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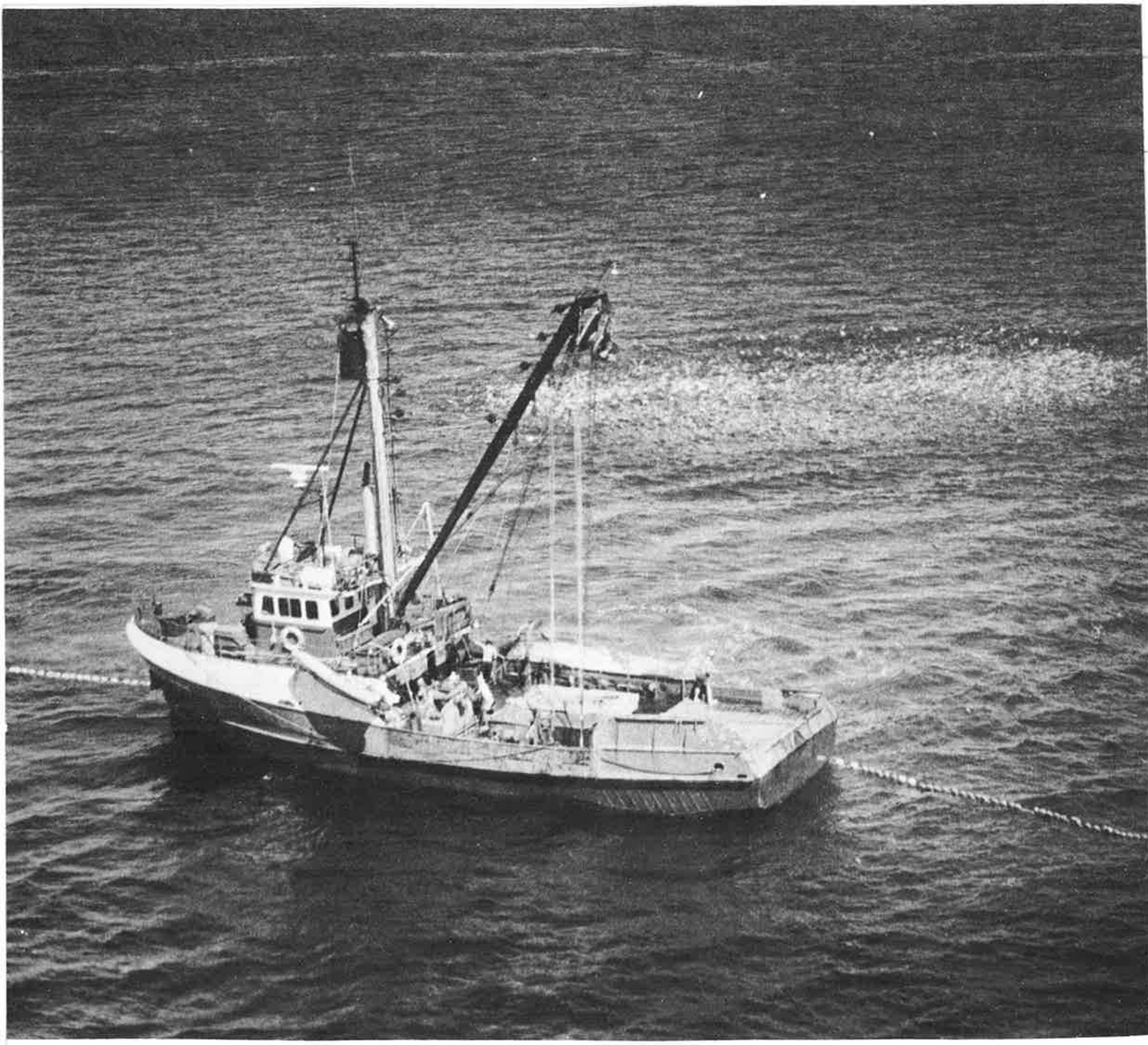


The purse seiner *Lindberg* in set on a school of skipjack in the Bay of Plenty.

Introduction

In the early and mid 1970s purse-seine surveys of New Zealand's skipjack (*Katsuwonus pelamis* Linnaeus, 1758) resource established that there were good prospects for a commercial fishery (Hinds 1974, Eggleston 1976). This led to the formation of a joint venture between two companies -- one New Zealand and one American – in which several large American purse-seine vessels were to further investigate the commercial prospects for skipjack fishing. At the same time interest was raised in the local industry, and two small New Zealand seiners also began to seek skipjack. Since then there has been a rapidly developing summer fishery for skipjack in which landings have risen from 5000 t in 1975–76 (1976 season) to about 9000 t in each of the last three seasons.

Each season the Ministry of Agriculture and Fisheries (MAF) has monitored catch-per-effort of the commercial fleet fishing skipjack and related this to environmental parameters, skipjack biology, and fluctuations in size of the skipjack resource. The results of observations on earlier seasons are presented in Clement 1976, 1978; Habib 1976, 1978a, 1978b; Vooren 1976; Eggleston and Paul 1978; Richardson 1978; and Habib, Clement, and Fisher (in press), 1980. This publication contains information on the 1980 purse-seine skipjack fishery in New Zealand.

Materials and methods

Vessels

These were *Adriatic Sea* (formerly *Apollo,* 1558 gross tonnes, 79 m overall length, 2000 t carrying capacity); *Tifaimoana* (1435 t, 72 m, 1470 t); *Captain M.J. Souza* (1172 t, 67 m, 1150 t); *Frontier* (as for *Captain M.J. Souza*); *Finisterre* (1063 t, 62 m, 1150 t); *Voyager* (1472 t, 73 m, 1600 t); *Royal Pacific* (1080 t, 66 m, 1150 t); *Island Princess* (1274 t, 69 m, 1350 t); *Jeanette C* (1091 t, 54 m, 813 t); *Western Pacific* (544 t, 36 m, 350 t); *Janet D* (498 t, 35 m, 330 t); *Waihola* (as for *Janet D*); *San Benito* (248 t, 33 m, 120 t); *Marine Countess* (135 t, 27 m, 130 t); and *Lindberg* (159 t, 23 m, 90 t).

The first four vessels fished under charter to the New Zealand Pelagic Fisheries Development Company (1976) Limited (NZPFDC) with *Finisterre,* the company-owned vessel. *Voyager* and *Royal Pacific* fished under charter to J. Wattie Canneries Ltd, and *Island Princess* and *Jeanette C* were under charter to Jaybel Nichimo Ltd. In this publication these vessels constitute the large purse seiners.

Adriatic Sea, Tifaimoana, Captain M.J. Souza, Finisterre, and *Royal Pacific* joined the New Zealand fishery from the eastern Pacific Ocean, *Tifaimoana* being on her maiden voyage. *Voyager, Island Princess,* and *Jeanette C* joined the fishery from the western Pacific tuna grounds between Papua New Guinea and the Trust Territory of the Pacific Islands. *Frontier* joined from grounds around Australia.

Janet D and *Marine Countess* were operated by J. Wattie Canneries Ltd, *San Benito* and *Lindberg* by Sanford Ltd, *Waihola* by Skeggs Foods Ltd, and *Western Pacific* by Nelson Fisheries Ltd. All these vessels except *Western Pacific* joined the fishery from other New Zealand pelagic fisheries. *Western Pacific,* which is the largest fishing vessel built in New Zealand, remained unfinished until late in the season, when she joined the fishery on her maiden voyage.

Fishing gear and auxiliary equipment

The purse-seine nets ranged from 640 to 1682 m (2100 to 5518 ft) in length and 64 to 263 m (210 to 863 ft) in depth.

Most vessels used a motorised skiff during fishing. The exceptions were the Norwegian-style seiners *Janet D, Waihola,* and *Marine Countess,* which used Dahn buoys during net setting. Skiffs ranged in size from 7 to 11 m in length, 3.5 to 6 m in width, and 7 to 30 t in weight.

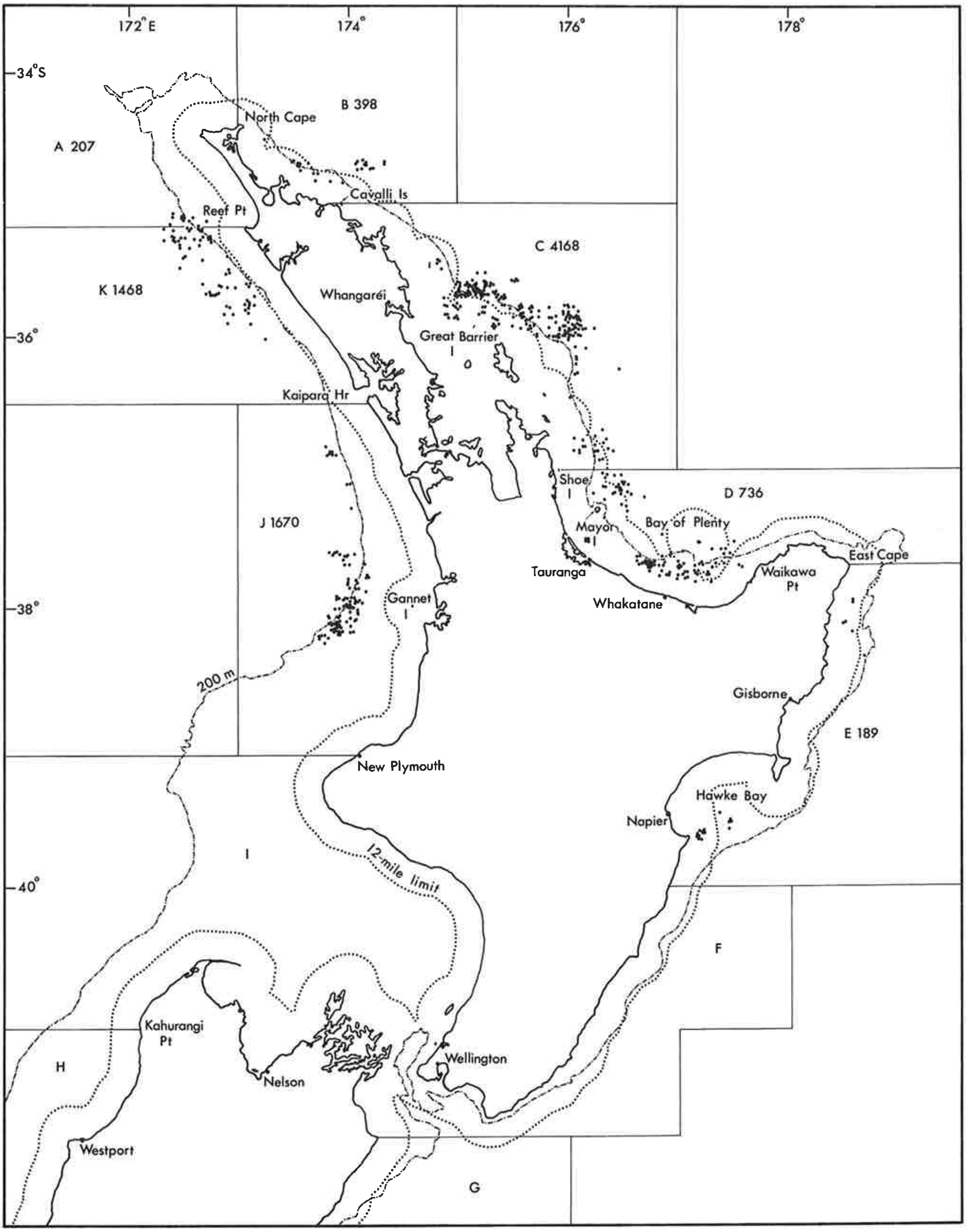


Fig. 1: Set positions and quantities (t) of skipjack caught by area in the 1980 purse-seine skipjack fishery in New Zealand.

Many vessels were equipped with satellite navigation, sonar, and weather facsimile machines, and all had radar, depth sounders, and sophisticated radio equipment.

Six vessels carried helicopters for fish finding and directing net setting, and most carried speedboats for herding the skipjack schools during fishing.

Fish storage aboard the vessels was in refrigerated brine.

Observer programme

As in previous seasons, the Fisheries Divisions of MAF placed observers aboard the purse-seine vessels to record:

1. Vessel activity, subdivided into time and place searching, travelling, at anchor or in port carrying out repairs or survey requirements, discharging fish, taking stores, sheltering from poor weather, or taking time off.
2. Vessel fishing activity, with location, date, time, depth, size, and success of sets.
3. Weather and sea conditions.
4. Location and size of surface schools of skipjack and other pelagic fishes.
5. Lengths of skipjack and other species in the catches.
6. Reproductive state and food contents of skipjack and other species in the catches.

In addition, on some vessels skipjack gills and alimentary tracts were collected for joint parasite studies between MAF and the University of Queensland.

Fork lengths were measured to the whole centimetre below the actual length in randomly selected samples of 40 to 600 fish from all catches while observers were aboard the vessels. For studies on reproduction and feeding, 5 to 30 fish were dissected from occasional catches. The developmental stage of the gonads was judged by use of criteria described by Orange (1961) and Raju (1964). Gonads which were larger than rudimentary, thread-like structures were preserved in formalin and later weighed and dissected ashore. All stomachs which contained food were also preserved in formalin and later examined ashore. The contents were removed from the stomachs, lightly blotted to remove excess liquid, and then weighed to the nearest 0.1g. A record was also kept of all empty stomachs.

Ministry of Agriculture and Fisheries logs were kept by observers and pilots aboard "spotter" aircraft flying in support of the skipjack fishery. This applied mainly to the four fixed-wing shore-based aircraft. Occasionally, observers were also on vessel-based helicopters during fish-spotting flights.

Sightings of numbers and sizes of schools were recorded with the date, time of day, locality, and weather and sea state. The behaviour and likely "catchability" of the fish were also often noted. Schools of skipjack were located and identified and school sizes estimated by use of criteria outlined by Bell (1976). These tasks were carried out by spotters with specialised training and considerable experience gained over several years of assisting pelagic fishing vessels (for discussion of these requirements see Squire 1972). Most observations were made from commercial fish-spotting flights, supplemented by observations from wider-ranging MAF aerial surveys. Sightings effort by aircraft and purse-seine vessels is recorded in Table 1.

Abundance

Two measures of abundance are used in this publication, apparent and real abundance.

Apparent abundance is defined by Marr (1951) as ". . . abundance as affected by availability, or the absolute number of fish accessible to a fishery." In this publication apparent abundance refers to the quantity of fish which was apparent at the surface each half-day and which was accessible to the purse-seine fleet on each half-day. The half-day estimate was chosen because during each half-day period it was usually possible to eliminate double sightings of schools and so derive good estimates of the quantity of fish present at the surface. It should, however, be appreciated that in adding together such amounts, fish which were quantified on one half-day probably often contributed to subsequent half-day totals. Therefore the total of all half-day measures of apparent abundance does not represent the quantity which could have been taken in the fishery and is to some extent an overestimate.

However, there are other factors which caused the measures of apparent abundance on each half-day to be underestimated. These are the cursory nature of much sightings effort, the inadequate sightings effort in all skipjack fishing areas at some time during the season, and the movement of schools through the different depths of the sea during the day, which would have resulted in some proportion of the skipjack resource passing through the New Zealand region unsighted.

Real abundance refers to estimates of the absolute quantity of skipjack which passed through New Zealand waters. This measure depends on the acceptance of the concept of a "body" of skipjack. In this publication, this refers to a close-knit group of schools of skipjack that could be seen (through aerial and shipboard observation) to be moving through the New Zealand area as a unit. If this concept is accepted, a measure of real abundance can be gained for each body by addition of the largest half-day sighting of each body to the quantity of fish caught from it before the largest sighting. By summing estimates obtained in this way for all bodies seen, and adding the isolated fish which probably did not contribute to any of the main bodies, it was possible to derive a measure of real abundance of fish for the season (see page 21). The measure should be largely free of double sightings, as it was based on half-day sightings which recorded schools only once.

This measure of real abundance should be regarded as a minimum, as it is unlikely that the largest half-day sightings recorded all fish in the bodies or that all bodies or isolated groups of fish which passed through the New Zealand area were seen. Furthermore, little account was taken of the large number of scattered fish seen throughout the area during the season.

Hydrology

Sea surface temperatures were available from two sources: observers recorded temperatures from the purse-seine vessels during every set by use of insulated water bottles and hand-held thermometers; and, as in previous seasons (Eggleston and Paul 1978, Habib, Clement, and Fisher in press, 1980), MAF received sea surface temperature charts for the New Zealand region from the National Oceanic and Atmospheric Administration of the United States Department of Commerce. The manner in which the satellites measured the temperature and the limitations on these data are discussed in Eggleston and Paul (1978).

Water samples for salinity analyses were collected by the observers during every successful set.

Tagging

In February-March 1979 the South Pacific Commission (SPC) conducted a skipjack survey and assessment programme in New Zealand waters (Kearney and Hallier 1979a), in which 11 614 skipjack were tagged and released from the Commission's pole and line vessel *Hatsutori Maru.* Nine hundred and forty-five of these fish were recaptured shortly after along the north-east coast of the North Island, mainly by the purse seiners fishing the resource. Some preliminary analyses of the tagging data were presented by Habib, Clement, and Fisher (1980) to verify movements of bodies of skipjack during the 1979 season. These data will be analysed in more detail and will form the basis of future publications by SPC.

More tagged skipjack were recaptured in New Zealand waters in 1980, once again mainly by the seiners. Most had been tagged in New Zealand waters in 1979 by *Hatsutori Maru*; the remainder by the same vessel off Australia in 1979 (Kearney and Gillett 1979). Data on these recoveries, and on skipjack tagged in New Zealand in 1979 and recaptured overseas, are discussed later in this publication.

Definitions of effort

In the following analyses a **season-day** is defined as any day that a purse seiner spent in activity related to the skipjack fishery. This includes days searching and fishing, travelling, in port, at anchor or at sea drifting, and days off.

Days fished are days on which a net was set or there was searching activity with the aim of setting.

A **set** is defined as any time a net was released into the water to entrap a skipjack school and then retrieved; and sets were **successful** if at least 1 t of skipjack was caught, even if this represented only part of a school.

Areas

The fishery is discussed in terms of the areas shown in Fig. 1.

TABLE 1: Sightings effort from aircraft (+) and purse-seine vessels (x) by half-day by area in the 1980 purse-seine skipjack fishery in New Zealand; poor weather is indicated (o).

