13							10		155
2651	QLD		3																						1		2		24			1			2						33
48	SCK																																								
1725	SOC																											36													36
6221	SOL			1	1			1																	20				518												541
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		4		11						4									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	35	1997	405	1	37	42	182	11	36	1	42	9	70	1	4	1	1	4	107	5	6	32	1062	92	3	54	597	2	13	70	25	10	5	1	68	41	52	1022	6152

FIGURE 6. STRAIGHT LINE REPRESENTATIONS OF MOVEMENTS BY SKIPJACK TAGGED IN OTHER COUNTRIES AND RECOVERED IN FIJI. Tick marks on the arrows represent 30-day periods between release and recapture.

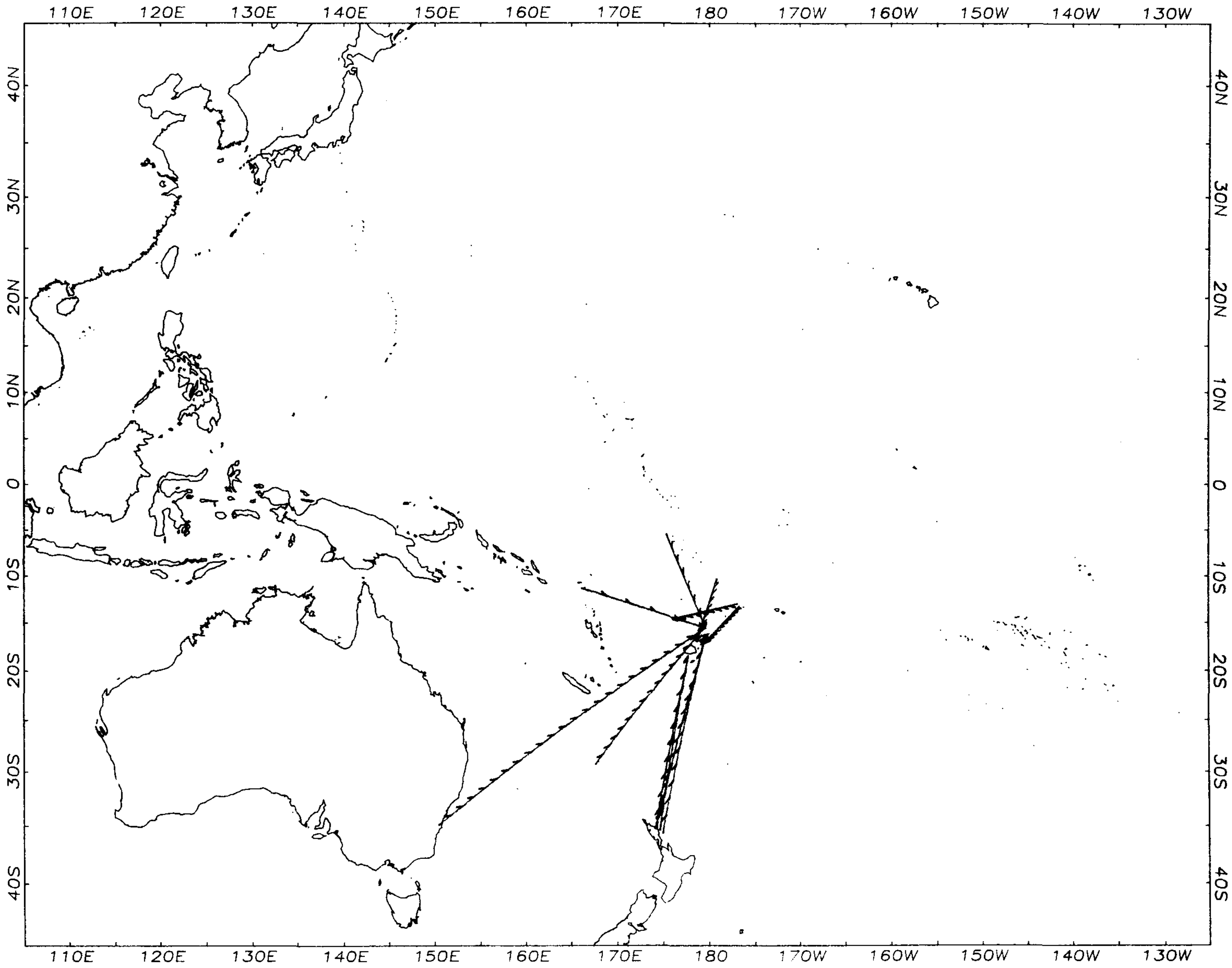


TABLE 7
NUMBERS OF SKIPJACK TAG RECOVERIES BY DISTANCE TRAVELLED FOR ALL SKIPJACK RELEASED AND FOR SKIPJACK RELEASED IN FIJI IN APRIL-MAY 1980

Miles Travelled	Number of Skipjack Recaptured from All Countries	Number of Skipjack Recaptured from Fiji
0	4234	1712
100	420	109
200	143	41
300	75	3
400	103	2
500	110	2
600	113	4
700	73	2
800	55	2
900	47	3
1000	36	2
1100	53	2
1200	38	2
1300	24	0
1400	25	1
1500	13	0
1600	14	1
1700	14	0
1800	8	0
1900	10	0
2000	5	0
2100	13	0
2200	4	0
2300	4	0
2400	4	1
2500	2	0
2600	2	0
2700	2	0
2800	2	0
2900	0	0
3000	0	0
3100	1	0
3200	1	0
3300	0	0
3400	1	0

released west of 160°E. Considering the large number of releases in western areas this was most surprising, but was consistent with the lack of recovery of Fiji releases in the west of the study region. The apparent low level of migration of tagged fish between Fiji and Solomon Islands and Papua New Guinea was a notable feature of the movement patterns established from tag recoveries, but no explanation for the anomaly was obvious.

