The 1977–78 Purse-seine Skipjack Fishery in New Zealand Waters

G. Habib
I. T. Clement
K. A. Fisher

Fisheries Research Division Occasional Publication No. 25

The 1977–78 Purse-seine Skipjack Fishery in New Zealand Waters

By G. Habib,
I. T. Clement*,
and K. A. Fisher

*Fisheries Management Division,
Ministry of Agriculture and Fisheries,
Tauranga

Fisheries Research Division
Occasional Publication No. 25
1980

Published by the New Zealand Ministry of
Agriculture and Fisheries
Wellington
1980

ISSN 0110–1765

Contents

Introduction

Since successful purse-seine surveys of New Zealand's skipjack (*Katsuwonus pelamis* Linnaeus, 1758) resource were carried out in 1974 and 1975 (Hinds 1974, Eggleston 1976), there has been a rapidly developing summer fishery for this species. Landings have risen from 5000 t in 1975–76 (1976 season) to 9500 t in 1977–78 (1978 season). 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 were presented to the fishing industry and others at conferences in 1976 (Clement 1976, Habib 1976, Vooren 1976) and 1977 (Clement 1978a, Eggleston and Paul 1978, Habib 1978a, Richardson 1978). This publication presents information on the 1977–78 (1978) purse-seine skipjack fishery in New Zealand, which was previewed by Habib (1978b).

Materials and methods

Vessels

These were *Apollo* (1558 gross tonnes, 79 m overall length, 2000 t carrying capacity); *Zapata Discoverer* (1499 t, 69 m, 1650 t); *Michelangelo* (1066 t, 62 m, 1270 t); *Kerri M* (930 t, 54 m, 740 t); *Finisterre* (1063 t, 62 m, 1150 t); *Voyager* (1472 t, 73 m, 1600 t); *Janet D* (498 t, 35 m, 330 t); *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 New Zealand Pelagic Fisheries Development Company (1976) Limited with *Finisterre*, the company-owned vessel. These vessels, which operated in the eastern Pacific Ocean tuna fishery outside the New Zealand season, travelled to New Zealand during November-December for the skipjack season.

Voyager joined the New Zealand fishery from Papua New Guinea in February and fished on a freelance basis outside the 12-mile territorial sea.

The remaining vessels, operated by other New Zealand companies, joined the skipjack fishery from other New Zealand pelagic fisheries.

The vessels' nets ranged from 640 to 1463 m (2100 to 4800 ft) in length and 64 to 252 m (210 to 827 ft) in depth.

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 and fishing, 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, food contents, and details of blood samples from skipjack.

Skipjack fork lengths were measured to the whole centimetre below the actual length in samples of fish from all catches taken while observers were aboard the vessels. For studies on reproduction and feeding, 5 to 20 fish were dissected from occasional catches. The developmental stage of the gonads was judged by use of criteria described by Orange (1961) and Raju (1964a). Stomach contents were either identified *in situ* or stored frozen for later identification ashore.

Blood samples were collected from seven skipjack catches by the method outlined by Sharp (1969). These were for continuation of genetic studies on skipjack subpopulation identification.

Ministry of Agriculture and Fisheries logs were also kept by observers and pilots in "spotter" aircraft flying in support of the skipjack fishery. Sightings of numbers and sizes of schools were recorded with notes on the date, time of day, locality, weather, and sea state. Most observations were made from commercial fish-spotting flights, supplemented by observations from wider-ranging MAF aerial surveys. These surveys were conducted around the North Island and part of the South Island in November-December 1977 (Clement and Habib 1978), January and April 1978 (Clement 1978b), and May 1978 (Clement 1978c).

The areas from the Bay of Plenty to North Cape received the most consistent and intensive sightings effort. However, as the season progressed and the location of the fishery changed, effort was also directed at west coast waters of both North and South Islands and at Hawke Bay (Clement 1978d).

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).

Sea surface temperatures were available from three sources: observers used insulated bottles to record temperatures from the purse-seine vessels; an infrared thermometer (described in Robertson 1975) in one of the spotter aircraft recorded temperatures; and, as in 1977 (Eggleston and Paul 1978), MAF received sea surface temperature charts for the New Zealand region from the National Environmental Satellite Service in the National Oceanic and Atmospheric Administration of the United States Department of Commerce. The manner in which the satellites measured the temperatures and the limitations of these data are discussed in Eggleston and Paul (1978).

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 spent searching and fishing, travelling, in port, at anchor, or at sea drifting and days taken off. **Days fished** are days on which a net was set or searching activity occurred 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.

The ranges given with mean catch-effort data refer to the range of catch per unit of effort between the performances of the top and bottom vessels in the purse-seine fleet.

Standardisation of fishing effort

Generally a stock of fish has different vulnerability to different types of fishing gear. In purse seining for tuna, large vessels catch more fish per unit of effort than small vessels. They are therefore said to have a higher fishing power than small seiners. To use a homogeneous measure of fishing effort in assessing the dynamics of a tuna fishery in which different sized purse seiners are used, the amount of effort expended by each vessel or class of vessel must be related to that which would have been expended by some "standard" vessel or class of vessel in catching the same amount of fish. In this way, in any given time and area, the total amount of standard effort used can be calculated irrespective of the composition of the fleet. The standard effort can then be related to the total catch taken in that time and area.

A measure of relative fishing power is used to standardise fishing effort. It is usually obtained by relating the catch per unit of effort of a vessel or class of vessel to the catch per unit of effort of the standard vessel or class of vessel.

Catch of skipjack per day fished was computed from logbook data for each vessel in the New Zealand fleet for each area by 2-week periods. These data were analysed by the maximum likelihood estimates method outlined by Joseph and Calkins (1969). The fishing power of each vessel was estimated relative to the standard vessel *Kerri M*.(This vessel was chosen as the standard because its size and fishing performance were near the mid point for the fleet.) Each day fished by *Kerri M* was a standard day fished. Days fished by all other vessels were then standardised according to their fishing capabilities relative to those of *Kerri M*. For each *Kerri M* standard day fished, the equivalent number of standard days fished by the fleet ranged from 3.35 for the top vessel to 0.24 for the bottom vessel. That is, the top vessel had 3.35 times the fishing power of *Kerri M* and therefore each day it spent fishing was equal to 3.35 standard days. Conversely, the bottom vessel had to do 4 days' fishing for every standard day fished.

Kerri M was also the standard vessel during the last two seasons. However, because the composition of the fleets and performance of the vessels changed between seasons, the range of standard days fished for each *Kerri M* day in 1976 was 1.70 (top vessel) to 0.31 (bottom vessel) and in 1977, 4.06 to 0.13.

Abundance

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

Apparent abundance has been 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. 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, moderating this overestimate are other factors which probably caused the measure of apparent abundance on each half-day to be underestimated. These factors are the cursory nature of much sightings effort, the inadequate sightings effort in all skipjack fishing areas at some time during the season (see Table 1), and the movement of schools through the different levels 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, which is discussed more fully later, refers to estimates of the absolute quantity of skipjack which passed through New Zealand waters. This measure was largely free of double sightings.

Comparisons with other seasons

Throughout this publication comparisons are made between the 1978 season and previous seasons. This is done to show the changes from one season to another, and possible explanations are given for these changes.

Results and discussion

Distribution and apparent abundance of skipjack

Skipjack were seen in New Zealand waters from 25 December 1977 to 30 May 1978. Half-day estimates of quantities were derived for each area investigated throughout the season (Fig. 1, Table 1), and these estimates were totalled to yield overall half-day estimates for all areas (Fig. 2). Each day's spotting effort could usually be divided into morning and afternoon periods, and 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.

Skipjack concentrations—"bodies" of fish

Much of the following discussion centres on the concept of a "body" of fish. Often during the season when a large quantity of skipjack was present off the coast, the fish were found in a number of schools distributed in a defined area. Such groups of schools, here referred to as bodies, tended to move along the coastline as discrete units and, in terms of distribution and abundance, were studied as units.

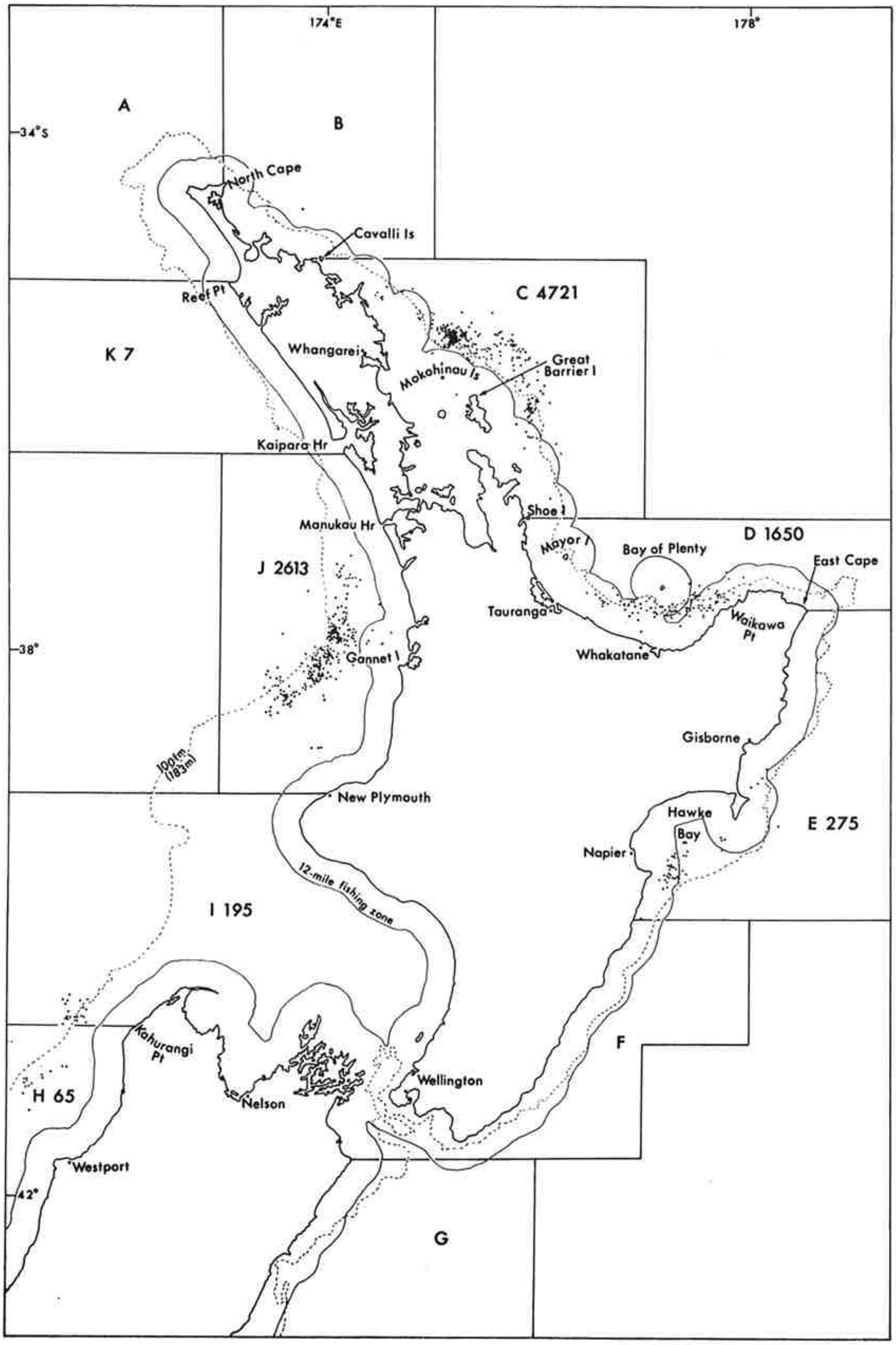


Fig. 1: Set positions and quantities (t) of skipjack caught by area in the 1978 purse-seine skipjack fishery in New Zealand.

TABLE 1: Sightings effort from aircraft (+) and purse-seine vessels (x) by half-day by area in the 1978 purse-seine skipjack fishery in New Zealand

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

Sig. 2*

TABLE 1: Sightings effort from aircraft (+) and purse-seine vessels (x) by half-day by area in the 1978 purse-seine skipjack fishery in New Zealand—*continued*

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

TABLE 1: Sightings effort from aircraft (+) and purse-seine vessels (x) by half-day by area in the 1978 purse-seine skipjack fishery in New Zealand—*continued*

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

TABLE 1: Sightings effort from aircraft (+) and purse-seine vessels (x) by half-day by area in the 1978 purse-seine skipjack fishery in New Zealand—*continued*

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

TABLE 1: Sightings effort from aircraft (+) and purse-seine vessels (x) by half-day by area in the 1978 purse-seine skipjack fishery in New Zealand—*continued*

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

TABLE 1: Sightings effort from aircraft (+) and purse-seine vessels (x) by half-day by area in the 1978 purse-seine skipjack fishery in New Zealand—*continued*

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

Early season sightings, 25 December to 10 January, north-east North Island

Although searching began on 1 December, the first skipjack were not sighted until Christmas Day. They were in two schools totalling about 120 t of fish on "the Cross", the position east of Great Barrier Island where latitude 36° S crosses longitude 176° E. During the following 12 days, up to 1950 t of skipjack per half-day appeared in this area and moved slowly as a body of fish north-west along the edge of the continental shelf (that is, along the 200-m depth contour) to east of Cape Brett (Fig. 3). Many large schools, some containing up to 400 t of fish, were sighted during this period. For example, on 2 January 1978, 16 large schools were seen. During the second week in January sightings in this area declined significantly. There were no sightings at the end of December because of poor weather (see Fig. 2).

Although there was sightings effort around most of the North Island in December and early January, the only other sighting of skipjack during this period was of an 80-t school off Cavalli Islands (area B) on 3 January.

Sightings, 11–27 January, north-east North Island

On 11 January another body of skipjack appeared on the Cross. This moved to north of Mokohinau Islands and remained there in often large, stable schools for over a week (Fig. 4). On 18 January 10 schools were sighted there of 100 t to 250 t; on 20 January there were 20 large schools. The largest sightings were during the afternoon. These built up from 500 t on the 11th, through 650 t on the 14th, 1120 t on the 16th, 1875 t on the 18th, to 2975 t on the 20th. Sightings then rapidly declined to 200 t on 26 January. No fish were seen on the Cross on the 27th. The maximum morning sighting during this period was 2345 t on 20 January.

The only other sightings outside area C during this period were of 200 t (3 schools) north of Cavalli Islands on the 15th, and 492 t (69 small schools) north of North Cape on the 16th. Most of the sightings effort was restricted during this time to the north-east coast of the North Island between Bay of Plenty and North Cape (see Table 1). The fish seen off North Cape were possibly the forerunners of another body of skipjack. However, despite regular surveys throughout the season, this was the only significant sighting in the north. Schools were seen there on only three further occasions.

Sightings, 25 January to end of season, Bay of Plenty

During the last week of January, skipjack schools were sighted for the first time in the Bay of Plenty (Fig. 2, area D). Quantities of fish built up to 694 t on 8 February, and 300 to 650 t showed on most afternoons through to that date. Sightings then declined to the end of February; only on occasional days were more than 100 t seen, and on many days none were seen at all. No skipjack showed in this area in March and only small quantities in April and May.