			Area				
	Day		A	B	C	D	E
Nov	13	a.m.					
		p.m.			+		
	14						
	15						
	16						
	17					+ x	
						+ x	
	18					+ x	
						+ x	
	19					+ x	
						+ x	
	20						+
	21						+
	22			+	+	+ x	+ x
	23			+ x	+ x		
				+ x	+ x		
	24			+ x			+ x
							+ x
	25		+	+ x		+ x	+ x
				+ x			+ x
	26			+ x			
				+ x	+	+	
	27			x			
				+ x	+		
	28			+ x			
				+ x			
	29			+ox	+	+	+
				+ x	+		
	30			+ x			
				+ x			

TABLE 1: Sightings effort from aircraft (+) and purse-seine vessels (x) by half-day by area in the 1980 purse-seine skipjack fishery in New Zealand; poor weather is indicated (o) – ***continued***

	Day		Area						Area					
			A	B	C	D	E		A	B	C	D	E	K
Dec	1	a.m.		+ x			+ x	Jan			+ x	+		
		p.m.		+ x							+ x			
	2			+ x			+ x				+ x			
				+ x			x				+ x			
	3			+ox	+	+	x				+ox			
				o			+ x				+ x	+		
	4			+ x	+	+					+ x	+		
				+ x							+ x			
	5		+	+ x			+ x				+ox			
			+	+ x			+ x			+	+ox	+		
	6			+ x	+						+ x	+	+	
				+ x	+						+ x	+		
	7			+ x							+ x	+		
				+ x							+ x	+		
	8		+	+ x							+ x	+ x		
				+ x							+ x	+ x		
	9		ox								+ x	+ x		
			ox								+ x	+ x		
	10		+ x			+ x					+ x	+ x		
			+ x			x					+ x	+ x		
	11		+ x	+	+	+ x					+ x	+ x		
			+ x	+	+	+ x					+ x	+ x		
	12			+	+ x	+ x					+ x	+ x		
				+	+ x	+ x					+ x	+ x		
	13										+ x	+ x		
											+ x	+ x		
	14				+ x						+ x	+ x		
					+ x						+ x	+ x		
	15										+ x	+ x		
											+ x	+ox		
	16			+	+	+ x					o	o		
				+	+	x					o	o		
	17				+ x						ox	o		
					+ x						o	o		
	18										o	o		
						+					o	o		
	19										+ox	+ox		
											+ox	+o		
	20										o	o		
											o	o		
	21			+	+						ox	+ox		
				+	+						ox	+ x		
	22										ox	o		
											o	o		
	23										+o	+o	+	
											+o	+o		
	24										+ x	+ox		
										+	+ x	+o		
	25			x							+ x	+		
				x							+ x			
	26			o					+	+	+ x			
				o					+	+	+ x	+		
	27			x							+ x	+		
										+ x	+ x			
	28			x	+ x					+ x	+ x	+		
				x	+ x					+ x	+ x	+	+	
	29			+ x	+ x	+			+	+ x	+ x			
				+ x	+ x	+			+	+ x	+ x			+
	30				+ x				+	+	+ x	+ x		
					+ x					+	+ x	+ x		
	31		+	+ox	+					+	+ x	x		
										+	+ x	x		

TABLE 1: Sightings effort from aircraft (+) and purse-seine vessels (x) by half-day by area in the 1980 purse-seine skipjack fishery in New Zealand; poor weather is indicated (o) – *continued*

	Day		Area							
			A	B	C	D	E	I	J	K
Feb	1	a.m.		+ x	+ x	+ x	+ x			
		p.m.	+ x	x	+ x	+ x	+ x			+ x
	2		+ x	+	+ x	+ x				+ x
			+ x		+ x	+ x				
	3		+ x	+	+ x	+ x				+ x
			+ x	+	+ x	+ x				+ x
	4		+ x	x	+ x				+	+ x
			+ x	x	+ x				+	+ x
	5		+ x		+ x	+	+ x			x
			+ x		+ x		+ x			+ x
	6		+ x	+	+ x		+			+ x
			+ x	+	+ x		+			+ x
	7		+ x	+	+ x		+			+ x
			+ x		+ x		+ x			+ x
	8		+		+ x	+	+ x		+	+ x
			+	+	+ x		+ x		+ x	+ x
	9			+	+ x		+		+ x	+ x
			+	+	+ x		+		+ x	+ x
	10		+	+	+ x		+ x		+ x	+ x
			+	+	+ x		+ x		+ x	+ x
	11		+ x	+ x	+	+	+ x		+ x	+ x
			+ x	+ x	+ x		+ x			+ x
	12		o	o	+ox	o	+o			ox
			o	ox	+ox	o	+o			ox
	13		o	ox	o	o	o		o	o
			o	ox	o	o	o		o	o
	14		o	o	o	o	o		o	o
			o	o	o	o	o		o	o
	15		o	o	o	o	o		o	o
			o	o	o	o	o		o	o
	16		o	o	o	o	o		o	o
			o	o	o	o	o		o	o
	17		o	o	o	o	o		o	o
			o	o	o	o	o		o	o
	18		o	o	o	o	o		o	o
			o	o	o	o	o		o	o
	19					+ x	+		+ x	
						+ x		+ x	+ x	
	20				+ x	+ x	+ x	+ x	+ x	
					+ x	+ x	+ x	+ x	+ x	
	21		+	+	+ox	+ x	+ x		o	+
				+	+ox	+ x	+ x		o	+
	22		o	o	+o	+ x	+ x		o	+o
			o	o	+o	+ x	+ x		o	o
	23		o	o	o	o	+ x		o	o
			o	o	o	o	+ x		o	o
	24		o	o	+ox	o	+ x		+ox	
			+o	+o	+ox	o	+ x		+ox	+
	25		+o	+ x	+	+ox	+ox	ox	+ox	+
				+ x	+	o	+o	ox	ox	
	26		+ox	o	+ox	+o	o		+ox	+ox
			+ox	+ox	+ox	+o	+o		+ox	+ox
	27		ox	ox	o	o	o		o	o
			ox	ox	o	o	o		o	o
	28			+ox	+ x	+ x	o			
				+ox	+ x	+ x	o			
	29				+ x	+ x	+o			
					+ x	+ x	o			

TABLE 1: Sightings effort from aircraft (+) and purse-seine vessels (x) by half-day by area in the 1980 purse-seine skipjack fishery in New Zealand; poor weather is indicated (o) – *continued*

	Day		A	B	C	D	E	F	H	I	J	K
			Area									
Mar	1	a.m.	o	o	o	o	o				o	o
		p.m.	o	o	o	o	o				o	o
	2		o	o	o	o	o				o	o
			o	o	o	o	o				o	o
	3		o	o	o	o	o				o	o
			+o	+o	+o	+o	o				+o	+o
	4		+	+	+ox	+ x					+	+
					+ox	+ x					+	
	5				+ x	+ox	o			+	+	
			+ x	+ x	+ x	+o	o				+	
	6		+ x			+ox	o				+ x	+ x
						o	o				+ x	+ x
	7				+ x	o	o				+ x	
				+ x		+o	o				+ x	
	8					o	o			+	+ox	+ox
						o	o			+	+ x	o
	9					+ x	+o		+	+	+ x	
					+	+ x	+o		+	+	+ x	
	10		+	+	+	+ x	+				+ x	
			+		+	+ x	+				+ x	+
	11				+	+ x	+				+ x	
					+ x	+ x	+		+	+	+ x	+
	12			x	+ x	+ x					+ x	
			+ x	+ x	+ x	+o	+	+		+	+ x	+
	13		ox		+ x	+ x				o	+ox	+o
			o	+ x		+ x				o	+ox	+ox
	14		o			o				o	+ox	o
			o			+o				o	+ox	+o
	15		o			o				o	o	o
			o			o				o	o	o
	16		o			o				o	o	o
			o			o				+o	+o	o
	17		o			o	+o			o	o	o
			o			o				o	o	o
	18		o			+ x			o	o	o	o
			o			x			+o	o	o	o
	19					+ x			+			
				+	+	+ x			+	+ x	x	
	20		x	+ x	+ x						+ x	
				+ x	+ x					x	+ x	+
	21		+ox	+ x	+ x	+						+ox
			+ox	+ox	+ x	+					+	
	22			+ x	+ x	+ x						
					+ x	+ x	+					
	23		+o	+	+ x	+ x	x					
					+ x	+ x	x					
	24				+ x	+ x						
					+ x	+ x					+	
	25				x	+ x						
						+ x						
	26					+ x					+	
						+ x					+	+
	27					+ x						
						+ x						
	28					+ x						
						+o						
	29					o						
						o	+	+				
	30					o						
						o						
	31											

TABLE 1: Sightings effort from aircraft (+) and purse-seine vessels (x) by half-day by area in the 1980 purse-seine skipjack fishery in New Zealand; poor weather is indicated (o) – *continued*

	Day		Area D	Area E	Area J		Area D		Area D
Apr	1	a.m.		+		May	+ x	Jun	+ x
		p.m.		+			+ x		+ x
	2						+ x		+ x
							+ x		+ x
	3						+ x		+ x
							+ x		+ x
	4						+ x		+
							+ x		+
	5						+ x		+
							+ x		+
	6						+ x		+
							+ x		+
	7								+ x
									+ x
	8								+ x
									+ x
	9						+ x		+ x
							+ x		+ x
	10		+						+ x
			+						+ x
	11						+ x		+ x
							+ x		+ x
	12						+ x		
							+ x		
	13		+		+				
			+		+				
	14						+		
							+		
	15								+
									+
	16								+
									+
	17						+ x		+ x
			+				+ x		+ x
	18						+		x
							+		x
	19						+		
							+		
	20						+		
							+		
	21								
	22		+ x						
			+ x						
	23						+		
							+		
	24								
			+						
	25						+		
							+		
	26		+						
			+						
	27								
			+	+					
	28								
	29								
	30		+				+ x		
			+				+ x		
	31						+ x		
							+ x		

Results and discussion

Distribution and apparent abundance of skipjack

Surface schools of skipjack were seen in New Zealand waters from 13 November 1979 to 17 June 1980. Half-day estimates of quantities seen were derived for each area investigated throughout the season and these were totalled to yield overall half-day estimates for all areas (Fig. 2).

Early season sightings, 24 November to 6 December, east Northland

The first schools of skipjack were sighted in this area on 24 November 1979 north of Cavalli Islands. Sightings effort during the previous 2 days failed to find any skipjack (Table 1). From the 24th, fish were seen consistently through to 6 December (Fig. 3). The largest half-day sighting during this period was 310 t (six schools). The schools were often swimming at such depth that their disturbance of the sea surface was minimal. This made them difficult to see and led the spotters to comment that there were probably more fish in the area than they reported.

Early season sightings, east and north of Great Barrier Island

The first skipjack were seen in this area on 13 November 1979 (one 5-t school). Through to mid December, sightings effort was intermittent and unrewarding apart from a small sighting on 11 December (three schools, 36 t). The first substantial sighting (15 schools, 342 t) was made on the 16th, north-east of Mokohinau Islands (Fig. 4). Further intermittent effort failed to relocate these or any other schools until the 25th, when three schools were sighted near "the Cross", the position east of Great Barrier Island where latitude 36° S crosses longitude 176° E (see Figs. 1 and 4). Quantities seen increased rapidly to 1000 t on the 27th. Skipjack were probably present in this area for most of December, but the lack of consistent and effective sightings effort during the month failed to test this likelihood.

On 1 January the quantity of skipjack sighted near the Cross had increased to 1125 t. Over the next 4 days this body of fish circled an area within 30 km of the Cross and progressively decreased in size; the quantity of skipjack it contained fell to 330 t by the afternoon of the 5th. This decrease was not caused by fishing pressure, as only 184 t was caught from this body in early January (Fig. 2). Nor was it caused by a downturn in sightings effort, which was consistently high during this period (Table 1). There are three possible explanations:

1. The fish were disappearing from the surface near the Cross and reappearing shortly afterwards near The Aldermen Islands, some 50 km to the south.
2. The fish were disappearing from the surface near the Cross and reappearing north of Mokohinau Islands, some 70 km to the north-west.
3. The fish were disappearing from the surface near the Cross and leaving New Zealand waters.

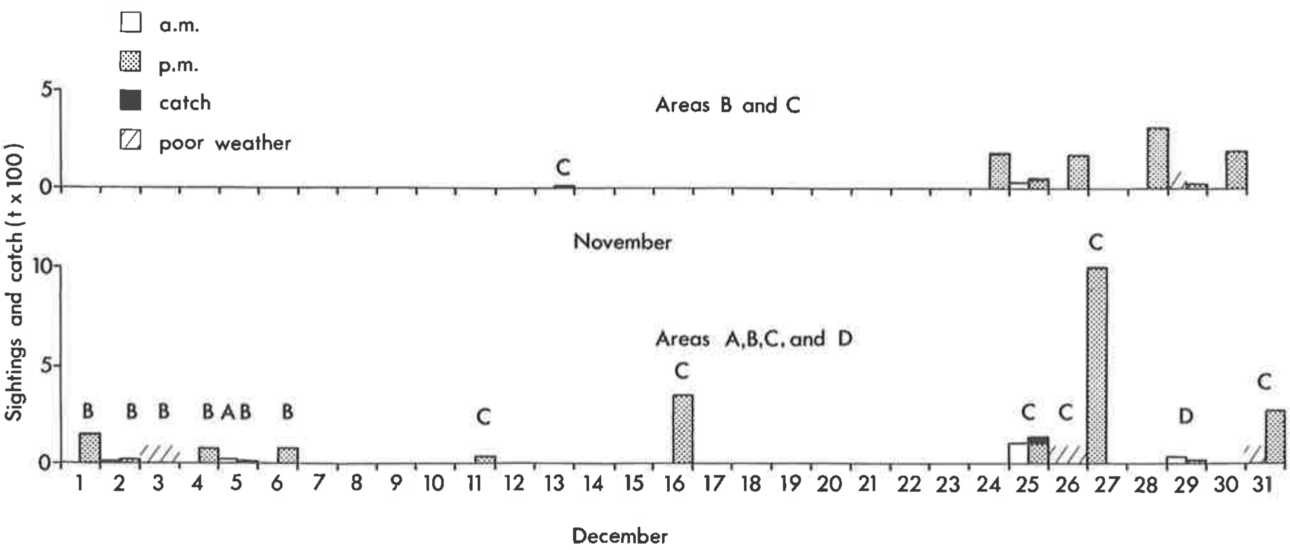


Fig. 2 (above and following pages): Half-day sightings by area and for all areas combined during the 1980 skipjack season in New Zealand.

