https://doi.org/10.24199/j.mmv.1983.44.23 30 June 1983

FISHERY AND BIOLOGY OF *NOTOTODARUS GOULDI* (McCOY, 1888) IN WESTERN BASS STRAIT

By Heather K. Smith

South Australian Department of Fisheries, 25 Grenfell Street, Adelaide, S.A. 5000

Abstract

Data on the abundance of *Nodododarus gouldi* from 134°E to 146°E collected during the 1979/80 squid jigging season is presented. In some areas, the full moon can depress catch rates by as much as 50 per cent. The length-weight relationship for males and females is significantly different, and data on reproductive maturity suggest a protracted mating season.

Introduction

The squid *Nototodarus gouldi* (McCoy 1888) occurs in oceanic and open coastal waters of southern Australia. As yet, its biology, geographic limits and taxonomic affinity to the two New Zealand species *Nototodarus sloani* (Gray) and *Nototodarus* sp. (Smith *et al.*, 1981) are poorly known.

Harrison (1979) described three 'broods' or subpopulations of *N. gouldi* in Tasmanian waters but it cannot be assumed that this will be the situation throughout southern Australia. Kawakami (1976) identified eight subpopulations of *N. sloani* in waters around New Zealand on the basis of size composition, gonad maturity, spawning area and season. Investigations by Smith and co workers (1981) indicated the presence of two species of *Nototodarus*.

Feasibility fishing for *N. gouldi* commenced in the summer of 1978/79, with 19 Japanese squid jigging vessels operating in south east Australian waters (Figure 1). Since catch rates obtained by these vessels were promising, large scale feasibility fishing, involving 63 Japanese and one Taiwanese squid-jigging vessels was undertaken in the summer of 1979/80. Twenty-seven of these vessels operated off South Australia and Victoria in accordance with an agreement to distribute effort throughout the area during the season. Vessels began fishing on December 21, 1979 and concluded on April 6, 1980.

This paper presents the results of fishing by these 27 vessels, with some preliminary observations on the morphometry, reproduction and stomach contents of *N. gouldi*. Such observations will be of value for management of the fishery, and in the identification of distinct subpopulations of the species.

Materials and Methods

Each fishing vessel kept a daily log of its fishing operations, including data on daily catch, hours fished, depth and sea state. Observers on board vessels verified the log book data and collected the following additional data on a daily sample (N = 50) of *N. gouldi*.

Mantle Length: Measured dorsally (to the nearest mm) using a measuring board

Body Weight: Measured to the nearest 10 g using a Salter spring balance.

Sexual Maturity: Recorded for males and females using the index in Appendix I.

Hectocotylisation: Adult males of the genus *Nototodarus* have both ventral arms hectocotylised. Presence of hectocotylisation was recorded for all individuals.

Copulation: Mated females were readily identified by the presence of spermatophores in the buccal region.

Stomach Fullness: Recorded as empty, ¼, ½, ¾, full.

Stomach Contents: Analysed macroscopically with a hand lens (×10 magnification).

Results and Discussions

Catch Rates: The mean monthly catch rates (kg/hour) by half degree squares for all 27 vessels are shown in Figure 2 for consecutive months from December 1979 to March 1980. The highest catch rates occurred from longitude 136°-141°E in December 1979 and January

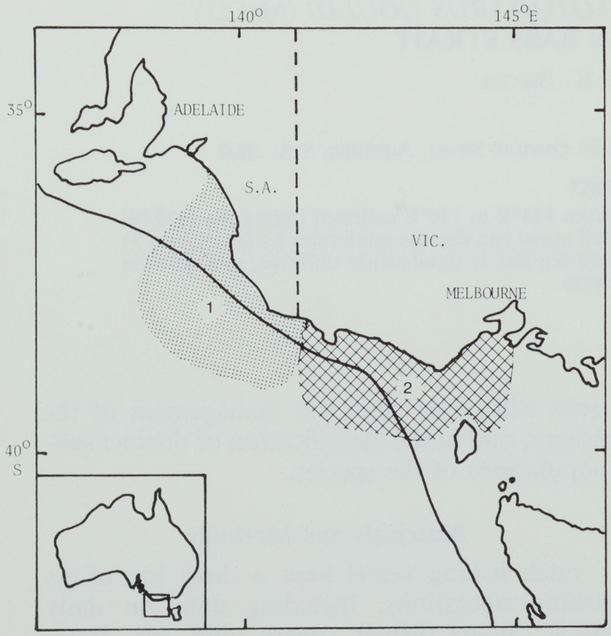

Figure 1. Location of major fishing areas in South Australian (Area 1) and Victorian (Area 2) waters. (Contour line represents the edge of the Continental Shelf.)