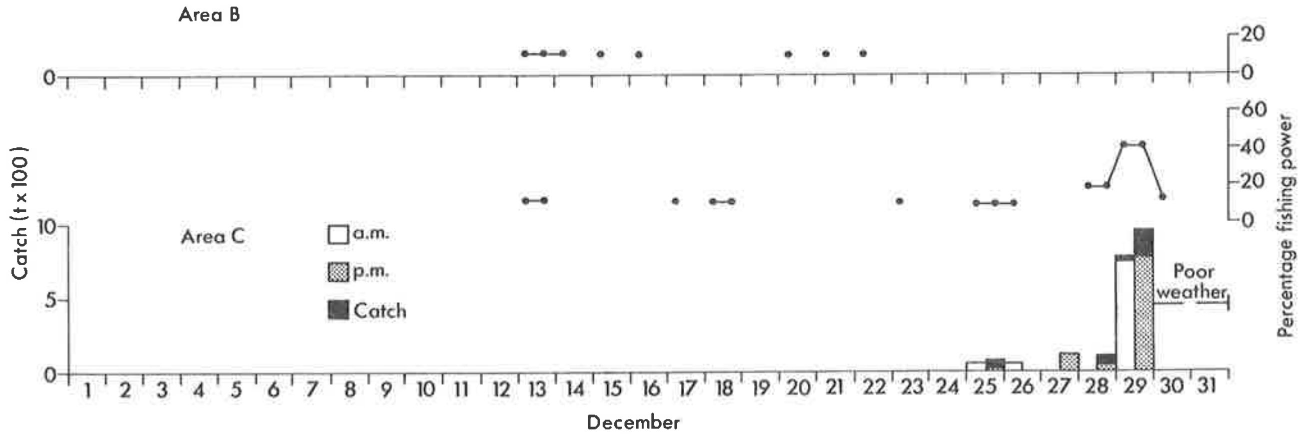


Fig. 2 (above and following pages): Half-day sightings and catches by area and for all areas combined during the 1978 skipjack season in New Zealand, and half-day percentages of fishing power used by the purse-seine fleet.

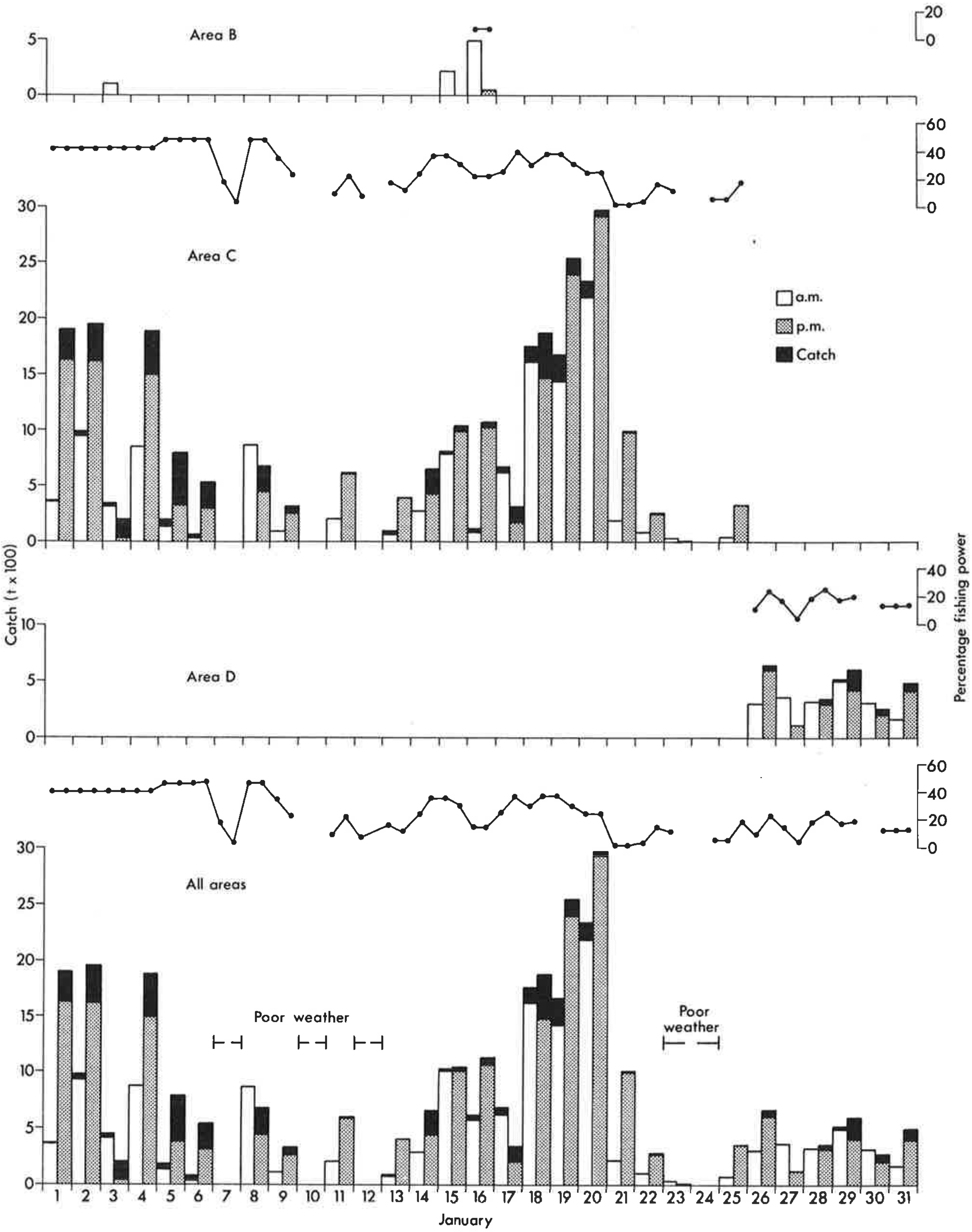


Fig. 2—*continued.*

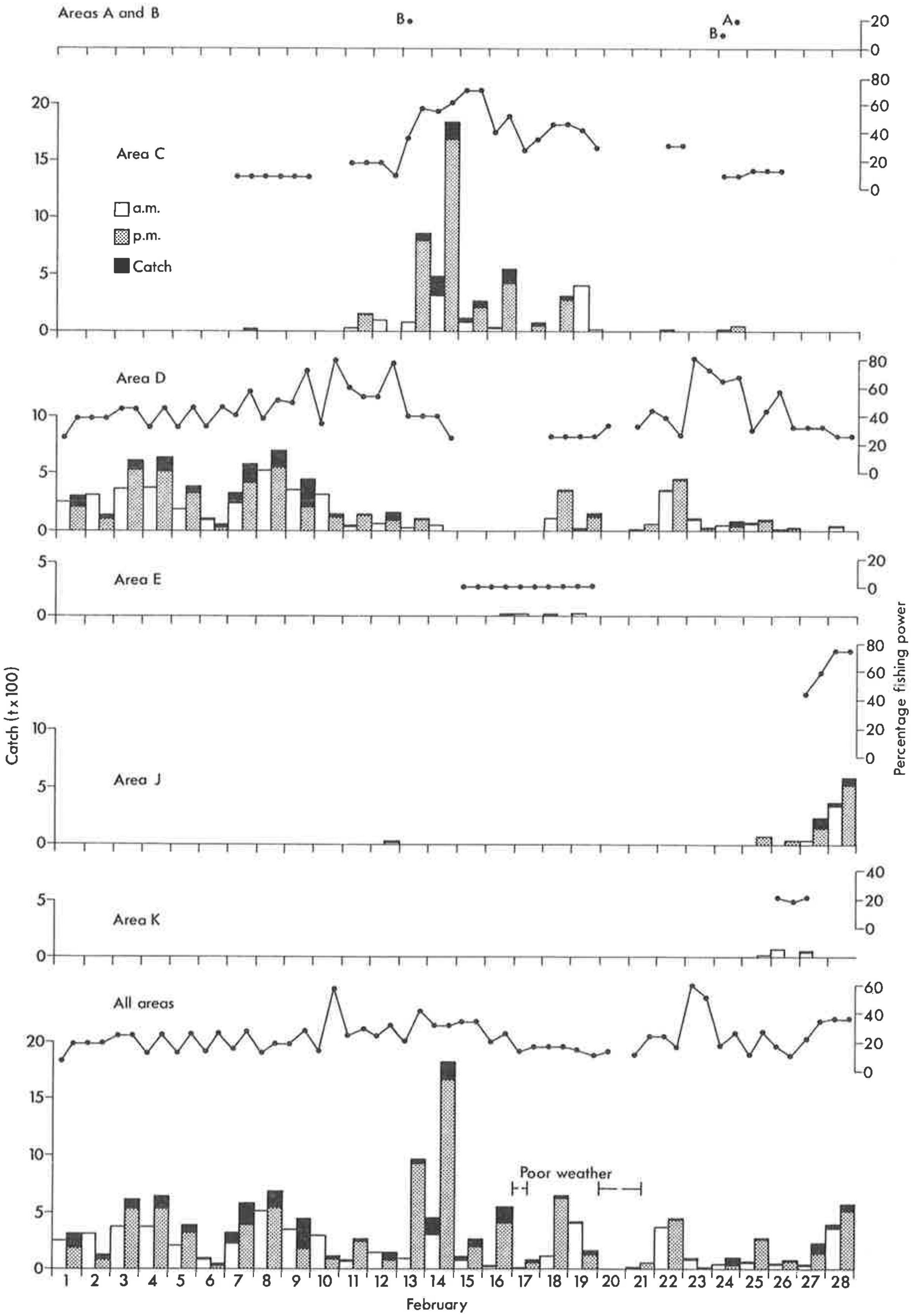


Fig. 2—*continued.*

Sig. 3*

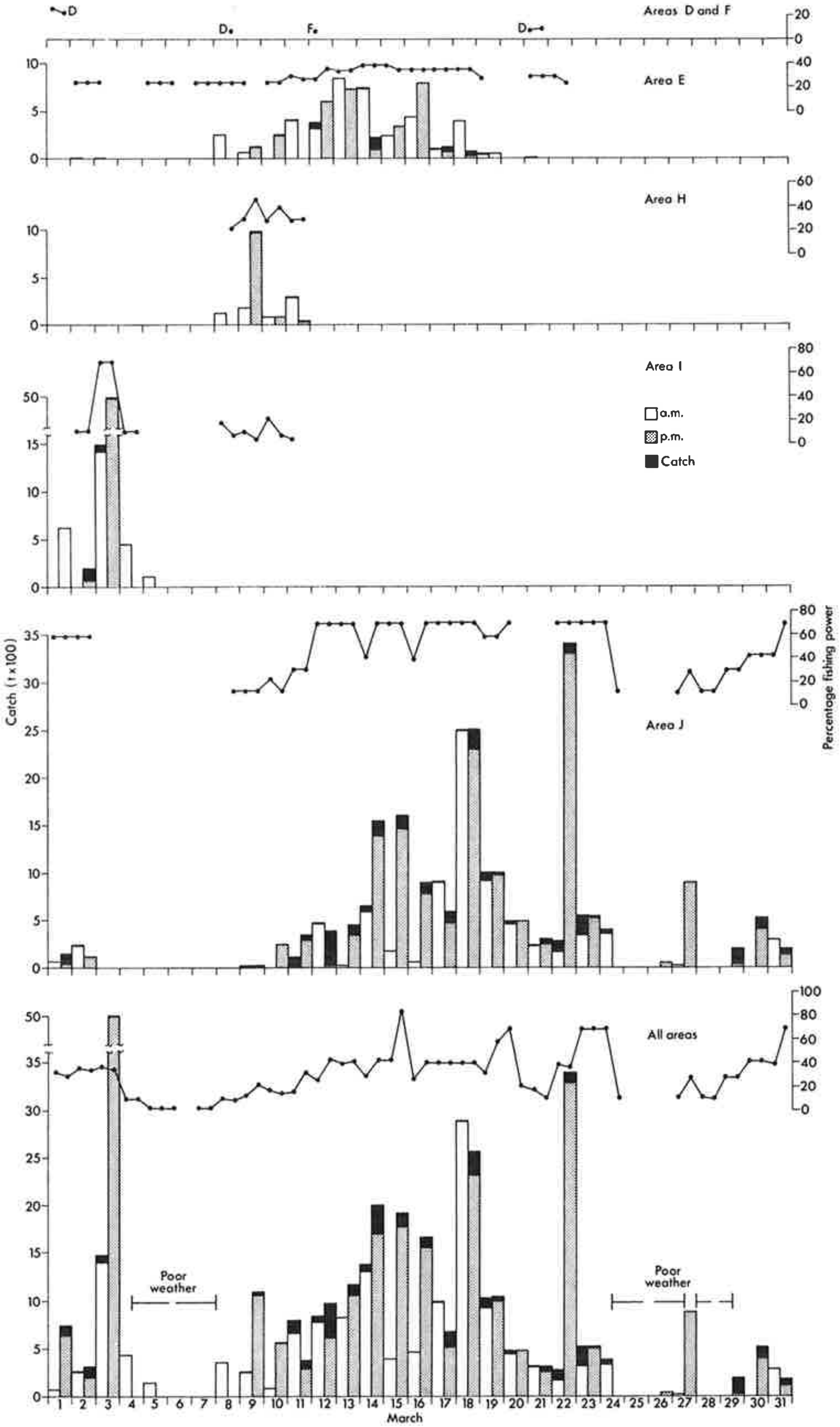
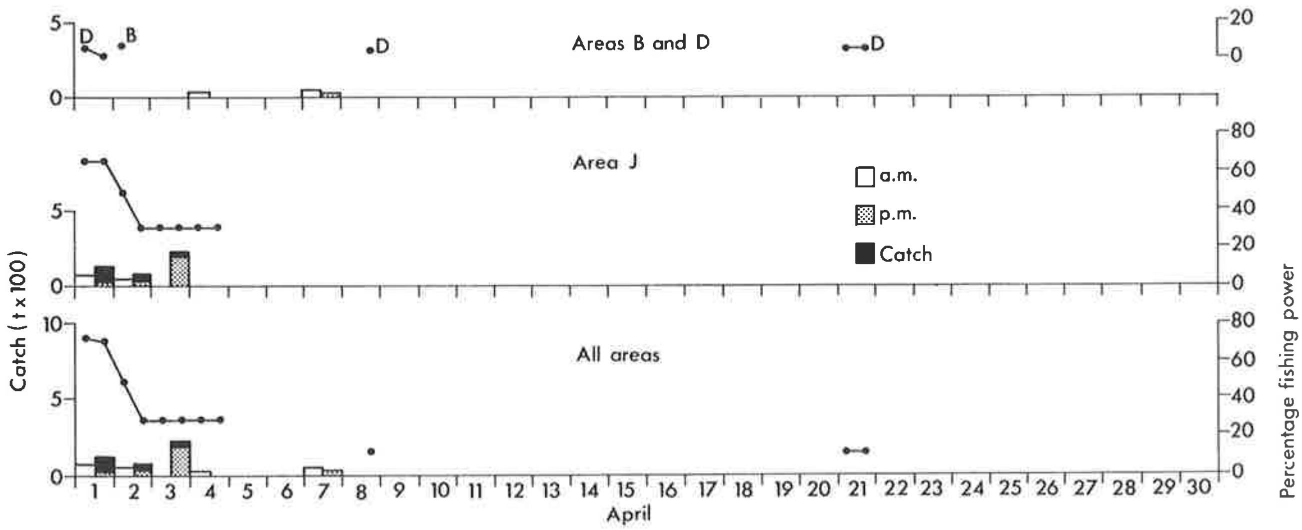


Fig. 2—*continued.*



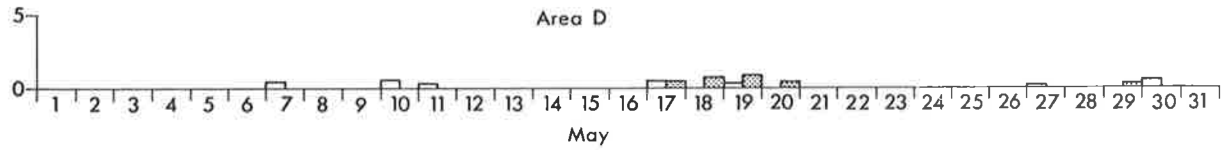


Fig. 2—*continued.*

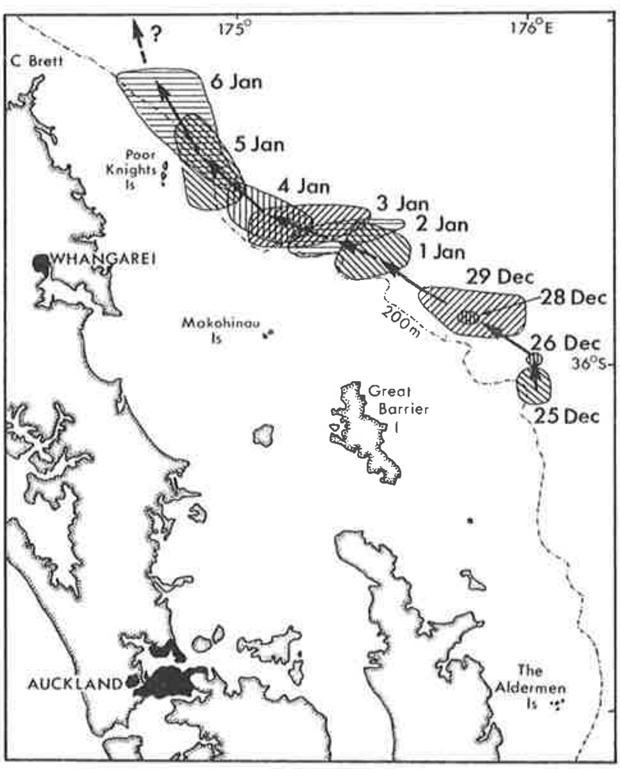


Fig. 3: Daily location of the main concentration of skipjack off the north-east coast of the North Island, 25 December 1977 to 6 January 1978.

