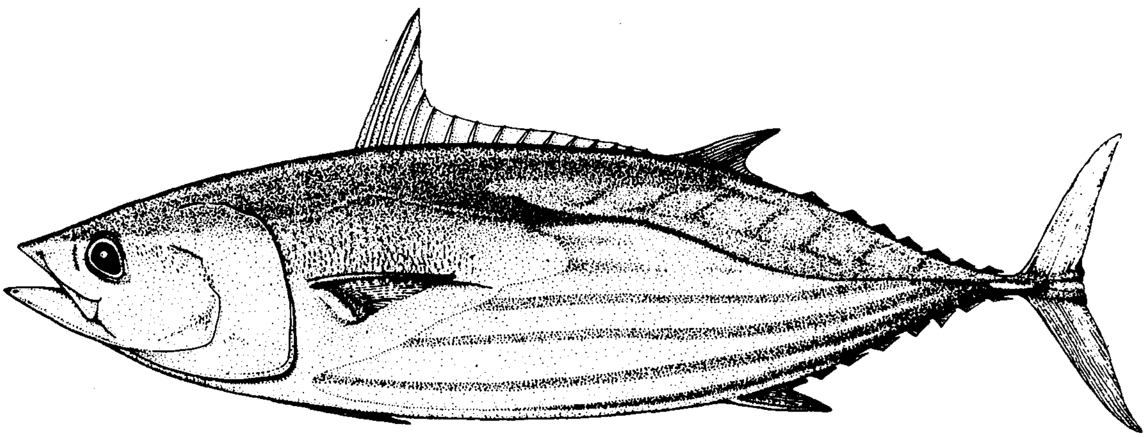
AN ASSESSMENT OF THE SKIPJACK AND BAITFISH RESOURCES OF WESTERN SAMOA



Skipjack Survey and Assessment Programme
Final Country Report No. 14

South Pacific Commission
Noumea, New Caledonia
May 1984

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PREFACE

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

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

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

The Skipjack Programme is grateful for the assistance provided by the Fisheries Division in Western Samoa. Particular thanks are due to the Chief Fisheries Officer, A. Philipp, and to D. Popper, FAO Aquaculturist.

Tuna Programme
South Pacific Commission

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AN ASSESSMENT OF THE SKIPJACK AND BAITFISH RESOURCES OF WESTERN SAMOA

1.0 INTRODUCTION

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

The Programme's field research spanned almost three years between October 1977 and August 1980, and included 847 days of tagging and survey operations. Visits were made to all countries and territories in the area of the South Pacific Commission (Figure A, inside front cover) as well as New Zealand and Australia. Fourteen days were spent in the waters of Western Samoa from 6 to 14 June 1978 and 22 to 26 February 1980. Preliminary results from the 1978 visit were given by Kearney & Hallier (1978). This report presents the final analyses of the work by the Programme in the waters of Western Samoa, compares them to previous data and to results from elsewhere in the Programme's study area, and considers their implications for skipjack and baitfish resource management.

1.1 History of the Tuna Fishery

Skipjack has long been an important resource to Western Samoa. Traditionally, skipjack fishing was carried out by groups of masterfishermen, using specialised canoes and pearl-shell lures typical of other Polynesian areas (Hiroa 1930). By 1960, outboard motors were used to power some of the fishing canoes (van Pel 1960). The introduction of "alia"-type, 8.5-metre catamarans by a Food and Agriculture Organization/United Nations Development Programme (FAO/UNDP) project in 1975 was followed by the rapid expansion of the alia fleet to about 120 vessels at the end of 1982 (Philipp 1983). These vessels fish predominantly by surface trolling.

The development of such a large artisanal fleet is reflected in the increases in annual tuna catch between 1972 and 1982 (Table 1). Most of the catch was skipjack (average 77% between 1972 and 1978) with yellowfin, *Thunnus albacares*, the only other species listed in catch summaries (Philipp pers. comm.). According to 1982 data, Western Samoa's artisanal tuna fishery is second only to that of French Polynesia in the South Pacific Commission region, even though its Exclusive Economic Zone is the smallest (Sevele & Bollard 1979). Tuna is now the most important component of Western Samoa's fish catch, contributing about 60 per cent by weight of all landings (Philipp 1980). Increasing demand for fish will ensure the continuing significance of tuna, since reef-based resources are considered to be already fully exploited (Johannes 1982), while the deep-bottom fishery meets only a relatively small proportion of the total demand, and is unlikely to expand greatly (Walkden Brown 1981). Wider and more effective deployment of fish aggregation devices (FAD), first used in 1979 and numbering 15 by late 1982 (Philipp 1983), will further enhance future artisanal tuna catches. Innovative techniques such as gill-netting around FADs are presently being explored (Anon. 1983a).

TABLE 1. ANNUAL ARTISANAL CATCH OF TUNA (tonnes) IN WESTERN SAMOAN WATERS by surface-trolling canoes and alias. Data from Philipp (1982 and pers. comm.). NA = not available.

Year	Catch (tonnes)	% Skipjack
1972	413	90
1973	536	84
1974	505	76
1975	675	68
1976	665	72
1977	950	75
1978	985*	76
1979	NA	-
1980	NA	-
1981	NA	-
1982	1440	NA

* Includes exploratory fishing by the 16-tonne pole-and-line vessel, Tautai Samoa.

Locally based pole-and-line fishing has been attempted on only a small scale in Western Samoa. In early 1978, the government acquired the Tautai Samoa, a 16-tonne, Japanese-style pole-and-line vessel, which was used for training and exploratory fishing until August 1980, resuming operations in 1982. Aggregate catch during 1979 and 1980 was about 8 tonnes (Philipp, Popper & Teppen 1980). An alia modified for pole-and-line operations, the Tautai Nouei, has been utilised by the Fisheries Division since October 1980 for exploratory fishing around FADs. Commercial fishing was undertaken by two privately owned, similarly modified alias in 1981 (Philipp 1981), but catch data are not available. For most of the fishing by both government and private vessels, live cultured mollies (*Poecilia mexicana*) were used as bait, although the Tautai Samoa also used limited quantities of wild bait.

In contrast to the situation in many other parts of the South Pacific Commission region, there has been little fishing in Western Samoan waters by the Japanese distant-water pole-and-line fleet, which relies on live bait transported from Japan. Only 11 boat-days of fishing activity in 1975 and 1976, yielding 54 tonnes of skipjack and 7 tonnes of bigeye (*Thunnus obesus*) were reported between 1972 and 1978 (Skipjack Programme 1980a), and there are no subsequent records of pole-and-line fishing by Japanese vessels. However, longline fishing by Asian vessels, mainly from Japan, Korea and Taiwan, has been conducted in Western Samoan waters for at least three decades (van Pel 1960; Skipjack Programme 1981a). The catch in 1976, the most recent year for which complete longline catch data are available (Klawe 1978), was 159.8 tonnes of tuna, of which 0.6 tonne was skipjack. Longlining by Japanese vessels apparently ceased in Western Samoan waters in 1979 (Philipp 1980).

The proximity of Western Samoa to canning and port facilities in Pago Pago, American Samoa, and the growing number and success of purse-seiners operating in the central and western Pacific may provide Western Samoa with an opportunity for involvement in an industrial fishery for skipjack. Two purse-seine vessels, one from Nauru and one from the United States, reported limited fishing in Western Samoa in 1980 (Philipp 1982). In August 1983 an agreement permitting access of United States purse-seiners in return for licence fees was reached between the American Tunaboat Association and a group of four central Pacific countries, including Western Samoa (Anon. 1983b).

1.2 Previous Research

Several surveys of the surface tuna and baitfish resources of Western Samoa have been conducted since 1950. The first were by the United States Bureau of Commercial Fisheries, which spent 26 hours sighting for tuna in the general area of the Samoa Islands between 1950 and 1961 during research cruises through the Pacific (Waldron 1964). Exploratory fishing using live-bait, pole-and-line techniques was first attempted in the early 1960s, on a visit by an Hawaiian vessel, Broadbill (Anon. 1969). The United States National Marine Fisheries Service (NMFS) undertook two surveys using pole-and-line gear, the first in 1970 with the Charles H. Gilbert (Hida 1970), and the second in 1972, mainly in adjacent American Samoan waters, using the Anela (Uchida & Sumida 1973). During the 1970 survey, 840 skipjack and 91 yellowfin were tagged in Western Samoan and American Samoan waters. A pole-and-line fishing survey was made by an FAO team in 1974 (Sperling pers. comm.), but published results are unavailable. The Pacific Tuna Development Foundation (PTDF) conducted exploratory pole-and-line fishing in 1978, using the J-Ann operating out of American Samoa (Vergne, Bryan & Broadhead 1978).

The sources of live bait for these pole-and-line surveys were not stated in all cases. However, the NMFS vessels used both beach-seining and night-lighting techniques in attempts to capture live bait, but reported little success. A NMFS cruise in 1979 on the Townsend Cromwell also failed to catch live bait by night-lighting (Anon. 1979). The J-Ann utilised cultured mollies from American Samoa in its fishing operations. The American Samoan baitfish culture programme, as well as an earlier one in Hawaii, encouraged an FAO/UNDP-supported attempt in 1978 to culture mollies in Western Samoa as bait for future pole-and-line fishing ventures (Popper 1979). The project was terminated at the end of 1982 because of high costs and low catch-to-bait ratios (Philipp 1983). Renewed attempts to identify natural baitfish resources have involved beach-seining around Upolu Island (Philipp 1981).

Trolling surveys were conducted in 1975 by the PTDF using the American Samoan vessel Alofaga (Anon. 1975), and in 1979 by the NMFS research vessel Townsend Cromwell (Anon. 1979). Aerial spotting for schools of surface tuna was carried out over four days in June and October 1979 by the Noumea-based Office de la recherche scientifique et technique outre-mer (ORSTOM) (Marsac 1981).

The Fisheries Division of the Department of Economic Development was established in Western Samoa in January 1970. The Division has been active in tuna research through exploratory fishing using the Tautai Samoa and the Tautai Nouei, deployment of FADs, development training programmes and marketing facilities, conduct of baitfish surveys and the baitfish culture programme, and collection of catch and effort statistics (e.g. Philipp 1980, 1981, 1982).

2.0 METHODS

2.1 Vessels and Crew

Two Japanese commercial fishing vessels, the *Hatsutori Maru No.1* and the *Hatsutori Maru No.5*, were chartered at different times by the Skipjack Programme from Hokoku Marine Products Company Limited, Tokyo, Japan. Details of both vessels are given in Kearney (1982a). The 192-gross tonne *Hatsutori Maru No.1* was used during the first survey of Western Samoa in June 1978 and the *Hatsutori Maru No.5* of 254 gross tonnes was used during the second, in February 1980.

The *Hatsutori Maru No.1* was operated with at least three Skipjack Programme scientists, nine Japanese officers and twelve Fijian crew. On the *Hatsutori Maru No.5*, twelve to fourteen Fijian crew were employed. Names of all personnel and details of the times scientists and observers spent on board are given in Appendix A.

2.2 Baitfishing

Baitfishing was carried out at night using a "bouki-ami" net set around bait attraction lights. In some countries, beach-seining during daylight hours supplemented night catches, but it was not attempted in Western Samoa. Night baiting procedures were similar to those used by commercial vessels, but were modified where necessary to meet the Programme's special requirements. Details of techniques and modifications employed are given in Hallier, Kearney & Gillett (1982).

2.3 Skipjack Fishing and Tagging

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

The numbers of crew on the *Hatsutori Maru No. 1* and *No. 5* were fewer than either of these vessels carry under commercial fishing conditions. The effective number of fishermen was further reduced, because at least one crew member was required to assist each scientist in the tagging procedures. Additionally, the need to pole skipjack accurately into the tagging cradles reduced the speed of the individual fishermen. Clearly, these factors decreased the fishing power of the research vessel. During the first survey in the waters of Fiji (26 January-18 February, 28 March-10 April 1978), the relative fishing power of the *Hatsutori Maru No.1* was calibrated by comparing its catches with those of the commerical fleet operating in the same area, and with catches achieved during a period of one month when the vessel fished commercially under the same captain while using an enlarged crew complement. From these comparisons, it was estimated that the fishing power of the *Hatsutori Maru No.1* under survey conditions was 29 per cent of its commercial fishing power (Kearney 1978). It was assumed that the same ratio of 3.47 applied to the operations of the *Hatsutori Maru No.5*.