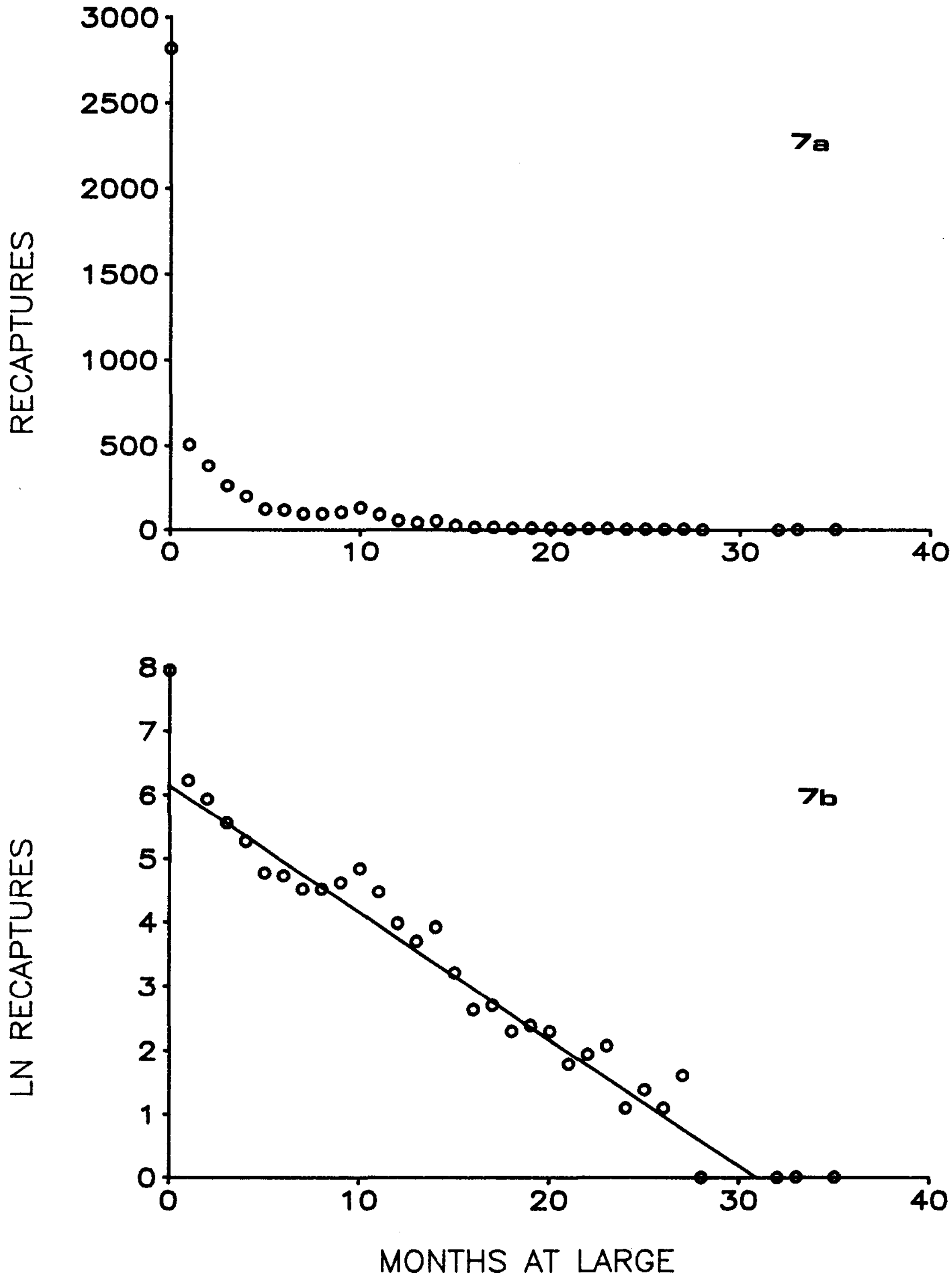
6.2.2 Skipjack mortality

Some analyses of skipjack mortalities based on the whole of the Programme's data set have been completed (Skipjack Programme 1981b and Kleiber MS). In order to estimate the average attrition rate (total mortality plus emigration to areas beyond all existing fishing grounds) for the whole region, skipjack returns were examined in aggregate. Figure 7 shows the natural log of the returns received per monthly period at liberty plotted against time at large, exclusive of returns with imprecise date of recapture and recaptures by the Programme's tagging vessel. The values represent the returns per month which would have resulted had all the tags been released on the same day. As expected, the return rate declines with time and follows a relatively straight line on the logarithmic plot. It has been proposed that the initial high value on the left of Figure 7 occurs because of insufficient time during the first month for the tagged fish to become mixed with the total population. If this first point is ignored then the best fitting slope of this line (attrition coefficient) is 0.19 month^{-1}. To the extent that tagged fish behave like untagged ones, and to the extent that the post-recruit population is at a steady state, this attrition rate would also be the turnover rate of the population. The extrapolated intercept of 6.14 is equivalent to the return of 466 returns per month, which out of a tagged population of 140,443 skipjack, implies a harvest rate for the region as a whole of 0.003/p per month where p corrects for initial mortality due to tagging and non-reporting of recaptured tags. The harvest rate for the fished areas, based on an estimated 2,820 tag recoveries in the first month, was estimated at 0.02/p per month. The difference between the observed (2,820) and extrapolated (466) total number of recoveries in the first month was attributed to the difference between exploitation rates in the heavily fished and unfished areas. This in turn suggested that only 17 per cent (466/2820) of the total area of the stocks was at the time being exploited. This estimate of the fraction of the total stocks which is being exploited was not proposed as an inflexible, tightly defined measurement. It was derived from average tag recovery rates over the whole of the SPC region. Variability across the region, and within individual countries, is such that a regional average such as this must be regarded as an approximation with wide confidence limits. It may not be particularly applicable to individual countries.

Variability in tag recovery patterns within and amongst countries also detracts from the value of a tag recovery pattern derived from releases during only one or two brief visits to a country. On the other hand, an underlying component of tag recovery patterns resulting from all batches of releases by the Skipjack Programme is an exponential decrease with time in the number of recoveries. This pattern is, as expected, most uniformly represented in the overall data set (Figure 7) and discussion of patterns within individual countries is facilitated by comparison with the total data base.

Two separate data sets were available for Fiji, one from each visit. Unfortunately, the lapse in effort for recovering tags in Fiji in 1979 (see Section 5) meant that data from the 1978 releases were of little value for estimating attrition from tag recaptures. These data have been listed in Tables 5 and 6, but have not been included in the following analyses. Reliable recovery data is therefore restricted to that generated from the second visit. The number of recoveries per tonne of skipjack landed for each

FIGURE 7. PLOTS OF SKIPJACK RETURNS BY MONTHLY TIME-AT-LARGE CATEGORIES FOR THE WHOLE OF THE SKIPJACK PROGRAMME DATA SET



month since the month of release is given in Table 8, and a plot of these averages against time-at-large is given in Figure 8. This figure is the basis for one evaluation of the dynamics of the Fijian skipjack resource.

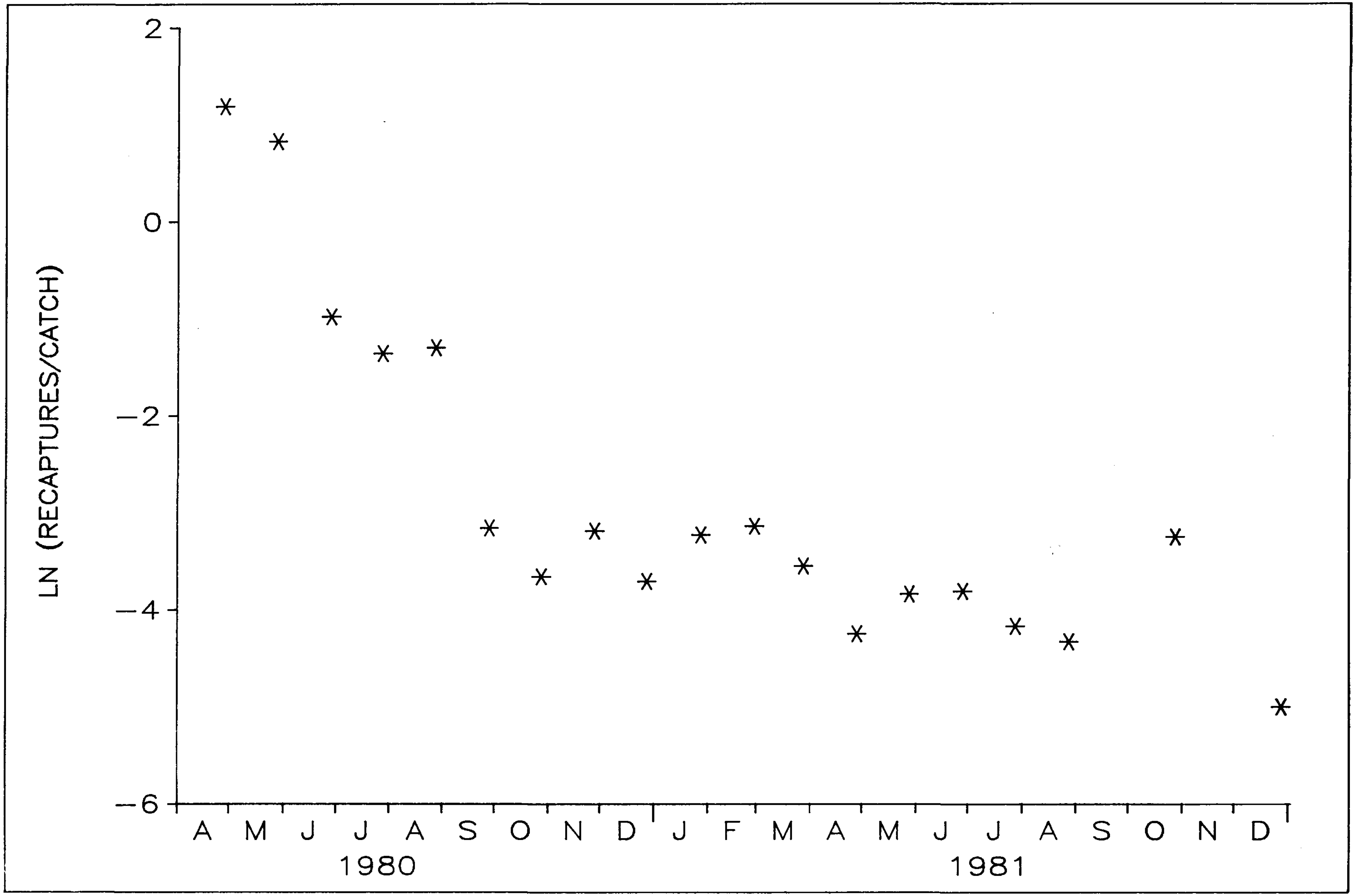
A linear regression taking account of all points in Figure 8 has an intercept of -0.40, equivalent to 0.67 tags per tonne of population, or a total population size of 17,374 tonnes at the time of release of the 11,646 tags ($11646/e^{-0.40}$). The turnover rate of this population (slope of the line) was 0.24 per month. The harvest rate (fraction of the population being taken per month by the fishery) was represented by the catch in the part of the month in which releases were made (187 tonnes) over the population size (17,374), or 1.1 per cent per month. This, then, means that even though the resource available to the fishery over this period was not particularly large (approx. 17,000 tonnes), it was turning over at a rapid rate (approx. 24 per cent per month), and the existing fishery was responsible for only about four per cent of this turnover. The resource would therefore be adequate to sustain substantially increased catches.