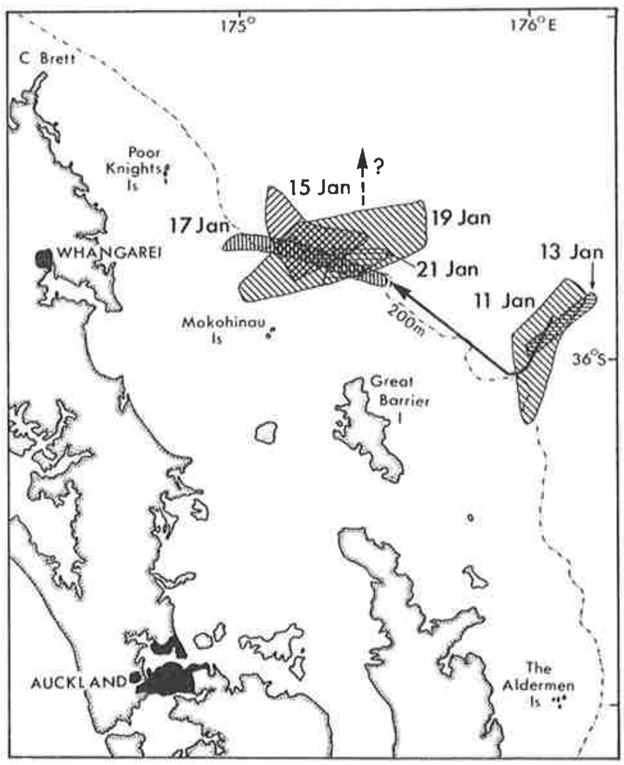


Fig. 4: Daily location of the main concentration of skipjack off the north-east coast of the North Island, 13 to 21 January 1978.

Sightings, mid February to end of season, north-east North Island

In mid February large quantities of skipjack were again sighted off Great Barrier Island on the Cross. Between 11 and 18 February some of these fish moved north-west along the shelf edge to north of Poor Knights Islands and others moved south to The Aldermen Islands (Fig. 5). Sightings of up to 1843 t per half-day were recorded during this period (Fig. 2). However, after 14 February quantities seen declined and sightings effort through to the end of May failed to find any further large numbers in this area.

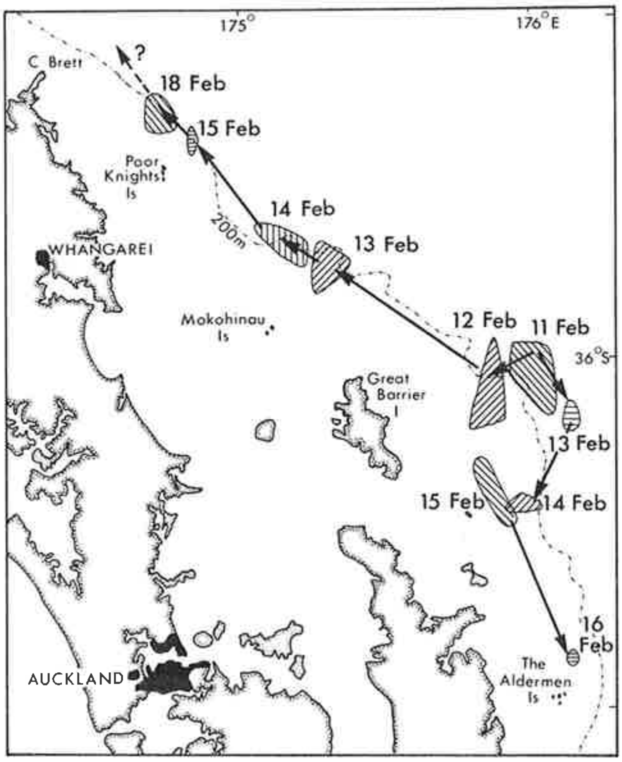


Fig. 5: Daily location of the main concentration of skipjack off the north-east coast of the North Island, 11 to 18 February 1978.

Sightings, late February-early March, west coast North Island

During February, skipjack were also sighted off the west coast. The first sightings were on 25 February off and south of Kaipara Harbour (Fig. 2, February, areas K and J). Over the next 5 days these fish moved south-west along the shelf edge to west of Tirau Point (Fig. 6). Quantities increased during this time to almost 600 t per half-day (Fig. 2, February, area J). Between 3 and 7 March there was little sightings effort in this area.

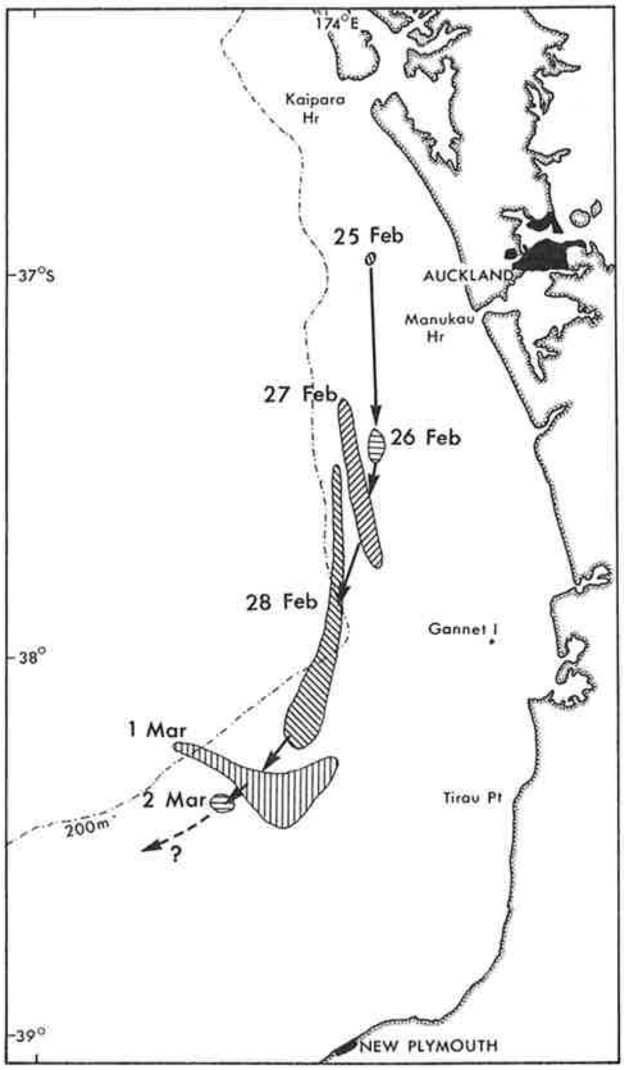


Fig. 6: Daily location of the main concentration of skipjack off the west coast of the North Island, 25 February to 2 March 1978.

Sightings, west coast South Island

In early March, skipjack were sighted to the west of Cape Farewell in the South Island (Fig. 7). Quantities increased rapidly from 610 t on 1 March to a conservatively estimated 5000 t on 3 March (Fig. 2, March, area I). Most schools seen on that day contained over 100 t of fish; many were larger than 200 t and some exceeded 400 t. On 4 March the quantity seen fell to 450 t, on the 5th 100 t, and no fish were seen off this coast on the 6th and 7th. However, on the 8th fish were found to the south (Fig. 2, March, area H). Searching in this area earlier in March had been unproductive and therefore it seems likely that the fish which had been off Cape Farewell had moved

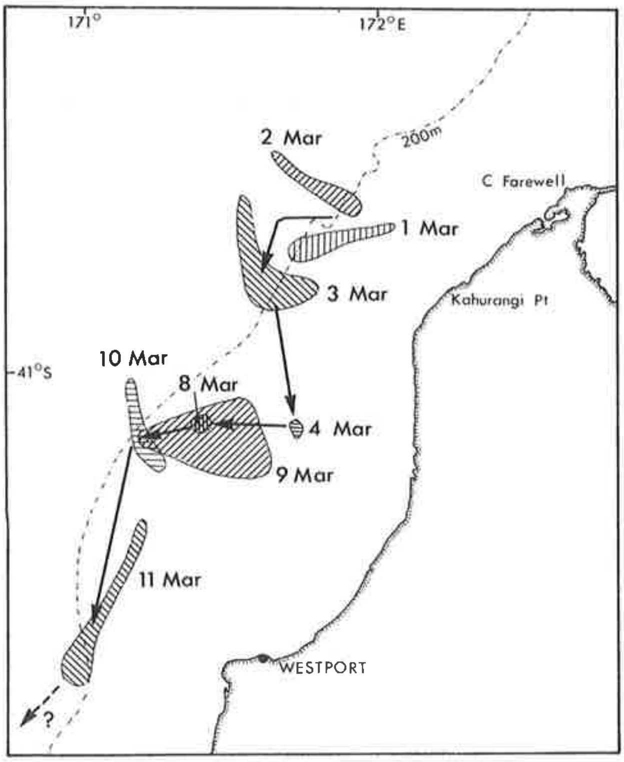


Fig. 7: Daily location of the main concentration of skipjack off the north-west coast of the South Island, 1 to 11 March 1978.

south. Quantities were 970 t on 9 March and 300 t on 11 March. Flights off the west coast of the South Island on 20 March and 1 April saw no signs of skipjack.

Sightings, 10 March to end of season, west coast North Island

At about the same time as sightings decreased off Westport, fish were again found west of the North Island near Gannet Island. They moved south-west in a similar manner to those recorded in this area in late February-early March and finally disappeared from the surface west of Tirau Point on 15 March (Fig. 8). It is thought that the fish seen earlier in this area disappeared in the same way (see Fig. 6).

While the above body was moving south-west another body, which appeared north of Manukau Harbour on 10 March, also moved south-west to arrive off Tirau Point on 18 March. Skipjack remained in this general area until the end of the month (Fig. 9).

We believe that at least a further two bodies of skipjack moved south-west off this coast during the second half of March. This is based on sightings off Kaipara Harbour on 15 March and Manukau Harbour on the 17th (one body) and a large concentration of fish seen north of Gannet Island at the end of March (another body). In addition, the quantity of fish seen off this coast increased significantly from about 340 t on 10 March to 3400 t on the 22nd. It is possible that several bodies of fish contributed to this high total. Quantities then fell to 190 t on 3 April (Fig. 2, April, area J).

Sightings, Hawke Bay

In February and March skipjack were sighted in Hawke Bay (Fig. 2, February and March, area E). Quantities increased steadily from 345 t on 8 March to 800 t on the 13th. Schools ranged in size from 2 to 150 t and were located mostly in a small area about

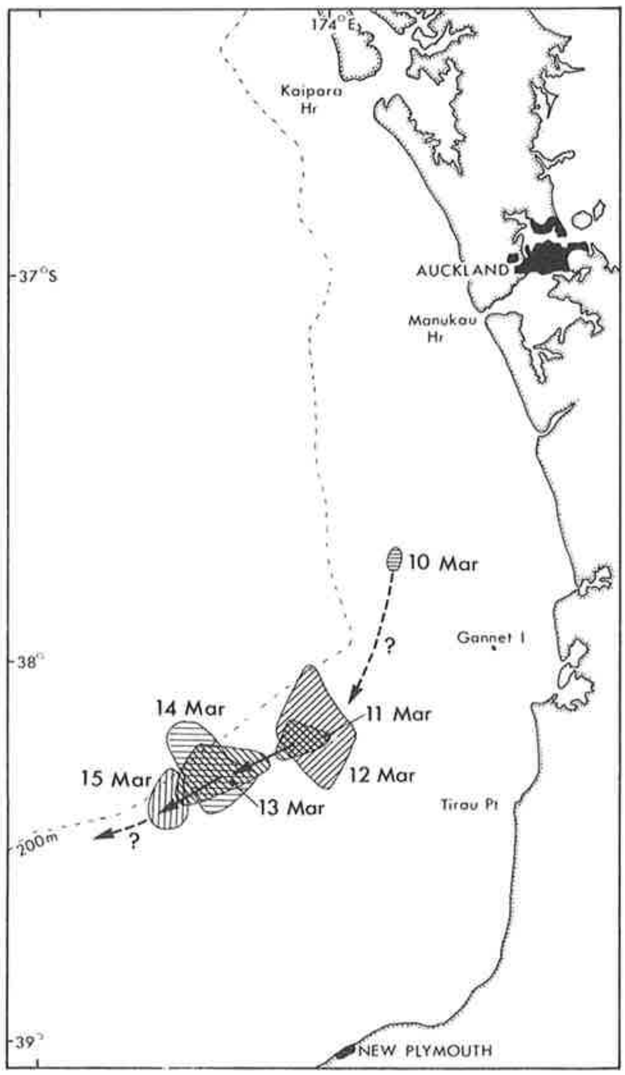


Fig. 8: Daily location of the main concentration of skipjack off the west coast of the North Island, 10 to 15 March 1978.

TABLE 2: Monthly skipjack sightings in New Zealand, 1976 to 1978, computed by totalling maximum half-day sightings*. (Data for 1976 and 1977 from Clement (1978a))

Season	Period of sightings effort	No. of days of sightings effort	Mean quantity sighted per day (t)	Quantity sighted Oct (t)	Quantity sighted Nov (t)	Quantity sighted Dec (t)	Quantity sighted Jan (t)	Quantity sighted Feb (t)	Quantity sighted Mar (t)	Quantity sighted Apr (t)	Quantity sighted May (t)	Total quantity sighted (t)
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

* For example, in December of the 1978 season, maximum sightings were made in the morning on the 26th and in the afternoon on the 25th and the 27th to 29th (see Fig. 2); these sightings totalled 1225 t for that month.

\+ Percentage of season's total.

++ No sightings effort.

40 km south-east of Napier. Small quantities were sighted further south and also to the north off Gisborne. Sightings declined rapidly after 16 March and no further skipjack were sighted in this area after 21 March.

