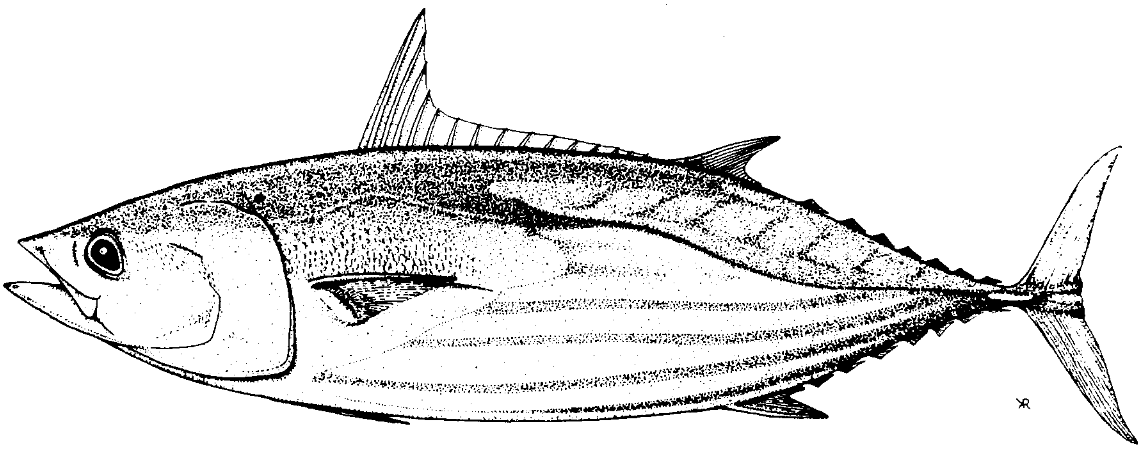
AN ASSESSMENT OF THE SKIPJACK AND BAITFISH RESOURCES OF NEW ZEALAND

A.W. Argue
and
R.E. Kearney



Skipjack Survey and Assessment Programme
Final Country Report No. 6

South Pacific Commission
Noumea, New Caledonia
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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.

The Skipjack Programme has been succeeded by the Tuna and Billfish Programme which is receiving funding from Australia, France, New Zealand and the United States of America. The Tuna Programme is designed to improve understanding of the status of the stocks of commercially important tuna and billfish species in the region. Publication of final results from the Skipjack Programme 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 Tuna Programme at the time of preparation of this report comprised the Programme Co-ordinator, R.E. Kearney, Research Scientists, A.W. Argue, C.P. Ellway, R. 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 Skipjack Programme is indebted to officials of the Fisheries Management and Fisheries Research Divisions of the New Zealand Ministry of Agriculture and Fisheries for assisting staff of the Skipjack Programme in many aspects of the New Zealand surveys. For supplying catch statistics, sampling statistics and tag returns from the New Zealand fishery, the authors wish to thank George Habib, Fisheries Research Division, Wellington, and George Clement, Fisheries Management Division, Tauranga. The assistance of Graham Bell, Bell-Air Executive Air Travel Limited, Tauranga, and his spotter pilots was appreciated.

Earlier drafts of the report were reviewed by scientists of the New Zealand Ministry of Agriculture and Fisheries.

Tuna Programme
South Pacific Commission

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AN ASSESSMENT OF THE SKIPJACK AND BAITFISH RESOURCES OF NEW ZEALAND

1.0 INTRODUCTION

New Zealand commenced its skipjack fishery in 1974 with chartered purse-seine vessels and, initially, limited involvement by New Zealand seiners. Since 1974 New Zealand seiners have become increasingly active in the fishery and in the 1980/1981 season they harvested just under half of the catch of 8,555 tonnes (Habib, Clement and Fisher 1981). Over the longer term, increased participation by local vessels is anticipated, as is a several-fold increase in the annual catch which averaged 8,500 tonnes between 1977/1978 and 1980/1981 (Habib 1981). This would clearly establish skipjack as the dominant tuna species in the commercial harvest from New Zealand's 200-mile exclusive economic zone.

Since the New Zealand skipjack fishery is a seasonal one that catches immature fish, and there are growing fisheries on mature skipjack in several countries and territories in tropical waters to the north of New Zealand, it was important to evaluate the degree of interaction amongst these fisheries. Similar concerns, shared by many countries in the region, led to development of the South Pacific Commission's Skipjack Survey and Assessment Programme. It was the purpose of the Skipjack Programme to assess the status of the skipjack resource through tagging and biological sampling. Three years of tagging over a broad area of the central and western Pacific, and amongst all major fisheries, provided the data necessary to assess fishery interactions.

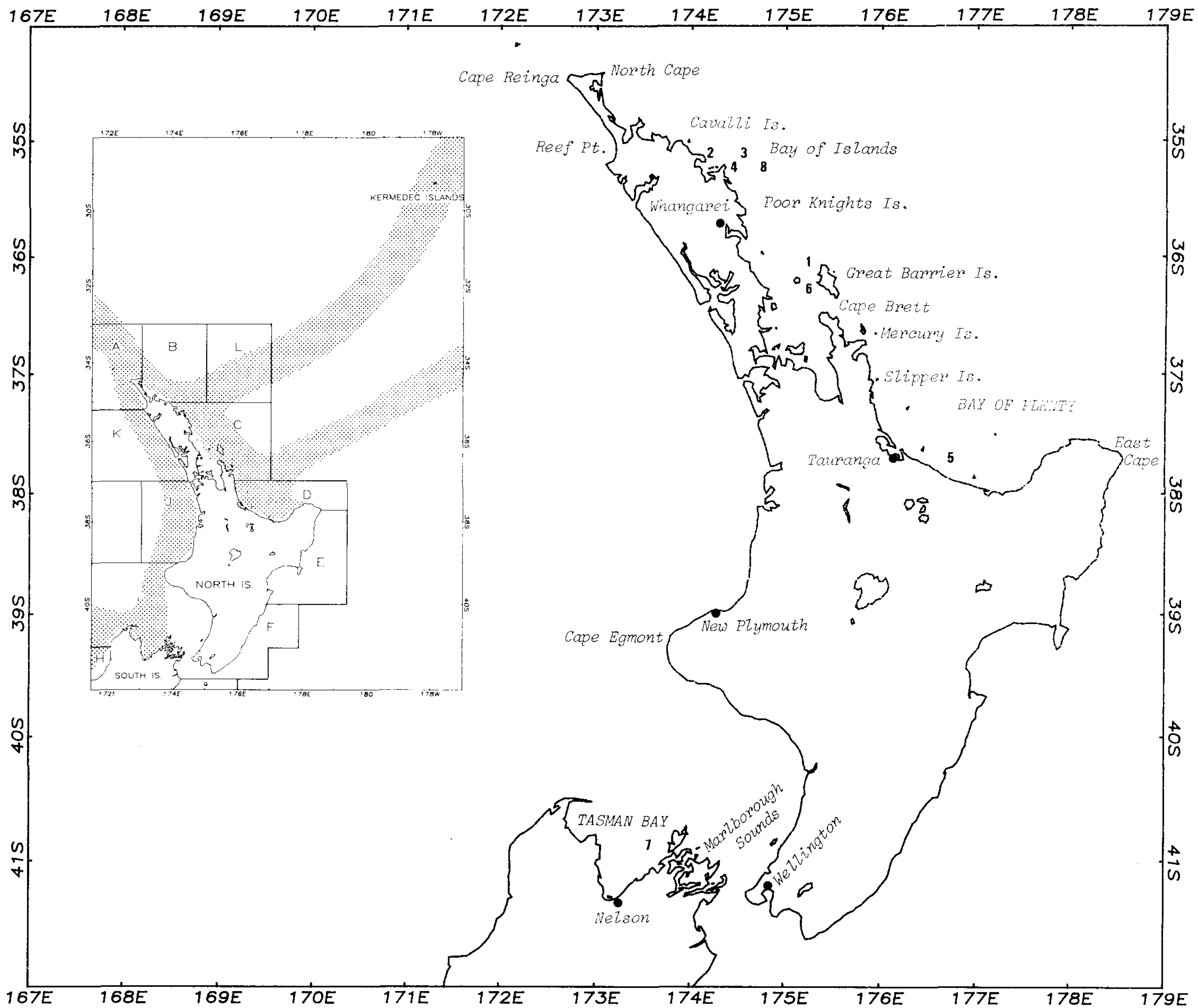
Fishing in the waters of New Zealand with a Japanese live-bait pole-and-line vessel had been attempted only once prior to 1979 (Webb 1974). The Skipjack Programme provided a second opportunity to evaluate the effectiveness of this method of fishing for skipjack in southern subtropical waters using local species of live-bait.

The Skipjack Programme conducted two surveys in the waters of New Zealand. The first, from 15 February to 28 March 1979, followed the Programme's survey in the waters of Cook Islands. Preliminary results for the first New Zealand survey were reported in Kearney and Hallier (1979). The second survey was from 10 to 25 March 1980, towards the end of the 1979/1980 commercial fishing season in New Zealand. The surveys ranged from the Kermadec Islands, 600 nautical miles northeast of the North Island of New Zealand, to Tasman Bay on the northwest coast of the South Island, and included considerable time in the main commercial fishing area between North Cape and the Bay of Plenty (Figure 1). This report presents final results from both surveys and discusses management implications of these findings.

1.1 Background to the Skipjack Fishery

New Zealand implemented its Exclusive Economic Zone (EEZ) legislation on 1 April 1978 thus bringing conservation and management of fisheries resources in over 4.1 million square kilometres of ocean under national control. In this large ocean area the 1979 New Zealand catch of 105,000 metric tonnes of fish and shellfish is estimated to represent less than one-quarter of the sustainable biological yield (Anon 1981a). Tunas, most of which are caught in northern subtropical waters of the New Zealand EEZ, are estimated to have a yield potential of over 30,000 tonnes per year, of which the potential annual harvest of skipjack is thought to be 20,000 to 24,000 tonnes (Habib 1981).

FIGURE 1. SURVEY AREA AND BAITFISHING LOCALITIES (NUMBERS) FOR THE 1979 AND 1980 SKIPJACK PROGRAMME SURVEYS IN THE WATERS OF NEW ZEALAND



The New Zealand purse-seine fishery for skipjack began in December 1975 after a successful survey the previous summer by the United States seiner Paramount (Eggleston 1976). Earlier purse-seine surveys, dating back to 1966, had focused on other pelagic species since at that time markets and catch potential were uncertain for tuna from the waters of New Zealand. However, even during these early years there was considerable optimism about the tuna potential in New Zealand. In a message to the 1971 Tuna Seminar organised by the Fishing Industry Board (Fishing Industry Board 1971), the New Zealand Minister of Marine and Fisheries drew attention to the target of NZ$7 million for pelagic fish exports by 1978, and suggested that "... tuna could well form a large part of these exports." By 1978 the catch of skipjack exceeded 9,000 tonnes thus making skipjack the third most important species in terms of tonnage caught from New Zealand waters, and a major contributor to this export target.

Skipjack catches rose from 4,715 tonnes by five purse-seine vessels during the 1975/1976 season, to a peak of 9,526 tonnes by ten vessels during the 1977/1978 fishing season (Table 1). Catches remained roughly constant at just under 9,000 tonnes through the 1980/1981 season, while the fleet increased from 10 to 19 vessels. During the 1980/1981 season, a higher than normal proportion of the skipjack resource appeared to be distributed close to shore (inside 12 nautical miles), and thus were not available to the bulk of the fishing fleet (Habib et al. 1981). Skipjack appeared late in the 1981/1982 season after many vessels had left for other tuna fisheries. As a result the 1981/1982 catch was only 5,000 tonnes (Habib, personal communication).

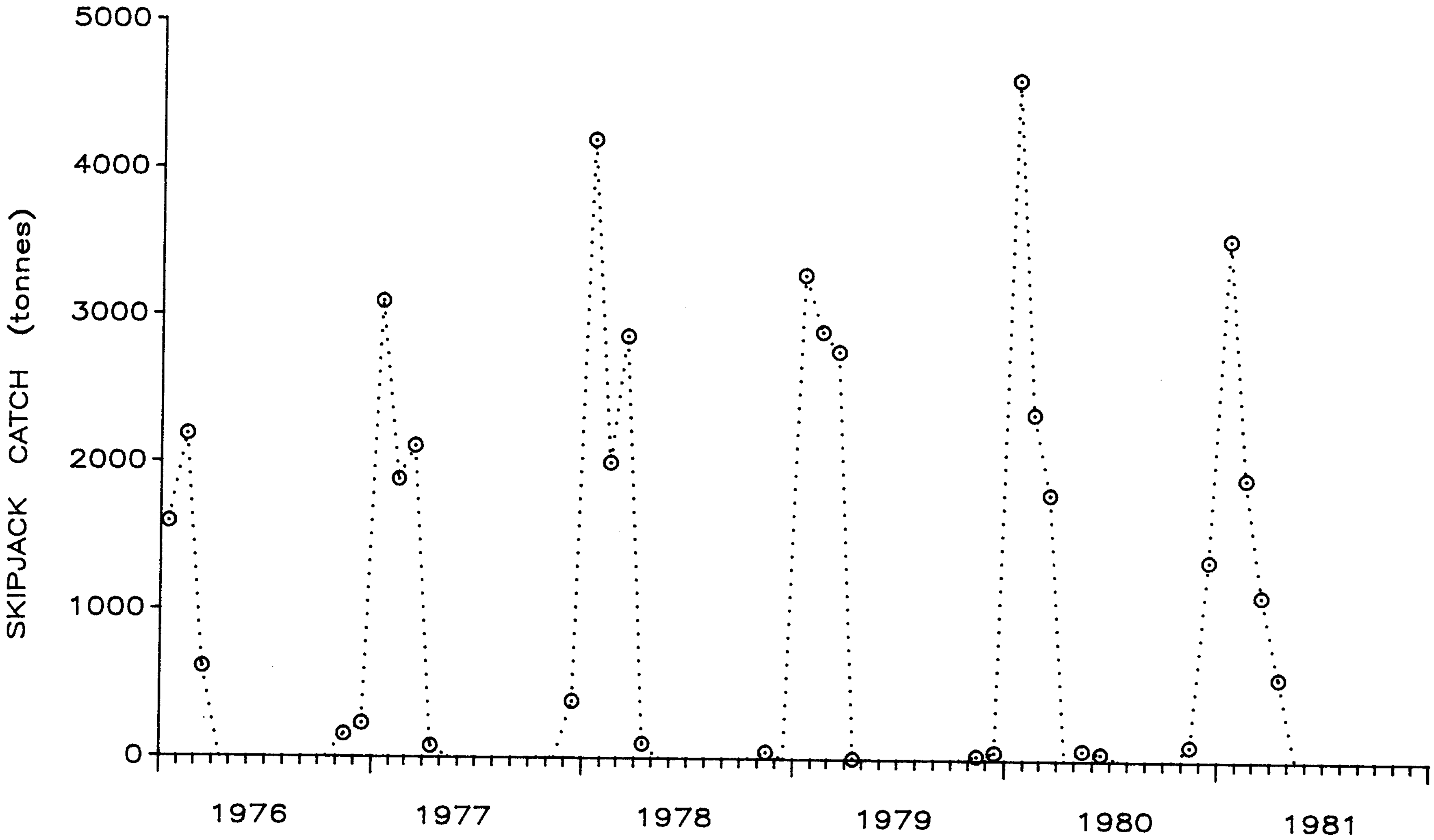
TABLE 1. ANNUAL SKIPJACK CATCH AND EFFORT STATISTICS FOR THE COMMERCIAL PURSE-SEINE FISHERY IN THE WATERS OF NEW ZEALAND*

	Skipjack Catch (tonnes)	Days Searching and Fishing	Numbers of Sets	Tonnes per Day Searching and Fishing	Tonnes per Set	Number of Vessels
1975/1976	4,715	224	304	21.05	15.51	5
1976/1977	7,541	449	609	16.80	12.38	11
1977/1978	9,526	401	704	23.76	13.53	10
1978/1979	8,975	419	667	21.42	13.46	12
1979/1980	8,931	420	625	21.26	14.29	15
1980/1981	8,555	946	960	9.04	8.91	19

* Source catch statistics: Habib (1976, 1978)
Habib et al. (1980a, 1980b, 1980c, 1981)

The New Zealand fishery is highly seasonal (Figure 2). Aerial surveys have established that skipjack usually appear first between late November and early December, often in the vicinity of "The Cross", the position east of Great Barrier Island where latitude 36°S crosses longitude 176°E (e.g. Habib, Clement and Fisher 1980a). In the ensuing months skipjack bodies (groups of schools) are common in waters from North Cape to the Bay of Plenty on the east side of the North Island, and from Cape Reinga to New Plymouth on the west side of the North Island. In the four seasons prior to 1981/1982, peak monthly catches of 3,000 to 4,500 tonnes were taken in January, and catches of over 1,000 tonnes continued through March. Detailed catch

FIGURE 2. MONTHLY CATCH (TONNES) OF SKIPJACK IN NEW ZEALAND BY PURSE-SEINE GEAR, 1976 TO 1981



statistics are not yet available for the 1981/1982 season. It is thought that skipjack rapidly depart the New Zealand zone during April and May as surface waters cool below the temperature (19°C-22°C) of so-called "skipjack water" (Eggleston and Paul 1978; Habib, Clement and Fisher 1980a). In most years over three-quarters of the season's successful seine sets occur in waters within this temperature range.

Each year the New Zealand Ministry of Agriculture and Fisheries (MAF) places observers on most of the purse-seine vessels to collect detailed biological and fishing data. Catch statistics are obtained from logbooks maintained by all vessels, supplemented by data from the MAF observer programme and from observers and pilots on board "spotter" aircraft.

Catch areas, shown in the Figure 1 inset, cover the fishing grounds of the purse-seine fleet. Between the 1977/1978 and 1980/1981 seasons an average of 50 per cent of the catch (and effort) occurred in area C on the east coast of the North Island, primarily near the 200-metre depth contour in the vicinity of Poor Knights Island and to the east of Great Barrier Island. Lesser and more variable percentages of the catch were taken to the north in area B (0 to 35%) and in area D, the Bay of Plenty (6 to 17%). Catches from statistical areas on the west coast of the North Island contributed a lower percentage of the total season's catch, varying from less than 3 per cent in 1980/1981 to 35 per cent in 1979/1980, and averaged 18 per cent between 1977/1978 and 1980/1981. West coast catches were also concentrated near the 200-metre contour.

Fishing and spotting operations are frequently hampered, at times interrupted, by poor weather conditions during the skipjack season. These conditions tend to be more severe on the west coast of the North Island, which, coupled with few sheltered anchorages, discourages seine vessels from fishing this area.

Purse-seiners fishing skipjack in New Zealand fall into three size classes: small vessels, less than 500 tonnes carrying capacity, all of which are owned and operated by New Zealand fishing companies (six in 1980/1981); medium vessels, 500 to 1,000 tonnes carrying capacity (one in 1980/1981); and large "superseiners", over 1,000 tonnes carrying capacity (12 in 1980/1981), most of which are owned by United States of America interests (11 in 1980/1981). Most United States vessels operate under joint venture agreements with a number of New Zealand fishing companies. They are all restricted by government regulation to fishing outside the twelve-mile limit of the New Zealand territorial sea. New Zealand vessels have virtually unrestricted fishing access and have increased their share of the total catch from less than five per cent in 1975/1976 (only two New Zealand vessels), to 44 per cent of the catch in 1980/1981 when skipjack were closer to shore and appeared in smaller concentrations, more suitable to vessels under 1,000 tonnes.

Other tuna species are fished in New Zealand waters, although catches by New Zealand vessels are at a lower level than for skipjack (Habib and Clement 1981). Approximately 200 New Zealand vessels, most less than 100 gross tonnes, troll for albacore (*Thunnus alalunga*) on a part-time basis landing just under 2,000 tonnes per year, mostly from west coast waters of the South Island and southern North Island. Approximately 50 local vessels participate in a unique line fishery for southern bluefin tuna (*Thunnus maccoyi*) that are attracted to the surface by waste from fish processing operations on board large foreign groundfish trawlers, and by chum thrown from local vessels. In 1980, about 100 tonnes of bluefin were caught by these local vessels on the west coast of the South Island; most of this catch was processed for the Japanese sashimi market. In 1980, Japanese, Korean and Taiwanese longliners were licensed to fish for tuna in the New Zealand EEZ, although only the Japanese reportedly fished New Zealand waters that year. They landed an estimated 6,952 tonnes, of which 6,481 tonnes were southern bluefin; the remainder were albacore, bigeye (T. obesus), and yellowfin (T. albacares) (Habib and Clement 1981).

Several of the bait species caught by the Skipjack Programme in the waters of New Zealand, namely jack mackerels (Trachurus spp.), pilchard (Sardinops neopilchardus) and southern anchovy (Engraulis australis), have on occasion been subjected to small local fisheries (<1,000 tonnes harvested per year). These species are all thought to be in sufficient abundance to support sizeable local fisheries if markets could be developed (Robertson 1978a, 1978b).

1.2 Previous Surveys

Development of the New Zealand purse-seine fishery for skipjack was preceded by fishing and research surveys on tunas dating back to the early 1960s (McKenzie 1963, Campbell 1971). Much of the early work centred on use of small coastal fishing vessels for pole-and-line fishing, trolling and gill-netting on surface concentrations of albacore and skipjack tuna (York 1969, 1977), and included attempts to attract tuna with acoustic equipment (York 1974). Catch rates were encouraging in the waters surrounding the North Island but did not result in any major increase in commercial fishing activity for skipjack or other tuna species. Some of the early surveys were complemented by collection of various biological and oceanographic data, much of which was reviewed, along with fishing results, at the May 1971 seminar to explore prospects for development of a New Zealand tuna industry (Fishing Industry Board 1971). About this time the use of small aircraft to locate, identify and quantify abundance of pelagic fish species became a common practice in northern New Zealand waters (Webb 1971, Bell 1976).

In the early 1970s there were two surveys for tuna with pole-and-line gear. In the first, a converted Japanese tuna longliner, the 400-tonne Lloret Lopez II, used live pichards caught with "bouki-ami" gear to pole-and-line fish for albacore off the northwest coast of the South Island (Webb 1972a, 1972b, 1973). Poling off the modified stern was not particularly successful, nor was bouki-ami fishing, although holding pilchards in floating net-pens showed promise for increasing baitfish survival time (28 days in floating pens) (Webb 1972a). In the second survey, the Hoko Maru No.15, a 300-tonne Japanese live-bait pole-and-line vessel, conducted survey pole-and-line fishing and trolling from 8 February to 21 March 1972 on the west coasts of the North and South Islands, between Cape Reinga and Bruce Bay. Skipjack accounted for 59 tonnes of the total catch of 123 tonnes of skipjack and albacore. Skipjack catches were confined to waters north of Cape Egmont. The average catch rate of 9.8 tonnes of skipjack per fishing day in these waters was considered excellent for a vessel of the size of the Hoko Maru (Webb 1974). More than adequate quantities of pilchards (~80 per cent of the bait catch) and anchovies were purse-seined from various locations in the Marlborough Sounds area using two small multi-purpose fishing vessels of New Zealand registry (Webb 1972c). Purse-seined bait totalling 6,400 kg were transferred to floating net-pens; 5,700 kg were later loaded on board the Hoko Maru for pole-and-line fishing.

Size, age, reproduction, and distribution of the major New Zealand bait species has been presented in a number of publications, for example see Baker (1972), Tunbridge (1969), and Webb (1972d) for pilchards; Webb (1972d) for anchovies; and James (1975), Nosov and Shurunov (1975), and Stephenson and Robertson (1977) for jack mackerel.

The survey of North Island waters by the United States purse-seine vessel Paramount, between January 1974 and May 1975, was jointly financed by the New Zealand Government and Star-Kist Foods Inc. of California. The 40-metre Paramount, a converted pole-and-line vessel, fished surface schools of skipjack with a 550x55 fathom seine net and had a carrying capacity of approximately 350 tonnes of tuna. Skipjack sightings from the air and survey catches were highest between North Cape and the Bay of Plenty, and together suggested that a sizeable resource of skipjack was catchable by purse-seiners in New Zealand waters. Between 3 January and 2 March 1975 the Paramount caught 1,000 tonnes of skipjack in this area over 35 fishing days during which 45 of 102 sets were successful, for an average of just under 10 tonnes per set. Eggleston (1976), in his description of this survey, suggested that a vessel of the size of the Paramount could be expected to catch between 1,500 and 1,800 tonnes of skipjack in the four month season between early December and the end of March.