TABLE 8
NUMBER OF TAG RECOVERIES AND FIJIAN POLE-AND-LINE SKIPJACK CATCH SINCE TAGGING IN APRIL 1980

Date Year/Month	Number of Tag Recoveries	Skipjack Catch (tonnes)
80/04	596	187+
80/05	181	78.8
80/06	6	16.0
80/07	14	54.8
80/08	18	66.2
80/09	2	47.2
80/10	2	77.4
80/11	5	122
80/12	6	246
81/01	31	780
81/02	40	922
81/03	31	1082
81/04	9	628
81/05	12	556
81/06	9	407
81/07	6	387
81/08	1	76.1
81/09	0	0
81/10	3	77.0
81/11	0	143
81/12	2	298

+ Indicates only part of total monthly catch taken after tagging commenced.

FIGURE 8. PLOT OF LOG OF NUMBER OF SKIPJACK RETURNS WEIGHTED-FOR-CATCH BY MONTHLY TIME-AT-LARGE CATEGORIES FOR TAG RELEASES IN FIJI IN APRIL-MAY 1980



It is of course possible that the regression referred to above is not the best representation of the relationship between the points in Figure 8. Kleiber (MS) argues that at least one month is required for tagged fish to mix to the point where they approximately represent the population. He suggests the exclusion of at least the first, and in extreme cases the first two, month's results when estimating population size and turnover rates for some individual countries. If the first two points in Figure 8 are omitted, the estimate of the population by linear regression is increased three times to 49,154 tonnes, while the turnover rate is reduced to 17 per cent per month and the harvest rate to 0.4 per cent per month (or 2.3 per cent of the total turnover).

Other extreme cases can also be considered. It could be argued that the relationship depicted in Figure 8 is markedly curvi-linear or even biphasic, with a rapid decline in the first six months, levelling out from about September 1980. It is certainly different from that observed in the results from other countries in which the Skipjack Programme worked (Kleiber MS), but it does show some similarity to the first 12 months of the overall data set (Figure 7). Arguments such as variability in natural mortality with age, or differential emigration by parts of the population, could be used to support acceptance of the biphasic relationship in Figure 8. However, such marked bimodality is not found in the overall data set and is not a consistent characteristic of other individual country results. It is possible that it is a chance characteristic of this particular small data set or, more likely, a chance exaggeration of the curvi-linear relationship between tag recovery rate and time anticipated for this type of experiment and as demonstrated in Figure 7. However, it is worth noting the extreme population estimates which result from considering Figure 8 as representing two linear relationships, one incorporating the first nine points (April to December 1980), overlapping with the second from September 1980 onwards. In the first of these cases, the population estimate would be a low 2,522 tonnes, but the turnover rate would be a prodigious 65 per cent per month or approximately nine times the harvest rate of 7.4 per cent per month. In the second case, the population estimate increases to 178,566 tonnes, while the turnover rate falls to eight per cent and the harvest rate to 0.1 per cent (or 1.3 per cent of the turnover). Both of these extreme cases require the elimination of at least 9 of the 19 data points in Figure 8 and are therefore not considered a good representation of the overall situation. However, regardless of which interpretation is used, the overall result lies between a very large population (>100,000 tonnes), turning over at about 10 per cent per month, or a relatively small one (<5,000 tonnes) turning over at an extremely high rate (>50 per cent per month). In both extremes the available resource is large compared to the present level of exploitation.

The inverse relationship which exists between estimated population size and turnover is such that the population's ability to provide exploitable resource is perhaps best expressed in terms of throughput of biomass of skipjack through the fishery. This can be defined as the product of the population size and turnover rate. For all points shown in Figure 8, it is 4,172 tonnes per month (17,382x0.24). When the first two points are excluded, it is 8,356 tonnes per month (49,154x0.17). Even the lower estimate of throughput is 14 times the average monthly Fijian catch (297 tonnes) during the period of this study (April 1980-December 1981). Refinements to the analyses which estimate the population parameters in each country and for the overall data set are continuing, and an alternative regression technique, based on the least squares regression method, has been developed by Kleiber (MS) and applied to the Fiji data. Kleiber's results are summarised in Table 9 in which the similarity with the linear regression estimates is apparent for all but the total data set.

TABLE 9

ESTIMATES AND 95 PER CENT CONFIDENCE LIMITS OF ATTRITION RATE (OR TURNOVER), THROUGHPUT, AND STANDING STOCK OBTAINED BY FITTING A TAG RECOVERY AND DECAY EQUATION TO VARIOUS SUBSETS OF THE TAG RECOVERY DATA IN FIGURE 9

Details of the fitting procedure are given by Kleiber (MS). Note that the throughput, which is a better indicator of the resource than is the standing stock, is also more robust, i.e. its value varies by a factor of 8 for the different data subsets while the standing stock estimate varies by a factor of 30. Also, the confidence intervals are proportionally smaller for throughput than for standing stock.

Subset	Attrition Rate (Mo^{-1})	Throughput (tonnes/Mo)	Standing Stock (tonnes)
All points	.474 [.39-.58]	1480 [1150-1950]	3130 [2300-4400]
Excluding 1 and 2	.222 [.12-.33]	7260 [4000-13000]	32700 [10000-100000]
Only points 1 to 9	.682 [.52-.95]	1730 [1400-2300]	2540 [1800-3500]
Excluding 1 to 5	.134 [.05-.23]	12300 [7000-17000]	92300 [30000-250000]

6.2.3 Fishery interactions

Estimates of the degree of migration between fisheries based on estimates of the dilution of tags in the population into which they were released and tag recovery rates in the destination country, have previously been presented (Skipjack Programme 1981b). These results suggest that the tonnages of skipjack migrating between certain widely separated fisheries represent, on average, a small fraction (less than one per cent) of the population in the destination country. Figures for New Zealand to Fiji were higher, but less precise, than average and approximately 400 tonnes per month may have been migrating (Skipjack Programme 1981b), contributing about ten per cent to the estimated throughput of 4,172 tonnes through the exploited population in Fiji estimated at about 17,000 tonnes (Section 6.2.2). This estimated contribution by fish from New Zealand is increased to approximately 25 per cent when the lower estimate of throughput of 1,640 tonnes per month (derived from the first nine points in Figure 8) is considered. It is even slightly higher when the throughput estimate of 1,480 from Table 9 is used. Catch data from Wallis and Futuna were inadequate to enable estimation of population size. It was therefore impossible to evaluate throughput to Fiji from this area.