Sightings, 1976, 1977, and 1978 seasons

More skipjack were seen at the surface during 1978 than in the past two seasons (Table 2). Although the amount of sightings effort varied between seasons, the mean quantity of fish seen per day of sightings effort was about the same in 1976 (545 t) as in 1978 (523 t); it was less in 1977 (285 t). In 1977 and 1978 the major sightings were made in January and March; in 1976 they were in January and February.

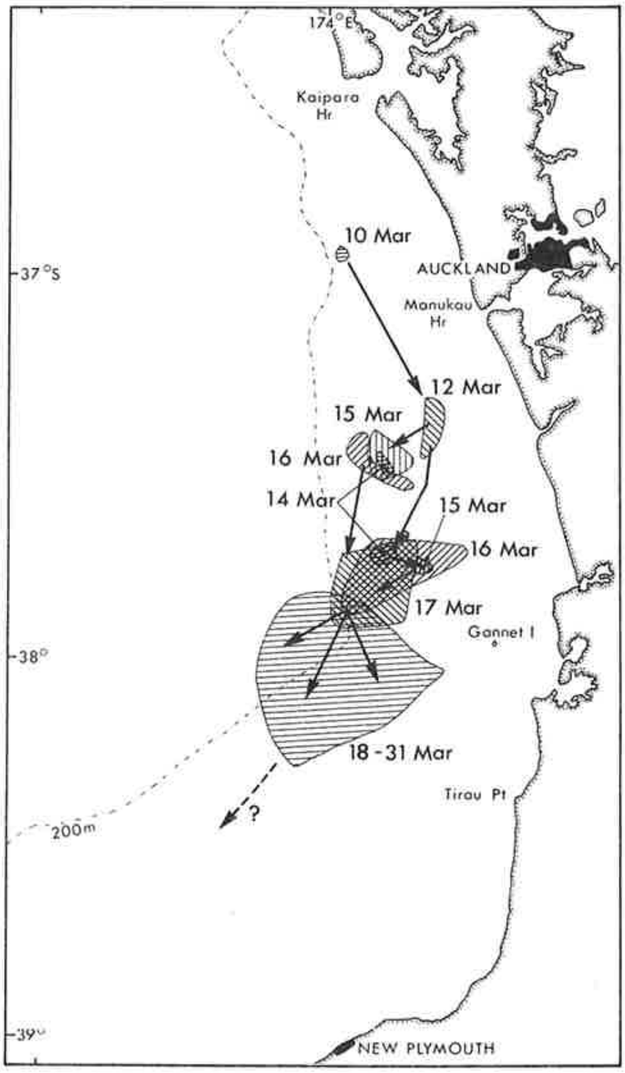


Fig. 9: Daily location of the main concentration of skipjack off the west coast of the North Island, 10 to 31 March 1978.

Fluctuations in apparent abundance

These were considerable (see Fig. 2) and coincided largely with the appearance and disappearance of various bodies of skipjack which moved through the New Zealand area during the season. Reports on earlier seasons (Clement 1976, 1978a) indicate that similar fluctuations occurred as bodies moved through the area. However, the underlying reasons for such movements remain unclear. What seemed to be possible correlations between fluctuating quantities of skipjack, changing weather patterns, and moon phase in 1976 (Clement 1976) have not been borne out in later seasons (Clement 1978a, Habib 1978b).

Apparent abundance, catch, and fishing power

Apparent abundance was little affected by the size of catches or the amount of fishing power used to make the catches (see Standardisation of fishing effort, page 6). A summary of the data in Fig. 2 (see Table 3) shows that of skipjack sighted, only a small proportion was caught. This ranged from 5% in the morning in February-March to 28% in the afternoon in April. On average, only about 6% of the fish seen during the mornings was caught, and 12% during the afternoons. Similarly, the fishing power used to make the catches was small. Only about 30% of the fleet's catching capability (that is, possible fishing power or full effort by the whole fleet) was used during the season (Table 3). These observations seem to indicate that the resource was under little pressure from fishing, a contention supported by the following examples.

On 29 December 1977 off Great Barrier Island (see Fig. 2, December and January, area C) the morning sighting of skipjack at the surface was 795 t, of which 72 t was caught. In the afternoon the quantity seen increased to 940 t, of which 190 t was caught. Poor weather prevented fishing until 1 January 1978. On the morning of the 1st, 360 t was seen, of which 10 t was caught. Despite a further 270 t being caught in the afternoon, the quantity of fish still at the surface at the end of the day was over 1600 t. Over the next 3 days a further 977 t was caught, and yet by the evening of the 4th there was still over 1500 t at the surface in this area. Fishing power used throughout this period was consistently about 40%.

On the morning of 13 January (see Fig. 2, January, area C) 75 t was seen, of which 25 t was caught, and yet the afternoon sighting increased to 390 t. Over the next 7 days almost 1800 t was taken in catches, yet during this period the quantity seen rose steadily to over 2900 t. Although only a further 19 t was caught in this area over the next 5 days, the quantity seen declined rapidly until no fish were seen. Fishing power used was once again consistent at about 35%.

These and similar examples (see Fig. 2, March, area J) show that there were large natural fluctuations in apparent abundance of skipjack. It is impossible at this stage to say what factors might have influenced the fluctuations; however, it is clear that the level of fishing in New Zealand was not one of them. Because of this and the great increase in abundance which occurred despite the large catches, we believe that the amount of fishing and the quantity taken could have been doubled without having a measurable effect on the apparent abundance of skipjack. This belief is only intuitive and will need to stand the test of further research.

An estimate of 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 north-west through area C between 25 December and 6 January produced a maximum sighting of 1950 t on the afternoon of 2 January. Before that, the vessels had caught 651 t from the body. The estimated amount of fish in that body was the sum of the sighting and the catch, that is, 2601 t.

TABLE 3: Quantities of fish seen and caught, and percentage of the fleet's fishing power used to make the catches, by half-day in the 1978 purse-seine skipjack fishery in New Zealand

	Morning				Afternoon			
Month	Quantity sighted (t)	Quantity caught (t)	% caught of quantity sighted	% of possible fishing power used	Quantity sighted (t)	Quantity caught (t)	% caught of quantity sighted	% of possible fishing power used
Dec	595	65	11	20	1 225	290	24	17
Jan	14 206	833	6	41	23 813	3 371	14	25
Feb	5 781	312	5	31	10 601	1 690	16	31
Mar	15 002	768	5	39	26 207	2 082	8	39
Apr	90	20	22	59	342	95	28	42
May	258	0	0	10	0	0	0	0
Total	35 932	1 998	6	30	62 188	7 528	12	31

TABLE 4: Estimated minimum real abundance of skipjack in the New Zealand region during the 1978 season

Period that bodies present	Area	Max. sighting (t)	Catch from body before max. sighting (t)	Estimated min. real abundance (t)
25 Dec–9 Jan	C	1 950	651	2 601
2 Jan	B	80	0	80
11–23 Jan	C	2 975	1 583	4 558
15 Jan	B	200	0	200
16 Jan	B	492	0	492
26 Jan–14 Feb	D	694	1 068	1 762
10 Feb	B	65	0	65
11–18 Feb	C	1 843	191	2 034
24 Feb	B	9	0	9
26 Feb–2 Mar	J	575	119	694
2–11 Mar	H, I	5 000	186	5 186
10–15 Mar	J	1 800	623	2 423
10–18 Mar	J	2 500	0	2 500
15–31 Mar	J	1 700	0	1 700
20–31 Mar	J	1 700	0	1 700
8–21 Mar	E	815	71	886
7–31 May	D	50	0	50
				26 940

By summing similar estimates for all bodies seen and adding the isolated fish which probably did not contribute to any of the main bodies (for example, Table 4, 2 January), it was possible to derive a measure of real abundance of fish for the season. This measure, which was almost 27 000 t, is largely free of double sightings, as it was based on half-day sightings which recorded schools only once.

The 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 which passed through the New Zealand area were seen. Furthermore, little account was taken of the large number of scattered fish which were present throughout the New Zealand area during the season.

Our conservative measure of real abundance was almost three times the catch taken.

School size

A feature of the 1978 season was the abundance of large schools seen (Table 5). Smaller numbers of large schools were seen in the fishery throughout the season. The average size of school was 33 t in the morning, 70 t in the afternoon, and 39 t per day—considerably larger than the 25 t average on any day in 1976, and 23 t in 1977 (Clement 1978a).

Effort in the skipjack fishery

The season was about 4 months long, beginning on Christmas Day and finishing in April. During this time the fleet worked 806 season-days (Fig. 10). Changes from 1977 (see Habib 1978a) were in number of season-days (up 9 days), number of days searching and fishing (down 52 days), number of days spent travelling (up 52.5 days), number of days spent

TABLE 5: Notable concentrations of large schools seen in the 1978 purse-seine skipjack fishery in New Zealand

Date	No. of schools	Size of schools (t)	General area	Position
1 Jan	10	100–400	N of Mokohinau Is	35°38′ S, 175°12′ E
2 Jan	16	100–250	N of Mokohinau Is	35°35′ S, 175°15′ E
8 Jan	12	100–200	N of Mokohinau Is	35°33′ S, 175°09′ E
14 Jan	10	100–150	N of Mokohinau Is	35°33′ S, 175°12′ E
18 Jan	10	120–250	NE of Great Barrier I	35°43′ S, 175°52′ E
20 Jan	20	100–150	N of Great Barrier I	35°40′ S, 175°32′ E
29 Jan	8	100–150	Bay of Plenty	37°42′ S, 177°14′ E
4 Feb	6	100–200	Bay of Plenty	37°27′ S, 177°44′ E
13 Feb	7	100–150	E of Great Barrier I	36°08′ S, 176°00′ E
3 Mar	26	100–400	W of Kahurangi Pt	40°47′ S, 171°35′ E
12 Mar	10	100–200	W of Tirau Pt	38°13′ S, 173°50′ E
13 Mar	8	100–200	Hawke Bay	39°41′ S, 177°13′ E
14 Mar	10	100–200	W of Tirau Pt	38°11′ S, 173°26′ E
15 Mar	10	100–250	Hawke Bay	39°39′ S, 177°20′ E
15 Mar	7	100–150	W of Tirau Pt	38°22′ S, 173°24′ E
18 Mar	10	100–200	W of Tirau Pt	38°08′ S, 173°57′ E
22 Mar	10	100–200	W of Gannet I	38°00′ S, 174°04′ E

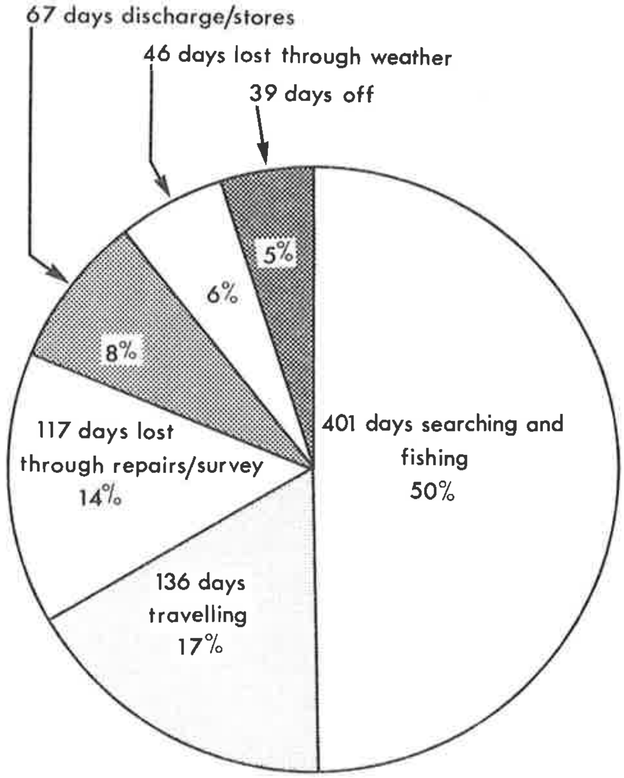


Fig. 10: Days fished and days lost in the 1978 purse-seine skipjack fishery in New Zealand.

on repairs or survey (up 47.5 days), and number of days spent discharging fish and/or taking on stores (down 21.5 days). Fewer days were lost through weather (down 51 days), and 38.5 days were taken off for reasons such as the Christmas holiday period. Similar comparisons can be made with the 1976 season (see Habib 1976 for a description of effort in the 1976 season).

An additional measure of effort in 1978 was standardised fishing days, of which there were 441. Analysis of data from earlier seasons showed that there were 214 standard days fished in 1976, and 1007 in 1977.

The season was later starting than the previous one, when the first skipjack were seen and caught near North Cape on 22 November 1976. Sea temperatures were favourable for skipjack in northern North Island waters from late November 1977 (see page 32). It is therefore possible that skipjack were present earlier than Christmas Day, though sightings effort by spotter aircraft through November and December failed to find them any earlier. Spotter aircraft search large areas of sea at speed, effectively scrutinising narrow bands of water only briefly. This type of searching can easily miss the highly mobile skipjack schools, which swim not only at the surface, but also up and down through the water column. Future observations should show how closely tied the first appearance of skipjack in northern New Zealand waters is to the first encroachment of waters of favourable temperature on northern shores.

Although there was more fine weather than in the previous season, fewer days were spent searching and fishing. This resulted largely from the fishing time lost by *Apollo* in January while she underwent extensive repairs after running aground. These repairs also contributed to the increase in time spent on repairs by the fleet compared with last season.

Travelling time increased, mainly because three of the large seiners made mid-season trips to Pago Pago, in American Samoa, to offload. Only one vessel made such a journey last season. Travelling occupied time that the vessels could have spent searching and fishing.

Catch and effort by month

During the 401 days fished, 9526 t of skipjack were caught; 355 t in December, 4204 t in January, 1993 t in February, 2859 t in March, and 115 t in April (Fig. 11).

Effort, measured as number of season-days, days fished, standard days fished, sets, and successful sets generally peaked in February-March (Fig. 11, left-hand axis). However, the best catch rates were in January, when vessels averaged 20 t per season-day, 46 t per day fished, and 49 t per standard day fished (Fig. 11, right-hand axis). Set catch rates were also high during January (19 t per set, 47 t per successful set), but not as high as during late December, when a 3-day period of fishing yielded a high tonnage for four vessels.

As in past seasons, the rise and fall of catch and effort resulted partly from fluctuations in the number of vessels in the fishery (4 in December, 8 in January, 10 in February and March, 5 in April). The quality of vessels on the fishing grounds also influenced catch and effort. For example, though all vessels fished in February and March, the vessel with the greatest fishing power fished only 2 days in February, but 16 days in March. As each day that this vessel spent fishing contributed 3.35 standard fishing days to the monthly totals, its greater effort in March accounts for the larger number of standard days fished in that month compared with February (Fig. 11). This vessel was one of the two absent from the fishery in January, and consequently effort during that month was low.

