Northwest Atlantic Fisheries Organization

Serial No. N915

NAFO SCR Doc. 84/IX/118

SCIENTIFIC COUNCIL MEETING - SEPTEMBER 1984

Distribution, Abundance and Size Structure of Arrow Squid (*Nototodarus* sp.) off New Zealand

by

R. H. Mattlin, R. E. Scheibling[1], and E. C. Forsch

Fisheries Research Division, Ministry of Agriculture and Fisheries
P. O. Box 297, Wellington, New Zealand

Abstract

Two species of arrow squid (Nototodarus) were sampled by bottom trawling during nine research cruises along the north and east coast of South Island, New Zealand, between January, 1982 and April, 1983. There was minimal overlap between the two species. Species 1 was associated with subtropical water along the north coast (Tasman Bay) of South Island and Species 2 with the Subantarctic Convergence Zone and subantarctic water along the east coast. Catch rates of Species 2 varied markedly with geograpahic location, depth (from 50-500 m) and sampling period, but were consistently lowest in January, of both years. Differences in population size structure of Species 2 with depth were associated with differences in the relative abundance of juveniles. Juveniles of Species 2 were most abundant at 50 and 100 m but were rare to absent at 300 and 500 m. Size distributions of males and females were similar for each depth and sampling period for both species. Size distributions of Species 1 indicated growth rates (change in dorsal mantle length) of 3-4.5 $cm \cdot mo^{-1}$ for 3 cohorts separated by about 6 mo. Assuming a linear growth curve, spawning of Species 1 occurs biannually around November and April, and maximal size (~ 40 cm) is attained in about 1 y. Size distributions of Species 2, were polymodal and did not give clear indications of growth or spawning period. This is attributed to the pooling of size distributions from several subpopulations of

[1] Present address: Department of Biology, Dalhousie University, Halifax, Nova Scotia, Canada, B3H 4J1

Species 2 along the east coast of South Island, differing in age structure, spawning period and/or growth rate.

Introduction

Arrow squid of the genus Nototodarus (family Ommastrephidae) occur throughout the continental shelf waters of New Zealand, eastwards to Chatham Islands and Southwards to the Campbell Islands (Roberts, 1978). Two species of Nototodarus have been identified from New Zealand on the basis of genetic and morphologic differences (Smith, et al., 1981; Kawakami and Okutani, 1981). Their taxonomy remains unresolved: they are referred to in this study as Nototodarus species 1 (probably N. sloani) and N. Species 2. The two species occupy different geographical ranges with limited overlap. In general, Species 1 occurs to the north of the subtropical convergence and Species 2 occurs to the south (Mattlin, 1983).

A major arrow squid fishery has developed off New Zealand since the early 1970's. The squid are jigged or trawled primarily by foreign vessels (from Japan, Korea, Taiwan and Russia) licensed to fish in New Zealand's 200 mile Exclusive Economic Zone. The total catch of Natotodarus spp. in the 1981-82 fishing season was approximately 64,000 tonnes, earning New Zealand over $58 million (Mattlin, 1983).

Previous studies of the population biology of Nototodarus have been based mainly on data collected during commercial fishing operations or short-term research programs (Hamabe et al., 1974; Kawakami, 1976; Kawakami et al., 1972, 1973; Tung, 1978). This study investigates the distribution, abundance and population structure of Nototodarus spp. in Tasman Bay and along the east coast of South Island, as part of a broader study of the population biology of Nototodarus spp. based on a series of research cruises in 1982-83.

Sampling Methods

Nototodarus spp. were sampled during nine research cruises by the New Zealand research vessel "James Cook" between January 1982 and April 1983. Squid were caught using a Mark IV Boston trawl with a 60 mm mesh cod-end towed near bottom at about 3 knots for 1 hour. All trawling was done during the day between 7:00 and 17:00 h.

Trawling for Nototodarus was done at two to five stations along six transects: Transect 1 (two stations) was in Tasman Bay, Transects 2-6

(five stations each) spanned the east coast of the South Island from Kaikoura to Stewart Island (Fig 1). Stations 1 to 5 were at depths of 50, 100, 200, 300, and 500 m respectively. Stations were selected according to depth records from hydrographic charts and located by satellite navigation. Bottom depth and trawl depth were recorded continuously during each trawl.

Freshly caught Nototodarus were individually measured (dorsal mantle length, DML) and weighed. Sex was determined by the presence of the hectocotylus in males or by macroscopic examination of the gonads; the sex of juvenile squid (without identifiable gonads) was not determined. Male squid were identified as Nototodarus species 1 or 2 by the morphology of the hectocotylus (Smith, et al., 1981). Samples (1-5 g) of mantle tissue from female and juvenile squid were frozen at -20°C for subsequent electrophoretic identification of species (Smith, et al., 1981). For large catches random subsamples of squid were analyzed and the total catch was weighed.

