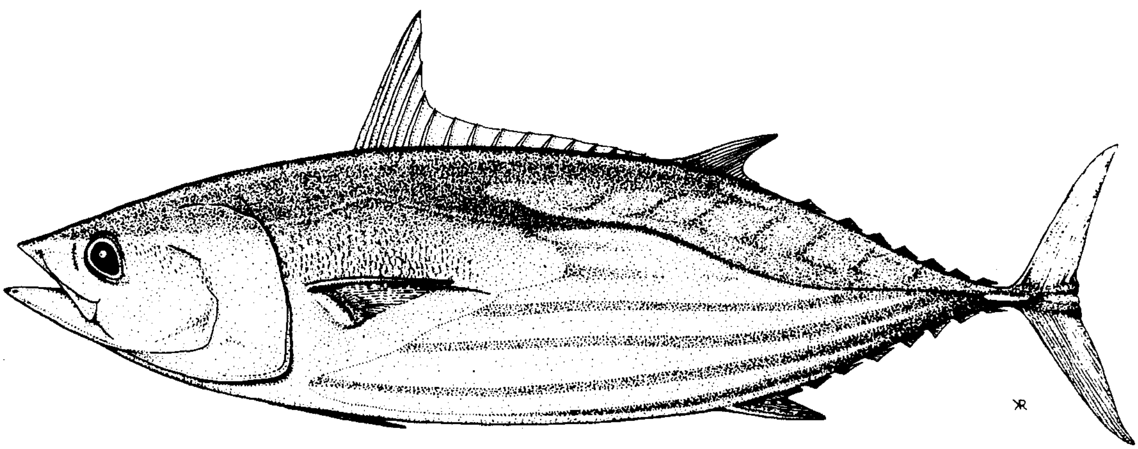
AN ASSESSMENT OF THE SKIPJACK AND BAITFISH RESOURCES OF PITCAIRN ISLANDS

A.W. Argue
and
R.E. Kearney



Skipjack Survey and Assessment Programme
Final Country Report No. 4

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. Governments which provided funding for the Programme were Australia, France, Japan, New Zealand, United Kingdom and the United States of America.

The Skipjack Programme has been succeeded by the Tuna and Billfish Programme which is receiving external funding from Australia, France, New Zealand and the United States of America. The Tuna Programme is designed to improve understanding of the status of the stocks of commercially important tuna and billfish species in the region. Publication of final results from the Skipjack Programme is continuing under the Tuna Programme. Papers referred to as manuscripts in this final country report will be released over the duration of the Tuna Programme.

The staff of the 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. Farman, R.D. Gillett, P.M. Kleiber, W.A. Smith and M.J. Williams; Research Assistants, Susan Van Lopik and Veronica van Kouwen; and Programme Secretary, Carol Moulin.

The Programme's survey in the waters of Pitcairn Islands was both enjoyable and productive, and benefitted substantially from assistance that the scientists and crew received from Pitcairn Island residents, in particular from Ivan and Steve Christian. Mr Garth Harraway, Commissioner for Pitcairn Islands, accompanied us on our return through the waters of French Polynesia during which time he patiently answered many questions on the history of Pitcairn Islands.

The Skipjack Programme is grateful to the Inter-American Tropical Tuna Commission for contributing staff and funds to the survey of Pitcairn Islands.

Tuna Programme
South Pacific Commission

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AN ASSESSMENT OF THE SKIPJACK AND BAITFISH RESOURCES OF PITCAIRN ISLANDS

1.0 INTRODUCTION

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

The Skipjack Programme carried out 847 days of tagging and survey operations in the central and western Pacific between October 1977 and August 1980. The total study area included all of the countries and territories in the area of the South Pacific Commission and also New Zealand and Australia (Figure A). The Programme surveyed the waters of Pitcairn Islands between 3 and 5 February 1980, which marked the first and, to date, only visit by officers of the South Pacific Commission to Pitcairn Islands. This report summarises results from the Pitcairn Islands survey and relates these results to those for the region as a whole.

1.1 Pitcairn Islands

Pitcairn Island is located in subtropical waters 1,166 nautical miles southeast of Tahiti at 25°S latitude and 130°W longitude. Pitcairn Island became a British dependency on 29 November 1838 (Nicolson 1965). Oeno atoll, 65 nautical miles northwest of Pitcairn Island, Ducie atoll, 254 nautical miles east of Pitcairn Island, and Henderson Island, an upraised limestone atoll 91 nautical miles east-northeast of Pitcairn Island, were annexed by Great Britain in 1902 and were included in the dependency in 1938 (Carter 1981). Together these four islands constitute the colony of Pitcairn Islands. These islands have a combined land area of less than 10 square kilometres, but the recently declared (1980) 200-mile fisheries zone surrounding these islands encompasses approximately 800,000 square kilometres (Sevele and Bollard 1979).

Pitcairn Island is the second largest of the four islands with a land area of approximately 450 hectares. As at the latest census on 31 December 1981, the population of Pitcairn was 47 islanders, most of whom are descendants of the Bounty mutineers, and 7 non-islanders (Whiting 1981a). The other islands are uninhabited although Pitcairn islanders visit Oeno atoll every few years for recreational outings, and visit Henderson Island to gather miro (Thespesia populnea) which is a timber specially suited for wood carving. The nearest inhabited islands are those of the Gambier Group in French Polynesia, approximately 600 nautical miles west-northwest of Pitcairn Island.

The number of ships calling at Pitcairn has declined in recent years; 31 vessels called in 1981 (Whiting 1981), 52 in 1972, and 65 in 1965 (British High Commission, Wellington - unpublished information). There are four scheduled calls each year by supply ships travelling between New Zealand and Panama. The islanders must launch their diesel-powered long boats with great skill from the small beach at Bounty Bay in order to ferry goods to and from the supply ships. Weather permitting, the islanders meet all visiting ships in their long boats in order to sell handicrafts, local agricultural products and stamps. Sales of stamps represent the main source of revenue for Pitcairn Islands; they totalled NZ$828,440 for the 1980/81 financial year (British High Commission, Wellington - unpublished information).

1.2 Tuna Fishing

Fishing by residents of Pitcairn Island for recreation and food is done mostly from shore, and on calm days from the long boats. At the time of the Skipjack Programme survey the Island Magistrate reported that local tuna catches in 1979 totalled one skipjack and about 20 yellowfin (*Thunnus albacares*). He indicated that the season for tunas was from April to November, which is, surprisingly, the period of lowest ocean temperatures. Tunas constitute a small percentage of the local catch since most fishing is from rocks or close to shore, somewhat removed from the tuna's preferred habitat in deeper waters.

The Japanese distant-water pole-and-line fleet does not operate in the waters of Pitcairn Islands; however, Japanese longline vessels have fished these waters in every year for which the Skipjack Programme has data, 1962 to 1977, as have Taiwanese longline vessels, 1967 to 1977 (Klawe 1978, Skipjack Programme 1981). Over three-quarters of Japanese longline effort occurs between September and January, with November and December being the peak months. By comparison, Taiwanese longline effort is evenly distributed throughout the year. These fleets take very few skipjack, which is to be expected with longline gear. Bigeye tuna, *Thunnus obesus*, accounted for 43 per cent of the average annual Japanese catch of 405 tonnes (1972-1976), followed by several species of billfishes totalling 39 per cent of the catch, and then yellowfin and albacore (*T. alalunga*) each at nine per cent of the Japanese catch (Klawe 1978). Klawe reports an average annual catch of 489 tonnes for Taiwanese longline vessels for the same period; however, their catch is dominated by albacore (76%), followed by bigeye (13%), billfishes (7%) and then yellowfin (4%). The different species composition for these fleets probably reflects the depth at which their longline gear operates (bigeye tending to be taken by deeper fishing gear) and differences in seasonal distribution of fishing effort. Korean longline vessels, for which only 1975 and 1976 data were available to Klawe, caught 102 tonnes of mainly albacore (54%) and bigeye (30%) from the waters of Pitcairn Islands in 1976.

2.0 METHODS

2.1 Vessel 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 254-tonne *Hatsutori Maru No.5* was used during the survey of Pitcairn Islands.

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

2.2 Fishing, Tagging and Biological Sampling

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

The number of crew on the Hatsutori Maru No.1 and No.5 was less than either of these vessels carry when fishing commercially. The effective number of fishermen was further reduced because at least one crew member was required to assist each scientist in the tagging procedures. Moreover, the need to pole tuna accurately into the tagging cradles reduced the speed of individual fishermen. Clearly these combined effects would decrease the fishing power of the research vessel. During the first survey in the waters of Fiji (26 January to 10 April 1978), the Hatsutori Maru No.1 fished commercially for approximately one month, under an agreement between the Programme and the vessel's owners. From comparison of survey and commercial catches at this time, it was estimated that the fishing power of the Hatsutori Maru under survey conditions was 28 per cent of its fishing power during commercial fishing (Kearney 1978).

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

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

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

Beginning in December 1979, body cavities of skipjack were examined for the presence of macro-parasites and complete sets of gills and viscera were taken from five fish from each school (up to a maximum of three schools per day), frozen, and subsequently air freighted to the University of Queensland, St Lucia, Australia, for detailed examination for the presence of parasites.

2.3 Baitfishing

Most baitfishing activity was carried out at night using fish attraction lights and a "bouki-ami" net. In some countries, beach seining during daylight hours supplemented night catches (Hallier and Gillett 1982). Neither method was attempted in the waters of Pitcairn Islands. However, the vessel carried a large amount of cultured milkfish, *Chanos chanos*, kindly provided by the Service de la Pêche, French Polynesia, from their baitfish ponds on Rangiroa atoll.

2.4 Data Compilation and Analysis

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

Assessment of the skipjack resource and possible interactions among skipjack fisheries were approached from several viewpoints. Studies of the migration of tagged skipjack, using analytic techniques described in Skipjack Programme (1981a) and Kleiber (MS), have formed the basis of investigations of movement patterns, fishery interactions and population dynamics. Methods employed in biological studies of growth are described in Lawson and Kearney (MS), and for juvenile abundance, in Argue, Conand and Whyman (MS). Argue and Hallier (MS) describe procedures used to compare fishing effectiveness between different baitfish families. Evaluation of population structuring across the whole of the western and central Pacific has centred on a comparison of the blood genetics work with tagging results (Anon 1980, 1981; Skipjack Programme 1981c). Occurrence and distribution of skipjack parasites has also been evaluated (Lester 1981).

3.0 SUMMARY OF FIELD ACTIVITIES

Fishing activities, including school sightings, tag releases, and catches are summarised in Table 1 for the Pitcairn Islands survey area which is shown by Figure 1. While in the waters of Pitcairn Islands the Hatsutori Maru No.5 carried more than 600 kg of cultured milkfish. An average of 10.2 hours per day were spent searching and fishing over a two and one-half day period. During this period a total of 14 schools were sighted for an average of 0.55 schools sighted per hour, which is below the overall Programme average of 0.77 schools per hour. Of ten identified schools, five had some skipjack and seven had some yellowfin. When catches were taken into account, yellowfin appeared more abundant overall.