The New Zealand purse-seine fishery grew rapidly after the 1974/1975 Paramount survey. However, in the early years there was considerable concern over the appropriateness of allowing large United States purse-seiners to harvest substantial tonnages of skipjack from New Zealand waters (Waugh 1976). Reasons included the degree to which other nations harvested the same skipjack resource found in New Zealand; the origin, timing and distribution of harvestable quantities of skipjack in New Zealand waters; and the size of the skipjack resource in New Zealand waters, in particular with reference to development of a locally based fleet which might find heavy competition from United States seiners if the resource was indeed limited. A number of papers on these and other topics were presented to industry and fishermen at a Skipjack Tuna Conference organised by the Fisheries Research Division of the Ministry of Agriculture and Fisheries at the end of the 1975/1976 fishing season (Anon 1976).

To thoroughly document the fishery and to improve the biological data base on skipjack, the New Zealand Government expanded its skipjack research and stock assessment programme at the time the fishery commenced. The programme now includes placing observers on board purse-seine vessels to record catch, effort, biological and environmental data; issuing log-books for all vessels in the fishery; and obtaining aerial sightings data on the number, size and movement of skipjack aggregations. Results from the first year of this programme were presented at the 1976 Tuna Conference (Clement 1976; Habib 1976) and have been published for each subsequent year of the commercial fishery (Clement 1978; Habib 1978; Habib, Clement and Fisher 1980a, 1980b, 1980c, 1981; Habib et al. 1982).

After the 1976/1977 fishing season a second conference was held for industry and fishermen to provide an update on what had been learned from the first years of the seine fishery, as well as a prospective view of the potential harvest from other pelagic fish resources in the waters of New Zealand (Habib and Roberts 1978). Both conferences strongly endorsed the South Pacific Commission's Skipjack Survey and Assessment Programme, since results from this regional Programme were expected to substantially improve the body of information on skipjack population dynamics, and in particular the degree of interaction between the New Zealand skipjack fishery and skipjack fisheries to the north of New Zealand, areas of concern to both the New Zealand Government and the fishing industry.

2.0 SKIPJACK PROGRAMME RESEARCH PLAN

The objectives of the Skipjack Programme were to survey the skipjack and baitfish resources of all countries within the area of the South Pacific Commission and to assist with the assessment of the status of the stocks and the degree of interaction between individual fisheries for skipjack within the region and beyond. These assessments would provide a basis for rational development of skipjack fisheries throughout the region and sound management of the resource. The Programme's fieldwork spanned almost three years, from October 1977 to August 1980 inclusive, and incorporated visits to all of the countries and territories in the area of the South Pacific Commission as well as to New Zealand and Australia (Figure A, inside front cover). Eight hundred and forty-seven days of chartered vessel time were spent in the region and 25 countries and territories were visited. Fifty-seven days were spent in the waters of New Zealand in 1979 and 1980.

3.0 VESSEL AND CREW

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

The *Hatsutori Maru No.1* was operated with at least three Skipjack Programme scientists, nine Japanese officers and between nine and twelve Fijian crew. For the *Hatsutori Maru No.5*, between 13 and 15 Fijian crew were employed. Observers from the New Zealand Ministry of Agriculture and Fisheries were on board for varying times throughout the survey. All personnel and details of the times scientists and observers spent on board are given in Appendix A.

4.0 METHODS

Visual scanning and exploratory fishing for tunas and baitfish were the primary survey techniques. Tagging and biological sampling, including blood and parasite studies, were the basic tools used to assess skipjack resources. Analysis of results from these studies, together with available catch and effort data, constitute the basis for assessment of the resource of skipjack. Baitfish resources were surveyed by exploratory fishing, predominantly at night. Assessments of the baitfish resources were based on these results, estimates of the magnitude of suitable baitfish habitat, and knowledge of the utility of the common species as skipjack bait.

4.1 Skipjack 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 for commercial vessels, 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. While in New Zealand waters the research vessels had assistance in locating fishable skipjack concentrations from spotter aircraft that were working for the New Zealand Ministry of Agriculture and Fisheries and for some of the purse-seine vessels.

The number of crew on the *Hatsutori Maru No.1* and *No.5* was less than either of these vessels carry when fishing commercially. As at least one crew member was required to assist each scientist in the tagging procedures, the effective number of fishermen was further reduced. Moreover, the need to pole skipjack accurately into the tagging cradles reduced the speed of individual fishermen. Clearly these combined effects would decrease the fishing power of the research vessel. During the first survey in the waters of Fiji (26 January-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 No.1* under survey conditions was 28.8 per cent of its potential fishing power during commercial fishing (Kearney 1978).

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

Specimens of all tuna and other pelagic species that 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 (aggregations) 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.

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).

During the second visit to New Zealand, skipjack body cavities were examined for the presence of macro-parasites. Complete sets of gills and viscera were taken from five fish from each school, up to a maximum of three schools per day. Samples were frozen and subsequently air freighted to the University of Queensland, St Lucia, Australia, for detailed examination for the presence of parasites.

4.2 Baitfishing

Baitfishing carried out by the Programme in the waters of New Zealand employed a "bouki-ami" net set at night around bait attraction lights. Procedures were similar to those used by commercial vessels, but were modified where necessary to meet the Programme's special requirements. In some countries beach seining during daylight was used as an alternative bait-catching technique. Details of both techniques and all modifications employed by the Skipjack Programme are given by Hallier and Gillett (1982).

4.3 Data Compilation and Processing

Five separate logbook systems formed the basis for compiling data accumulated during the fieldwork outlined in Sections 4.1 and 4.2. The techniques used to enter data into computer files and to process data are discussed by Kleiber and Maynard (1982). Data processing was carried out on the Programme's Hewlett Packard 1000 computer in Noumea. Electrophoretic data from blood samples and parasite identifications from viscera specimens were also coded and entered into files on the computer.

4.4 Data Analysis

Assessment of the skipjack resource and possible interactions between skipjack fisheries in New Zealand and those in other countries 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, population dynamics and fishery interactions. Methods employed in biological studies of growth are described in Lawson and Kearney (MS), and for juvenile abundance, in Argue, Conand and Whyman (MS). Comparison of fishing effectiveness between different baitfish families follows on procedures described in Argue and Hallier (MS). 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, 1981b; Skipjack Programme 1981c). Occurrence and distribution of skipjack parasites have also been evaluated (Lester 1981).

5.0 SUMMARY OF FIELD ACTIVITIES

During the two surveys in the waters of New Zealand 36 days were spent skipjack fishing, 4 baiting, 9 steaming, and 8 in port (Table 2). Three of the eight port days were due to adverse weather conditions at the beginning of the second survey.

Baitfishing activities are summarised in Table 3. Eight separate localities were fished using the bouki-ami night-baiting technique; seven were between North Cape and Whale Island in the Bay of Plenty, and one was in Tasman Bay on the northern coast of the South Island.

While in New Zealand waters the survey vessels fished primarily between North Cape and the Bay of Plenty on the east side of the North Island (29 days). Five days were spent fishing on the southwest coast of the North Island and on the northwest coast of the South Island at the end of the first survey prior to departing for Australia. During the second visit, the Kermadec Islands were briefly surveyed while the vessel was en route to New Zealand from the waters of Tonga. The Figure 1 inset shows the areas surveyed in New Zealand for tuna and baitfish.

TABLE 2. SUMMARY OF DAILY FIELD ACTIVITIES IN THE WATERS OF NEW ZEALAND BY THE SKIPJACK PROGRAMME. Schools sighted are given by species: SJ skipjack or skipjack with other species except yellowfin; YF yellowfin or yellowfin with other species except skipjack; OT other species without skipjack or yellowfin, UN unidentified.

Date	General Area	Principal Activity	Bait Carried (kg)	Hours Fishing and Sighting	Schools Sighted (numbers) SJ	YF	OT	UN	Fish Tagged (numbers) SJ	OT	Fish Caught (kg) SJ	Total Catch (kg)
15/02/79*	NE New Zealand	Steaming	0	12	0	0	0	0	-	-	-	-
17/02/79	N Bay of Plenty	Steaming	0	14	0	0	0	1	-	-	-	-
18/02/79	Tauranga	In Port	0	0	-	-	-	-	-	-	-	-
19/02/79	Tauranga	In Port	0	0	-	-	-	-	-	-	-	-
20/02/79	Great Barrier Is	Steaming	0	0	-	-	-	-	-	-	-	-
21/02/79	Great Barrier Is	Fishing	405	14	2	0	0	6	0	0	2	2
22/02/79	Poor Knights	Fishing	381	14	3	0	0	1	1571	0	4432	4432
23/02/79	Poor Knights	Fishing	303	14	2	0	0	3	0	0	8	10
24/02/79	Cape Brett	Fishing	287	5	0	0	0	1	0	0	0	0
25/02/79	Cape Brett	Fishing	519	13	3	0	0	0	0	0	10	10
26/02/79	NW Cape Brett	Fishing	489	13	6	0	1	2	247	0	724	724
27/02/79	Cavalli Is	Fishing	527	12	4	0	2	2	683	0	1566	1568
28/02/79	Poor Knights	Fishing	435	8	4	0	0	0	177	0	396	396
01/03/79	Poor Knights	Fishing	1208	13	0	0	0	0	0	0	0	0
02/03/79	Poor Knights	Fishing	1208	13	7	0	0	0	3689	0	9724	9724
03/03/79	Poor Knights	Fishing	375	5	3	0	2	4	574	0	1469	1475
04/03/79	Poor Knights	Fishing	800	11	1	0	1	2	3	0	8	16
05/03/79	Bay of Islands	Fishing	1020	9	2	0	0	0	168	0	426	426
06/03/79	Great Barrier Is	Fishing	1005	13	5	0	0	1	1144	0	3001	3001
07/03/79	Bay of Plenty	Fishing	948	13	11	0	0	4	86	0	310	310
08/03/79	Bay of Plenty	Fishing	858	12	6	0	1	1	634	0	2566	2566
09/03/79	Bay of Plenty	Fishing	998	8	0	0	1	1	0	0	0	2
10/03/79	Bay of Plenty	Steaming	995	0	-	-	-	-	-	-	-	-
11/03/79	Tauranga	In Port	450	0	-	-	-	-	-	-	-	-
12/03/79	Tauranga	In Port	450	0	-	-	-	-	-	-	-	-
13/03/79	Tauranga	Fishing	449	3	1	0	0	5	605	0	2528	2528
14/03/79	Bay of Plenty	Fishing	369	12	8	0	0	4	513	1	2194	2198
15/03/79	Bay of Plenty	Steaming	180	12	1	0	0	0	0	0	0	0
16/03/79	Great Barrier Is	Fishing	1029	8	2	0	1	3	0	0	5	9
17/03/79	Great Barrier Is	Baiting	1649	0	-	-	-	-	-	-	-	-
18/03/79	Mercury Is	Steaming	1647	3	0	0	0	0	0	0	0	0
19/03/79	Slipper Is	In Port	1638	0	-	-	-	-	-	-	-	-
20/03/79	Poor Knights	Fishing	1632	11	2	0	0	2	976	0	2553	2553
21/03/79	North Cape	Fishing	1575	10	1	0	0	1	0	0	0	0
22/03/79	W North Is	Fishing	1574	12	11	0	0	5	204	0	510	514
23/03/79	W North Is	Fishing	1446	12	4	0	2	0	302	0	698	702
24/03/79	W North Is	Fishing	1326	12	6	0	5	0	47	2	162	200
25/03/79	South Is	Fishing	1185	10	1	0	0	0	0	0	0	0
26/03/79	Nelson Harbour	Baiting	1328	0	-	-	-	-	-	-	-	-
27/03/79	NW South Is	Fishing	1328	12	4	0	9	5	0	0	32	52
28/03/79	W New Zealand	Steaming	1314	12	0	0	1	0	0	0	0	0
10/03/80	N Kermadec Is	Fishing	95	12	0	0	0	1	0	0	0	0
11/03/80	Kermadec Is	Fishing	89	12	0	1	0	3	0	0	0	0
12/03/80	NE North Is	Fishing	50	10	0	0	0	1	0	0	0	0
13/03/80	Whangarei	Steaming	50	0	-	-	-	-	-	-	-	-
14/03/80	Whangarei	In Port	0	0	-	-	-	-	-	-	-	-
15/03/80	Whangarei	In Port	0	0	-	-	-	-	-	-	-	-
16/03/80	Whangarei	In Port	0	0	-	-	-	-	-	-	-	-
17/03/80	Bay of Islands	Steaming	0	0	-	-	-	-	-	-	-	-
18/03/80	Bay of Islands	Baiting	0	0	-	-	-	-	-	-	-	-
19/03/80	Great Barrier Is	Fishing	21	7	6	0	0	0	0	0	2	2
20/03/80	Great Barrier Is	Baiting	86	0	-	-	-	-	-	-	-	-
21/03/80	Great Barrier Is	Fishing	1284	10	14	0	0	0	1	0	45	45
22/03/80	Poor Knights	Fishing	1433	8	6	0	0	1	0	0	12	12
23/03/80	Poor Knights	Fishing	1388	8	8	0	0	2	1110	0	3997	3997
24/03/80	Whangarei	Fishing	1748	4	5	0	0	1	0	0	8	8
25/03/80	N New Zealand	Fishing	1703	11	0	0	0	0	0	0	0	0
TOTALS				427	139	1	26	63	12734	3**	37388	37482

* Date-line crossing
** Albacore

TABLE 3. SUMMARY OF SKIPJACK PROGRAMME BAITFISHING EFFORT AND CATCH IN THE WATERS OF NEW ZEALAND

Locality Number	Anchorage	Time of Hauls	Number of Hauls	Dominant Species	Est. Av. Catch per Haul (kg)	Mean Length (mm)	Other Common Species
1	Port Fitzroy			*Sardinops neopilchardus*	748	172	*Trachurus novaezealandae*
	36°10'S	Night	5	*Trachurus declivis*	41	141	*Engraulis australis*
	175°21'E			*Scomber australasicus*	40	152	*Zeus faber*
2	Deep Water Cove			*Trachurus declivis*	120	121	*Zeus faber*
	35°12'S	Night	2	*Engraulis* sp. (juvenile)			*Optivus elongatus*
	174°18'E			Sp. of Anguillidae (juvenile)			
	Deep Water Cove			*Trachurus declivis*	109	121	*Decapterus koheru*
	35°11'S	Night	2	*Scomber australasicus*	7	131	Sp. of Hemirhamphidae
	174°18'E			*Trachurus novaezealandae*	6	242	
3	Renown Anchorage			*Sardinops neopilchardus*	197	98	Sp. of Sphyraenidae
	35°15'S	Night	1	*Engraulis australis*	90	63	*Arripis trutta*
	174°09'E			*Trachurus declivis*	17		*Zeus faber*
	Renown Anchorage			*Arripis trutta*	572	357	*Zeus faber*
	35°14'S	Night	1	*Trachurus novaezealandae*	527	228	*Scomber australasicus*
	174°07'E			*Engraulis australis*	12	79	*Sardinops neopilchardus*
4	Te Roa Bay			*Scomber australasicus*	192	152	*Engraulis australis*
	35°13'S	Night	3	*Trachurus declivis*	148	120	Sp. of Squid
	174°18'E			*Sardinops neopilchardus*	115	207	Sp. of Exocoetidae
5	Whale Island			*Trachurus declivis*	261	150	Sp. of Squid
	37°52'S	Night	1	*Engraulis australis*	78	78	*Arripis trutta*
	176°58'E			*Sardinops neopilchardus*	15		*Scomber australasicus*
6	Nagle Cove			*Sardinops neopilchardus*	487	171	*Arripis trutta*
	36°09'S	Night	3	*Trachurus novaezealandae*	7	147	
	175°19'E			Sp. of Squid			
	Nagle Cove			*Trachurus novaezealandae*	32	147	Sp. of Squid
	36°08'S	Night	2	*Aldrichetta forsteri*	2	204	
	175°19'E			Sp. of Hemirhamphidae			
7	Okure Bay			*Sardinops neopilchardus*	63	43	Sp. of Hemirhamphidae
	40°58'S	Night	2	*Engraulis australis*	11	45	*Thyrsites atun*
	173°46'E			Sp. of Squid			*Trachurus declivis*
8	Whangamumu Harbour			*Trachurus declivis*	302	132	Sp. of Hemirhamphidae
	35°14'S	Night	1	*Trachurus novaezealandae*	3		Sp. of Squid
	174°19'E			*Scomber australasicus*			*Engraulis* sp. (juvenile)

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) : The average catch in kilograms per haul is given for the dominant three species for each anchorage and gear type. This average catch is the product of the total catch in kilograms for the particular anchorage and gear type and the weighted proportion of the particular species in this catch. The weighted proportion of each species was determined from the numerical proportion in the catch multiplied by the cube of the mean standard length for that species, anchorage and gear type, and by a scaling factor. The scaling factor was chosen so that the sum of weighted proportions would equal the sum of numerical proportions. If the mean standard length was unknown, the numerical proportion was used. Since the average catch per haul is given for only the dominant three species, the total of the three is in general less than the total catch for the anchorage and gear type.

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

Baitfish Taxonomy : *Trachurus declivis* and *T. novaezealandae* are very difficult to separate. They are presented individually in this table so as to be consistent with preliminary results for New Zealand presented in Kearney and Hallier (1979).

Skipjack fishing activities, including school sightings, tag releases and catches, are summarised in Table 2. On fishing days an average of 10.4 hours were spent searching and fishing. A total of 229 schools were sighted, for an average of 0.54 schools sighted per hour. Of the 166 identified schools, 139 (84%) were skipjack schools, or schools of skipjack in association with other species, principally albacore.

A total of 37.4 tonnes of skipjack were caught; other species accounted for less than 0.1 tonne. This represents an average catch of 1,038 kg per fishing day. Other species in the catch included albacore (*Thunnus alalunga*), blue mackerel (*Scomber australasicus*) and dolphin fish (*Coryphaena hippurus*).

The first visit to New Zealand was very successful. The scientists and crew of the *Hatsutori Maru No.1* tagged a total of 11,623 skipjack, for an average of 284 tag releases per survey day. During the second visit, the *Hatsutori Maru No.5* was hampered by bad weather and poor bait catches at the beginning of the survey. A total of 1,111 skipjack were tagged during 16 survey days; however, all but one of these skipjack were released on 23 March. As of 1 March 1982, the SPC had received 1,088 tag returns from the total of 12,734 skipjack that were tagged in the waters of New Zealand. There have been no recoveries from three releases of tagged albacore.

A summary of numbers of fish sampled for biological data is given in Table 4. The size distribution of tagged skipjack shows a range of 38 to 67 cm fork length (Figure 3 upper). Their average length was 48.2 cm, which is almost identical to the average length of skipjack in the New Zealand biological sample (Figure 3 lower), but is 2.2 cm less than the Skipjack Programme's overall average of 50.4 cm for tagged skipjack. Skipjack maturity data is summarised in Figure 4. Skipjack diet items are listed in Table 5. Three skipjack blood samples of approximately 100 specimens each were taken during the first survey from separate schools that were fished between Great Barrier Island and the Bay of Plenty.

TABLE 4. SUMMARY OF NUMBERS OF FISH SAMPLED FOR BIOLOGICAL DATA FROM THE WATERS OF NEW ZEALAND

Species	Measured Total No. Measured	Weighed Total No. Weighed	Total No. Examined for Sex	Total No. Examined for Stomach Content	Total No. Examined for Tuna Juveniles
Skipjack *Katsuwonus pelamis*	1493	715	726	377	700
Albacore *Thunnus alalunga*	35	35	35	35	35
Dolphin Fish *Coryphaena hippurus*	2	2	2	2	2
Blue Mackerel *Scomber australasicus*	4	0	0	0	0
Totals	1534	752	763	414	737

FIGURE 3. LENGTH FREQUENCY DISTRIBUTIONS FOR TAGGED (UPPER GRAPH) AND SAMPLED (LOWER GRAPH) SKIPJACK FOR BOTH SKIPJACK PROGRAMME SURVEYS IN THE WATERS OF NEW ZEALAND. Mean length, standard deviation of the mean, and sample size are indicated on the graphs.

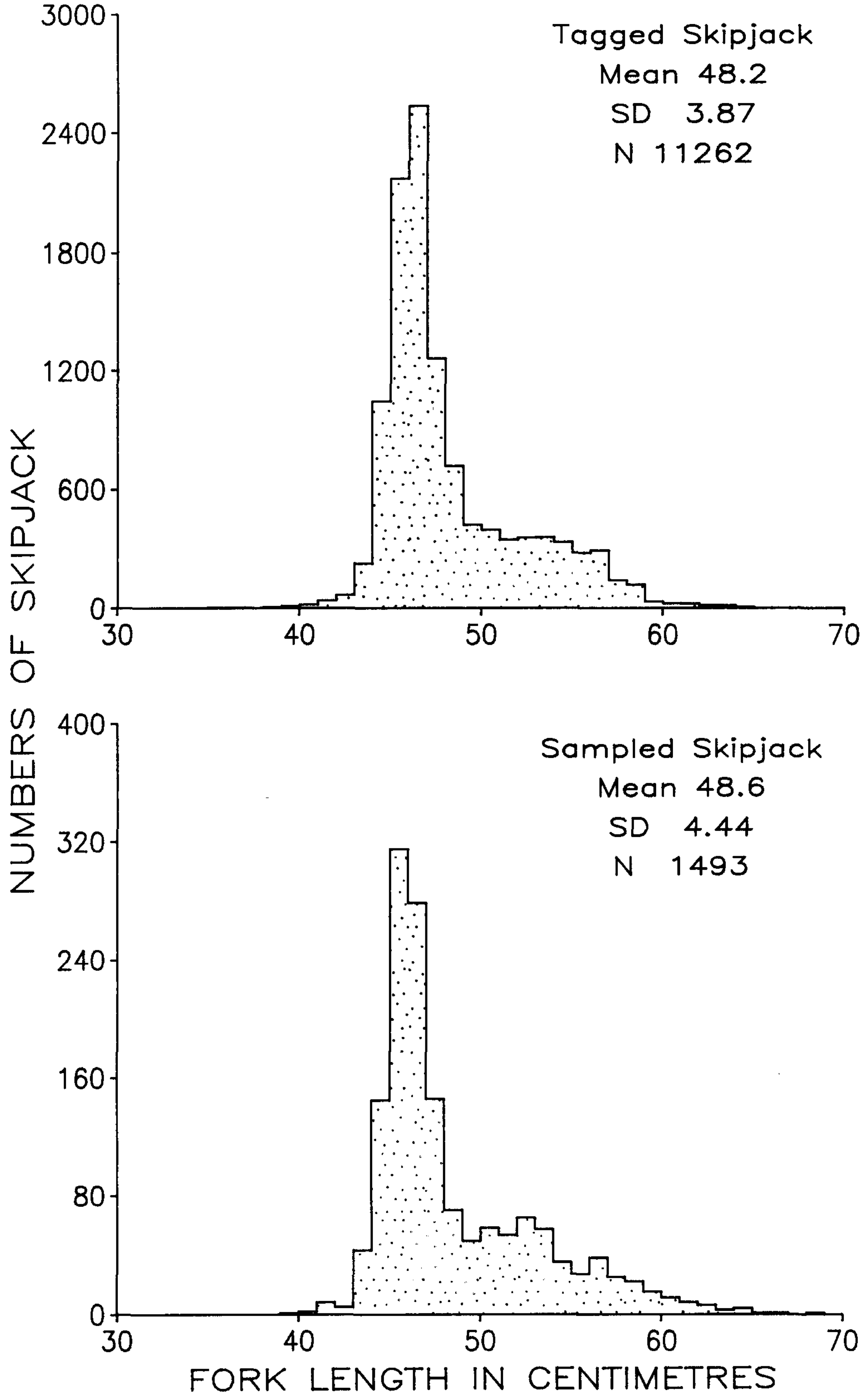


FIGURE 4. DISTRIBUTION OF FEMALE SKIPJACK MATURITY STAGES FOR BOTH VISITS TO NEW ZEALAND (UPPER GRAPH) AND IN TROPICAL WATERS SURVEYED BY THE SKIPJACK PROGRAMME (LOWER GRAPH)