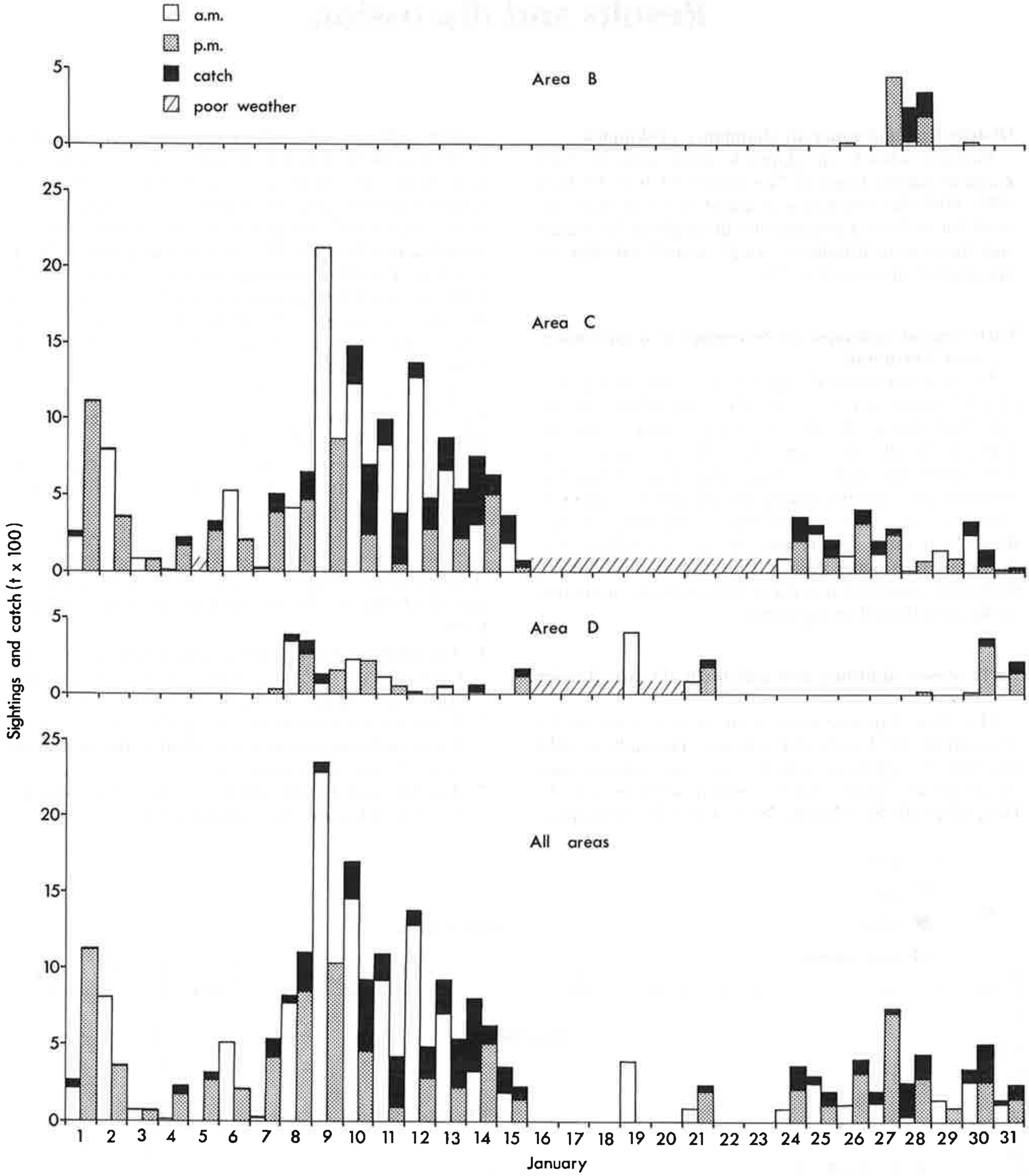


Fig. 2 – *continued.*

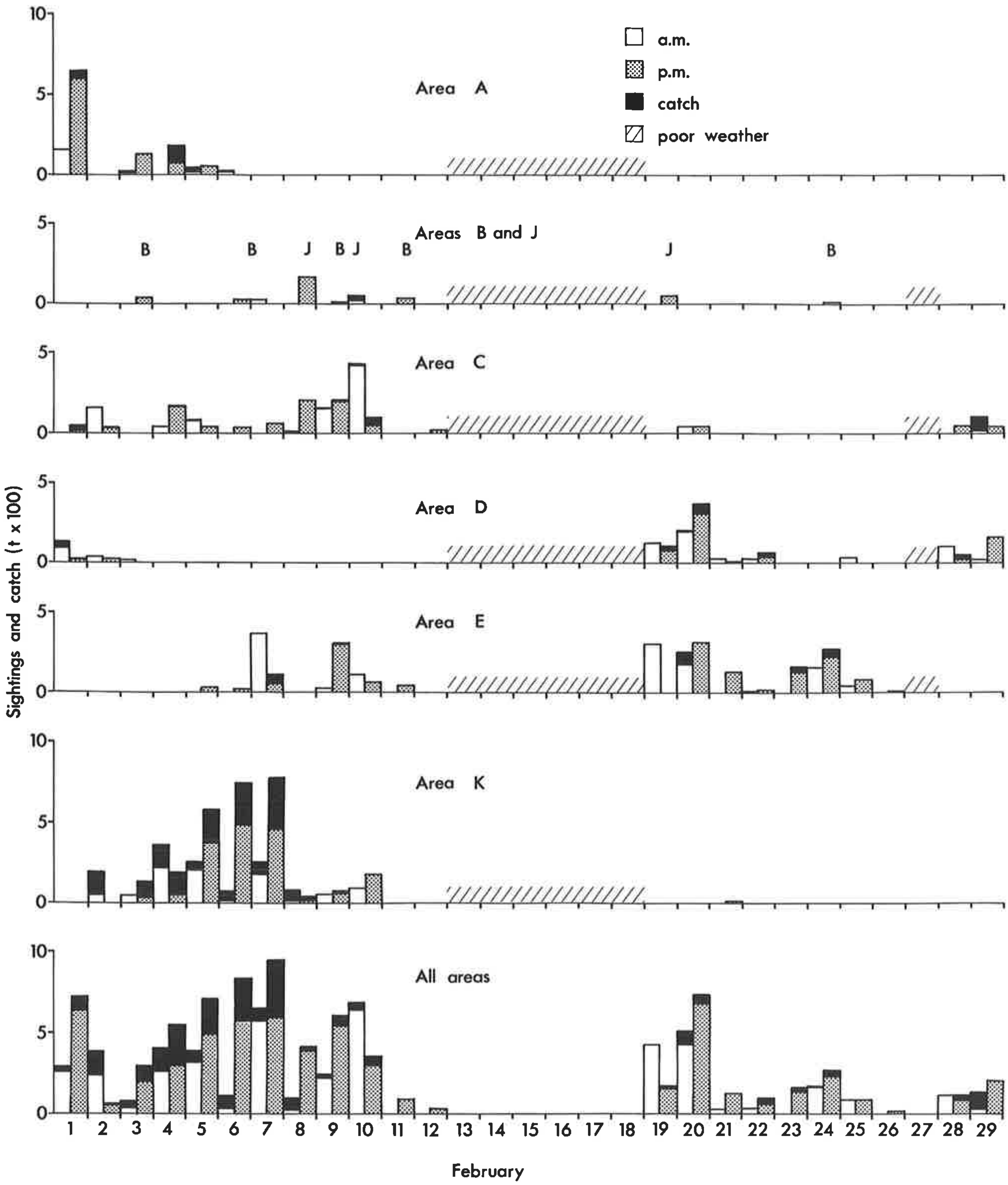
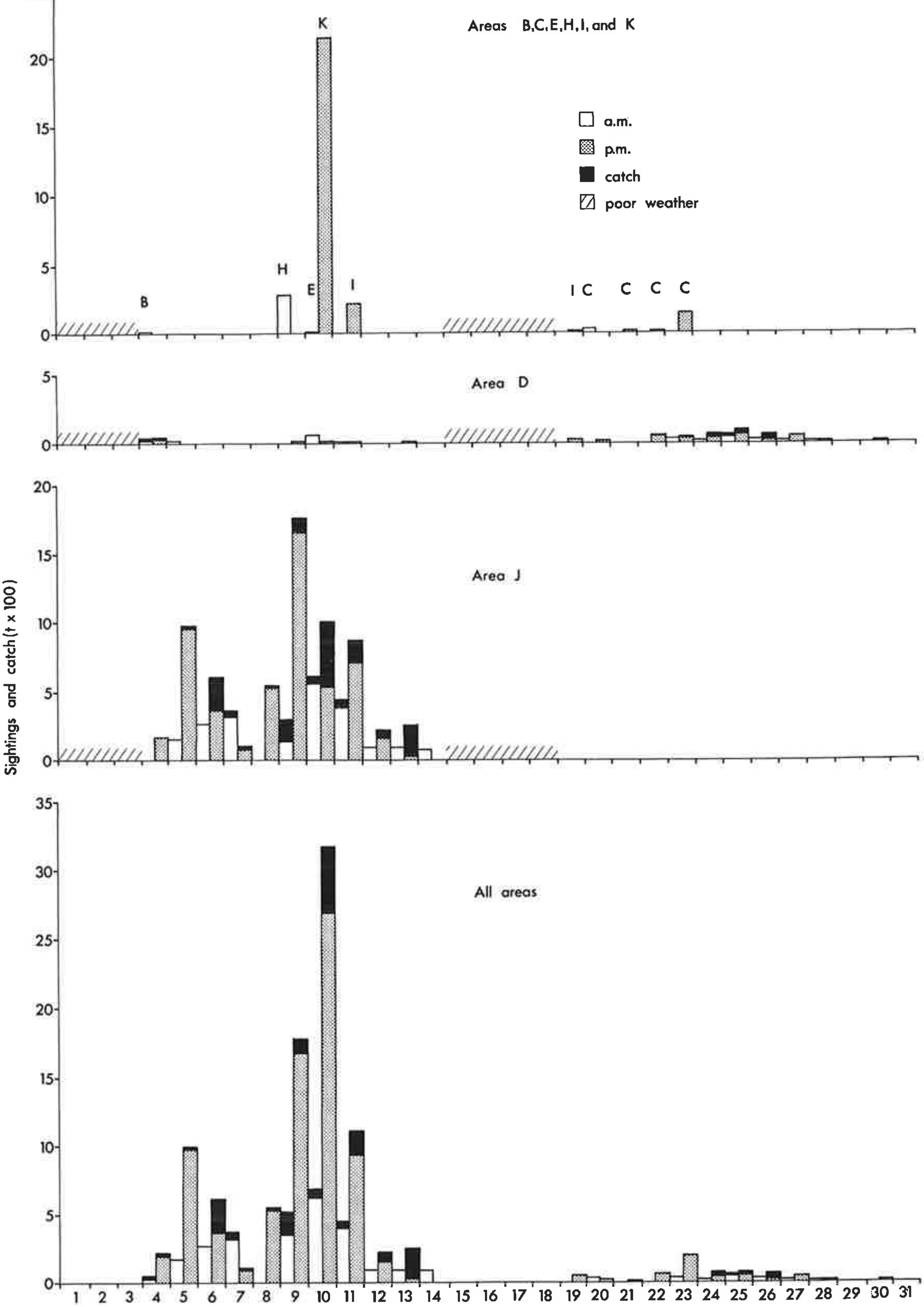


Fig. 2 – *continued.*



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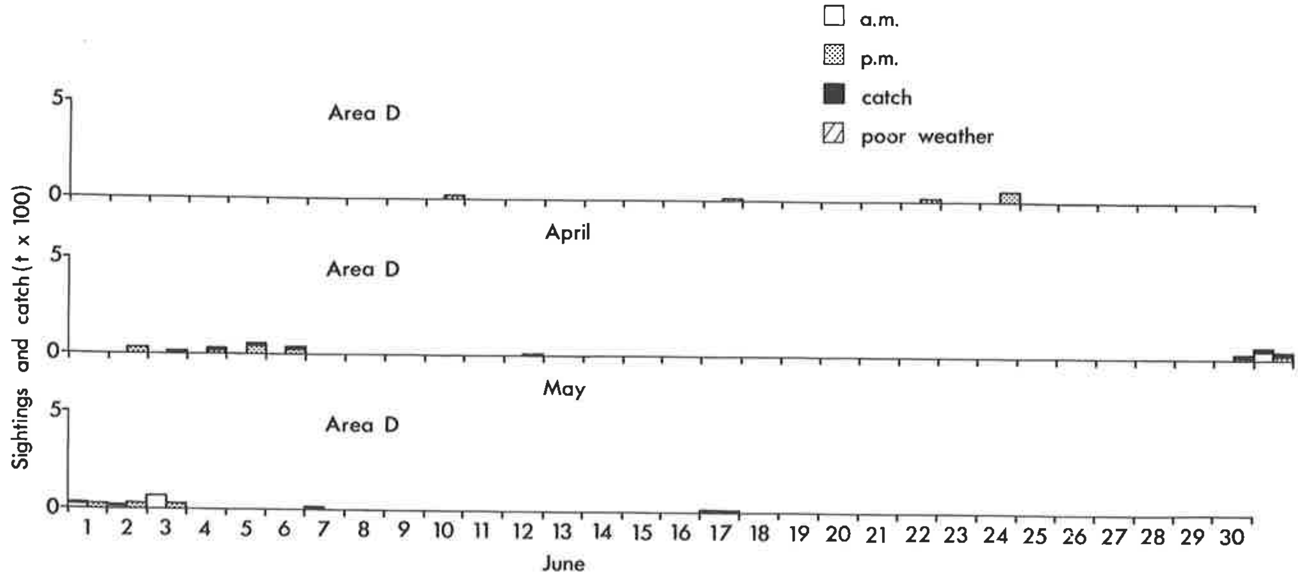


Fig. 2 — *continued.*

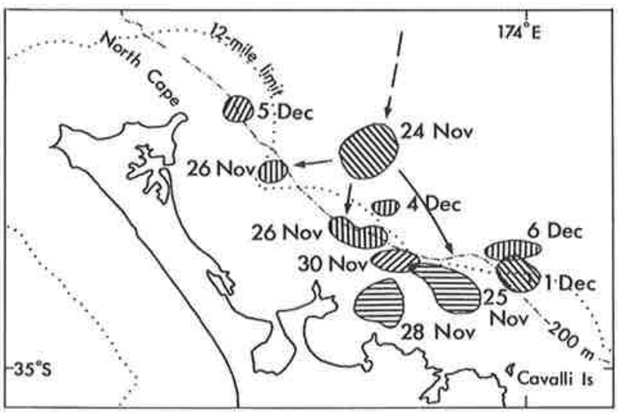


Fig. 3: Daily location of the main concentration(s) of skipjack in Northland waters, 24 November to 6 December 1979.

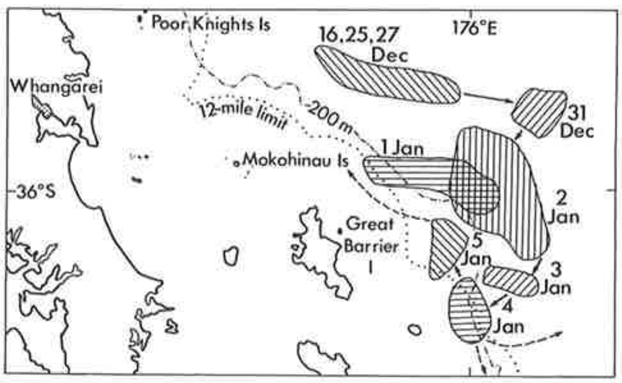


Fig. 4: Daily location of the main concentration of skipjack east and north of Great Barrier Island, 16 December 1979 to 5 January 1980.

We believe all explanations are possible, either singly or in some combination of the three. The bodies of skipjack which subsequently surfaced to the south and to the north-west (discussed in following sections) contained fish which were indistinguishable in length from those near the Cross in early January.

Sightings, 6 to 15 January, east and north of Great Barrier Island

A body of fish became distinguishable just north of Mokohinau Islands on 6 January (Fig. 5). These fish may have been derived from the body present earlier near the Cross, or they may have been new arrivals. Over the following 9 days the body moved first towards Poor Knights Islands and then south-east along the shelf edge to the Cross. The quantity of fish sighted in the body rose from 521 t on the 6th to 2120 t on the 9th and fell to 1365 t on the 12th, 861 t on the 13th, 635 t on the 14th, and 72 t on the 15th (Fig. 2, area C). Sightings were discontinued over the next 8 days because of poor weather.

Sightings, 24 January to end of season, east and north of Great Barrier Island, and east Northland

Only small sightings were made in these areas during this period (Fig. 2, areas B and C). For 4 days in late January and 4 in early February, fish were located in a small area north of Mokohinau Islands. On the intervening days, fish were also sighted near the Cross and north-east of Cavalli Islands (Fig. 6). Fish may have moved from Mokohinau Islands to the Cross and back again between 29 January and 1 February. Between 7 and 10 February, the fish moved north towards Poor

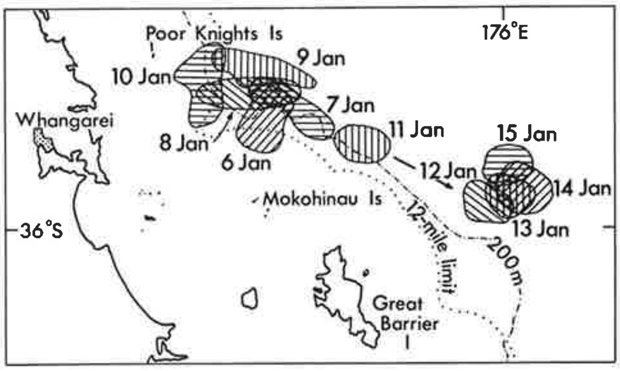


Fig. 5: Daily location of the main concentration of skipjack east and north of Great Barrier Island, 6 to 15 January 1980.

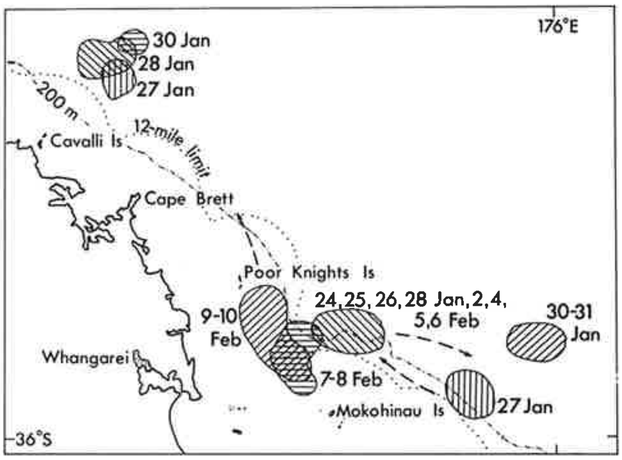


Fig. 6: Daily location of the main concentration(s) of skipjack east and north of Great Barrier Island and in Northland waters, 24 January to 10 February 1980.

Knights Islands and were then lost during the subsequent period of poor weather. We believe those found between Poor Knights Islands and the Cross comprised one body, and those off Cavalli Islands another.

Sightings in these areas through to the end of the season were small and infrequent.

Early season sightings, Bay of Plenty

Although there was early season sightings effort in this area (Table 1), fish were not found until 29 December in three schools near Motiti Island. The first body to move into the Bay of Plenty surfaced near The Aldermen Islands between 5 and 7 January (Fig. 7)*. As already indicated, this body was possibly derived from the body which was near the Cross in early January (see Fig. 4). Alternatively, it may have arrived from the north-east as a new body of fish. Whatever its origin, the body moved south-east to near Mayor Island by 8 to 9 January. From there, it may have continued south-east towards White Island, where skipjack were found in mid January, or it may have moved back to contribute to the sightings which were made near The Aldermen Islands in mid January (see Fig. 8). If this occurred, the fish near White Island in mid January may well have been derived from another immigration from the north-east (Fig. 7).

Whether there was one body of skipjack or more in these movements, quantities seen were generally small, with the maximum sighting of 390 t north-east of Mayor Island on 8 January (Fig. 2, area D).

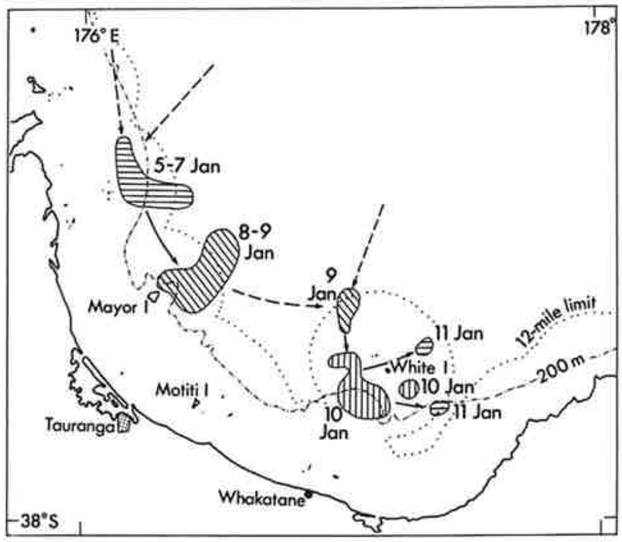


Fig. 7: Daily location of the main concentration(s) of skipjack in the Bay of Plenty, 5 to 11 January 1980.

Sightings, 11 January to 3 February, Bay of Plenty

On 11 January, skipjack were found at the surface off Mercury Bay. Over the next 3 weeks, this body moved around the area between Mayor Island and The Aldermen Islands. Eventually it travelled south-east to White Island (Fig. 8). Quantities sighted were small and sightings effort was frequently interrupted by poor weather (Fig. 2, area D).

Sightings, 19 February to end of season, Bay of Plenty

From 2 February, when the previous body of fish in this area disappeared, to 19 February, there were 5 unproductive days of sightings effort (Table 1). This period was severely affected by poor weather. On the 19th, 122 t (nine schools) were sighted near Plate Island. This body moved into the eastern Bay of Plenty over the next 9 days (Fig. 9) and the maximum half-day sighting was 377 t (Fig. 2, area D).

* Note that the 5 to 7 January sightings referred to in Fig. 7 are shown in Fig. 2 under area C and not area D, where the rest of the Fig. 7 sightings are shown. These sightings are discussed here rather than with the rest of the area C sightings, as the fish moved from The Aldermen Islands into the Bay of Plenty.

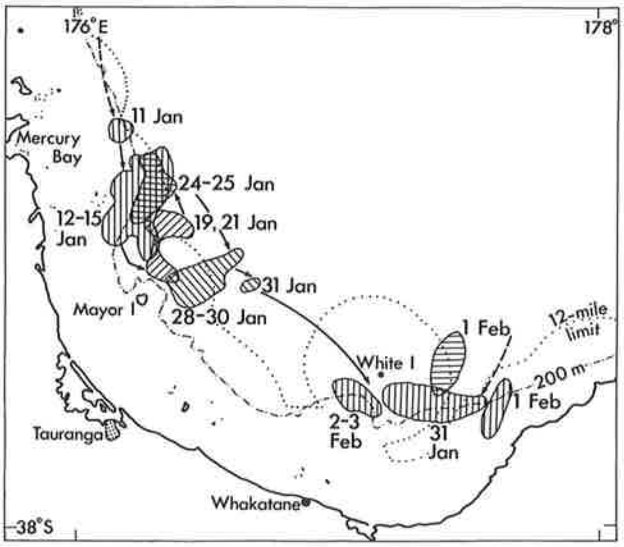


Fig. 8: Daily location of the main concentration(s) of skipjack in the Bay of Plenty, 11 January to 3 February 1980.

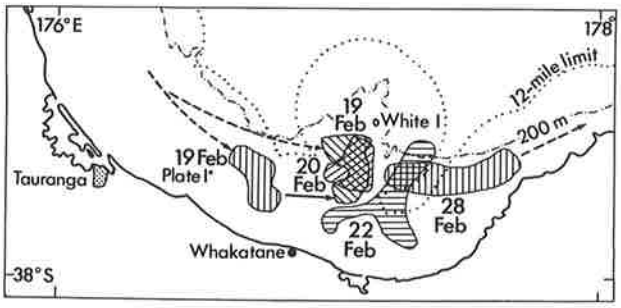


Fig. 9: Daily location of the main concentration(s) of skipjack in the Bay of Plenty, 19 to 28 February 1980.

As in past seasons, occasional small and scattered sightings were made on most days that there was sightings effort during March, April, and May. However, for the first time sightings were also made in June. The sea surface temperatures in the Bay of Plenty in June were close to the minimum tolerated by skipjack of the size that visit New Zealand each summer (see page 29).

Season's sightings, west coasts of North and South Islands

Skipjack schools were first sighted in the west near Reef Point on 5 December. One day of sightings effort before that, a further 5 days in December, and 3 days in January (Table 1) were unproductive. The next sightings in this area were in early February (Fig. 2, areas A and K; Fig. 10). A body of fish which surfaced off Reef Point generally moved south-east along the shelf edge over a 10-day period. The maximum half-day sighting for this body was 771 t. The fish were lost in mid February during poor weather.

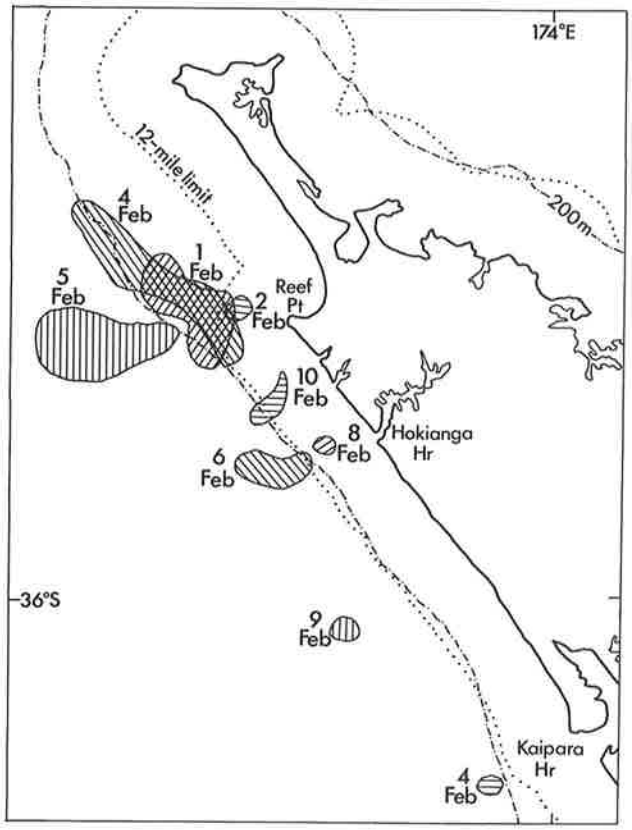


Fig. 10: Daily location of the main concentration(s) of skipjack between Reef Point and Kaipara Harbour, 1 to 10 February 1980.