A total of 191 kg of skipjack, 2,551 kg of yellowfin and 20 kg of other tunas were caught with pole-and-line gear, 2,762 kg in all. This gives an average of 1,105 kg per fishing day, slightly above the overall Programme average of 987 kg per day. However, the vessel carried a large supply of cultured bait so bait was not a limiting factor in the waters of the Pitcairn Islands, as it often was in other parts of the study area. Tag releases totalled 349, predominantly (83 per cent) yellowfin. Most tag releases were near Pitcairn Island.

A summary of fish sampled for biological data is given in Table 2. The size distribution for 53 of the 59 tagged skipjack (Figure 2 upper) shows a range of 44 to 59 cm. The average length was 51.6 cm, slightly larger than the average of 50.4 cm for all skipjack tagged during the Programme (Figure 2 lower). Some of the largest yellowfin captured by the Programme were released with tags in the waters of Pitcairn Islands (Figure 3 upper). Their average length was 65.7 cm, over 10 centimetres longer than the average of 54.1 cm for all yellowfin that were tagged by the Programme (Figure 3 lower). A single skipjack blood sample of 53 specimens was taken on 5 February 1980 approximately 60 nautical miles southeast of the Gambier Islands, soon after the vessel had left the waters of Pitcairn Islands.

TABLE 1. SUMMARY OF DAILY FIELD ACTIVITIES IN THE WATERS OF PITCAIRN ISLANDS. 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; 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	UN	SJ	YF	OT	SJ	YF	
03/02/80	Oeno to Pitcairn	Fishing	747	10.5	0	0	1	4	10	33	0	24	97	126
04/02/80	Pitcairn	Fishing	710	10	0	2	4	3	49	257	0	167	2454	2635
05/02/80	Pitcairn to Gambier	Fishing	633	5	0	0	0	0	0	0	0	0	0	0
TOTALS				25.5		2	5	7	59	290	0	191	2551	2761

FIGURE 1. SURVEY AREA FOR THE 1980 SKIPJACK PROGRAMME VISIT TO THE WATERS OF PITCAIRN ISLANDS

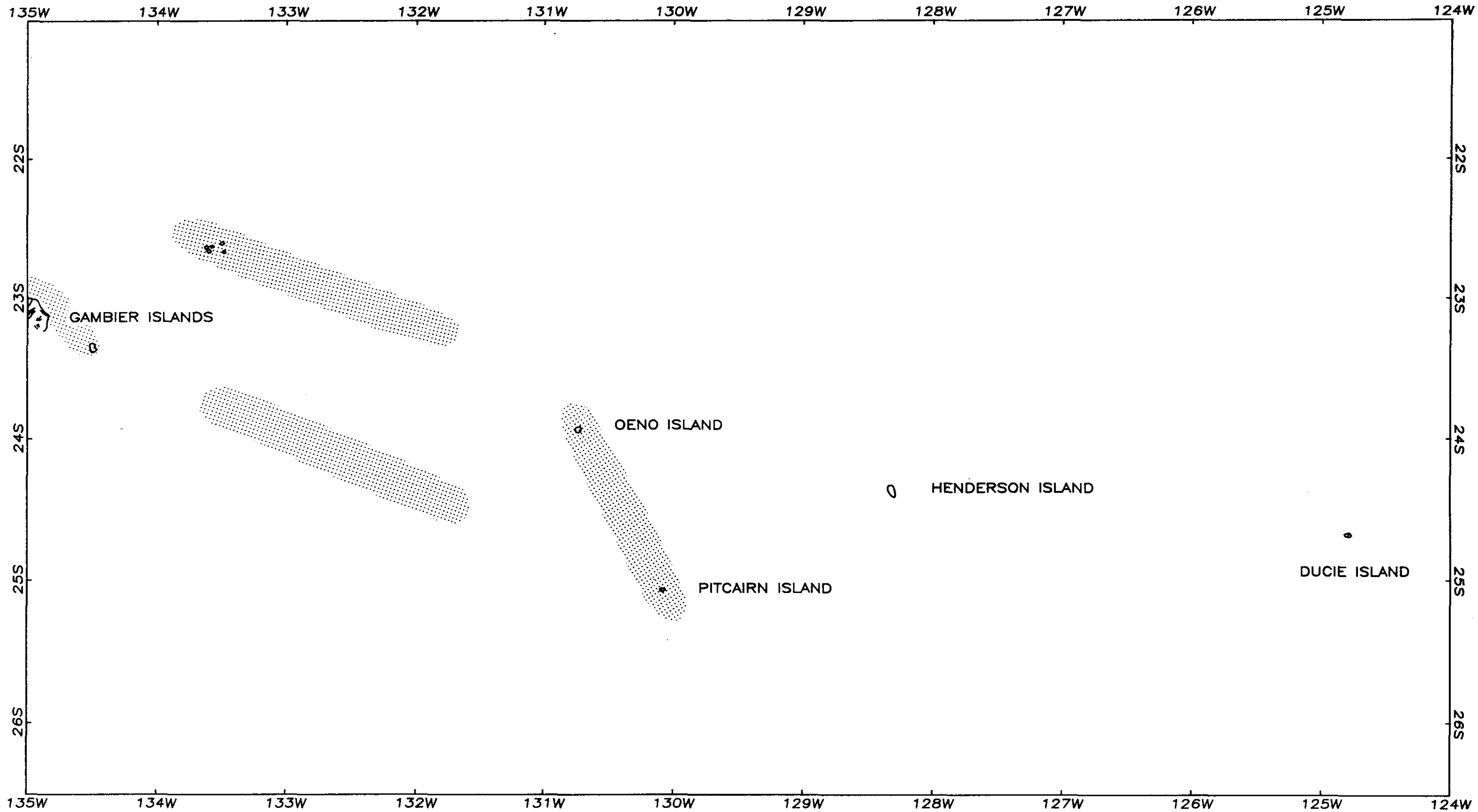

FIGURE 2. LENGTH FREQUENCY DISTRIBUTION FOR TAGGED SKIPJACK FROM PITCAIRN ISLANDS (UPPER GRAPH) AND FOR THE TOTAL SKIPJACK PROGRAMME STUDY AREA (LOWER GRAPH). N is the sample size.

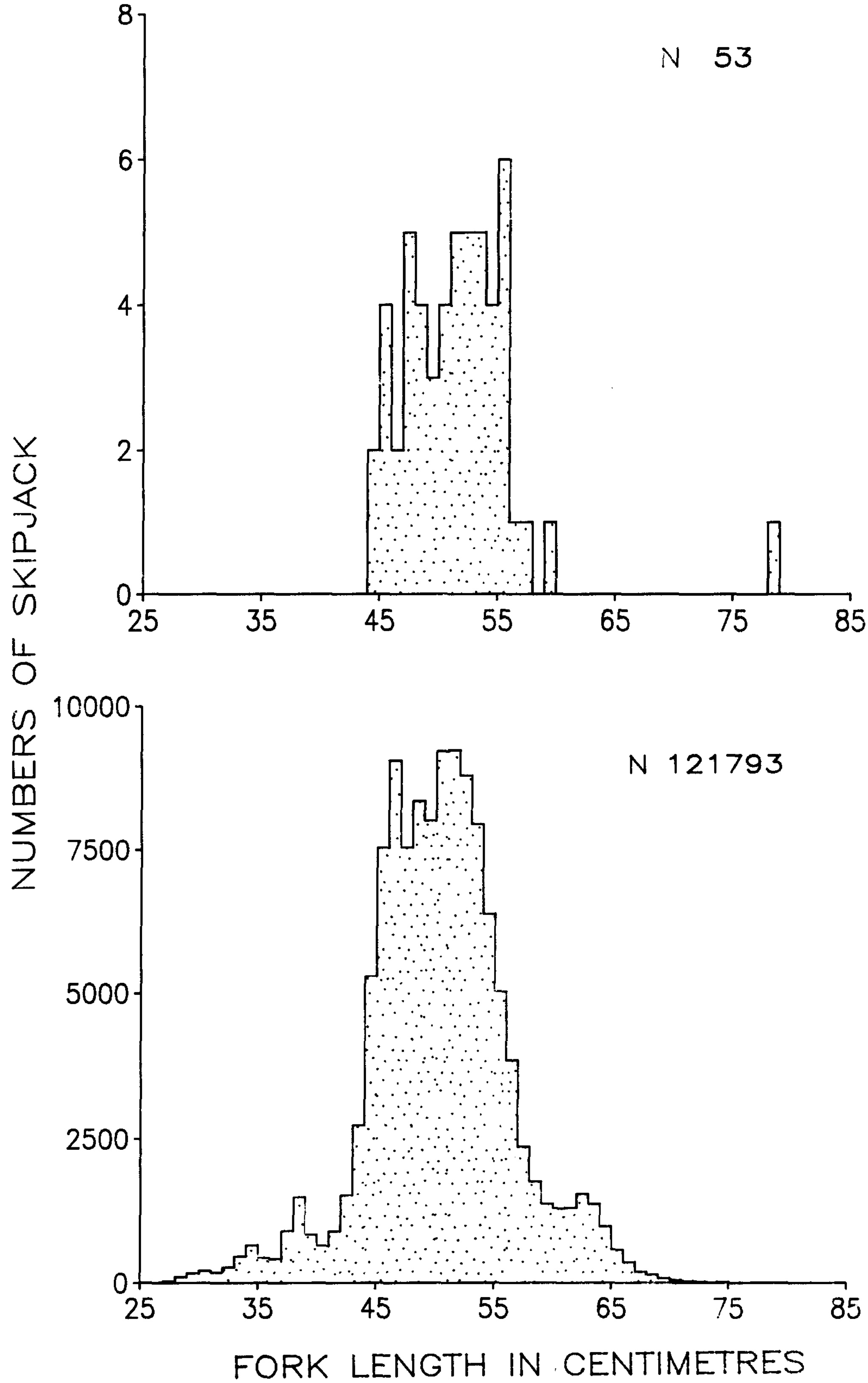

FIGURE 3. LENGTH FREQUENCY DISTRIBUTION FOR TAGGED YELLOWFIN FROM PITCAIRN ISLANDS (UPPER GRAPH) AND FOR THE TOTAL SKIPJACK PROGRAMME STUDY AREA (LOWER GRAPH). N is the sample size.