The recapture of tagged fish in Fiji more than a season after release (Table 6) suggests that some fish either remained in the area for long periods or returned to the area after leaving it; there is no evidence for preference for either alternative. There is, however, no need to differentiate between the two alternatives when estimating from tag recoveries the proportion that the population from one year contributes to the following year's fishery. Analyses similar to those for assessing the significance of the 31 recoveries from New Zealand (i.e. based on estimation of tonnes per tag in the donor population), suggest that the 154 tagged fish released in Fiji in April/May 1980 and recovered in Fiji in the following season (September 1980-August 1981) represented a contribution of approximately half of one per cent (230 tonnes) of April/May 1980 fish to the population passing through the Fijian fishery at a rate of more than 4,000 tonnes per month in the 1980/81 season (see Section 6.2.2). If the five-week period during which the 1980 tagging took place is considered average for the year, then fish which were present in Fiji in 1979/80 contributed approximately five per cent to 1980/81 catches. In this case, 154 tags represented a smaller quantity of skipjack than the 31 from New Zealand (465 tonnes) because the size of the exploited population in Fiji in 1979/80, and hence the tonnes per tagged fish, was lower than in the New Zealand case.

6.2.4 Skipjack population biology

In conjunction with evaluation of skipjack migrations, as evidenced by tag release and recovery data, skipjack population structuring and biology were investigated by analyses of blood genetics data, gonad maturities, stomach contents, including occurrence of juveniles, and growth.

Blood samples were collected from individual skipjack schools from throughout the study area and analysed to estimate the gene frequency of several enzymes assumed to be genetic population markers (Anon 1981). In Figure 9 the gene frequency of the most important of these markers, serum esterase, is plotted against the longitude of the location from which the samples were taken. Average gene frequency is observed to decline from west to east, with high variation in gene frequencies at any particular location. There were only three samples from Fiji (denoted by open circles in Figure 9). Gene frequencies for all three samples were close to the average values of the regression of gene frequency against longitude.

Several hypotheses on population structure that are consistent with the trend and variability exhibited by the overall data set have been proposed (Anon 1981); all include an isolation-by-distance component. The premises underlying the isolation-by-distance concept are that the probability of two fish mating is a decreasing function of the distance between them, and that there are no severe restrictions to gene flow at any point across the range. Thus the genetic data provide no evidence of barriers that restrict the movement of adult skipjack in the study area.

Gills and viscera from 100 skipjack from Fijian waters were collected by the Skipjack Programme and examined by scientists at the University of Queensland for the presence of parasites which could possibly be used as population markers. Results were compared with those from other countries in the study area (Table 10). Analyses of these results and those collected from other areas are continuing; therefore, only preliminary results are available. These have been summarised and discussed by Lester (1981). Lester concluded that "within the limits of our small number of samples, there is no parasitological evidence for more than one stock of skipjack in the SPC area."

FIGURE 9. SKIPJACK SCHOOL SERUM ESTERASE GENE FREQUENCY BY LONGITUDE OF THE SAMPLE LOCATION. Gene frequencies for a total of 163 samples from numerous sources are plotted, with the samples from Fiji given as open circles. The regression line was fitted to data for 145 samples west of 120°W (dotted line); the correlation coefficient was -0.81.

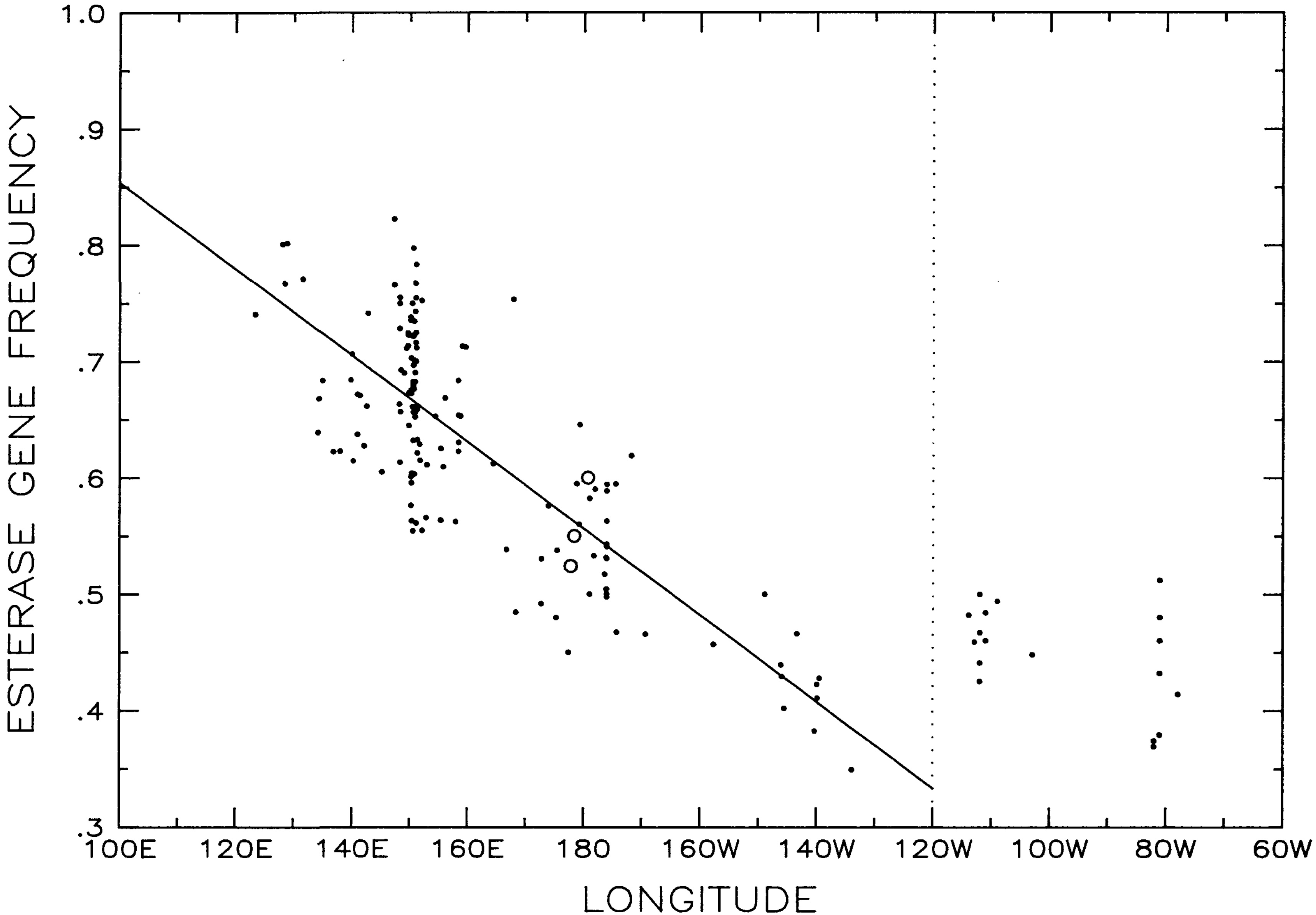


TABLE 10. AVERAGE NUMBER OF PARASITES PER SKIPJACK SAMPLED IN SEVEN AREAS OF THE PACIFIC. From Lester (1981)