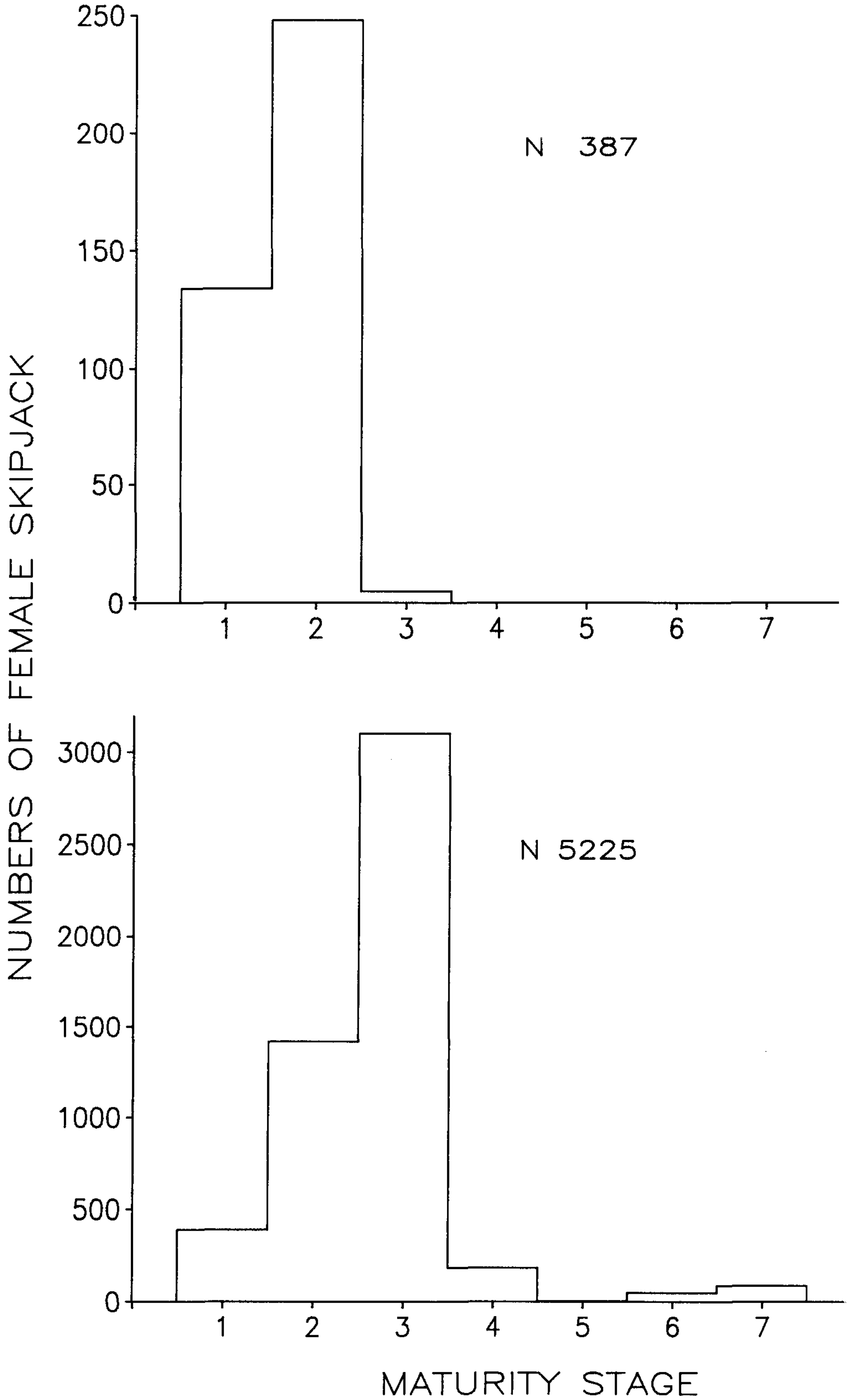


TABLE 5. STOMACH CONTENTS OF SKIPJACK SAMPLED IN THE WATERS OF NEW ZEALAND

Item No.	Diet Item Fish and Invertebrates	Number of Stomachs	Percentage Occurrence
1	Euphausiid (Euphausiacea)	245	64.99
2	Empty stomach	96	25.46
3	Chum from *Hatsutori Maru*	51	13.53
4	Fish remains (not chum)	7	1.86
5	Megalopa stage (Decapoda)	6	1.59
6	Amphipoda	6	1.59
7	Squid (Cephalopoda)	3	.80
8	Juvenile fish	3	.80
9	Gastropoda	2	.53
10	Octopus (Cephalopoda)	2	.53
11	Stomatopoda	2	.53
12	Argonauta (Cephalopoda)	2	.53
13	Zoaea stage (Crustacea)	1	.27
14	Scombrid juvenile (Scombridae)	1	.27
15	*Scomber australasicus* (Scombridae)	1	.27
16	Engraulidae	1	.27
	Total Stomachs Examined	377	

6.0 RESULTS AND DISCUSSION

6.1 Baitfishing

Results from the Programme's baiting at each of eight localities in New Zealand are summarised in Table 3. For larger localities, such as Deep Water Cove and Renown Anchorage in the Bay of Islands, results are shown for all anchorages that were further than one nautical mile apart. Table 6 presents a summary of these data for the five dominant species. Twenty-one species were identified from 23 bait hauls in the waters of New Zealand (Appendix B) with five species comprising 99 per cent of the total catch of 9,959 kg (Table 6). Note that in this and subsequent tables the total catch includes a percentage of the catch (~30%) that was discarded while being loaded on board the research vessel because the bait were either in excess of baitwell holding capacity, were dead or in poor condition, or were predominantly predator species.

Two species of jack mackerel, *Trachurus novaezealandae* and *T. declivis*, are abundant in coastal waters of New Zealand (Robertson 1978a); however, separation of these species, particularly juveniles, is very difficult. Skipjack Programme scientists used criteria described by Stephenson and Robertson (1977), principally the length of the dorsal accessory lateral line and curvature of the main lateral line, but experienced some difficulty with use of these criteria in the field since many specimens appeared intermediate to the examples shown by Stephenson and Robertson. Consequently the different catch rates estimated for each species, by locality in Table 3 and by survey in Appendix B, should be interpreted with caution. Catches of the two species were combined in the remaining baitfish tables and in the discussion of baiting results.

TABLE 6. THE DOMINANT SPECIES OF BAITFISH CAUGHT WITH BOUKI-AMI GEAR BY THE SKIPJACK PROGRAMME IN THE WATERS OF NEW ZEALAND

Bait Species	1979			1980			Total			Average (1979+1980)*	
	Total Kg	Kg per Haul	% per Haul	Total Kg	Kg per Haul	% per Haul	Total Kg	Kg per Haul	% per Haul	Kg per Haul	% per Haul
Sardinops neopilchardus	2137	143	47	3741	468	70	5878	256	59	306	63
Trachurus spp.	1392	93	30	1034	130	19	2426	105	24	111	23
Arripis trutta	-	-	-	571	71	10	571	25	6	35	7
Scomber australasicus	787	53	17	-	-	-	787	34	8	27	6
Engraulis australis	188	13	4	16	2	<1	204	9	2	7	1
Total Loaded Alive	4152	277		2862	358		7014	305		318	
Grand Total Caught	4577	305	98**	5382	673	99	9959	433	99	489	99
Hauls	15			8			23				
Nights	10			6			16				
Total Catch per Night		458			897			622		678	

* Average of 1979 and 1980 kg per haul.
** The above species accounted for 98 per cent of the average catch of 305 kg per haul.

Column 11 of Table 6 presents the average of 1979 and 1980 catch per haul figures. The Programme's bouki-ami catches averaged 489 kg per haul, which was by far the highest average catch experienced by the Programme in all of the countries and territories visited. The New Zealand pilchard, *Sardinops neopilchardus*, accounted for 59 per cent of the catch from the two visits, and jack mackerels, *Trachurus* spp., accounted for a further 24 per cent of the catch. Together, catches of these species averaged 417 kg per haul and were among the dominant species in the catch at all eight baiting locations. Pilchards and jack mackerels generally averaged between 120 mm and 180 mm in standard length, which is somewhat larger than ideal for pole-and-line fishing for skipjack. Occasionally these species averaged over 200 mm in standard length. Pilchards in the optimum size range, 50 to 120 mm, were encountered at only one locality, Okure Bay near Nelson on the South Island, at the end of the first survey. Other problems with jack mackerel were that they seldom schooled after being chummed, and they often sounded taking some of the skipjack with them. Unfortunately the anchovy, *Engraulis australis*, an effective species for skipjack pole-and-line fishing owing to its small size, colour and behaviour, made up only two per cent of the catch, and was present at only four of eight localities. The scombrid, *Scomber australasicus*, accounted for eight per cent of the average catch per haul. Large specimens of this species are of little value as bait, and were only abundant in the catch at one location, Te Roa Bay, during the first survey. Kahawai (*Arripis trutta*) in the size range captured by the Programme are worthless as bait, being principally a predator. In one set at Renown Anchorage, kahawai and large jack mackerel ate an estimated 100 kg of anchovies while the bouki-ami haul was being completed. Fortunately kahawai accounted for only seven per cent of the total baitfish catch.

The Programme made repeat surveys of four localities, Deep Water Cove and Renown Anchorage in the Bay of Islands, and Port Fitzroy and Nagle Cove on Great Barrier Island. Catches per haul, and species composition did vary somewhat between years at each location (Table 7). However, if the catch of *Arripis trutta* at Renown Anchorage and one exceptionally large haul of pilchards (1,800 kg) during the second visit to Port Fitzroy are disregarded, the overall species composition and average catch per haul were reasonably similar for the two visits.

Table 8 presents the Programme's bait catch and species composition, averaged over both visits, for four general areas. The similarity in species composition of survey catches for each of the areas is evident.

Baitfish species in New Zealand survived the effects of capture, loading, and confinement very well. Daily mortality was seldom more than one per cent of bait held, even when the vessel carried in excess of 1.5 tonnes. Relatively low water temperature and high oxygen content are thought to have contributed to excellent survival of temperate bait species such as *Sardinops neopilchardus*, *Engraulis australis* and *Trachurus* spp. in the baitwells. Good survival was also experienced by the previous New Zealand surveys using these live bait species (Webb 1972a, 1972c). As Kearney and Hallier (1979) pointed out in the preliminary New Zealand report, these bait species adapted well to confinement and readily accepted food; thus keeping them on board for long range fishing should be no problem.

At the end of the second visit the *Hatsutori Maru No.5* transported 1,703 kg of pilchards to Norfolk Island for four days of successful fishing. Afterwards, the remaining 125 kg were transported to Matthew and Hunter

TABLE 7. A COMPARISON OF SKIPJACK PROGRAMME BAITFISH CATCHES FOR REPEAT VISITS TO THE SAME BAITING LOCALITIES IN NEW ZEALAND

	1979			1980		
Baiting Locality	Bait Species	Average Catch per Haul (kg)	(%)	Bait Species	Average Catch per Haul (kg)	(%)
Deep Water Cove (Bay of Islands)	*Trachurus* spp.	150	(97)	*Trachurus* spp.	19	(90)
	Scomber australasicus	5	(3)			
	3 hauls Total	155	(100)	1 haul Total	21	(90)
Renown Anchorage (Bay of Islands)	*Sardinops neopilchardus*	197	(65)	*Arripis trutta*	572	(51)
	Engraulis australis	90	(30)	*Trachurus* spp.	527	(47)
	Trachurus spp.	17	(5)	*Engraulis australis*	12	(1)
	1 haul Total	304	(100)	1 haul Total	1121	(99)
Port Fitzroy (Great Barrier Island)	*Trachurus* spp.	103	(51)	*Sardinops neopilchardus*	1247	(97)
	Scomber australasicus	100	(49)	*Trachurus* spp.	42	(3)
				Engraulis australis	2	(<1)
	2 hauls Total	203	(100)	3 hauls Total	1291	(100)
Nagle Cove (Great Barrier Island)	*Sardinops neopilchardus*	487	(98)	*Trachurus* spp.	32	(94)
	Trachurus spp.	7	(1)	*Aldrechetta forsteri*	2	(6)
	3 hauls Total	496	(99)	2 hauls Total	34	(100)
Average over Localities	*Sardinops neopilchardus*	171	(59)	*Sardinops neopilchardus*	312	(50)
	Trachurus spp.	70	(24)	*Trachurus* spp.	155	(25)
	Scomber australasicus	26	(9)	*Arripis trutta*	143	(23)
	Engraulis australis	23	(8)	*Engraulis australis*	4	(1)
				Aldrechetta forsteri	<1	(<1)
	Average Total	290	(100)	Average Total	617	(100)

TABLE 8. AVERAGE BAIT CATCH AND SPECIES COMPOSITION FOR GENERAL BAITING AREAS FISHED BY THE SKIPJACK PROGRAMME WHILE IN THE WATERS OF NEW ZEALAND

Bait Species, Baiting Localities (Number of hauls)	Average Kg Caught per Haul	(% Total)	Bait Species, Baiting Localities (Number of hauls)	Average Kg Caught per Haul	(% Total)
BAY OF ISLANDS			GREAT BARRIER ISLAND		
Trachurus spp.	211	(53)	*Sardinops neopilchardus*	520	(90)
Arripis trutta	72	(18)	*Trachurus* spp.	27	(5)
Sardinops neopilchardus	54	(13)			
Scomber australasicus	49	(12)			
Engraulis australis	13	(3)			
Total	402	(99)	Total	581	(98)
Deep Water Cove (4)			Port Fitzroy (5)		
Renown Anchorage (2)			Nagle Cove (5)		
Te Roa Bay (3)					
Whangamumu Harbour (1)					
BAY OF PLENTY			TASMAN BAY		
Trachurus spp.	261	(73)	*Sardinops neopilchardus*	63	(85)
Engraulis australis	78	(22)	*Engraulis australis*	11	(15)
Sardinops neopilchardus	15	(4)			
Total	357	(99)	Total	74	(100)
Whale Island (1)			Okure Bay (2)		

Islands in the tropical waters east of New Caledonia where they were used during the tagging of 52 skipjack from one school. Over the seven-day period after loading the baitwells to full capacity in New Zealand, only 27 kg of bait were estimated to have died in the wells, in spite of an increase in surface water temperature from 19.4°C at Whangarei to 26.3°C at Hunter Island. Virtually all of the mortality took place during the first three days when more than 1,000 kg of bait were being carried.

Of interest, the Programme carried 95 kg of tropical bait species (Herklotsichthys punctatus, Spratelloides delicatulus, Selar crumenophthalmus and juvenile species of the family Acanthuridae) in one baitwell from the waters of Tonga to New Zealand with similar low losses in spite of a 10°C drop in water temperature. Regulations governing the introduction of non-native fish species required the crew to destroy these bait on reaching Whangarei.

6.2 Skipjack Fishing Results

Both surveys by the Skipjack Programme occurred towards the end of the seasonal fishery in New Zealand waters. In 1979, 65 per cent of the commercial catch had been taken prior to 21 February, the first fishing day for the Hatsutori Maru No.1; and 97 per cent of the season's catch occurred prior to 21 March 1980, the first fishing day for the Hatsutori Maru No.5.

During the 1979 survey the vessel covered a wide area (Table 2), from North Cape to the Bay of Plenty (statistical areas B to D), the west coast of the North Island (statistical areas A to J) and the northwest coast of the South Island (statistical area I). Approximately half of the skipjack "schools" were identified by strikes on the trolling lines, which could have represented subsurface schools of indeterminate size, or random encounters with scattered individuals. Thus, it is difficult to put much emphasis on the similar sighting rates in the different statistical areas; 0.26 schools per hour from 21 to 28 February in areas B and C; 0.36 per hour from 1 to 10 March in areas C and D; and 0.36 per hour on the west coast (areas A, K-I) from 21 to 28 March.

Schools that were observed were often very large, 100 plus tonnes, and were commonly "breezing" or "rippling" at the surface. Since these schools were seldom associated with birds or other visible surface objects, and weather conditions were often poor, the assistance of spotter airplanes was of value in locating fishable aggregations. This was helpful in locating a large body of skipjack that had apparently moved from outside the New Zealand zone to the vicinity of Poor Knights Island at the end of February, and from which the crew and scientists completed the Programme's most successful day of operation on 2 March 1979, tagging 3,689 skipjack from a total catch of 9.7 tonnes of skipjack.

While operating amongst the commercial seine fleet on the east coast of the North Island in 1979 the Hatsutori Maru No.1 experienced generally good fishing conditions. Research catches, converted to estimated commercial catches using a 3.47:1 conversion ratio (Kearney 1978), ranged between 3.10 and 6.76 tonnes of skipjack per fishing day during three ten-day periods (Table 9). Although the Hatsutori Maru's overall converted catch of 4.3 tonnes per day (5.3 tonnes on the east coast) was lower than the 9.8 tonnes for the previous pole-and-line survey using a larger Japanese vessel (Section 1.2), it was above the level that would be considered economical for commercial fishing by a vessel of the size of the Hatsutori Maru No.1 in waters as distant from Japan as New Zealand; and would be expected to improve with increased fishing experience. Of interest, catch per unit effort (CPUE) by the Hatsutori Maru was 15 per cent (range from 13 to 73 per cent) of CPUE by the purse-seiners operating in the same area at the same time (Table 9, column 8). If pole-and-line vessels could catch an average of 4.3 tonnes of skipjack per day in New Zealand, then somewhat more than 1,900 pole-and-line fishing days would be required to catch 8,500 tonnes of skipjack in a season, assuming that there was little interaction between purse-seine and pole-and-line fisheries and that overall exploitation rate was low.

TABLE 9. CATCH, DAYS FISHING, AND CATCH PER FISHING DAY (CPUE) FOR THE SKIPJACK PROGRAMME RESEARCH VESSEL HATSUTORI MARU NO.1 AND THE COMMERCIAL SEINE FLEET, FOR TEN-DAY PERIODS ON THE EAST COAST OF THE NORTH ISLAND OF NEW ZEALAND IN 1979

	Skipjack Programme Pole-and-Line			Commercial Purse-Seine			Pole-and-Line CPUE Divided by Seine CPUE
	Catch (tonnes)	Fishing Days	Catch per Day	Catch (tonnes)	Days Fishing and Searching	Catch per Day	
79/02/21-28 Areas B and C	24.8	8	3.10	108.9	8.5	12.81	0.24
79/03/01-10 Areas C and D	60.8	9	6.76	2073.9	40.5	51.21	0.13
79/03/11-20 Areas C and D	25.3	4	6.32	147.9	17.0	8.70	0.73
Totals	110.9	21	5.28	2330.7	66.0	35.31	0.15

Kearney and Hallier (1979) made the following interesting observation on skipjack biting response during the first visit. They suggested "... that many of the schools fished in New Zealand waters bit because the vessel was forcibly associated with them, rather than in response to chum. The fishing technique relied upon slowly steaming the Hatsutori Maru directly into the large skipjack schools, then commencing to pole the fish from the bow of the vessel." Their speculation that substantial pole-and-line catches might be possible with little or no bait was borne out, to a degree, during the second visit when the single school from which large catches were made rose around the nearly stationary vessel before chumming commenced, and continued to bite on several occasions when chumming was purposely stopped or was greatly reduced. Not unexpectedly, as chum was not the only reason fish associated with the vessel, the Programme experienced very low chumming success in New Zealand. Only 33.8 per cent of the schools that were chummed responded positively (at least one fish poled on deck), which is well below the overall Programme average of 46.7 per cent.

At the beginning of the second visit the Hatsutori Maru No.5 entered New Zealand waters via the Kermadec Islands. No schools were sighted as the vessel approached Raoul Island, the northernmost island in the Kermadec chain of islands, at dusk on 10 March, nor had any schools been sighted over the previous eleven hours of spotting that day. The next morning, Macauley Island was approached just after dawn. Scattered birds were present, but there was little evidence of tuna schools other than one isolated yellowfin observed jumping as the vessel passed the island. At Curtis Island, approximately 15 nautical miles to the south of Macauley Island, scattered birds were again abundant (many were observed roosting on the island), and occasionally birds were concentrated at the surface, suggesting the presence of tuna. However, chumming of four of these concentrations produced no visual evidence of tuna, nor were there any strikes on the trolling lines.

At the end of the second visit on 25 March, the Hatsutori Maru No.5 left New Zealand steaming in a northwesterly direction to Norfolk Island. No schools were sighted until mid-afternoon on 26 March when the vessel was over the shallow bank that extends some 40 nautical miles to the south of Norfolk Island.

6.3 Skipjack Population Biology

Several aspects of skipjack biology were considered by the Skipjack Programme. Mortality, production, migration and recruitment are discussed in later sections. Additional factors investigated included sexual maturity, juvenile ecology, feeding, growth, population structure and parasite infestations.

6.3.1 Maturity and juvenile recruitment

Figure 4 presents female skipjack maturity data for both visits to New Zealand (upper graph) and for all Skipjack Programme samples from tropical waters (lower graph). Virtually all New Zealand skipjack were classified as immature (stages 1 and 2); gonads from 74 skipjack weighed less than one gram each and could not be sexed by visual inspection. These results are consistent with those from several years sampling of New Zealand catches by the MAF Fisheries Research Division (e.g. Habib et al. 1980a, 1980b).

Gonad indices[1] skipjack sampled by the Programme from other subtropical waters off New South Wales and Norfolk Island show that these fish were also immature, but this was not the case for skipjack sampled at similar times from tropical waters of countries and territories immediately to the north and northeast of New Zealand (Table 10). Here skipjack appeared to be much closer to spawning, if not actually spawning. Seasonal change in female gonad index for all Skipjack Programme samples from tropical waters south of the Equator suggests that skipjack spawning is most intense during the southern summer, between October and March (Figure 5). This trend is very similar to that presented by Naganuma (1979) for a wide collection of samples from tropical south Pacific waters, and to that presented by Lewis (1981) for samples from the Papua New Guinea fishery, just a few degrees south of the Equator.

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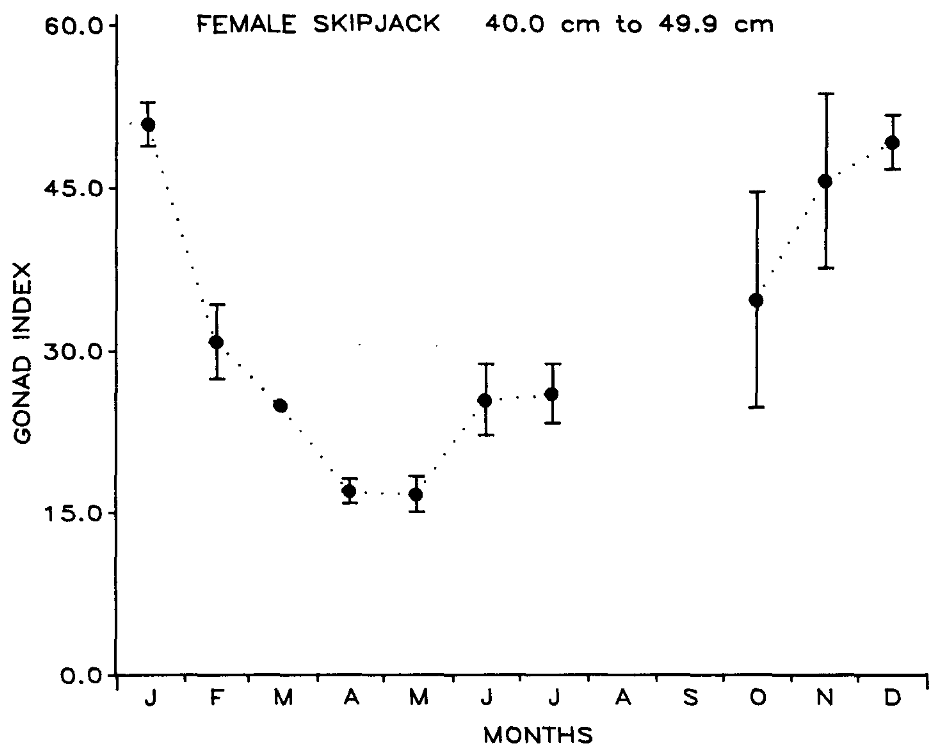
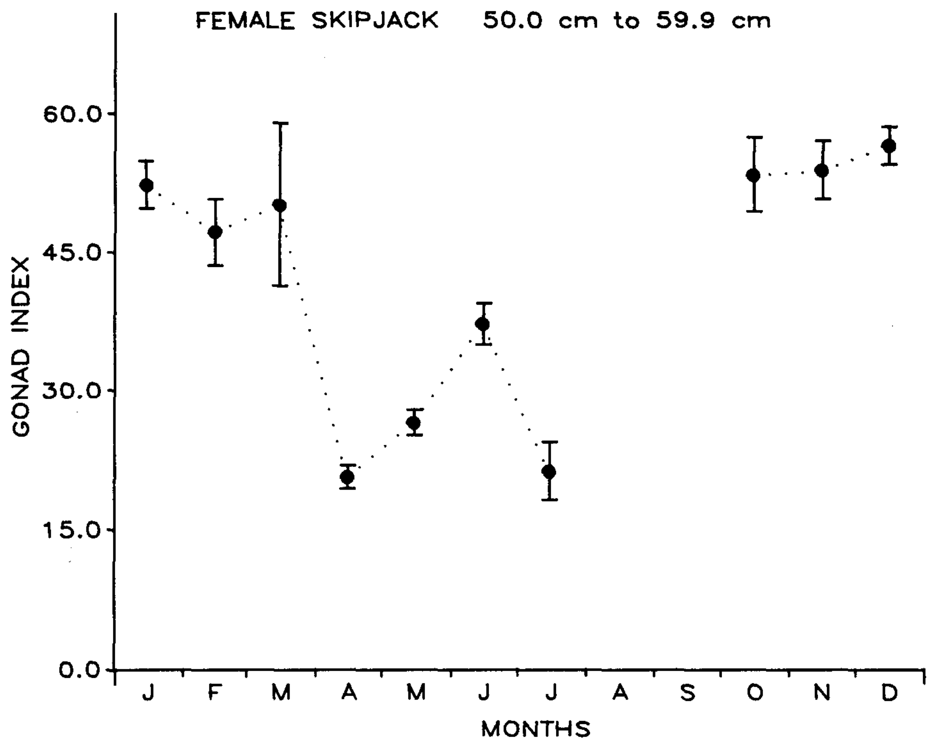
[1] Gonad index=10^7(gonad weight gm/(fish length mm)^3).
High index values, particularly over 50, are associated with skipjack whose gonads have a high percentage of eggs that are ready to be spawned (Raju 1964).