Catch and effort also rose and fell because of fluctuations in the availability, size, and "catchability" of the skipjack resource. During the first and

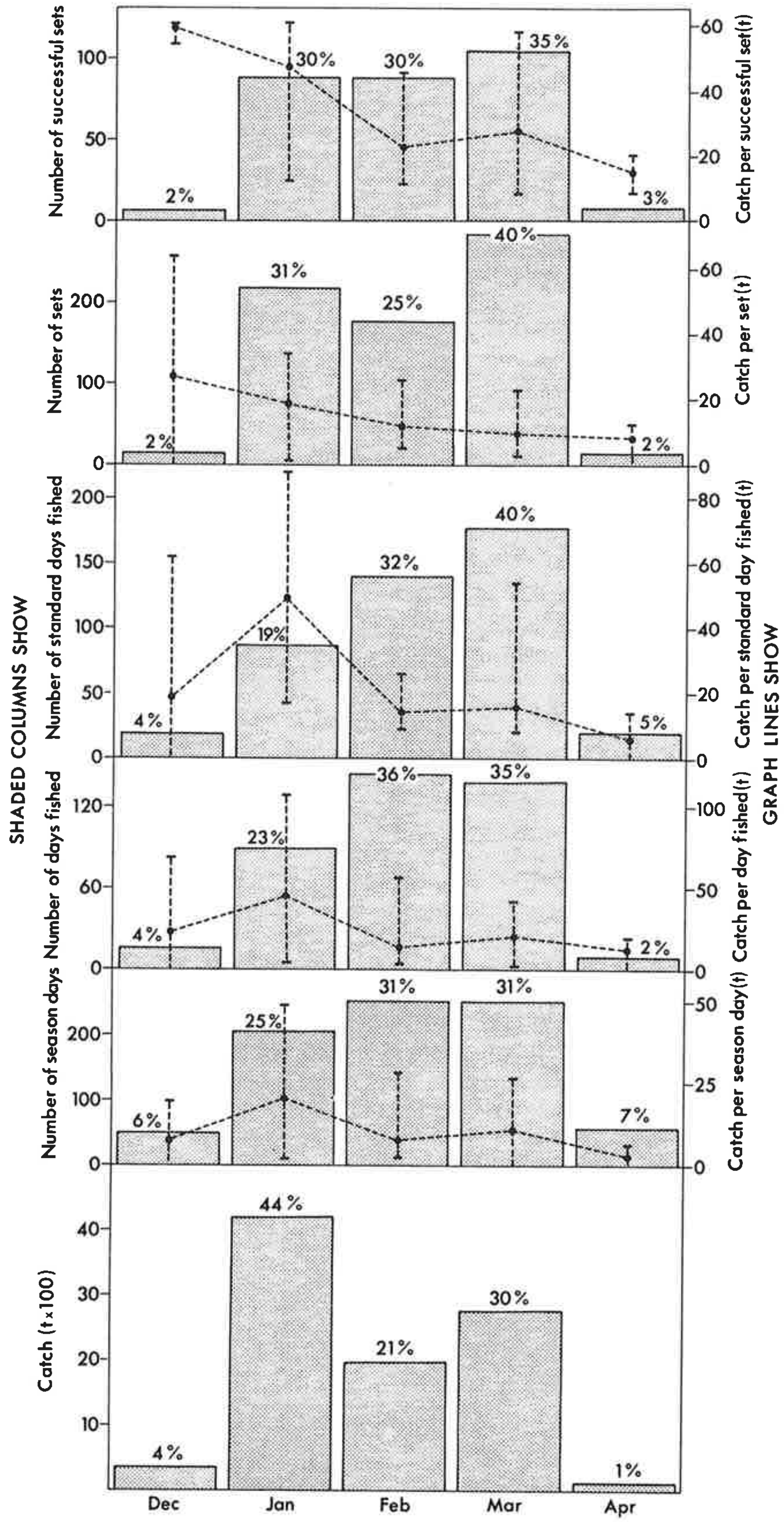


Fig. 11: Monthly catch, effort, and catch per unit of effort in the 1978 purse-seine skipjack fishery in New Zealand.

TABLE 6: Catch, effort, and catch per unit of effort by area in the 1978 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	Standard days fished No.	Standard days fished % 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 standard day fished (t)	Catch per set (t)	Catch per successful set (t)
A	–*	–	4.0	0.5	2.0	0.5	2.0	0.4									
B	0	0	15.5	1.9	8.5	2.1	11.0	2.5	2	0.3							
C	4 721	49.6	263.0	32.6	134.5	33.5	138.5	31.4	260	36.9	111	37.5	17.9	35.1	34.1	18.2	42.5
D	1 650	17.3	182.5	22.7	94.5	23.6	79.0	17.9	122	17.3	59	19.9	9.0	17.5	20.9	13.5	28.0
E	275	2.9	81.0	10.0	39.5	9.9	16.0	3.7	52	7.4	20	6.8	3.4	7.0	17.2	5.3	13.7
F	–	–	1.5	0.2	0.5	0.1	0.5	0.1									
G	–	–															
H	65	0.7	7.5	0.9	7.0	1.7	14.0	3.2	13	1.9	7	2.4	8.7	9.3	4.6	5.0	9.3
I	195	2.0	40.0	5.0	11.5	2.9	13.5	3.1	25	3.6	4	1.3	4.9	17.0	14.4	7.8	48.7
J	2 613	27.4	132.5	16.5	101.5	25.3	164.5	37.3	229	32.5	94	31.8	19.7	25.7	15.9	11.4	27.8
K	7	0.1	2.0	0.2	1.5	0.4	2.0	0.4	1	0.1	1	0.3	3.5	4.7	3.5	7.0	7.0
			76.5†	9.5													
Total	9 526		806.0		401.0		441.0		704		296		11.8	23.8	21.6	13.5	32.2

* No fishing.
† Outside New Zealand—days spent travelling to and from, and discharging fish at, the cannery in American Samoa.

third weeks of January many large schools were present off Mokohinau Islands and Great Barrier Island (area C) (Table 5) during fine weather. These schools were particularly catchable, as the high January catch rates show (Fig. 11). The spotters reported that the schools were very stable, reacting little to aircraft noise, and that they remained at the surface for long periods. (Unstable schools typically sound frequently and reappear some distance from the point of sounding, a long time after sounding, or not at all.)

A large quantity of skipjack was also present in March (see Fig. 2 and Table 2). The weather during most of this month was fine. However, the fish were much less catchable than they were in January, as is shown by the lower March catch and catch rates (Fig. 11).

For much of the time skipjack were present in large unstable schools, which are difficult to purse seine successfully. One reason for this relates to the extent to which such a school fills the area enclosed by a purse-seine net. The more the area is filled, the greater is the chance of part of the school finding an opening in the net. For example, if a school 40 m deep has its progress blocked early in a set when the net has fallen to only 35 m, the bottom 5 m of the school will pass out under the net and usually draw the rest of the school with it. If large size combines with school instability, such schools are difficult to capture. On 3 March only 3 of 19 sets on large schools were successful; on that day over 5000 t of skipjack was seen at the surface and only 85 t was caught (Fig. 2, March, area I).

Most of the fishing in March was off the west coast of the North Island (area J). Although no measurements of water clarity were made, the water was often very clear on the fishing grounds in this area. This clarity possibly contributed to the low fishing success here (compared with area C), as the fish could easily see escape routes out of the nets. A correlation between water clarity and fishing success has been found in other studies (for example, Whitney 1969).

Catch and effort by area

Catches were made in seven areas on the New Zealand coast (see Fig. 1). Half of the season's catch (4721 t) was taken in area C (off Great Barrier Island) with about one-third of the fishing effort (Table 6). As in previous seasons, this area was fished in January; and as in 1977, it was the major fishing area. Catch rates were high (for example, 34.1 t per standard day fished), much higher than the rates in this or any other area since commercial purse seining began in New Zealand (see Habib 1976, 1978a). All area C catch rates were greater than the season's means (Table 6).

Area J (west coast North Island) was next in importance; about one-quarter of the season's catch was taken here with about one-quarter of the fishing effort. This was proportionately more of the season's catch than in 1977 (14.9%), and much more than in 1976 (3.1%). As in previous seasons, this area was fished in March.

The fish were less catchable than those in area C and therefore the catch rates were lower (Table 6). However, in the last two seasons there has been a trend towards fishing deeper nets; in 1977 the deepest was 165 m, and in 1978, 252 m. Coincidentally or otherwise, 33% of sets made in area J in 1977 were successful, and 41% in 1978. We believe that the rate of success in this area will continue to rise as the move towards deeper nets becomes general. As already suggested, the greater water clarity may have been implicated in the lower success rate of sets in this area compared with area C. Deeper nets make one of the major escape routes—the hole at the bottom of the net circle—less obvious.

Another factor which was probably relevant was the thermocline, defined by Green (1967) as "The layer [of sea water] of relatively sharp temperature gradient separating the mixed layer above [upper waters] from the colder waters beneath." Tuna will consistently sound out of a purse-seine net where the top of the thermocline is deeper than the maximum depth of the net (Murphy and Niska 1953). This lends support to the belief that the thermocline acts as a barrier to vertical movement of tuna. Although bathythermographs were not used to record water temperature during the last three seasons, unpublished MAF data from earlier purse-seine surveys (Eggleston 1976) indicate that the mid point of the thermocline in New Zealand "skipjack waters" (see Catch and effort by sea surface temperature, page 29) in March is at about 65 m. Obviously the deeper nets will fish more effectively, as they extend well below this depth.

During this season the most successful vessel in area J fished the deepest net.

The only other area of any significance was area D (Bay of Plenty), where about one-fifth of the catch was taken with the same proportion of the fishing effort (Table 6). Over 1000 t of this catch was taken by one vessel in a 12-day period in late January-early February.

Small quantities of fish were also taken in area E (Hawke Bay), areas H and I (off the north-west of the South Island), and area K (off Kaipara Harbour).

For the first time in three seasons no fish were caught in areas A (north-west of North Cape) and B (North Cape to Cavalli Islands), where substantial catches have been made in the past (1976, 3584 t; 1977, 1608 t). Although there was sightings effort in these areas throughout the season (see Table 1), few fish were seen (see Fig. 2).

Catch and effort by depth

Skipjack were caught where bottom depths were between 30 and 1100 m (Table 7). However, most (8240 t) were caught where the water was 100 to 399 m deep. There the greatest effort (sets) was expended and the highest catch rates (per set, per successful set) recorded.

We believe that where the depth range 100 to 400 m coincides with the distribution of major aggregations of skipjack (for 1978, as indicated by the set positions in Fig. 1), there are concentrations of zooplankton which provide food for skipjack. Data presented by Bradford and Roberts (1978, see Fig. 6) lend little support to this. However, the planktonic euphausiid *Nyctiphanes australis*, the main food species for skipjack in New Zealand waters, has been observed at the surface in great abundance in one such area (by G. Habib, on 10 March 1978, position 41° 13.4′ S, 171° 10.8′ E, at 1400 h). Further work is planned in area C to determine the relationships between *Nyctiphanes*, skipjack, and bottom depth.

TABLE 7: Catch, sets, and set success by bottom depth in the 1978 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)
30–99	794	8.3	71	10.1	11.2	37	12.5	21.5
100–199	4 565	47.9	382	54.3	11.9	165	55.7	27.7
200–299	1 698	17.8	134	19.0	12.7	41	13.8	41.4
300–399	1 977	20.8	76	10.8	26.0	36	12.2	54.9
400–499	195	2.0	15	2.1	13.0	4	1.4	48.7
500–599	160	1.7	10	1.4	16.0	5	1.7	32.0
600–699	50	0.5	4	0.6	12.5	2	0.7	25.0
700–799	41	0.4	3	0.4	13.7	2	0.7	20.5
800–899	0	0	1	0.1	0	0	0	0
900–999	23	0.3	4	0.6	5.7	1	0.3	23.0
1 000–1 100	23	0.3	4	0.6	5.7	3	1.0	7.7
Total	9 526		704		13.5	296		32.2

Catch and effort by water colour

Most of the skipjack (8751 t) were taken in blue offshore water. There, most of the sets (635, 268 successful) were made for catch rates of 13.8 t per set and 32.6 t per successful set. In the blue-green or green in-shore water 775 t of skipjack were caught in 69 sets (28 successful) at catch rates of 11.26 t per set and 27.7 t per successful set.

Catch and effort by time of day

Almost two-thirds of the skipjack (6069 t) were caught during the afternoon (noon to 5.59 p.m.), one-fifth (1944 t) in the morning (6.00 a.m. to 11.59 a.m.), and the remainder (1513 t) in the evening (6.00 p.m. to 11.59 p.m.). Effort was similarly apportioned, with 402 sets in the afternoon, 188 in the morning, and 114 in the evening. The best fishing, as mean catches per set and per successful set, was in the afternoon (15.1 t and 36.8 t respectively), then the evening (13.3 t and 26.1 t), and the morning (10.3 t and 26.6 t).

It is not surprising that so much of the season's catch was taken in the afternoon, as that was when the largest quantities of skipjack were sighted at the surface (Fig. 2).

Catch and effort through the day was similar in past seasons (Habib 1976, 1978a).

Catch and effort by moon phase

There was a fairly even distribution of catches through the moon's cycle, except for a lower catch during full moon. However, more sets were made during the first two quarters (63.6% of sets) for lower set catch rates than during the last two quarters (Table 8).

The new moon and first quarter periods yielded the largest proportions of the catch in past seasons (Habib 1976, 1978a). However, set catch rates were highest during new and full moon in 1976 and during the first two quarters in 1977. Therefore there has been no clear trend in skipjack fishing related to moon phase.

Catch and effort by sea surface temperature

Skipjack were caught in areas where surface water temperatures ranged from 17° to 25°C (Table 9). However, most (8098 t, 85% of the season's catch) came from 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 longer than the cooler or warmer water. As a result, most of the fishing effort (80% of sets and successful sets, made during 18 of the season's 31 fortnightly fishing periods) was expended in skipjack water. Catch rates, too, were generally higher in this water than in water of other temperatures.

A similar pattern of fishing by sea surface temperature was found in 1977 (Eggleston and Paul 1978).

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

Weekly satellite sea surface temperature charts for the New Zealand region for 25 October to 30 May are presented (Fig. 12). The charts cover the 1978 skipjack season and some time before and after the season.