Results

There was little overlap in the distribution of Notododarus spp. among transects. Species 1 represented 96% (N = 793) of the total catch at Transect 1 and 13% (N = 136) of the total catch at Transect 2 for all sampling periods. Species 1 was not caught at Transects 3-6.

Juveniles represented a smaller portion (15%) of the total catch of Species 1 at 50 m than at 100 m (47%) (Fig 3). Juveniles of Species 1 were most abundant in February, 1982 (38% of the total catch for Cruise 3) and were rare to absent in January, 1982 (Cruise 1) and between May, 1982 and January, 1983 (Cruises 4-8), (Fig 4). Modal progressions in the size distributions of Species 1 over time (Fig 4) may indicate the growth of 3 cohorts of squid differing in age by about 6 mo. (Fig 5). Growth rates of squid between 10 and 34 cm DML (modal size) are approximately linear and range from 3 to 4.5 $cm \cdot mo^{-1}$ (Fig 5). Size distributions of males and females of Species 1 were similar between depths (Fig 3) and among sampling periods (Fig 4).

Catch rates of Species 2 varied markedly with geographic location (transect), depth (station) and sampling period (cruise) (Table 1, Fig. 2). Maximal catch rates were recorded in 1982 in February (330 $kg \cdot h^{-1}$) and June (267 $kg \cdot h^{-1}$) at 50 m depth on Transects 4 and 3 respectively, and September (301 $kg \cdot h^{-1}$) at 300 m on Transect 6. Catch rates at

other locations and times ranged from 0 to 57 $kg \cdot h^{-1}$. Catches were consistently low at all stations in January of 1982 and 1983, ranging from 0 to 4 $kg \cdot h^{-1}$. Total catch and mean catch rate, measured by pooling catch data from all transects during each sampling period, were highest between February and June and in September, 1982 (Fig 2).

Juveniles of Species 2 were most abundant at 50 and 100 m where they represented 47% of the total catch at those depths (Fig 3). Juveniles represented 27% of the catch at 200 m but were rare to absent at 300 and 500 m. Juveniles of Species 2 increased in size with depth: modal sizes were 5 and 10 cm at 50 m and 13 cm at 200 m (Fig. 3). The relative abundance of juveniles of Species 2 was highest in January of 1982 and 1983 (63% and 87% of the total catch for Cruises 1 and 8 respectively) (Fig 4). Juveniles were also abundant in April 1982 (46% of the catch for Cruise 3) but rare to absent in July and November, 1982 (Cruises 5 and 7 respectively) and March, 1983 (Cruise 9). Size-frequency distributions of Species 2, based on data pooled over all transects, are polymodal (Fig 4). There is no consistent pattern in the number or progression of modes to indicate the growth of cohorts. Size distributions of males and females of Species 2 were similar for each depth (Fig 3) and sampling period (Fig 4).

Mean size was similar between sexes and between species of Nototodarus (Table 2). The maximal sizes recorded for Species 2 were greater than those for Species 1 (although sample size was greater for Species 2). The maximal size of females was greater than that of males for Species 2 (Table 2).

Least square regression equations were calculated from the $\log_e$ transformed length and weight data for both species. Due to non-linearity of the transformed data, a spline technique was applied (Draper and Smith 1981) giving separate equations for squid $\leq$ 12.0 cm DML and > 12.0 cm DML. The resulting power functions are:

$$W = 1.73 \times 10^{-3} \cdot DML^{2.63} \quad \text{for Species 1} \leq 12.0 \text{ cm DML}$$

$$W = 2.90 \times 10^{-4} \cdot DML^{3.00} \quad \text{for Species 1} > 12.0 \text{ cm DML}$$

$$W = 4.90 \times 10^{-3} \cdot DML^{2.35} \quad \text{for Species 2} \leq 12.0 \text{ cm DML}$$

$$W = 1.20 \times 10^{-4} \cdot DML^{3.11} \quad \text{for Species 2} > 12.0 \text{ cm DML}$$

where W is weight (g) and DML is dorsal mantle length (cm).

Discussion

Nototodarus spp. off New Zealand are fished by foreign trawl and jig fleets mainly between December and May, i.e., the austral summer and fall (Roberts, 1979). Although it is not clear whether commercial concentrations of arrow squid are present in winter and spring, this study and others (Roberts, 1979) indicate the potential for a year-round fishery. The highest catch rates by weight in this study (though not of commercial scale) were in July and September, 1982. In contrast, the lowest catch rates were in January of 1982 and 1983. New Zealand trawlers catch arrow squid throughout the year and there are no clear seasonal trends in domestic landings (Roberts, 1979).