TABLE 10. GONAD INDICES AND PERCENTAGE OF MATURING/MATURE, RIPE/SPENT, RECOVERING GONADS (STAGES 3/4,5/6,7) FOR FEMALE SKIPJACK SAMPLED DURING SUMMER MONTHS IN THE WATERS OF NEW ZEALAND AND COUNTRIES AND TERRITORIES TO THE NORTH AND WEST OF NEW ZEALAND

	TROPICAL WATERS						SUBTROPICAL WATERS					
Country/Territory	New Caledonia Vanuatu Fiji		Niue Tonga Western Samoa American Samoa		Northern Cook Islands Society Islands		New Zealand		New South Wales		Norfolk Island	
Sampling Months	Dec./Jan. Dec./Jan. Jan.-April		February March February February		February Dec./Jan.-Feb.		Feb./Mar. March		March		March	
Fork Length Interval for Female Skipjack (cm)	Gonad Index	Per cent ≥Stage 3	Gonad Index	Per cent ≥Stage 3	Gonad Index	Per cent ≥Stage 3	Gonad Index	Per cent ≥Stage 3	Gonad Index	Per cent ≥Stage 3	Gonad Index	Per cent ≥Stage 3
40-49.9 Mean	32.76	69.7	48.91	88.2	36.26	100.0	7.35	1.9	7.26	0	8.99	0
Standard Error	1.18	-	5.41	-	2.31	-	.18	-	.21	-	1.41	-
Sample Size	328	340	17	17	17	17	254	268	147	149	6	6
50-59.9 Mean	56.15	93.4	45.81	100.0	60.64	100.0	9.99	0	7.39	0	9.40	0
Standard Error	1.47	-	3.36	-	1.87	-	.31	-	.18	-	1.05	-
Sample Size	307	316	29	29	77	78	106	104	155	156	10	10
60-69.9 Mean	56.63	98.6	65.93	100.0	-		11.64	0	8.80	0	9.61	0
Standard Error	4.44		2.71	-	-		.47	-	.50	-	.41	-
Sample Size	29	31	16	16	-		14	14	13	13	35	35

FIGURE 5. AVERAGE FEMALE GONAD INDICES, BY MONTH, FOR SKIPJACK SAMPLED BY THE SKIPJACK PROGRAMME FROM TROPICAL WATERS SOUTH OF THE EQUATOR. Circles denote averages and bars denote two standard deviations about the means. Sample sizes generally exceeded 75.





Another index of spawning activity is the incidence of skipjack juveniles observed in the stomachs of predators. None were found in stomachs of 700 skipjack, 35 albacore and 2 dolphin fish that were examined in New Zealand. In fact, skipjack juveniles were absent from all samples taken in subtropical waters, a result consistent with the low gonad indices of adult skipjack in these waters, and the rare occurrences of larval skipjack previously reported for subtropical waters (Ueyanagi 1969).

Occurrence of skipjack juveniles in tropical waters has ranged from high values of 25-50 juveniles per 100 adult stomachs in the Marquesas Islands, Wallis and Futuna, and Vanuatu, to low values of 0-4 juveniles per 100 adult stomachs in samples from Micronesia, southern Cook Islands and Society Islands. Argue, Conand and Whyman (MS) present more detailed analyses of the tuna juvenile data, taking into account size selective predation by adults, and the time of day, distance from land and season that adults were sampled. They hypothesise that during the 1977 to 1980 survey period, abundance of juvenile skipjack within the SPC region was highest in two areas, one roughly bounded by Solomon Islands, Papua New Guinea and Vanuatu, and the other including the Marquesas and Tuamotu Islands. Skipjack juveniles also occurred most frequently in the stomachs of skipjack predators between October and March in the Programme's samples from tropical waters south of the Equator, which is roughly the period of maximum gonad development in skipjack in these waters. However, as virtually nothing is known about the movements of juvenile skipjack, the source of recruits to the skipjack stock that is fished during summer months in New Zealand waters, although clearly originating from spawning in waters at lower latitudes than New Zealand, cannot be established with precision.

6.3.2 Diet

Skipjack diet in the waters of New Zealand (Table 5) differed greatly from the diet of skipjack sampled from tropical waters. In New Zealand, euphausiids, principally *Nyctiphanes australis*, were by far the dominant item, occurring in 65 per cent of 377 stomachs examined. Furthermore, 26 per cent of the stomachs were empty, the highest level found by the Skipjack Programme in 25 countries and territories; and from the stomachs with food there were only 13 diet items other than chum and fish remains. Occurrence of empty stomachs and stomachs with low numbers of food items is apparently common in New Zealand (e.g. Habib *et al*. 1981). In tropical waters there are usually considerably more individual diet items in skipjack stomachs, many of which are present at relatively high percentage occurrence levels. For example, there were 50 diet items, other than chum and fish remains, in a sample of 287 skipjack from the waters of Solomon Islands (Argue and Kearney 1982), and four of these items, squid, stomatopods, anchovies (*Stolephorus buccaneeri*) and surgeonfish (Ancanthuridae) occurred in over ten per cent of the stomachs examined. In contrast, only one of the 13 diet items in skipjack stomachs from New Zealand occurred in more than ten per cent of the stomachs examined.

It was suggested in Section 6.2 that skipjack were less attracted by chum in the temperate waters of New Zealand compared to tropical waters. This was borne out by the very low percentage occurrence of chum in skipjack stomachs from New Zealand, 14 per cent, compared to a level of 69 per cent for all skipjack diet samples from tropical waters.

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

6.3.3 Growth

Growth of skipjack in the SPC region has been analysed by Lawson and Kearney (MS). Table 11 presents growth rate estimates, by size at release and time-at-large, for tagged skipjack from Fiji, Kiribati, Papua New Guinea and Solomon Islands that were released and recovered in the same country. Growth of skipjack that made international migrations is the subject of continuing analyses.

TABLE 11. 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

Growth rates, measured in centimetres per year, varied among areas, with smaller fish from Fiji appearing to grow fastest and larger fish from Kiribati and the Solomon Islands appearing to grow slowest. Slow growth of 40-49 cm skipjack from Solomon Islands, as contrasted with more rapid growth of fish of similar size from Papua New Guinea and Fiji, suggests that this size of skipjack would be vulnerable to the Solomon Islands fishery for a longer period of time; assuming, of course, that natural mortality and emigration are the same in all areas. Growth rates could not be estimated for local recaptures of New Zealand tagged skipjack since only 19 of 1,032 local recoveries were at large for a long enough period or had sufficiently reliable estimates of size at recapture for estimating growth.

Temporal variation was observed in growth rates estimated from data for several years of tagging in Papua New Guinea both by the South Pacific

Commission (Lawson and Kearney MS) and the Department of Primary Industry, Papua New Guinea (Josse et al. 1979). Geographic and temporal variability of skipjack growth is thought to reflect variation in environmental conditions, but as yet, neither the degree of environmental heterogeneity nor the precise effects of the environment on skipjack growth is well understood.

6.3.4 Population structure

6.3.4.1 Blood genetics and tagging results

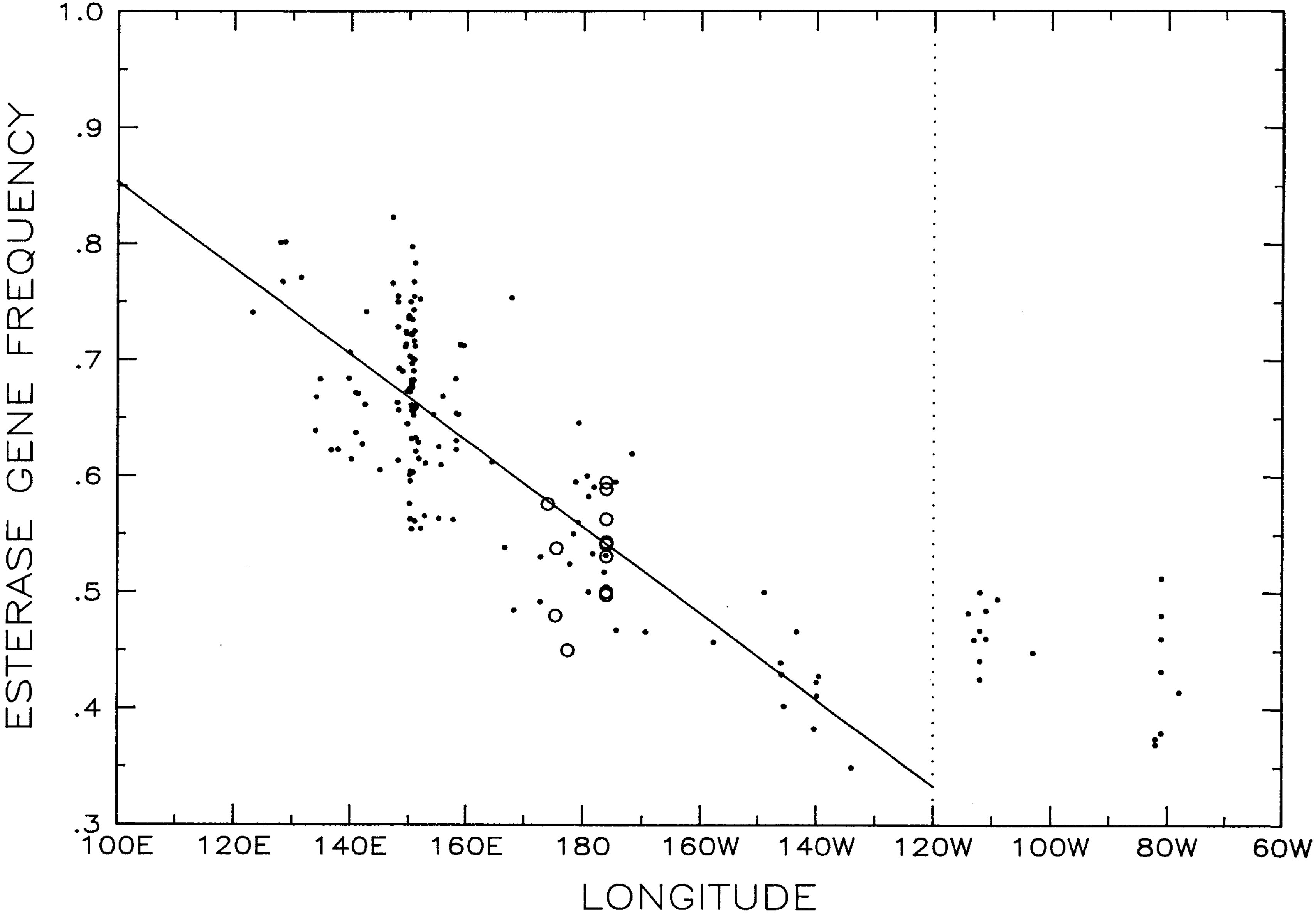
There is movement of some skipjack adults over much of the western and central Pacific (Figure B, inside back cover), and such movement suggests that genetic exchange is possible among all countries within the Programme's study area. On the other hand, fishery interaction analyses completed to date suggest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

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 6). The esterase gene frequencies for samples taken in the waters of New Zealand were scattered about 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, but were within the 95 per cent prediction limits for the regression line. There was considerable variation in individual esterase gene frequency values along this average line, although the cause of this variability was unclear (Anon 1981b).

Several population structure models are consistent with the tagging and blood genetics data (Anon 1981b). 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 hypotheses advanced by Fujino (1970, 1976) and Sharp (1978). Sharp (1978) and Francis (1978) have previously discussed management implications that would apply if New Zealand skipjack were shown to be from a separate subpopulation.

The gradient in esterase gene frequency is consistent with a relatively even distribution of skipjack spawning in tropical waters across the study area. One can 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 6) 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.

FIGURE 6. SKIPJACK SERUM ESTERASE GENE FREQUENCY VERSUS LONGITUDE OF THE SAMPLE LOCATION. Open circles denote samples taken in the waters of New Zealand by the Skipjack Programme (3) and by other co-operative studies (12). The regression line was fitted to data for 145 samples to the left of the dotted line; the correlation coefficient was -0.81. Esterase gene frequencies for 18 eastern Pacific samples are shown to the right of the dotted line.



After two workshops hosted by the SPC to examine the question of skipjack population structure, it was concluded that due to limitations of the extant blood genetics, tagging and ancillary data, it is difficult to choose between the various population structure hypotheses (Anon 1981b; Skipjack Programme 1981c). However, the genetics data supported the conclusions that there should be minimum short-term interactions between fisheries at the extremes of the Programme's study area, and that the potential for interactions should increase as the distance between fisheries decreases. In the case of New Zealand, these interactions would probably be strongest with nearby countries at lower latitudes due to north/south movement of skipjack in response to seasonal climatic events.

6.3.4.2 Parasite results

Samples of skipjack gills and viscera were collected from one skipjack school during the Programme's second visit to New Zealand and by the New Zealand Ministry of Agriculture and Fisheries from purse-seined skipjack during the 1979/1980 and 1980/1981 seasons. These samples have been compared with viscera samples collected over a wide range of tropical waters. Preliminary results presented by Lester (1981) suggested 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 is quite similar. Average numbers of each of eight didymozoid parasites, a subset of the total of over 28 identified parasites, differed little for samples of 44 to 54 cm skipjack from both New Zealand and tropical waters (generally over three-quarters of the New Zealand catch are within this size range). This, coupled with knowledge of the life history for this group of parasites, suggested that skipjack in this size range had recently arrived in New Zealand from tropical waters (Lester, personal communication).

Analyses of these data are continuing; however, the preliminary results do not hold out much hope for 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 the existing parasite data.

6.4 Skipjack Tagging Results

The cut-off date for tag recoveries presented in this report was 1 March 1982. The Programme had received less than 50 tags from all releases in the six-month period preceding March, and considerably fewer tags are expected in the future. Thus, virtually all tag recoveries that will result from the releases during the two visits to New Zealand have been considered in this report.

6.4.1 General observations

Skipjack were tagged during two time periods, 22 February to 24 March 1979 and 21 to 23 March 1980. Table 12 gives the numbers of tags that were released each year and the number of recoveries from these releases, divided into local recoveries, international recoveries (outside the New Zealand 200-mile zone) and recoveries for which recovery location could not be determined.

TABLE 12. RELEASES OF TAGGED SKIPJACK DURING 1979 AND 1980 IN THE WATERS OF NEW ZEALAND, NUMBERS OF RECOVERIES MADE INSIDE AND OUTSIDE THE NEW ZEALAND EXTENDED ECONOMIC ZONE, AND NUMBERS OF RECOVERIES FROM UNKNOWN RECOVERY LOCATIONS. Percentage of tags recovered in brackets.

	1979	1980	Total
Numbers Tagged	11623	1111	12734
Local Recoveries	1002(8.6)	1(0.1)	1003(7.9)
International Recoveries	45(0.4)	11(1.0)	56(0.4)
Unknown Location	28(0.2)	1(0.1)	29(0.2)
Total Recoveries	1075(9.3)	13(1.2)	1088(8.5)

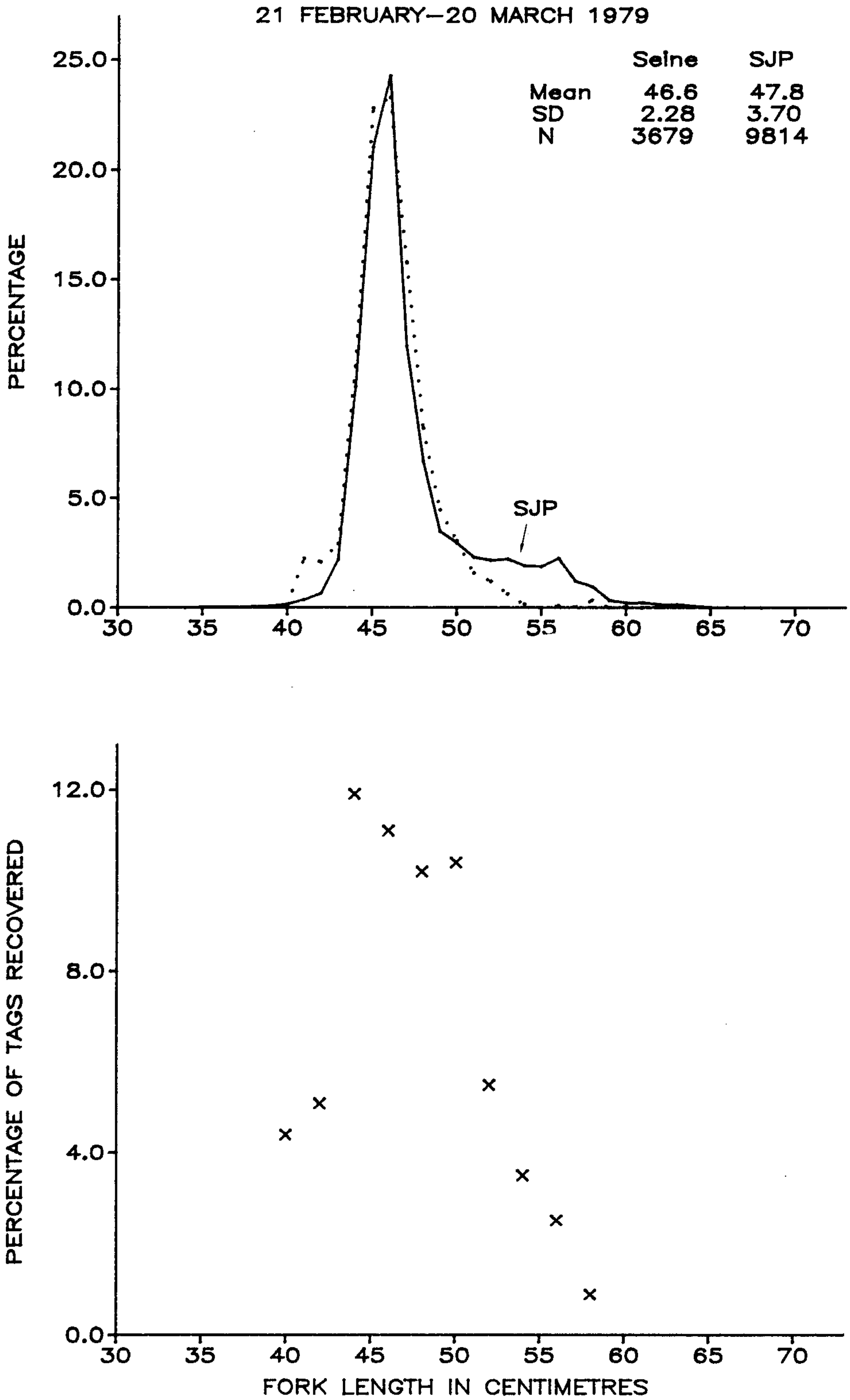
Most (92%) of the tag recoveries were from purse-seine catches made in the waters of New Zealand; approximately three-quarters of these were returned from shore facilities, principally the canneries in American Samoa. Five per cent of the recoveries were from international fisheries in other areas and three per cent were from fisheries of unknown location. There were 29 tag returns in this latter category. Most of these (23) were recovered from transhipped fish that were handled at processing plants in American Samoa and California. Considerable effort to determine accurate recapture information for these fish proved fruitless. However, in the process of checking bills-of-lading and other transhipment and company records, it became apparent that these recoveries were probably caught by purse-seine vessels fishing in New Zealand.

The percentage of tags that were recovered locally differed greatly between 1979 and 1980 releases (8.6% versus 0.1%). In 1979, tag releases were evenly distributed amongst the fleet and over a one-month period during and after which there were 142.5 days of searching and fishing effort by seiners. In 1980, all tagged skipjack (except one) were released on 23 March after which there were only 11 days of searching and fishing effort. Thus, skipjack tagged in 1979 were exposed to considerably more fishing effort, particularly within the first few weeks after tagging when most local recoveries normally occur, hence the higher overall recovery rate for 1979 releases.

Skipjack tagged in 1979 were from a relatively narrow, unimodal size distribution, almost identical to that for the commercial catch (Figure 7, upper graph). Of some interest is the variation in tag recovery rate for fish in two centimetre interval groupings of the tagged population (Figure 7, lower graph). This variability suggests that mortality may change with skipjack size and/or that skipjack may undergo behavioural changes such that their vulnerability varies with their size. A similar pattern for tag recovery rate and size of tagged fish was observed in Solomon Islands for skipjack tagged and recovered by pole-and-line gear (Argue and Kearney 1982). Analysis of the Skipjack Programme's tag data base, disaggregated into different sizes of tagged fish, is continuing under the South Pacific Commission's Tuna Programme.

Tagging in the waters of New Zealand in 1979 took place over a wide area (see Figure 1), at times somewhat removed from the main commercial fishery. Table 13 shows the tag releases within each of the New Zealand statistical areas. Most releases were in area C, the main commercial fishing area on the

FIGURE 7. LENGTH FREQUENCY DISTRIBUTIONS FOR SAMPLED SKIPJACK FROM THE NEW ZEALAND PURSE-SEINE CATCH DURING THE PERIOD OF TAGGING, CONTRASTED WITH SIZE FREQUENCY DISTRIBUTIONS OF TAGGED SKIPJACK THAT WERE RELEASED IN THE COMMERCIAL FISHING AREA (UPPER GRAPH). In the lower graph the Xs denote the tag recovery percentages for tagged skipjack within two centimetre length intervals. Mean fork length, standard deviation of the mean and sample size are indicated.



east coast of the North Island. Lesser numbers were released in area D, where generally less than 15 per cent of the season's catch is taken, and in area B where fishing effort was at a relatively low level at time of tagging. On the west side of the North Island, area J, tags were released after fishing there had stopped for the season. In general, it would appear that the tag recovery rates for the individual statistical areas roughly parallel the distribution of fishing effort in the weeks immediately following tagging.

TABLE 13. NUMBERS OF SKIPJACK TAGGED, TOTAL RECOVERED (LOCAL RECOVERIES IN BRACKETS), PERCENTAGE OF TAGS RECOVERED, AND SEINE FISHING EFFORT FROM THE TIME OF TAGGING TO THE END OF THE FISHING SEASON FOR SKIPJACK PROGRAMME TAG RELEASES IN STATISTICAL AREAS OF THE NEW ZEALAND FISHERY. Tag recoveries received by the Programme as of 1 March 1982, and including those recoveries with unknown date and location of capture. Boundaries for statistical areas are illustrated in Figure 1 (inset).