TABLE 8: Catch, sets, and set success by moon phase in the 1978 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	2 487	26.1	238	33.8	10.4	85	28.7	29.2
First quarter	2 670	28.0	210	29.8	12.7	95	32.1	28.1
Full moon	1 989	20.9	122	17.4	16.3	59	19.9	33.7
Last quarter	2 380	25.0	134	19.0	17.8	57	19.3	41.7

TABLE 9: Catch, sets, set success, and fishing effort (searching and fishing) by sea surface temperature in the 1978 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)	Fishing effort expended during 2-week periods						
									25/12–7/1	8/1–21/1	22/1–4/2	5/2–18/2	19/2–4/3	5/3–18/3	19/3–1/4
17.0–17.9	238	2.5	25	3.6	9.5	9	3.0	26.4	√					√	
18.0–18.9	563	5.9	33	4.7	17.1	12	4.1	46.9	√	√				√	
19.0–19.9	2 258	23.7	145	20.6	15.6	58	19.6	38.9	√	√		√	√	√	
20.0–20.9	3 559	37.4	229	32.5	15.5	87	29.4	40.9	√	√	√	√	√	√	√
21.0–21.9	2 281	23.9	202	28.7	11.3	91	30.7	25.1		√	√	√	√	√	√
22.0–22.9	567	5.9	60	8.5	9.4	34	11.5	16.7		√	√	√	√		
23.0–23.9	53	0.6	8	1.1	6.6	4	1.4	13.2			√	√	√		
24.0–25.0	7	0.1	2	0.3	3.5	1	0.3	7.0				√			
Total	9 526		704		13.5	296		32.2							

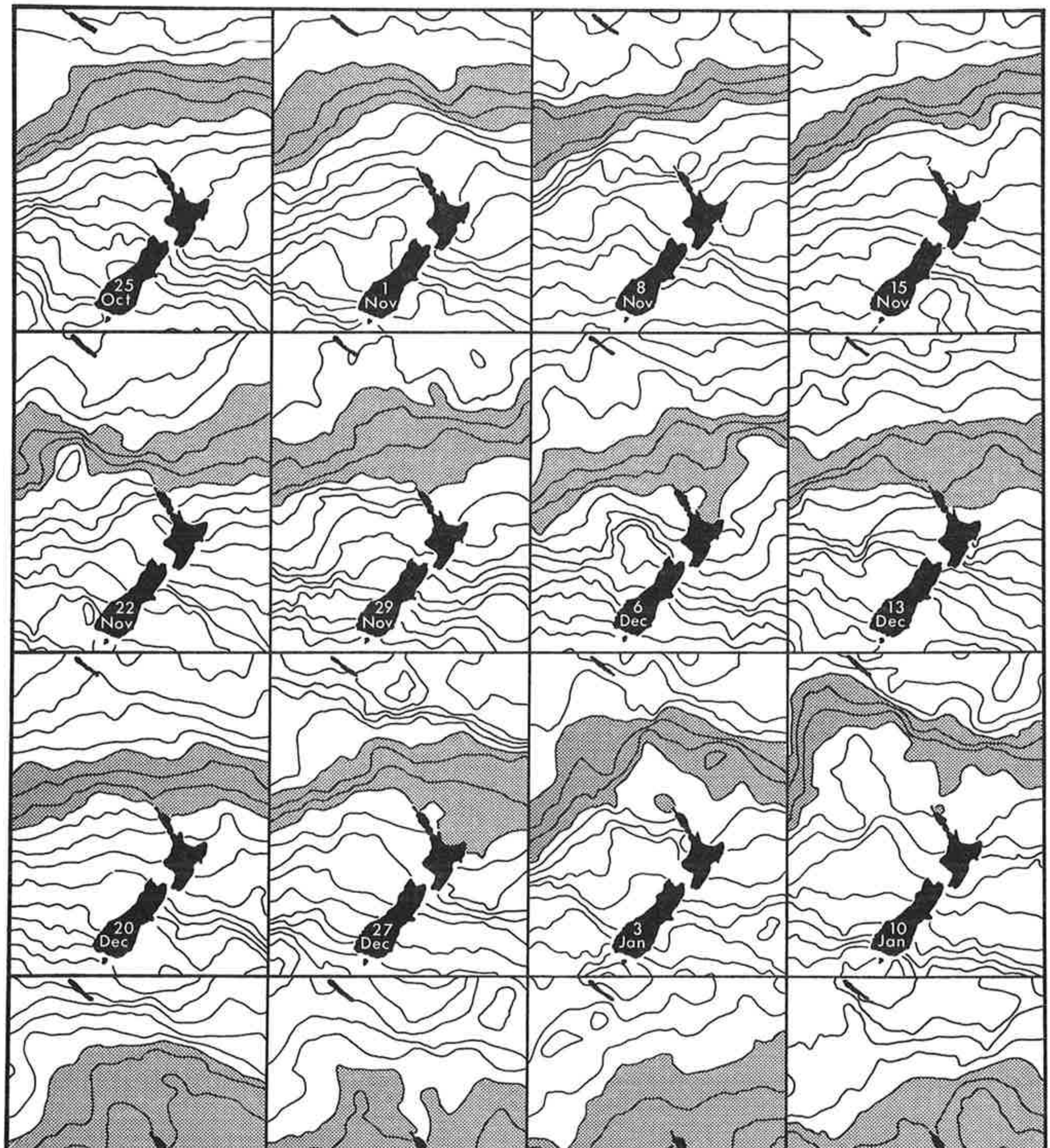
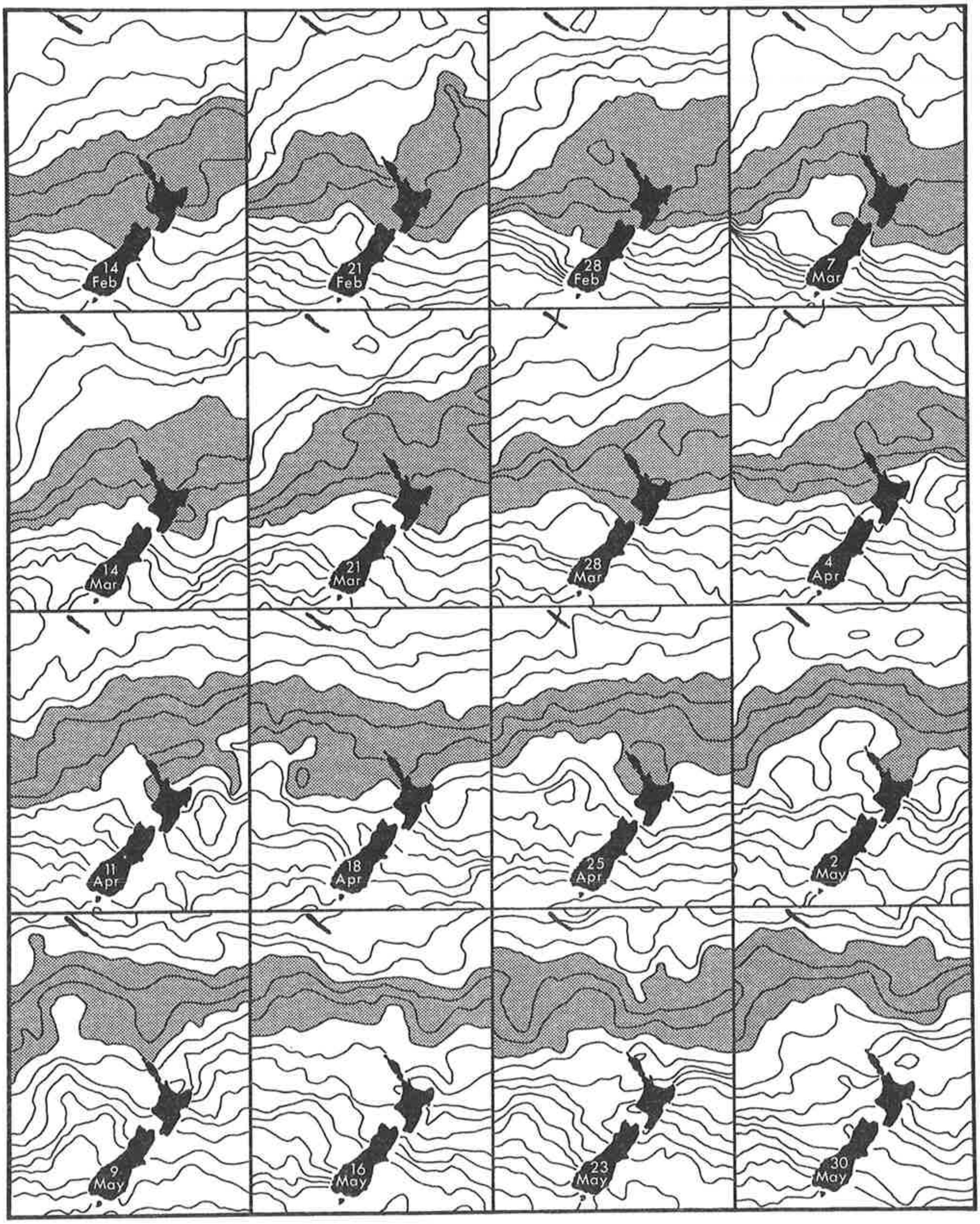


Fig. 12 (above and right): Weekly sea surface temperature charts for the New Zealand region, from satellite measurements, for the 1978 skipjack season. Water of 19°–21.9°C ("skipjack water") is shaded; isotherms are at 1°C intervals.


14 Feb
21 Feb
28 Feb
7 Mar
14 Mar
21 Mar
28 Mar
4 Apr
11 Apr
18 Apr
25 Apr
2 May
9 May
16 May
23 May
30 May

Skipjack water was first present in New Zealand at North Cape in late November and extended as a tongue into the Bay of Plenty in early December. In the Bay of Plenty and on the north-east coast of the North Island there were periods of cooling in mid December, warming in late December, and cooling in early January. From mid January there was a general warming around the North Island and some warming to the west of the South Island. From early April there was a general cooling, and by mid May skipjack water was no longer on the New Zealand coast.

Some of the sea surface temperature charts from satellites (see Fig. 12, charts for the weeks ending 6 December, 10 January, 11 and 25 April, and 2 May) 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) found a similar occurrence 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 movement of surface water. They suspected, though, that there might also have been some water movement. We believe that both processes took place in 1978.

As in 1977 (Eggleston and Paul 1978), skipjack were generally found and fished in skipjack water. Notable exceptions were the fish in cooler water in area C in early January and in area H in March. Fishing also took place in warmer waters (see Table 9), though this is not apparent from a comparison of the satellite temperature charts with the distribution of fishing. This is because the temperatures used to calculate catch rates by temperature were recorded by shipboard observers. These temperatures were at times higher than satellite-recorded temperatures, particularly if taken in mid afternoon on warm, still days. This type of detail does not appear on the charts constructed by the satellite data processors, who use temperatures derived from averaged readings from large areas (Eggleston and Paul 1978).

More elaborate satellite systems are planned and future sea surface temperature data should be much more refined (Eggleston and Paul 1978). In the meantime, the present satellite data are useful in leading to a broad understanding of skipjack distribution in New Zealand in summer. Some refinement of this understanding can be gained by evaluating the satellite data in conjunction with temperatures collected by shipboard observers.

In the future satellite data will be used for predicting optimum fishing areas and times. For this, data would need to become available more quickly than is possible with the present mailing of charts from the United States. The New Zealand Meteorological Service plans to be able to receive same-day satellite sea surface temperature charts in the future.

Temperature has long been considered the key factor in the distribution and behaviour of skipjack (Radovich 1963, Blackburn 1965), particularly near the northern (for example, northern Japan) and southern (for example, New Zealand) extremes of their distribution (see Fig. 2 *in* Joseph and Calkins 1969 for map of skipjack distribution in the Pacific Ocean). In the light of the observed relationships between skipjack and water temperature in New Zealand during the last two seasons, the skipjack fishing industry should consider pre-season and post-season prospecting for skipjack water to the north of New Zealand by aircraft (as in Hynd 1968, 1969) and/or by fishing vessels. If skipjack travel to and from New Zealand in this water and at the surface, the fishing season could be greatly lengthened.

Purse-seine fishing and the 12-mile territorial sea

Since large purse seiners were introduced to the New Zealand skipjack fishery in 1975, there has been considerable controversy about whether they should be allowed to fish within the 12-mile territorial sea. The controversy has revolved around two points: firstly, whether the large seiners should be considered as foreign fishing vessels and, as such, be subject to the normal ruling that these vessels must operate outside 12 miles; secondly, if not considered foreign vessels, whether the large seiners should be allowed to fish inside the territorial sea in competition with the small New Zealand owned seiners.

The large seiners have all been United States registered or ex-United States registered and have operated in New Zealand under charter to a New Zealand-United States joint venture company. While on charter they have been registered as New Zealand fishing vessels and have been issued fishing permits. Technically, therefore, they were no longer foreign vessels, and the joint venture company fully expected to be able to operate them within the laws applying to all New Zealand fishing vessels. This included freedom of movement inside the 12-mile limit. However, in fishing inside the limit, the company attracted an adverse reaction from the operators of the small seiners in the fishery who did not acknowledge that charter vessels had any privileged status. They also claimed that the large seiners fished in unfair competition with the small seiners, particularly when fishing occurred inside the 12-mile limit, the main fishing area for the small seiners (Table 10).

There is no doubt that the large seiners do have much greater capabilities when fishing for skipjack than the small ones. During the last three seasons, their size and speed and the large size of their gear have enabled them to record an average fishing power

TABLE 10: Catch and set data for catches made 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 1976 to 1978 skipjack seasons in New Zealand (1976 and 1977 data from MAF files)

Season (total catch (t))	Vessel	Catch (t) (% of season's total)	Sets (% of season's total)	Catch per set (t)	Successful sets (% of season's total)	Catch per successful set (t)
	Il	3 558 (75.4)	190 (62.5)	19	118 (65.6)	30
1976	Is	201 (4.3)	50 (16.4)	4	26 (14.4)	8
(4 715)	Ol	942 (20.0)	62 (20.4)	15	35 (19.4)	27
	Os	14 (0.3)	2 (0.7)	7	1 (0.6)	14
	Il	1 141 (15.1)	159 (26.1)	7	89 (28.3)	13
1977	Is	418 (5.5)	106 (17.4)	4	49 (15.6)	9
(7 541)	Ol	5 963 (79.1)	334 (54.8)	18	174 (55.2)	34
	Os	19 (0.3)	10 (1.7)	2	3 (0.9)	6
	Il	1 280 (13.4)	59 (8.4)	22	32 (10.8)	40
1978	Is	802 (8.4)	121 (17.2)	7	47 (15.9)	17
(9 526)	Ol	7 147 (75.0)	471 (66.9)	15	199 (67.2)	36
	Os	297 (3.2)	53 (7.5)	6	18 (6.1)	16

4.5 times greater than that of the small seiners and to take most of the catch at much higher catch rates (Table 11).

Various measures have been tried to remove the size-related competition from the fishery. Under the Fisheries Act, the Minister of Fisheries imposed various conditions on the fishing permits of the charter vessels. These were a ban on fishing inside the 12-mile limit (lifted after protests by the joint venture company), a ban on fishing in the Bay of Plenty except when invited in to fish particular schools by a MAF observer, access to the 12-mile fishing zone only to take schools over 25 t, and a direction that New Zealand vessels be given first right to set on schools of skipjack inside the zone. These measures were only partly successful, owing to the impracticality of some and the lack of adherence to others.

We believe it is not unreasonable for the large vessels to be restricted to fishing outside 12 miles. Most of their fishing was done there in the 1977 and 1978 seasons (see Table 10), and most of the skipjack were seen there (this publication and Clement 1978d). In comparison, the small seiners spent little time outside the limit, because with their small nets, they are unable to capture the generally large, mobile, and unsettled schools found in the off-shore waters. The 12-mile limit appears a reasonable dividing line between the operating ranges of the two classes of vessel, and MAF should give official recognition to this in future recommendations for the harmonious development of the skipjack fishery.

The option of varying the conditions on the fishery could be retained by Government if circumstances show that some variation is necessary for the continued viability of all sectors of the fishery and for the best use of the resource. For example, the 12-mile limit might be too restrictive on the large seiners if large quantities of skipjack surfaced inside the limit, as they did in 1976 (see catch and set data for 1976 in Table 10). In addition, the present small in-shore fleet might be incapable of catching more than a small proportion of such quantities of skipjack. Some form of limited entry for the larger seiners to the in-shore zone would be desirable in these circumstances. Adequate supervision of the large seiners would then be required.

Annual catch rates

It is timely to appraise the 1978 rates and compare them with those of past seasons (Table 12).

With the doubling of the annual catch from 1976 to 1978, there was variation in the catch rates—catch per day searching and fishing (cpdsf) and catch per standard day fished (cpsdf). Both measures were high in 1976 and 1978 and low in 1977, and they broadly reflect the relative abundance of fish available in these seasons (see Table 2). The resource in 1976 was less than in 1978, but in 1976 fewer vessels fished. This meant that there were fewer days spent searching and fishing and fewer standard days fished, and the smaller resource was therefore sufficient to yield catch rates of 1978 proportions.