Despite consistent sightings effort in the west during the rest of February (Table 1), the next substantial body of skipjack was not found until 4 March (Fig. 11). During the next 7 days this body moved south-west along the shelf edge and the maximum half-day sighting was 1750 t (Fig. 2, area J). In shore and south of this body, smaller quantities were found on 4 and 5 March.

Other skipjack bodies were also sighted in the west in March. One was in Karamea Bight (9 March, 10 schools, 280 t, centre of distribution 41° 00′ S, 171° 25′ E), another off Kaipara Harbour (10 March, 69 schools, 1600 t), and another off Hokianga Harbour (10 March, 16 schools, 558 t) (see Fig. 2, March, areas H and K).

After 13 March, few skipjack were sighted off the west coast.

Season's sightings, East Cape to Hawke Bay

Skipjack schools were found in this area between 5 and 26 February (Fig. 2, area E; Fig. 12). Skipjack may have been present at other times, but sightings effort in this area was sporadic outside this period (Table 1). Quantities seen were mainly small, the largest half-day sighting being 375 t.

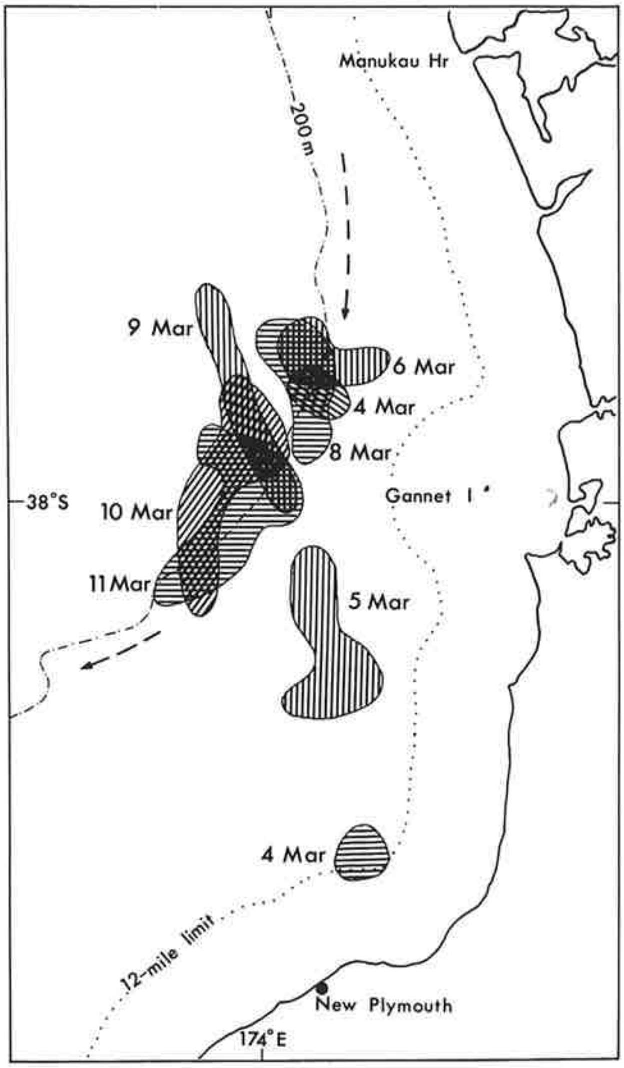


Fig. 11: Daily location of the main concentration(s) of skipjack between Manukau Harbour and New Plymouth, 4 to 11 March 1980.

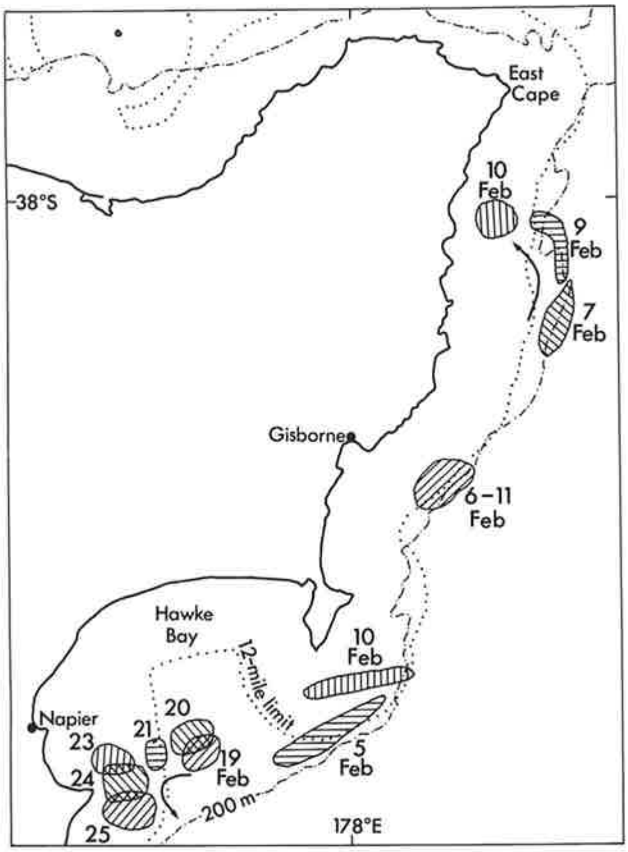


Fig. 12: Daily location of the main concentration(s) of skipjack between East Cape and Hawke Bay, 5 to 26 February 1980.

Sightings by time of day

The greatest numbers of fish were seen in the afternoon (Fig. 2, Table 2), partly because of more daylight hours in the afternoon period during which a maximum sighting could be made.

We reiterate that these sightings were measures of **apparent abundance** which probably included some multiple quantification of skipjack schools from morning to afternoon, day to day, and even month to month. Therefore the totals in Fig. 2 do not necessarily

TABLE 2: Quantities of fish seen and caught by half-day in the 1980 purse-seine skipjack fishery in New Zealand

Month	Morning Quantity sighted (t)	Morning Quantity caught (t)	Morning % caught of quantity sighted	Afternoon-evening Quantity sighted (t)	Afternoon-evening Quantity caught (t)	Afternoon-evening % caught of quantity sighted
Nov	33	0	0	937	24	2.6
Dec	1 150	7	0.6	1 105	43	3.9
Jan	13 219	1 883	14.2	11 553	2 722	23.6
Feb	4 785	817	17.1	7 525	1 525	20.3
Mar	2 510	338	13.5	9 460	1 459	15.4
Apr	0	0	0	62	0	0
May	60	15	25.0	215	52	24.2
Jun	142	40	28.2	110	6	5.4
Nov-Jun	21 899	3 100	14.1	30 967	5 831	18.8

TABLE 3: Monthly skipjack sightings in New Zealand, 1976 to 1980, computed by totalling maximum half-day sightings.* (Data for 1976 and 1977 from Clement (1978), for 1978 from Habib, Clement, and Fisher (in press), and for 1979 from Habib, Clement, and Fisher (1980))

	Sightings effort			Quantity sighted (t)									
Season	Period	No. of days	Mean per day	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Total
1976	7 Oct-27 Mar	102	545	3 337 (6%)†	1 112 (2%)	9 455 (17%)	13 905 (25%)	17 798 (32%)	10 012 (18%)	–‡	–	–	55 619
1977	21 Nov-14 Apr	139	285	–	0	1 190 (3%)	12 697 (32%)	9 126 (23%)	15 871 (40%)	793 (2%)	–	–	39 677
1978	25 Dec-31 May	131	523	–	–	1 225 (1.7%)	25 286 (37%)	11 779 (17.2%)	29 674 (43.3%)	342 (0.5%)	258 (0.3%)	–	68 564
1979	20 Nov-27 May	91	362	–	819 (2.4%)	240 (0.7%)	9 409 (28.6%)	11 967 (36.3%)	10 339 (31.4%)	119 (0.4%)	65 (0.2%)	–	32 958
1980	13 Nov-17 Jun	139	235	–	937 (2.9%)	1 150 (3.5%)	13 219 (40.4%)	7 525 (23%)	9 460 (29%)	62 (0.2%)	215 (0.6%)	142 (0.4%)	32 710

* For example, in November of the 1980 season, maximum half-day sightings were made in the afternoon of the 13th, 24th, 25th, 26th, 28th, 29th, and 30th (see Fig. 2); these sightings totalled 937 t for that month.

† Percentage of season's total.

‡ No sightings effort.

represent quantities of fish which could have been taken in the purse-seine fishery, but simply indicate the quantities which were seen at the surface during each half-day.

Fluctuations in apparent abundance

These were considerable and coincided largely with the appearance and disappearance of various bodies of skipjack which moved through the New Zealand area during the season (Figs. 2 to 12). The frequent and often long periods of poor weather also contributed to the fluctuations by precluding sightings effort and the keeping of sightings records. Whether the fish were induced by poor weather to leave the coast is not known, but quantities sighted after poor weather were often considerably smaller than those sighted before.

Apparent abundance and catch

A summary of the data in Fig. 2 (see Table 2) shows that of skipjack sighted, only a small proportion was caught; this ranged from no catches in the morning in November, and in the morning and afternoon in April, to 28.2% in the morning in June. On average, about 14% of the fish seen during the mornings was caught and 11% during the afternoons. By this measure the resource seemed to be under little pressure from fishing.

Skipjack schools

There were 2172 schools seen during the 1980 season. On average, 16 schools were seen per day of sightings effort, and the mean size of school was about 24 t. As discussed above, it is likely that there was some multiple quantification of these schools.

Sightings, 1976, 1977, 1978, 1979, and 1980 seasons

Fewer skipjack were seen at the surface during 1980 than in the previous four seasons (Table 3). As in 1979 there were long spells of poor weather which curtailed sightings effort (see Table 1 and Fig. 2). The smaller quantities of fish seen per day of sightings effort in 1980 may also indicate that fewer skipjack passed through New Zealand waters than in previous seasons. As in the past, most fish were seen from January to March.

Real abundance

If the concept of bodies of skipjack is accepted (see page 7), a measure of real abundance can be gained for each body by addition of the largest half-day sighting of each body to the quantity of fish caught from it before the largest sighting (Table 4). For example, the body which moved south-east through areas A and K between 1 and 10 February (see Figs. 2 and 10) produced a maximum sighting of 771 t on the afternoon of the 7th. Before that, the purse-seine vessels had caught 1281 t from the body. The estimated amount of fish in the body was the sum of the maximum sighting and the catch made before the sighting, that is, 2052 t.

TABLE 4: Estimated minimum real abundance of skipjack in the New Zealand region during the 1980 season

Period that bodies or distinguishable quantities present	Area	Max. sighting* (t)	Catch from body before max. sighting (t)	Estimated min. real abundance (t)
5 Nov	A	15	0	15
1–10 Feb	A & K	771	1 281	2 052
24 Nov–6 Dec	B	310	24	334
27–30 Jan	B	348	216	564
Feb	B	40	0	40
Mar	B	5	0	5
13 Nov	C	5	0	5
16 Dec–5 Jan	C	1 125	70	1 195
6–15 Jan	C	1 365	1 493	2 858
24 Jan–10 Feb	C	435	827	1 262
Mar	C	150	0	150
5–11 Jan	C & D	521	47	568
11 Jan–3 Feb	C & D	368	139	507
Dec	D	35	0	35
19–28 Feb	D	377	14	391
Mar	D	60	68	128
Apr	D	50	0	50
May	D	40	88	128
Jun	D	63	27	90
5–25 Feb	E	310	120	430
9 Mar	H	220	0	220
11 Mar	I	220	0	220
Feb	J	170	0	170
4–10 Mar	J	1 750	521	2 271
10 Mar	K	2 158	0	2 158
				15 846

* Or a smaller sighting, as explained in text.

Occasionally a smaller half-day sighting was used as a starting point, when such a sighting, added to the previous catch from a body, resulted in a larger estimate of real abundance than the sum of the largest sighting and previous catch. For example, the maximum half-day sighting for the body in area B from 27 to 30 January was 450 t (see Fig. 2), but there was no catch from the body before this sighting and therefore the estimated quantity of fish would have been 450 t. The half-day sighting used was the 348 t of the afternoon of the 28th. This, added to the 216 t caught on the morning of the 28th, gave an estimate of minimum real abundance for the body of 564 t (Table 4).

By summing estimates for all bodies and adding the isolated fish which probably did not contribute to any of the bodies, a measure of real abundance for the season — 15 846 t — was derived. This measure, as already explained, should be regarded as a minimum.

Catch, effort, and catch per unit of effort

The season began in November and finished in June. During this time the fleet worked 1192 season-days, divided among various activities (Fig. 13). This was the greatest number of season-days worked so far in this fishery.

Another notable feature of the 1980 season was that the proportion of season-days spent searching and fishing (35%) was the lowest for any season (range for

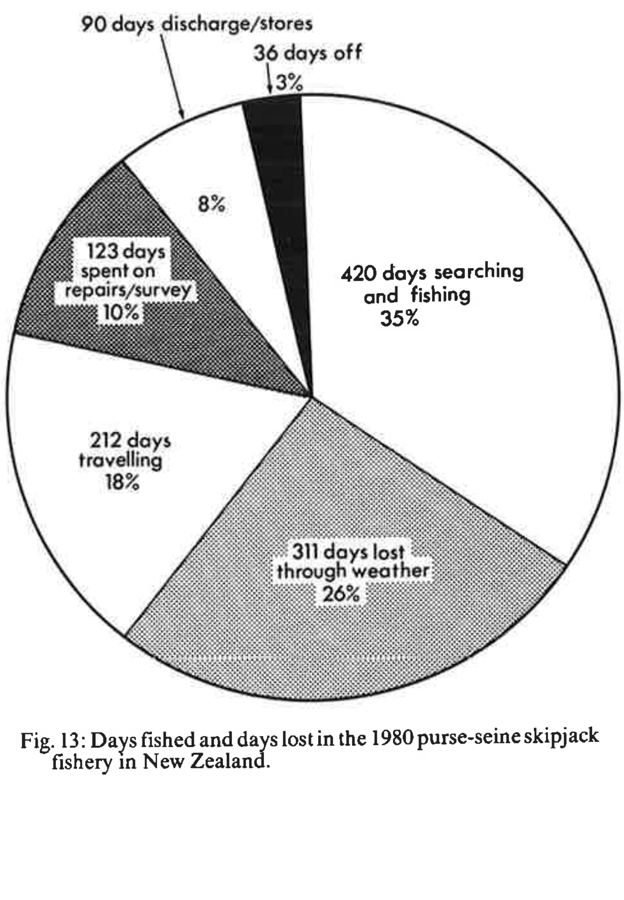


Fig. 13: Days fished and days lost in the 1980 purse-seine skipjack fishery in New Zealand.

the last four seasons 40% to 57%), a direct result of the large number of season-days lost through poor weather (26%, compared with 6% to 18% in previous seasons). Periods of poor weather were frequent and often long (for example, 16 to 23 January, 14 to 19 February).

During the 420 days fished, 8931 t of skipjack were caught: 24 t in November, 50 t in December, 4605 t in January, 2342 t in February, 1797 t in March, 67 t in May, and 46 t in June (Fig. 14). No fish were caught in April. This is the first season that catches have been made in May and June; skipjack have been seen during these months in the past, but not in purse-seinable quantities.

Effort, measured as number of season-days, peaked in February; the other measures of effort – days fished, sets, and successful sets – peaked in January (Fig. 14, left-hand axis). All measures of catch rate peaked in January, when vessels averaged 15.2 t per season-day (season's mean 7.5 t), 27.8 t per day fished (season's mean 21.3 t), 17.2 t per set (season's mean 14.3 t), and 39 t per successful set (season's mean 30.3 t) (Fig. 14, right-hand axis).

The rise and fall of catch and effort resulted partly from fluctuations in the number of vessels in the fishery (3 in November, 4 in December, 12 in January, 15 in February, 14 in March, 7 in April, and 2 in May and June), and partly because of variation in the availability, size, and catchability of the skipjack resource. The largest quantities were seen between January and March, with only small sightings in the other months. Catchability varied with time and place. The fish which moved south-east along the edge of the continental shelf (200-m depth contour) between Mokohinau and Great Barrier Islands in January were particularly catchable, as is borne out by the high January catch rates in this area. We believe that the extended period of fine weather at that time contributed considerably to the catchability. Skipjack were less catchable in February and March (lower catch rates), when weather and sea conditions were often only marginal for purse seining.

Catch and effort by area

There was seining in seven areas on the New Zealand coast (see Fig. 1). Almost half of the season's catch (4168 t) was taken in area C (east and north of Great Barrier Island) with about two-fifths of the fishing effort. Most of the fishing in this area was done in January (192 season-days, 123 days fished, 213 sets, 91 successful sets, 3858 t caught), and catch rates for the area were higher than the season's means (Table 5).

The west coast areas J (north-west of New Plymouth) and K (south-west of Reef Point) were next in importance; the combined catch from these areas was about one-third of the season's total, taken with about one-quarter of the effort. The fishing in these areas was in February and March, and catch rates were considerably higher than the season's means.

Small quantities of skipjack were also caught in areas A (west of Reef Point) in February, B (east Northland) in November to January, D (Bay of Plenty) throughout the season, and E (East Cape to Hawke Bay) in February. Although there was also fishing effort in area I (Kahurangi Point to New Plymouth), no catches were made there.

TABLE 5: Catch, effort, and catch per unit of effort by area in the 1980 purse-seine skipjack fishery in New Zealand

Area	Catch Quantity (t)	Catch % of total	Effort: Season-days No.	Season-days % of total	Days searching and fishing No.	Days searching and fishing % of total	Sets No.	Sets % of total	Successful sets No.	Successful sets % of total	Catch/effort: Catch per season-day (t)	Catch per day searching and fishing (t)	Catch per set (t)	Catch per successful set (t)
A	207	2.3	30.5	2.6	5.0	1.2	10	1.6	7	2.4	6.8	41.4	20.7	29.6
B	398	4.5	56.5	4.7	29.5	7.0	26	4.2	16	5.4	7.0	13.5	15.3	24.9
C	4 168	46.7	447.0	37.5	190.5	45.4	270	43.2	109	36.9	9.3	21.9	15.4	38.2
D	831	9.3	252.0	21.1	85.0	20.3	122	19.5	64	21.7	3.3	9.8	6.8	13.0
E	189	2.1	79.0	6.6	14.0	3.3	20	3.2	9	3.1	2.4	13.5	9.5	21.0
F	–*	–	2.5	0.2										
G	–	–												
H	–	–												
I	0	0	38.0	3.2	2.0	0.5								
J	1 670	18.7	146.5	12.3	58.5	13.9	108	17.3	50	16.9	11.4	28.5	15.5	33.4
K	1 468	16.4	46.5	3.9	35.0	8.3	69	11.0	40	13.6	21.6	41.9	21.3	36.7
			93.5†	7.8										
	8 931		1 192.0		419.5		625		295		7.5	21.3	14.3	30.3

* No fishing.

† Outside New Zealand – days spent travelling to and from, and discharging fish at, the cannery in American Samoa.