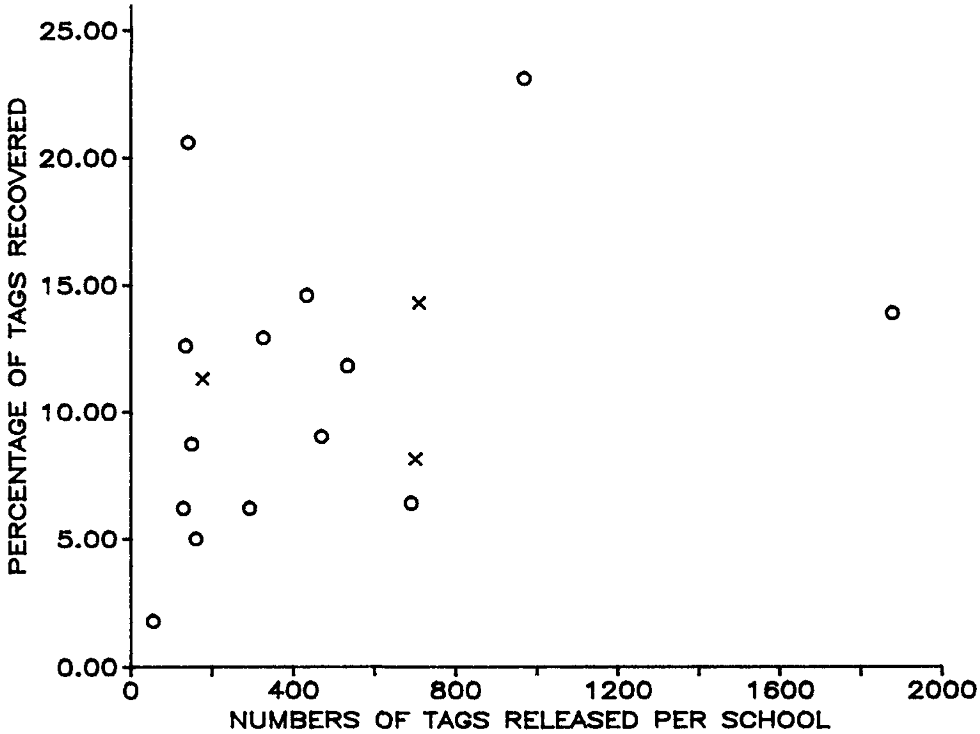
	Area B	Area C	Area D	Area J	Total
			1979		
Numbers Tagged	247	8985	1838	553	11623
Numbers Recovered	17(17)	1026(987)	21(16)	11(10)	1075(1030)
Percentage Recovered	6.88	11.42	1.14	1.99	9.3
Days Fishing	12.5	77.5	31.5	0	
			1980		
Numbers Tagged	-	1111	-	-	1111
Numbers Recovered	-	13(2)	-	-	13(2)
Percentage Recovered	-	1.17	-	-	1.17
Days Fishing	-	11.0	-	-	

On 28 February and 2 March 1979 the research vessel tagged skipjack from three schools that were subsequently thought to have been fished by a purse-seine vessel within a day following tagging. Recaptures of tagged fish soon after release could be expected to bias results from quantitative analyses of tag returns. Figure 8 shows the overall tag recovery percentage for each of these schools (denoted by crosses) and for 14 additional schools (denoted by circles). It can be seen that for these three schools, the recovery rates were not greatly different from recovery rates for releases in other schools on the east coast; thus, releases and recoveries from these three schools were included in the quantitative analyses. In general, the pattern of recoveries from tag releases within individual schools suggested that tagged skipjack underwent considerable mixing amongst schools soon after release.

6.4.2 International migrations from New Zealand

Fifty-six New Zealand tagged skipjack from releases in 1979 and 1980 made international migrations. Tagging and recovery information for these fish is listed at the beginning of Appendix C. Figure 9 depicts the straight line migration trajectories for 34 tagged New Zealand skipjack. Recoveries have been selected to show no more than two examples of movement in each direction between any pair of five degree squares. Table 14 shows the numbers and percentage of tag releases that were recovered outside New Zealand waters.

FIGURE 8. RELATIONSHIP BETWEEN NUMBERS OF SKIPJACK THAT WERE TAGGED IN A SCHOOL AND PERCENTAGE OF TAGS RECOVERED. The crosses denote schools that were thought to have been fished within a day of tagging. Schools with less than 50 tag releases were excluded from the graph.

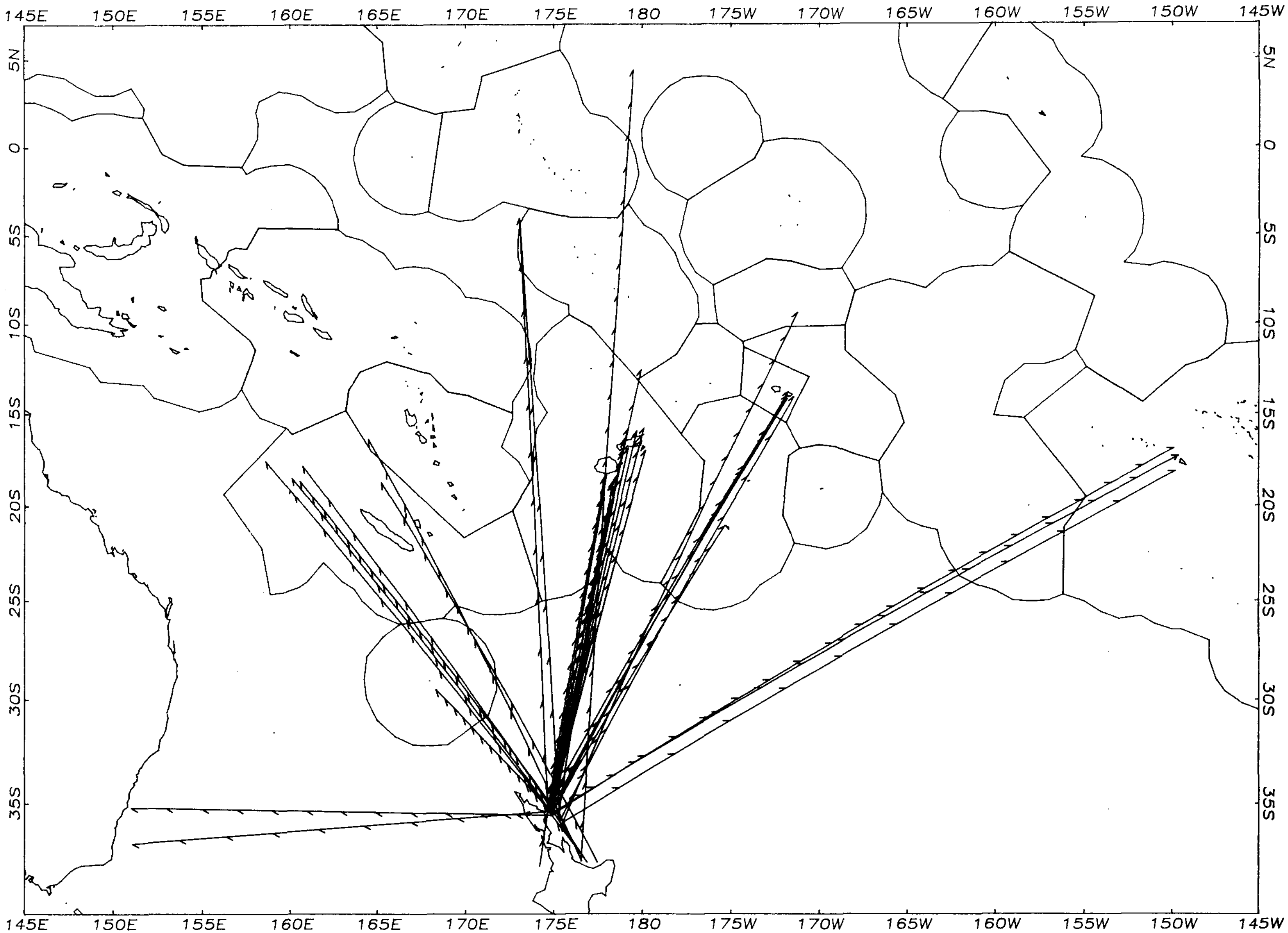


There were international recoveries (Table 14) from tagged skipjack released in three of the four statistical areas (Figure 1) in which tagging took place. The percentages of tag releases that made international migrations for these statistical areas were all similar in 1979, 0.2 to 0.5 per cent. The absence of international recoveries from area B releases was probably a result of the small numbers tagged. In 1980, all tags were released in area C; less than one per cent made international migrations.

International recoveries of tagged New Zealand skipjack occurred over a wide area, from New South Wales in the west to the Society Islands in the east. The pole-and-line fishery in Fiji accounted for the greatest number of these recoveries, 31 from 1979 and 1980 tagging; small fisheries in Western Samoa and the Society Islands recovered fewer New Zealand tags - five were reported from each fishery.

The five recoveries by bonitier fishermen near the Society Islands moved an average of 2,169 nautical miles to the northeast. The longest straight-line migration by a tagged New Zealand skipjack was 2,526 nautical miles to international waters over 250 miles north of the Equator where it was recovered by a Japanese distant-water pole-and-line vessel. The shortest international migration was by a skipjack recovered in March 1980, one year after tagging, in the waters of Norfolk Island by the crew of the Hatsutori

FIGURE 9. MIGRATION ARROWS FOR 34 OF 56 NEW ZEALAND TAGGED SKIPJACK THAT MADE INTERNATIONAL MIGRATIONS. Tick marks denote intervals of 30 days between release and recapture dates. In the absence of accepted zones for all countries, 200-mile boundaries were estimated by staff of the Tuna Programme. The boundaries shown below should not prejudice any boundaries that may be derived in the future.



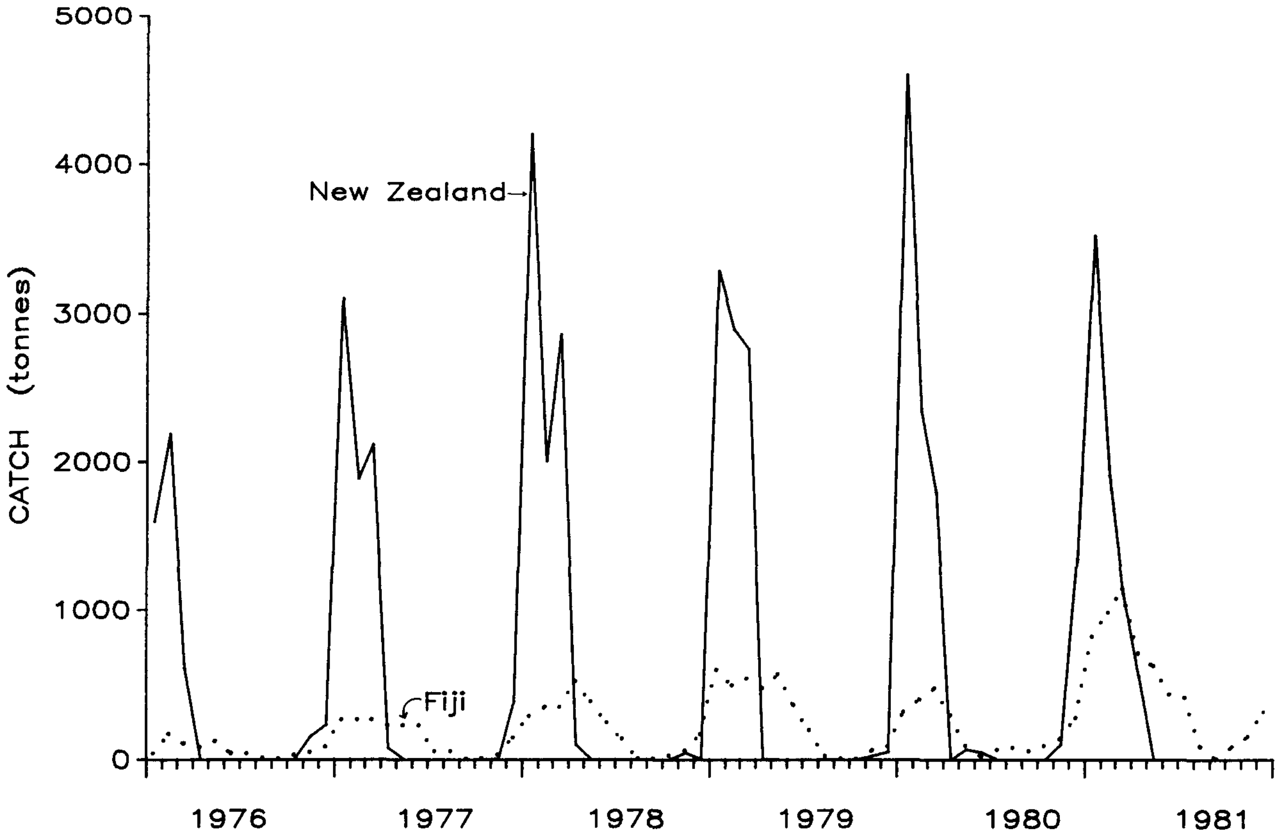
Maru No.5. Except for this fish and the two New South Wales tag recoveries, international migrants from New Zealand were all recovered in tropical waters. This is not surprising since there is virtually no fishing for skipjack in the study area between 20°S and 33°S. The absence of recoveries from the large Solomon Islands pole-and-line fishery, centred approximately 2,100 miles northwest of New Zealand, was noteworthy, particularly when contrasted with the five New Zealand tagged skipjack which were recovered by the much smaller Society Islands fishery, approximately the same distance to the northeast of New Zealand.

TABLE 14. INTERNATIONAL RECOVERIES OF TAGGED SKIPJACK RELEASED IN DIFFERENT NEW ZEALAND STATISTICAL AREAS IN 1979 AND 1980. See Appendix C for country abbreviations.

Tagging Area	Total Tagged	International Recoveries	International Recoveries as a Percentage of Total Tagged
		1 9 7 9	
Area B	247	0	0
Area C	8985	23 FIJ 4 SOC 4 WES 2 INT 2 CAL 1 NSW 1 NOR 1 TON 1 TOK	.48
Area D	1838	3 CAL 1 VAN 1 INT	.27
Area J	553	1 FIJ	.18
Total	11623	45	.38
		1 9 8 0	
Area C	1111	7 FIJ 1 SOC 1 WES 1 NSW 1 TUV	.99

Tagging in New Zealand took place at the end of the 1979 and 1980 seasons. Considering the large distance between the New Zealand fishery and fisheries in Fiji and Western Samoa, more than 1,000 nautical miles to the north, and the similarity in seasonal timing of all three fisheries (Figure 10), it is not surprising that most recoveries in Fiji and Western Samoa occurred in the season following tagging (Table 15). The fishery in French Polynesia near the Society Islands has more variable seasonality, and the New Zealand tag recoveries by this fishery, although few in number, appear to reflect this variability. It is possible that tagging in the waters of New Zealand at the beginning of the skipjack season, November/December, might produce more "same season" recoveries in fisheries to the north. For example, skipjack that enter the New Zealand zone earliest may depart well before the end of the New Zealand season, early enough to be caught in the same season by fisheries such as that in Fiji, which continues to make relatively high catches in the months after April (Kearney 1982b).

FIGURE 10. SEASONAL TIMING OF SKIPJACK FISHERIES IN FIJI, NEW ZEALAND, WESTERN SAMOA, AND THE SOCIETY ISLANDS OF FRENCH POLYNESIA



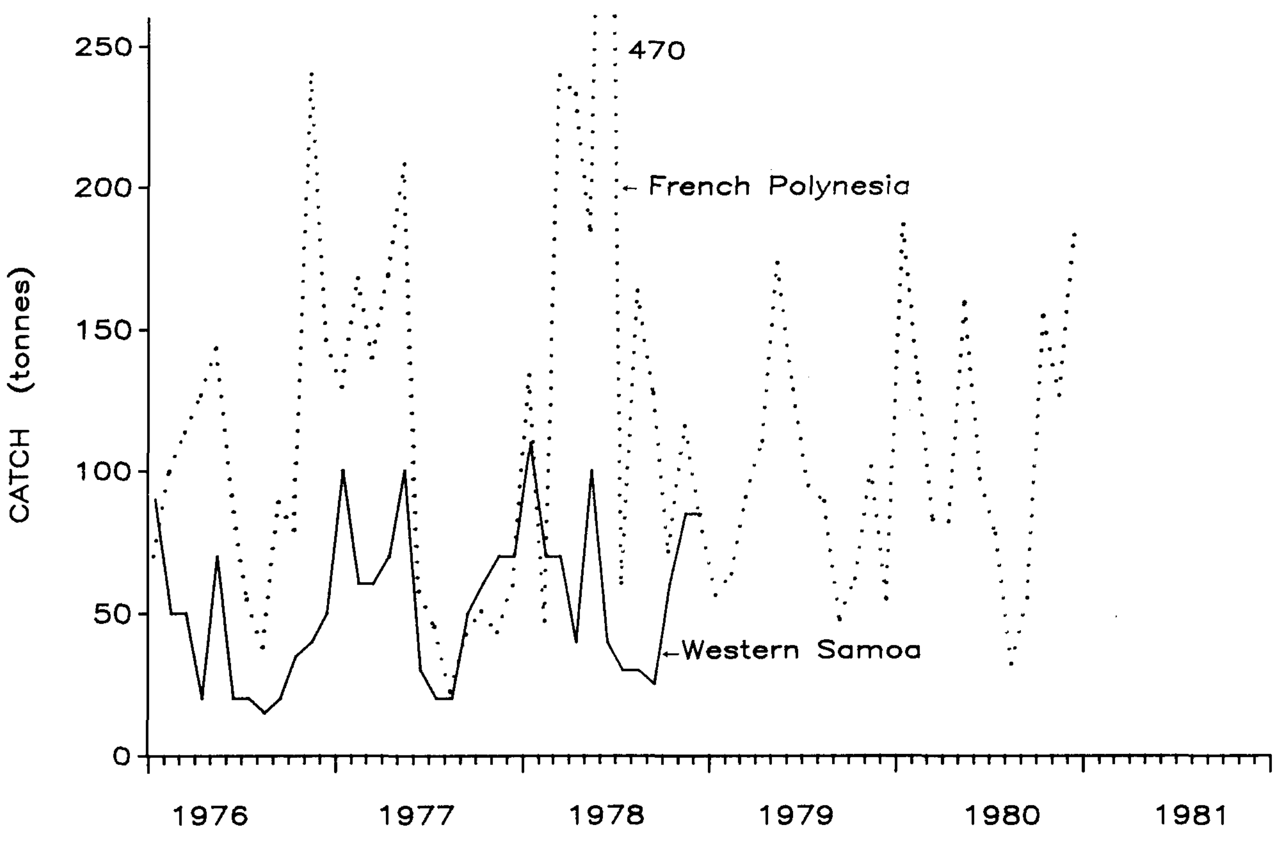


TABLE 15. NUMBERS AND TIMING OF RECOVERIES, FROM NEW ZEALAND TAGGING, IN THE WATERS OF COUNTRIES AND TERRITORIES OTHER THAN NEW ZEALAND. See Appendix C for country abbreviations.

	Returns from 79/02 and 79/03 Tag Releases											Returns from 80/03 Tag Releases						
Year/ Month	NSW	NOR	CAL	VAN	FIJ	TON	WES	TOK	SOC	INT	Total 1979	NSW	FIJ	TUV	WES	SOC	Total 1980	Grand Total
79/06					1						1							1
07																		
08																		
09																		
10					1						1							1
11	1				2						3							3
12			1				2		1		4							4
80/01			1		3		2				6							6
02			2		3	1			1	2	9							9
03		1		1	5						7							7
04					1						1							1
05									1		1							1
06																		
07					1						1							1
08					1						1							1
09																		
10									1		1							1
11								1			1							1
12			1								1							1
81/01													2				2	2
02					3					1	4		2		1	1	4	8
03												1		1			2	2
04																		
05													1				1	1
06					1						1		2				2	3
07					1						1							1
08																		
09																		
10					1						1							1
11																		
Total	1	1	5	1	24	1	4	1	4	3	45	1	7	1	1	1	11	56
Average Distance Travelled	1151	487	1380	1427	1120	1001	1475	1746	2162	2104	1343	1164	1161	1404	1500	2197	1308	1336

Size data for international migrants from New Zealand are of interest. The nine skipjack that were recovered in waters to the west of 170°E and for which there was reliable size data averaged 52.8 cm in length at time of tagging, significantly larger (t_{54df}=3.68, p<0.01) than the 47 skipjack with reliable size data recovered to the east of 170°E (average length 47.2 cm at tagging). The first average is similar to the dominant mode in the overall size frequency distribution for tagged skipjack in New Zealand and the second average occurs on the tail at the right hand side of the size frequency distribution (Figures 3 and 7). This suggests that skipjack of different sizes may take different migration routes once they depart New Zealand waters. The migrants from New Zealand waters, upon recovery in fisheries to the north, were almost all greater than 50 cm in length, with many exceeding 60 cm in length at time of recovery. This suggests that the skipjack present at the end of the New Zealand season were not making a significant contribution to the recruitment of small skipjack (<50 cm) which constitute a large percentage of catches in fisheries to the north of New Zealand.

6.4.3 International migrations into New Zealand

Tagging in areas surrounding New Zealand was expected to increase understanding of recruitment to the New Zealand fishery. Some 50,000 skipjack were tagged in countries and territories immediately to the north and west of New Zealand; approximately 40 per cent of these fish were less than 50 cm at time of tagging. However, only 19 of these releases were reportedly recovered in the New Zealand fishery. Figure 11 shows straight-line migration trajectories for these skipjack. Appendix C details tagging and recovery information for these fish. Table 16 arrays these tag recoveries by country of tagging and month of recapture.

Recoveries of international migrants to New Zealand were distributed throughout the New Zealand commercial fishing season. Migrants from Fiji and Wallis and Futuna Islands were all recaptured on the east coast of the North Island in area C, whereas recaptures of migrants from New South Wales waters were split between west (4) and east coasts (5) of the North Island. The percentage of each country's releases that were recovered in New Zealand was very small, less than 0.1 per cent for Fiji and Wallis and Futuna, and 0.2 per cent for New South Wales; and at the time these fish were recovered in New Zealand their lengths were generally well in excess of the average size of skipjack in the purse-seine catch at the same time. These results suggest that comparatively small, 40 to 50 cm skipjack, located in excess of 1,000 nautical miles from New Zealand, did not significantly contribute to the size class of skipjack that were exploited by the New Zealand seine fishery during the 1978/1979 and 1978/1980 seasons.

6.4.4 Mortality and production

6.4.4.1 The tagging data

In August 1980 the Programme presented estimates of skipjack mortality, population size and fishery interactions for the study area (Skipjack Programme 1981a). Since tag returns and accompanying catch statistics were incomplete for several countries at this time, individual country estimates of mortality and population size were based on a simple graphical analysis of monthly tag returns, corrected for catch, for the available data sets. Since then further tag and catch data have become available, and the data and methods used to calculate country estimates have been refined.

FIGURE 11. MIGRATION ARROWS FOR 18 TAGGED SKIPJACK THAT MADE INTERNATIONAL MIGRATIONS TO THE WATERS OF NEW ZEALAND. Recovery information for one skipjack was not sufficiently precise to allow it to be plotted. Tick marks denote intervals of 30 days between release and recapture dates. In the absence of accepted zones for all countries, 200-mile boundaries were estimated by staff of the Tuna Programme. The boundaries shown below should not prejudice any boundaries that may be derived in the future.