1980. In February and March 1980 catch rates declined in this area but increased in the blocks to the south and east in western Bass Strait. Catch rates in the area west of 136°E were low early in the season, and declined to even lower levels as the season progressed, despite a continuing fishing effort of 30 vessel days per month throughout the season.

Using the catch rate as a measure of stock abundance and assuming catchability is constant, the data suggest that the principal stocks occurred in western Bass Strait, with decreasing abundance westerly into the Great Australian Bight. A south-easterly migration into Bass Strait during the season could explain the increased abundance in that region.

Environmental Effects

Lunar cycle:

Areas 1 and 2 (Figure 1) were the only regions in which fishing was conducted continuously throughout the lunar cycle. Plots of mean daily catch rates against time for these regions (Figure 3) show that catch rates are markedly lower around the time of the full moon, although some variability is evident due to differences in catches between vessels. Grouping of the daily catch rate into four weekly periods in relation to the lunar cycle (Table 1) shows that during the week of the full moon catch rates are nearly 50 per cent lower in Area 1 and about 25 per cent lower in Area 2 than in any other week. A relationship between catch rates and the full moon in a squid jig fishery has been demonstrated for *Illex illecebrosus* by Ichikawa & Sato (1976) and for *N. gouldi* by Ichikawa (1978).

The high variability in catch rates both in time and place (Figure 3) may be due to a tendency for *N. gouldi* to school, as is the case with many species of pelagic squid (Bennett, 1978).

Depth: N. gouldi was generally taken in neritic waters over the continental shelf. Table 2, giving total catches according to depth for Areas 1 and 2, shows that a greater proportion of the catch was taken in somewhat deeper water in Area 1 than in Area 2. However, in the regions showing the greatest abundance of squid, the continental shelf break (177 m depth contour) occurs closer to shore in Area 1 than in Area 2 (Figure 1). Since vessels were excluded from State territorial waters (i.e. within 3 nautical miles of the coast), it is possible that these differences in catch rate according to depth are a result of greater fishing effort in deeper water in Area 1.

Biological Data

Length-Weight Relationship:

Least square regressions were calculated for length and weight data for *N. gouldi*, and gave the following equations.

Males W $= 0.0139\ L^{3.2128}$ ($N = 4723$; $r^2 = 0.91^{***}$)

Females W $= 0.0392\ L^{2.869}$ ($N = 3311$; $r^2 = 0.92^{***}$)

Combined Sexes W $= 0.0279\ L^{2.9878}$ ($N = 8034$; $r^2 = 0.92^{***}$)

where W = fresh weight and L = mantle length.

The slope of the regression calculated for males was found to be significantly different from that for females ($t = 17.0$, $p < 0.05$).