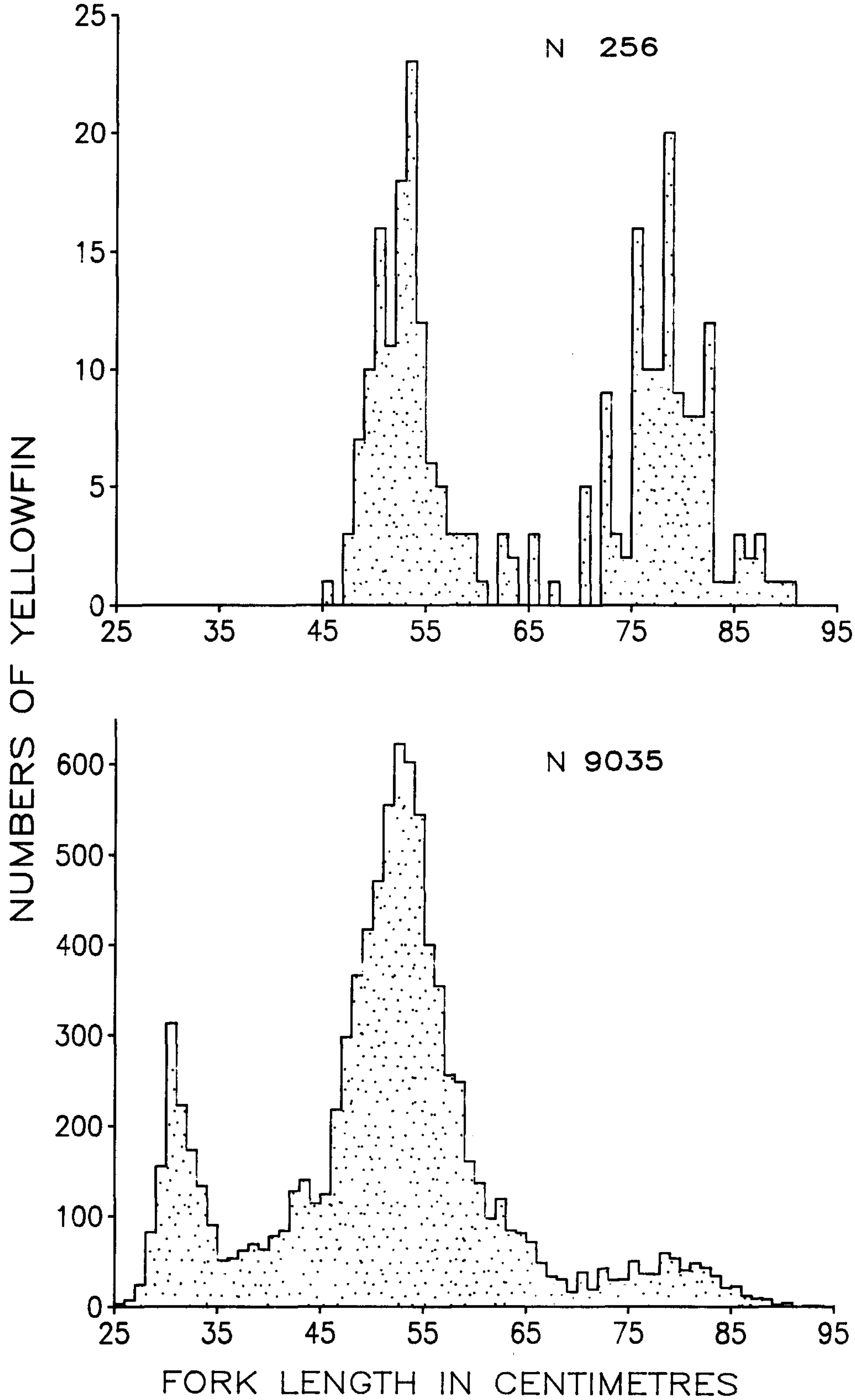

TABLE 2. SUMMARY OF NUMBERS OF FISH SAMPLED FOR BIOLOGICAL DATA FROM THE WATERS OF PITCAIRN ISLANDS

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 <u>Katsuwonus pelamis</u>	11	11	11	8	11
Yellowfin <u>Thunnus albacares</u>	115	72	68	30	77
Bigeye Tuna <u>Thunnus obesus</u>	2	2	2	2	2
Dogtooth Tuna <u>Gymnosarda unicolor</u>	8	8	8	8	8
TOTALS	136	93	89	48	98

4.0 RESULTS AND DISCUSSION

4.1 Baitfish

Little can be added to what was reported for baitfish in the Interim Report on Skipjack Programme activities in the waters of Pitcairn Islands (Kearney and Gillett 1980). Ducie and Henderson Islands have very little enclosed lagoon area, and where present, the lagoon and beach area are inaccessible to fishing vessels. Pitcairn Island has neither a barrier reef nor a fringing reef. The lagoon at Oeno atoll, although of reasonable size, would not be accessible for pole-and-line vessels and the surf at the boat passage would present serious problems for anyone attempting to transport bait from the lagoon to a waiting vessel. The lagoon was briefly explored for baitfish. A few small schools of rabbitfish (Siganidae) were observed. These fish are difficult for chummers to handle since they can release a mild poison from their dorsal spines, and for this reason they are not considered a desirable baitfish for pole-and-line fishing.

The absence of local bait was not a problem for the survey of Pitcairn Islands since the research vessel carried over 600 kg of cultured milkfish to Pitcairn from Rangiroa in the northern Tuamotu Islands. These bait survived the five-day trip from Rangiroa exceptionally well with less than one per cent dying en route.

4.2 Tuna Fishing Results

No schools were sighted during the last two days of steaming through the southern Tuamotu Islands prior to arriving at Oeno atoll on the morning of 3 February. While some of the crew and scientists scouted the lagoon at Oeno for bait, the remainder stayed on board the <u>Hatsutori Maru No.5</u> and fished around the atoll, unsuccessfully chumming one school of unidentified species composition. The vessel then steamed directly to Pitcairn Island. Four small schools were spotted near the island in the late afternoon, one of which responded to chum; 10 skipjack and 33 yellowfin were tagged from a catch of 126 kilograms (77% yellowfin). The next day catches improved substantially (Table 1). A total of nine schools were chummed, five responded positively for a release of 49 tagged skipjack and 257 tagged yellowfin from a catch of 2,635 kgl, 93 per cent of which were yellowfin, many in excess of 15 kg each. Several large bigeye were also captured, one fish weighing 23 kg. Most of the schools required little encouragement to bite. On several occasions chumming was reduced to small amounts of milkfish thrown every minute or so, and in one case chumming stopped completely, yet the tuna continued to bite.

On the evening of 4 February the Hatsutori Maru No.5 left Pitcairn Island for the Gambier Islands. The following morning no schools were seen during five hours spotting at the western edge of the Pitcairn Islands fishing zone. After leaving the Pitcairn Islands zone in the late afternoon, approximately 60 nautical miles from Gambier Islands, a moderately large school responded well to chumming for a total catch of 1,794 kg and tag releases of 302 yellowfin, 174 skipjack and 34 bigeye.

Schools were certainly not abundant in oceanic waters between the southern Tuamotu Islands and Oeno atoll, and between Pitcairn Island and the Gambier Islands, but were quite common near Pitcairn Island itself. Most schools were of small size and contained large yellowfin and bigeye, but few skipjack. Normally the Programme uses a 3.47 raising factor (Section 2.2) for estimating the equivalent catch of the vessel had it been fishing commercially. For reasons discussed in the preliminary report (Kearney and Gillett 1980), this factor is probably too high for the type of schools found near Pitcairn Island. Some raising factor is necessary, however, and a factor of two was considered appropriate. This would increase the catch for 4 February to an estimated commercial catch of 5.3 tonnes. This compares with the overall Programme average of 3.4 tonnes per fishing day, and with the average of 7.3 tonnes for four days fishing at a similar latitude in subtropical waters near Norfolk Island.

4.3 Skipjack Population Biology

4.3.1 Maturity and juvenile recruitment

Based on gonad indices (an approximate measure of the fraction of the fishes' body weight taken up by reproductive products2) skipjack spawning intensity in tropical waters south of the Equator shows evidence of seasonal periodicity. In Figure 4 it can be seen that gonad indices for female skipjack in two size classes, 40-49.9 cm and 50-59.9 cm, were lowest in autumn and winter months, April through August, for samples from tropical waters surveyed to the south of the Equator by the Programme. These results are similar to those presented by Lewis (1981) for female skipjack sampled from pole-and-line catches in the Bismarck Sea, just south of the Equator,

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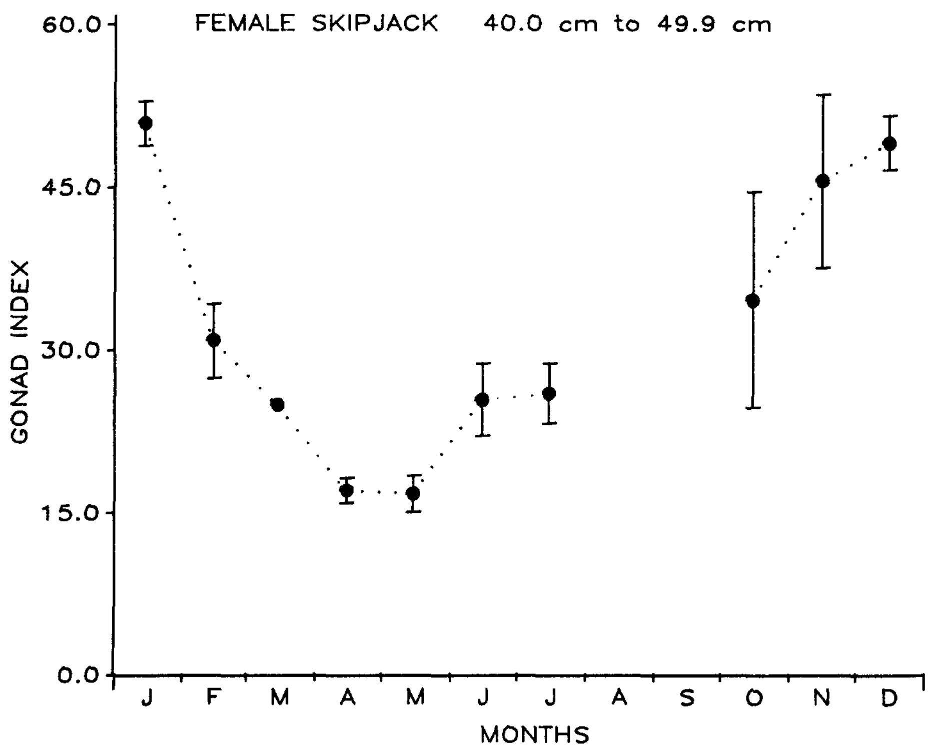
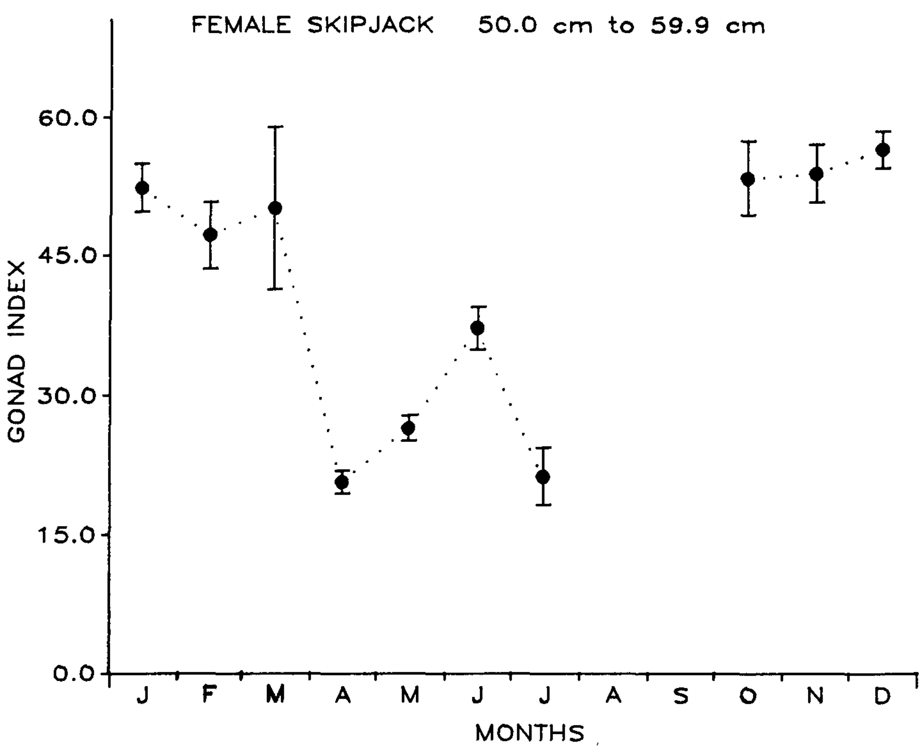
1. The figure of 3,661 kg in the preliminary country report for Pitcairn Islands was in error, since the average size of yellowfin caught that day had been overestimated.