	Marquesas	Fiji, Futuna	New Zealand	Norfolk Island	Solomon Islands	Ponape	Palau	Schooling factor Marquesas	Schooling factor New Zealand
No. of fish examined	150	100	150	20	30	45	35		
Anisakis sp. I	0.6	0.2	1.8	0.5	0.7	0.1	1.0	-0.03	-0.01
Raorhynchus terebra	12	25	2	66	15	16	22	0.04	0.16
stomach didymozoid	44	54	10	18	49	27	30	0.05	0.05
Tentacularia coryphaenae	9	8	6	7	4	23	2	0.08	0.03
sessile oesophageal didymozoid	6	6	5	7	9	4	13	0.10	0.07
Coeliodidymocystis sp.	0.8	1.2	1.3	0.5	0.9	0.8	1.3	0.11	0.13
Philometra sp.	5.3	1.8	0.8	0.8	4.6	2.6	0.6	0.12	-
Didymocylindrus filiformis	2.2	3.6	4.9	1.3	2.0	2.4	8.1	0.13	0.10
Pedunculate lower int. didymozoid	61	43	15	17	22	40	76	0.13	0.04
Pedunculate oesophageal didymozoid	8	9	7	3	8	6	12	0.14	0.15
Hirudinella marina	0.4	0.3	0.01	0.3	0.2	0.3	0.1	0.15	-
Didymocylindrus simplex	7	7	10	6	6	4	8	0.17	0.26
Didymoproblema fusiforme	1.4	2.0	1.3	0.6	0.9	0.8	1.8	0.18	0.13
Caligus sp.	3	2	1	1	5	9	3	0.21	0.16
Symcoelium filiferum	0	0	4.85	0.05	0	0	0	-	0.27
Dinurus euthynni	15	2	0.02	3	66	9	56	0.29	-
Anisakis sp. II	0.02	0.01	0.17	0.40	0	0.02	.10		
Terranova sp.	0.16	0.06	0.01	0	0	0.07	.03		
Lobatozoum multisacculatum	0.07	0.06	0.13	0.23	0	0.07	.10		
Ctenascarophis sp.	33	38	20	49	15	4	30		
Spinitectus sp.	13	9	13	10	12	4	6		
Digenean II	0.4	0.1	0.01	0	0.8	0.3	0.3		
Tergestia sp.	0.1	0.1	0	1.0	0	0	0		
Bucephalid	0.1	2.4	0	0	0.2	0.3	0.03		
Sessile upper int. didymozoid	8	5	5	8	3	3	14		
Sessile lower int. didymozoid	1.9	1.1	1.3	2.5	1.0	2.2	3.1		
Scolex pleuronectis, large	10	33	28	+	7	0.4	4		
S. pleuronectis, small	206	463	18	140	8854	124	200		

Data on gonad maturity for all female skipjack sampled in Fiji are summarised in Figure 10. Most female skipjack gonads, both in Fiji and in the region as a whole (Figure 11), were stages 2 and 3. Approximately 55 per cent were stages 3 to 7, and therefore showed strong evidence of sexual development and/or of recent spawning activity. Post-spawning gonads (stages 6-7) were uncommon as were well-developed gonads (stage 4). Running-ripe gonads (stage 5) were extremely rare.

The low occurrence of mature or recently spent gonads does not imply that skipjack seldom spawn in Fijian waters. In fact, it is strongly suspected that spawning does occur in this area and that ripe females are under-represented in the sampled population, probably because spawning is concentrated in the middle summer months (December to February) at these latitudes and was virtually completed by the time of the Programme's visits to Fiji, or because spawning fish seldom respond to chum, are not common at the surface, or because the last hours of development and spawning occur at night.

FIGURE 10. DISTRIBUTION OF FEMALE SKIPJACK BY MATURITY STAGE FOR SKIPJACK SAMPLED IN FIJI (BOTH VISITS COMBINED)

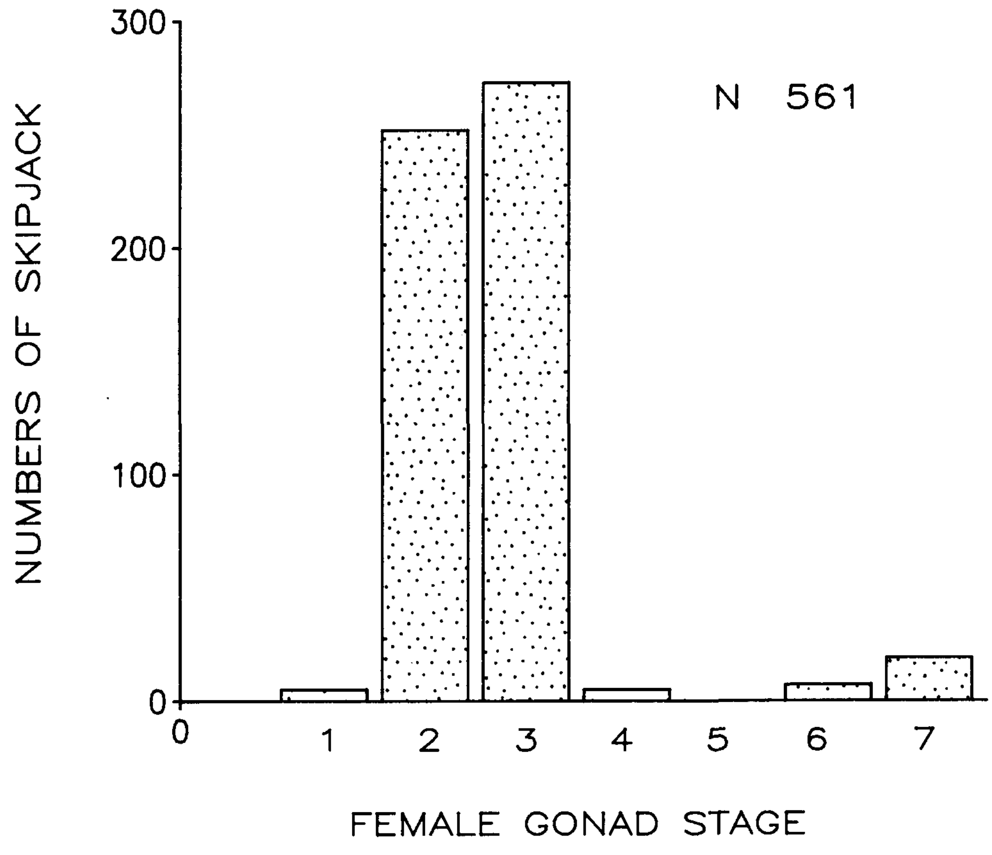
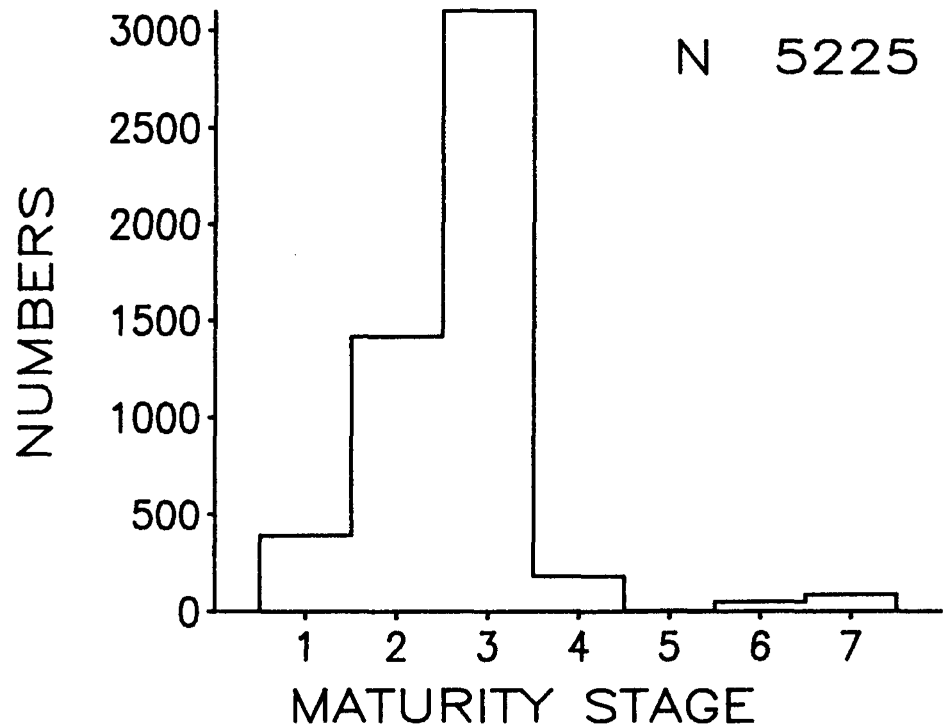


FIGURE 11. DISTRIBUTION OF FEMALE SKIPJACK BY MATURITY STAGE FOR ALL SKIPJACK SAMPLED BY THE SKIPJACK PROGRAMME



The occurrence of juvenile skipjack in Fijian waters endorses the contention that skipjack spawn here or at least nearby. Table 11 summarises data on the occurrence of tuna juveniles in the stomachs of numerous predators. An average of 4.4 skipjack were found in every 100 predator stomachs examined, with adult skipjack being the dominant predator. This occurrence of juveniles is much less than the 25-50 juveniles per 100 stomachs found in Vanuatu, Wallis and Futuna and the Marquesas Islands, but much higher than the absence, or almost so, of juveniles in higher latitudes of the study area (Argue, Conand and Whyman, MS). It is probable that Fiji lies towards the southern extreme of the area of maximum skipjack spawning activity; thus juvenile abundance could be expected to show considerable seasonal variability, being higher in the southern summer. Unfortunately sampling in Fiji by the Skipjack Programme was inadequate to enable investigation of these hypotheses.