The limited overlap in the distribution of the two species of Nototodarus suggests that they are associated with different water masses: Species 1 in subtropical water and Species 2 in the Subtropical Convergence Zone and subantarctic water. On the east coast of South Island, Species 1 extends south to Kaikoura (Transect 1) where it co-occurs (but in low abundance) with Species 2 (Smith, et al., 1981; this study). Species 1 also occurs off the north (Tasman Bay) and west coasts of South Island and the east and west coasts of North Island with 1983). Species 2 occurs off the east and south coasts of South Island, south to the Aukland Islands shelf, the Campbell Plateau and Antipodes Islands, and east to the Chatham Islands (Mattlin, 1983). Two morphs of species 2 off the east coast of South Island have been distinguished by the number of suckers on the hectocotylus (Kawakami and Okutani, 1981), although genetic differences have not been found (Smith, et al., 1981; this study). The presence of 2 geographically separate species of arrow squid off New Zealand may ultimately necessitate separate management strategies. The logical geographic division of the fishery would be through Cook Strait between North Island and South Island.

Bimodal or polymodal size distributions of Species 1 and Species 2 indicate the presence of two or more cohorts of squid. A clear progression in modal size of Species 1 in Tasman Bay (Transect 1) indicated growth rates of 3-4.5 $cm \cdot mo^{-1}$ for 3 cohorts followed over the 15 mo. study period. Assuming that the growth curve is approximately linear over the entire life cycle, spawning of Species 1 in Tasman Bay occurs biannually around November and April (austral spring and fall) and squid attain maximal size after about 1 year. The

growth rates estimated for Species 1 are consistent with previous estimates for Nototodarus spp. and other ommastrephid species (Table 3).

Polymodal size distributions of Species 2, based on data pooled over all transects for each sampling period, do not give clear indications of the growth of cohorts or of spawning periods. This suggests the presence of several subpopulations of Species 2, differing in age structure, spawning period and/or growth rate along the east coast of South Island. Previous studies have distinguished up to eight subpopulations of Nototodarus spp. off New Zealand based on differences in spawning time and area, and size at spawning (Kawakami et al., 1972; Hamabe et al., 1974; Kawakami, 1976; Nesis, 1979). Different subpopulations or spawning groups also have been distinguished for ommastrephid species off Japan: Ommastrephes bartrami (Murata and Ishii, 1977) and Todorodes pacificus (Doi and Kawatami, 1979).

The marked decrease in the abundance of juveniles of Species 2 with depth suggests that hatching occurs in shallow, nearshore waters and that squid migrate to deeper offshore waters as they develop into adults.

Acknowledgements

We thank S.D. Canning and P.J. Tyson for their assistance throughout the planning and execution of this study, and P.J. Smith for his genetic verification of species. We also thank the officers and crew of the GRV JAMES COOK for their efforts, often under difficult conditions.

References

Doi, T. and Kawakami, T. 1979. Biomass of Japanese common squid Todarodes pacificus Steenstrup and the management of its fishery. Bull. Tokai Reg. Fish. Lab. 99: 65-83.

Draper, N.R. and Smith, H. 1981. Applied regression analysis. 2nd. Edition. John Wiley and Sons. New York. 709 pp.

Ehrhardt, N.M., Jacquemin, P.S., Garcia, B.F., Gonzalez, D.G., Lopez, B.J.M., Ortiz, C.J., and Solis, A. 1983. On the fishery and biology of the giant squid Dosidicus gigas in the Gulf of California, Mexico. Pages 306-340 in Caddy, J.F. (ed.), Advances in assessment of world cephalopod resources. FAO Fish. Tech. Pap. 231: 452 pp.

Forsch, E.C. 1983. Squid-current research. In, New Zealand finfish: the resources and their management. J.L. Taylor and G.G. Baird, eds. Trade Publications, N.Z.

Fridriksson, A. 1943. Remarks on the age and growth of the squid. Greiner 2(2): 170-174.

Hamabe, M.; Saito, R. and Kawakami, T. 1974. A trial to inference of locating fishing grounds for New Zealand Nototodarus sloani sloani (Gray) from the information concerning propagation of Japanese Todarodes pacificus Steenstrup. Bull. Tokai Reg. Fish. Res. Lab. 80: 1-10.

Kawakami, T. 1976. The fishery biological study on a squid, Nototodarus sloani sloani (Gray), in the New Zealand waters. Bull. Tokai Reg. Fish. Res. Lab. 85: 31-104.

Kawakami, T., Hamabe, M. and Saito, R. 1973. A preliminary note on the ecology of the ommastrephid squid Nototodarus sloani sloani (Gray) in New Zealand waters - II. Bull. Tokai Reg. Fish. Res. Lab. 76: 53-69.

Kawakami, T., Sasagawa, Y. and Hamabe, M. 1972. A preliminary note on the ecology of the ommastrephid squid Nototodarus sloani sloani (Gray) in New Zealand waters. Bull. Tokai Reg. Fish. Res. Lab. 70: 1-23.

Mattlin, R.H. 1983. Squid. In, New Zealand finfish: the resources and their management. J.L. Taylor and G.G. Baird, eds. Trade Publications, N.Z.