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

FIGURE 4. AVERAGE FEMALE SKIPJACK GONAD INDICES (CIRCLES), AND TWO STANDARD ERRORS ON EITHER SIDE OF THE AVERAGES (VERTICAL LINES), BY MONTH, FOR SKIPJACK FEMALES SAMPLED FROM TROPICAL WATERS SOUTH OF THE EQUATOR. Standard errors omitted for sample sizes less than 5; most sample sizes exceeded 5.



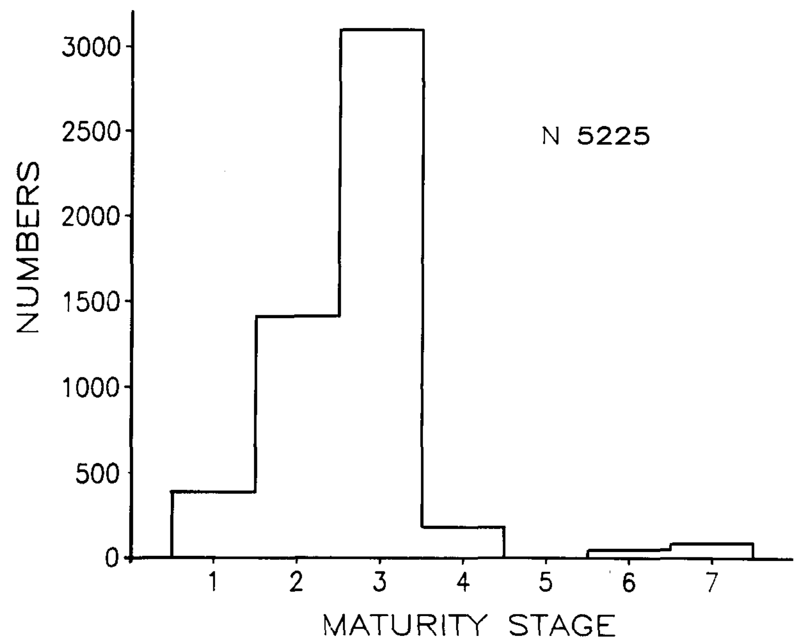


and to those presented by Naganuma (1979) for a large, widely distributed sample of female skipjack from south of the Equator. Together these results suggest that although skipjack do spawn during winter months in tropical waters, spawning is less intense at this time.

Argue and Kearney (1982b) present gonad index data for samples taken during summer months from both tropical and subtropical waters south of the Equator. Gonad indices averaged less than 10 for subtropical samples of skipjack in the length range of 40 to 59.9 cm from New Zealand, Norfolk Island and New South Wales waters, but were much higher, 34 to 64, for skipjack of similar size collected during the same summer months from tropical waters between New Caledonia and Society Islands. None of the skipjack examined from New Zealand, Norfolk Island and New South Wales showed evidence of spawning. Eight skipjack from catches near Pitcairn Island had an average gonad index of 23, which is intermediate to the high values from tropical samples and the low values from subtropical samples. Perhaps Pitcairn Islands is in a transition zone, related to water temperature, where summer spawning does occur but at lower intensity than in tropical waters further to the north.

Sexual maturity may also be expressed by assigning maturity stages to the gonads using criteria such as ovary colour, vascularisation, egg size and egg cohesiveness. On this basis five of the eight female skipjack from Pitcairn Island had immature gonads (stage 2), three had maturing gonads (stage 3) and one showed evidence of having spawned because it was in a recovery phase (stage 7). Figure 5 presents the numbers of females sampled during the entire Skipjack Programme in each of seven maturity stages. Stages three and two dominated the total sample as is typical of samples from pole-and-line catches in tropical waters. Stages 4 (mature) and five (ripe) were not common in the total sample even though they were presumably abundant at times in most of the tropical areas that were fished by the Programme. The reason for the low incidence of skipjack with stage 5 gonads is not clear, but is possibly due to a change in skipjack behaviour close to the time of spawning, such as a drop in feeding intensity, reduced schooling near the surface, or perhaps rapid maturation and spawning at night.

FIGURE 5. FREQUENCY DISTRIBUTION OF FEMALE SKIPJACK AT MATURITY STAGES 1 TO 7 FOR THE TOTAL SKIPJACK PROGRAMME SAMPLE. N is the sample size.



Another index of spawning activity is given by the incidence of skipjack juveniles observed in the stomachs of their predators. Argue et al. (MS) discuss analyses of the Programme's tuna juvenile data, taking into account size selective predation by adults, the time of day, distance from land, and season that adults were sampled. They suggest that occurrence of juvenile skipjack within the study area was highest in two tropical areas during the 1977 to 1980 survey period, one roughly bounded by Solomon Islands, Papua New Guinea and Vanuatu, and the other including the Marquesas and Tuamotu Islands. Skipjack juveniles also occurred most frequently in stomachs of skipjack predators south of the Equator between October and March, which is approximately the period of maximum gonad development in skipjack, but were absent from large samples examined in summer months from subtropical waters.

A single, large juvenile skipjack, 19 cm long, was found in the stomach of a 76 cm yellowfin, one of 98 tuna that were examined for juveniles in the waters of Pitcairn Islands. Based on its length, this juvenile was probably several months old (Uchiyama and Struhsaker 1981) and thus could have migrated to the vicinity of Pitcairn Island from a spawning area well to the north.

4.3.2 Skipjack diet

Eight skipjack caught near Pitcairn Island were examined for stomach contents - six contained only chum and two stomachs were completely empty. Much larger samples of skipjack stomachs from subtropical waters of Norfolk Island, New Zealand and New South Wales also had relatively high incidences of stomachs with no food - 13, 26 and 13 per cent respectively. This contrasts with samples of skipjack stomachs from tropical waters in which typically less than seven per cent are empty.

Table 3 presents the stomach contents for all skipjack sampled by the Programme from tropical waters. The four most common diet items in the stomachs, other than chum, were fish remains (43 per cent of the stomachs), squid (23 per cent), the alima stage of stomatopods (15 per cent), and surgeonfish (Acanthuridae) (14 per cent). Of interest is the wide variety of items, 120 in 3,888 stomach examinations. This is thought to reflect the opportunistic nature of skipjack feeding behaviour. The wide variety of diet items is also thought to reflect geographical differences in community groups of prey species. Identification of these groups is the subject of ongoing analyses.

4.3.3 Skipjack growth

The growth increments for tag returns within individual countries in the study area have been analysed by Lawson and Kearney (MS). Figure 6 shows the observed growth rates from skipjack tag returns for the total study area plotted against size at release. Table 4 summarises the growth results from tagging data for several countries in tropical waters west of 180° longitude.

It is evident from Figure 6 that growth rate drops dramatically with increased length of skipjack; and from Table 4, that growth rates of skipjack may vary in different parts of the region. This variability presumably reflects differences in food availability and other ecological factors that could affect growth.

TABLE 3. STOMACH CONTENTS OF ALL SKIPJACK SAMPLED FROM TROPICAL WATERS BY THE SKIPJACK PROGRAMME

Item No.	Diet Item Fish and Invertebrates	Number of Stomachs	Percentage Occurrence
1	Chum from Hatsutori Maru	2667	68.60
2	Fish remains (not chum)	1669	42.93
3	Squid (Cephalopoda)	907	23.33
4	Alima stage (Stomatopoda)	576	14.81
5	Acanthuridae	552	14.20
6	Holocentridae	387	9.95
7	Shrimp (Decapoda)	295	7.59
8	Tuna juvenile (Scombridae)	256	6.58
9	Empty stomach	250	6.43
10	Blue goatfish (Mullidae)	213	5.48
11	Balistidae	210	5.40
12	Gempylidae	185	4.76
13	Megalopa stage (Decapoda)	180	4.63
14	Unidentified fish	172	4.42
15	Stolephorus buccaneeri (Engraulidae)	169	4.35
16	Chaetodontidae	163	4.19
17	Juvenile fish	154	3.96
18	Synodontidae	152	3.91
19	Stomatopoda	133	3.42
20	Aluteridae	123	3.16
21	Exocoetidae	117	3.01
22	Siganidae	116	2.98
23	Anchovy juvenile (Engraulidae)	94	2.42
24	Decapterus sp. (Carangidae)	82	2.11
25	Euphausiid (Euphausiacea)	70	1.80
26	Carangidae	67	1.72
27	Gastropoda	67	1.72
28	Phyllosoma stage (Decapoda)	54	1.39
29	Carid shrimp (Decapoda)	42	1.08
30	Dactylopterus orientalis (Dacylopteridae)	40	1.03
31	Amphipoda	35	.90
32	Fistulariidae	34	.87
33	Priacanthidae	30	.77
34	Bramidae	30	.77
35	Ostraciidae	30	.77
36	Coryphaena hippurus (Coryphaenidae)	28	.72
37	Paralepidae	25	.64
38	Crustacean remains	21	.54
39	Pteropoda (Gasteropoda)	21	.54
40	Argonauta (Cephalopoda)	19	.49
41	Tetrodontidae	18	.46
42	Copepoda	18	.46
43	Oxystoma crab larva (Decapoda)	16	.41
44	Lutjanidae	16	.41
45	Nomeidae	15	.39
46	Heteropoda (Gastropoda)	15	.39
47	Xiphasia sp. (Xiphasiidae)	15	.39
48	Scaridae	14	.36
49	Selar sp. (Carangidae)	14	.36
50	Leptocephalus (Anguilliformes)	13	.33
51	Octopus (Cephalopoda)	13	.33
52	Blenniidae	13	.33
53	Clupeidae	12	.31
54	Mollusca	11	.28
55	Unidentified invertebrate	11	.28
56	Tunicate (Urochordata)	11	.28
57	Syngnathidae	11	.28
58	Crustacea	10	.26
59	Diodontidae	10	.26
60	Caesiodidae	8	.21
61	Serranidae	8	.21
62	Sternoptychidae	8	.21
63	Sphyraenidae	8	.21
64	Leiognathidae	7	.18