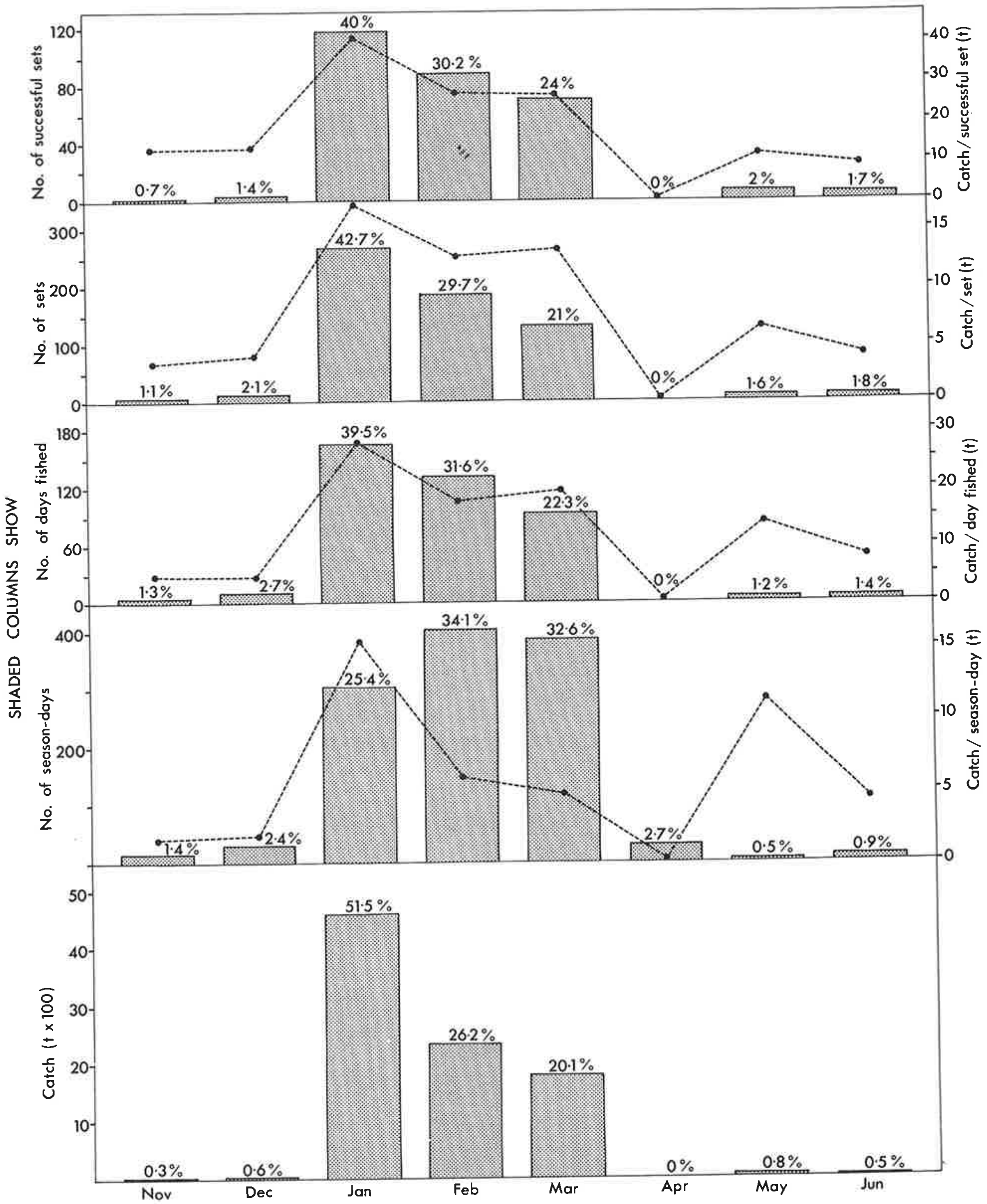


Fig. 14: Monthly catch, effort, and catch per unit of effort in the 1980 purse-seine skipjack fishery in New Zealand.

Catch and effort by depth

Skipjack were caught where bottom depths were between 30 and 1100 m (Table 6). However, fishing was concentrated along the edge of the continental shelf in depths of 100 to 399 m. There, three-quarters of the season's catch was taken with about the same proportion of the season's effort and at the highest catch rates (per set, per successful set).

Catch and effort by time of day

Sets were made between 0630 and 2130 hours. Over half the fish were taken in the afternoon with about the same proportion of the season's effort and at catch rates (per set, per successful set) close to the season's means. Fewer fish were caught in the morning, but at catch rates better than the season's means, and still fewer in the evening (Table 7).

Catch and effort by moon phase

Almost half of the season's catch was taken during full moon with about the same proportion of the season's effort and at catch rates (per set, per successful set) close to the season's means (Table 8). About one-third of the catch was taken in the last quarter at catch rates substantially higher than the season's means. Fewer fish were taken during the other phases and at lower catch rates.

Catch and effort by sea surface temperature

Skipjack were caught in areas where surface water temperatures ranged from 15.5° to 23.9°c (Table 9). However, most (7775 t) were caught in 19° to 21.9°c water (designated "skipjack water" by us). This water was present within the range of skipjack on the New Zealand coast for more time during the skipjack season

TABLE 6: Catch, sets, and set success by bottom depth in the 1980 purse-seine skipjack fishery in New Zealand

Depth (m)	Catch (t)	% of total	Sets	% of total	Catch per set (t)	Successful sets	% of total	Catch per successful set (t)
0–99	296	3.3	58	9.3	5.1	32	10.8	9.3
100–199	1 914	21.4	189	30.2	10.1	85	28.8	22.5
200–299	3 158	35.4	188	30.1	16.8	80	27.1	39.5
300–399	1 655	18.5	70	11.2	23.6	36	12.2	46.0
400–499	317	3.5	22	3.5	14.4	10	3.4	31.7
500–599	473	5.3	23	3.7	20.6	10	3.4	47.3
600–699	543	6.1	36	5.8	15.1	22	7.5	24.7
700–799	363	4.1	17	2.7	21.4	10	3.4	36.3
800–899	163	1.8	11	1.8	14.8	7	2.4	23.3
900–999	26	0.3	6	1.0	4.3	1	0.3	26.0
1 000–1 100	23	0.3	5	0.8	4.6	2	0.7	11.5
	8 931		625		14.3	295		30.3

TABLE 7: Catch, sets, and set success by time of day in the 1980 purse-seine skipjack fishery in New Zealand

Time of day	Catch (t)	% of total	Sets	% of total	Catch per set (t)	Successful sets	% of total	Catch per successful set (t)
0000–0559	0	0	0	0	0	0	0	0
0600–1159	3 095	34.7	192	30.7	16.1	90	30.5	34.4
1200–1759	4 869	54.5	352	56.3	13.8	173	58.6	28.1
1800–2359	967	10.8	81	13.0	11.9	32	10.8	30.2
	8 931		625		14.3	295		30.3

TABLE 8: Catch, sets, and set success by moon phase in the 1980 purse-seine skipjack fishery in New Zealand

Moon phase	Catch (t)	% of total	Sets	% of total	Catch per set (t)	Successful sets	% of total	Catch per successful set (t)
New moon	415	4.6	50	8.0	8.3	23	7.8	18.0
First quarter	1 362	15.3	130	20.8	10.5	74	25.1	18.4
Full moon	3 926	44.0	287	45.9	13.7	129	43.7	30.4
Last quarter	3 228	36.1	158	25.3	20.4	69	23.4	46.8
	8 931		625		14.3	295		30.3

TABLE 9: Catch, sets, set success, and fishing effort (searching and fishing) by sea surface temperature in the 1980 purse-seine skipjack fishery in New Zealand (temperatures from shipboard records)

Water temp. range (°C)	Catch (t)	% of total	Sets	% of total	Catch per set (t)	Successful sets	% of total	Catch per successful set (t)
15.0–15.9	12	0.1	2	0.3	6.0	2	0.7	6.0
16.0–16.9	83	1.0	14	2.3	5.9	6	2.1	13.8
17.0–17.9	18	0.2	5	0.8	3.6	3	1.0	6.0
18.0–18.9	44	0.5	18	3.0	2.4	4	1.4	11.0
19.0–19.9	2 349	26.9	144	23.8	16.3	82	28.6	28.6
20.0–20.9	2 825	32.4	215	35.6	13.1	93	32.4	30.4
21.0–21.9	2 601	29.8	125	20.7	20.8	58	20.2	44.8
22.0–22.9	689	7.9	76	12.6	9.1	35	12.2	19.7
23.0–23.9	105	1.2	5	0.8	21.0	4	1.4	26.3
	8 726*		604*		14.4	287*		30.4

Fishing effort expended during the fortnightly periods

Water temp. range (°C)	24/11-7/12	8/12-21/12	22/12-4/1	5/1-18/1	19/1-1/2	2/2-15/2	16/2-29/2	1/3-14/3	15/3-28/3	29/3-11/4	12/4-25/4	26/4-9/5	10/5-23/5	24/5-6/6	7/6-20/6
15.0–15.9															✓
16.0–16.9														✓	✓
17.0–17.9												✓			
18.0–18.0	✓				✓		✓								
19.0–19.9			✓	✓	✓	✓	✓	✓	✓						
20.0–20.9	✓		✓	✓	✓	✓	✓	✓	✓						
21.0–21.9				✓	✓	✓	✓	✓							
22.0–22.9				✓	✓	✓	✓	✓							
23.0–23.9					✓	✓									

* Temperatures were not recorded from 21 sets and therefore the totals of catch and sets are less than the season's totals.

than warmer and cooler water. As a result, a large proportion of the fishing effort (80% of monitored sets, 81% of monitored successful sets, searching and fishing during 20 of the fortnightly periods fished during the season) was expended in skipjack water. Catch rates, too, were highest in that water.

Sea surface temperature measurements from satellites in relation to the skipjack fishery

Weekly satellite sea surface temperature charts for the New Zealand region for 23 October 1979 to 24 June 1980 are presented (Fig. 15). The charts cover the 1980 skipjack season and some time before and after the season.

Skipjack water first appeared on the coast in late November. By late December it extended down the east coast to Hawke Bay and by early February to the Kaikoura Coast. In the west, warming began in late December and progressed southwards to Cook Strait by late January and to the north-west of the South Island by mid February. From this time there was a slow cooling in the east, with skipjack water extending only as far south as East Cape by late March. Cycles of warming and cooling followed, with skipjack water extending south to various localities between North Cape and East Cape at various times. In the west there was one cycle of cooling and warming between mid February and mid March, after which skipjack water rapidly disappeared from the west coast. By late June there was no skipjack water on the New Zealand coast.

Some of the sea surface temperature charts from satellites (Fig. 15, charts for the weeks ending 27 November, 21 January, 25 February, 21 April, 19 May, and 17 June) suggest that there was some mass "movement" of a tongue of warm water south to and north from New Zealand during the season. Eggleston and Paul (1978) described a similar feature in 1977 and suggested that such a movement may have been more apparent than real, resulting from a progressive southward warming (and by implication a northward cooling late in the season) rather than a movement of surface water. We suggest that there was progressive warming and cooling and also water movement.

Our suggestion of water movement is based on aerial and shipboard observations of skipjack water over the last five seasons. This water could often be clearly distinguished from the air as a tongue of deep blue water appearing to flow or "push" into the blue-green water on the New Zealand coast. These tongues seemed to be subtropical in origin, as they often carried a variety of subtropical species such as big-game fishes (for example, striped marlin *Tetrapturus audax*), sharks (for example, mako *Isurus oxyrinchus*), manta rays (*Mobula* sp.), and flying fish (*Cypsilurus* sp.). If

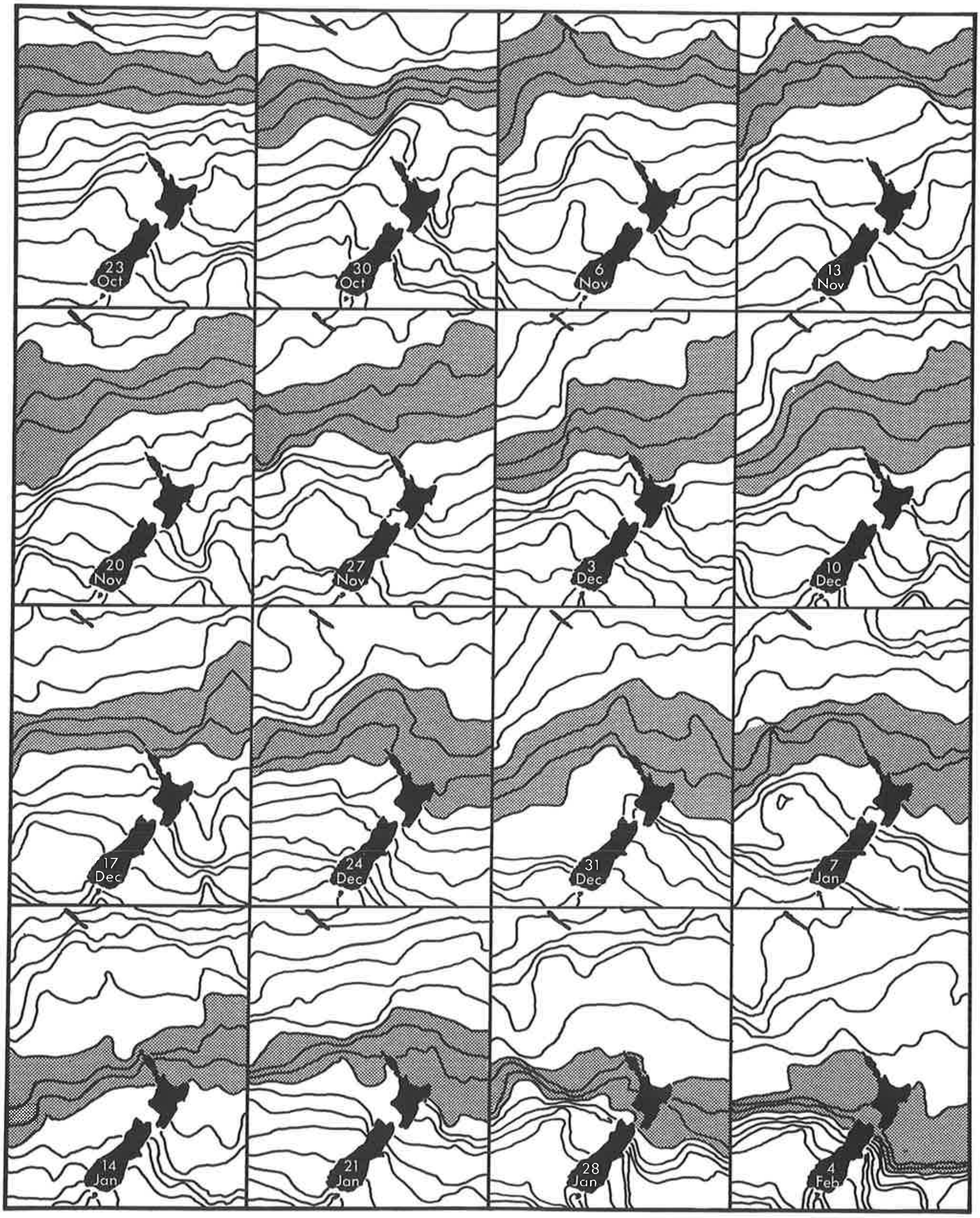


Fig. 15 (above and following pages): Weekly sea surface temperature charts for the New Zealand region, from satellite measurements, for the 1980 skipjack season. Water of 19° to 22°C ("skipjack water") is shaded; isotherms are at 1°C intervals.

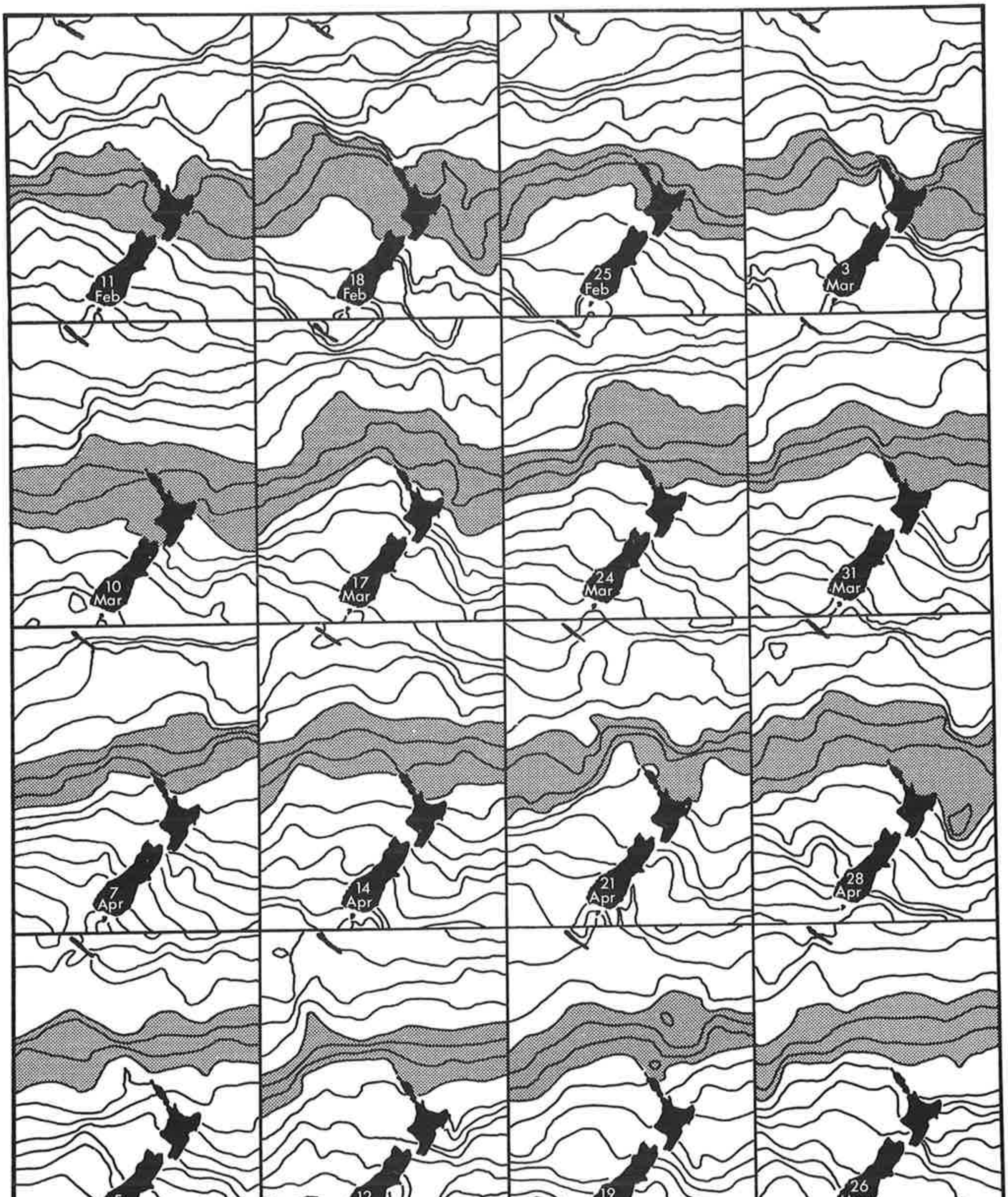


Fig. 15 — *continued.*

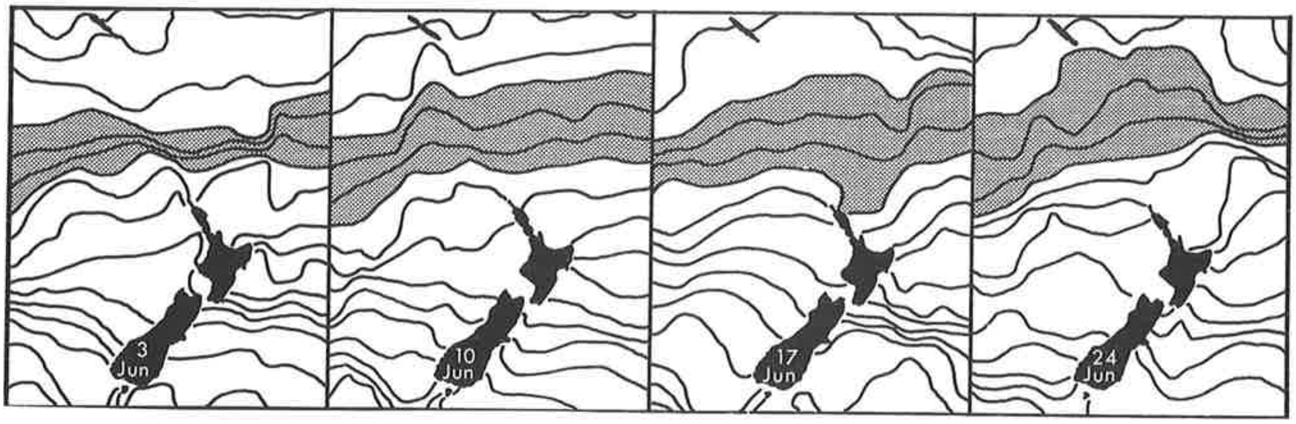


Fig. 15 — *continued.*

skipjack were present on the coast, they were most often distributed near the leading edge of the flow of skipjack water with the other subtropical species. Shipboard observations established that near its leading edge the skipjack water had a surface temperature close to 20°C and a salinity close to 35.5 parts per thousand.