Murata, M. and Ishii, M. 1977. Some information on the ecology of the oceanic squid, Ommastrephes bartrami (Lesueur) and Onychoteuthis borealijaponicus Okada, in the Pacific Ocean off Northeastern Japan. Bull. Hokkaido Reg. Fish. Res. Lab. 42: 1-23.

Nesis, K.N. 1979. Squid of the family Ommastrephidae in the Australian-New Zealand region. Tr. Inst. Oceanology 106: 140-146.

Roberts, P.E. 1978. New Zealand squid resources. In, Proceedings of the Pelagic Fisheries Conference, July 1977. G. Habib and P.E. Roberts, eds. New Zealand Fisheries Research Division Occasional Publication No. 15.

Roberts, P.E. 1979. Squid. In, Proceeddings of the Demersal Fisheries Conference, October 1978. R.D. Elder and J.L. Taylor, eds. New Zealand Fisheries Research Division Occasional Publ No. 19.

Roberts, P.E. 1983. The biology of jig-caught arrow squid (Nototodarus spp.) in New Zealand waters. Memoirs of the National Museum Victoria 44: 297-303.

Smith, P.J., Roberts, P. E. and Hurst, R.J. 1981. Evidence for two species of arrow squid in the New Zealand fishery. N.Z. J. Mar. Freshwat. Res. 15: 247-253.

Tung, I. H. 1978. On the biology and the fishing of the squid, Nototodarus sloani sloani (Gray), in the New Zealand waters. Reports of the Institute of Fishery Biology of Ministry of Economic Affairs and National Taiwan University 3(3): 44-64.

Table 1. Catch rates (fresh weight, $kg \cdot h^{-1}$) of Nototodarus spp. for all stations and sampling periods.

TRANSECT	STATION/ DEPTH (M)	CRUISE/SAMPLING PERIOD								
		1	2	3	4	5	6	7	8	9
		8-20 Jan 82	15-28 Feb 82	7-22 Apr 82	28 May - 10 Jun 82	23 Jul - 6 Aug 82	30 Aug - 12 Sep 82	12-25 Nov 82	8-19 Jan 83	4-16 Mar 83
1	50	0.6	12.3	12.6	10.7	0.5	1.3	19.0	18.2	11.8
	100	0	11.8	3.2	6.9	0.9	0.9	0.8		
2	50	4.2		0.3	16.5	3.4	1.0	2.5	1.5	31.2
	100	1.1		0.6	9.5	0	0.8		1.1	9.6
	200	3.8	0.8							
	300	1.0	0			1.5			1.9	3.2
	500	0.9	6.8			0.9				
3	50	0	24.0	4.0	267.0	0	0.2	0	1.8	42.8
	100	6.1	2.1	32.5	1.9	0.8	1.0	44.0	0.4	5.3
	200		5.3	9.6	15.0				0.8	
	300	1.9	6.3	0.9	3.5	8.5	46.0	1.8	1.5	4.7
	500							1.8		1.2
4	50	0.9	330.0	12.7	51.5	0	0	0.8	3.3	30.0
	100	1.7	17.0	25.3	1.8	1.2	0	0.8	1.1	40.0
	200	0.7	4.1	22.8	15.0		1.3	0.6	4.3	
	300	0.7	5.9	0.7	0.3		301.0	4.4	0.5	6.4
	500	3.6					1.5	3.9	4.2	1.0
5	50	0		1.6	1.5	0	8.0	0.5	1.1	1.8
	100	0.5		38.6	4.2	1.6	0	1.5	0.6	0.7
	200	0.9		38.9	5.5	31.0			0	0
	300	0		56.9	2.5	8.5	11.0	0	0	0.1
	500	1.3		1.2	2.7	3.4			0.7	0.6
6	50	2.8	3.7	4.2	2.5	0	1.5	0.2	0.1	0.2
	100	0.6	6.8	4.9	0.4	0	0	0.4	0.2	0.9
	200		4.5			0		5.8		
	300	1.6		0	11.5	27.3		1.9	0.3	2.0
	500					1.4				

Table 2. Size (DML, cm) description of Nototodarus spp.

	SPECIES 1		SPECIES 2	
	Male	Female	Male	Female
N	319	269	1265	1098
mean	22.5	24.0	24.7	25.9
median	22.7	23.8	26.0	26.4
S.D.	4.6	5.6	5.6	6.5
maximum	37.0	37.0	39.2	45.2

Table 3. Growth rates of ommastrephid squid.