As tagging was the primary tuna research tool, attempts to tag large numbers of fish usually dominated the fishing strategy. The tagging technique and alterations to normal fishing procedures are described in detail in Kearney & Gillett (1982).

2.4 Biological Sampling

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

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

After December 1979 skipjack body cavities were examined for the presence of macro-parasites. Five complete sets of gills and viscera from each school were frozen and subsequently shipped to the University of Queensland, St. Lucia, Australia, for detailed examination.

2.5 Data Compilation and Analysis

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

Assessment of the skipjack resource and possible interactions between fisheries for skipjack in Western Samoa and those in other countries required several different approaches. Records of the migration of tagged skipjack formed the basis of the investigations of movement patterns and fishery interactions, using analytic techniques described in Skipjack Programme (1981b) and Kleiber, Sibert & Hammond (ms.). Evaluation of the magnitude of the skipjack resource and its dynamics, based on tag recapture data, were described by Kleiber, Argue & Kearney (1983). Methods employed in studies of growth are described by Lawson, Kearney & Sibert (1984) and Sibert, Kearney & Lawson (1983), and of juvenile abundance, in Argue, Conand & Whyman (1983). Procedures used to compare fishing effectiveness of different baitfish families are described by Argue, Williams & Hallier (ms.). Evaluation of population structuring across the whole of the western and central Pacific was based on a comparison of the tagging results with the blood genetics analyses (Anon. 1980, 1981; Skipjack Programme 1981c), and analyses of the occurrence and distribution of skipjack parasites (Lester, Barnes & Habib ms.).

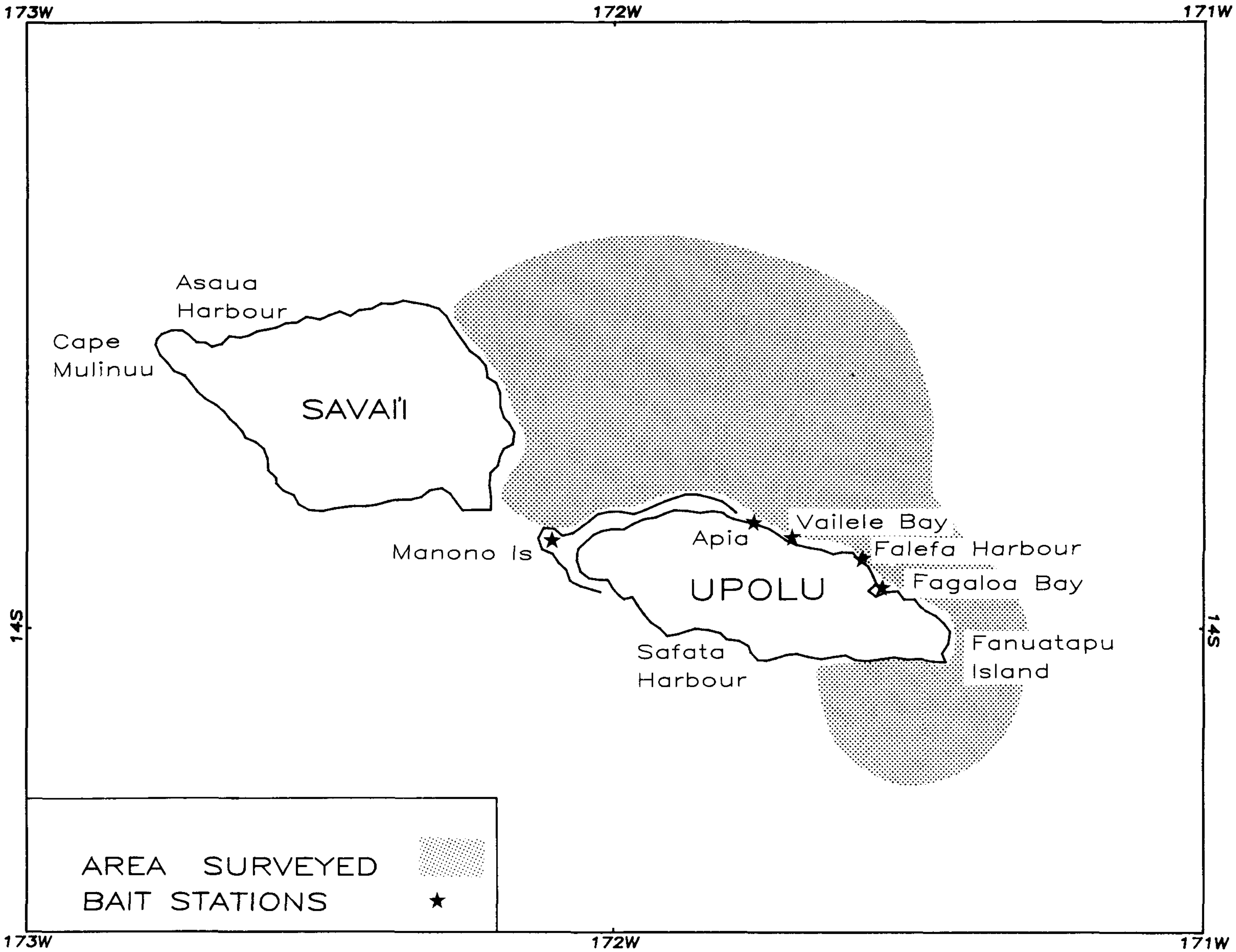
3.0 SUMMARY OF FIELD ACTIVITIES

Eight days were spent fishing, three days baiting and three days in port during the Skipjack Programme surveys of Western Samoa (Table 2). Figure 1 shows the area covered by the surveys, and the five localities at which baitfishing was conducted.

TABLE 2. SUMMARY OF DAILY FIELD ACTIVITIES BY THE SKIPJACK PROGRAMME IN THE WATERS OF WESTERN SAMOA. Schools sighted are identified by species: SJ = skipjack or skipjack with other species except yellowfin, YF = yellowfin or yellowfin with other species except skipjack, S+Y = skipjack with yellowfin or skipjack with yellowfin and other species, OT = other species without skipjack or yellowfin, UN = unidentified.

Date	General Area	Principal Activity	Bait Carried (kg)	Hours Fishing and Sighting	Schools Sighted (numbers)					Fish Tagged (numbers)			Fish Caught (kg)		Total Catch (kg)
					SJ	YF	S+Y	OT	UN	SJ	YF	OT	SJ	YF	
31/05/78	South of Savai'i	Steaming	0	8	0	0	0	0	0	-	-	-	-	-	-
06/06/78	Apia	In Port	0	0	-	-	-	-	-	-	-	-	-	-	-
07/06/78	N Upolu Island	Fishing	14	6	7	1	0	0	10	8	0	0	24	0	24
08/06/78	N Upolu Island	Fishing	113	5	0	0	1	2	1	118	22	0	317	124	448
09/06/78	E Upolu Island	Fishing	75	10	1	0	0	0	15	0	0	0	0	0	0
10/06/78	N Upolu Island	Fishing	75	6	3	0	0	0	11	0	0	0	3	0	23
11/06/78	Upolu Island - Savai'i Island	Fishing	15	9	5	1	0	2	24	4	0	0	10	1	17
12/06/78	N Upolu Island	Baiting	5	6	2	0	0	1	10	0	0	0	2	0	4
13/06/78	Upolu Island	Baiting	0	1	0	0	0	0	1	-	-	-	-	-	-
14/06/78	Apia	Fishing	732	3	0	0	1	0	0	1637	56	0	4342	502	4924
22/06/78	West of Savai'i	Steaming	605	9	0	0	0	0	13	0	0	0	0	0	0
22/02/80	E of Apia	In Port	5	0	-	-	-	-	-	-	-	-	-	-	-
23/02/80	Apia	In Port	374	0	-	-	-	-	-	-	-	-	-	-	-
24/02/80	Apia	Baiting	368	0	-	-	-	-	-	-	-	-	-	-	-
25/02/80	Upolu Island	Fishing	513	5	1	1	0	1	2	0	0	0	0	0	2
26/02/80	Upolu Island	Fishing	444	12	4	2	0	1	2	159	0	1	441	4	463
TOTALS	Days 16			80	23	5	2	7	89	1926	78	1	5139	631	5905

FIGURE 1. AREA SURVEYED FOR SKIPJACK AND LOCALITIES FISHED FOR BAIT BY THE SKIPJACK PROGRAMME IN THE WATERS OF WESTERN SAMOA



On fishing days, an average of seven hours were spent searching and fishing. One hundred and thirteen schools were sighted, at an average rate of 1.79 schools per hour. Almost six tonnes of tuna (87% skipjack) were caught, and 2,005 tuna (96% skipjack) were tagged (Table 2). The results of baitfishing activities carried out on three nights are summarised in Table 3. Fourteen hauls were made at five different locations around Upolo Island in June 1978 and February 1980.

A summary of numbers of fish sampled for biological data is given in Table 4. The length frequency distributions of tagged and sampled skipjack are shown in Figure 2. The fork length ranged from 36 to 72 cm, with a mean around 48.0 cm, slightly smaller than the Skipjack Programme's overall average of 50.4 cm. Maturity data are summarised in Figures 3 and 4, diet items in Table 5, and the incidence of tuna juveniles in the stomachs of sampled skipjack and other tuna species in Table 6. Blood samples were taken from 109 skipjack from a school near Apia on 14 June 1978; results of blood genetics analyses are included in Figure 5 (Section 4.3.3).

TABLE 4. NUMBERS OF FISH SAMPLED FOR BIOLOGICAL DATA BY THE SKIPJACK PROGRAMME IN WESTERN SAMOA

Species	Number Measured	Number Weighed	Number Examined for Sex	Number Examined for Stomach Content	Number Examined for Tuna Juveniles	Number Sampled for Blood Analyses
Skipjack <u>Katsuwonus pelamis</u>	170	75	75	33	66	109
Yellowfin <u>Thunnus albacares</u>	38	12	32	20	20	0
Mackerel Tuna <u>Euthynnus affinis</u>	12	12	12	9	12	0
Rainbow Runner <u>Elagatis bipinnulatus</u>	12	12	11	12	12	0
Dolphinfish <u>Coryphaena hippurus</u>	1	1	1	1	1	0
White-spotted Triggerfish <u>Canthidermis rotundatus</u>	1	1	1	1	1	0
Totals	234	113	132	76	112	109

4.0 RESULTS AND DISCUSSION

4.1 Baitfishing

The Skipjack Programme made 14 bouki-ami hauls at five locations in Western Samoa (Tables 3 and 7). A total of 1,130 kg of baitfish was caught; 94 per cent were loaded aboard the research vessel, while the remainder (63 kg) was discarded.

TABLE 3. SUMMARY OF BAITFISHING EFFORT AND CATCH BY THE SKIPJACK PROGRAMME IN THE WATERS OF WESTERN SAMOA

Anchorage	Time	Number of Hauls	Dominant Species*	Est. Av. Catch per Haul (kg)	Mean Length (mm)	Other Common Species
Apia Harbour			Selar crumenophthalmus	17	151	Gazza minuta
13°48′S	Night	2	Herklotsichthys quadrimaculatus	5	78	Sp. of Sphyraenidae
171°45′W			Sardinella melanura	3	100	Stolephorus devisi
Fagaloa Bay			Stolephorus devisi	31	69	Sp. of Acanthuridae
13°55′S	Night	8	Spratelloides delicatulus	1	23	Sp. of Balistidae
171°33′W			Priacanthus sp.	1	45	Gastrophysus sp.
Manono Island			Spratelloides delicatulus	9	46	Siphamia sp.
13°49′S	Night	1	Parapriacanthus sp.	3	39	Sp. of Acanthuridae
172°04′W			Xiphasia sp.			Bregmaceros sp.
Vailele Bay			Sardinella leiogaster	5	200	Spratelloides gracilis
13°50′S	Night	1	Spratelloides delicatulus			Stolephorus indicus
171°41′W			Atherinomorus lacunosa			Bregmaceros sp.
Falefa Harbour			Stolephorus devisi	252	62	Herklotsichthys quadrimaculatus
13°53′S	Night	2	Gazza minuta	130	89	Selar crumenophthalmus
171°34′W			Spratelloides delicatulus			Sp. of Holocentridae

* Until recently, Herklotsichthys quadrimaculatus was known as Herklotsichthys punctatus (Wongratana 1983) and Atherinomorus lacunosa was known as Pranesus pinguis (Whitehead & Ivantsoff 1983).