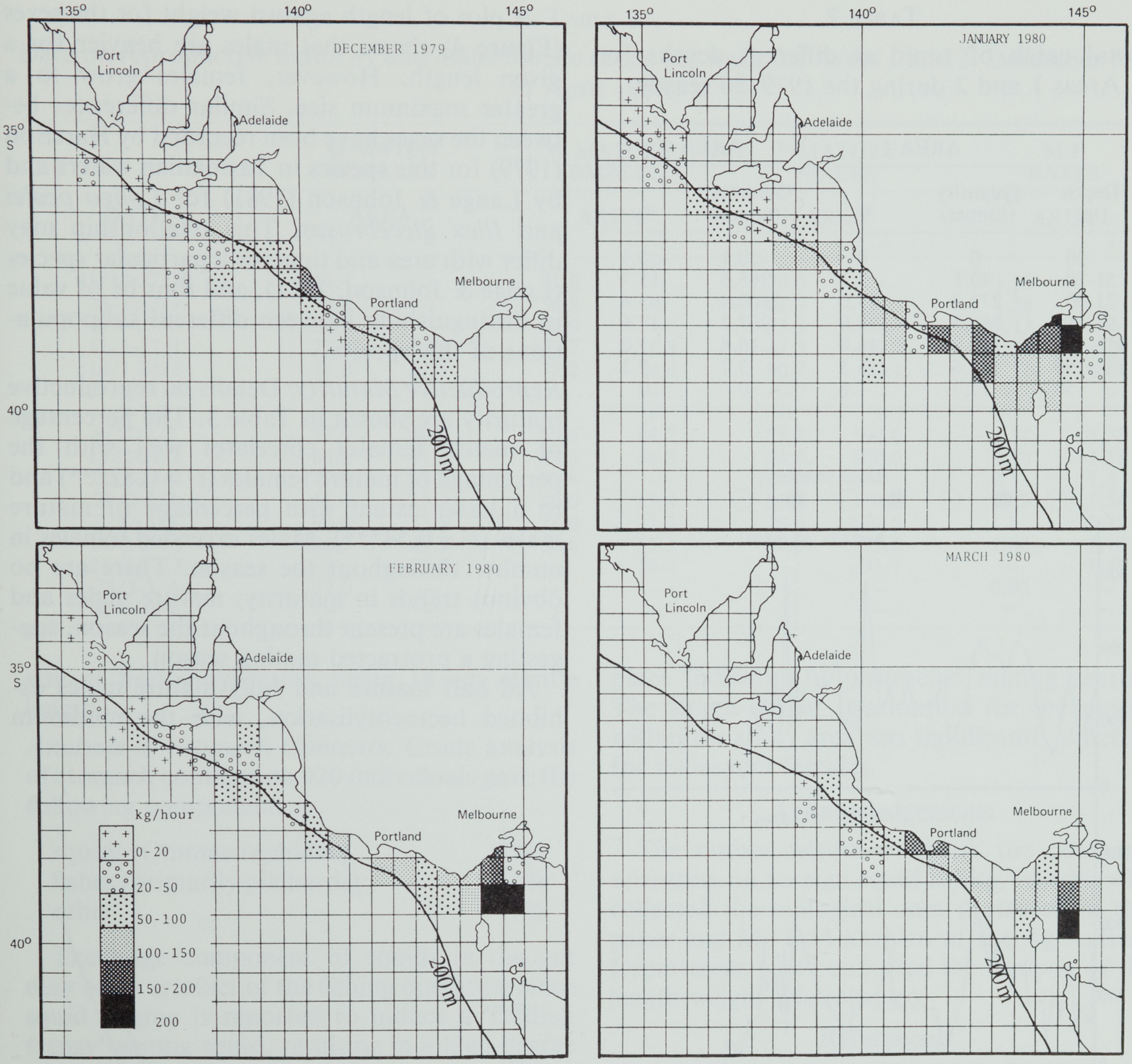

Figure 2. Catch per unit effort (kg/hour) by half degree square December 1979 to March 1980.

TABLE 1

Average catch rate (kg/hr) with respect to lunar phase for Areas 1 and 2, January 1980 to March 1980.

	AREA 1				AREA 2			
	Jan.	Feb.	Mar.	Average	Jan.	Feb.	Mar.	Average
Last Quarter	108	81	99	95	202	136	197	181
New Moon	123	103	107	112	162	164	141	157
1st Quarter	144	74	111	114	168	167	123	156
Full Moon	39	67	45	51	138	135	82	129

TABLE 2

Total catch of squid at different depths for Areas 1 and 2 during the 1979/80 season.