Further general analyses of the contents of the 426 skipjack stomachs examined in Fijian waters (Table 3) confirmed that skipjack are opportunistic feeders with approximately 50 families of fish and invertebrates being represented. Community groupings of skipjack prey species are thought to vary across the Commission region, and this is the subject of continuing analyses.

TABLE 11
INCIDENCE OF TUNA JUVENILES IN STOMACHS OF SKIPJACK AND YELLOWFIN TUNA SAMPLED IN FIJI

Predator	Predators Examined	Prey Species	No. of Prey	Predators with Prey	Prey per 100 Predators	Percentage of Predators with Prey
Skipjack	928	Skipjack	43	21	4.68	2.26
		Yellowfin	1	1	.11	.11
		Unidentified Tuna Juvenile	1	1	.11	.11
Yellowfin	267	Skipjack	6	3	2.25	1.12
		Yellowfin	2	1	.75	.37
Frigate Tuna	7					
Dolphin Fish	2					
Double-Lined Mackerel	2					
Total	1206		53			

For 89 of the skipjack tag recoveries reported from Fiji, the time-at-large was great enough and release and recovery information sufficiently accurate, for the information to be used in skipjack growth estimates. Estimates of rates of growth on an annual basis for skipjack in 40-49 and 50-59 cm size groups are shown in Table 12. Results are presented for fish from each country for which adequate data were available. Significant differences exist amongst the growth rates from the different areas (Lawson and Kearney MS). These differences are thought to reflect environmental variability, but, as yet, neither the degree of environmental heterogeneity nor the precise effects of the environment on skipjack growth are well understood.

TABLE 12
ESTIMATES OF SKIPJACK GROWTH RATES FOR SEVERAL AREAS OF THE SPC REGION, BY SIZE AT RELEASE AND TIME-AT-LARGE

Average growth rates with standard errors greater than 3 cm or for samples of less than six skipjack are considered unreliable, and are given in brackets.

Size At Release (cm)	Days At Large	Area of Release	Sample Size	Growth Rate (cm/yr)	Standard Deviation (cm)
40-49	31-180	Papua New Guinea	16	(20.85)	14.47
		Solomon Islands	87	12.72	11.23
		Fiji	38	17.23	14.89
		Kiribati	180	9.46	9.96
	181-450	Papua New Guinea	3	(19.38)	7.70
		Solomon Islands	77	11.37	7.90
		Fiji	20	16.60	3.91
		Kiribati	1	(5.43)	-
50-59	31-180	Papua New Guinea	292	5.40	11.75
		Solomon Islands	42	5.75	18.43
		Fiji	12	(11.95)	20.79
		Kiribati	39	1.42	12.78
	181-450	Papua New Guinea	15	8.23	2.45
		Solomon Islands	50	4.08	6.35
		Fiji	10	7.01	6.10
		Kiribati	0	-	-

6.2.5 Evaluation of double tagging

During the double tagging experiment conducted in Fiji in 1980, 5,399 skipjack were double tagged while 5,625 were released with a single tag. To the end of March 1982, 492 (9.1 per cent) double tagged and 529 (9.4 per cent) single tagged fish had been reported as recaptured. As a few recoveries are still being reported, the experiment has not been concluded. However, preliminary conclusions from the analyses of the results to August 1981, which have already been presented by the Skipjack Programme (Skipjack Programme 1981a), remain unchanged. These are summarised as follows:

- The estimated rate of tag shedding was 7.6 per cent per annum which was lower than that previously reported by other research organisations for similar tagging experiments.

- Reported recapture rates for single and double tagged skipjack were not significantly different.

- There were no significant differences in growth rates or migration distances between the single and double tagged fish.

These conclusions, in combination with the evaluation of tagging techniques carried out on the total (all countries) data set, suggest that tagging, as carried out by the Skipjack Programme, had minimal effect on skipjack. However, it was not possible to quantify such effects accurately.

6.3 Baitfish Resources

A previous Skipjack Programme report (Ellway and Kearney 1981) evaluated the Fijian baitfish fishery to the end of 1980. Results from the two visits by the Skipjack Programme vessels and those from the commercial fleets were combined to provide an overall assessment of the changes in the Fijian baitfish fishery, and, in particular, to evaluate the poor 1979/1980 baitfishing season. Little new data has become available since this earlier work and the following discussion is taken largely from Ellway and Kearney (1981).

Six factors were evaluated as possible explanations of the poor 1979/80 season: depletion of the resource as a result of fishing pressure, changed behaviour of the baitfish species, environmental phenomena (temperature and rainfall), natural variability in the abundance of the major species, mis-reporting of baitfish catches by the fleet, and a drop in incentive, and hence efficiency, within the fleet. Two - depletion of the total resource as a result of fishing pressure and changes in the behaviour of the bait species - were judged as unlikely causes. Furthermore, no correlation could be found between the environmental phenomena of temperature and rainfall and the poor season; that is, there were no apparent temperature or rainfall differences between good and bad baitfishing years. However, undetected abnormalities in temperature or rainfall could not be ruled out as a possible cause of "natural" fluctuations in abundance, particularly as there is seasonal variability in both which parallels seasonal fluctuations in baitfish abundance.

It was concluded that the reported poor 1979/1980 season was due in part to a late 1979 spawning season for *Sardinella sirm* and *Spratelloides delicatulus*, which are the dominant species in the Fijian baitfish fishery. Quite possibly, the season for both these species was poor as well as late and this kept abundance below normal well into 1980. Furthermore, as *Sardinella sirm* and *Spratelloides delicatulus* are both excellent skipjack bait, a decrease in their contribution to the catch would also almost certainly lower the effectiveness of the average unit of bait that was available. The abnormally high proportion of *Stolephorus indicus*, almost worthless as live bait, in the 1979/1980 catches, compounded this problem.

The initial impact of the poor baitfish season was to delay commencement of the skipjack fishery, which established uncertainties amongst the fishermen. It is probable that the skipjack abundance in this season was also below average, and, even when baitfish catches did begin to improve in January 1980, skipjack catches were still only marginally economical. Certainly, it was difficult for most vessels to achieve skipjack catch rates which resulted in a substantial bonus to fishermen. Incentive for extra effort was therefore minimal with the result that effective effort per vessel was less than in previous years. When fishermen were able to take good bait catches they were probably reluctant to declare them because of fear of competition at that particular baiting site. This, then, led to exaggeration of the magnitude of the reduction in total baitfish abundance and overemphasised the poor, or perhaps only late, baitfish season. The lack of bait was then given most of the blame for a generally bad year in the Fijian fishery.

Baitfish catches in the 1980/1981 season in Fiji were as good as those reported in previous years, thereby confirming that the poor 1979/1980 season was not a result of long-term drop in abundance.

The lack of suitable baitfish habitat around Rotuma Island indicates that there is little likelihood of making good baiting catches in this area. This was confirmed by the brief visit to this area in May 1980.