TABLE 11: Comparison of large and small vessels in the purse-seine skipjack fishery in New Zealand, 1976 to 1978 (1976 and 1977 data from Habib 1976, 1978a, Fisheries Research Division files)

Vessel	Length (m)	Fish holding capacity (t)	Speed (knots)	Net length by depth (m)	Average fishing power 1976–78	Total catch 1976–78 (t)	Average catch per standard day fished 1976–78 (t)
Large	53–79	740–2 000	to 17	to 1 460 by 250	2.01	20 031	12.05
Small	23–35	90–330	to 11	to 900 by 120	0.45	1 751	1.05

TABLE 12: Annual catch, effort, and catch per unit of effort in the purse-seine skipjack fishery in New Zealand, 1976 to 1978 (1976 and 1977 data from Habib 1976, 1978a, Fisheries Research Division files)

Year	No. of vessels	Catch (t)	Season-days	Catch per season-day (t)	Days searching and fishing	Catch per day searching and fishing (t)	Standard days fished	Catch per standard day fished (t)	Sets	Catch per set (t)	Successful sets	Catch per successful set (t)
1976	5	4 715	486	10	224	21	214	22	304	15	180	26
1977	11	7 541	797	9	458	16	1 007	7	609	12	315	24
1978	10	9 526	806	12	401	24	441	22	704	13	296	32

The cpsdf in 1977 was very low. This was because the moderate catch had to be divided by a large number of standard days fished. This number resulted partly from the relatively high number of days spent searching and fishing in 1977 and partly from a drop in performance level of the standard vessel that season, which effectively raised the fishing power, and hence the output, of standard days fished of most vessels in the fleet. To illustrate this, the standard vessel's fishing power of 1 (that is, when 1 day searching and fishing equalled 1 standard day fished) in 1976 was equal to 0.93 *Michelangelo* days, in 1977 to 2.38, and in 1978 to 1.56. These values should have been much the same if the relative fishing power of these vessels had remained similar over the different seasons. This illustrates one of the problems of comparing standardised catch and effort data from one season to the next.

Catch per season-day for the 1976 to 1978 seasons varied in a similar manner to cpdsf and cpsdf, but the variations were on a smaller scale. This was because the measure of effort of a season-day includes vessel activities other than fishing.

Catch per set varied only a little, and the variation in catch per successful set probably reflects changes in the average size of school available to the fishing fleet, which was 25 t in 1976, 23 t in 1977 (Clement 1978a), and 39 t (mean of 33 t in the morning, 70 t in the afternoon) in 1978.

Comparison of New Zealand and eastern tropical Pacific tuna fisheries

To obtain a measure of the relative productivity of the New Zealand skipjack fishery, the catch per day searching and fishing for the larger vessels in the fleet (*Kerri M* and larger) can be compared with equivalent catch rates for the larger vessels (of size class 6, that is, 401 short tons carrying capacity or greater) in the eastern tropical Pacific (ETP) tuna fishery (Table 13). There, both skipjack and yellowfin tuna are fished by purse seine, and the fairest comparison is between the New Zealand rates and the combined ETP skipjack and yellowfin rates.

Fishing in New Zealand has been about twice as productive per day of fishing as in the ETP fishery. It should, however, be realised that the New Zealand fishery is a virgin fishery which has a short but intense fishing season, is located in a small sea area, and has been fished by a small number of vessels, whereas the ETP fishery is year round and of long standing (since the early 1920s, according to Joseph and Calkins 1969), is located in a large sea area (off the west coasts of North, South, and Central America between 30° N and 20° S, and to 800 km off shore), and has been fished by many vessels (150 of class 6 in 1978, see Peterson 1978).

TABLE 13: Mean catch per day searching and fishing (t) for skipjack, yellowfin, and both species combined in the ETP purse-seine tuna fishery, and for skipjack in the New Zealand purse-seine fishery, by size class 6 vessels (ETP data from files of the Inter-American Tropical Tuna Commission, La Jolla, California)

Year	ETP Skipjack	ETP Yellowfin	ETP Combined	New Zealand Skipjack
1962	6.05	3.14	9.19	–*
1963	8.72	1.59	10.31	–
1964	5.19	4.46	9.65	–
1965	7.04	3.44	10.48	–
1966	5.83	6.23	12.06	–
1967	15.24	4.42	19.66	–
1968	6.93	8.96	15.89	–
1969	4.03	10.79	14.82	–
1970	1.61	12.68	14.29	–
1971	7.19	7.29	14.48	–
1972	1.47	12.24	13.71	–
1973	1.82	10.36	12.18	–
1974	3.66	8.01	11.67	–
1975	4.47	6.44	10.91	–
1976	4.15	7.34	11.49	26.81
1977	–	–	–	20.30
1978	–	–	–	32.11
1962–76	4.54	7.91	12.45	–
1976–78	–	–	–	25.67

* No data available.

Biology

Length-frequency distributions

During 1978 MAF observers on the purse seiners measured over 22 000 skipjack (0.6% of the estimated total number of fish caught during the season). Catches sampled by area were 80 in C, 48 in D, 5 in E, 2 in H, 2 in I, and 35 in J. All length measurements were grouped by 2-week intervals by area to provide a full record of the length composition of the catches throughout the season (Fig. 13). This figure also shows the changes in the location of the fishery during the season.

Early season catches in area C (off Great Barrier Island) were dominated by fish of two distinct size classes. These were 47- to 49-cm fish (2.2 to 2.4 kg in weight, 28% of fish caught in this area) and 52- to 53-cm fish (3 to 3.2 kg, 26%). In February small fish of about 40 cm (1.2 kg, 1.2%) also appeared in the catches in this area. The same size classes predominated in mid-season catches in area D (Bay of Plenty) (47 to 49 cm, 27%; 52 to 53 cm, 29%), with the small fish (40 cm, 3.4%) also appearing later.

Only the largest of these size classes was present in area E (Hawke Bay), and it comprised 31% of the catches. Some 20% of the fish were larger (56 to 58 cm, 3.8 to 4.3 kg).

West coast catches (areas H, I, and J) contained 49- to 51-cm fish (2.4 to 2.8 kg, 59%), intermediate in size between the two main size classes in east coast catches. Other fish ranged from 52 to 56 cm (3 to 3.8 kg).

The estimated numbers of fish of different sizes in the 1978 catches are presented in Table 14. Fish were predominantly of the same size as in 1975 and 1977, but larger than the fish in 1974 and 1976 (Fig. 14).

Possible reasons for year-to-year variability in the major size classes of skipjack are: variation in environment on the spawning grounds and/or the condition of the spawning stock; variations in the environment of juveniles and post-juveniles, such as the availability of food, which would contribute to variation in the time and length of the post-spawning period and the overall effectiveness of spawning; and variation in the growth rates of larval and juvenile stages, which results in the arrival of different size groups of fish. Such year-to-year variability occurs in other fisheries (Fig. 14).

TABLE 14: Estimated numbers of fish of different sizes in the 1978 purse-seine skipjack fishery in New Zealand

Length (cm)	Est. No. in season's catch	% of est. total No. of fish*	Length (cm)	Est. No. in season's catch	% of est. total No. of fish
35	764	–†	55	178 966	5.0
36	2 748	0.1	56	103 161	2.9
37	5 687	0.2	57	55 197	1.5
38	10 494	0.3	58	29 896	0.8
39	14 583	0.4	59	14 429	0.4
40	20 460	0.6	60	6 021	0.2
41	21 584	0.6	61	4 179	0.1
42	16 601	0.5	62	431	–
43	10 888	0.3	63	1 535	–
44	14 992	0.4	64	820	–
45	47 390	1.3	65	354	–
46	110 249	3.1	66	870	–
47	230 353	6.5	67	152	–
48	312 738	8.8	68	414	–
49	403 903	11.3	69	3	–
50	448 358	12.6	70	3	–
51	425 243	11.9	71	6	–
52	434 499	12.2	72	0	0
53	352 864	9.9	73	3	–
54	276 288	7.8	74	3	–

* Total 3 557 129.
† Less than 0.1% of total.

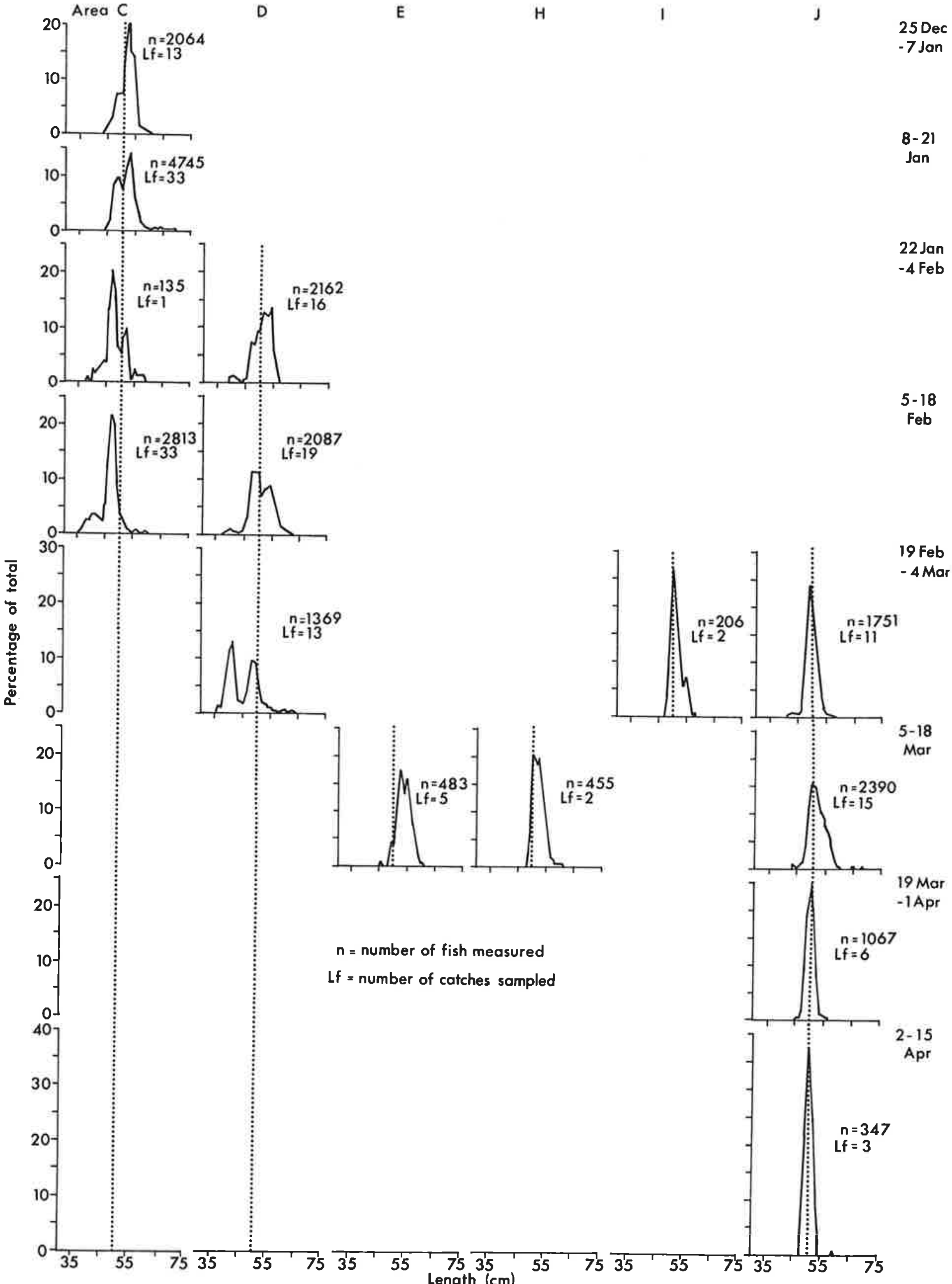


Fig. 13: Length-frequency distributions by area by 2-week intervals in the 1978 purse-seine skipjack fishery in New Zealand.

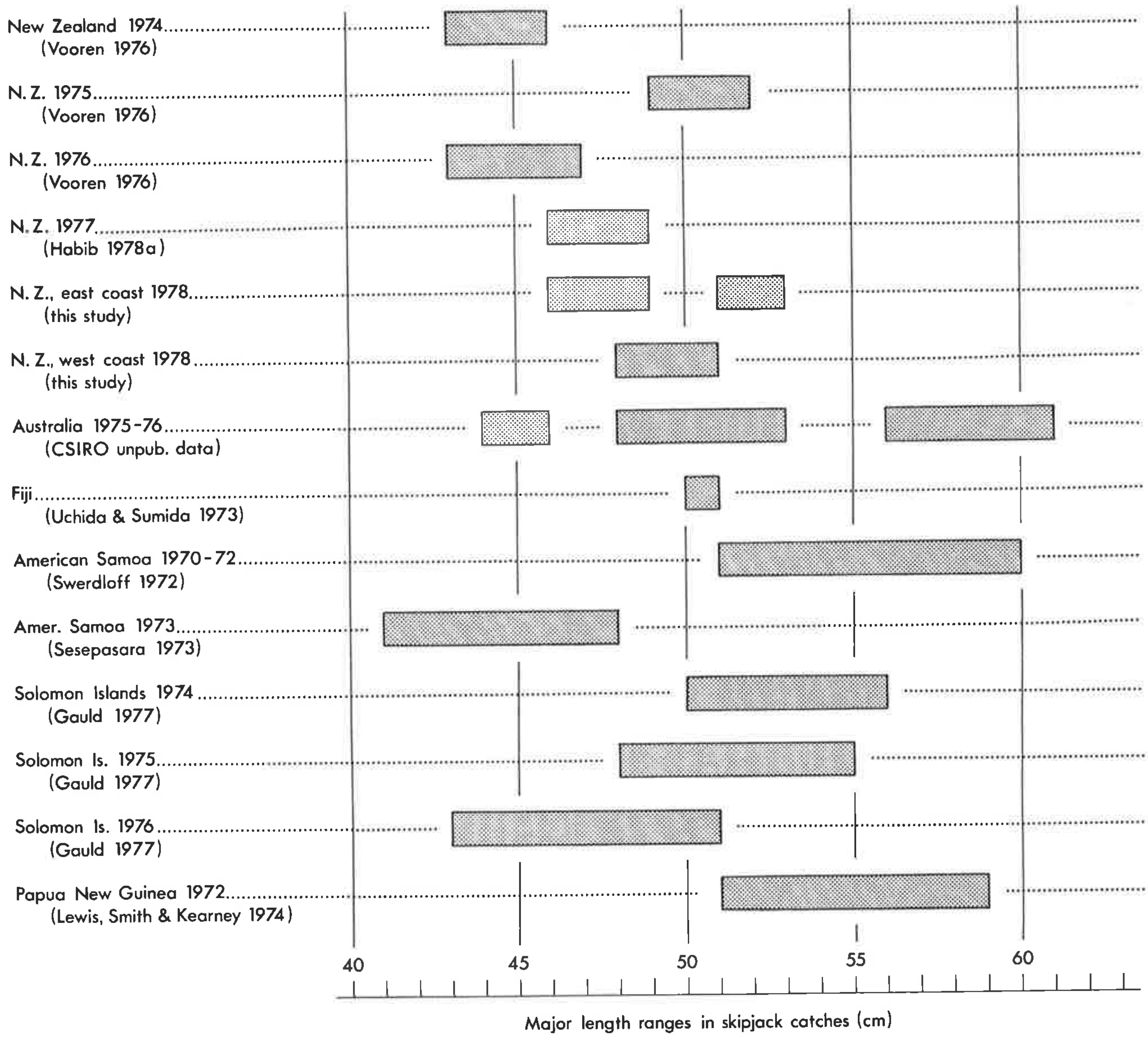


Fig. 14: Major length ranges in skipjack catches in New Zealand and in fisheries of some neighbouring western Pacific Ocean countries.

The area-to-area variation in size classes which was seen in 1978 could have resulted from fish being derived from different spawning grounds or from different spawnings on the same grounds.

The predominant length ranges of skipjack in catches in other parts of the Pacific Ocean were presented by Vooren (1976). These may be compared with the New Zealand ranges and those of various other countries close to New Zealand. As pointed out by Vooren, the length composition of New Zealand skipjack occurs at the lower end of the size range found in other skipjack fisheries in the Pacific Ocean. We agree with his conclusion that skipjack in the New Zealand fishery are young recruits which belong to cohorts that have not been subjected to fishing elsewhere in their geographical range. Kearney (1978a) has also observed that the New Zealand skipjack fishery is one of a number based on first-recruit post-juvenile fish.