	AREA 1		AREA 2	
Depth (m)	Quantity (tonnes)	%	Quantity (tonnes)	%
50	0	0	<0.1	<0.1
51-70	40.1	5.1	265.6	15.7
71-90	277.3	35.0	1100.9	65.4
91-110	285.3	36.0	297.2	17.6
111-130	132.8	16.8	16.8	1.0
131-150	43.6	5.5	3.7	0.2
150	12.7	1.6	0	0

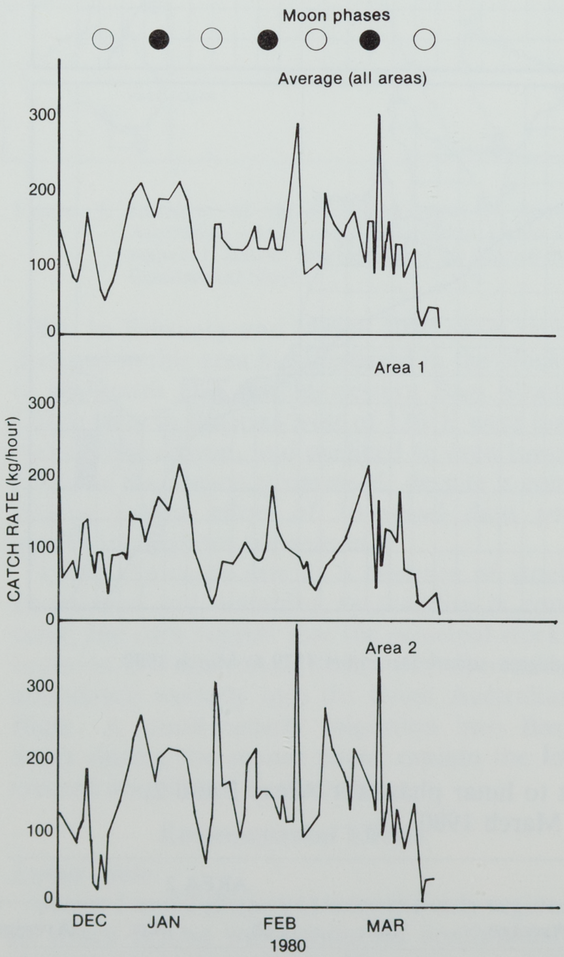

Figure 3. Relationship between lunar phase and daily catch rate for Areas 1 and 2, December 1979 to March 1980. (Open circles represent full moon, closed circles represent new moon.)

A plot of length against weight for the sexes (Figure 4) shows that males are heavier for a given length. However, females grow to a greater maximum size. Similar differences between the sexes have been recorded by Harrison (1979) for this species in Tasmanian waters and by Lange & Johnson (1981) for *Loligo pealei* and *Illex illecebrosus*. This relationship may differ with area and time for a particular species (Lange & Johnson, 1981), and thus be of value in distinguishing between different subpopulations of this species.

Reproductive Maturity: Details on reproductive maturity are shown in Table 3. The percentage of mated females correlates well with the percentage of mature females ($r^2 = 0.82^{***}$) and to a lesser extent with percentage of mature males ($r^2 = 0.54^{***}$). Males exceeded females in number throughout the season. There are no obvious trends in maturity; mature males and females are present throughout the season, suggesting a protracted mating season.

All half mature and fully mature males exhibited hectocotylisation, with the minimum

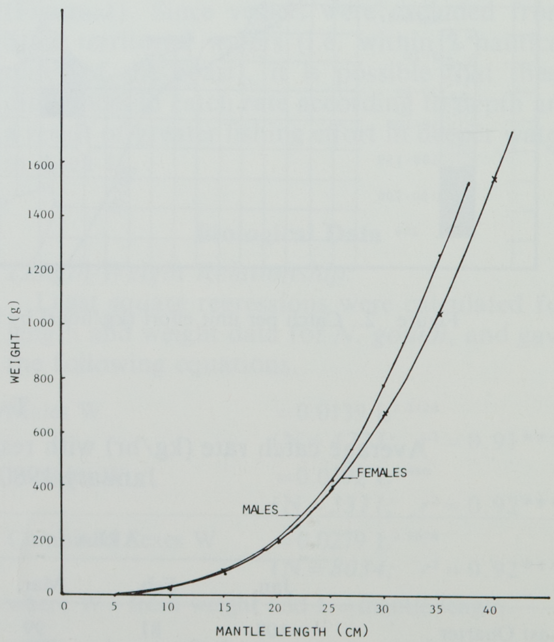

Figure 4. Relationship between dorsal mantle length and total live weight for male and female *N. gouldi*.