Skipjack were generally found and fished in skipjack water; notable exceptions were the sets made in cooler water in the Bay of Plenty in June, where sea surface temperatures ranged between 15.5° and 16.7°C. Skipjack have been found in cold water of similar temperatures in earlier seasons, for example, in October-November 1975 (see Clement 1976). These observations are significant in view of the commonly held belief that the lower temperature limit of skipjack is about 18°C (Barkley, Neill, and Gooding 1978). An important factor may be that these fish were larger than most other skipjack in the season's catches (see Length-frequency distributions, page 31). This has also been observed in past seasons (for example, see Table 11 and Fig. 12 in Habib, Clement, and Fisher 1980). These observations conform generally with estimates made by Barkley, Neill, and Gooding (1978) of tolerance of eastern Pacific Ocean skipjack to water temperature as a function of fish size. They contend that with increasing size, skipjack "... should be limited to lower and lower environmental temperatures ...". However, the limits they propose are much higher than those which have been found for skipjack in New Zealand.

Given the high correlation between the distribution of skipjack and skipjack water, the satellite data are useful in leading to a broad understanding of skipjack distribution in New Zealand in summer. If they were available closer to the time that they were collected, they would also have some predictive value.

Catch and effort by sea surface salinity

Skipjack were caught in areas where sea surface salinities ranged from 34.9 to 35.8 parts per thousand (Table 10). Almost two-thirds of the catch was taken in water of 35.0 to 35.5 parts per thousand salinity with about the same proportion of the season's effort and at catch rates (per successful set) close to the season's means. Most of the remaining catch was taken in water of higher salinity at catch rates much greater than the season's means. Only 34 t of skipjack were caught in low salinity water. This was in Hawke Bay in February

TABLE 10: Catch and successful sets by sea surface salinity in the 1980 purse-seine skipjack fishery in New Zealand

Salinity (‰)	Catch (t)	% of total	Successful sets	% of total	Catch per successful set (t)
34.90–34.99	34	0.4	3	1.3	11.3
35.00–35.09	104	1.3	5	2.1	20.8
35.10–35.19	1 306	16.3	38	15.9	34.4
35.20–35.29	1 022	12.7	34	14.2	30.1
35.30–35.39	1 111	13.8	40	16.7	27.8
35.40–35.49	1 458	18.2	49	20.5	29.8
35.50–35.59	1 984	24.7	48	20.1	41.3
35.60–35.69	663	8.3	13	5.4	51.0
35.70–35.80	341	4.3	9	3.8	37.9
	8 023		239*		33.6

* Water samples were not taken from 56 successful sets.

when fishing was near known areas of artesian upwelling of fresh water.

It is commonly believed, and physiological experiments seem to support the belief, that salinity itself has little direct effect on skipjack (see Blackburn 1965, Seckel 1972, Dizon 1977). Rather, salinity measurements can be important in characterising and detecting oceanic features with which skipjack associate.

Further comments on skipjack water

The high temperature and salinity and the possible subtropical origin of skipjack water have already been noted. Our conception of skipjack water appears to fit a description by Heath (1973) of Subtropical Water as being one of five water masses to affect the New Zealand region. This water mass, which has its origin in the central Pacific Ocean, is reported to have westward and southward components of flow near New Zealand, and it is further characterised by high temperature and salinity. It seems logical that such a water mass is the vehicle by which skipjack and other subtropical species are transported to and from New Zealand. A similar water mass transportation of skipjack has been proposed for the seasonal skipjack fishery in Hawaii (Seckel 1972).

Purse-seine fishing and the 12-mile limit

Almost nine-tenths of the season's catch (8031 t) was taken outside the 12-mile territorial sea and the remainder (900 t) inside (Table 11). As in past seasons, fishing was concentrated along the 200-m depth contour, which was close to the 12-mile limit (see set positions, Fig. 1).

The distribution of catches in relation to the 12-mile limit largely reflected the distribution of the resource; though, as in 1979, most of the fishing fleet was also restricted to fishing outside the limit. After expulsion from the New Zealand area of one of the chartered seiners in 1979 for allegedly fishing inside the limit, and an assurance that the New Zealand Government would act promptly on any future allegations of infringements, the restriction was rigidly observed in 1980. Fishing was even discontinued where skipjack schools were clearly outside the limit, but where on-shore winds and ocean currents might have carried vessels inside the limit while in set (data in MAF files).

Catch rates (per set, per successful set) were much higher in off-shore waters than in shore (Table 11). This was partly because the bulk of the resource was off shore, but also because that was where the larger seiners concentrated their efforts. Even the small vessels achieved their best catch rates off shore.

TABLE 11: Catch and set data for fishing inside the 12-mile limit by large (Il) and small (Is) purse-seine vessels and outside the limit by large (Ol) and small (Os) vessels in the 1980 purse-seine skipjack fishery in New Zealand

Vessel	Catch (t)	% of total	Sets	% of total	Catch per set (t)	Successful sets	% of total	Catch per successful set (t)
Il	118	1.3	11	1.8	10.7	6	2.0	19.7
Is	782	8.8	155	24.8	5.0	72	24.4	10.9
Ol	7 431	83.2	379	60.6	19.6	188	63.7	39.5
Os	600	6.7	80	12.8	7.5	29	9.8	20.7
	8 931		625		14.3	295		30.3

Biology

Length-frequency distributions

During 1980, 37 981 skipjack were measured (1.14% of the estimated total number of fish caught during the season). Catches sampled by area were 12 in B, 100 in C, 42 in D, 9 in E, 44 in J, and 37 in A and K. All length measurements were grouped by 2-week intervals by area to provide a record of the length composition of the catches throughout the season (Fig. 16). These data also show the changes in the location of the fishery during the season.

Catches made in late November off east Northland (area B) contained large 51- to 63-cm fish (2.8 to 5.6 kg in weight). The only other catches made in this area were in late January and most fish were 46 to 54 cm (2 to 3.4 kg). However, 3 of the 11 catches sampled at this time also contained a distinct group of fish of 37 to 41 cm (1 to 1.4 kg).

East and north of Great Barrier Island (area C) in December-January most fish were 46 to 54 cm with a peak (mode) in the length-frequency distributions at 51 cm. In early February these fish were joined by the same small size group that appeared in area B in January. In addition, a third size group (47 to 48 cm, 2.1 to 2.3 kg) appeared in the catches. All three groups persisted in the catches until fishing ceased in this area. The small and intermediate fish made up only a small part of the catches.

Length-frequency samples from catches made in the Bay of Plenty (area D) between early January and late February were similar to those from area C for the same period. However, by March the numbers of intermediate-sized fish (47 to 48 cm) had increased so that they constituted a similar proportion of the catches to that made up of larger (51-cm) fish. The small fish persisted in small numbers, and by the end of March they had apparently grown to 42 to 43 cm (1.4 to 1.6 kg). A few catches were sampled in this area late in the season, and the fish were larger as the season neared its end. On 31 May fish were 48 to 58 cm (2.3 to 4.3 kg), with a peak at 54 cm (3.4 kg); on 17 June, the last day of the season, they were 53 to 63 cm (3.2 to 5.6 kg), with a peak at 57 cm (4 kg).

Nine catches were sampled between East Cape and Hawke Bay (area E) in February. Early in the month fishing was in the north of the area. The catches there contained 46- to 57-cm fish (2 to 4 kg), with a peak at 51 cm (2.8 kg). Later in the month fishing was to the south, and the size range of skipjack in these catches was similar to that in the north. However, the peaks in the length-frequency distributions were at 54 to 55 cm (3.4 to 3.6 kg). This seems to indicate that there were two bodies of skipjack on this coast in February.

In February 37 catches were sampled near Reef Point, which is on the dividing line between areas A and K. As skipjack moved freely between these areas, length samples from the catches in both have been combined (see Fig. 16). The catches contained 46- to 56-cm fish (2 to 3.8 kg), but within this size range there were two close peaks in the length-frequency distributions. One, at 49 cm (2.4 kg), was the only peak present in the catches between the 1st and the 4th. On the 5th it was joined by a peak at 51 to 52 cm (2.8 to 3 kg). Subsequently the smaller peak disappeared from the catches, which became dominated by the larger fish. There may have been two bodies of skipjack near Reef Point at this time, represented by the two different dominant sizes of fish, and the smaller fish may have moved on as the larger ones arrived on the coast.

In March 44 catches were sampled north-west of New Plymouth (area J). The catches contained mainly 48- to 56-cm fish (2.3 to 3.8 kg), with a peak at 52 cm (3 kg). Also present, but in much smaller numbers, were small skipjack (38 to 45 cm, 1 to 1.8 kg, peak at 42 cm, 1.5 kg).

The estimated numbers of fish at different lengths in the 1980 catches are presented in Table 12. These estimates were obtained by converting the number of fish of each length to weight of fish at each length by use of a previously determined length-weight relationship (see below). These weights were scaled up by the weights of the catches to yield total weights of fish at each length, which were then converted back to total numbers at each length.

Length-weight relationship

A relationship was not calculated for 1980 fish, but it was probably similar to that derived for 1977 fish (see Fig. 6 and Table 4 in Habib 1978a). That relationship has been used here to calculate all the equivalents of weight for fish of given lengths.

Food and feeding

Stomachs were examined from 1237 skipjack during the season. The fish in the samples ranged in length from 38 to 67 cm, but most were close to 51 cm (see Table 12). Samples came from all areas in the fishery and were collected at various times of the day. Almost two-thirds of the stomachs were empty. Those with food contained predominantly the planktonic euphausiid *Nyctiphanes australis* (Fig. 17).

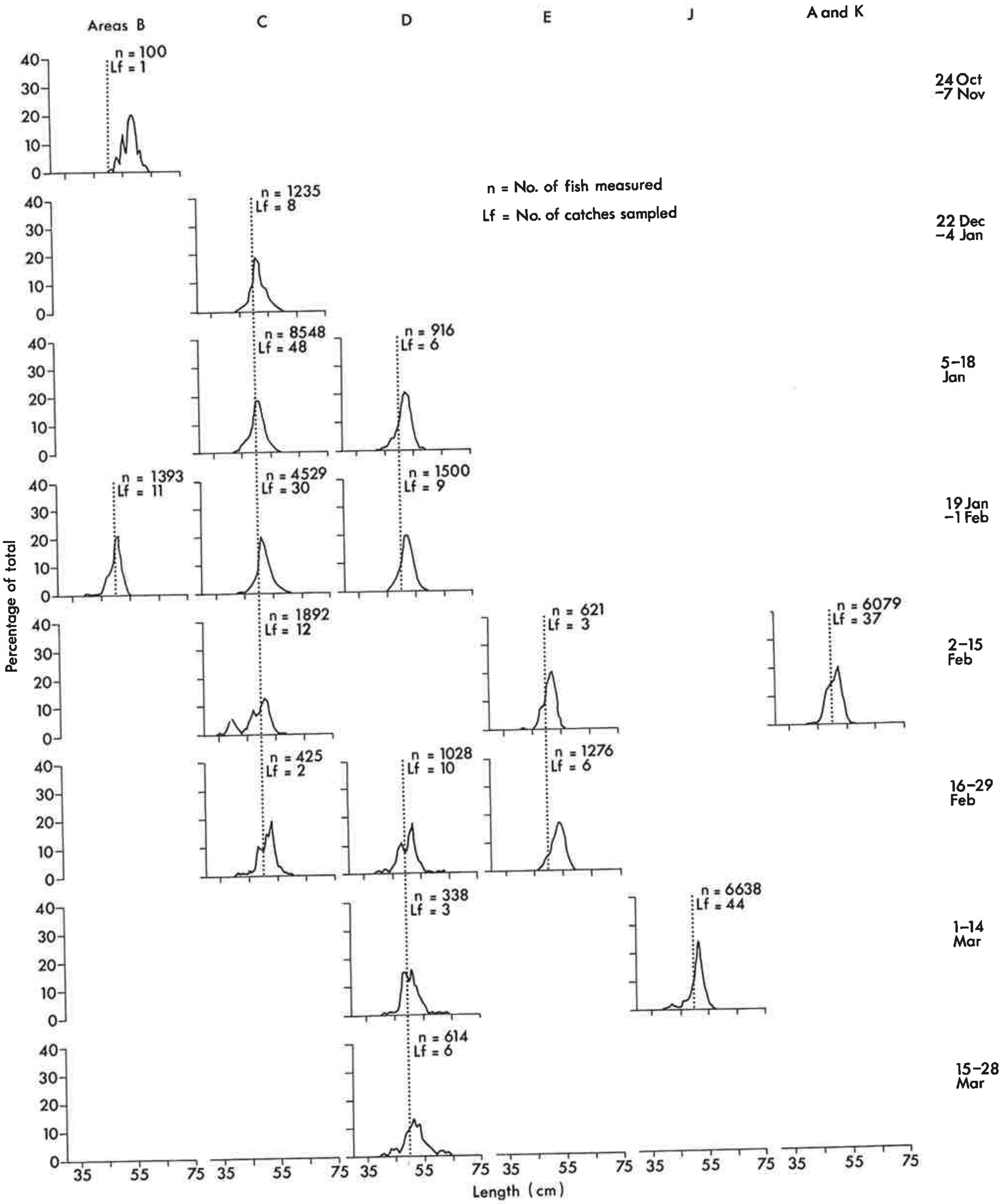
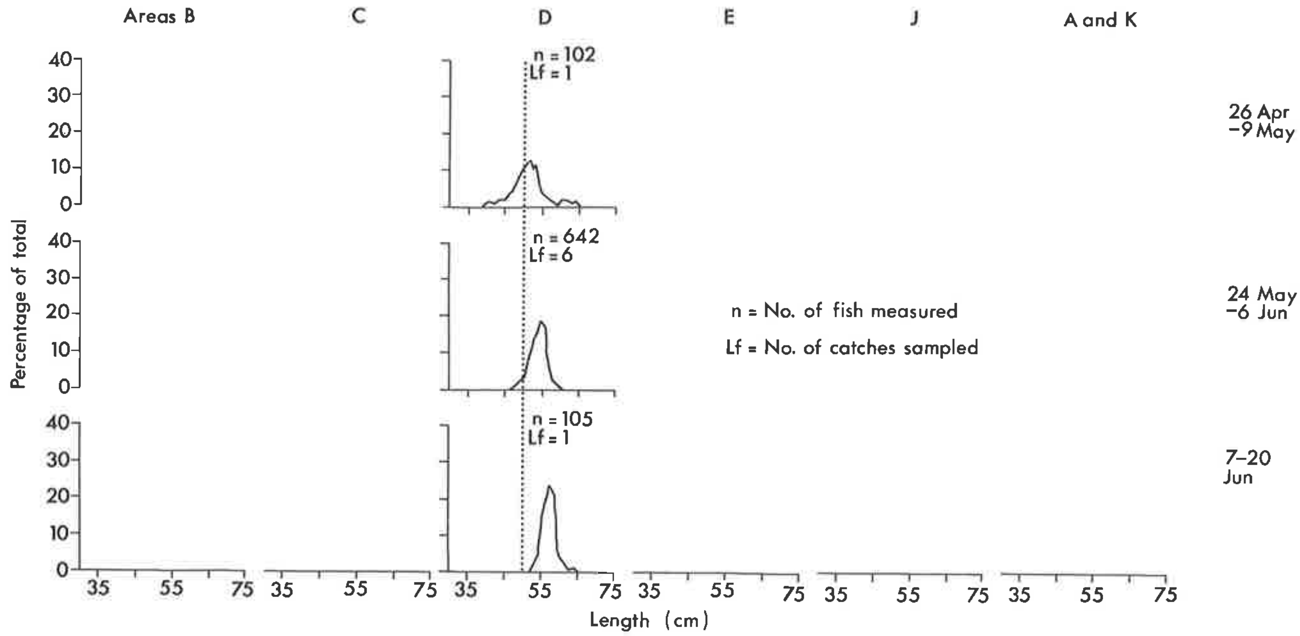


Fig. 16 (above and right): Length-frequency distribution by area by 2-week intervals in the 1980 purse-seine skipjack fishery in New Zealand.



A predominance of crustaceans in the diet of small (up to about 50-cm) skipjack has been found in numerous studies (for example, Nakamura 1965, Dragovich 1970). Magnuson and Heitz (1971), in their study of gill raker apparatus and food selectivity in tunas, pointed out that prevention of food loss through the opercular opening is the primary function of gill rakers. They measured the gaps between gill rakers in skipjack and found that these ranged from about 0.9 mm in 22-cm fish to 1.5 cm in 67-cm fish (see their Fig. 2). They then related their data to the percentage of crustaceans in the stomachs of central Pacific Ocean fishes (based on literature records). Generally the records supported their hypothesis that fish with a smaller gill raker gap have a greater proportion of smaller organisms in their diet. They viewed the relationship as functional. Other studies (for example, Yuen 1959, Waldron and King 1963) showed that as skipjack increased in size, there was a change in diet to larger prey species such as fish.

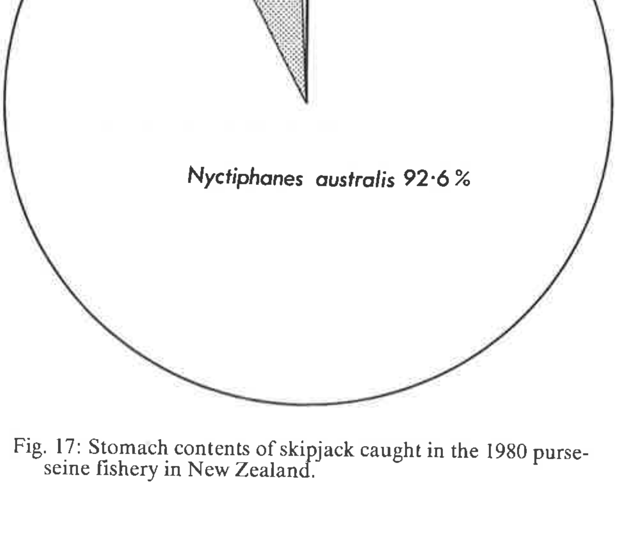


Fig. 17: Stomach contents of skipjack caught in the 1980 purse-seine fishery in New Zealand.

Other food items in fish sampled during the season included fish remains, with sufficient material occasionally present to enable identification of pilchard *Sardinops neopilchardus,* saury *Scomberesox saurus,* and marine hatchetfish *Maurolicus muelleri.* Small quantities of the squid *Nototodarus sloani* and liquid remains were also present.

Few fish contained much food. Seventy-nine percent of stomachs with food were less than one-quarter full, 17% between a quarter and half full, and 4% over half full (Fig. 18). The fullness curves in this figure are based on an observation that in all stomach samples collected in New Zealand in the last five seasons, the maximum recorded weight of food in any fish was 5.3% of the body weight. We believe, then, that 5.5% of the body weight is a fair estimate of the maximum (full) stomach capacity of skipjack of lengths from 38 to 66 cm which are taken in the purse-seine fishery in New Zealand. The other curves are half and one-quarter of those values.

The curves have lower values than those shown in Habib (1978a), which were derived from a maximum stomach capacity of 7% observed by Magnuson (1969) in feeding studies on captive skipjack. Habib (1978a) commented that the curves he used were probably too high, as some stomachs which he judged to be full did not register as such. No full stomachs were recorded in this study either, though some appeared full. Even 5.5% may be too high a maximum stomach capacity for the average purse-seine-caught skipjack. Nevertheless, the curves give a scale of reference to the scatter of food weights in the samples and indicate the approximate level of feeding.