Item No.	Diet Item Fish and Invertebrates	Number of Stomachs	Percentage Occurrence
65	Billfish juvenile (Istiophoridae)	7	.18
66	Myctophidae	7	.18
67	Decapoda	5	.13
68	_Anthias_ sp. (Scolopsidae)	5	.13
69	Mullidae	5	.13
70	_Pterycombus peterii_ (Bramidae)	5	.13
71	Hemirhamphidae	5	.13
72	Trichiuridae	5	.13
73	Penaeid shrimp (Decapoda)	4	.10
74	Trash material	4	.10
75	Apogonidae	4	.10
76	Stomiatidae	4	.10
77	Engraulidae	4	.10
78	Anthiidae	4	.10
79	_Ranzania_ sp. (Molidae)	3	.08
80	_Chiasmodon_ sp. (Chiasmodontidae)	3	.08
81	Invertebrate remains	3	.08
82	Polychaeta (Annelida)	3	.08
83	Coelenterata	3	.08
84	Hyperiidae (Amphipoda)	3	.08
85	Scombrid juvenile (Scombridae)	3	.08
86	Plant material	3	.08
87	_Mola mola_ (Molidae)	2	.05
88	_Rastrelliger_ sp. (Scombridae)	2	.05
89	Plastic material	2	.05
90	Gonostomidae	2	.05
91	Platycephalidae	2	.05
92	Cigarette material	2	.05
93	_Gastrophysus_ sp. (Lagocephalidae)	2	.05
94	Gobiidae	2	.05
95	Cirrhitidae	2	.05
96	Prawn (Decapoda)	2	.05
97	Callionymidae	1	.03
98	Skipjack dart tag	1	.03
99	_Megalaspis_ sp. (Carangidae)	1	.03
100	Theraponidae	1	.03
101	Paint material	1	.03
102	Feather tuna jig	1	.03
103	_Mulloidichthys samoensis_ (Mullidae)	1	.03
104	_Scomberoides_ sp. (Carangidae)	1	.03
105	Menidae	1	.03
106	Bothidae	1	.03
107	Eleotridae	1	.03
108	_Caranx_ sp. (Carangidae)	1	.03
109	Fish eggs	1	.03
110	Mollusc larvae	1	.03
111	_Cypselurus_ sp. (Exocoetidae)	1	.03
112	Mollusc egg case	1	.03
113	Bark (wood) material	1	.03
114	Scorpaenidae	1	.03
115	Percoidei	1	.03
116	Isopoda	1	.03
117	_Stolephorus indicus_ (Engraulidae)	1	.03
118	Shark egg case (Elasmobranchii)	1	.03
119	Echeneidae	1	.03
120	Zoaea stage (Crustacea)	1	.03
121	Scombridae	1	.03
	Total Stomachs Examined	3888	

FIGURE 6. AVERAGE MONTHLY GROWTH INCREMENTS (CM) FOR SKIPJACK IN ONE CENTIMETRE LENGTH INTERVALS AT TIME OF RELEASE

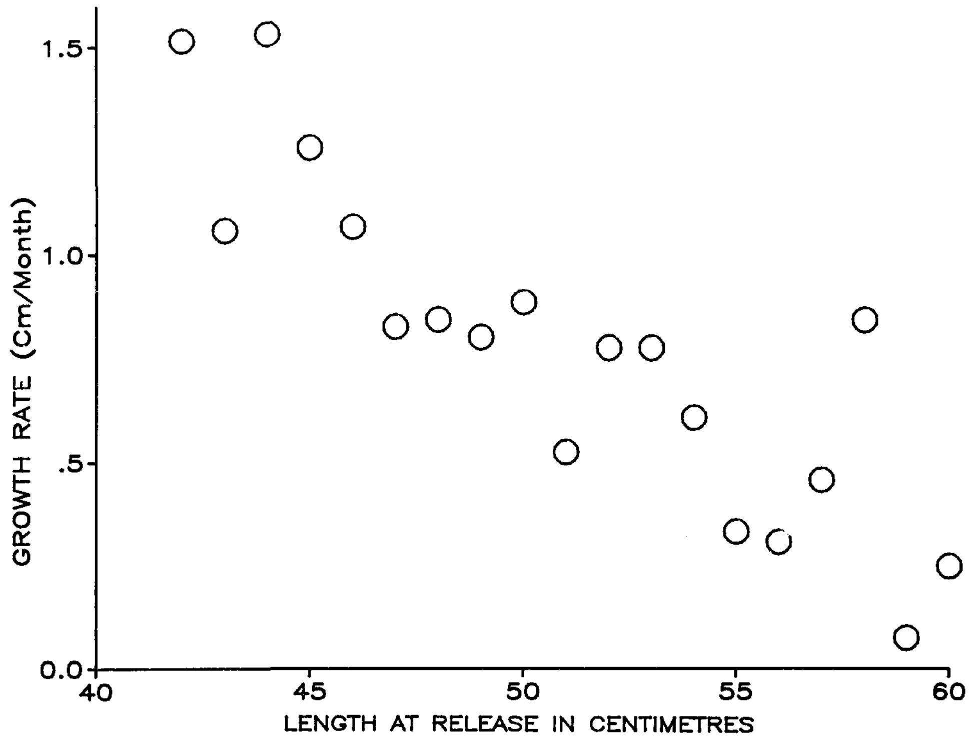


TABLE 4. ESTIMATES OF SKIPJACK GROWTH RATES FOR SEVERAL COUNTRIES IN THE SPC REGION, BY SIZE AT RELEASE AND TIME-AT-LARGE. Average growth rates with standard errors greater than 3 cm or for samples of less than six skipjack are considered unreliable, and are given in brackets.

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

4.3.4 Population structure

Blood Genetics and Tagging Results

Determination of population structure of the resource is often considered to be a cornerstone upon which much analysis of population dynamics rests. This aspect of skipjack biology has proven most difficult to assess, although it was approached by the Programme from many viewpoints including tagging and traditional genetic techniques.

From the overall pattern of Skipjack Programme tag returns there is clearly some movement of skipjack adults over much of the western and central Pacific (see Figure B), and such movement suggests that genetic exchange is possible among all countries within the Programme's study area. On the other hand, the fishery interaction analyses (see Section 4.4.3 below) suggest that the actual level of exchange, for skipjack of the size caught by pole-and-line gear, is low, at least among the locally based fisheries.

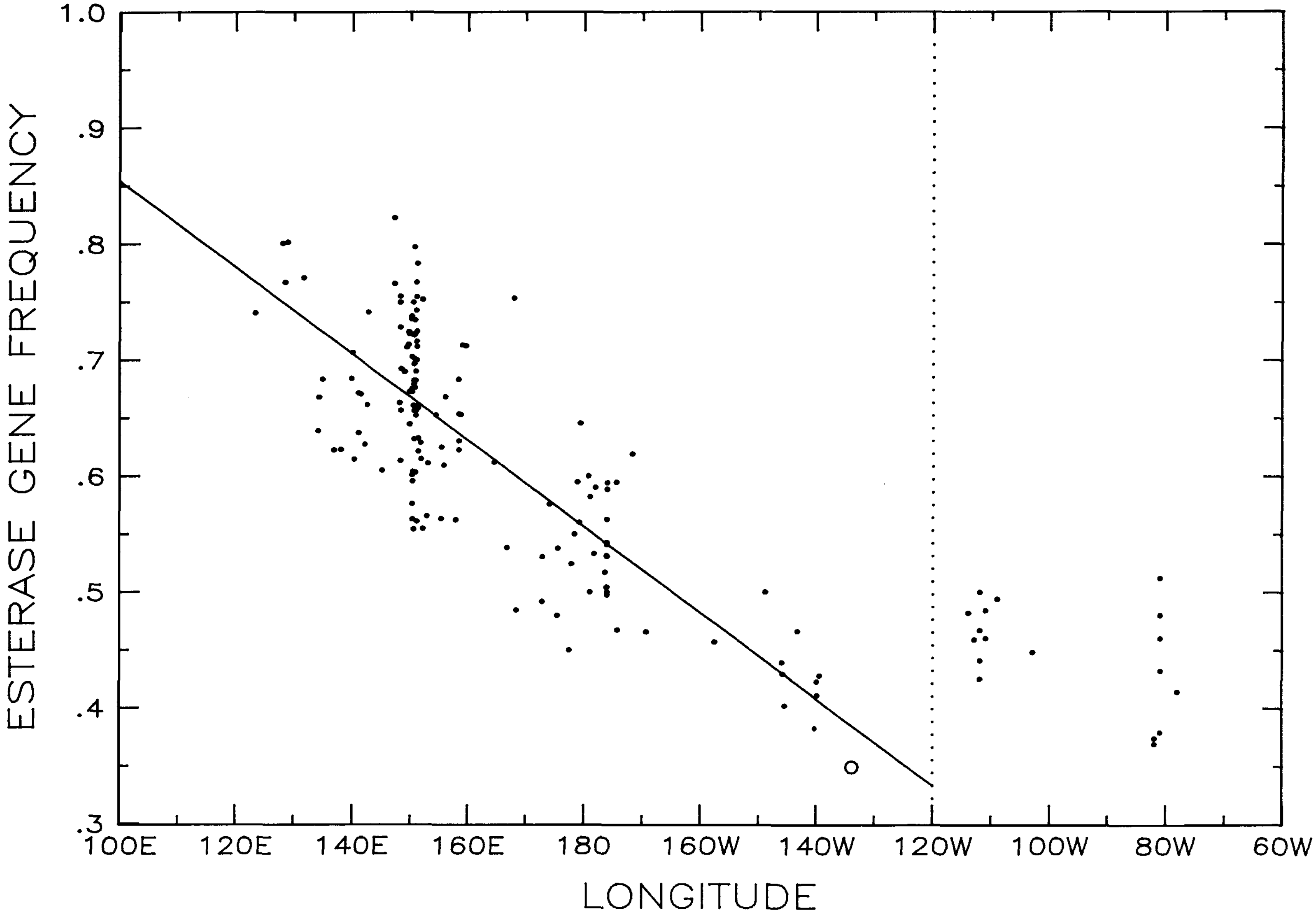
Results from electrophoretic analysis of skipjack blood samples show a gradient in esterase gene frequency (a genetic marker used to infer population structure) from west to east across the Pacific between approximately 120°E and 120°W (Figure 7). The esterase gene frequency for the closest sample to Pitcairn Islands, a sample taken near the Gambier Islands on 5 February 1980, is close to the regression line in the figure, which depicts the average gene frequency one would expect at any particular longitude between 120°E and 120°W. 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 population structure models are consistent with the tagging and blood genetics data (Anon 1981). One such model, called the clinal population structure model, has as a 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, which is contrary to previous hypotheses of Fujino (1970, 1976) and Sharp (1978).