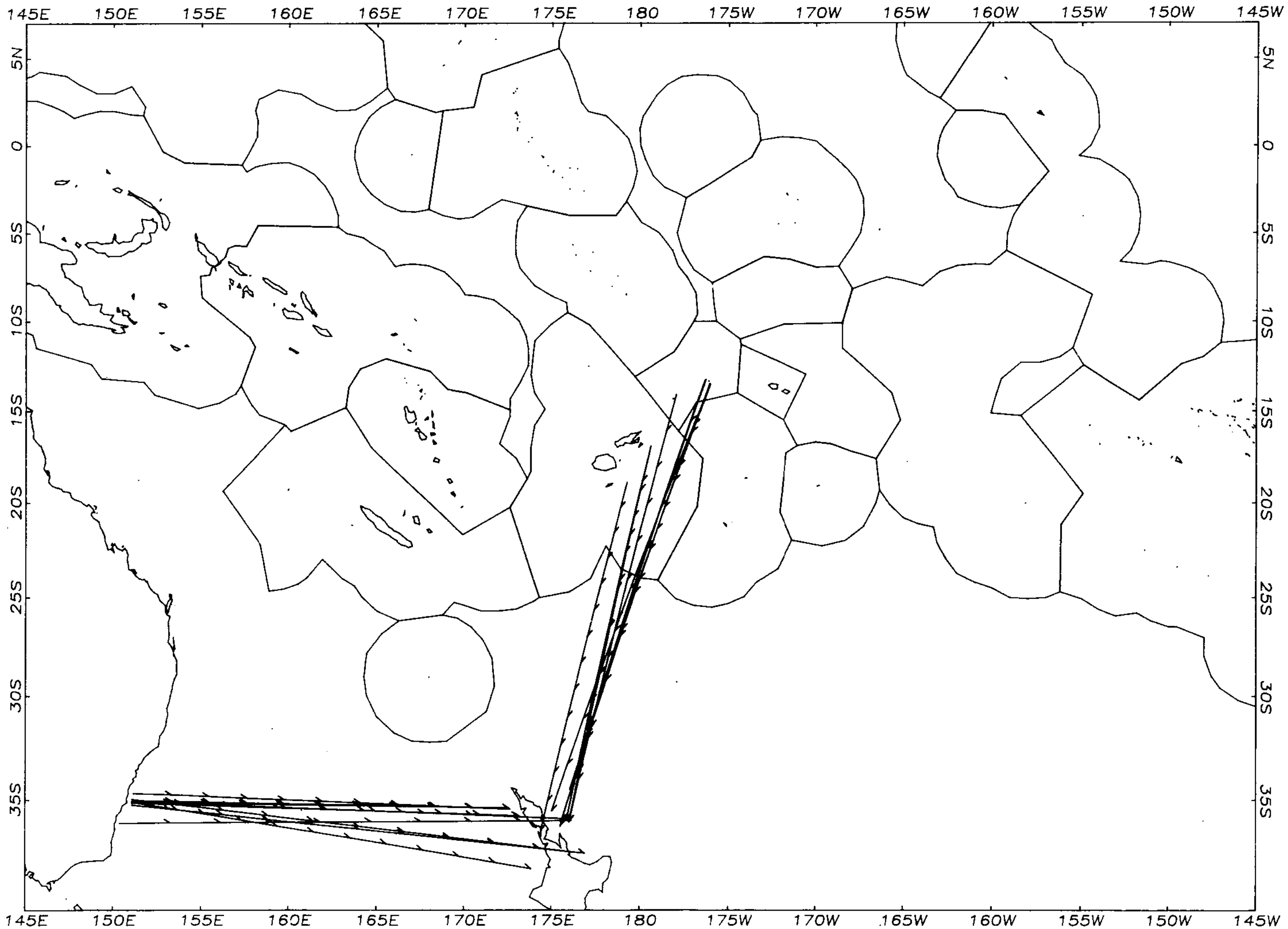


TABLE 16. SKIPJACK TAG RECOVERIES BY TEN-DAY PERIOD BY PURSE-SEINE GEAR IN THE WATERS OF NEW ZEALAND FROM TAG RELEASES IN OTHER COUNTRIES. Year/month of tagging, country abbreviation and number of tags released at the top of each column. Total New Zealand seine catch and catch per day searching and fishing (CPUE) in columns 2 and 3.*

Year/ Month/ Ten-Day Period	New Zealand Seine		Fiji		Wallis and Futuna	Western Samoa	New South Wales	
	Catch (tonnes)	CPUE	78/02 FIJ 3539	78/04 FIJ 4031	78/05 WAL 13513	78/06 WES 1767	79/04 NSW 4322	Total Tag Recoveries
78/11/21-30	44	7.3		1				1
78/12/01-10	-	-						
78/12/11-20	-	-						
78/12/21-31	-	-						
79/01/01-10	328	16.0		1				1
79/01/11-20	797	12.1			1			1
79/01/21-31	2153	27.1						
79/02/01-10	1580	32.3						
79/02/11-20	881	25.9						
79/02/21-28	431	11.2						
79/03/01-10	2396	47.4	1		3			4
79/03/11-20	148	8.7			1			1
79/03/21-31	215	4.6						
79/04/01-10	3	0.5			1**			1
79/11/21-30	25	4.5						
79/12/01-10	15	2.4						
79/12/11-20	-	-						
79/12/21-31	35	6.9						
80/01/01-10	1319	27.2					1	1
80/01/11-20	2100	48.3					1	1
80/01/21-31	1186	16.1					2	2
80/02/01-10	1981	24.9					4	4
80/02/11-20	142	10.9						
80/02/21-28	219	5.5						
80/03/01-10	1191	28.4					1	1
80/03/11-20	493	17.6						
80/03/21-31	113	4.8						
80/04/01-10	-	-						
80/04/11-20	-	-						
80/04/21-30	-	-						
80/05/01-10	18	6.1						
80/05/11-20	-	-						
80/05/21-31	49	24.5						
80/06/01-10	35	8.6						
80/06/11-20	12	5.9						
Unknown Month						1		1
Total			1	2	6	1	9	19

* Catch statistics source: New Zealand Ministry of Agriculture and Fisheries, Fisheries Research Division, Wellington.

** Recaptured by the pole-and-line vessel <u>Crescent Gypsy</u>.

For New Zealand, the following refinements were made to the tagging data base used in these analyses. First, release data were adjusted to include only those releases (and subsequent returns) that were in the area of the commercial fishery at the time of tagging. These data should more closely represent the dynamics of the stock under exploitation at the time of the study. Thus for 1979, 553 releases off the west coast of the North Island, at the end of the Programme's 1979 survey, were excluded since the 1978/1979 fishery was finished in this area at the time the releases were made. Releases of 2,094 tagged skipjack in areas C and D after 10 March were also excluded since they occurred after 95 per cent of the season's catch and effort had occurred and as a result there were only 12 useable recoveries (5 in the 1978/1979 season and 7 the following season). This left releases in areas B, C and D over two ten-day periods for quantitative analyses, the first between 21 and 28 February when 2,678 tagged skipjack were released, and the second between 1 and 10 March when 6,298 tagged skipjack were released. These releases are 77 per cent of the total releases in 1979 in New Zealand. Tag releases for both periods were widely distributed over the fished area and amongst the seine fleet on the east coast of the North Island. Table 17 presents recoveries from these releases, by ten-day period, and corresponding catch and effort (days fishing and searching, numbers of sets) for the New Zealand fishery. Figure 12 graphs the number of tag returns per purse-seine set and predicted number of tag returns (see below) per set for each time period. Releases from March 1980 tagging have not been considered since virtually all of these fish were released late in the season, from a single school, after 97 per cent of the catch and effort had occurred, and to date only one of these tags has been recovered in New Zealand waters.

6.4.4.2 Analytical methods

A non-linear, least squares fitting technique (Conway, Glass and Wilcox 1970) was used to fit a tag recapture and attrition model to the refined sets of New Zealand data (Kleiber MS). From the number of tag releases, N_o , the model predicts the number of tag returns per time period, r_i , as a function of fishing mortality per time period, F_i , and attrition of the tags at large, A , due to natural mortality, emigration, continuous tag mortality and tag shedding, and declining vulnerability; p takes into account other forms of tag loss as described below. The mathematical formulation of this model is:

$$r_i = \frac{pN_oF_i}{A} e^{-iA}\left(e^{A}-1\right)$$

F_i can be approximated by

$$F_i \cong \frac{C_i}{P} \cong QE_i$$

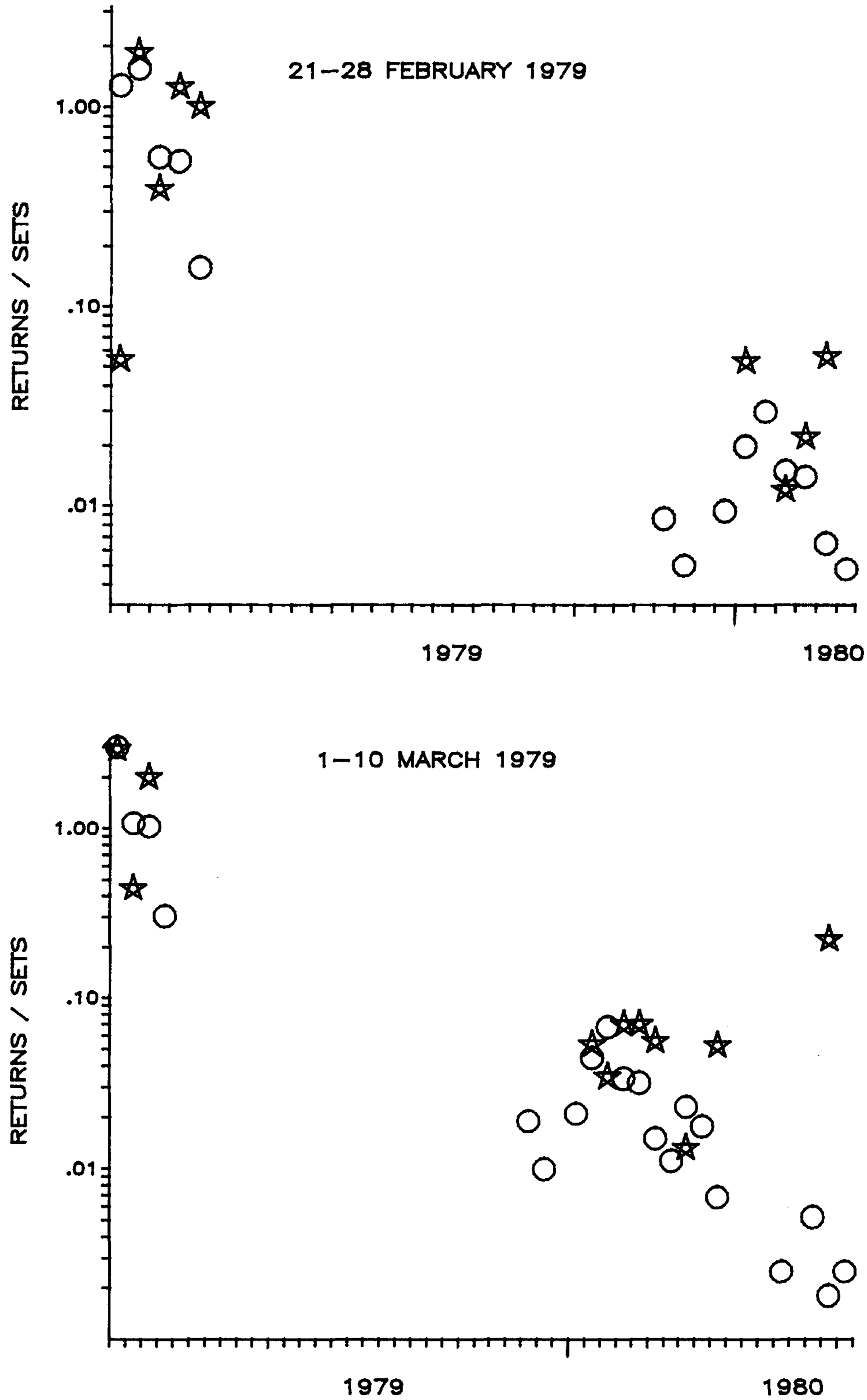
where C_i is the catch in time period i , P is the standing stock, Q is the catchability coefficient, and E_i is the fishing effort in time period i .

TABLE 17. TAG RETURNS, CATCH AND EFFORT BY TEN-DAY PERIOD FOR THE NEW ZEALAND PURSE-SEINE FISHERY. The table does not include recoveries by the Skipjack Programme survey vessel. Recoveries with imprecise or unknown date of recovery or unknown country of recovery are totalled separately. Date information on tag returns was considered imprecise if the range of possible values was more than half the span from the release date to the midpoint of the range of possible recovery dates. If the range was less than half of this span, the return was included and the date of recovery was taken to be the midpoint of the range. Catch statistics were supplied by the New Zealand Ministry of Agriculture and Fisheries.

Year/Month/Ten-Day Period	Tag Returns	Skipjack Catch (tonnes)	Fishing Effort: Days Searching and Fishing	Fishing Effort: Sets
21-28 February 1979 - Tags Released 2678				
79/02/21-28	2	431(336)*	39(31)*	47(37)*
79/03/01-10	223	2396	51	120
79/03/11-20	7	148	17	18
79/03/21-31	30	215	47	24
79/04/01-10	1	3	6	1
79/11/21-30	0	25	6	7
79/12/01-10	0	15	7	7
79/12/11-20	-	0	0	0
79/12/21-31	0	35	5	6
80/01/01-10	5	1319	49	94
80/01/11-20	0	2100	44	87
80/01/21-31	1	1186	74	86
80/02/01-10	3	1986	80	135
80/02/11-20	1	142	9	18
80/02/21-28	0	219	40	33
Total	273	10220	474	683
Unknown Date/ Location	112			
Grand Total	385			
01-10 March 1979 - Tags Released 6298				
79/03/01-10	280	2396(1917)	51(41)	120(96)
79/03/11-20	8	148	17	18
79/03/21-31	48	215	47	24
79/04/01-10	0	3	6	1
79/11/21-30	0	25	6	7
79/12/01-10	0	15	7	7
79/12/11-20	-	0	0	0
79/12/21-30	0	35	5	6
80/01/01-10	5	1319	49	94
80/01/11-20	3	2100	44	87
80/01/21-31	6	1186	74	86
80/02/01-10	6	1986	80	135
80/02/11-20	1	142	9	18
80/02/21-28	0	219	40	33
80/03/01-10	1	1191	42	76
80/03/11-20	0	493	28	36
80/03/21-31	1	113	24	19
80/04/01-10	-	0	0	0
80/04/11-20	-	0	0	0
80/04/21-30	-	0	0	0
80/05/01-10	0	18	3	5
80/05/11-20	-	0	0	0
80/05/21-31	0	49	2	5
80/06/01-10	2	35	4	9
80/06/11-20	0	12	2	2
Total	361	11700	540	788
Unknown Date/ Location	252			
Grand Total	613			

* For the quantitative analysis of tagging data, catch and effort were prorated to adjust for timing of tag releases during the first ten-day period.

FIGURE 12. TAG RETURNS DIVIDED BY SETS (STARS) BY NEW ZEALAND PURSE-SEINE GEAR FROM 1979 TAG RELEASES IN THE WATERS OF NEW ZEALAND, BY TEN-DAY PERIOD, AND PREDICTED TAG RETURNS DIVIDED BY SETS (CIRCLES) FROM THE FITTED TAG ATTRITION MODEL. Estimated returns presented for all time periods with some effort. Ordinate is in log scale.



Using catches and tag returns in Table 17, the analytical procedure provided estimates, and 95 per cent confidence intervals for average population size (tonnes), average tag attrition per ten-day period, average throughput (tonnes) per ten-day period and, when effort was substituted for catch, the average catchability coefficient. This latter parameter is simply the fraction, usually very small (<.001), of the vulnerable skipjack population that is harvested, on average, by one unit of fishing effort (e.g. a purse-seine set). Estimates of attrition rate and throughput per ten-day period were multiplied by three to express them as monthly rates.

It is assumed that the total population of skipjack is in a steady state. In other words, over the period of tag returns, recruits to the fishable stock through immigration and growth of small fish, are assumed, on average, to have equalled losses from the fishable stock due to fishing, natural death, reduced vulnerability and emigration. Thus one could view the attrition rate, less a small fraction (<0.01 per month due to continuous tag shedding with time (Skipjack Programme 1981b)), as the turnover rate, or the average fraction of the population that is renewed each time period. The product of turnover rate and population size is an estimate of throughput, the average tonnage of skipjack entering and leaving the fishable population each time period. Throughput is thus equivalent to recruitment to the fishable stock through growth and immigration.

The New Zealand fishery is a seasonal one in which skipjack first appear in New Zealand waters about November, build to a peak in abundance between January and March, then decline in abundance through April and May (Habib et al. 1980a, 1980b, 1980c, 1981). In other words, during initial months of the season, immigration, growth and recruitment exceed losses due to emigration, mortality and reduced vulnerability, and towards the end of the season losses exceed gains. Over the period of two fishing seasons, total recruitment is assumed to equal total losses, i.e. the steady state assumption. Since the exponential decay model integrates over the whole period of tag returns, the attrition rate estimates below should be viewed as averages for the months over which tags were recovered (approximately one year), and not representative of each month within this period.

There are circumstances where use of the tag attrition model for subsets of the total data base can result in biased parameter estimates. For example, if, at the time of tagging, some of the standing stock had emigrated from the fishing area and had not been replaced by recruitment, then the estimate of "steady state" standing stock would be underestimated since it is most representative of the stock at the time of and soon after tagging (this was verified by simulation). Throughput would also be underestimated since this is the product of population size and attrition rate. A similar situation would arise if exploitation had significantly reduced the standing stock prior to tagging. These are in effect violations of the steady state assumption that nonetheless undoubtedly occur over short time periods in all areas.

Both sources of bias very probably affected the estimates of "steady state" population size and throughput for the stock of skipjack upon which the New Zealand fishery depends. For instance, MAF sightings data suggest that several large bodies of skipjack migrated to the New Zealand zone prior to tagging. Changes in size composition of the catch based on sampling data (Habib et al. 1980b) suggest that some or all of the skipjack from the earliest of these bodies had left the fishing area by late February or early

March 1979. There was also a substantial catch of skipjack, over 5,600 tonnes, in the three months prior to tagging. Therefore New Zealand population estimates should be considered to simply depict the population size at the time of tagging in the approximate area of the fishery, and the catchability coefficient is an estimate of the fraction of this population that was harvested by one unit of fishing effort (this was verified by simulation). The total quantity of skipjack that entered the New Zealand zone over the whole season was probably somewhat greater than the population size so estimated plus the previous catch.

6.4.4.3 The correction factor "p"

In the model, p is a coefficient, ideally close to one, that corrects for the combined effects of short-term tagging mortality, short-term tag loss, the exclusion of tag recoveries for which recovery date or location were unknown, and non-reporting of tags. Further comment on the correction factor p is warranted.

Results from a double tagging experiment carried out by the Programme during the second visit to Fiji suggested that immediate tag mortality and tag shedding were low compared to that estimated for similar tagging experiments (Skipjack Programme 1981b). As well, there have been high tag return rates (50%+) from eastern Pacific skipjack tagging using similar but perhaps less exacting methods than those used by the Skipjack Programme (W.H. Bayliff, personal communication). This strongly suggests that the combination of short-term tagging mortality and tag shedding was low. Considering all available evidence, a figure of 20 per cent has been accepted as an estimate of immediate tagging mortality and shedding of tags.

For 364 (36%) of 998 local recoveries by purse-seine gear, recovery date and location could not be assigned (Table 17). Taking this into account and assuming that all tags that were caught were returned to SPC, a maximum estimate of p for the New Zealand fishery is the product of one minus the assumed immediate tag mortality rate (1-.2) and one minus the proportion of unuseable local recoveries (1-.36), which equals 0.5.

Because of the way purse-seiners catch and handle skipjack, it is difficult to recover tagged fish until the catch is unloaded and processed at shore facilities. For example, only 243 (24%) of the 998 tags caught by purse-seiners were recovered at sea, and many of these were found by trained MAF observers. An experiment to estimate the return rate from shore facilities for tags caught by seiners in New Zealand was conducted during the 1980/1981 New Zealand fishing season. The experiment consisted of placing 131 tagged dead skipjack amongst the catch in the fish-holds of ten purse-seine vessels and then monitoring the rate of recovery for planted tags. The resulting return rate from canneries was only 25 per cent for planted tags. However, as this experiment was carried out more than one year after the last recoveries from 1979 Skipjack Programme tag releases in New Zealand waters, it is possible that the low returns reflect a more recent problem in the tag recovery system. It is also possible that tags placed in dead fish are not representative of tags placed in live fish. Thus results from this experiment may overstate the tag return bias. Unfortunately, these possibilities are difficult to substantiate now, so as they stand, the results from this experiment add uncertainty to the estimates of population size, throughput and catchability coefficients beyond that which can be accounted for using appropriate statistical procedures. In the following discussion a p value of 0.5 ((proportion of survivors from immediate tag mortality (0.80), times proportion of useable tags (0.64), times proportion of tags that were returned (1.0)) has been applied to the parameter estimates, with a caution that p may well be 0.16 (0.80x0.64x0.31) for New Zealand releases.[2]

6.4.4.4 Estimates of population size, turnover and throughput

Table 18 presents parameter estimates and unconditional confidence intervals from the analysis of tag returns for the two sets of New Zealand releases in 1979. Figure 12 presents actual and estimated tag returns per unit of fishing effort. The fitted model accounted for approximately 90 per cent of the variation in tag returns with time for both data sets. As mentioned, the values for population size and catchability in Table 18 should be most representative of the fished stock and the fishery at the time of and soon after tagging, that is for the late February to early March period during the 1978/1979 season.

TABLE 18. ESTIMATES OF SKIPJACK POPULATION SIZE, TURNOVER RATE, THROUGHPUT AND CATCHABILITY COEFFICIENTS FOR THE NEW ZEALAND PURSE-SEINE FISHERY

Year/Month of Tagging (1)	Population Size (tonnes) (2)	Average Turnover ($month^{-1}$) (3)	Throughput (tonnes per month) (4)	Catchability Coefficient (per Set) (5)
79/02/21-28	28,300p*	.40	11,300p	5.0×10^{-4} /p
95% confidence limit	16,600p	.22	6,300p	1.8×10^{-4} /p
95% confidence limit	54,800p	1.27	28,800p	1.1×10^{-3} /p
79/03/1-10	39,900p	.39	15,300p	4.2×10^{-4} /p
95% confidence limit	31,700p	.31	11,900p	2.9×10^{-4} /p
95% confidence limit	55,500p	.50	20,800p	5.7×10^{-4} /p

* p is a coefficient (<1.0) that corrects for short-term tag slippage, short-term tagging mortality, non-reporting of recaptured tags, and exclusion of tags with poor recovery data (see text).

Estimates of population size (Table 18) for the late February early March period in 1979, after adjustment for p of 0.5, were 14,150 tonnes for 21 to 28 February tag releases and 19,950 tonnes for 1 to 10 March tag releases, and would have been 4,528 and 6,384 tonnes for these releases if p was 0.16. Simple Petersen estimates (Ricker 1975) of population size, using catch and tag recoveries for the last ten-day periods of the 1978/1979 season and adjusted for p of 0.5, were quite similar, 15,772 and 21,396 tonnes for February and March releases respectively. Petersen estimates were well within the confidence intervals for the least-squares estimates, that is 8,300 to 27,400 tonnes and 15,850 to 27,750 tonnes for February and March releases respectively (p=0.5).

The higher population estimate for March tag releases is consistent with the observation and presumed movement of a large body of skipjack into area C near Poor Knights Island at this time. This was one of three large bodies of

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[2] The estimated proportion of seine caught tags that were returned was estimated to be 0.31, as follows: $[(.24/1.0 + 1-.24)/.25)]^{-1}$. It is assumed that tags that were recovered from the catches on the vessels were all returned to SPC, hence 1.0 is the denominator in the first term within the brackets above.

skipjack that were observed on the east coast of the North Island during the 1978/1979 season. It may have added a significant tonnage of skipjack to that already present in the east coast fishing area at the end of February. Habib et al. (1980b) provide an estimate of "minimum real abundance" for this body based on the maximum tonnage that was sighted from it, plus the catch that was taken from it prior to this observation. Their estimate, so calculated, was 3,408 tonnes. Unfortunately it is difficult to determine what level of "minimum real abundance" was present in the fishing area just prior to sighting the large body, nor is it possible to say with certainty whether this body of skipjack had recently migrated into New Zealand waters, or whether it simply represented regrouping or increased visibility of skipjack that had migrated to New Zealand waters much earlier in the season.

It has been argued that "minimum real abundance" from sightings and catch data underestimates true abundance by reasoning that a significant proportion of the skipjack may be below the surface and thus not visible to spotters (Habib et al. 1981). Skipjack Programme population estimates of 14,150 and 19,950 tonnes, using a p of 0.5, support this supposition. On the other hand Skipjack Programme population estimates, using the lower p value of 0.16, were 4,528 tonnes and 6,384 tonnes, which were not much higher than the estimates of "minimum real abundance" from sightings data, and thus suggest that estimates of "minimum real abundance" may have been rather close to true abundance at this time.

The estimates of average monthly turnover rate based on February and March tag releases, subsequent returns and catches, were 0.40 and 0.39. Average turnover rates for the same tag releases, but substituting effort (sets) for catch, were similar (0.39 and 0.41) to the estimates of turnover from catch. Based on these estimates, only a small fraction of skipjack would be expected to return to New Zealand for a second fishing season. Simulation analyses showed that estimates of turnover rate were relatively insensitive to the timing of tag releases within the skipjack season (see below). The estimates of monthly turnover (attrition) rate were well above the value of 0.19 estimated from all Skipjack Programme tag returns (Kleiber MS), and the estimate of 0.23 from Joseph and Calkins (1969) for eastern Pacific skipjack in the northern fishing area. This difference suggests that natural mortality was higher here; or that a fairly large proportion of survivors from the skipjack that seasonally migrate from New Zealand waters, remained outside New Zealand in the season following tagging; or that exploitation in New Zealand may have been relatively high. If it is assumed that catchability measured at the end of the 1978/1979 season is representative for the 1978/1979 and 1979/1980 seasons, then the product of the average of the two catchability coefficients in Table 18 (p assumed to be 0.5) and average monthly effort for the 1978/1979 and 1979/1980 seasons of 54 sets (1292/24) provides an estimate of fishing mortality of 0.05, which represents close to 13 per cent of average monthly attrition. If p was 0.16, then average monthly fishing mortality would be 0.16, and would represent over 40 per cent of average monthly attrition. Thus fishing mortality may have been a significant component of average monthly attrition for the stock of skipjack that was exploited by the New Zealand fishery during the 1978/1979 and 1979/1980 seasons, perhaps more important than emigration, natural mortality and other forms of loss.