Species	Location	Period	Size Range (DML, cm)	Growth Rate (cm mo^{-1})	Reference
Nototodarus sp 1	Tasman Bay, New Zealand	Jan, 1982-March 1983	10-34	3.0-4.5	this study
Nototodarus spp	New Zealand	1980-81	25	3.0	Forsch, 1983
Nototodarus spp	West Coast, New Zealand	Dec. 1976-April 1977	18-24 24-33	2.5-4.0 1.5-3.0	Roberts, 1983
Nototodarus spp	New Zealand	Dec.-Apr.		2.0-2.5	Tung, 1978
Ommastrephes bartrami	Japan	summer winter		3.0-4.0 0.5-1.0	Murata and Ishii, 1977
Todaroides saggittaus	Iceland	summer winter		5.0-7.5 2.0	Fridrikson, 1943
Dosidicus gigas	Gulf of California			1.0-9.0	Ehrhardt et al. 1983

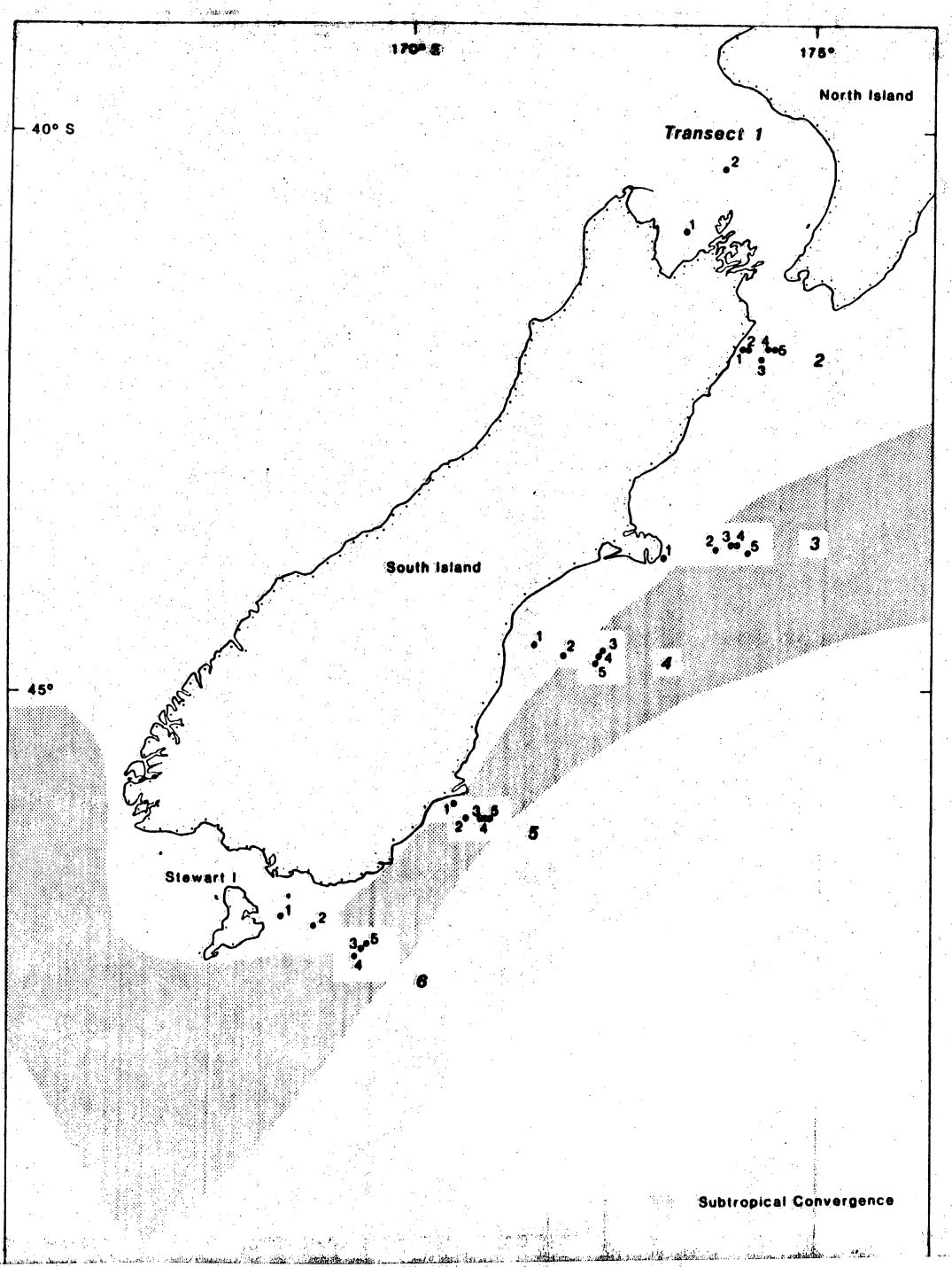
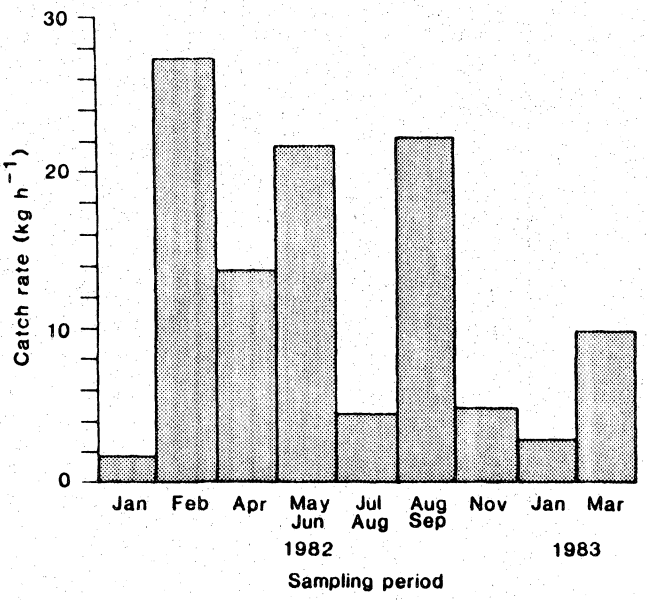
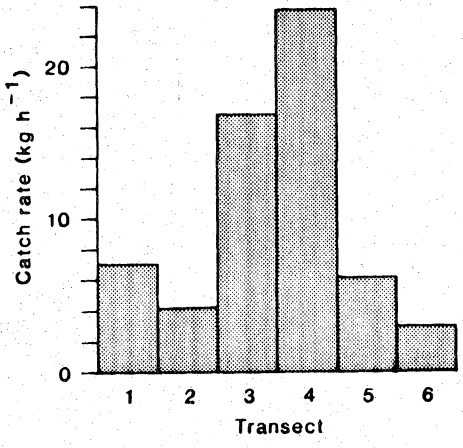