7. CONCLUSIONS

7.1 Skipjack Resources

It is appreciated that there are limitations to resource assessments which are based largely on data from two short visits to a country. However, the data generated by the Skipjack Programme throughout the central and western Pacific are relevant to the overall evaluation of the Fijian resources. Furthermore, data from six years of the Fijian commercial skipjack and live bait fisheries are now available. Therefore, these data, in combination with other documents referenced, provide assessments which were not previously possible and which are submitted as being the best available at the present time.

Tag release and recovery data, blood genetics studies, and analyses of parasite distribution suggest that there are no discrete subpopulations of skipjack in the central and western Pacific. Tagging has shown that skipjack from Fiji travel to many countries in the region, although patterns in this migration were not readily apparent. Migration into Fiji of skipjack tagged elsewhere was dominated by fish from the north-northeast (Wallis Island) and south-southwest (New Zealand), and implies a significant north-south component to the overall diffuse pattern of skipjack movements in this area.

Evaluation of the contribution of post-recruit sized fish from other tagged populations suggests that fish from New Zealand could be contributing up to 25 per cent of the population passing through the Fijian fishery. Fish from other individual countries, for example, Wallis and Futuna, could be contributing similar amounts. However, fisheries in the waters of countries surrounding Fiji are individually exploiting only a small fraction of the stocks in each country; hence, they presently have a negligible effect on recruitment into the Fijian fishery. The effects of individual neighbouring fisheries would be further reduced if recruitment of adult fish to the Fijian fishery is dependent on the density of fish already recruited from alternate sources, which it could well be.

Estimates of the size of the resource in Fiji by the techniques used are greatly influenced by the area over which the fishery operates. Values given in this report are based on figures derived from the area exploited by the Fijian fishery in the 1979/80 and 1980/81 seasons and are not really estimates for the entire Fijian 200-mile zone. Owing to the small area of the fishery and where tags were released, population estimates are lower than they would be for the zone as a whole. Conversely, turnover rates, but not necessarily total turnover, are higher.

Owing to the nature of both the resource and the techniques used to estimate it, the confidence limits for all estimates are wide. In most cases, estimates presented are indicators of the order of magnitude only. Regardless of wide confidence limits, it is apparent that the skipjack resources of Fiji are capable of supporting catches at least several times the present levels.

Other fisheries operating throughout the Pacific are at present having little impact on the abundance in Fiji of skipjack of the same generation. This situation would be expected to change dramatically only if a large fishery was to be developed closer to Fiji than existing fisheries. Between-generation effects are also felt to be minimal. At the present levels of exploitation, recruitment into the population of Pacific skipjack would appear to be independent of catches. In the absence of a demonstrable relationship between catches and subsequent recruitment for skipjack anywhere, there would appear to be no need for anxiety over decimation of the spawning population.

The tagging and genetic data suggest that mixing of adult stock between two areas decreases with increasing distance between the areas. The implication of this conclusion is that interaction would be greatest between fisheries which overlap in time and space, such as the pole-and-line and purse-seine fisheries which operate simultaneously in Fiji. As the purse-seine fishery was developed in Fiji after the tagging experiments referred to in this report were virtually completed, results included herein are of little value for the present Fijian fishery for directly measuring interaction between this gear and pole-and-line. For the same reason, the present data is not of value for assessing the influence of the use of fish aggregating devices (FADs) on skipjack behaviour. Further tagging work would provide valuable information on both these recent and significant changes in the Fijian fishery and is therefore recommended.

7.2 Baitfish Resources

Although there remain inshore areas of Fiji which have not been investigated for their baitfishing potential, most of the country's larger baiting grounds have now been surveyed. Results from the research voyages since 1973, together with the performances of the commercial fleet which has been operating since 1976, now enable some evaluations.

The existence of the commerical live bait and pole fishery for skipjack in Fiji is evidence of the view that the baitfish resources are adequate for at least a modest sized industry. However, variability in the bait supply, which was most noticeable in the 1979/1980 season, indicates that the total resource displays marked seasonal fluctuations. This seasonality is in keeping with the geographical characteristics of the Fiji Islands, that is, moderate-sized land masses and lagoons at latitudes which are high enough to show pronounced seasonal variability in climate. There seems little doubt that the lack in Fiji of substantial quantities of Stolephorid anchovies and of the silver sprat, *Spratelloides gracilis*, which are the mainstays of the baitfish fisheries in Papua New Guinea and Solomon Islands, detracts from the comparative stability of the baitfish resources. *Stolephorus devisi*, *S. heterolobus* and *Spratelloides gracilis* appear to be more resilient to continued fishing pressure than do the sardines and blue sprats (*S. delicatulus*) which dominate catches in Fiji. On the other hand, Fiji has many lagoons and bays which harbour baitfish resources which are seldom, if ever, exploited. These are anticipated to be an effective buffer against the long term decimation of the stocks of the important species.

In summary, it is suggested that the Fijian baitfish resources should remain resilient to heavy exploitation to the extent that the future survival of the species would not be endangered and the level of recruitment at the beginning of each season would, at present levels of exploitation, not be able to be demonstratively linked to the level of fishing in the preceding season. However, the resources will probably show some effects of heavy fishing pressure within the same season in localised areas.

It seems probable that the overall yield from the Fijian baitfish resources could be improved by the introduction of a few basic management strategies, such as the co-ordinated deployment of effort during the fishing season and the maintenance for fishermen of incentives that encourage efficient use of baitfishing time.

More accurate catch effort and species composition data than were available prior to 1980 will be necessary to monitor accurately changes in the fishery. The efforts by the Fisheries Division to improve the collection of appropriate statistics, particularly since early 1981, appear adequate for these purposes.

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

<u>Scientists and Consultants</u>

Charles Ellway	1980, April 9 - May 8
Robert Gillett	1978, March 28 - April 10
	1980, April 9 - May 8
Lionel Haeffner	1978, January 26 - February 18
	1978, March 28 - April 8
Jean-Pierre Hallier	1978, January 26 - February 18
	1980, April 1 - 2
Richard Kinney	1978, March 28 - April 7
Antony Lewis	1978, January 26 - February 7
Christopher Thomas	1978, January 26 - February 18
	1978, March 28 - April 11
Desmond Whyman	1978, March 28 - April 10
	1980, April 1 - 2

<u>Observers</u>

Ian Brown	)
Gary Preston	) Fiji Ministry of Agriculture, Forests
Krishna Swamy	) and Fisheries
Bendito Tikomainiusiladi	)

<u>Vessel Crew</u>

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

<u>Fishing Crew</u>

Lui Andrews*
Vonitiese Bainamoli
Jovesa Buarua
Mosese Cakau
Samuela Delana*
Lui Diva
Eroni Dolodai
Luke Kaidrokai
Veremalua Kaliseiwaga
Kitione Koroi*
Metuisela Koroi
Aminiasi Kuruyawa
Sovita Lequeta
Jone Manuka

Fishing Crew (cont.)

Eroni Marawa*
Joshua Raguru
Jona Ravasakula*
Napolioni Ravitu
Ravaele Tikorakaca*
Tuimasi Tuilekutua
Samuela Ue*
Taniela Verekila

* Crewed on board both the *Hatsutori Maru No.1* and *No.5*.