Estimates of monthly throughput in Table 18, adjusted for p of 0.5, were 5,650 tonnes and 7,650 tonnes respectively for February 1979 and March 1979 tag releases, and would be 1,808 tonnes and 2,448 tonnes if p was 0.16. As previously mentioned, these estimates are probably too low since population size at time of tagging was probably less than the steady state population size. It must be remembered that monthly throughput estimates are the product of average monthly attrition rate over the period of tag returns (approximately one year) and population size. Thus, throughput is not equivalent to the tonnage of skipjack that recruits to the New Zealand fishery during any particular month within the fishing season.

6.4.4.5 Simulation results

The steady state assumption was tested by producing tag returns from a simulation model that was not at steady state and then fitting the analytical model to the simulated tag return, catch and effort data (manuscript in preparation). Results showed that the attrition rate estimated from catch and tag returns reflected the mean recruitment, as a proportion of stock size, for the period of tag returns. Attrition rate estimated from effort and tag returns reflected the mean total mortality rate for the period of tag returns. Population size and catchability coefficients reflected the population size and catchability in effect near the time of tagging, under a wide variety of non-steady state conditions. Similar attrition rate estimates obtained from catch and effort data implied that the population was in or close to steady state. The ratio of fishing mortality to total attrition was relatively insensitive to perturbations from steady state.

The New Zealand fishery was explicitly simulated by a non-steady state model where a population of 24,000 tonnes was assumed to migrate to the New Zealand zone over a one- to two-month period, was fished by a pattern of fishing effort similar to that of the 1978/1979 and 1979/1980 seasons, and then migrated from the New Zealand zone over a one- to two-month period. Recruitment and attrition rate (excluding fishing mortality) were fixed at 6,000 tonnes and 0.25 per month. Tags were released into the simulated fishery either in December, toward the end of the period of migration into the New Zealand zone, or in March, shortly after migration from New Zealand began. A catchability coefficient of 0.001 per purse-seine set was assumed, and the simulation was run over two seasons with time steps of one one day. The simulated tag returns, catch and effort were then used to fit the analytical model.

As with the general simulation, results from the New Zealand simulation showed that population size and catchability estimated from fitting the analytical model reflected the simulated values at the time the values at the time of tagging, population size being lower for March tagging since catch and migration from New Zealand had reduced the standing stock available to the fishery at this time (Table 19). The attrition rate was relatively insensitive to the timing of tagging, and was higher than the assumed rate of 0.25 by an amount approximately equal to the average monthly fishing mortality over the period of simulation. Throughput was underestimated for March tag releases by approximately the same fraction that steady state population was underestimated.

6.4.5 Fishery interactions

6.4.5.1 New Zealand fishery interactions

Table 18 presents estimates of the size of the stock of skipjack in New Zealand waters at the time of tagging, or shortly thereafter. Using the 1 to

10 March population estimate, since this estimate included skipjack that were presumed to have recently migrated to the fishing area, and p values of 0.5 and 0.16, the catch from the time of tagging to the end of the season, as a percentage of population size, ranged between 11.4 per cent (2,283 tonnes from Table 18 divided by 19,950 tonnes) and 35.8 per cent (2,283 tonnes divided by 6,384 tonnes). If migration into the New Zealand zone had effectively ceased by the time of tagging, then these percentages estimate the exploitation rate of the fishery from the time of tagging to the end of the 1978/1979 season (catch divided by initial population size). Observation of the distribution, size and movement of skipjack bodies at this time (Habib et al. 1980b) suggest that this could well have been the case. Of interest, catch to the end of the season as a percentage of "minimum real abundance" for the same period (from Table 6 in Habib et al. 1980b) is similar to the 36 per cent estimate of exploitation from Skipjack Programme data.

TABLE 19. SIMULATION RESULTS FOR THE NEW ZEALAND FISHERY

	Model Parameter Values	Estimated Parameter Values from Fitting the Analytical Model to Simulated Catch and Tagging Data	
		December Tagging	March Tagging
Population Size (tonnes)	24000	23123	17119
Catchability Coefficient	.001	.0009	.0009
Average Monthly Effort (sets)	55	55	55
Attrition Rate (months^{-1})	.25	.306	.298
Throughput (tonnes/month)	6000	7083	5100

If late season exploitation by the New Zealand fishery was close to the higher of the two previous estimates, competition amongst the purse-seine fleet at the end of the 1978/1979 season would have been significant. On the other hand it is possible that the fishery was unusually effective late in the 1978/1979 season (skipjack may have been more available offshore where the larger purse-seine vessels were operating), or that the tag return rate was close to 100 per cent. In either case the above results would be exaggerating the need for concern over competition amongst units of seine gear.

It must be emphasised that results from Skipjack Programme tag analyses are for the end of the 1978/1979 season. To extrapolate these results to a whole season requires assumptions regarding the total amount and timing of skipjack immigration to (and emigration from) the New Zealand zone, regarding the availability of surface concentrations of skipjack within the New Zealand zone, particularly in relation to the 12-mile fishing limit that separates foreign and New Zealand vessels, and regarding the effectiveness of individual purse-seine vessels. Sightings and size composition data collected by New Zealand since the beginning of the fishery (Habib et al. 1980a, 1980b, 1980c, 1981) has led to the hypothesis that skipjack move through the fishing zone throughout the season, and that over the season a substantial tonnage of skipjack, considerably more than the total sighted - called "total minimum real abundance" - is available for capture, often predominantly inside the 12-mile fishing limit where fishing effort is much less than that outside the 12-mile limit. Under this hypothesis, competition amongst vessels in the fleet would be minimal, in part because it is implicitly assumed that individual purse-seiners have relatively low catchability coefficients. Alternatively, it can be hypothesised that the total tonnage entering the zone is similar to the total sighted, based on the lower of the Skipjack Programme's population estimates for the end of the 1978/1979 season, and that immigration to New Zealand waters is complete relatively early in the season. Skipjack then move throughout the zone and are repetitively fished by a very effective (based on the higher of Skipjack Programme estimates of catchability) fleet of purse-seine vessels. This would suggest a high total season exploitation rate (low tonnage available for exploitation) and hence a potentially high degree of competition within the present seine fleet.

These hypotheses cannot be differentiated with the available data. Further tagging over the duration of New Zealand's seasonal fishery would greatly reduce any uncertainty surrounding quantitative estimates of the New Zealand skipjack resource.

6.4.5.2 International fishery interactions

Interactions among fisheries can be measured in various ways; 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 amongst individual countries. The absence of a demonstrable relationship between catch per unit effort and effort for intense skipjack fisheries suggests that between-generation fishery interactions would be negligible for present or expanded fisheries in the central and western Pacific. Therefore the evaluation of interactions within one generation is more urgent.

The approach followed in Skipjack Programme (1981a) was to use tagging data plus catch statistics to estimate coefficients of migration from particular fisheries. The product of population size in the donor fishery and migration coefficient gave 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 from these analyses demonstrated a generally low level of stock interaction amongst 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 (manuscript in preparation). It is independent of p, if p is the same in the donor and destination countries.

Table 20 presents results for estimates of interaction between New Zealand and three countries and territories to the north and northeast of New Zealand from which more than one tag recovery was made and for which catch data were available. From column six it can be seen that migrants from New Zealand, represented by recoveries from the two 1979 tag releases, may have contributed between 8 and 12 per cent of the recruitment to Fiji's pole-and-line fishery, and similar percentages of recruitment to the Western Samoa fishery, and to the Society Islands bonitier fishery over 2,000 nautical miles to the northeast of New Zealand. These estimates may well be too high if p in the destination countries was significantly greater than

TABLE 20. RESULTS OF FISHERY INTERACTION BETWEEN NEW ZEALAND AND OTHER COUNTRIES. Column 4 gives the number of skipjack tag returns in the destination country's fishery. p_1 and p_2 are coefficients (≤ 1.0) in, respectively, the donor and destination countries (see text).

Year/Month/Ten-Day Period of Tagging (1)	No. of Tags Released (2)	Monthly Throughput (tonnes per month) (3)	No. of Tags Recovered (4)	Average Monthly Catch (tonnes) (5)*	Estimated Percentage of Throughput from Migrants (6)**
NEW ZEALAND TO FIJI					
79/02/21-28	2678	11300 p_1	6	331	7.7% p_1/p_2
79/03/1-10	6298	15300 p_1	13	259	12.2% p_1/p_2
NEW ZEALAND TO WESTERN SAMOA					
79/02/21-28	2678	11300 p_1	2	62	13.6% p_1/p_2
NEW ZEALAND TO SOCIETY ISLANDS					
79/03/1-10	6298	15300 p_1	4	108	9.0% p_1/p_2

* Catches averaged over a 12-month period bracketing the period of tag returns, or averaged from one month before the first return to one month after the last return when tag returns spanned a period of more than one year. Monthly Fiji catch supplied to SPC by the Fiji Ministry of Agriculture and Fisheries. Average monthly Western Samoa catch from Economic Development Department, Fisheries Division, Government of Western Samoa, unpublished data. Society Islands monthly catch from annual catch in Gillett and Kearney (1982) divided by 12.

** Column 6 = [(column 3 x column 4) / (column 2 x column 5)] 100 that for New Zealand. For example, if p for Fiji is taken to be 0.7, a value thought to be reasonable for a pole-and-line fishery where every fish is handled several times by fishermen on board the catcher vessels and again when catches are unloaded, and p for New Zealand is assumed to be 0.16, then estimates of Fiji throughput originating from New Zealand drop to between 1.8 and 2.8 per cent. Percentages for the other fisheries would be similarly reduced if these p values were applied. Alternatively, interactions may have been underestimated since average monthly throughput values for New Zealand in Table 20 are thought to be too low, a result of the late timing of tagging in New Zealand. It is also possible that skipjack present early in the New Zealand season would be available for capture by more northerly fisheries within the same fishing season, which implies a seasonal component to interaction with the New Zealand fishery that could be quite substantial. Further tagging early in the New Zealand season would help to resolve this question.

There were few migrants to the New Zealand fished area (Table 21). Of the three sources from which tagged skipjack migrated to New Zealand - Fiji, Wallis and Futuna, and New South Wales - the latter was relatively the most significant. Even so, in terms of contribution to throughput in New Zealand, New South Wales skipjack in the size range of 40-55 cm were estimated to have contributed less than four per cent.

TABLE 21. ESTIMATED CONTRIBUTION TO NEW ZEALAND THROUGHPUT BY IMMIGRANTS FROM TAGGING LOCATIONS OUTSIDE THE NEW ZEALAND FISHING AREA

			New Zealand Seine Fishery		
	No. of Tags Released (1)	Throughput (tonnes per month) (2)*	Tag Recoveries (3)	Average Monthly Catch (tonnes) (4)**	Estimated Percentage of Throughput from Migrants (5)***
Fiji (78/02 tagging)	3539	$1500p_1$	1	748	<0.1% p_1/p_2
Fiji (78/04 tagging)	4031	$1500p_1$	2	748	0.1% p_1/p_2
Wallis and Futuna	13513	7500	5	748	0.4%
New South Wales	4322	13300	9	748	3.7%

* Fiji throughput from Table 9, Kearney (1982). Wallis and Futuna throughput assumed to be the average of New Zealand and Fiji throughput. New South Wales throughput assumed to be the same as average throughput in New Zealand.

** Average annual catch for the 1978/1979 and 1979/1980 New Zealand fishing seasons divided by 12.

*** Column 5 = [(column 3 x column 2) / (column 4 x column 1)] 100

7.0 CONCLUSIONS

7.1 Baitfish

Baiting results from both Skipjack Programme surveys and from earlier New Zealand surveys (Webb 1971, 1972a, 1972c) leave little doubt that bait resources in northern waters of New Zealand are more than adequate to support a sizeable pole-and-line fishery. Although bait catches by the Programme contained pilchards (*Sardinops neopilchardus*) above the optimum size range for skipjack fishing, and catches were often mixed with predators (e.g. *Arripis trutta*) and some species less suitable for bait (e.g. *Scomber australasicus*, *Trachurus* spp.), it is likely that these relatively minor problems would soon be overcome once pole-and-line fishermen gained experience baiting in northern New Zealand waters. Presumably experience would also show that reasonable catches of the highly desirable anchovy species, *Engraulis australis*, could be taken at certain localities and times.

Previous surveys in New Zealand have proven the feasibility of holding pilchards for extended periods in net pens after capture by purse-seine or bouki-ami (Webb 1972a, 1972c), and holding pens have long been used to maintain a supply of anchovies (*Engraulis japonicus*) and sardines (*Sardinops melanosticta*) for the Japanese homewater pole-and-line fishery. In the event that a pole-and-line fishery develops in New Zealand, a similar approach might be worth exploring, since it would minimise time lost to baiting during the skipjack season.

In brief, the supply of local baitfish should not be a limiting factor to development of a pole-and-line fishery in the waters of New Zealand. There would appear to be no need to acquire bait from outside the country with all the attendant ecological risks associated with introduction of non-native species.

7.2 Skipjack General

It would appear that other Pacific skipjack fisheries are having a negligible impact on abundance and recruitment in New Zealand of skipjack of the same generation.

Skipjack departing the New Zealand zone were estimated to be contributing between two and fourteen per cent of recruitment to fisheries in Fiji, Western Samoa and the Society Islands in French Polynesia. The accuracy of estimates for departing New Zealand skipjack is in doubt, however, since the effects of seasonal fluctuations in abundance and emigration could not be estimated, and there was uncertainty surrounding the tag return rate from catches by the New Zealand fishery. For example, interaction estimates would be in the lower part of the range if the coefficient that corrects for short-term tag mortality, tag loss and non-return of tags was, as suspected, substantially lower for New Zealand tag returns compared to returns from the other fisheries. On the other hand, bias could have been in the other direction if throughput for New Zealand was underestimated, as it probably was, and if there are significant migrations between New Zealand and these fisheries within the same fishing season. Further tagging would help to resolve these questions.

In general, mixing of skipjack stocks is believed to depend strongly on the distance separating them. On the basis of analyses of available tagging data, interactions amongst most locally based fisheries in the SPC region, though present, are thought to be relatively minor. Nevertheless the evidence from tagging and blood genetics data does not support the hypothesis that skipjack in New Zealand, or in other parts of the region, belong to any identifiable subpopulations that can be considered as genetically isolated from the rest of the central and western Pacific resource.

Eventually, as fisheries in neighbouring countries increase their levels of exploitation, and as areas of exploitation expand and begin to overlap, the importance of fishery interactions within a skipjack generation can be expected to increase. Recruitment to the New Zealand fishery will probably remain little affected by these international events unless fisheries develop in waters closer to New Zealand than, for example, Fiji and New Caledonia.

7.2 Skipjack in New Zealand

Development of the purse-seine fishery for skipjack in New Zealand was preceded by several years of surveys and commencement of an overall tuna research programme. Then, at the onset of the commercial fishery in 1974, the Ministry of Agriculture and Fisheries intensified the tuna research programme and initiated collection of catch statistics and considerable stock assessment information. On the basis of early performance of the fishery and analysis of data from the research programme, the Ministry predicted that the skipjack catch could be increased to between 20,000 and 24,000 tonnes from an average of approximately 8,500 tonnes in the four seasons prior to 1981/1982 (Habib 1981).

Results from the Skipjack Programme tagging experiment in New Zealand waters, supported by some data collected by the MAF tuna research programme, have cast doubt on the ease with which catches could be increased to this level.

Unfortunately, there is a measure of uncertainty surrounding results from both programmes. In the case of the MAF tuna research programme, it is unknown to what degree visual estimates of skipjack tonnage are underestimates of the total tonnage of skipjack entering the New Zealand zone, or whether they are underestimates at all. For the Skipjack Programme tagging data, it is not clear to what degree results were representative of a complete New Zealand fishing season, or were biased by non-return of recaptured tags. An experiment to assess tag return bias was conducted after most returns from 1979 tagging had been received. Results suggested that close to 70 per cent of tags from skipjack caught by purse-seiners in New Zealand went unreported. However, it is possible that the low return rate for planted tags reflected a recent breakdown in the tag return system at processing facilities, rather than a problem that was ongoing when recaptured tags from 1979 releases were being processed.

In view of this uncertainty and the importance of the skipjack fishery to New Zealand, there is a need for further quantitative assessment of the New Zealand skipjack resource, in particular there is a need to assess the within-season dynamics of the New Zealand fishery. This would involve a comprehensive tagging programme, over the duration of the skipjack season, which, if coupled with the present research programme, should provide reasonable estimates of the total tonnage of skipjack entering the New Zealand zone, the timing of immigration to and emigration from the zone, and the level of exploitation while skipjack are in the New Zealand zone.

REFERENCES

ANON (1976). Proceedings of the Skipjack Tuna Conference, July 1976. New Zealand Ministry of Agriculture and Fisheries, Fisheries Research Division Occasional Publication No.11, 62pp.

ANON (1980). Review of preliminary results from genetic analysis of skipjack blood samples collected by the Skipjack Survey and Assessment Programme. Skipjack Survey and Assessment Programme Technical Report No.1, South Pacific Commission, Noumea, New Caledonia. 23pp.

ANON (1981a). New Zealand Official Yearbook 1981. New Zealand Department of Statistics, Wellington. 1040pp.

ANON (1981b). Report of the second Skipjack Survey and Assessment Programme workshop to review results from genetic analysis of skipjack blood samples. Skipjack Survey and Assessment Programme Technical Report No.6, South Pacific Commission, Noumea, New Caledonia. 45pp.

ARGUE, A.W., F. CONAND and D. WHYMAN (Manuscript). Observations on juvenile tunas from stomachs of skipjack and other surface tunas caught by pole-and-line gear in the Pacific Ocean. Tuna and Billfish Assessment Programme Technical Report, South Pacific Commission, Noumea, New Caledonia.

ARGUE, A.W. (1982). Methods used by the Skipjack Survey and Assessment Programme for collecting biological, tuna school and ancillary data from a pole-and-line fishing vessel. In Kearney, R.E. (ed.). Methods used by the South Pacific Commission for the survey and assessment of skipjack and baitfish resources. Tuna and Billfish Assessment Programme Technical Report No.7, South Pacific Commission, Noumea, New Caledonia.

ARGUE, A.W. and J.-P. HALLIER (Manuscript). Observations on fishing performance of baitfish species used by tuna pole-and-line gear in the central and western Pacific Ocean. Tuna and Billfish Assessment Programme Technical Report, South Pacific Commission, Noumea, New Caledonia.

ARGUE, A.W. and R.E. KEARNEY (1982). An assessment of the skipjack and baitfish resources of Solomon Islands. Skipjack Survey and Assessment Programme Final Country Report No.3, South Pacific Commission, Noumea, New Caledonia.

BAKER, A.N. (1972). Reproduction, early life history, and age growth relationships of the New Zealand pilchard, *Sardinops neopilchardus* (Steindachner). New Zealand Marine Department, Fisheries Research Division Research Bulletin No.5. 64pp.

BELL, G.D. (1976). Aerial spotting for pelagic fishes. In Proceedings of the Skipjack Tuna Conference, July 1976. New Zealand Ministry of Agriculture and Fisheries, Fisheries Research Division Occasional Publication No.11:47-48.

CAMPBELL, J.S. (1971). Historical background to New Zealand tuna investigations. In Report on Tuna Seminar, May 1971. Fishing Industry Board, Wellington, New Zealand. pp. 1-4.

CLEMENT, I.T. (1976). Distribution and abundance of skipjack, 1975-76. *In* Proceedings of the Skipjack Tuna Conference, July 1976. *New Zealand Ministry of Agriculture and Fisheries, Fisheries Research Division Occasional Publication* No.11:36-39.

CLEMENT, I.T. (1978). School fish sightings around New Zealand, 1976-77. *In* Habib, G. and P.E. Roberts (eds). Proceedings of the Pelagic Fisheries Conference, July 1977. *New Zealand Ministry of Agriculture and Fisheries, Fisheries Research Division Occasional Publication* No.15:35-42.

CONWAY, G.R., N.R. GLASS and J.C. WILCOX (1970). Fitting non-linear models to biological data by Marquardts algorithm. *Ecology* 51(3):503-507.

EGGLESTON, D. (1976). The *Paramount* project: a purse-seine survey of New Zealand's skipjack resource. *In* Proceedings of the Skipjack Tuna Conference, July 1976. *New Zealand Ministry of Agriculture and Fisheries, Fisheries Research Division Occasional Publication* No.11:31-35.

EGGLESTON, D. and L.J. PAUL (1978). Satellites, sea temperatures and skipjack. *In* Habib, G. and P.E. Roberts (eds). Proceedings of the Pelagic Fisheries Conference, July 1977. *New Zealand Ministry of Agriculture and Fisheries, Fisheries Research Division Occasional Publication* No.15:75-84.

ELLWAY, C.P. and R.E. KEARNEY (Manuscipt). An assessment of the skipjack and baitfish resources of Papua New Guinea. *Skipjack Survey and Assessment Programme Final Country Report*, South Pacific Commission, Noumea, New Caledonia.

FISHING INDUSTRY BOARD (1971). Report on Tuna Seminar, May 1971. Fishing Industry Board, Wellington, New Zealand. 117pp.

FRANCIS, R.C. (1978). Skipjack research in the Pacific - prospects and priorities. *In* Habib, G. and P.E. Roberts (eds). Proceedings of the Pelagic Fisheries Conference, July 1977. *New Zealand Ministry of Agriculture and Fisheries, Fisheries Research Division Occasional Publication* No.15:10-16.

FUJINO, K. (1966). Instructions for collecting blood and serum samples from tuna fishes. *FAO Circular* 26, Food and Agriculture Organization, Rome, Italy.

FUJINO, K. (1970). Skipjack tuna subpopulation identified by genetic characteristics in the western Pacific. *In* Marr J.C. (ed.). The Kuroshio: A symposium on the Japan current. East-West Center Press, Honolulu, 1968. pp. 385-393.

FUJINO, K. (1976). Subpopulation identification of skipjack tuna specimens from the southwestern Pacific Ocean. *Japanese Society of Scientific Fisheries Bulletin* 42(11):1229-1235.

GILLETT, R.D. and R.E. KEARNEY (1982). Methods used by the Skipjack Survey and Assessment Programme for tagging skipjack and other tuna. *In* Kearney, R.E. (ed.). Methods used by the South Pacific Commission for the survey and assessment of skipjack and baitfish resources. *Tuna and*

Billfish Assessment Programme Technical Report No.7, South Pacific Commission, Noumea, New Caledonia.

HABIB, G. (1976). The 1975-76 purse-seine skipjack fishery. _In_ Proceedings of the Skipjack Tuna Conference, July 1976. _New Zealand Ministry of Agriculture and Fisheries Occasional Publication_ No.11:40-46.

HABIB, G. (1978). Skipjack biology and the 1976-77 purse-seine fishery. _In_ Habib, G. and P.E. Roberts (eds). Proceedings of the Pelagic Fisheries Conference, July 1977. _New Zealand Ministry of Agriculture and Fisheries, Fisheries Research Division Occasional Publication_ No.15:17-26.

HABIB, G. (1981). Marine fisheries policy group: growth opportunities, industry development: tuna and inshore pelagic fish species. New Zealand Ministry of Agriculture and Fisheries, Fisheries Research Division, Wellington. (Unpublished report.)

HABIB, G. and I.T. CLEMENT (1981). New Zealand country paper. The Tuna Fisheries. New Zealand Ministry of Agriculture and Fisheries, Wellington. 39pp. plus 8 Appendices. (Unpublished report.)

HABIB, G., I.T. CLEMENT, K.N. BAILEY, C.L. CAREY, P.M. SWANSON and G.J. VOSS (1982). Incidential fish species in the purse-seine skipjack fishery, 1975-81. _New Zealand Ministry of Agriculture and Fisheries, Fisheries Research Division Occasional Publication: Data Series_ No.5. 49pp.

HABIB, G., I.T. CLEMENT and K.A. FISHER (1980a). The 1977-78 purse-seine skipjack fishery in New Zealand waters. _New Zealand Ministry of Agriculture and Fisheries, Fisheries Research Division Occasional Publication_ No.25. 42pp.

HABIB, G., I.T. CLEMENT and K.A. FISHER (1980b). The 1978-79 purse-seine skipjack fishery in New Zealand waters. _New Zealand Ministry of Agriculture and Fisheries, Fisheries Research Division Occasional Publication_ No.26. 39pp.

HABIB, G., I.T. CLEMENT and K.A. FISHER (1980c). The 1979-80 purse-seine skipjack fishery in New Zealand waters. _New Zealand Ministry of Agriculture and Fisheries, Fisheries Research Division Occasional Publication_ No.29. 43pp.

HABIB, G., I.T. CLEMENT and K.A. FISHER (1981). The 1980-81 purse-seine skipjack fishery in New Zealand waters. _New Zealand Ministry of Agriculture and Fisheries, Fisheries Research Division Occasional Publication_ No.36. 52pp.