Explanatory Notes

Anchorage : Recorded positions are truncated to the nearest minute. For large bays there may be more than one position tabulated.

Time of Hauls : Day hauls - 0600-1759 hrs inclusive
Night hauls - 1800-0559 hrs inclusive

Number of Hauls : Number of hauls at the anchorage position, either day or night as specified. A haul is defined as any time the net was placed in the water.

Species : Those species that made up at least one per cent of the numbers caught from one or more bait hauls at a particular location.

Average Catch (species) : Total catch includes bait loaded, bait discarded alive and bait discarded dead at the location. The average catch in kilograms per haul is the product of total catch in kilograms and weighted numerical percentage of the catch for a particular species, divided by the total number of hauls at the location. The weighted numerical percentage is the product of numerical percentage, a constant, and the cube of the species′ average standard length. (In the absence of a mean SL for the species, the numerical percentage itself is used.) The sum of the weighted percentages equals the sum of the total of the numerical percentages. In this way the smaller (numerically abundant) fish are suppressed in their contribution to the catch while the less common, larger fish are proportionally enhanced in their representation. Catches are expressed in kilograms for the dominant three species; thus, the sum of the average species catches will often be less than the average location catch.

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

FIGURE 2. LENGTH FREQUENCY DISTRIBUTIONS OF SKIPJACK TAGGED OR SAMPLED BY THE SKIPJACK PROGRAMME IN WESTERN SAMOA

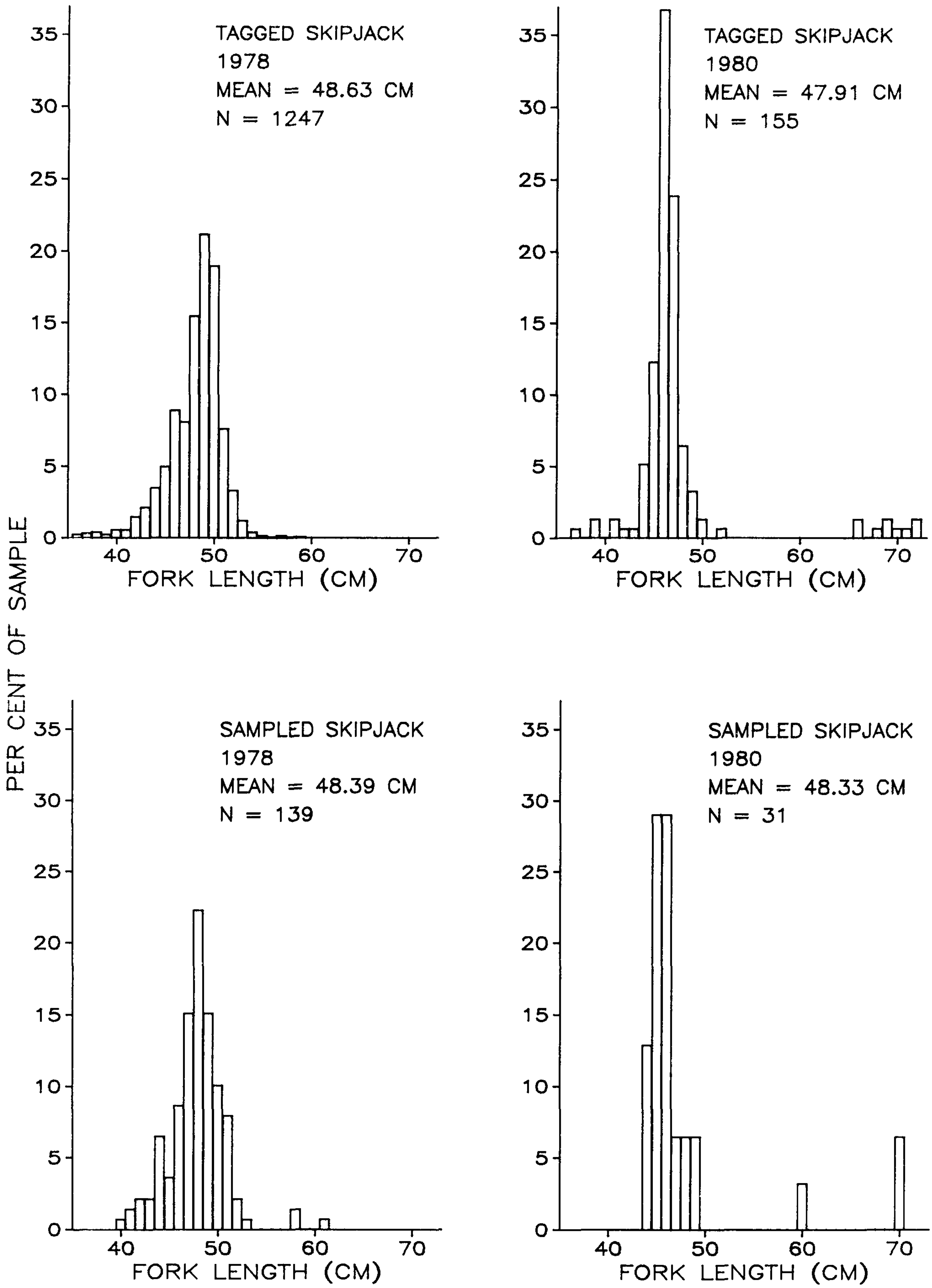


FIGURE 3. DISTRIBUTION OF FEMALE SKIPJACK BY MATURITY STAGE FOR SAMPLES FROM (a) WESTERN SAMOA AND (b) FROM THE ENTIRE SKIPJACK PROGRAMME STUDY AREA

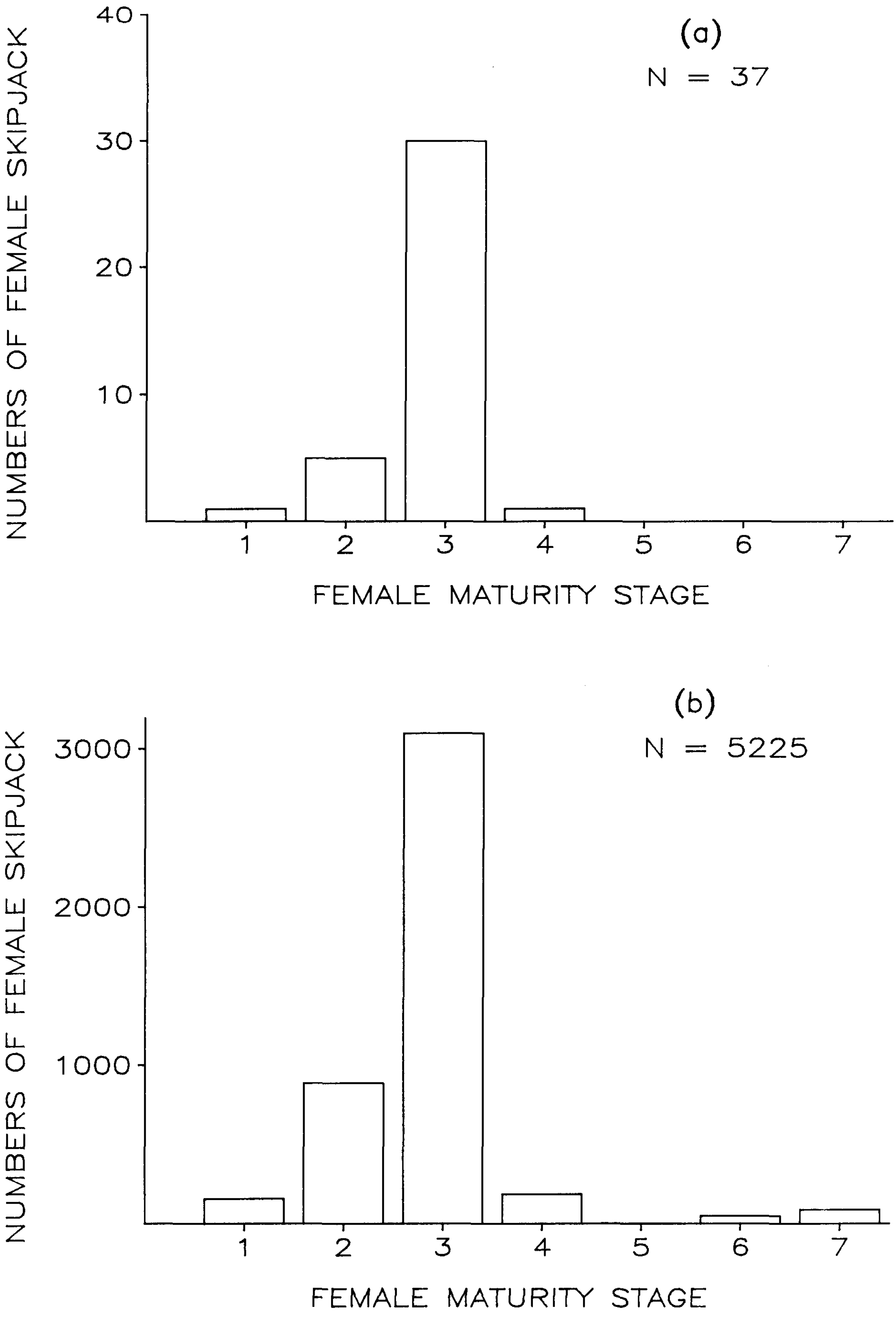


FIGURE 4. AVERAGE GONAD INDICES ($\pm$ two standard errors), BY MONTH, FOR FEMALE SKIPJACK SAMPLED BY THE SKIPJACK PROGRAMME FROM TROPICAL WATERS SOUTH OF THE EQUATOR. Standard errors omitted for one small (<5) sample (top graph, March); other sample sizes were at least 8 and most exceeded 100. No samples for August and September.