APPENDIX B
INTERNATIONAL TAG RECOVERIES OF SKIPJACK TAGGED IN FIJI

		DATE	LATITUDE	LONGITUDE	SIZE	COUNTRY
SC00656	release data:	78/02/04	19deg 18'S	177deg 56'E	44.0cm	FIJ1
	recapture data:	78/07/07	08deg 42'S	179deg 11'E	55.7cm	TUV
At large for 153 days.		Distance = 640.1 naut. miles in direction 7.deg. true.				
SC02289	release data:	78/02/05	18deg 40'S	177deg 52'E	45.0cm	FIJ1
	recapture data:	79/10/10	20deg 04'N	163deg 14'E	54.0cm	WAK
At large for 612 days.		Distance = 2478.3 naut. miles in direction 339.deg. true.				
SC03726	release data:	78/02/09	18deg 53'S	179deg 16'E	45.0cm	FIJ1
	recapture data:	79/02/26	34deg 34'S	173deg 23'E	55.5cm	ZEA
		to	to	to		
		79/03/05	38deg 15'S	175deg 27'E		
SC03859	release data:	78/02/09	18deg 53'S	179deg 16'E	48.0cm	FIJ1
	recapture data:	79/05/10	18deg 38'S	174deg 04'W	. cm	TON
At large for 455 days.		Distance = 379.0 naut. miles in direction 89.deg. true.				
SC04101	release data:	78/02/09	18deg 51'S	179deg 12'E	53.0cm	FIJ1
	recapture data:	78/07/22	21deg 08'S	175deg 12'W	. cm	TON
At large for 163 days.		Distance = 344.2 naut. miles in direction 114.deg. true.				
SC04653	release data:	78/02/10	17deg 13'S	179deg 17'W	44.0cm	FIJ1
	recapture data:	79/02/09	08deg 34'S	179deg 13'E	. cm	TUV
At large for 364 days.		Distance = 526.3 naut. miles in direction 350.deg. true.				
SD00632	release data:	78/04/02	17deg 04'S	178deg 54'W	50.0cm	FIJ1
	recapture data:	78/08/24	13deg 50'S	171deg 37'W	56.0cm	WES
At large for 144 days.		Distance = 463.7 naut. miles in direction 66.deg. true.				
SD01270	release data:	78/04/04	17deg 10'S	179deg 14'W	48.0cm	FIJ1
	recapture data:	80/05/22	14deg 21'S	178deg 17'W	61.5cm	WAL
At large for 779 days.		Distance = 177.7 naut. miles in direction 18.deg. true.				
SD02264	release data:	78/04/05	17deg 06'S	179deg 03'W	51.5cm	FIJ1
	recapture data:	79/02/09	14deg 03'S	171deg 42'W	50.0cm	WES
At large for 310 days.		Distance = 462.5 naut. miles in direction 68.deg. true.				
SD03192	release data:	78/04/06	16deg 56'S	179deg 24'W	48.0cm	FIJ1
	recapture data:	79/04/15	01deg 05'N	165deg 11'E	55.0cm	NAU
At large for 374 days.		Distance = 1414.4 naut. miles in direction 318.deg. true.				
SD03391	release data:	78/04/06	16deg 56'S	179deg 24'W	51.0cm	FIJ1
	recapture data:	79/01/19	35deg 53'S	175deg 52'E	58.5cm	ZEA
At large for 288 days.		Distance = 1164.7 naut. miles in direction 192.deg. true.				
SD03421	release data:	78/04/06	16deg 56'S	179deg 24'W	48.0cm	FIJ1
	recapture data:	80/02/20	05deg 36'S	167deg 34'E	52.0cm	INT
At large for 685 days.		Distance = 1023.9 naut. miles in direction 310.deg. true.				
SD03593	release data:	78/04/06	16deg 56'S	179deg 24'W	51.0cm	FIJ1
	recapture data:	78/09/29	03deg 55'S	177deg 56'W	54.0cm	INT
At large for 176 days.		Distance = 785.8 naut. miles in direction 6.deg. true.				
SD03771	release data:	78/04/06	16deg 56'S	179deg 24'W	50.4cm	FIJ1
	recapture data:	78/11/21	36deg 00'S	176deg 00'E	58.5cm	ZEA
At large for 229 days.		Distance = 1170.0 naut. miles in direction 191.deg. true.				
SD03944	release data:	78/04/06	16deg 56'S	179deg 24'W	52.0cm	FIJ1
	recapture data:	78/09/16	04deg 00'S	173deg 20'W	54.0cm	PHO
At large for 163 days.		Distance = 854.2 naut. miles in direction 25.deg. true.				
SD04005	release data:	78/04/06	16deg 56'S	179deg 24'W	57.0cm	FIJ1
	recapture data:	79/01/05	17deg 34'S	149deg 55'W	65.0cm	SOC
At large for 274 days.		Distance = 1688.2 naut. miles in direction 96.deg. true.				

		DATE	LATITUDE	LONGITUDE	SIZE	COUNTRY
2B24775	release data:	80/04/10	18deg 34′S	177deg 50′E	48.0cm	FIJ2
	recapture data:	80/07/01 to 80/07/31	08deg 00′S	177deg 30′E	. cm	TUV
		Distance = 634.3 naut. miles in direction 358.deg. true.				
2B25018	release data:	80/04/10	18deg 37′S	177deg 49′E	50.0cm	FIJ2
	recapture data:	80/10/05	03deg 28′S	179deg 29′W	62.0cm	INT
At large for 178 days.		Distance = 922.7 naut. miles in direction 10.deg. true.				
1C19301	release data:	80/04/11	18deg 35′S	177deg 49′E	54.0cm	FIJ2
	recapture data:	81/02/24	05deg 08′S	172deg 54′W	61.0cm	PHO
At large for 319 days.		Distance = 973.0 naut. miles in direction 35.deg. true.				
2C25224	release data:	80/04/18	16deg 42′S	177deg 22′E	53.0cm	FIJ2
	recapture data:	81/02/09	02deg 18′N	173deg 42′W	69.0cm	INT
At large for 297 days.		Distance = 1256.8 naut. miles in direction 26.deg. true.				
2C25933	release data:	80/04/18	16deg 44′S	177deg 21′E	57.0cm	FIJ2
	recapture data:	80/11/12	17deg 24′S	160deg 46′E	75.0cm	CAL
At large for 208 days.		Distance = 951.7 naut. miles in direction 265.deg. true.				
2C27709	release data:	80/04/20	15deg 52′S	179deg 58′W	50.0cm	FIJ2
	recapture data:	80/09/20	06deg 00′S	175deg 00′W	59.0cm	PHO
At large for 153 days.		Distance = 660.2 naut. miles in direction 27.deg. true.				
2C28400	release data:	80/04/20	15deg 52′S	179deg 58′W	48.0cm	FIJ2
	recapture data:	81/04/12	01deg 35′S	177deg 15′E	68.0cm	KIR
At large for 357 days.		Distance = 872.7 naut. miles in direction 349.deg. true.				
2C28834	release data:	80/04/22	15deg 55′S	179deg 03′E	54.0cm	FIJ2
	recapture data:	80/09/06	04deg 30′S	174deg 16′W	60.8cm	PHO
At large for 137 days.		Distance = 790.2 naut. miles in direction 31.deg. true.				
1E10421	release data:	80/04/22	15deg 55′S	179deg 03′E	48.0cm	FIJ2
	recapture data:	81/07/09	11deg 25′S	178deg 25′E	67.0cm	TUV
At large for 443 days.		Distance = 272.5 naut. miles in direction 352.deg. true.				
SK47293	release data:	80/04/23	16deg 01′S	179deg 02′E	50.0cm	FIJ2
	recapture data:	80/10/03	05deg 45′S	178deg 40′W	62.0cm	TUV
At large for 163 days.		Distance = 630.7 naut. miles in direction 13.deg. true.				
SK47310	release data:	80/04/23	16deg 01′S	179deg 02′E	48.0cm	FIJ2
	recapture data:	81/04/10	13deg 21′S	179deg 12′W	61.0cm	WAL
At large for 352 days.		Distance = 190.0 naut. miles in direction 33.deg. true.				
SK51785	release data:	80/04/25	16deg 12′S	179deg 03′E	55.0cm	FIJ2
	recapture data:	80/08/01 to 80/08/31	08deg 00′S	177deg 30′E	34.3cm	TUV
		Distance = 500.3 naut. miles in direction 349.deg. true.				
SK53894	release data:	80/04/27	16deg 07′S	179deg 09′E	50.0cm	FIJ2
	recapture data:	81/02/24	01deg 58′N	170deg 30′W	63.5cm	INT
At large for 303 days.		Distance = 1246.5 naut. miles in direction 30.deg. true.				

APPENDIX C
ABBREVIATIONS OF COUNTRY NAMES USED IN TABLES

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)
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