The gradient in esterase gene frequency is consistent with a relatively even distribution of skipjack spawning in tropical waters across the study area. One could also view the gradient as a region of "overlap" of skipjack from two or more centres of higher spawner density at the approximate extremes of the study area or beyond. The similarity between eastern Pacific esterase gene frequencies (to right of the dotted line in Figure 7) and those from French Polynesia suggests that eastern Pacific skipjack have the same genetic origin as skipjack in French Polynesia and thus could collectively represent the group at one extreme. Occurrence of skipjack juveniles (Argue et al. MS) also appeared highest at the longitudinal extremes of the Programme study area, thus lending some support to this latter view of the distribution of skipjack spawning.

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

FIGURE 7. SKIPJACK SERUM ESTERASE GENE FREQUENCY FOR 163 SAMPLES FROM INDIVIDUAL SKIPJACK SCHOOLS, VERSUS LONGITUDE OF THE SAMPLE LOCATION. The circle represents the esterase gene frequency for the single sample from Gambier Islands. The regression line on the left of the dotted line includes 145 samples collected between Palau and the Marquesas Islands (correlation coefficient -.81). Esterase gene frequencies for 18 eastern Pacific samples are shown to the right of the dotted line.



potential for interactions should increase as the distance between fisheries decreases. The exploitation rates of adjacent fisheries must increase substantially over present levels, and the distance between centres of exploitation must decrease substantially, before interactions will be of overriding importance.

Parasite Results

Samples of skipjack gills and viscera were collected commencing in December 1979, during the Programme's last survey year. Samples were taken over a wide range of tropical waters, and also from subtropical waters of New Zealand and Norfolk Island. Preliminary results presented by Lester (1981) suggest that skipjack from New Zealand have a different overall parasite fauna to that of skipjack from tropical waters to the north, and that the parasite fauna of tropical samples from widely separated areas are quite similar.

Analyses of parasite data are continuing; however, preliminary results do not suggest there is much hope of clarifying regional fishery interactions in tropical waters based on parasite fauna, nor is it likely that definition of skipjack population structure will be greatly improved based on further analysis of existing parasite data.

4.4 Skipjack Tagging Results

There have been no recoveries from the 59 skipjack tagged in the waters of Pitcairn Island, nor from 174 tagged skipjack released nearby in the Gambier Islands. This is unfortunate since these skipjack were released in the extreme southeast corner of the South Pacific Commission region (Figure A), and any recoveries from these fish would have been of great interest. On the other hand the absence of recoveries was not entirely unexpected since, with the exception of the small fishery in the Society Islands, which generally catches less than 2,000 tonnes per year, fisheries of any size are located over 2,000 nautical miles distant and only 36, less than 0.1 per cent of 140,433 Skipjack Programme tag releases, have been recovered more than 2,000 miles from their point of release.

The following three sections highlight general results from the Programme's releases of tagged skipjack, in particular, results that bear on skipjack stock assessment and fishery interactions within the region as a whole and which are therefore relevant to Pitcairn Islands.

4.4.1 International migrations

Figure B on the inside of the back cover presents a selection of Skipjack Programme tag returns plotted as straight line arrows between tagging and recovery location. Returns were selected by plotting no more than one example of a migration in each direction between any pair of ten degree squares and no more than one example of a migration wholly within any ten degree square. The impression from this figure is one of considerable mixing of skipjack in the study area, with skipjack from southern subtropical waters appearing to move great distances to the north. Clearly there are few barriers to movement of <u>some</u> skipjack within the South Pacific Commission area. The lack of apparent movement beyond these approximate borders reflects poor chances for recovery as a result of low fishing effort, and environmental barriers to migration at the latitudinal extremes (skipjack are seldom encountered in waters less than 16°C such as polewards of 35 degrees latitude).

It should be noted, however, that the overall impression of wide-ranging international migrations depicted by Figure B is not the average case when all the tag recoveries are considered. This figure over emphasises long distance, relatively rare migrations, due to the procedure used to select recoveries for the figure. In fact, the vast majority (86%) of tag recoveries were made less than 250 nautical miles from their release site and within 180 days of tagging (Figure 8). Long-distance migrations are prevalent only within the group of skipjack that were at large for more than 180 days (lower graph in Figure 8). The implication here is that few skipjack of the size that were tagged are available for a long enough period to be recovered at great distances from their release site.

4.4.2 Mortality and production

Many skipjack were tagged in the vicinity of important fisheries and equally large numbers were tagged in waters quite remote from these fisheries. If movement of tagged skipjack away from fished areas is assumed to be balanced by movement back into fished areas, then the decline in numbers of tag recoveries with increasing time-at-large can be assumed to be due to the following factors: death of tagged fish, from natural and man-induced causes (e.g. predation, starvation, disease, "old age" and fishing); changes in vulnerability to surface fishing gears; and, to a lesser extent, emigration away from the study area as a whole, for example, into unfished eastern Pacific waters. Figure 9 shows the numbers of tag returns versus the numbers of months these tags were at large after release. This picture is what would be expected with time if all tags were released simultaneously in the different areas. The straight line in the figure depicts the average numbers of tag recoveries one would predict per month from fitting a mathematical model to the commercial catch and resulting tag returns.

As can be seen from the figure, the actual data points (stars) deviate little from the line depicting the average number of tag returns per month. The instantaneous rate of decrease of the average tag returns estimated from the fitting procedure, is called the tag attrition rate, which results from mortality, changed vulnerability and emigration. An additional component, presumably small (Skipjack Programme 1981b), includes the continuous shedding of tags and continuous mortality from the effects of tagging. The estimate of attrition rate was 0.19 per month, which is similar to the rate of 0.23 estimated for skipjack from the large fished area north of the Equator in the eastern tropical Pacific (Joseph and Calkins 1969). Thus after six months at large close to 70 per cent of the Skipjack Programme tag releases were unavailable for recapture, for one reason or another, and after a year this had increased to 90 per cent.

The model also provides an estimate of the population size or standing stock in the SPC area that is vulnerable to surface fisheries. This was estimated to be approximately two to four million tonnes.[3] Average monthly catch, 17,000 tonnes, divided by population size provides an estimate of average monthly fishing mortality, in this case approximately 0.01, which is a small proportion of the attrition rate. This leaves losses through natural death, changed vulnerability with increased size, and emigration. It is

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

FIGURE 8. NUMBERS OF SKIPJACK TAG RECOVERIES BY DISTANCE TRAVELLED AND TIME-AT-LARGE

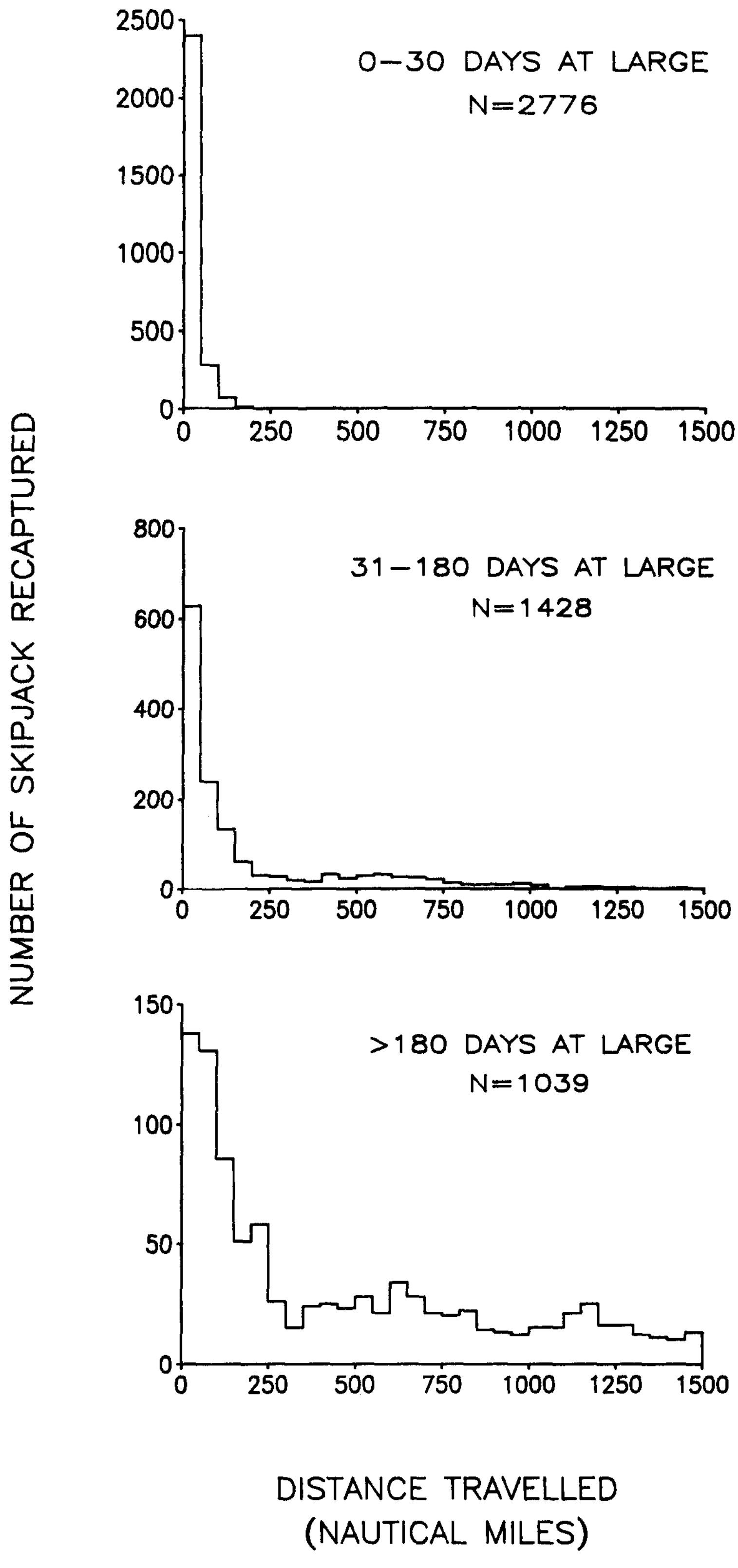
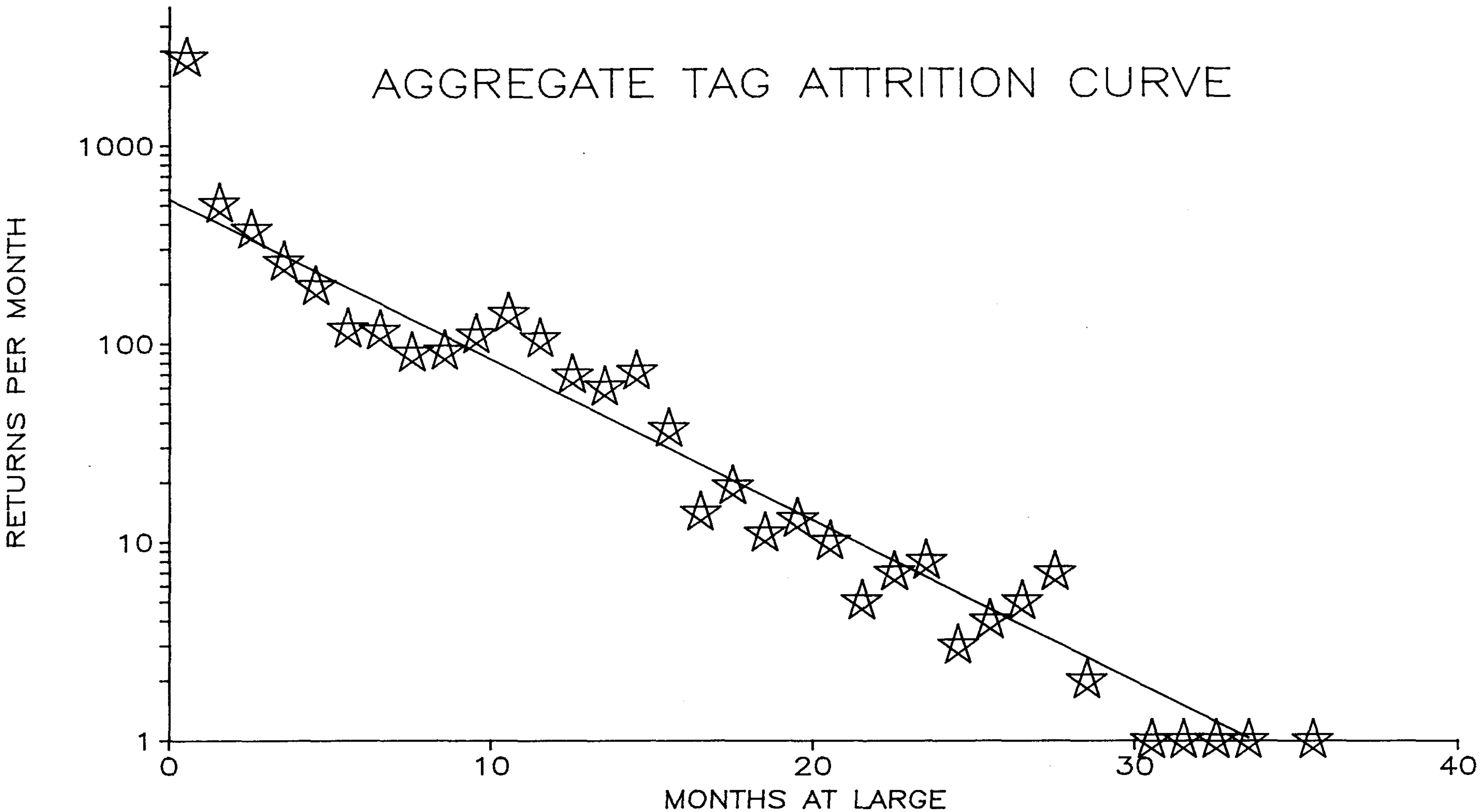