Fig. 1 Map of South Island, New Zealand, showing location of transects and stations sampled and position of the Subtropical Convergence Zone.





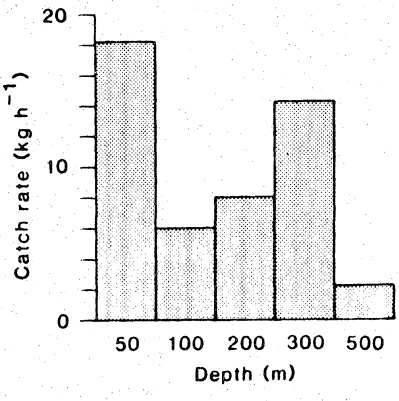


Fig. 2 Mean catch rate (kg·h^{-1}) for Nototodarus sp. 2 for each sampling period, transect and depth.

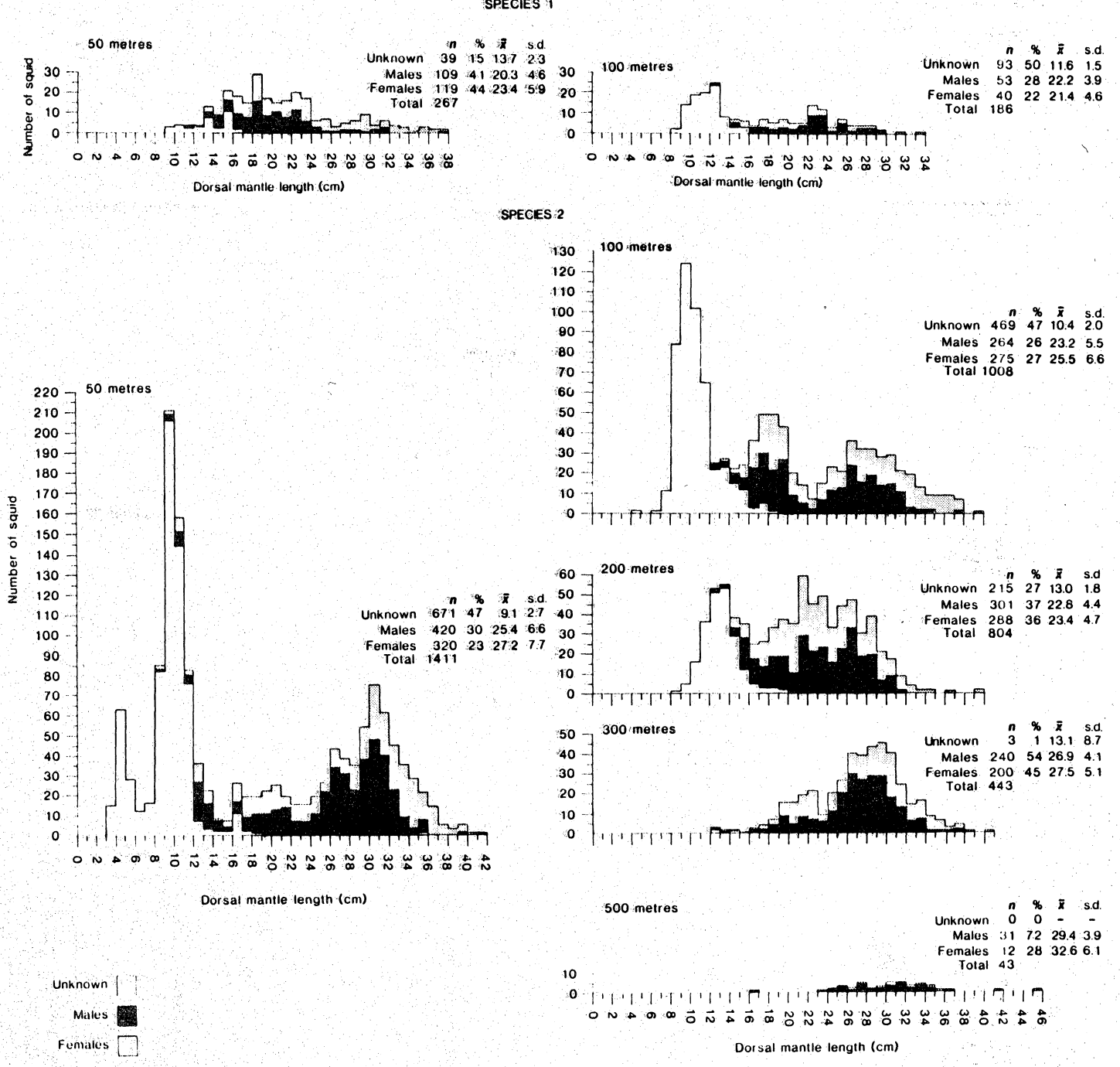


Fig. 3 Size (DML, cm) distributions of Nototodarus sp. 1 and N. sp. 2 by depth (m).