TABLE 3

Data on reproductive maturity and male/female ratios per week for Areas 1 and 2, December 1979 to April 1980.

DATE	% MATED FEMALES		% MATURE FEMALES		%MATURE MALES		M:F RATES	
	AREA		AREA		AREA		AREA	
	1	2	1	2	1	2	1	2
21/12-27/12	64.4	–	71.8	–	79.5	–	1.26	–
28/12-3/1	59.8	–	56.8	–	81.7	–	1.58	–
4/1-10/1	22.4	–	29.9	–	53.5	–	1.42	–
11/1-17/1	27.9	55.8	23.7	55.8	45.5	90.7	1.21	1.21
18/1-24/1	75.0	81.7	72.2	74.4	90.7	90.1	2.37	1.87
25/1-31/1	–	–	–	–	–	–	–	–
1/2-7/2	–	–	–	–	–	–	–	–
8/2-14/2	57.9	86.7	59.6	86.7	77.7	92.0	1.31	1.73
15/2-21/2	64.2	51.2	63.3	48.8	94.4	100.0	2.79	1.58
22/2-28/2	79.9	21.0	91.6	–	100.0	–	2.1	1.5
29/2-6/3	51.4	25.7	46.0	13.4	86.7	58.5	1.55	1.54
7/3-13/3	90.9	32.8	71.8	37.3	79.0	52.6	1.5	1.12
14/3-20/3	86.3	43.9	62.6	55.3	81.8	78.8	1.88	1.18
21/3-27/3	–	72.0	–	76.7	–	91.7	–	1.46
28/3-3/4	77.0	–	–	–	–	–	0.92	–
4/4-10/4	–	–	–	–	–	–	–	–

size at hectoctoylisation being 14 cm mantle length.

Analysis of Stomach Contents: Crude analysis of stomach contents on 920 individuals gave the following components.

squids (Ommastrephidae)	57%
fishes (primarily pilchards)	42%
other	1%

The large component of squids in the gut may be an artefact of the fishing operation since squid jigging is reported to induce a 'feeding frenzy' among squid, resulting in a high degree of cannibalism (Bennett, 1978; Merdsoy, 1978).

Conclusions

Feasibility fishing has indicated the presence of considerable numbers of *N. gouldi* in south east Australian waters. Victorian waters were more productive than South Australian waters during the months January to March with populations apparently moving southerly and easterly during the season. Catches were predominantly in neritic waters over the continental shelf. Catch rates were markedly affected by the lunar cycle, the magnitude of which differed between areas. No differences in reproductive state were found with time or with place indicating a protracted mating season. The length-weight relationship for the species within the study area was significantly different for males and females.

Acknowledgements

The author wishes to thank the observers operating on foreign squid fishing vessels, who collected the biological data presented in this paper and Mr Rod Kenyon of the Agriculture Department who conducted the analysis of the length-weight relationship.

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Appendix I

Males

Immature: Vas deferens invisible; testes small, soft and clear; no spermatophores; hectocotylus difficult to distinguish.

Half Mature: Vas deferens invisible or small; testes longer, firmer and less transparent; spermatophores small, usually visible; hectocotylus readily distinguished.

Mature: Vas deferens white and ridged; testes large and white with central ridge; some spermatophores usually ejaculated into mantle cavity; Needham's sac full and large; hectocotylus obvious.

Females

Immature: Oviduct glands not visible; nidamental gland small, thin and transparent—almost imperceptible; ovaries small, clear and soft; oviduct small.

Half Mature: Oviduct glands larger—'Squiggles' obvious; nidamental glands longer and thicker, whitening; ovaries whitening; oviduct not obvious.

Mature: Oviduct glands large, translucent brown/yellow, containing visible eggs; nidamental glands large, thick and white; ovaries cream colour with visible eggs; oviduct white and obvious.