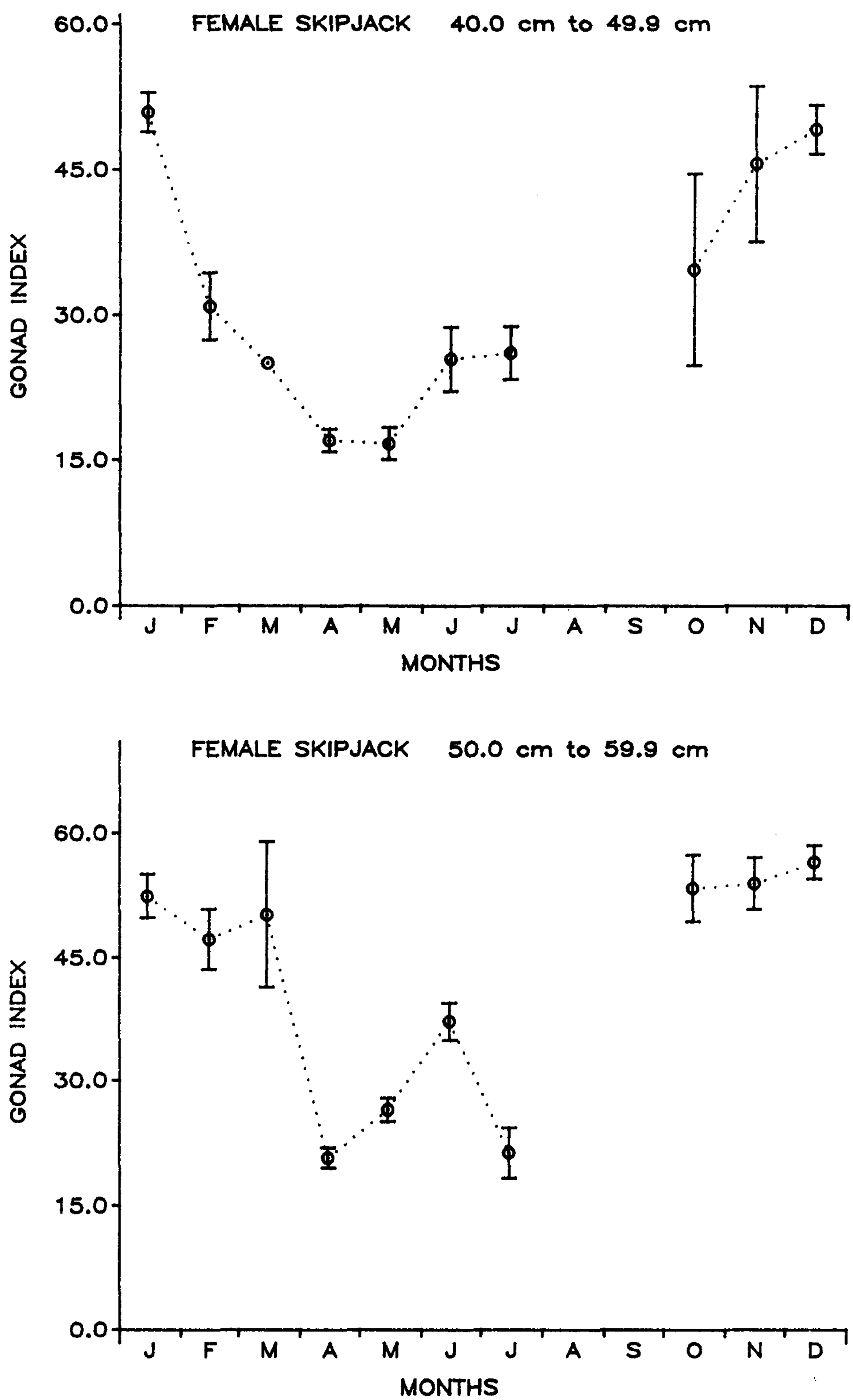


TABLE 5. ITEMS FOUND IN STOMACHS OF SKIPJACK SAMPLED IN WESTERN SAMOA

Item No.	Diet Item	Number of Stomachs	Percentage Occurrence
1	Chum from Hatsutori Maru	29	87.88
2	Unidentified fish	13	39.39
3	Fish remains (not chum)	8	24.24
4	Aluteridae	7	21.21
5	Acanthuridae	7	21.21
6	Decapoda (shrimp)	6	18.18
7	Cephalopoda (octopus)	5	15.15
8	Holocentridae	5	15.15
9	Cephalopoda (squid)	5	15.15
10	Stomatopoda	4	12.12
11	Balistidae	2	6.06
12	Empty stomach	2	6.06
13	Stomatopoda (alima stage)	2	6.06
14	Mullidae	1	3.03
15	Mullidae (blue goatfish)	1	3.03
16	Crustacean remains	1	3.03
17	Hemirhamphidae	1	3.03
18	Leiognathidae	1	3.03
19	Sphyraenidae	1	3.03
20	Theraponidae	1	3.03
21	Gempylidae	1	3.03
22	Syngnathidae	1	3.03
23	Chaetodontidae	1	3.03
	Total Stomachs Examined	33	

TABLE 6. INCIDENCE OF TUNA JUVENILES IN STOMACHS OF PREDATOR TUNA SAMPLED IN WESTERN SAMOA

Predator	Predators Examined	Prey Species	No. of Prey	No. of Predators with Prey	Prey per 100 Predators	Percentage of Predators with Prey
Skipjack	66	Skipjack	3	1	4.55	1.52
		Albacore	4	1	6.06	1.52
Yellowfin	20	-				
Rainbow Runner	12	-				
Mackerel Tuna	12	-				
Dolphinfish	1	-				
Triggerfish	1	-				
Totals	112		7			

FIGURE 5. **SKIPJACK SERUM ESTERASE GENE FREQUENCY FOR 163 SAMPLES VERSUS THE LONGITUDE OF THE SAMPLE LOCATION.** Each point is the average of approximately 100 specimens sampled from a single school on the same day. The Western Samoa sample is shown as a circle.

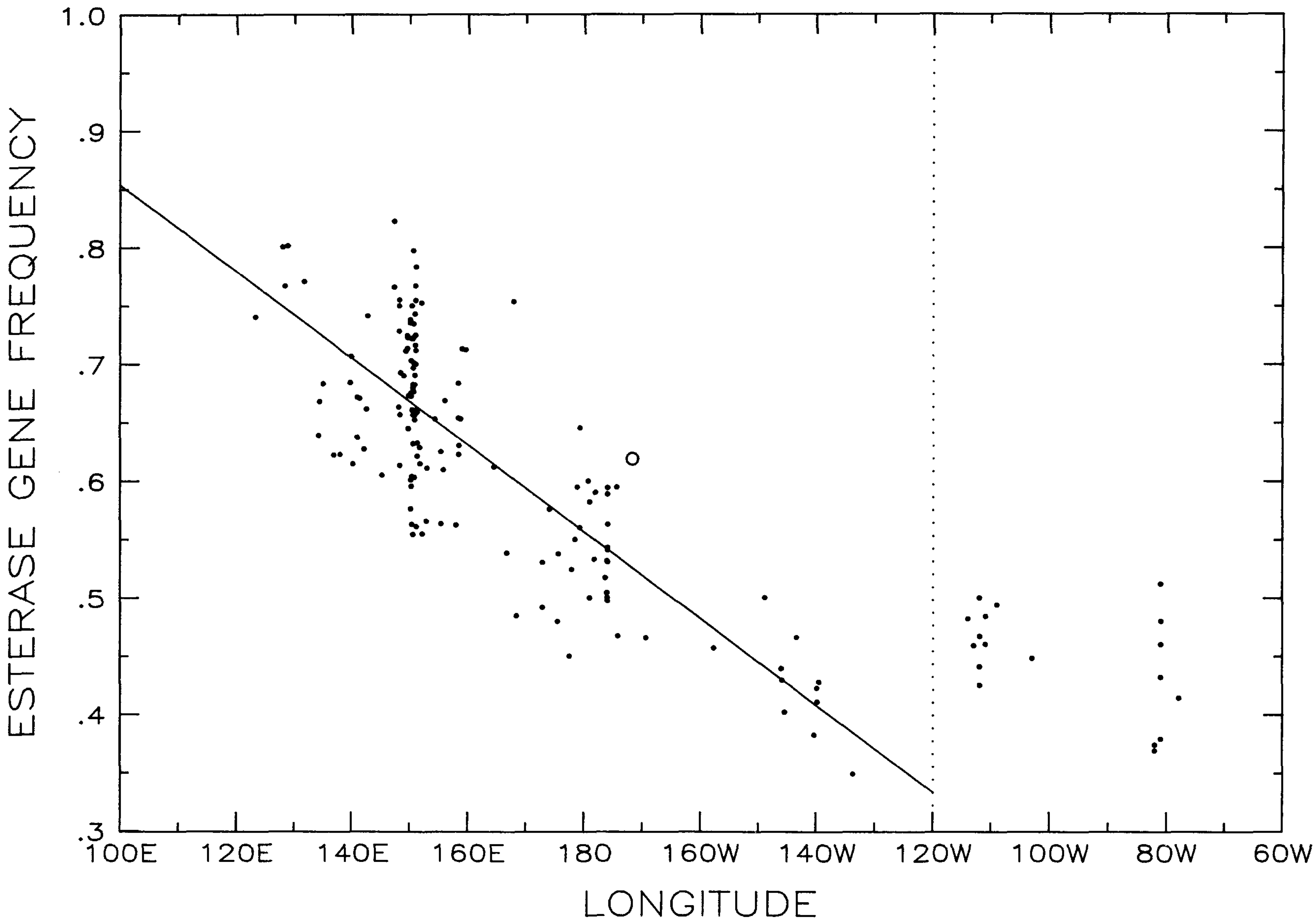


TABLE 7. CATCH OF THE 10 DOMINANT BAITFISH SPECIES IN BOUKI-AMI HAULS MADE BY THE SKIPJACK PROGRAMME IN WESTERN SAMOA

	Catch (kg)	% of Total
Stolephorus devisi	752	66.5
Gazza minuta	263	23.3
Selar crumenophthalmus	33	2.9
Spratelloides delicatulus	16	1.4
Herklotsichthys quadrimaculatus	9	0.8
Sardinella clupeoides	4	0.4
Sardinella melanura	4	0.4
Sp. of Sphyraenidae	3	0.3
Parapriacanthus sp.	3	0.3
Priacanthus sp.	2	0.2
		96.5
Number of bouki-ami hauls		14
Total bait caught		1130.0 kg
Total bait catch loaded		1067.0 kg
Average catch per haul		130.3 kg
Average catch loaded per haul		119.6 kg

The catch per haul was consistently low (Table 3), averaging only 20 kg, except for a single haul made at Falefa Harbour on northern Upolu Island which yielded 870 kg. Another haul earlier the same evening at the same location yielded only 12 kg. The large haul is considered unrepresentative and unlikely to be achieved regularly.

The bait catch was dominated by one species of anchovy, *Stolephorus devisi*, which comprised 67 per cent by weight of the total catch (Table 7). About one-third of the *S. devisi* was taken in the single large haul at Falefa Harbour (Table 3), but the species also dominated catches at Fagaloa Bay. Sprats, sardines and herrings, including *Spratelloides delicatulus*, *Sardinella* spp. and *Herklotsichthys quadrimaculatus*, which are almost as effective as anchovies as live bait (Argue et al. ms.), were very low in abundance although they occurred in many hauls (Table 7). The leiognathid *Gazza minuta* was moderately abundant, but it is not highly regarded as a baitfish. The relative abundances of baitfish species captured during all surveys undertaken by the Programme throughout the central and western Pacific are given in Skipjack Programme (1981d).

Published results of other baitfish surveys in Western Samoa have been similarly low. In 1970 the *Charles H. Gilbert* caught very little bait while fishing in Apia Harbour at night and only about 63 kg of silversides and sardines in five sets of a beach seine during daylight hours (Hida

1970). The Anela crew reported only one very small school of sprats in daylight hours in Apia Harbour in 1972 and no baitfish in Asau Harbour. Night baiting was attempted at Asau but "appreciable quantities" of bait were not attracted (Uchida & Sumida 1973). Night-baiting by the Townsend Cromwell in 1979 yielded only low catches (Anon. 1979). The Western Samoan pole-and-line vessel, the Tautai Samoa, occasionally has attempted to capture bait, also without success (Philipp 1980). The results of these surveys run counter to the optimistic projections by the UNDP South Pacific Tuna Mission (Anon. 1969), based on only anecdotal evidence, which suggested that the baitfish resource could adequately support the operations of at least one pole-and-line vessel.

The paucity of the baitfish resource can undoubtedly be attributed to the absence of suitable habitat. In general, baitfish require extensive shallow areas, usually within reef lagoons, adjacent to freshwater inflows which carry nutrients to support high local productivity. Exploitation of such a resource by bouki-ami techniques requires anchorages protected from the wind, with little current and between 25 and 40 metres depth to allow deployment of the net (Hallier et al. 1982). Few such areas exist in Western Samoa, and previous surveys have tended to concentrate on what were thought to be the best available grounds. The poor results suggest that other unsurveyed areas are unlikely to contain extensive baitfish resources.

The culture of mollies as an alternative source of bait was initiated in Western Samoa in 1978 (Popper 1979). Fishing trials using mollies began in 1979 on the Tautai Samoa and in 1980 on the Tautai Nouei (Philipp et al. 1980). Initially successful operations, with catch-to-bait ratios of 15:1-20:1 (Popper 1979) were not sustained, and average ratios lower than 3:1 were obtained by the Tautai Samoa (Philipp 1982). Higher ratios (average 6:1) were achieved by the Tautai Nouei around FADs (Philipp 1982). Similar results were reported by the Skipjack Programme (1980b, 1981e) during trials conducted at various times between June 1978 and February 1980. Production costs also affect the viability of a pole-and-line fishery relying on the culture of bait; in Western Samoa costs rose from around WS$3.50 per kg in mid-1981 (Philipp pers. comm.) to WS$14.50 in mid-1982 (Philipp 1983). Because of this cost increase and the low catch-to-bait ratios, the culture project was terminated at the end of 1982 (Philipp 1982). Further discussion of economic aspects of baitfish culture to supply commercial-scale operations may be found in Kearney & Rivkin (1981).