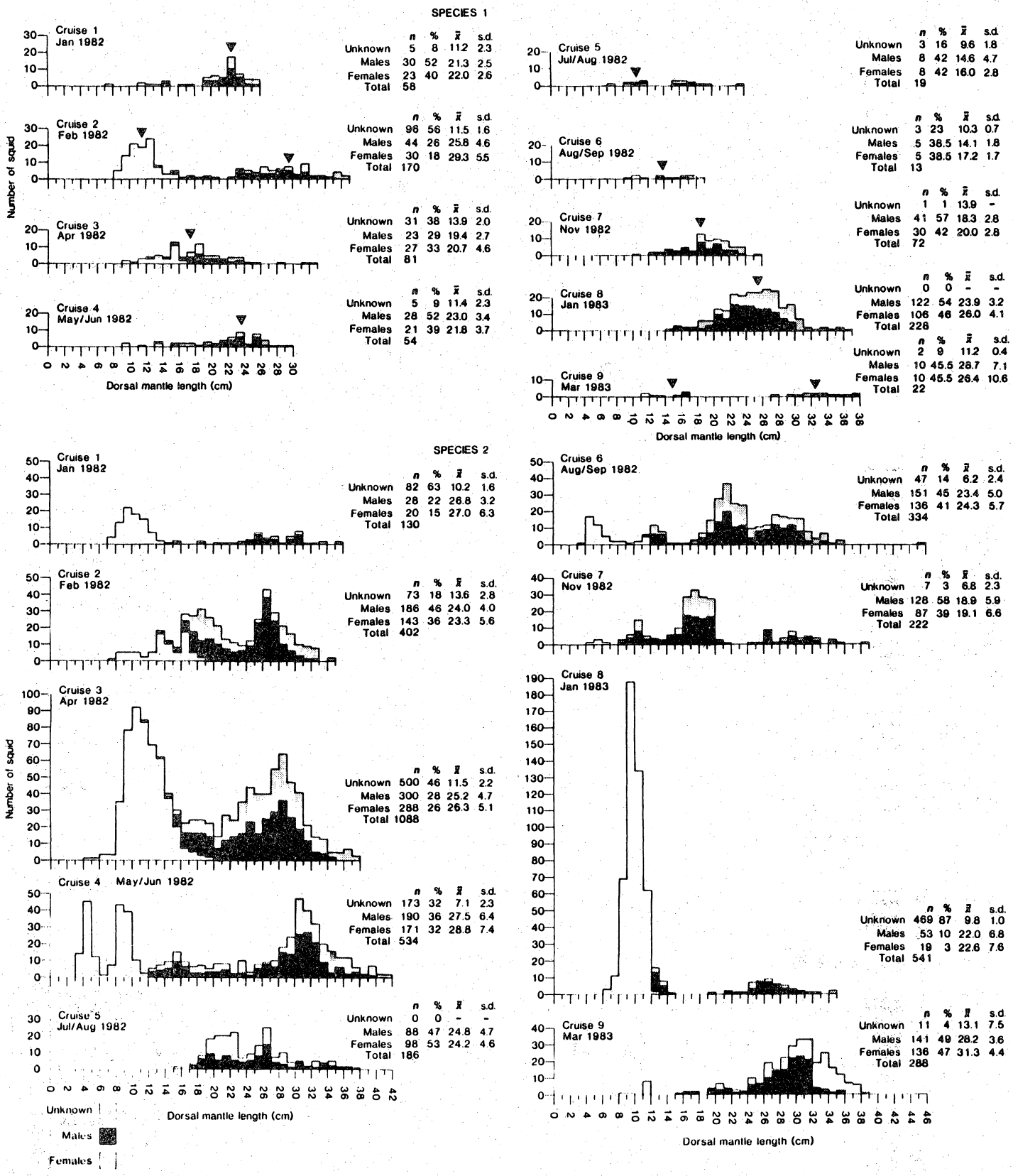


Fig. 4 Size (DML, cm) distributions of Nototodarus sp. 1 and N. sp. 2 by sampling period. Letters indicate modal classes (visually determined) for N. sp. 1.