All feeding data were analysed in the examination of diurnal variation in stomach contents. The proportions of stomachs containing food were calculated for five time periods through the day (Fig. 19). There was an early morning low in feeding followed by a late morning peak, an early afternoon low, and a rise through the afternoon to a peak in the evening. Similar diurnal variations have been found in other studies (for example, Nakamura 1965).

The diurnal feeding pattern may be associated with the availability of food. Our observations on the main food organism, *Nyctiphanes australis* (our unpublished data), show that this species is present in surface waters in smallest numbers in the early afternoon and in largest numbers at night. Diurnal variation in feeding may also reflect the effects of satiation with food. As explained by Nakamura (1965), "Skipjack, starting the day with their stomachs empty, feed actively during the early morning hours, and food consumption reaches a peak sometime before noon. A period of satiety occurs midday while digestive processes reduce the stomach contents. As the stomach empties, skipjack forage again, and the volume reaches a second peak prior to darkness."

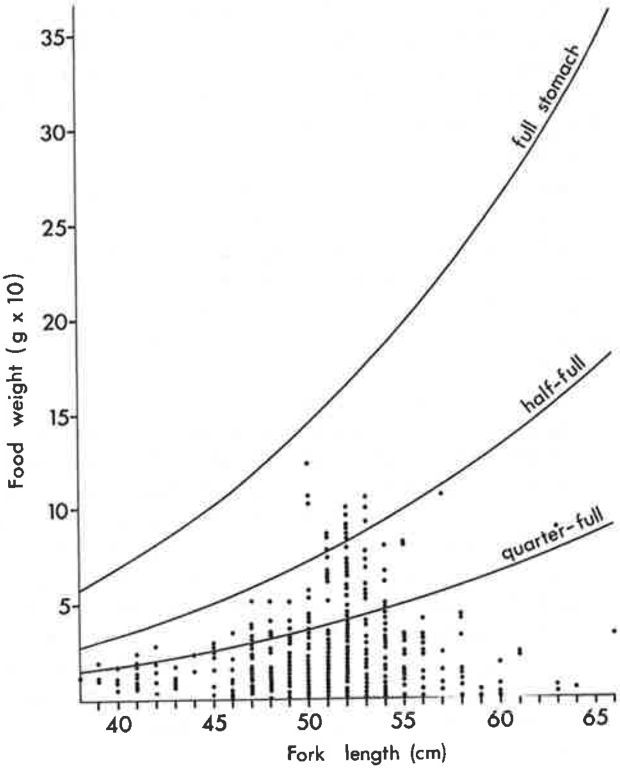


Fig. 18: Stomach fullness plotted against body length of skipjack caught in the 1980 purse-seine fishery in New Zealand.

TABLE 12: Estimated number of skipjack of different lengths in the 1980 purse-seine catch in New Zealand

Length (cm)	Est. No. in season's catch	% of est. total No.
31	40	–*
32	0	0
33	0	0
34	180	–
35	290	–
36	60	–
37	560	–
38	2 180	–
39	7 330	0.2
40	8 260	0.2
41	13 000	0.4
42	19 800	0.6
43	17 620	0.5
44	19 740	0.6
45	47 530	1.4
46	97 140	2.9
47	162 700	4.8
48	238 480	7.1
49	348 800	10.4
50	500 560	14.9
51	609 920	18.2
52	546 180	16.3
53	338 520	10.1
54	175 520	5.2
55	82 700	2.5
56	48 170	1.4
57	26 830	0.8
58	18 000	0.5
59	11 260	0.3
60	9 110	0.3
61	3 840	0.1
62	2 910	–
63	1 570	–
64	270	–
65	0	0
66	360	–
67	170	–
	3 359 600	

* Less than 0.1% of total.

Gonad condition

Gonads were examined in the fish dissected for stomach analyses: 668 were female, 569 male. Ninety gonads (49 female, 41 male) were weighed and dissected in the laboratory. The female gonads ranged in weight from 2 to 21 g. All ova in these gonads were less than 0.15 mm in diameter, which has been classed as "immature" in various classifications (see Raju 1964). The male gonads ranged in weight from 0.2 to 13 g and showed no signs of development.

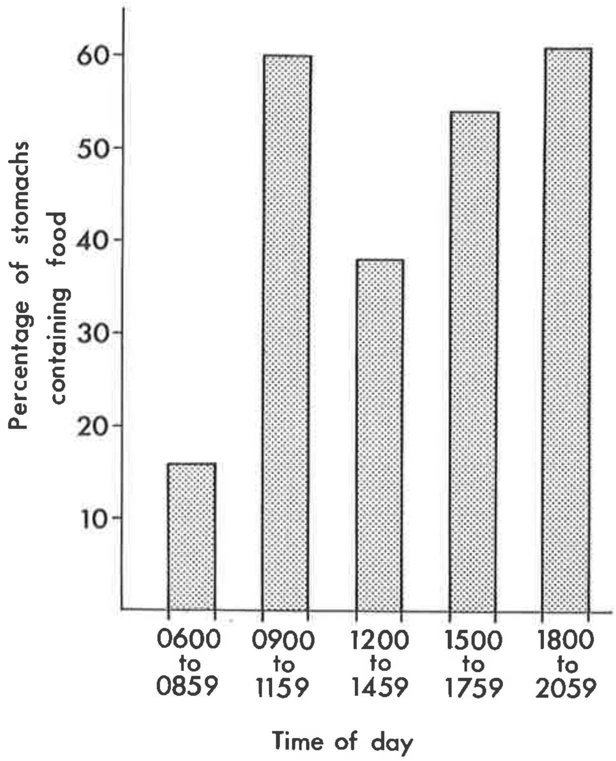


Fig. 19: Diurnal feeding rhythm of skipjack caught in the 1980 purse-seine fishery in New Zealand.

The skipjack from which gonads were dissected ranged from 38 to 66 cm. Most were over 45 cm, the length at which this species usually undergoes first spawning (Brock 1954, Yoshida 1964). As there were no signs that these fish had spawned, they were probably soon to spawn in other parts of their range.

Skipjack population identification

In earlier seasons large numbers of blood samples were collected from the purse-seine catches for genetic studies on skipjack population identification. The samples were sent to Australian National University (ANU) for analysis. The results of the analyses are being prepared for publication.

In 1979, further blood samples were collected from skipjack in New Zealand by SPC staff (see Kearney and Hallier 1979a). These samples were also analysed at ANU. Electrophoretic techniques were used to determine the gene frequencies of the enzyme serum esterase. The New Zealand samples showed the greatest affinity with samples collected in Fiji and Wallis Islands (see Fig. 1 and Tables 1 and 2 in South Pacific Commission 1980).

Skipjack parasites

A large number of samples of skipjack viscera (gills, alimentary tracts, and gonads) were collected from purse-seined fish during the 1980 season. These were sent to the University of Queensland to initiate a joint study on the parasites of New Zealand skipjack, and they are being analysed.

Skipjack tagging and migrations

Since we last reported on skipjack migrations in New Zealand waters and migrations to and from New Zealand (Habib, Clement, and Fisher 1980), data on further migrations have come to hand through SPC's Skipjack Survey and Assessment Programme (see Kearney 1977a, 1978, 1980, interim reports listed in Kearney and Hallier 1979b).

Many of the data are from fish which were tagged in New Zealand in 1979 on SPC's research vessel *Hatsutori Maru* (Table 13) (see Kearney and Hallier 1979a). Most were recaptured in New Zealand in 1980 by the purse seiners. Periods that the fish were at liberty ranged from 284 to 463 days. The data therefore appear to describe movements of skipjack in New Zealand waters over periods including the winter of 1979. However, these skipjack are unlikely to have overwintered in New Zealand waters. We suggest that they left New Zealand with the autumn cooling and returned during the following season.

That the ocean cooled sufficiently to produce an environment unsuitable for skipjack is borne out by satellite recordings (data in MAF files). Sea surface temperatures on the fishing grounds around the North Island during the 1979 winter fell to between 11° and 15°c. Some recent hydrological work by us on the main New Zealand skipjack fishing ground east and north of Great Barrier Island showed that in winter the temperature of the sea water is fairly uniform between the surface and a depth of 120 m (data in MAF files). It is likely, therefore, that the surface temperatures from satellites for the 1979 winter were representative of temperatures to at least 120 m deep, which makes it improbable that skipjack remained on the New Zealand coast, at the surface or at depth. (Note that skipjack generally occur between the surface and a depth of about 100 m, though they have been found deeper; see Yabe, Yabuta, and Ueyanagi 1963, Strasburg, Jones, and Iversen 1968.)

Further evidence for skipjack leaving New Zealand waters by the 1979 autumn is that no schools were sighted at the surface after that time by the aerial fish spotters flying in support of the winter New Zealand pelagic fishery. This has been true of the last four seasons.

We also have direct evidence from tagging that skipjack left New Zealand waters at some time during or after the 1979 season. Table 14 lists 12 fish which left the area. Nine of these were tagged in the same schools as the fish which we claim (above) also left New Zealand (compare release and recapture data in Tables 13 and 14), but whereas these nine were recaptured in latitudes north of New Zealand, the others returned to

TABLE 13: Data for skipjack released in New Zealand waters during the 1979 skipjack season and recaptured in New Zealand during the 1980 season (data from Kearney and Hallier 1979a, Kearney pers. comm.)

Release data				Recapture data				
Date	Position	General area	Fish length (cm)	Date	Position	General area	Fish length (cm)	Distance* (km)
22.2.79	35°36′ S, 175°15′ E	Poor Knights Is	47.0	10.1.80	35°37′ S, 175°06′ E	Poor Knights Is	54.0	14
22.2.79	35°36′ S, 175°15′ E	Poor Knights Is	50.0	10.1.80	35°34′ S, 175°02′ E	Poor Knights Is	–†	20
22.2.79	35°36′ S, 175°15′ E	Poor Knights Is	45.0	24.1.80	35°39′ S, 175°10′ E	Poor Knights Is	54.4	9
22.2.79	35°20′ S, 174°48′ E	Poor Knights Is	46.0	19.2.80	37°40′ S, 176°43′ E	Bay of Plenty	–	311
22.2.79	35°20′ S, 174°48′ E	Poor Knights Is	46.0	10.1.80	35°34′ S, 175°02′ E	Poor Knights Is	–	34
22.2.79	35°20′ S, 174°48′ E	Poor Knights Is	44.0	1.1.80	35°52′ S, 176°02′ E	The Cross	51.4	126
26.2.79	34°55′ S, 173°54′ E	Cavalli Is	48.0	7.2.80	35°28′ S, 172°55′ E	Hokianga Harbour	52.8	109
27.2.79	35°13′ S, 174°35′ E	Cape Brett	48.0	9.2.80	37°57′ S, 178°35′ E	East Cape	53.0	469
27.2.79	35°13′ S, 174°35′ E	Cape Brett	48.0	1.1.80	35°52′ S, 176°02′ E	The Cross	56.0	150
27.2.79	35°13′ S, 174°35′ E	Cape Brett	46.0	4.2.80	35°48′ S, 175°14′ E	Mokohinau Is	–	88
2.3.79	35°24′ S, 174°54′ E	Poor Knights Is	45.0	26.1.80	35°55′ S, 175°40′ E	NE of Great Barrier I	51.0	90
2.3.79	35°26′ S, 174°53′ E	Poor Knights Is	45.0	7.6.80	37°22′ S, 176°12′ E	Mayor I	57.0	245
2.3.79	35°26′ S, 174°53′ E	Poor Knights Is	48.0	1.1.80	35°52′ S, 176°02′ E	The Cross	55.3	115
2.3.79	35°26′ S, 174°53′ E	Poor Knights Is	46.5	28.1.80	34°39′ S, 174°09′ E	Cavalli Is	52.0	100
2.3.79	35°26′ S, 174°53′ E	Poor Knights Is	45.0	27.3.80	37°46′ S, 176°50′ E	Bay of Plenty	–	312
2.3.79	35°26′ S, 174°53′ E	Poor Knights Is	46.0	7.2.80	38°21′ S, 178°41′ E	S of East Cape	53.0	468
2.3.79	35°27′ S, 174°52′ E	Poor Knights Is	47.0	9.1.80	35°35′ S, 175°11′ E	Poor Knights Is	55.0	32
2.3.79	35°27′ S, 174°52′ E	Poor Knights Is	47.0	13.1.80	36°44′ S, 176°16′ E	The Aldermen Is	51.5	190
3.3.79	35°32′ S, 174°49′ E	Poor Knights Is	47.0	26.1.80	35°55′ S, 175°40′ E	NE of Great Barrier I	55.0	88
3.3.79	35°32′ S, 174°49′ E	Poor Knights Is	52.0	10.1.80	35°33′ S, 175°02′ E	Poor Knights Is	60.0	20
3.3.79	35°31′ S, 174°50′ E	Poor Knights Is	50.0	27.1.80	35°34′ S, 175°32′ E	NE of Mokohinau Is	59.0	64
5.3.79	35°37′ S, 175°11′ E	Poor Knights Is	44.5	14.1.80	35°52′ S, 176°07′ E	The Cross	–	89
6.3.79	35°51′ S, 175°30′ E	N of Great Barrier I	48.0 ?	9.3.80	37°51′ S, 177°09′ E	Bay of Plenty	47.0 ?	266
6.3.79	35°51′ S, 175°30′ E	N of Great Barrier I	46.0	14.1.80	35°51′ S, 176°06′ E	The Cross	–	54
6.3.79	35°51′ S, 175°30′ E	N of Great Barrier I	47.0	7.2.80	35°28′ S, 172°55′ E	Hokianga Harbour	50.1	237
6.3.79	35°51′ S, 175°30′ E	N of Great Barrier I	46.0	26.1.80	35°51′ S, 175°36′ E	N of Great Barrier I	–	9
6.3.79	35°51′ S, 175°30′ E	N of Great Barrier I	46.0	7.2.80	38°21′ S, 178°41′ E	S of East Cape	53.0	396
6.3.79	35°51′ S, 175°30′ E	N of Great Barrier I	46.0	31.1.80	35°28′ S, 174°52′ E	Poor Knights Is	53.5	71
6.3.79	35°51′ S, 175°30′ E	N of Great Barrier I	49.0	20.2.80	39°35′ S, 177°27′ E	Hawke Bay	53.0	449
6.3.79	35°51′ S, 175°30′ E	N of Great Barrier I	49.0	1.1.80	35°52′ S, 176°02′ E	The Cross	–	48
6.3.79	35°53′ S, 175°34′ E	N of Great Barrier I	47.5	4.2.80	35°19′ S, 172°35′ E	Reef Point	–	277
6.3.79	35°53′ S, 175°34′ E	N of Great Barrier I	47.0	10.1.80	35°42′ S, 175°00′ E	NW of Mokohinau Is	53.0	55
6.3.79	35°53′ S, 175°34′ E	N of Great Barrier I	46.5	2.6.80	37°28′ S, 176°21′ E	Bay of Plenty	54.0	189
6.3.79	35°46′ S, 175°28′ E	N of Great Barrier I	47.5	9.2.80	35°50′ S, 175°00′ E	NW of Mokohinau Is	–	43

6.3.79	35°53′ S, 175°34′ E	N of Great Barrier I	44.0 ?	6.2.80 ‡	35°40′ S, 172°46′ E	Hokianga Harbour	63.0 ?	117
				to	to			
				7.2.80	35°47′ S, 172°56′ E	Hokianga Harbour		102
13.3.79	37°38′ S, 176°33′ E	Bay of Plenty	50.5	30.1.80	36°00′ S, 175°53′ E	The Cross	60.3	191
20.3.79	35°47′ S, 175°20′ E	Mokohinau Is	45.5	1980	–	New Zealand (cannery)	–	–
20.3.79	35°47′ S, 175°20′ E	Mokohinau Is	45.5	26.3.80	37°41′ S, 176°50′ E	Bay of Plenty	–	250
20.3.79	35°47′ S, 175°20′ E	Mokohinau Is	45.0	10.1.80	35°52′ S, 176°02′ E	The Cross	–	64
20.3.79	35°47′ S, 175°20′ E	Mokohinau Is	45.0	27.3.80	37°46′ S, 176°54′ E	Bay of Plenty	–	246
20.3.79	35°47′ S, 175°20′ E	Mokohinau Is	47.0	10.1.80	35°34′ S, 175°02′ E	Poor Knights Is	–	36
20.3.79	35°47′ S, 175°20′ E	Mokohinau Is	46.0	12.1.80	36°00′ S, 175°58′ E	The Cross	57.2	62
23.3.79	37°45′ S, 174°19′ E	Gannet I	47.0	12.1.80	36°00′ S, 175°58′ E	The Cross	54.7	244
23.3.79	37°45′ S, 174°19′ E	Gannet I	45.8 ?	14.1.80	35°51′ S, 176°06′ E	The Cross	–	264
23.3.79	37°45′ S, 174°19′ E	Gannet I	45.8 ?	10.1.80	35°52′ S, 176°02′ E	The Cross	52.5	259
23.3.79	37°45′ S, 174°19′ E	Gannet I	45.8 ?	4.2.80	35°48′ S, 175°14′ E	Mokohinau Is	–	232
24.3.79	37°45′ S, 174°17′ E	Gannet I	46.0	1980	–	New Zealand (cannery)	–	–
24.3.79	37°45′ S, 174°17′ E	Gannet I	47.0	10.1.80	35°35′ S, 175°06′ E	Poor Knights Is	52.0	252

* Straight line distances between the release and recapture positions.
† No data.
‡ Where ranges of dates, positions, and distances are given, exact data are not available.

TABLE 14: International data for skipjack released or recaptured in New Zealand waters in 1979 or 1980 (data from Kearney and Hallier 1979a, Kearney pers. comm.)

Release data				Recapture data				
Date	Position	Country	Fish length (cm)	Date	Position	Country	Fish length (cm)	Distance* (km)
5.4.79	36°04′ S, 150°24′ E	Australia	45.0	14.1.80	35°57′ S, 176°08′ E	New Zealand	50.2	2 308
8.4.79	35°08′ S, 151°04′ E	Australia	44.0	7.2.80	35°44′ S, 173°07′ E	New Zealand	–†	1 995
8.4.79	35°06′ S, 151°04′ E	Australia	45.0	10.3.80	38°09′ S, 173°52′ E	New Zealand	55.5	2 057
8.4.79	35°06′ S, 151°04′ E	Australia	45.0	5.2.80 ‡	35°05′ S, 172°25′ E	New Zealand	50.0	1 993
				to	to			
				6.2.80	35°40′ S, 172°46′ E	New Zealand		1 968
8.4.79	35°04′ S, 151°05′ E	Australia	47.6	1.1.80	35°52′ S, 176°02′ E	New Zealand	51.1	2 255
9.4.79	34°41′ S, 151°10′ E	Australia	47.0	5.2.80	35°05′ S, 172°25′ E	New Zealand	–	1 927
				to	to			
				7.2.80	35°47′ S, 172°56′ E	New Zealand		1 975
10.4.79	35°02′ S, 151°12′ E	Australia	45.0	5.2.80	35°05′ S, 172°25′ E	New Zealand	50.0	1 922
				to	to			
				6.2.80	35°40′ S, 172°46′ E	New Zealand		1 955
2.3.79	35°25′ S, 174°53′ E	New Zealand	50.0	26.3.80	29°28′ S, 168°20′ E	Norfolk Island	62.1	902
28.2.79	35°13′ S, 174°39′ E	New Zealand	45.0	28.2.80	04°00′ S, 173°00′ E	Kiribati	58.0	3 475
20.3.79	35°47′ S, 175°20′ E	New Zealand	45.0	28.2.80	04°00′ S, 173°00′ E	Kiribati	50.5	3 542
22.2.79	35°20′ S, 174°48′ E	New Zealand	48.0	16.11.79	36°50′ S, 151°05′ E	Australia	–	2 132
27.2.79	35°13′ S, 174°35′ E	New Zealand	47.0	30.1.80	14°00′ S, 171°50′ W	Western Samoa	52.0	2 723
6.3.79	35°51′ S, 175°30′ E	New Zealand	45.0	2.2.80	18°10′ S, 149°50′ W	French Polynesia	49.6	3 926
22.2.79	35°20′ S, 174°48′ E	New Zealand	47.0	1980	–	American Samoa (cannery)	52.1	–
6.3.79	35°51′ S, 175°30′ E	New Zealand	45.0	1980	–	American Samoa (cannery)	46.2	–
8.3.79	37°46′ S, 177°04′ E	New Zealand	50.0	1980	–	American Samoa (cannery)	53.8	–
13.3.79	37°38′ S, 176°33′ E	New Zealand	45.0	1980	–	American Samoa (cannery)	–	–
20.3.79	35°47′ S, 175°20′ E	New Zealand	44.0	1980	–	American Samoa (cannery)	–	–
23.3.79	37°45′ S, 174°19′ E	New Zealand	47.0 ?	1980	–	American Samoa (cannery)	47.1 ?	–

* Straight line distances between the release and recapture positions.
† No data.
‡ Where ranges of dates, positions, and distances are given, exact data are not available.