4.2 Skipjack Fishing

A total of 5.9 tonnes of skipjack and yellowfin were captured in eight fishing days during the two Skipjack Programme surveys of Western Samoa, an average catch of 0.74 tonnes per day. Using the conversion ratio of 3.47 (Section 2.3), the Skipjack Programme catches under commercial conditions would have been approximately 3.1 tonnes per day for the June 1978 survey and 1.6 tonnes in February 1980. The 1978 figure reflects very good fishing on one day (estimated commercial catch: 15 tonnes) as a result of one very large bait haul (Section 4.1). The result during the second survey can be mainly attributed to the poor live-bait characteristics of mollies, which were used exclusively. The estimated average commercial catch during the entire period of the Skipjack Programme was 3.5 tonnes per day.

Catches from the much smaller, Western Samoan pole-and-line vessel, the Tautai Samoa, have been as high as one tonne per day, but the average catch for 58 fishing days between July 1979 and July 1980 was about 0.28 tonnes/day (Philipp et al. 1980). When bait supplies were not a limiting factor, higher catch rates have been obtained. Fishing operations in American Samoan waters close to Western Samoa's 200-mile zone by the Anela in 1972, using bait transported from the Marshall Islands and Fiji, produced an average of 4 tonnes per day during 3 fishing days (Uchida & Sumida 1973). The Japanese pole-and-line fleet, using live bait transported from Japan, caught 5.5 tonnes of tuna per day during 11 boat days spent in Western Samoan waters (Skipjack Programme 1980a).

Since the Programme's fishing success was strongly affected by baitfish supplies in Western Samoa, the rate of sighting tuna schools is probably more informative of the abundance of surface tuna than is catch rate. A total of one hundred and twenty-six schools of tuna were sighted by the Skipjack Programme in the waters of Western Samoa during the two surveys. During the first survey 2.15 schools were sighted per hour, and during the second, the rate was 0.82 per hour. The figure for the first survey was the highest recorded anywhere in the study area by the Skipjack Programme, and the rates on both surveys of Western Samoa were higher than the average sighting rate of 0.75/hour during the entire Skipjack Programme. Most of the 37 schools identified to species were skipjack (Table 2). Yellowfin occurred in seven schools and there were occasional schools of other species, mainly rainbow runner (*Elagatis bipinnulatis*) and mackerel tuna (*Euthynnus affinis*). A large proportion (71%) of schools were not identified, and may have contained species less commercially valuable than skipjack or yellowfin.

During 26 hours of searching for tuna schools in the Samoa area in the 1950s and early 1960s, the U.S. Bureau of Commercial Fisheries spotted only one tuna school (Waldron 1964). From February to April 1970, the crew of the NMFS vessel Charles H. Gilbert observed 144 schools in the Samoa area in 31 days of spotting, an average rate of 4.6 schools per day. In four days in March and April of 1972 the crew of another NMFS vessel Anela, sighted an average of 6.2 schools per day.

The two Skipjack Programme surveys demonstrate that surface tuna may be very abundant in Western Samoa. Differences between the Skipjack Programme results and those from previous surveys undoubtedly result from differences between spotters, vessels and weather conditions, as well as variations in the numbers of tuna schools. The pattern of temporal variation in tuna abundance in Western Samoa is not known although anecdotal reports suggest that skipjack are most available between October and May (Anon. 1975). Other areas at similar latitudes in the South Pacific, such as Fiji and French Polynesia, report abundance and catches peaking in summer (Kearney 1982b; Gillett & Kearney 1983). However, the very high sighting rate in June 1978 suggests that skipjack may be abundant throughout the year in Western Samoa.

4.3 Skipjack Biology

4.3.1 Diet

Table 5 lists 22 food items found in the 33 skipjack stomachs examined by the Skipjack Programme in Western Samoa. The stomach contents were typical of those from skipjack from other tropical waters in the South Pacific Commission area. Apart from chum from the research vessel, unidentified fish, fish remains, leather jackets (Aluteridae) and surgeonfish (Acanthuridae) were the most common food items, occurring in over 20 per cent of the stomachs examined. The results in Table 5 indicate the importance of fish to the diet, but also emphasise the opportunistic nature of skipjack feeding. Analyses based on contents of all skipjack stomachs sampled throughout the entire region are currently in progress.

4.3.2 Maturity and reproduction

Female gonad maturity stages for skipjack samples from Western Samoa are shown in Figure 3. Seven stages of gonad maturity were recognised using criteria in Argue (1982), representing a progression in reproductive condition from immature (stage 1) to post-spawning (stages 6 and 7). Maturing gonads were classified as stages 2 and 3, mature gonads as stage 4 and ripe gonads as stage 5. On both visits, stage 2 and 3 gonads were predominant, with few mature fish. This distribution of maturity stages is similar to that found for 5,225 female skipjack examined by the Programme between 1977 and 1980 (Figure 3), except that no stage 6 or 7 fish were found in Western Samoa. The absence of running ripe female gonads (stage 5) is not unusual, as only two were sampled during the entire Programme.

Seasonal changes in female gonad index[1] for all Skipjack Programme samples from tropical waters suggest that skipjack spawning is most intense south of the Equator between October and March (Figure 4). This trend is very similar to that presented by Naganuma (1979) for samples collected from a wide area of the tropical south Pacific waters, and by Lewis (1981) for samples from the Papua New Guinea fishery, a few degrees south of the Equator. Skipjack sampled from Western Samoa in December 1977 and January 1978 had gonad index values (30.6 for 40-49.9 cm skipjack and 64.4 for 50-59.9 cm skipjack) similar to summer averages in Figure 4 for skipjack of these sizes.

A further index of breeding is the incidence of skipjack juveniles in the stomachs of predators (Table 6). Only one of the 66 skipjack examined from Western Samoa had skipjack juveniles in its stomach. It contained three skipjack juveniles, giving a frequency of 4.55 per 100 predator stomachs. This was among the lowest figures recorded during the entire Skipjack Programme, and may be compared to values of 25-50 juveniles per 100 predator stomachs found in Vanuatu, Wallis and Futuna or the Marquesas Islands (Argue et al. 1983). The overall average for the Programme was 10.8 in tropical waters. Argue et al. (1983) presented detailed analyses of the tuna juvenile data, taking into account size-selective predation by adults, time of day, distance from land and sampling season. Skipjack juveniles occurred most frequently in the stomachs of skipjack captured by the Programme between October and March in tropical waters south of the Equator, coinciding with the period of maximum gonad development in skipjack in these waters. The data also indicate that during the 1977 to 1980 survey period, abundance of juvenile skipjack within this region was highest in two areas, one centred approximately on Solomon Islands - Papua New Guinea - Vanuatu, and the other on the Marquesas and Tuamotu Islands. As virtually nothing is known about the movements of juvenile skipjack, the relative contributions of spawning in these areas or in local waters to

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1 Gonad index=10^7(gonad weight gm/(fish length mm)^3) (Schaefer & Orange 1956). High index values, particularly over 50, are associated with skipjack whose gonads have a high percentage of eggs that are ready to be spawned (Raju 1964).

recruitment in Western Samoa cannot be established.

4.3.3 Blood genetics and population structure

There is movement of some skipjack adults over much of the western and central Pacific (Figure B, inside back cover), suggesting that genetic exchange is possible among all parts of the Programme's study area. However, detailed examination of tag recapture data (Section 5.0) and preliminary analyses of fishery interactions (Section 5.3) indicate that the actual level of exchange of skipjack, at least of the size caught by pole-and-line gear, may be quite low. Analyses of the genetic variation in skipjack throughout the central and western Pacific were undertaken by the Skipjack Programme to provide additional information on migration, population structure, and, ultimately, potential interactions between fisheries.

Electrophoretic analyses of skipjack blood samples reveal a gradient in esterase gene frequency, a genetic marker used to infer population structure, across the tropical Pacific between approximately 120°E and 130°W (Figure 5). The esterase gene frequency for the sample taken in the waters of Western Samoa was within the 95 per cent prediction limits for the regression line of average gene frequency on longitude. There was considerable variation in individual esterase gene frequency values along this average line, although the cause of this variability was unclear (Anon. 1981).

Several models of population structure of skipjack in the Pacific Ocean have been proposed (Fujino 1972, 1976; Sharp 1978; Anon. 1981). One of these models, suggested by the Programme's tagging and blood genetics data, is called the clinal population structure model (Anon. 1981). It has the basic premise that the probability of breeding between skipjack is inversely proportional to the distance between them. Acceptance of this model implies that there are no genetically isolated skipjack subpopulations in the study area, separated by geographical boundaries, which is contrary to hypotheses advanced by Fujino (1972, 1976) and Sharp (1978).

The gradient in esterase gene frequency is consistent with several possible distributions of skipjack spawning, one being a relatively even distribution of skipjack spawning in tropical waters across the study area. Alternatively, it may be considered a product of "overlap" of skipjack from two or more centres of higher spawner density at the approximate extremes of the study area or beyond. The similarity between eastern Pacific esterase gene frequencies (east of 130°W) and those from French Polynesia suggests that skipjack from these areas may have the same genetic origin, and collectively may represent a spawning group at the eastern extreme of the study area. The geographic pattern of occurrence of juvenile skipjack in predator stomachs (Section 4.3.2) tentatively supports the latter view of skipjack spawning.

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

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

4.3.4 Growth

The growth of skipjack, as in other tunas, is a function of size. Larger fish increase in length more slowly than smaller fish (Joseph & Calkins 1969). Therefore, when a tagged fish is recovered, its increase in size depends on not only the length of time it was at liberty, but also its size when released. These considerations complicate the evaluation of growth by the analysis of tagging data. Table 8 presents a summary of size and growth information for skipjack tagged and released in the Skipjack Programme study area for each size class for which there were sufficient data. Mean size-at-release varied from 41 to 55 cm, time-at-liberty from 0 to over 300 days, and growth increments from -0.3 to 12 cm. The effects of time-at-liberty can be seen by noting the difference in growth increment between FIJ1 and FIJ2 data sets, in which the fish were released at approximately the same size but the mean times-at-liberty were different. The effects of size-at-release can be seen in the different growth increments in the PAL3 and PNG0 data, in which the fish were at liberty for approximately the same period of time but the mean sizes-at-release were different. Growth increments were in most instances quite small, and the proportion of fish which did not show any measurable growth was high (40%). There are several possible reasons for this apparent lack of growth. Firstly, the time-at-liberty may have been too short for much growth to have occurred. Secondly, skipjack may have been near their maximum size when tagged and released. Thirdly, they may have encountered conditions unfavourable for growth. Fourthly, errors in length measurement at both release and recovery may have obscured what little growth occurred.

It is possible to calculate corrections for the effects of size-at-release and time-at-liberty on the observed growth increment. These calculations used analysis of covariance and a linearised version of the von Bertalanffy growth equation, to produce a standard growth increment for an arbitrary size-at-release and time-at-liberty (Sibert et al. 1983). Standardised growth increments are presented in Table 9. Growth varied considerably from country to country, and differed significantly between visits to a country and between fish recovered inside or outside the country of release (Sibert et al. 1983). Thus, skipjack growth seems to be highly variable in time and space. The growth observed in tagged skipjack was a function of where and when the fish were tagged, and where they were recovered. It may be closely coupled to environmental conditions such as temperature and the oceanographic variables that are thought to regulate the abundance of food.

None of the skipjack released in Western Samoa was recovered with reliable information on time-at-liberty and size-at-release and -recapture. Thus, there are no data on which to make an assessment of the growth of these fish.

TABLE 8. SUMMARY OF LENGTH INCREMENTS FOR SKIPJACK TAGGED BY THE SKIPJACK PROGRAMME IN VARIOUS COUNTRIES AND TERRITORIES IN THE SKIPJACK PROGRAMME STUDY AREA. Fish were at large for periods between 10 and 365 days. Country abbreviations are explained in Appendix C.

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

* Results for skipjack tagged and released in Papua New Guinea from 1972 to 1974 (see Kearney, Lewis & Smith 1972; Lewis, Smith & Kearney 1974).

TABLE 9. STANDARDISED INCREMENTS (cm) OF LENGTH FOR FISH 50 CM LONG AT RELEASE AND AT LIBERTY FOR 90 DAYS. The 95 per cent confidence interval of each increment is given in parentheses. Country abbreviations are explained in Appendix C.