HABIB, G. and P.E. ROBERTS (eds) (1978). Proceedings of the Pelagic Fisheries Conference, July 1977. _New Zealand Ministry of Agriculture and Fisheries, Fisheries Research Division Occasional Publication_ No.15. 102pp.

HALLIER, J.-P. and R.D. GILLETT (1982). Baitfishing methods used by the Skipjack Survey and Assessment Programme and their comparison with those used by commercial Japanese pole-and-line vessels. _In_ Kearney, R.E. (ed.). Methods used by the South Pacific Commission for the survey and assessment of skipjack and baitfish resources. Tuna and Billfish Assessment Programme Technical Report No.7, South Pacific Commission, Noumea, New Caledonia.

JAMES, G.D. (1975). Size composition of jack mackerel catches from the west coast of New Zealand. New Zealand Journal of Marine and Freshwater Research 9(1):45-52.

JOSEPH, J. and T.P. CALKINS (1969). Population dynamics of the skipjack tuna (Katsuwonus pelamis) of the eastern Pacific Ocean. Inter-American Tropical Tuna Commission Bulletin 13(1):1-273.

JOSSE, E., J.C. LE GUEN, R. KEARNEY, A. LEWIS, A.(i.e. B.R.) SMITH, L. MAREC and P.K. TOMLINSON (1979). Growth of skipjack. South Pacific Commission Occasional Paper No.11. 83pp.

KEARNEY, R.E. (1978). Interim report of the activities of the Skipjack Survey and Assessment Programme in the waters of Fiji. Skipjack Survey and Assessment Programme Preliminary Country Report No.5, South Pacific Commission, Noumea, New Caledonia. 13pp.

KEARNEY, R.E. (ed.) (1982a). Methods used by the South Pacific Commission for the survey and assessment of skipjack and baitfish resources. Tuna and Billfish Assessment Programme Technical Report No.7, South Pacific Commission, Noumea, New Caledonia.

KEARNEY, R.E. (1982b). An assessment of the skipjack and baitfish resources of Fiji. Skipjack Survey and Assessment Programme Final Country Report No.1, South Pacific Commission, Noumea, New Caledonia.

KEARNEY, R.E and J.-P. HALLIER (1979). Interim report of the activities of the Skipjack Survey and Assessment Programme in the waters of New Zealand. Skipjack Survey and Assessment Programme Preliminary Country Report No.16, South Pacific Commission, Noumea, New Caledonia. 17pp.

KLEIBER, P. (Manuscript). Estimates of production, mortality and migration of skipjack (Katsuwonus pelamis) in the central and western Pacific Ocean. Tuna and Billfish Assessment Programme Technical Report, South Pacific Commission, Noumea, New Caledonia.

KLEIBER, P. and R.E. KEARNEY (1983). An assessment of the skipjack and baitfish resources of Kiribati. Skipjack Survey and Assessment Programme Final Country Report No.5, South Pacific Commission, Noumea, New Caledonia.

KLEIBER, P. and C.A. MAYNARD (1982). Data processing procedures of the Skipjack Survey and Assessment Programme. In Kearney, R.E. (ed.). Methods used by the South Pacific Commission for the survey and assessment of skipjack and baitfish resources. Tuna and Billfish Assessment Programme Technical Report No.7, South Pacific Commission, Noumea, New Caledonia.

LAWSON, T.A. and R.E. KEARNEY (Manuscript). Estimates of growth rates and length measurement errors for skipjack (Katsuwonus pelamis) from the western Pacific Ocean based on tagging data. Tuna and Billfish Assessment Programme Technical Report, South Pacific Commission, Noumea, New Caledonia.

LESTER, R.J.G. (1981). Preliminary results of observations on the parasites of Pacific skipjack tuna. Regional Technical Meeting on Fisheries 1981, 13 : Background Paper, South Pacific Commission, Noumea, New Caledonia. 10pp.

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

McKENZIE, Miss M.K. (1963). A review of present knowledge relative to a possible tuna fishery in New Zealand. New Zealand Marine Department, Wellington. Fisheries Technical Report No.4. 48pp.

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

NOSOV, E.V. and N.A. SHURUNOV (1975). Some features of seasonal and year to year variation in the distribution of the jack mackerel (*Trachurus declivis* Jenyns). Translation from Russian. The Pacific Ocean Scientific Research Institute for Fisheries and Oceanography (TINRO). Research into the Biology of Fish and Commercial Oceanography Number 6, Vladivostok 1975. 12pp.

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

RICHARDSON, B.J. (Manuscript). The distribution of protein variation in skipjack tuna (*Katsuwonus pelamis*) from the central and south-western Pacific. Department of Population Biology, Research School of Biological Sciences, Australian National University, Canberra.

RICKER, W.E. (1975). Computation and interpretation of biological statistics for fish populations. Fisheries Research Board of Canada Bulletin 191. 382pp.

ROBERTSON, D.A. (1978a). The New Zealand jack mackerel fishery. *In* Habib, G. and P.E. Roberts (eds). Proceedings of the Pelagic Fisheries Conference, July 1977. New Zealand Ministry of Agriculture and Fisheries, Fisheries Research Division Occasional Publication No.15:43-47.

ROBERTSON, D.A. (1978b). Blue mackerel, pilchard, anchovy, sprat, saury, and lanternfish. *In* Habib, G. and P.E. Roberts (eds). Proceedings of the Pelagic Fisheries Conference, July 1977. New Zealand Ministry of Agriculture and Fisheries, Fisheries Research Division Occasional Publication No.15:85-89.

SHARP, G.D. (1969). Electrophoretic study of tuna hemoglobins. Comparative Biochemistry and Physiology, 31:249.

SHARP, G.D. (1978). Behavioural and physiological properties of tunas and their effects on vulnerability to fishing gear. *In* Sharp, G.D. and A.E. Dizon (eds). The physiological ecology of tunas. Academic Press, New York. pp. 397-450.

SKIPJACK PROGRAMME (1981a). Skipjack migration, mortality and fishery interaction. _Regional Technical Meeting on Fisheries 1981_, 13 : Working Paper No.9, South Pacific Commission, Noumea, New Caledonia. 35pp.

SKIPJACK PROGRAMME (1981b). Effects of skipjack tagging procedures on subsequent tag recoveries. _Regional Technical Meeting on Fisheries 1981_, 13 : Working Paper No.8, South Pacific Commission, Noumea, New Caledonia. 14pp.

SKIPJACK PROGRAMME (1981c). An appraisal of the genetic analysis of skipjack blood samples. _Regional Technical Meeting on Fisheries 1981_, 13 : Working Paper No.10, South Pacific Commission, Noumea, New Caledonia. 8pp.

STEPHENSON, A.B. and D.A. ROBERTSON (1977). The New Zealand species of _Trachurus_ (Pisces: Carangidae). _Journal of the Royal Society of New Zealand Volume_ 7(2):243-253.

TUNBRIDGE, B.R. (1969). Pilchard survey, Nelson 1964. New Zealand Marine Department, Wellington. _Fisheries Technical Report_ No.32. 23pp.

UEYANAGI, S. (1969). Observations on the distribution of tuna larvae in the Indo-Pacific Ocean with emphasis on the delineation of the spawning areas of albacore, _Thunnus alalunga_. _Far Seas Research Laboratory of Japan Bulletin_ 2:177-215.

WAUGH, G.D. (1976). Opening address, first day. _In_ Proceedings of the Skipjack Tuna Conference, July 1976. _New Zealand Ministry of Agriculture and Fisheries, Fisheries Research Division Occasional Publication_ No.11:7.

WEBB, B.F. (1971). Survey of pelagic fish in the Nelson area (1968-1969) by spotter-plane. _New Zealand Marine Department Wellington, Fisheries Technical Report_ No.69. 29pp.

WEBB, B.F. (1972a). Report on the investigation of the _Lloret Lopez II_, 8 January to 2 April 1970, Section 1. General Introduction, Section 2. Baitfishing: Boke Net, Squid Ocean Piper. _New Zealand Ministry of Agriculture and Fisheries Fisheries Technical Report_ No.96. 59pp.

WEBB, B.F. (1972b). Report on the investigation of the _Lloret Lopez II_, 8 January to 2 April 1970, Section 6. Tuna Catch Analysis and Sea Water Temperatures. _New Zealand Ministry of Agriculture and Fisheries Fisheries Technical Report_ No.108. 105pp.

WEBB, B.F. (1972c). Report on a tuna polefishing and live-bait venture, _Hoko Maru No.15_, 8 February to 24 March 1972, Section 1: General Introduction; Section 2: Baitfishing. _New Zealand Ministry of Agriculture and Fisheries Fisheries Technical Report_ No.112. 61pp.

WEBB, B.F. (1972d). Length frequencies, catch data and gonad maturity of pilchards, _Sardinops pilchardus_ (Steindachner) and anchovy, _Engraulis australis_ (White) caught Tasman Bay and Marlborough Sounds, 1969-1970. _New Zealand Marine Department Fisheries Technical Report_ No.91. 51pp.

WEBB, B.F. (1973). Report on the investigations of the _Lloret Lopez II_, 8 January to April 1970, Section 4. Polefishing and Trolling Method, Section 5. Longlining Method. New Zealand Ministry of Agriculture and Fisheries Fisheries Technical Report No.105. 38pp.

WEBB, B.F. (1974). Report on a tuna polefishing and live bait venture, Hoko Maru No.15, 8 February to 21 March 1972. Section 3: Polefishing, Hydrology, and Tuna Analysis. New Zealand Ministry of Agriculture and Fisheries Fisheries Technical Report No.106. 57pp.

YORK, A.G. (1969). Tuna investigations - east coast area of New Zealand 1965-1967. New Zealand Marine Department Fisheries Technical Report No.40. 80pp.

YORK, A.G. (1974). Acoustic detection and attraction of tuna in New Zealand waters. In Proceedings of a symposium on coastal and high seas pelagic resources. Indo-Pacific Fisheries Council, Fifteenth Session, Wellington, New Zealand, October 1972. IPFC Secretariat, United Nations Food and Agriculture Organization, Regional Office, Bangkok. pp. 470-480.

YORK, A.G. (1977). Tuna investigations, Bay of Plenty, New Zealand 1969-1971. New Zealand Ministry of Agriculture and Fisheries Fisheries Technical Report No.151. 90pp.

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

South Pacific Commission Scientists

Jean-Pierre Hallier	3-28 March 1979 10-25 March 1980
Bob Gillett	17 February - 5 March 1979
Charles Ellway	18 February - 28 March 1979
Des Whyman	13-25 March 1980
A.W. Argue	10-24 March 1980
Jim Ianelli	17 February - 28 March 1979 10-16 March 1980

Observers

Ben Tikomainiusiladi Fiji Fisheries Division Fiji	17 February - 27 February 1979
George Clement Fisheries Biologist Fisheries Management Division New Zealand Ministry of Agriculture and Fisheries	19 February - 2 March 1979
Nigel Marsack Fisheries Technician New Zealand Ministry of Agriculture and Fisheries	19 February - 2 March 1979
George Habib Fisheries Scientist New Zealand Ministry of Agriculture and Fisheries	3-7 March 1979
Richard Cade Fisheries Technician New Zealand Ministry of Agriculture and Fisheries	3-26 March 1979
Gavin James Fisheries Biologist New Zealand Ministry of Agriculture and Fisheries	13-16 March 1979
Brent Wood Fisheries Technician New Zealand Ministry of Agriculture and Fisheries	13-16 March 1979

Observers (cont.)

Gary Voss Fisheries Technician New Zealand Ministry of Agriculture and Fisheries	13-25 March 1980
Gwiedo Kucerans Fisheries Technician New Zealand Ministry of Agriculture and Fisheries	13-25 March 1980
John Gordon Film Crew Director New Zealand Broadcasting Corporation	13-16 March 1979
Stephen Payne Cameraman New Zealand Broadcasting Corporation	13-16 March 1979
Gail Windle Recording Technician New Zealand Broadcasting Corporation	13-16 March 1979

Japanese Crew
Cruise One

Masahiro Matsumoto, Captain
Sakae Hyuga
Yoshio Kadono
Yoshihiro Kondoh
Yoshio Kozuka
Yoshikatsu Oikawa
Nozomo Origuichi
Kohji Wakasaki
Mikio Yamashita

Japanese Crew
Cruise Two

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

Fijian Crew
Cruise One

Eroni Marawa
Lui Andrews
Vonitiese Bainimoli
Mosese Cakau
Samuela Delana
Eroni Dolodai
Veremalua Kaliseiwaqa
Kitione Koroi
Josua Raguru
Jona Ravasakula
Ravaele Tikovakaca
Samuela Ue

Fijian Crew
Cruise Two

Eroni Marawa
Lui Andrews
Samuela Delana
Eroni Dolodai
Kitione Koroi
Metuisela Koroi
Aminisasi Kuruyawa
Josua Raguru
Jona Ravasakula
Napolioni Ravitu
Ravaele Tikovakaca
Samuela Ue

APPENDIX B. BAIT SPECIES COMPOSITION, PERCENTAGE OF BOUKI-AMI HAULS CONTAINING A PARTICULAR SPECIES, AND CATCH BY SPECIES (KILOGRAMS) FOR 1979 AND 1980 SKIPJACK PROGRAMME SURVEYS IN THE WATERS OF NEW ZEALAND

Species	Percentage Occurrence	Estimated Catch (kg)
1 9 7 9		
Sardinops neopilchardus	60	2137
Trachurus declivis	73	1373
Scomber australasicus	47	787
Engraulis australis	40	188
Trachurus novaezealandae	13	19
Sp. of Anguillidae (juveniles)	7	0
Optivus elongatus	13	0
Engraulis sp. (juveniles)	20	0
Sp. of Hemirhamphidae	27	0
Zeus faber	20	0
Sp. of Mullidae	7	0
Sp. of Sparidae	7	0
Sp. of Clupeidae	7	0
Decapterus koheru	7	0
Sp. of Carangidae	7	0
Sp. of Exocoetidae	13	0
Arripis trutta	27	0
Thyrsites atun	7	0
Sp. of Squid	60	0
Sp. of Sphyraenidae	7	0
1 9 8 0		
Sardinops neopilchardus	50	3741
Trachurus novaezealandae	100	726
Arripis trutta	25	571
Trachurus declivis	25	308
Engraulis australis	38	16
Aldrichetta forsteri	25	3
Decapterus koheru	13	1
Sp. of Exocoetidae	13	0
Engraulis sp. (juveniles)	13	0
Sp. of Hemirhamphidae	25	0
Sp. of Squid	50	0
Zeus faber	50	0
Scomber australasicus	38	0

APPENDIX C. LISTING OF TAG AND RECOVERY DATA FOR EACH TAGGED SKIPJACK THAT MADE AN INTERNATIONAL MIGRATION OUT OF OR INTO THE WATERS OF NEW ZEALAND. Release data are presented for the school from which one or more tagged fish were recovered. The inset lines present release data as follows: country abbreviation; 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 abbreviations (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; tag recovery gear (see list). The Appendix does not include recoveries for which country of recovery was unknown. 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.

Migrants from the waters of New Zealand to other countries

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        ZEA 429 790222 1430 3536S 17515E  469    0    0
S FIJ 800101 313 1840S 17820E 1029 520M 580W SB02842 FIJPOL

        ZEA 431 790222 1835 3520S 17448E  967    0    0
S NSW 791116 267 3650S 15105E 1151 480M    U SB02965 USASEN
S WES 791227 308 1410S 17150W 1460 450M 510E SB04229 WESSUB
S FIJ 800102 314 1850S 17820E 1008 450M 510B SB03224 FIJPOL
S FIJ 800224 367 1815S 17830E 1044 440M    U SB03276 FIJPOL
S FIJ 810213 722 1816S 17759E 1038 440M 550E SB03950 FIJPOL

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

        ZEA 436 790227 2000 3516S 17441E  150    0    0
S FIJ 810615 840 1615S 17905E 1165 430M    U SK00166 FIJPOL
S FIJ 810713 867 1550S 17910E 1191 460M    U SK00149 FIJPOL

        ZEA 437 790228 1330 3513S 17439E  177    0    0
S INT 800228 365 0400S 17300E 1875 450M 580W SK00265 JAPPOL

        ZEA 438 790302 1045 3526S 17453E  709    0    0
S CAL 791202 275 1829S 16007E 1284 500M 625W SK00931 JAPPOL
S SOC 800514 439 1720S 14940W 2176 460M 570E SK00938 POLSHE

        ZEA 439 790302 1300 3527S 17452E  700    0    0

S WES 791229 302 1348S 17146W 1486 480M 520E SK01445 WESSUB
S FIJ 800315 379 1700S 17950W 1143 460M    U SK01345 FIJPOL

        ZEA 441 790302 1645 3525S 17453E  326    0    0
S NOR 800326 390 2928S 16820E 0487 500M 621A SK01585 SPCPOL

        ZEA 443 790302 1800 3524S 17454E 1875    0    0
S FIJ 790617 107 1556S 17941E 1196 460M 514B SK02786 FIJPOL
S FIJ 791015 227 1840S 17820E 1020 440M    U SK02426 FIJPOL
S FIJ 800205 340 1652S 17912E 1136 450M 493B SH06271 FIJPOL
S TON 800220 355 2104S 17522W 1001 470M 525E SK02519 TONPOL
S FIJ 800316 380 1730S 17900E 1096 440M    U SH06786 FIJPOL
S FIJ 800408 403 1600S 17900E 1185 450M 510B SK02815 FIJPOL
S FIJ 800812 529 1605S 17900E 1180 450M 660B SK02439 FIJPOL
S FIJ 811016 959 1615S 17905E 1171 450M    U SH06732 FIJSUB

        ZEA 444 790303 1540 3532S 17449E  433    0    0
S FIJ 800315 378 1700S 17950W 1148 460M    U SH07216 FIJPOL
S FIJ 810204 704 1725S 17929W 1129 450M 520E SH07229 FIJPOL

        ZEA 445 790303 1650 3531S 17450E  141    0    0
S SOC 801013 590 1655S 14955W 2183 470M 650E SH07646 POLSHE

        ZEA 447 790305 1645 3537S 17511E  160    0    0
S FIJ 791115 256 1730S 17900E 1106 470M    U SH07926 FIJPOL

        ZEA 449 790306 0700 3551S 17530E  690    0    0
S FIJ 791115 255 1730S 17900E 1117 450M    U SH08126 FIJPOL
S SOC 800128 328 1735S 14910W 2170 460M    U SH08494 POLSHE
S SOC 800202 333 1810S 14950W 2119 450M 496W SH07763 POLSHE
S FIJ 800316 376 1730S 17900E 1117 450M    U SH07874 FIJPOL
S TOK 801104 609 0923S 17113W 1746 465M 679E SH08459 TOKSUB

        ZEA 450 790306 1000 3553S 17534E  292    0    0
S FIJ 800222 353 1641S 17952W 1177 450M 510E SH08357 FIJART
S CAL 801222 657 1839S 16034E 1304 445M 542W SH08732 JAPPOL

        ZEA 452 790306 1300 3546S 17528E  129    0    0
S FIJ 800102 302 1850S 17820E 1027 465M 500B SH08793 FIJPOL

        ZEA 456 790308 0920 3741S 17726E  556    0    0
S CAL 800108 306 1843S 16515E 1305 580M 682W SH09044 JAPPOL

        ZEA 460 790313 1650 3738S 17633E  605    0    0
S VAN 800318 371 1621S 16431E 1427 520M 710W SK03054 JAPPOL

        ZEA 461 790314 0720 3738S 17632E  206    0    0
S INT 810214 704 0423N 17930E 2526 520M    U SK03486 JAPPOL

        ZEA 463 790314 1605 3741S 17651E  210    0    0
S CAL 800209 332 1749S 16043E 1463 595B 735W SK03707 JAPPOL
S CAL 800217 340 1734S 15835E 1543 595B 695W SK03390 JAPPOL

        ZEA 464 790320 0810 3547S 17520E  976    0    0
S WES 800109 295 1404S 17126W 1485 450M 520E SH09846 WESSUB
S INT 800228 345 0400S 17300E 1911 450M 505W SK04017 JAPPOL
S FIJ 800317 363 1720S 17955W 1136 460M 510B SK04084 FIJPOL
S FIJ 810205 688 1600S 17950E 1211 470M 590W SH09883 FIJPOL

        ZEA 465 790322 0955 3750S 17411E  135    0    0
S FIJ 800715 481 1830S 17750E 1176 450M    U SK04989 FIJPOL
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	ZEA	796	800323	1230	3531S	17450E	1058	0	0	
S	FIJ	810120	303	1710S	17935E	1130	485M	550E	1B19426	FIJPOL
S	FIJ	810127	310	1813S	17950E	1071	410M	535W	2B20103	FIJPOL
S	FIJ	810208	322	1650S	17845W	1172	550M	620B	1B18586	FIJPOL
S	SOC	810210	324	1700S	14933W	2197	620M	650E	1B19465	POLSHE
S	WES	810221	335	1340S	17140W	1500	490M	545E	1B19194	WESART
S	FIJ	810225	339	1602S	17804E	1182	550M	580B	1B19616	FIJPOL
S	NSW	810318	360	3510S	15100E	1164	540M	U	1B18585	AUSPOL
S	TUV	810330	372	1234S	17955E	1404	550M	620W	2B20057	JAPPOL
S	FIJ	810512	415	1710S	17950W	1137	540M	520E	1B19040	FIJPOL
S	FIJ	810613	447	1546S	17955W	1218	550M	U	1B18743	FIJPOL
S	FIJ	810613	447	1546S	17955W	1218	480M	U	2B20086	FIJPOL

Migrants from the waters of other countries to New Zealand

	FIJ	144	780209	0720	1853S	17916E	197	12	0	
S	ZEA	790301	386	3624S	17425E	1082	450M	555D	SC03726	USASEN
	FIJ	171	780406	1052	1656S	17924W	1642	0	0	
S	ZEA	781121	229	3600S	17600E	1170	504B	585D	SD03771	ZEASEN
S	ZEA	790119	288	3553S	17552E	1165	510M	585D	SD03391	USASEN
	NSW	483	790405	1030	3604S	15024E	218	0	0	
S	ZEA	800114	284	3557S	17608E	1245	450M	502D	SK05367	UUUSEN
	NSW	497	790406	1520	3514S	15105E	41	0	0	
S	ZEA	800131	300	3728S	17654E	1251	460M	505K	SK06875	ZEASEN
	NSW	506	790408	0840	3508S	15104E	194	0	0	
S	ZEA	800207	305	3544S	17307E	1076	440M	U	SK07016	ZEASEN
	NSW	507	790408	0920	3506S	15104E	745	0	0	
S	ZEA	800205	304	3523S	17236E	1053	450M	500J	SK07562	USASEN
S	ZEA	800310	337	3809S	17352E	1110	450M	555D	SK07502	UUUSEN
	NSW	511	790408	1610	3504S	15105E	285	0	0	
S	ZEA	800101	268	3552S	17602E	1217	476B	511E	SK08189	USASEN
	NSW	514	790409	1325	3441S	15110E	96	0	0	
S	ZEA	800206	303	3526S	17240E	1055	470M	U	SK08494	USASEN
	NSW	515	790409	1605	3458S	15105E	764	0	0	
S	ZEA	800131	297	3728S	17654E	1255	460M	505K	SK08808	ZEASEN
	NSW	518	790410	1050	3502S	15112E	106	0	0	
S	ZEA	800205	302	3523S	17236E	1047	450M	500J	SK09396	USASEN
	WAL	214	780517	1150	1329S	17607W	1034	0	0	
S	ZEA	790314	302	3556S	17535E	1419	530M	U	SE01223	USASEN
	WAL	215	780518	0850	1331S	17605W	742	0	0	
S	ZEA	790119	246	3429S	17603E	1329	540M	541D	SE01940	USASEN
	WAL	219	780519	1030	1330S	17605W	1028	0	0	
S	ZEA	790304	289	3530S	17501E	1405	490M	540D	SE03518	USASEN
	WAL	222	780520	0850	1317S	17623W	350	0	0	
S	ZEA	790304	288	3612S	17530E	1443	480M	515W	SE04967	USASEN
	WAL	223	780520	1030	1315S	17620W	1565	0	0	
S	ZEA	790304	288	3612S	17530E	1446	505B	560W	SK16687	USASEN
	WAL	235	780529	0830	1405S	17758W	308	0	0	
S	ZEA	790411	317	3600S	17600E	1354	510M	560J	SK19390	USAPOL
	WES	241	780614	1000	1342S	17145W	1637	56	0	
S	ZEA						520M	U	SK20706	ZEASEN

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 *Hatsutori Maru No.1* (SPC staff)
B	Measured by joint local 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	Long-line
SHE	Pearl-shell trolling
ART	Artisanal
GIL	Gill net
REC	Recreational (sport fishing)
SUB	Subsistance (village)
UUU	Unknown