New Zealand. It is tempting to conclude that the fish which returned had performed similar migrations to those of their counterparts which were tagged in the same schools and undertook international migrations.

If the fish listed in Table 13 did leave New Zealand and return, the recapture data illustrate some interesting phenomena. Ten fish showed a remarkable "homing" ability by returning to within 50 km of where they were tagged 10 to 11 months earlier, after possibly traversing thousands of kilometres of ocean. Two fish returned to within 10 km. Others, which were often tagged from the same schools as the homing fish, returned to areas far from where they were tagged. For example, five fish were tagged from a school near Poor Knights Islands (35° 26′ S, 174° 53′ E) in March 1979. Ten months later one was recaptured near the Cross; after 11 months one was recaptured at Cavalli Islands and one south of East Cape; after 13 months one in the Bay of Plenty; and after 15 months one near Mayor Island in the north-western Bay of Plenty. There were numerous other examples of this kind of dispersion.

These findings seem to indicate that though certain skipjack which visit New Zealand waters do so along fixed routes, others are possibly less fixed in their migrations. Alternatively, fish which comprise the New Zealand stock may be fixed in their migrations inasmuch as they have the propensity to visit New Zealand some time during their lives.The timing of the migration could vary from year to year, as could the migration path and the point of contacting the New Zealand coast. These could depend on such factors as hydrological and feeding conditions at the sites where migration is initiated, along the way to New Zealand, and on the New Zealand coast. There will be more discussion in future SPC publications on the results of further analyses by SPC of skipjack tagging data with some New Zealand content.

Skipjack tagging and growth

Data on fish lengths at time of release and recapture also came to hand from SPC's skipjack tagging programme (see Tables 13 and 14). When lengths were standardised to periods of a year, a wide range of growth rates was found. Among the fish tagged and recaptured in New Zealand, rates ranged from 3.3 to 13.7 cm per year (mean 7.9 cm). Growth rates for fish which migrated between New Zealand and Australia ranged from 4.8 to 11.4 cm per year (mean 7.7 cm). The two fish which migrated from New Zealand to Kiribati had growth rates of 5.8 and 13.0 cm; the fish which migrated from New Zealand to French Polynesia was growing at a rate of about 5 cm a year; and the one which migrated from New Zealand to Western Samoa, 5.4 cm.

Similar analyses on the 1979 data (see Table 14 in Habib, Clement, and Fisher 1980) showed that fish which moved between New Zealand and Fiji grew at rates between 9.5 and 18.4 cm per year (mean 12.8 cm). The New Zealand-Wallis Islands migrants grew from 4.4 to 6.9 cm per year (mean 5.9 cm) and the New Zealand-Futuna fish at 6.1 cm.

Analysis of all these data showed that skipjack which passed through New Zealand waters during the last two seasons were growing at about 8 cm a year. This is less than the rate of 21 cm per year calculated by Vooren (1976) from length-frequency distributions. However, the above analyses show that growth rates calculated from tagging data can vary widely from fish to fish on similar migrations and among fish migrating between different areas.

South Pacific Commission staff are carrying out further analyses on these and other tagging data to produce more definitive growth estimates. We therefore urge that our findings be viewed as a "first cut", the limitations of which will be made apparent in future SPC publications on skipjack growth.

International management

The international tagging data presented here (Table 14), in Habib, Clement, and Fisher (1980), and in Kearney (1980) show that New Zealand shares its skipjack resource with many other Pacific nations, including Australia, New Caledonia, Vanuatu, Kiribati, Fiji, Wallis Islands, Futuna, Tonga, Samoa, and French Polynesia. If indirect sharing, as outlined in Habib, Clement, and Fisher (1980) and alluded to in Kearney (1977b, page 12), is considered, the list is even longer and probably includes most nations of the central and western Pacific.

Most of these countries are developing or seeking to develop their skipjack fisheries (Kearney 1979a, 1979b). This results partly from the recent establishment of 200-mile exclusive economic zones by most Pacific nations and the associated requirement that they accept the responsibility for managing the oceanic resources within their zones. Skipjack is also the major fish resource in the Pacific, and initiatives to develop fisheries are bolstered by the generally held belief that the resource is underexploited. The developments in skipjack fisheries in the Pacific have inevitably led to discussions on management and there are moves to establish an international body with the responsibility for managing the Pacific skipjack resource. The arguments for establishing such a body are outlined in Kearney (1976, 1977b, 1979a, 1979b). If an international body were established, we would hope that all the Pacific nations, including New Zealand, would be signatories to it and that, with wide consultation on management matters, sound and rational exploitation of the Pacific skipjack resource would follow.

Summary

The 1979–80 (1980) purse-seine fishery for skipjack was pursued by 15 vessels which ranged from 23 to 79 m overall length and 135 to 1558 t gross weight.

Observations were made from aircraft and purse-seine vessels of surface schools of skipjack during the season. Skipjack migrated into New Zealand waters in November and were present in purse-seinable quantities intermittently until June. Although there was sightings effort over a wide area off both the North and South Islands, the effort was most concentrated in areas where, and at times when, large bodies of skipjack moved along the coast. Most of the sightings were made east and north of Great Barrier Island in January and off the west coast of the North Island in February-March. Up to 3163 t was seen at the surface on any half-day. Sightings effort was frequently interrupted by poor weather. As such weather was often followed by poor sightings, it is intimated that the poor weather induced the skipjack to leave the New Zealand coast. More skipjack were seen in the afternoon than at any other time during the day. The season's sighting, obtained by totalling the best half-day measures of apparent abundance, was 32 710 t. Real abundance was estimated to be 15 846 t.

The purse-seine fleet worked 1192 season-days: 420 were spent searching and fishing, 212 travelling, and 90 discharging fish or taking stores. There were 311 days lost through weather, 123 lost through repairs or survey, and 36 days were taken off.

During the 420 days fished 8931 t of skipjack were caught: 24 t in November, 50 t in December, 4605 t in January, 2342 t in February, 1797 t in March, 67 t in May, and 46 t in June. Most measures of effort and all measures of catch per effort also peaked in January. During that month the vessels averaged 15 t per season-day, 28 t per day fished, 17 t per set, and 39 t per successful set.

There was seining in seven areas on the New Zealand coast. Almost half the season's catch (4168 t) was taken east and north of Great Barrier Island (area C) in January and February with about two-fifths of the fishing effort. Next in importance was the west coast of the North Island between New Plymouth and Reef Point (areas J and K), where one-third of the season's catch was taken in February-March with about one-quarter of the effort. The remainder of the effort was expended in four other areas to take the rest of the catch.

Although fishing was conducted where bottom depths ranged from 30 to 1100 m, most skipjack were caught where the water was 100 to 399 m deep, that is, above the continental shelf edge.

Over half the fish were caught in the afternoon with about the same proportion of the season's effort and at catch rates close to the season's means. Fewer fish were caught in the morning and still fewer in the evening.

Almost half the season's catch was taken during full moon with about half the season's effort and at catch rates close to the season's means. About one-third of the catch was taken in the last quarter at the best catch rates. Fewer fish were taken during the other phases and at low catch rates.

Fishing was conducted where surface water temperatures ranged from 15.5° to 23.9°C, but most skipjack were caught in 19° to 21.9°C water (designated "skipjack water" by us). There, most of the fishing effort was expended and the best catch rates were obtained.

Skipjack were caught in areas where sea surface salinities ranged from 34.9 to 35.8 parts per thousand. However, the best fishing was in water of 35.0 to 35.5 parts per thousand salinity, where two-thirds of the fish were taken at catch rates close to the season's means. Most of the remaining catch was taken in waters of higher salinity and at the best catch rates.

Most (8031 t) of the season's catch was taken outside the 12-mile limit where the limit coincided with the continental shelf edge. This distribution of fishing largely reflected the distribution of the resource, though most of the fishing fleet was also restricted to fishing outside the limit.

Almost 38 000 skipjack were measured from 244 catches. Early and late season catches were predominantly of big fish (51 to 63 cm in length, 2.8 to 5.6 kg in weight). However, for most of the season, most fish were smaller (46 to 54 cm, 2 to 3.4 kg). Small fish (35 to 46 cm, 0.8 to 2 kg) were also present in the catches.

Stomach contents were investigated in 1237 skipjack during the season. Almost two-thirds of the stomachs were empty. Those with food contained predominantly the euphausiid *Nyctiphanes australis*. Other items of

food were fish and squid. Few fish contained much food: almost four-fifths were less than one-quarter full, almost one-fifth between a quarter and half full, and the remainder over half full. There was an early morning low in feeding followed by a late morning peak, an early afternoon low, and an evening peak.

Gonads were examined in the fish dissected for stomach analyses; 668 were female and 569 male. All gonads were undeveloped.

Analysis of some of SPC's skipjack tagging data indicated that the skipjack which passed through New Zealand waters during the last two seasons were growing at about 8 cm a year.

International tagging data have recently established that New Zealand shares its skipjack resource with other Pacific nations, including Australia, New Caledonia, Vanuatu, Kiribati, Fiji, Wallis Islands, Futuna, Tonga, Samoa, and French Polynesia. This raises the question of international management of the skipjack resource in the Pacific Ocean. Further tagging apparently indicated that skipjack overwinter in New Zealand waters, but reasons are advanced to show that this is unlikely. These include the low winter sea temperatures, the lack of sightings of skipjack in winter, and the confirmed movement of skipjack from New Zealand to the waters of other nations established through tagging.

References

Barkley, R.A., Neill, W.H., and Gooding, R.M. 1978: Skipjack tuna, *Katsuwonus pelamis,* habitat based on temperature and oxygen requirements. *Fishery Bulletin (NOAA) 76 (3)*: 653–62.

Bell, G.R. 1976: Aerial spotting for pelagic fishes. *In* Proceedings of the Skipjack Tuna Conference, July 1976, pp. 47–8. *Fisheries Research Division Occasional Publication, N.Z. Ministry of Agriculture and Fisheries, No. 11.*

Blackburn, M. 1965: Oceanography and the ecology of tunas. *In* Barnes, H. (Ed.), "Oceanography and Marine Biology: An Annual Review", Vol. 3, pp. 299–322. George Allen and Unwin, London.

Brock, V.E. 1954: Some aspects of the biology of the aku, *Katsuwonus pelamis,* in the Hawaiian Islands. *Pacific Science 8*: 94–104.

Clement, I.T. (George). 1976: Distribution and abundance of skipjack, 1975–76. *In* Proceedings of the Skipjack Tuna Conference, July 1976, pp. 36–9. *Fisheries Research Division Occasional Publication, N.Z. Ministry of Agriculture and Fisheries, No. 11.*

———1978: School fish sightings around New Zealand, 1976–77. *In* Habib, G., and Roberts, P.E. (Comps.), Proceedings of the Pelagic Fisheries Conference, July 1977, pp. 35–42. *Fisheries Research Division Occasional Publication, N.Z. Ministry of Agriculture and Fisheries, No. 15.*

Dizon, A.E. 1977: Effect of dissolved oxygen concentration and salinity on swimming speed of two species of tunas. *Fishery Bulletin (NOAA) 75 (3)*: 649–53.

Dragovich, A. 1970: The food of skipjack and yellowfin tunas in the Atlantic Ocean. *Fishery Bulletin, U.S. Fish and Wildlife Service 68 (3)*: 445–60.

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, pp. 31–5. *Fisheries Research Division Occasional Publication, N.Z. Ministry of Agriculture and Fisheries, No. 11.*

Eggleston, D., and Paul, L.J. 1978: Satellites, sea temperatures, and skipjack. *In* Habib, G., and Roberts, P.E. (Comps.), Proceedings of the Pelagic Fisheries Conference, July 1977, pp. 75–84. *Fisheries Research Division Occasional Publication, N.Z. Ministry of Agriculture and Fisheries, No. 15.*

Habib, G. 1976: The 1975-76 purse seine skipjack fishery. *In* Proceedings of the Skipjack Tuna Conference, July 1976, pp. 40–6. *Fisheries Research Division Occasional Publication, N.Z. Ministry of Agriculture and Fisheries, No. 11.*

———1978a: Skipjack biology and the 1976–77 purse-seine fishery. *In* Habib, G., and Roberts, P.E. (Comps.), Proceedings of the Pelagic Fisheries Conference, July 1977, pp. 17–26. *Fisheries Research Division Occasional Publication, N.Z. Ministry of Agriculture and Fisheries, No. 15.*

———(Comp.) 1978b: Supplement on N.Z. 1977–78 tuna season. *Catch '78, August Supplement.* 24 pp.

Habib, G., Clement, I.T., and Fisher, K.A. 1980: The 1978–79 purse-seine skipjack fishery in New Zealand waters. *Fisheries Research Division Occasional Publication, N.Z. Ministry of Agriculture and Fisheries, No. 26.* 39 pp.

———(in press): The 1977–78 purse-seine skipjack fishery in New Zealand waters. *Fisheries Research Division Occasional Publication, N.Z. Ministry of Agriculture and Fisheries, No. 25.*

Heath, R.A. 1973: Present knowledge of the oceanic circulation and hydrology around New Zealand — 1971. *Tuatara 20 (3)*: 125–40.

Hinds, V.T. 1974: Purse seining. *Catch '74 1 (4)*: 5–16.

Kearney, R.E. 1976: A regional approach to fisheries management in the South Pacific Commission area. Paper presented to the South Pacific Forum Meeting on the Law of the Sea, Suva, 13 and 14 October, 1976. South Pacific Commission, Noumea, New Caledonia. 19 pp.

———1977a: Interim report of the activities of the Skipjack Survey and Assessment Programme in the waters of Papua New Guinea (2 October-1 November 1977). *Skipjack Survey and Assessment Programme Preliminary Country Report, South Pacific Commission, Noumea, New Caledonia, No. 1.* 39 pp.

———1977b: The Law of the Sea and regional fisheries policy. *Occasional Paper, South Pacific Commission, Noumea, New Caledonia, No. 2.* 53 pp.

———1978: Skipjack Survey and Assessment Programme annual report for the year ending 31 December 1977. South Pacific Commission, Noumea, New Caledonia. 28 pp.

———1979a: Some problems of developing and managing fisheries in small island states. *Occasional Paper, South Pacific Commission, Noumea, New Caledonia, No. 16.* 18 pp.

———1979b: An overview of recent changes in the fisheries for highly migratory species in the western Pacific Ocean and projections for future developments. *South Pacific Bureau for Economic Co-operation, SPEC (79)17.* 99 pp.

———1980: Skipjack Survey and Assessment Programme annual report for the year ending 31 December 1979. South Pacific Commission, Noumea, New Caledonia. 21 pp.

Kearney, R.E., and Gillett, R.D. 1979: Interim report of the activities of the Skipjack Survey and Assessment Programme in the waters of Australia (1 April-13 May 1979). *Skipjack Survey and Assessment Programme Preliminary Country Report, South Pacific Commission, Noumea, New Caledonia, No. 17.* 17 pp.

Kearney, R.E., and Hallier, J-P. 1979: Interim report of the activities of the Skipjack Survey and Assessment Programme in the waters of New Zealand (17 February-27 March 1979). *Skipjack Survey and Assessment Programme Preliminary Country Report, South Pacific Commission, Noumea, New Caledonia, No. 16.* 20 pp.

———1979b: Second interim report of the activities of the Skipjack Survey and Assessment Programme in the waters of Papua New Guinea (14 May-2 July 1979). *Skipjack Survey and Assessment Programme Preliminary Country Report, South Pacific Commission, Noumea, New Caledonia, No. 18.* 17 pp.

Magnuson, J.J. 1969: Digestion and food consumption by skipjack tuna (*Katsuwonus pelamis*). *Transactions of the American Fisheries Society 98 (3)*: 379–92.

Magnuson, J.J., and Heitz, J.G. 1971: Gill raker apparatus and food selectivity among mackerels, tunas, and dolphins. *Fishery Bulletin (NOAA) 69 (2)*: 361–70.

Marr, J.C. 1951: On the use of the terms abundance, availability and apparent abundance in fishery biology. *Copeia 1951*: 163–9.

Nakamura, E.L. 1965: Food and feeding habits of skipjack tuna (*Katsuwonus pelamis*) from the Marquesas and Tuamotu Islands. *Transactions of the American Fisheries Society 94 (3)*: 236–42.

Orange, C.J. 1961: Spawning of yellowfin tuna and skipjack in the eastern tropical Pacific, as inferred from studies of gonad development. *Bulletin of the Inter-American Tropical Tuna Commission 5*: 459–502.

Raju, G. 1964: Studies on the spawning of the oceanic skipjack *Katsuwonus pelamis* (Linnaeus) in Minicoy waters. *In* Proceedings of the Symposium on Scombroid Fishes held at Mandapam Camp from January 12–15, 1962, pp. 744–68. Marine Biological Association of India, Mandapam Camp, Southern India.

RICHARDSON, B.J. 1978: Skipjack tuna stock identification. *In* Habib, G., and Roberts, P.E. (Comps.), Proceedings of the Pelagic Fisheries Conference, July 1977, pp. 63–4. *Fisheries Research Division Occasional Publication, N.Z. Ministry of Agriculture and Fisheries, No. 15.*

SECKEL, G.R. 1972: Hawaiian-caught skipjack tuna and their physical environment. *Fishery Bulletin (NOAA) 72 (3)*: 763–87.

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

SQUIRE, J.L. 1972: Apparent abundance of some pelagic marine fishes off the southern and central California coast as surveyed by an airborne monitoring program. *Fishery Bulletin (NOAA) 70 (3)*: 1005–19.

STRASBURG, D.W., JONES, E.C., and IVERSEN, R.T.B. 1968: Use of a small submarine for biological and oceanographic research. *Journal du Conseil permanent international pour l'Exploration de la Mer 31 (3)*: 410–26.

VOOREN, C.M. 1976: Biological data on skipjack in New Zealand waters, 1973–76. *In* Proceedings of the Skipjack Tuna Conference, July 1976, pp. 12–6. *Fisheries Research Division Occasional Publication, N.Z. Ministry of Agriculture and Fisheries, No. 11.*

WALDRON, K.D., and KING, J.E. 1963: Food of skipjack in the central Pacific. *In* Rosa, H., Jr. (Ed.), Proceedings of the World Scientific Meeting on the Biology of Tunas and Related Species, pp. 1431–57. *FAO Fisheries Reports, No. 6, Vol. 3.*

YABE, H., YABUTA, Y., and UEYANAGI, S. 1963: Comparative distribution of eggs, larvae and adults in relation to biotic and abiotic environmental factors. *In* Rosa, H., Jr. (Ed.), Proceedings of the World Scientific Meeting on the Biology of Tunas and Related Species, pp. 979–1009. *FAO Fisheries Reports, No. 6, Vol. 3.*

YOSHIDA, H.O. 1964: Skipjack tuna spawning in the Marquesas Islands and Tuamotu Archipelago. *Fishery Bulletin, U.S. Fish and Wildlife Service 65 (2)*: 479–88.

YUEN, H.S.H. 1959: Variability of skipjack response to live bait. *Fishery Bulletin, U.S. Fish and Wildlife Service 60 (162)*: 147–60.