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

5.0 TAG RECAPTURE DATA

As of 10 October 1983, 23 recoveries of the 1,926 tagged skipjack (1.2%) released in the waters of Western Samoa had been notified to the Skipjack Programme. Nineteen were recovered locally, that is in Western Samoan waters, and four were recovered in the waters of other countries and territories in the central and western Pacific. Nine of the local recoveries were by Western Samoan subsistence and artisanal fishermen and three were by the Government vessel Tautai Samoa, on average 89 days after and 24 nautical miles from release. The remaining seven were recovered by the Skipjack Programme research vessel, usually on the day of release, but in one case, six days after release and approximately 13 nautical miles from the release point. Full details of each recovery of skipjack released in Western Samoa are given in Appendix B.

None of the 78 yellowfin tagged and released in Western Samoan waters has been recovered.

5.1 Skipjack Migrations

Four skipjack tagged by the Skipjack Programme in Western Samoa were recaptured in waters external to Western Samoa's EEZ, after periods of up to 700 days at liberty. One fish was recaptured in each of New Zealand, Solomon Islands, American Samoa and the Society Islands of French Polynesia, indicating movement to points east, south and west of Western Samoa. More detailed analysis of patterns of movement out of Western Samoa is precluded by the few tag recapture data and the lack of catch and effort statistics throughout much of the Skipjack Programme's study area.

Straight-line representation of movement of these four external recaptures of skipjack tagged in Western Samoa are shown in Figure 6. Also represented are selected movements into Western Samoan waters of skipjack tagged elsewhere by the Skipjack Programme. Twenty-three fish, tagged mainly in Wallis and Futuna (11), New Zealand (5) and Fiji (2), with one fish from each of American Samoa, Kiribati[2], New South Wales (Australia),

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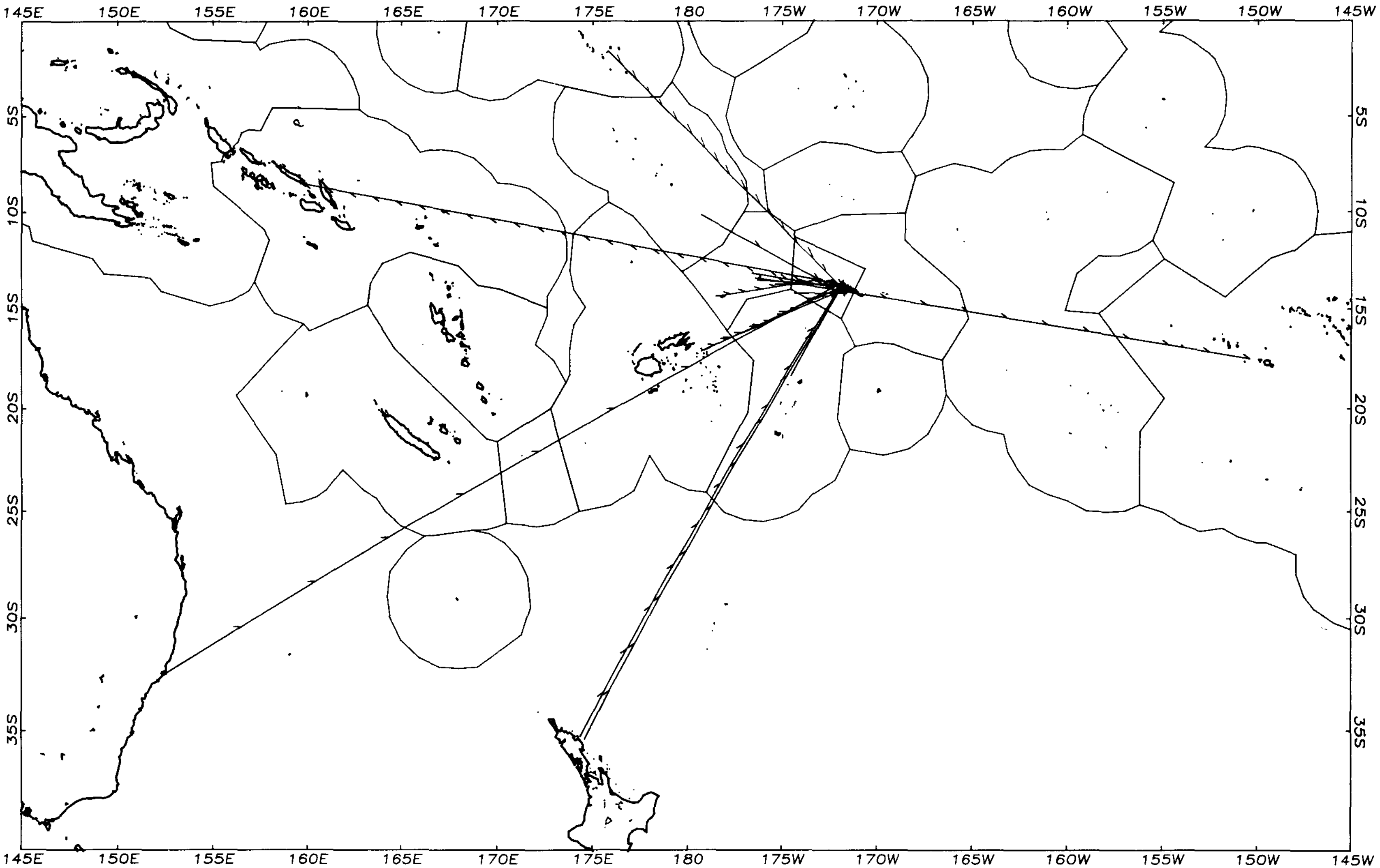
2 The recovery location of this tag was previously erroneously reported as being in American Samoan waters (Kleiber & Kearney 1983, Appendix C).

FIGURE 6. STRAIGHT-LINE REPRESENTATIONS OF MOVEMENTS OUT OF WESTERN SAMOAN WATERS OF SKIPJACK TAGGED IN WESTERN SAMOA, AND INTO WESTERN SAMOAN WATERS OF SKIPJACK TAGGED ELSEWHERE BY THE SKIPJACK PROGRAMME. The migration from Western Samoan waters to New Zealand waters is not plotted, because details of the recovery date and position are not available. Only 14 of the 23 recorded migrations into Western Samoan waters are plotted, by choosing only one example of movement in each direction between any pair of one degree squares. Tick marks on the arrows represent 30-day periods at large.



Tonga and Tuvalu, were recaptured in Western Samoan waters, all by the artisanal fishery. Thus, there is evidence that some proportion of the skipjack stock in Western Samoan waters originates in other parts of the central and western Pacific. Full details of each of these recoveries are given in Appendix B.

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

However, the impression of many wide-ranging international migrations gained from Figure B does not accurately reflect the average over all the tag recoveries. The figure overemphasises long distance, relatively rare migrations, due to the procedure used to select recoveries for the figure. The majority (86%) of tag recoveries were made less than 250 nautical miles from their release site and within 180 days of tagging (Figure 7). Long-distance migrations are prevalent only within the group of skipjack that were at large for more than 180 days.

5.2 Resource Assessment

The Programme's tag recapture data provide a basis for assessing the magnitude of the skipjack resource and its resilience to fishing pressure. A model formulated by Kleiber et al. (1983) was used to analyse tag attrition rates (the frequency of tag returns as a function of time) to derive estimates of various parameters of skipjack stock dynamics. Separate analyses were performed for the whole study area covered by the Programme and for the 200-mile zones of Papua New Guinea, Solomon Islands, the Gilbert Group of Kiribati, Fiji, New Zealand, and the Society Islands of French Polynesia, for each of which there were sufficient tag recapture statistics, as well as data on either catch or effort by fishing fleets. The absence of catch and effort data for the artisanal fishery in Western Samoa in the periods immediately following the tag releases there precludes an assessment of Western Samoa's skipjack stock. Figure 8 shows the numbers of tag returns for the whole Skipjack Programme study area versus the numbers of months these tags were at large after release. The straight line in the figure depicts the average number of tag recoveries one would predict per month from fitting the mathematical model of Kleiber et al. (1983) to the catch and tag return data.

The data points (stars) in Figure 8 deviate little from the line predicting the average number of tag returns per month. The instantaneous rate of decrease of tag returns estimated from the fitting procedure is called the tag attrition rate, which results from natural and fishing mortality, changes in vulnerability, and emigration. An additional component, presumably small, includes both continual shedding of tags and continual mortality from the effects of tagging. The estimate of attrition rate was 0.17 per month (Kleiber et al. 1983), which is similar to the rate of 0.23 estimated for skipjack stocks from the large fished area north of the Equator in the eastern tropical Pacific (Joseph & Calkins 1969).

FIGURE 7. NUMBERS OF SKIPJACK TAG RECOVERIES, BY DISTANCE TRAVELLED AND TIME-AT-LARGE, FOR THE ENTIRE SKIPJACK PROGRAMME DATA SET. Data are for tag returns received by 10 October 1983. Recaptures for 103 fish which travelled more than 1,500 nautical miles are included in the sample sizes, but are not shown in the figure.