Length-weight relationship

A relationship was not calculated for 1978. However, it would probably have been similar to that derived for 1977 (see Fig. 6 and Table 4 *in* Habib 1978a).

Age and growth

Unlike the growth rates observed in 1976 (Vooren 1976), growth as indicated by the movements of modal size classes of fish was not apparent during the 1978 season. Based on growth curve figures by Vooren, the possible age range of skipjack in 1978 was 14 to 42 months, with the fish in the main size classes being about 20 to 24 months. This is similar to earlier years; fish of the main size class in 1976 were possibly about 20 months and in 1977 about 22 months (Habib 1978a).

It is hoped that the skipjack tagging programme at present being implemented by the South Pacific Commission in the western Pacific Ocean (Kearney 1978b) will yield sufficient information to enable the determination of growth rates of skipjack which contribute to the New Zealand fishery.

Food and feeding

Stomach contents were investigated in 413 skipjack (241 females, 172 males) during the season. Samples came from all areas in the fishery and were collected at various times during the day. Almost two-thirds of the stomachs were empty. Those with food contained predominantly the euphausiid *Nyctiphanes australis.* This small shrimp-like animal, about 1 cm long, (see plate 20 *in* Sars 1885) is distributed widely in New Zealand coastal waters (see references to distribution *in* Bartle 1976), and it constitutes an important food for fish (Thomson 1913, Mehl 1969, James 1974, Habib 1978a) and sea birds (Bartle 1976). Other food items in the stomachs were lanternfish *Lampanyctodes hectoris,* anchovy *Engraulis australis,* squid, amphipods, decapods, and unidentifiable fish remains (Fig. 15).

Crustaceans typically comprise the bulk of the food of small skipjack (Raju 1964b). However, as the skipjack grow beyond 50 cm long, fish have been seen to form an increasing proportion of their food (Yuen 1959, Nakamura 1965). Information here and in York (1969, see Fig. 30 and Table 15) shows this trend also in New Zealand skipjack.

Gonad condition

Gonads were examined in the fish dissected for stomach analyses. All fish had undeveloped gonads.

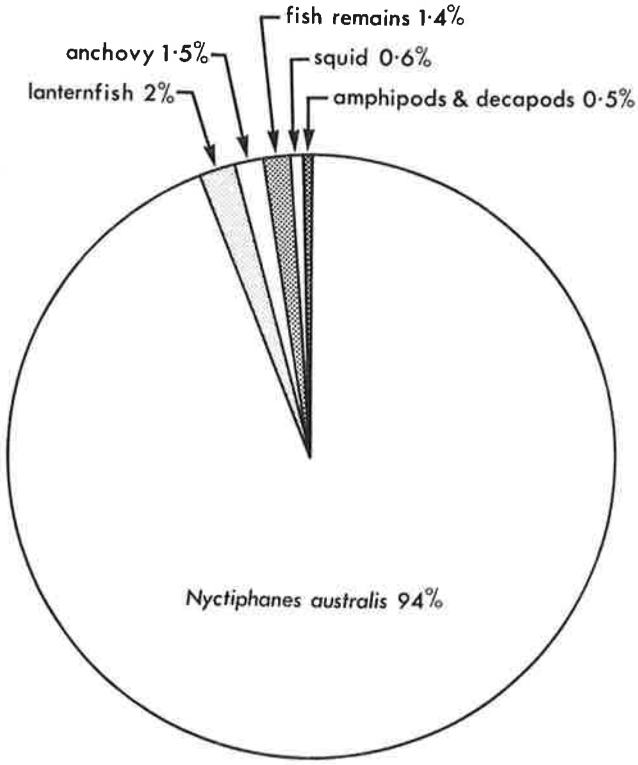


Fig. 15: Stomach contents of skipjack caught in the 1978 purse-seine skipjack fishery in New Zealand.

Skipjack first spawn after reaching 45 cm in length (Brock 1954, Yoshida 1964). Because the mean lengths of skipjack in 1978 catches were greater than 45 cm and the gonads were undeveloped, it is likely that these fish had not yet spawned, but would spawn in other parts of their range.

A possible spawning ground for the New Zealand skipjack stock is near Samoa between 5° and 20° S, where a protracted spawning season is indicated from locations and times of capture of skipjack larvae (Matsumoto 1966) and juveniles (Yoshida 1971). Yoshida also found evidence for a southward migration of juveniles of over 30 cm long between June and September, which could conceivably contribute to the summer fishery in New Zealand.

TABLE 15: Blood samples collected from skipjack taken in purse-seine catches during the 1978 season in New Zealand

Date	Position		Bottom depth (m)	No. in sample	Length range of sample (cm)	Main fish length (cm)
	Latitude	Longitude				
19 Jan	35°39′ S	175°46′ E	364	202	46–58	53
19 Jan	35°43′ S	175°38′ E	324	203	46–58	53
27 Feb	37°43′ S	174°10′ E	119	200	41–56	49
28 Feb	37°37′ S	174°11′ E	146	200	42–57	49
11 Mar	41°49′ S	170°58′ E	166	200	48–58	52
12 Mar	38°13′ S	173°50′ E	134	100	48–59	54
22 Mar	37°57′ S	174°15′ E	82	100	47–55	50

Skipjack population identification

Genetic studies for skipjack population identification were continued, with a further 1205 blood samples being collected (Table 15). These were sent for electrophoretic analysis to Dr B. J. Richardson of Australian National University in Canberra (see Richardson 1978). According to Fujino (1970, 1972, 1976), Pacific skipjack can be divided into western and central-eastern populations. Recent work points to the existence of as many as five subpopulations within Fujino's larger population units (Sharp 1976). Preliminary analyses of New Zealand samples (Richardson pers. comm.) show some similarities with samples from eastern Australia, Lord Howe Island, Fiji, and New Caledonia. Work is continuing in this field.

Summary

The 1977–78 (1978) purse-seine fishery for skipjack was pursued by 10 vessels, which ranged from 23 to 79 m in overall length and 135 to 1558 t in gross weight.

Observations of surface schools of skipjack were made from aircraft and purse-seine vessels during the season. Skipjack migrated into New Zealand waters in December and were present in purse-seinable quantities until early April. Although sightings effort was expended over a wide area off both the North and South Islands, it was most concentrated in areas where and at times when large bodies of skipjack moved along the coast. Most of the sightings were made off Great Barrier Island in January and north of New Plymouth in March. Up to 5000 t was seen at the surface on any half-day. Large schools of 100 t or more were present in abundance throughout the season.

The purse-seine fleet worked 806 season-days: 401 searching and fishing, 136 travelling, 117 making repairs or undergoing survey, 67 discharging or taking stores, 46 sheltering from poor weather, and 39 days off.

During the 401 days fished 9526 t of skipjack was caught. Almost half this quantity was caught off Great Barrier Island (area C) in January, one-fifth in the Bay of Plenty (area D) in February, and over one-quarter north of New Plymouth (area J) in March. Most measures of effort peaked in March, though catch per unit of effort peaked in January.

Most skipjack were caught in blue off-shore water where the bottom depth ranged from 100 to 400 m and sea surface temperature ranged from 19° to 22°C.

Almost two-thirds of the skipjack was caught during the afternoon, one-fifth in the morning, and the remainder in the evening. Effort was similarly apportioned.

There was a fairly even distribution of catches through the moon's cycle. However, effort was greater and catch rates were lower during the first two quarters than during the last two.

Over three-quarters of the catch was taken outside the 12-mile limit and the remainder inside. Effort was similarly apportioned.

All measures of catch rate in 1978 were similar to those in 1976 and higher than those in 1977.

The productivity of the New Zealand purse-seine fishery for tuna (skipjack), as measured by catch per day searching and fishing, is about twice that of the purse-seine tuna fishery (skipjack and yellowfin) in the eastern tropical Pacific Ocean.

Over 22 000 skipjack were measured during the season. The major length ranges in east coast catches were 47 to 49 cm and 51 to 53 cm. On the west coast, fish intermediate in size (49 to 51 cm) predominated. Fish were mainly of the same size as in 1975 and 1977, but larger than those in 1974 and 1976.

Stomach contents were investigated in 413 skipjack during the season. Almost two-thirds of the stomachs were empty. Those with food contained predominantly the euphausiid *Nyctiphanes australis.* Fish, squid, amphipods, and decapods were also present.

Gonads were examined in the fish dissected for stomach analyses. All gonads were undeveloped.

Blood samples were collected for genetic studies on New Zealand skipjack. Preliminary analyses show some similarities with samples from eastern Australia, Lord Howe Island, Fiji, and New Caledonia.

References

BARTLE, J. A. 1976: Euphausiids of Cook Strait: a transitional fauna? *N.Z. Journal of Marine and Freshwater Research 10 (4)*: 559–76.

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.

BRADFORD, J. M., and ROBERTS, P. E. 1978: Distribution of reactive phosphorus and plankton in relation to upwelling and surface circulation around New Zealand. *N.Z. Journal of Marine and Freshwater Research 12 (1)*: 1–15.

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.*

——— 1978a: 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.*

——— 1978b: Summer survey revealed large kahawai schools. Few trevally spotted in reef haunts. *Catch '78 5 (4)*: 14–5.

——— 1978c: Warm sea explains unusually late showing of tuna inshore. *Catch '78 5 (7)*: 14–5.

——— 1978d: Sightings of skipjack on N.Z.'s coast. *Catch '78, August Supplement*: 14–7.

CLEMENT, I. T., and HABIB, G. 1978: Aerial surveys move south to take in new grounds. *Catch '78 5 (1)*: 8–9.

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.*

FUJINO, K. 1970: Immunological and biochemical genetics of tunas. *Transactions of the American Fisheries Society 99 (1)*: 152–78.

——— 1972: Range of the skipjack tuna subpopulation in the western Pacific Ocean. *In* Sugawara, K. (Ed.), "The Kuroshio II. Proceedings of the Second Symposium on the Results of the Cooperative Study of the Kuroshio and Adjacent Regions", pp. 373–84. Saikon Publishing Co., Tokyo.

——— 1976: Subpopulation identification of skipjack tuna specimens from the southwestern Pacific Ocean. *Bulletin of the Japanese Society of Scientific Fisheries 42 (11)*: 1229–35.

GAULD, J. A. 1977: A review of the tuna fishery in the Solomon Islands—1971–76. Unpublished report to Fisheries Division, Ministry of Natural Resources, Solomon Islands.

GREEN, R. E. 1967: Relationship of the thermocline to success of purse seining for tuna. *Transactions of the American Fisheries Society 96 (2)*: 126–30.

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.

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

HYND, J. S. 1968: How sea surface temperature maps aid tuna fishermen. *Australian Fisheries Newsletter 27 (5)*: 23–9.

———1969: Isotherm maps for tuna fishermen. *Australian Fisheries 28 (7)*: 13–22.

JAMES, G. D. 1974: Food of a surface school of trevally (Teleostei: Carangidae) in the north-west Bay of Plenty. *Indo-Pacific Fisheries Council Proceedings, 15th Session, Section III*: 387–9.

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

KEARNEY, R. E. 1978a: Some hypotheses on skipjack (*Katsuwonus pelamis*) in the Pacific Ocean. *Occasional Paper, South Pacific Commission, Noumea, New Caledonia, No. 7.* 23 pp.

———1978b: Skipjack survey and assessment programme annual report for the year ending 31 December 1977. South Pacific Commission, Noumea, New Caledonia. 28 pp.

LEWIS, A. D., SMITH, B. R., and KEARNEY, R. E. 1974: Studies on tunas and baitfish in Papua New Guinea waters—II. *Research Bulletin, Department of Agriculture, Stock and Fisheries, Port Moresby, No. 11.* 112 pp.

MARR, J. C. 1951: On the use of the terms abundance, availability and apparent abundance in fishery biology. *Copeia 1951 (2)*: 163–9.

MATSUMOTO, W. M. 1966: Distribution and abundance of tuna larvae in the Pacific Ocean. *In* Manar, T. A. (Ed.), Proceedings of the Governor's Conference on Central Pacific Fishery Resources, pp. 221–30. State of Hawaii.

MEHL, J. A. P. 1969: Food of barracouta (Teleosti: Gempylidae) in eastern Cook Strait. *N.Z. Journal of Marine and Freshwater Research 3 (3)*: 389–94.

MURPHY, G. I., and NISKA, E. L. 1953: Experimental tuna purse seining in the central Pacific. *Commercial Fisheries Review 15 (4)*: 1–12.

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 (6)*: 459–502, 525–6.

PAUL, L. J. 1978: Satellites and sea temperatures. *Catch '78, August Supplement*: 20–1.

PETERSON, C. L. (Ed.) 1978: Bi-monthly report (September-October, 1978) of the Inter-American Tropical Tuna Commission. 13 pp.

RADOVICH, J. 1963: Effects of water temperature on the distribution of some scombrid fishes along the Pacific coast of North America. *In* Proceedings of the World Scientific Meeting on the Biology of Tunas and Related Species, pp. 1459–75. *FAO Fisheries Reports No. 6, Vol. 3.*

RAJU, G. 1964a: 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.

———1964b: Observations on the food and feeding habits of the oceanic skipjack, *Katsuwonus pelamis* (Linnaeus) of the Laccadive Sea during the years 1958–59. *In* Proceedings of the Symposium on Scombroid Fishes held at Mandapam Camp from January 12–15, 1962, pp. 607–25. 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.*

ROBERTSON, D. A. 1975: Aerial survey of pelagic fish. *Catch '75 2 (6)*: 3–4.

SARS, G. O. 1885: Report on the schizopoda collected by H.M.S. "Challenger" during the years 1873 to 1876. *Challenger Reports, Zoology 13*: 1-225.

SESEPASARA, H. 1973: Further studies of the nearshore tuna resources of American Samoa. Project 4-22-D, July 1972–June 1975. Unpublished progress report to Office of Marine Resources, Pago Pago, American Samoa. 14 pp.

SHARP, G. D. 1969: Electrophoretic study of tuna hemoglobins. *Comparative Biochemistry and Physiology 31*: 749–55.

———1976: Physiology and environmental restrictions on skipjack tuna, *Katsuwonus pelamis.* Working Paper 9, cited in Annex 2 of "*Ad Hoc* Meeting of Scientists to Discuss Skipjack Fisheries Developments and Research Requirements." South Pacific Commission, Noumea.

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.

SWERDLOFF, S. N. 1972: Development of a pole and line skipjack tuna fishery in American Samoa. Project H-15-D, March 1970–June 1972. Unpublished completion report to Office of Marine Resources, Pago Pago, American Samoa. 25 pp.

THOMSON, G. M. 1913: The natural history of Otago Harbour and the adjacent sea, together with a record of the researches carried on at the Portobello Marine Fish-hatchery. *Transactions and Proceedings of the N.Z. Institute 45*: 225–51.

UCHIDA, R. N., and SUMIDA, R. F. 1973: Tuna: pole-and-line fishing trials in central and western Pacific. *Marine Fisheries Review 35 (1–2)*: 30–41.

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.*

WHITNEY, R. R. 1969: Inferences on tuna behavior from data in fishermen's logbooks. *Transactions of the American Fisheries Society 98 (1)*: 77–93.

YORK, A. G. 1969: Tuna investigations—east coast area of New Zealand 1965–1967. *Fisheries Technical Report, N.Z. Marine Department, No. 40.* 80 pp.

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.

———1971: The early life history of skipjack tuna, *Katsuwonus pelamis*, in the Pacific Ocean. *Fishery Bulletin (NOAA) 69 (3)*: 545–54.

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

BY AUTHORITY:
P. D. HASSELBERG, GOVERNMENT PRINTER, WELLINGTON, NEW ZEALAND—1980

51878E—80PT