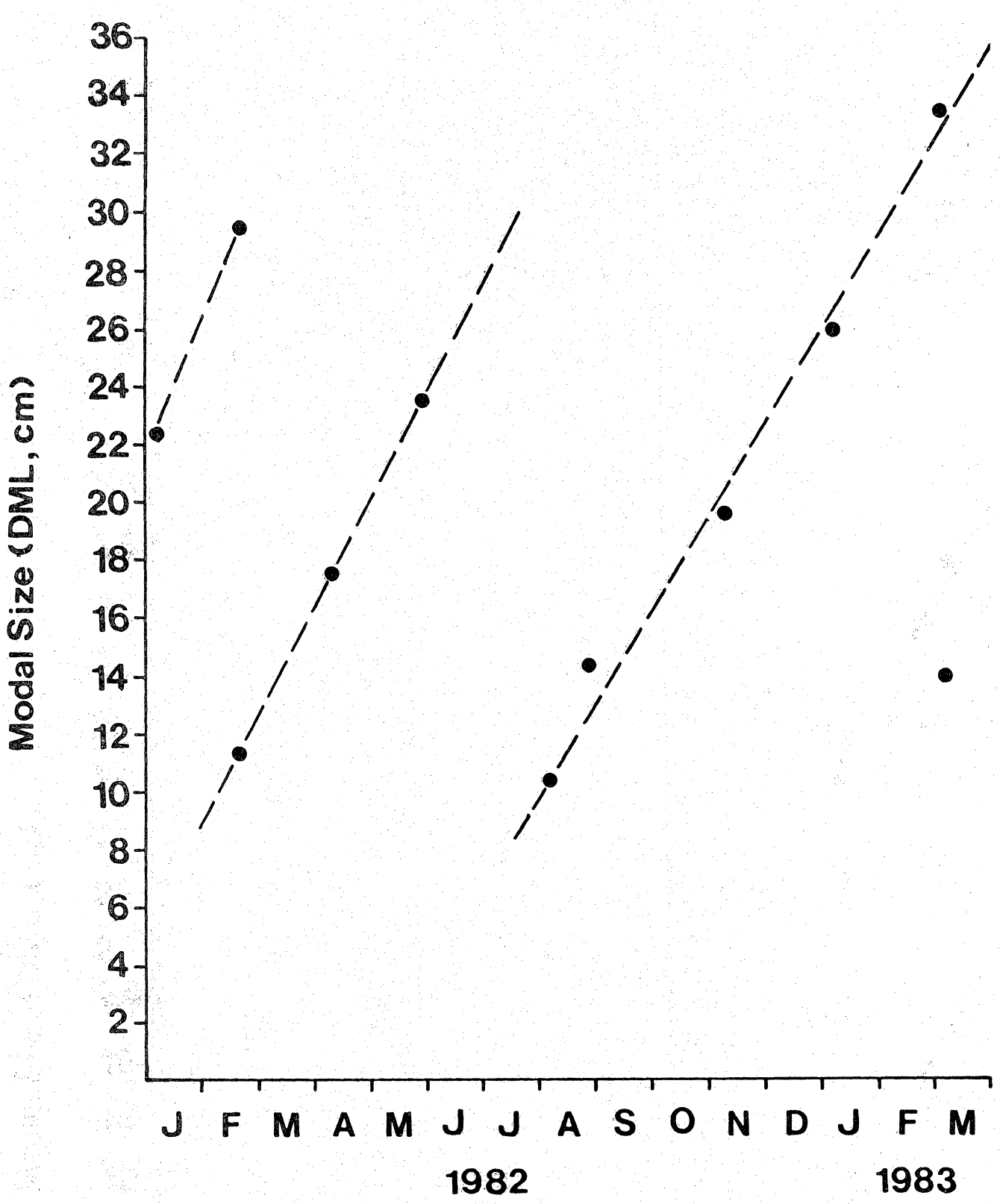


Fig. 5 Relationship between modal sizes (DML, cm) of Nototodarus sp. 1 (see Fig. 4) and sampling time, showing growth of cohorts. Dashed lines are fitted visually.