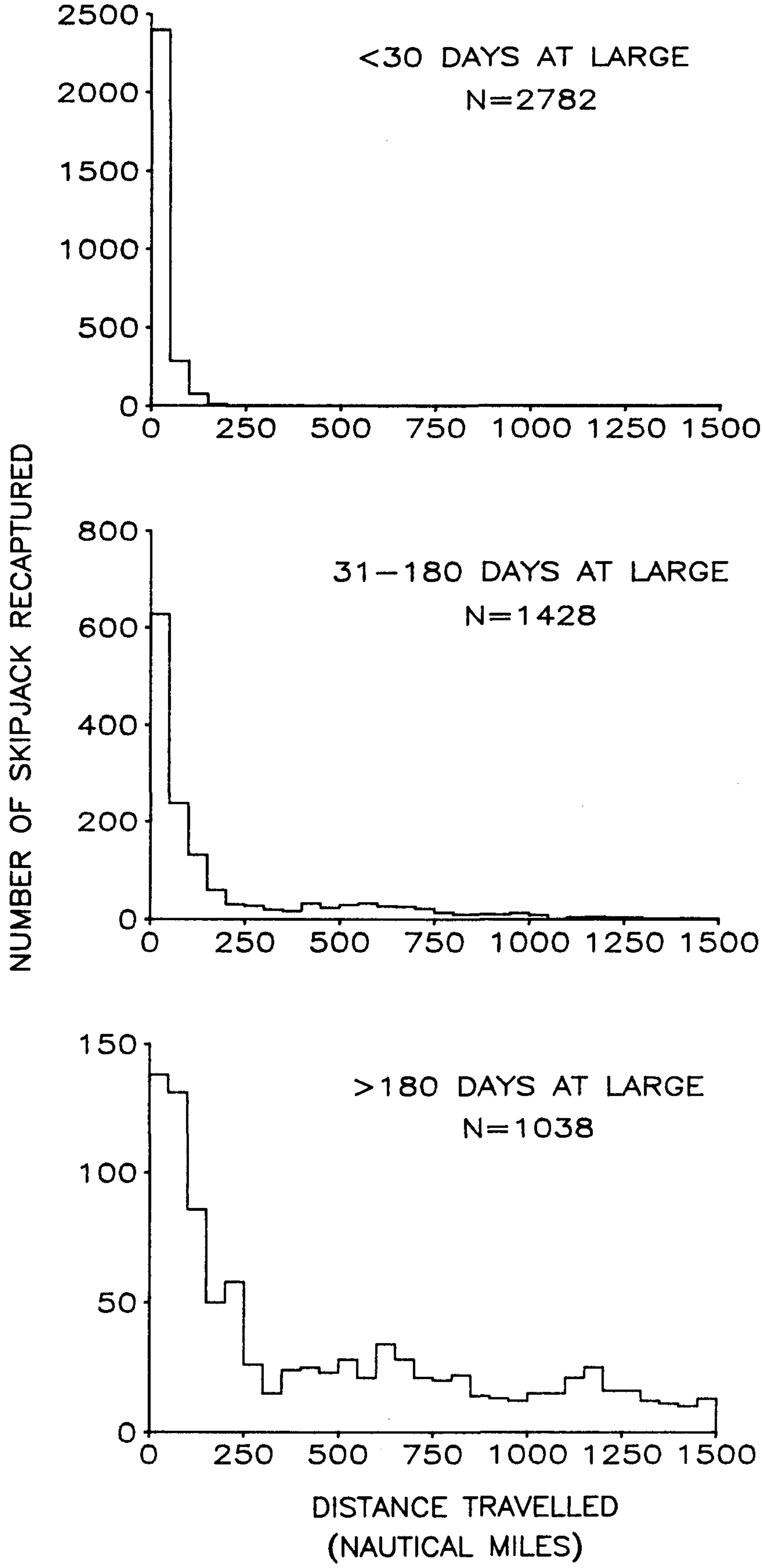
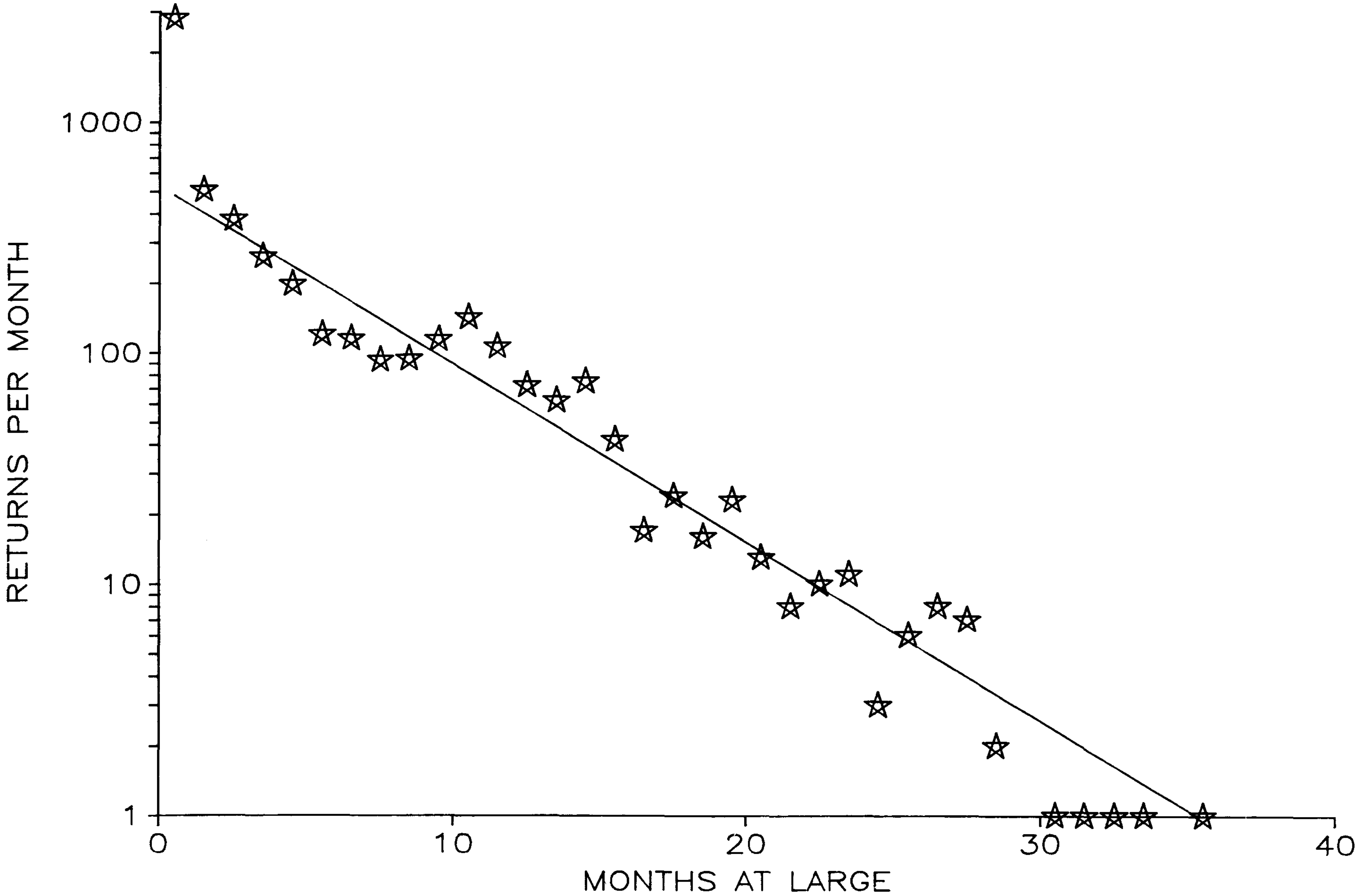


FIGURE 8. NUMBERS OF SKIPJACK TAG RECOVERIES VERSUS MONTHS AT LARGE, FOR THE ENTIRE SKIPJACK PROGRAMME DATA SET. The Y axis has a logarithmic scale.



Thus, after six months at large, close to 70 per cent of the tag releases by the Skipjack Programme were unavailable for recapture, for one or another of the reasons above, and after a year this had increased to 90 per cent. Assuming steady-state conditions in the stock, these fish were replaced by new recruits through reproduction, growth and immigration.

The model also provided estimates of several other parameters of the skipjack stock, but in doing so a correction factor was applied to account for non-return of recaptured tags, return of tags without sufficient or accurate recapture data, and loss of tags immediately after application through shedding or mortality. In the entire study area, the population size or "standing stock" which was vulnerable to surface fisheries was estimated to be approximately three million tonnes during the 1977 to 1980 study period (95% confidence range of 2.5 million to 3.7 million tonnes). Average monthly catch, in the Programme's study area, 19,000 tonnes, divided by population size, provided an estimate of average monthly fishing mortality of approximately 0.006, which is only a small proportion of the monthly attrition rate. Other losses, through natural death, decreased vulnerability to fishing and emigration are difficult to partition, but because the study area was vast and covered much of the area of skipjack distribution in central and western Pacific waters, it has been assumed that emigration is the smallest of the three.

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

The resource of skipjack in the waters of Western Samoa is obviously some small fraction of the total standing stock in the study area. Although the data for Western Samoa are insufficient to estimate the size of the local skipjack resource quantitatively, it is likely that the fishery for skipjack in the waters of Western Samoa could increase, even by as much as an order of magnitude without significantly impairing recruitment. However, a great increase in skipjack fisheries in neighbouring countries could have a detrimental impact on the quantity of skipjack available in Western Samoa (see Section 5.3).

5.3 Fishery Interactions

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

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

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

Table 10 summarises the recoveries from skipjack released throughout the total study area, by country/territory of release and recovery and offers a simple index of the degree of interaction between fisheries. However, this form of presentation takes no account of tag recovery effort, that is, the catch from which the tags were recovered. Reliable catch data are necessary for quantifying the interactions. These were available to the Programme for some locally based fisheries during the period tags were at large, but not for catches between 1979 and 1982 by the large United States and Japanese distant-water purse-seine fisheries and the Japanese distant-water pole-and-line fishery. These fisheries operate in much of the western Pacific and over the period of tag recoveries they accounted for a significant percentage (~20%) of Skipjack Programme tag returns. Until the Programme receives catch data from these fisheries, accurate estimates of interaction between distant-water and locally based fisheries cannot be made.

The Skipjack Programme has calculated coefficients of interaction in at least one direction for as many pairs of countries and territories in the South Pacific Commission region as possible with the available data. A selection of the results are shown in Table 11, including figures for interactions due to fish migrating from New Zealand and Fiji. These figures have been calculated using data for the New Zealand, Fiji and Western Samoan fisheries given in Argue & Kearney (1983). They indicate relatively low levels of interactions between the Western Samoan fishery and those operating in New Zealand and Fiji. Many of the other coefficients shown in Table 11 were similarly small, with over half of them less than 2 per cent, but they span a wide range, from less than 0.1 per cent for movements from Kiribati to the Federated States of Micronesia to 37 per cent for movements from the Federated States of Micronesia to the

TABLE 10. **SUMMARY OF SKIPJACK RELEASE AND RECOVERY DATA FOR THE ENTIRE SKIPJACK PROGRAMME, AS OF 10 OCTOBER 1983.** Releases and recoveries are arrayed by tagging or recovery location, usually a country or territory except in cases where smaller geographical divisions were more informative; abbreviations are explained in Appendix C. Not included in the table are returns for which the country or area was unknown.

COUNTRY OF RECAPTURE

NUMBER OF RELEASES BY COUNTRY

		AMS	CAL	FIJ	GIL	GUM	HAW	HOW	IND	INT	JAP	KOS	LIN	MAQ	MAR	MAS	MTS	NAU	NCK	NOR	NSW	PAL	PAM	PHL	PHO	PNG	PON	QLD	SOC	SOL	TOK	TON	TRK	TUA	TUV	VAN	WAK	WAL	WES	YAP	ZEA	TOT
775	AMS	3																																					1			4
10219	CAL		18		1					2					1											2	2			10			1									37
20094	FIJ		1	1948	1					5								1							4				1			2			6		1	2	2		3	1977
174	GAM																																									
4569	GIL	1			385			24		32		1	1			14		1					2		1		1															463
108	JAP				1				2	3	7				1	1																										15
297	KOS									3						2																										5
20282	MAQ				1			1		4				42											1				1													50
195	MAR									2	1				2		1										1						2									9
327	MAS									2						1		1																								4
1229	NCK																		1																							1
91	NIU																																									
1113	NOR		2	1																										1												4
4322	NSW	1	6	2						1											2								1	8									1		9	31
7233	PAL				3				28	69		3			1	6						108		6		77	9			2			23							31		366
367	PHO				1																																					1
59	PIT																																									
8550	PNG				1	1		5	7	18		1				7						2	2			958	3	1		26			11							3		1046
5518	PON				1			2		17	2	23			1	30								1		1	113			1			13							10		215
2651	QLD		3																									2		25			1			2						33
48	SCK																																									
1725	SOC																												36													36
6221	SOL			1	1				1	2																16				526												547
64	TOK																														1											1
1969	TON																								1				1			10							1			13
1054	TRK									4		5				5											19						16							2		51
5528	TUA																												5					25								30
2904	TUV			2	2		1	1		7		1				4		1					1		1	1				2					2				1	1		28
1254	VAN																									1				4						2						7
16065	WAL		1	14	5			5		11						3									24	2			3				1		1			66	11		6	153
1926	WES	1																											1	1									19		1	23
778	YAP				2				3	7	1				3							1					1						3							5		26
12734	ZEA		5	31						3										1	2								5		1	1			1	1			5		1003	1059
140443	TOT	6	36	1999	405	1	1	38	41	192	11	34	1	42	9	73	1	4	1	1	4	111	5	7	32	1058	149	3	54	606	2	13	71	25	10	5	1	68	41	52	1022	6235

TABLE 11. COEFFICIENTS OF INTERACTION BETWEEN FISHERIES OPERATING IN VARIOUS COUNTRIES AND TERRITORIES IN THE CENTRAL AND WESTERN PACIFIC (from Kleiber, Sibert & Hammond ms.) Country abbreviations are explained in Appendix C. The numerals following country codes indicate tag release data sets from separate visits to the same country.

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

a assuming β_r=0.76 and T_d=7300

b assuming β_r=0.76

c local pole-and-line fishery

d Japanese pole-and-line fishery

e local purse-seine fishery

f local artisanal and subsistence fishery

Marshall Islands. Most of those omitted from the selection in Table 11 were also very low, from 0.1 to 1.0 per cent (e.g. Argue & Kearney 1982; Tuna Programme 1984). Thus, with very few exceptions, interactions at the time of tagging were quite low, at least between the particular fisheries listed in Table 11. Developments in these areas since then may have already altered the levels of interaction. It should also be noted that these results apply only to skipjack of the size tagged by the Programme (mostly >45 cm). Skipjack smaller than this could very well move large distances and contribute significantly to interactions between stocks in the fished areas.

Fishery interactions increase as the distance between fisheries decreases. If fisheries in neighbouring countries expand their areas of operation to include waters adjacent to common borderlines, the degree of interaction may increase. Furthermore, if different gear types were to operate in the same area, such as purse-seine and pole-and-line fleets working in the same or nearby fishing grounds of a country, then the degree of interaction would be much higher than present figures indicate. The tagging data indicate some exchange of fish between Western Samoa and its neighbours, especially Wallis and Futuna, showing the need to monitor fisheries developments in areas adjacent to Western Samoa.