FIGURE 9.   NUMBERS OF SKIPJACK TAG RECOVERIES VERSUS MONTHS AT LARGE



difficult to partition these last three loss factors, although considering that the study area was vast and covered much of the area of skipjack distribution in tropical waters, it is reasonable to assume that emigration is the smallest of the three.

One further point should be emphasised: the product of standing stock (population size) and monthly attrition rate provides an estimate of monthly throughput for the study area. In this context, throughput measures the tonnes of skipjack being recruited to the standing stock each month, which is assumed for the duration of the tagging experiment to be matched by an equal amount leaving each month (for reasons noted above). From Skipjack Programme data, recruitment was estimated to fall between 0.4 and 0.7 million tonnes per month. Average monthly loss due to catch represents approximately three per cent of the estimated monthly recruitment. Hence there would appear to be room for greatly increased catches in the region before recruitment would be affected. The experience with much more intense skipjack fisheries off the coast of Japan and in the eastern Pacific, where there has been no relationship between catch per unit effort and effort over a period of 20 or more years, supports this claim (Joseph and Calkins 1969, Kearney 1979).

The resource of skipjack in the waters of Pitcairn Islands is obviously only a small fraction of the total standing stock in the region, and it may be subject to seasonal fluctuations in abundance similar to those occurring for skipjack in subtropical waters, e.g. New Zealand (Argue and Kearney 1982b). Although the data for Pitcairn Islands are insufficient to estimate the size of the local skipjack resources, it is safe to say that should any fishery for skipjack develop in the waters of Pitcairn Islands, there should be no immediate concern that recruitment to Pitcairn Islands would be significantly impaired.

4.4.3 Fishery interactions

One of the principal reasons for tagging skipjack was to investigate the degree of interaction among skipjack fisheries throughout the western and central Pacific. Table 5 summarises the recoveries from skipjack released throughout the total study area, by country/territory of release and recovery. This form of presentation, however, takes no account of tag recovery effort, that is, the catch from which the tags were recovered. Reliable catch data is necessary for quantifying the interactions and these were available to the Programme for most of the locally based fisheries during the period tags were at large, but not for catches (1979-1982) by the large Japanese distant-water pole-and-line fishery, nor for catches by the growing United States and Japanese distant-water purse-seine fisheries. 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 their monthly catch data, estimates of interaction between distant-water and locally based fisheries cannot be concluded.

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

TABLE 5. SKIPJACK TAG RELEASE/TAG RECOVERY MATRIX FOR ALL TAG RELEASES AND FOR ALL TAG RECOVERIES RECEIVED BY THE PROGRAMME AS AT 28 SEPTEMBER 1982. Releases and recoveries are arrayed by tagging or recovery location, usually a country or territory except in cases where small geographical divisions were more informative; country abbreviations are explained in Appendix B. Not included in the table are returns for which the country or area was unknown.

COUNTRY OF RECAPTURE

NUMBER OF RELEASES BY COUNTRY		AMS	CAL	FIJ	GIL	GUM	HAW	HOW	IND	INT	JAP	KOS	LIN	MAQ	MAR	MAS	MTS	NAU	NCK	NOR	NSW	PAL	PAM	PHL	PHO	PNG	PON	QLD	SOC	SOL	TOK	TON	TRK	TUA	TUV	VAN	WAK	WAL	WES	YAP	ZEA	TOTAL
775	AMS	3																																					1			4
10219	CAL		18		1					2					1											2	2			10			1									37
20094	FIJ		1	1949	1					5								1							4				1			2			6		1	2	2		3	1978
174	GAM																																									
4569	GIL	1			385			24		32		1	1			14		1					2		1		1															463
108	JAP				1				2	3	7				1	1																										15
297	KOS									3						2																										5
20282	MAQ				1			1		4				42											1				1													50
195	MAR									2	1				2		1										1						2									9
327	MAS									2						1		1																								4
1229	NCK																		1																							1
91	NIU																																									
1113	NOR		2	1																										1												4
4322	NSW	1	6	2						1											2								1	8									1		9	31
7233	PAL				3				28	67		3			1	6						104		5		77	7			2			23							30		356
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	29								1		1	58			1			13							10		159
2651	QLD		3																									2		25			1			2						33
48	SCK																																									
1725	SOC																												36													36
6221	SOL			1	1				1	2																15				525												545
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		10						3									24	2			3				1		1			66	11		6	152
1926	WES	1																											1	1									19		1	23
778	YAP				2				3	7	1				3							1					1						3							5		26
12734	ZEA		5	31						3										1	2								5		1	1			1	1			5		1003	1059
140443	TOT	6	36	2000	405	1	1	38	41	189	11	34	1	42	9	72	1	4	1	1	4	107	5	6	32	1057	92	3	54	605	2	13	71	25	10	5	1	68	41	51	1022	6187

The initial approach followed by the Skipjack Programme was to use tagging data plus catch statistics to estimate coefficients of migration between particular fisheries (Skipjack Programme 1981a). The product of population size in the donor fishery and migration coefficient gives an estimate of the tonnes of skipjack migrating between fishing areas. Comparison of these estimates with estimates of population size in the recipient country, or in the donor country, illustrated stock interactions within one skipjack generation, since they measured the fraction of the standing stock that migrated to or from a particular area. Results demonstrated a generally low level of stock interaction for existing locally based fisheries.

A simpler expression of interaction is the percentage of recruitment (throughput) in the destination country that is due to immigration from the donor country (Kleiber MS). This estimate of interaction is independent of p (see Footnote 3), assuming that p is the same in the donor and destination countries.

There were four pairs of countries and territories in the Skipjack Programme study area for which it was possible to obtain quantitative estimates of interaction due to skipjack movement (Table 6). These were Papua New Guinea - Solomon islands, New Zealand - Fiji, New Zealand - Society Islands, and New Zealand - Western Samoa (Argue and Kearney 1982a, 1982b; Ellway and Kearney MS; Kearney 1982b). As shown in Column 4 of the table, skipjack immigrants from the fished area in the donor countries were generally a small fraction of recruitment (throughput) in the destination countries' fished area (less than 10 per cent), which implies that interactions amongst present fisheries in these countries are minor. It should be noted that this situation only applies to skipjack of the size tagged by the Programme (most were between 40 and 60 cm). Skipjack smaller than this range could very well move large distances and contribute significantly to interactions between stocks in the fished areas. However, as fisheries of the study area are not yet exploiting fish less than 40 cm to any great degree, it can be reasonably assumed that fishery interactions resulting from movement of these small fish are presently negligible.

TABLE 6. SUMMARY OF FISHERY INTERACTION RESULTS BETWEEN SIX REGIONAL FISHERIES

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

It has been pointed out that fishery interactions increase as the distance between fisheries decreases. Thus if fisheries in neighbouring countries were to expand their areas of operation to include waters adjacent to their common borderlines, the degree of interaction could be expected to increase. Furthermore, if substantial fisheries were to develop in overlapping areas, such as purse-seine and pole-and-line fleets operating in the same waters of a country, then the degree of interaction would be much higher than that measured amongst present locally based fisheries. Interactions affecting the skipjack resource in the waters of Pitcairn Islands will undoubtedly remain negligible until large fisheries develop much closer than the 2,000 plus miles presently separating Pitcairn Islands from major skipjack fisheries.

4.5 Yellowfin Biology and Tagging Results

The length frequency distribution for yellowfin tagged in the waters of Pitcairn Islands was bimodal with approximately equal numbers of fish centred around the 53 cm and 77 cm modes (Figure 3 upper). The Programme's overall length frequency distribution for tagged yellowfin was trimodal (Figure 3 lower) with substantial numbers of small yellowfin (<45 cm) represented and relatively few large yellowfin (>75 cm).