6.0 CONCLUSIONS

Bouki-ami catches by the Skipjack Programme confirm that the live bait resources of Western Samoa are small, and probably inadequate to support more than occasional pole-and-line fishing by small vessels. These results are consistent with those from previous baitfish surveys by other agencies.

Surface schooling tuna are apparently abundant in Western Samoan waters. Both the school sighting rate and, when live bait was available, the catch rate during the Skipjack Programme surveys were much higher than the average recorded by the Programme. Moreover, they were achieved during mid-winter (June), when the abundance of surface tuna in waters adjacent to Western Samoa is thought to be relatively low. Unfortunately the low number of tag returns and lack of catch statistics between 1979 and 1981 precluded an assessment of the size of the skipjack resource in Western Samoan waters. However, extrapolating from analyses for the entire Skipjack Programme study area in the central and western Pacific, Western Samoa's EEZ is likely to support much larger catches than presently are being made.

Techniques such as trolling and gill-netting around FADs appear to be effective alternatives to live-bait pole-and-line operations, for artisanal or small-scale, locally based commercial operations. Another technique which does not depend on live bait is purse-seining, which has become a very efficient and successful method of harvesting tuna in the central and western Pacific in the last few years. Licensing of foreign vessels may present an opportunity to generate revenue through a large-scale commercial fishery in Western Samoa; proximity to canning and port facilities in American Samoa would favour such a development. However, if large-scale operations such as purse-seining are established in the future, careful monitoring of the performance of the various types of vessels and of the underlying resource base, perhaps through further tagging studies, will be essential. Since the Western Samoan EEZ is relatively small, interaction between the artisanal fishery and any large-scale commercial fishery will occur.

No estimates of interaction between skipjack stocks in Western Samoan waters and those in other areas could be made, but tag recapture studies confirm that there is exchange with adjacent areas. Since interactions will increase as catches increase and distance between fisheries decreases, fisheries in Western Samoa and adjacent regions should be monitored closely for evidence of interaction.

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

South Pacific Commission Scientists

Jean-Pierre Hallier	6-14 June 1978 22-27 February 1980
Desmond Whyman	6-14 June 1978
Charles Ellway	6-14 June 1978
A.W. Argue	22-27 February 1980
James Ianelli	22-25 February 1980

Observers

Savali Time Fisheries Officer Western Samoa	25-27 February 1980
Dan Popper Food and Agriculture Organization	25-27 February 1980

Japanese Crew Cruise One

Masahiro Matsumoto, Captain
Ryoichi Eda
Sakae Hyuga
Yoshihiro Kondoh
Yoshio Kozuka
Yoshikatsu Oikawa
Akio Okumura
Kohji Wakasaki
Mikio Yamashita

Japanese Crew Cruise Two

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

Fijian Crew Cruise One

Eroni Marawa
Lui Andrews
Vonitiese Bainimoli
Mosese Cakau
Samuela Delana
Lui Diva
Kitione Koroi
Jone Manuku
Jona Ravasakula
Ravaele Tikovakaca
Samuela Ue
Taniela Verekila

Fijian Crew Cruise Two

Ravaele Tikovakaca
Lui Andrews
Samuela Delana
Eroni Dolodai
Luke Kaidrokai
Veremalua Kaliseiwaga
Metuisela Koroi
Aminiasi Kurugawa
Kitione Naivaurerega
Jona Ravasakula
Napolioni Ravitu
Samuela Ue

APPENDIX B. TAG AND RECOVERY INFORMATION FOR EACH TAGGED SKIPJACK WHICH MADE A MIGRATION OUT OF OR INTO WESTERN SAMOA'S 200-MILE EXCLUSIVE ECONOMIC ZONE. A list at the end of this appendix gives the meanings of the codes used. The inset lines present release data as follows: country abbreviation (see Appendix C); school number; year/month/day of release; time of release; latitude of release; longitude of release; numbers of tagged skipjack released; numbers of tagged yellowfin released; numbers of species other than skipjack and yellowfin that were tagged and released. Line(s) following that for release data present the following data for each tag recovery: species, S for skipjack, Y for yellowfin; recovery country abbreviation (see list); year/month/day of recovery; days at large; recovery latitude; recovery longitude; great circle distance in nautical miles between release and recovery location; fork length in millimetres at time of tagging and length credibility code (see list); fork length at recovery and credibility code (see list); tag number; nationality of recapture vessel (or country chartering vessel), and tag recovery gear (see list). Date or position of recovery was excluded if the range of possible values was more than half the span from the release date or release position to the midpoint of the range of possible recovery dates or positions. If the range was less than half of this span, the information was included and the date or position of recovery was taken to be the midpoint of the range.

<u>Migrants from the waters of Western Samoa to other areas</u>

```
      WES 239 780608 1315 1348S 17128W  118   22    0

S WES 780614 006 1342S 17145W 0018 475M    U SK20147 SPCPOL

      WES 241 780614 1000 1342S 17145W 1637   56    0

S WES 780614 000 1342S 17145W 0000 500M 500A SF01186 SPCPOL
S WES 780614 000 1342S 17145W 0000 470M    U SF01221 SPCPOL
S WES 780614 000 1342S 17145W 0000 485B 510A SF01351 SPCPOL
S WES 780614 000 1342S 17145W 0000 460M 460A SF00896 SPCPOL
S WES 780614 000 1342S 17145W 0000 470M    U SF00853 SPCPOL
S WES 780623 009 1350S 17137W 0011 440M 440E SK20977 WESSUB
S WES 780624 010 1403S 17126W 0028 485B 500E SF01405 WESSUB
S WES 780628 014 1345S 17155W 0010 480M 480E SK20556 WESSUB
S ZEA                              520M    U SK20706 ZEASEN
S WES 780628 014 1351S 17230W 0045 485B 480E SF01325 WESSUB
S WES 780705 021 1405S 17142W 0023 510M 503E SK20784 WESSUB
S WES 781008 116 1405S 17148W 0023 485B 500E SF00839 WESSUB
S WES 781014 122 1350S 17137W 0011 485B    U SK20252 WESSUB
S WES 781121 160 1351S 17135W 0013 480M 513E SK20489 WESSUB
S AMS 790124 224 1420S 17037W 0076 485B 513W SF00878 AMSART
S WES 790510 330 1356S 17157W 0018 480M 540E SK20401 WESSUB
S SOL 800514 700 0830S 16000E 1691 475M 580W SK20351 SOLPOL
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WES 782 800226 1715 1406S 17124W 60 0 0

S WES 800506 070 1340S 17144W 0032 460Q 530E 2B21579 WESPOL
S SOC 801219 297 1730S 15010W 1242 460M 590E 2B21565 POLSHE

WES 783 800226 1800 1410S 17124W 90 0 0

S WES 800226 000 1410S 17124W 0000 470M 473A 2B23026 SPCPOL
S WES 800430 064 1340S 17144W 0036 370M 520E 2B23010 WESPOL
S WES 800430 064 1340S 17144W 0036 460M 525E 2B23002 WESPOL

Migrants from other areas to the waters of Western Samoa

AMS 777 800221 1415 1420S 16923W 610 0 0
S WES 800415 054 1404S 17126W 0120 540M 560E 2B21236 WESSUB

FIJ 161 780402 1609 1704S 17854W 389 0 0
S WES 780824 144 1350S 17137W 0464 500M 560E SD00632 WESSUB

FIJ 168 780405 0630 1706S 17903W 236 2 0
S WES 790209 310 1403S 17142W 0462 515M 500E SD02264 WESSUB

* KIR 272 780705 1500 0217S 17541E 291 0 0
S WES 791214 527 1325S 17223W 1064 470M 550E SK23573 WESSUB
NSW 522 790421 1020 3227S 15246E 33 0 0
S WES 800112 266 1344S 17150W 2237 460M 510E SK09902 WESSUB

TON 182 780425 0955 1820S 17416W 144 23 0
S WES 780614 050 1405S 17150W 0291 480M 510E SE00366 WESSUB

TUV 250 780625 1645 1008S 17905W 180 0 0
S WES 780814 050 1330S 17250W 0419 516B 500K SK22104 WESSUB

WAL 207 780515 1035 1309S 17622W 410 0 0
S WES 780722 068 1347S 17237W 0222 600M 680J SK12564 WESSUB

WAL 211 780516 1215 1325S 17609W 263 0 0
S WES 780814 090 1330S 17250W 0194 500M 500K SK13686 WESSUB

WAL 212 780516 1350 1330S 17605W 768 0 0
S WES 780726 071 1350S 17137W 0261 490M 520E SK14204 WESSUB

WAL 214 780517 1150 1329S 17607W 1034 0 0
S WES 780712 056 1350S 17205W 0236 500M U SK15048 WESSUB

WAL 215 780518 0850 1331S 17605W 742 0 0
S WES 780831 105 1354S 17130W 0268 540M 570E SE02274 WESSUB

WAL 216 780518 1105 1334S 17612W 293 0 0
S WES 780815 089 1350S 17137W 0268 540M 550E SE02446 WESSUB

WAL 217 780519 0735 1324S 17610W 363 26 0
S WES 780829 102 1403S 17137W 0268 514B U SE02530 WESSUB

```
        WAL 219 780519 1030 1330S 17605W 1028    0    0

S WES 780824 097 1405S 17140W 0260 500M 525E SE03722 WESSUB
S WES 781024 158 1405S 17142W 0258 520B 540E SE03446 WESSUB

        WAL 223 780520 1030 1315S 17620W 1565    0    0
S WES 780728 069 1327S 17242W 0212 510M    U SK16143 WESSUB

        WAL 873 800522 1545 1420S 17816W  477   42    0
S WES 801203 195 1329S 17241W 0329 450M 565E 1E10095 WESSUB

        ZEA 431 790222 1835 3520S 17448E  967    0    0
S WES 791227 308 1410S 17150W 1460 450M 510E SB04229 WESSUB

        ZEA 435 790227 1715 3513S 17435E  533    0    0
S WES 800130 337 1400S 17150W 1469 470M 520E SB04786 WESSUB

        ZEA 439 790302 1300 3527S 17452E  700    0    0
S WES 791229 302 1348S 17146W 1486 480M 520E SK01445 WESSUB

        ZEA 464 790320 0810 3547S 17520E  976    0    0
S WES 800109 295 1404S 17126W 1485 450M 520E SH09846 WESSUB

        ZEA 796 800323 1230 3531S 17450E 1058    0    0
S WES 810221 335 1340S 17140W 1500 490M 545E 1B19194 WESART
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* The recovery location of this tag was previously erroneously reported as being in American Samoan waters (Kleiber & Kearney 1983, Appendix C).

CODES FOR LENGTH MEASUREMENTS, RECAPTURE GEARS AND COUNTRY ABBREVIATIONS

Release Length Credibility

M	Measured
B	Estimated from Biological Data
T	Estimated from Tagging Data
G	Guessed
U	Unknown
Q	Length Questionable

Recapture Length Credibility

A	Measured by SPC staff on research vessel
B	Measured by local joint ventures
C	Measured by Japanese long-range boats, or long-liners of other nationalities
D	Measured by other supposedly reliable sources

E	Measured by unreliable sources
W	Measured length verified by weight
J	Estimated from weight
K	Estimated from other sources (string, etc.)
U	Unknown

Nationality of Recapture Vessel (Country Abbreviations)

AMS	American Samoa
CAL	New Caledonia
FIJ	Fiji
IND	Indonesia
INT	International waters
JAP	Japan
KIR	Kiribati
KOR	Korea
NOR	Norfolk Island
NSW	New South Wales (Australia)
PAL	Palau
PHL	Philippines
PNG	Papua New Guinea
POL	French Polynesia
PON	Ponape (Federated States of Micronesia)
QLD	Queensland (Australia)
SOC	Society Islands (French Polynesia)
SOL	Solomon Islands
TAW	Taiwan
TOK	Tokelau
TON	Tonga
TUV	Tuvalu
USA	United States
VAN	Vanuatu
WAL	Wallis and Futuna
WES	Western Samoa
ZEA	New Zealand

Type of Recapture Vessel

SEN	Purse-seine
POL	Pole-and-line
LON	Longline
SHE	Pearl-shell trolling
ART	Artisanal
GIL	Gill net
REC	Recreational (sport fishing)
SUB	Subsistence (village)
UUU	Unknown

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

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