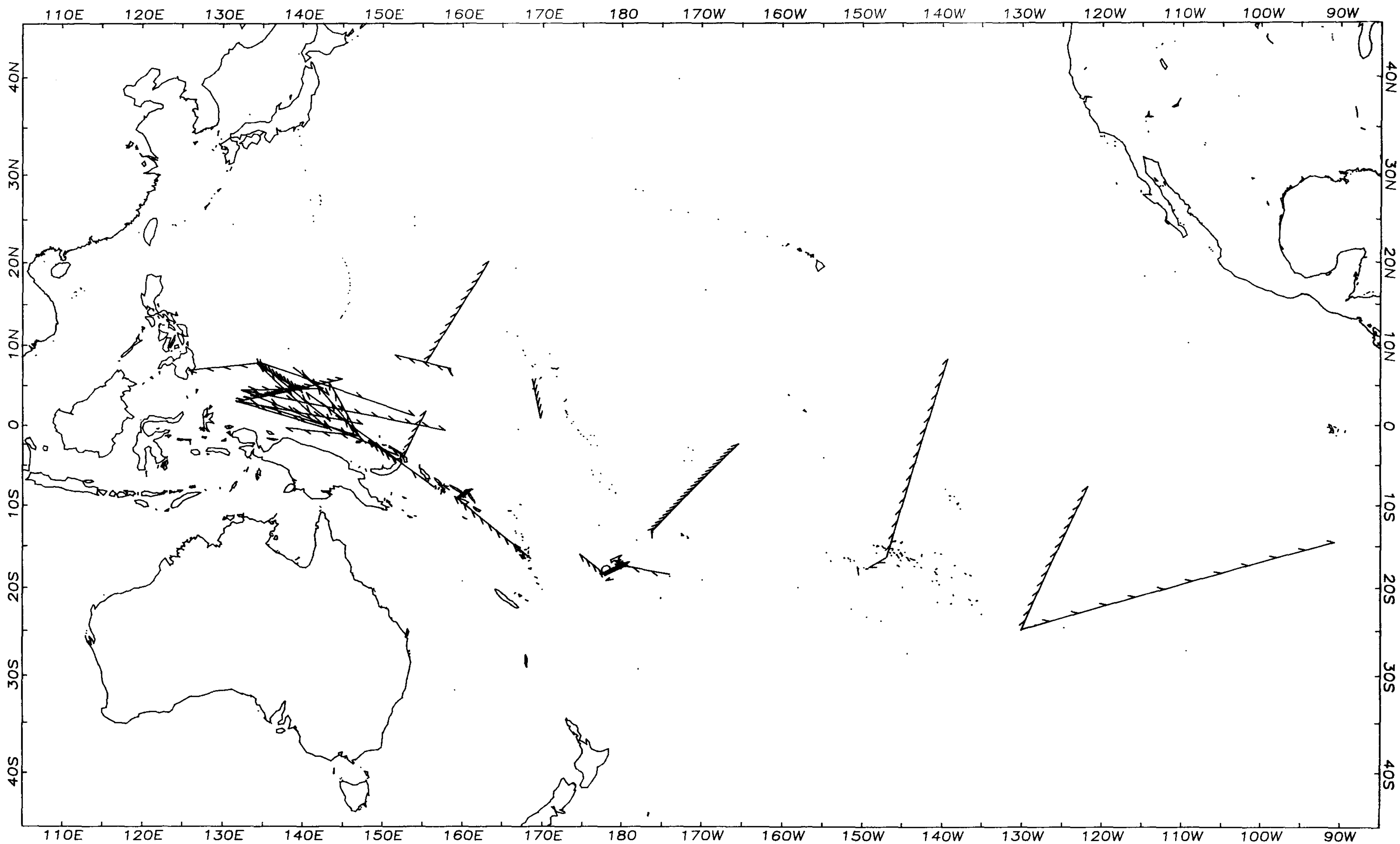
Most of the Pitcairn yellowfin had small, immature gonads. Of 68 fish that were examined, gonads of 29 were too small for visual determination of sex; 16 of the remainder were male and 23 were female. One 81 cm female yellowfin was recorded as having stage 3 gonads; however, its gonads were so small, 20 gms, that it is likely that this fish was incorrectly staged.

Yellowfin stomach contents are presented in Table 7. Over one-quarter had empty stomachs. Squid were the most common diet item occurring in 23 per cent of the stomachs.

TABLE 7. STOMACH CONTENTS OF YELLOWFIN SAMPLED BY THE SKIPJACK PROGRAMME FROM THE WATERS OF PITCAIRN ISLANDS

Item No.	Diet Item Fish and Invertebrates	Number of Stomachs	Percentage Occurrence
1	Chum from _Hatsutori Maru_	15	50.00
2	Fish remains (not chum)	12	40.00
3	Empty stomach	8	26.67
4	Squid (Cephalopoda)	7	23.33
5	Exocoetidae	4	13.33
6	Siganidae	4	13.33
7	Acanthuridae	4	13.33
8	_Mola mola_ (Molidae)	1	3.33
9	Balistidae	1	3.33
10	Bramidae	1	3.33
11	Holocentridae	1	3.33
12	Sternoptychidae	1	3.33
13	Crustacean remains	1	3.33
14	Unidentified invertebrate	1	3.33
	Total Stomachs Examined	30	

FIGURE 10. STRAIGHT LINE REPRESENTATIONS OF MOVEMENTS OF YELLOWFIN TAGGED BY THE SKIPJACK PROGRAMME AND SUBSEQUENTLY RECOVERED. Recoveries have been selected to show no more than one example of movement in each direction between any pair of two degree squares. Tick marks denote intervals of 30 days between release and recapture dates.



Two of 290 yellowfin tagged near Pitcairn Island were recovered by Japanese longliners operating in the eastern Pacific Ocean. Figure 10 presents migration arrows for these fish, along with a selection of migration arrows for all of the Programme's yellowfin tag recoveries. Appendix C lists detailed tagging and recovery information for the two recoveries of Pitcairn Island yellowfin.

The two Pitcairn migrations were among the longest recorded for tagged yellowfin released in the Pacific Ocean. The yellowfin caught to the south of the Galapagos Islands was at large for 316 days, travelled 2,290 nautical miles, and grew from 75 cm to 120 cm. The other migrant moved to oceanic waters to the east of French Polynesia and north of the Equator, a distance of 1,139 nautical miles in 456 days during which it grew from 76 cm to an estimated 140 cm (estimated from its weight of 43 kg at recapture).

Cole (1980) reviewed earlier yellowfin tagging studies in the eastern Pacific which suggested that inshore to offshore movement by eastern Pacific yellowfin is slight. The two Pitcairn recoveries, plus two migrations of smaller yellowfin tagged in French Polynesia by the Inter-American Tropical Tuna Commission and the Skipjack Programme, and recovered in the offshore eastern Pacific fishery (Bayliff and Hunt 1981, Gillett and Kearney 1982b), offer some support to the hypothesis that central Pacific yellowfin stocks are closely related to the stocks exploited in the offshore eastern Pacific fishery (the fishery that is outside of the Inter-American Tropical Tuna Commission's Yellowfin Regulatory Area).

In other parts of the Programme's study area yellowfin migrations were more limited than those for skipjack (compare Figure 10 and Figure B). Further investigation of yellowfin migrations and biology is continuing under the Tuna and Billfish Programme.

5.0 CONCLUSIONS

Skipjack were present, but did not appear abundant during the short Skipjack Programme survey in the waters of Pitcairn Islands. Although skipjack may be more abundant at other times, the remote location of Pitcairn Islands and the lack of live-bait make it very unlikely that skipjack will ever be heavily exploited by pole-and-line vessels in these waters. If a locally based pole-and-line fishery develops in the southern waters of French Polynesia it is possible that these vessels might, on occasion, wish to fish in the vicinity of Pitcairn Islands. The Programme's success in poling yellowfin and bigeye near Pitcairn Island could add some incentive to this type of operation, although such fishing would have to rely on natural or cultured bait from other countries or territories.

Purse-seining is, of course, not limited by supplies of bait. However, purse-seiners would be faced with logistical problems in order to fish amongst the four Pitcairn Islands. They would be unlikely to do so until seining develops in less isolated waters, to the northwest and west of Pitcairn Islands, where there are close to one hundred atolls and small islands which suggest more favourable conditions for occurrence of surface schools of skipjack and yellowfin.

The regular presence of longline fisheries for a variety of tuna and billfish species in the waters of Pitcairn Islands, and the success of the Programme's survey vessel on relatively large yellowfin and bigeye close to Pitcairn Island, are evidence that that there is a substantial resource within reasonable distance of Pitcairn Island. Thus if Pitcairn Islanders ever have the need to increase their catch of tuna, as a source of protein, for recreation, for trade with passing vessels or for whatever reason, this should be feasible but might require some modification of present fishing methods.

In the event that skipjack are exploited in the waters of Pitcairn Islands by surface fishing techniques, there would appear to be no need for concern that such fishing would affect established fisheries in other parts of the western and central Pacific within a skipjack generation. The fishery interaction analysis presented here also implies that present locally based and distant-water fisheries in the western and central Pacific are having negligible impact on the abundance of skipjack in the waters of Pitcairn Islands.

Mixing of skipjack stocks is believed to depend strongly on the distance separating them. On the basis of tagging analyses, interactions between skipjack stocks in areas currently supporting skipjack fisheries, though present, are minor. Furthermore, tagging and blood genetics analyses failed to identify subpopulations that could be shown to be genetically isolated from the whole of the Pacific resource.

Between-generation effects are also felt to be minimal. At the present levels of exploitation, recruitment into the population of Pacific skipjack appears to be independent of catches taken from this population. In the absence of a demonstrable relationship between catches and subsequent recruitment for skipjack anywhere, there would appear to be no need for concern over reduction of the spawning stock. Rather, there appears to be great potential for a substantial increase to catches by regional fisheries so long as exploitation is distributed over the widespread skipjack resource.

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APPENDIX A. LIST OF SCIENTISTS, OBSERVERS AND CREW ON BOARD THE RESEARCH VESSEL

South Pacific Commission Scientists

Robert Gillett	2-5 February 1980
A.W. Argue	2-5 February 1980
James Ianelli	2-5 February 1980

Inter-American Tropical Tuna Commission Scientists

William Bayliff	2-5 February 1980
Terry Foreman	2-5 February 1980

Observers

Bruno Ugolini Service de la Pêche French Polynesia	2-5 February 1980
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Seima Kobayashi
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Yoshikatsu Oikawa
Tsunetaka Ono
Yukio Sasaya
Kohji Wakasaki
Mikio Yamashita

APPENDIX B. ABBREVIATIONS FOR COUNTRIES, TERRITORIES AND SUBDIVISIONS THEREOF

AMS - American Samoa
CAL - New Caledonia
COK - Cook Islands
FIJ - Fiji
GAM - Gambier Islands (French Polynesia)
GIL - Gilbert Islands (Kiribati)
GUM - Guam
HAW - Hawaii
HOW - Howland and Baker Islands (U.S. Territory)
IND - Indonesia
INT - International waters
JAP - Japan
JAR - Jarvis (U.S. Territory)
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

APPENDIX C. DETAILED RELEASE AND RECAPTURE INFORMATION FOR RECOVERIES OF YELLOWFIN TAGGED IN THE WATERS OF PITCAIRN ISLANDS

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1B15960   release data:  80/02/04  25deg 00'S  130deg 07'W   76.0cm  PIT1
        recapture data:  81/5/05   07deg 45'S  121deg 50'W  140.0cm  INT
At large for 456 days. Distance = 1138.6 naut. miles in direction 26.deg. true.

1B16645   release data:  80/02/04  24deg 54'S  130deg 03'W   75.0cm  PIT1
        recapture data:  80/12/16  14deg 37'S  090deg 50'W  120.0cm  INT
At large for 316 days. Distance = 2289.8 naut. miles in direction 82.deg. true.
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