

**POSSIBLE SPAWNING BY THE JAPANESE COMMON SQUID, *TODARODES PACIFICUS*  
AT YAMATO RISE, SEA OF JAPAN**

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**ABSTRACT:** *Todarodes pacificus* is a commercially important squid in Japan and Korea. Its main spawning area is located in north East China Sea during fall. However, in the present study, we found out that spawning can also occur much further north in the Sea of Japan based on squid-maturity and paralarval-distribution data. Mature squids were collected at 13 stations with automatic jigging machines and hand jigging. Paralarvae were collected at 12 stations with paired-Bongo nets (70cm diameter). One 15-min double-oblique tow was conducted at each station to about 100m depth. Post-spawning females were collected at the rise, shelf and slope. At positive stations, temperatures at 50m depth were more than 15°C. Post-spawning (spent) females were mainly collected near Yamato Rise. The mantle length of paralarvae ranged from 1.0 to 6.5 mm. Since smaller paralarvae were more abundant at and adjacent to Yamato Rise than in the other areas, the present study suggests that spawning occurs near Yamato Rise during fall.

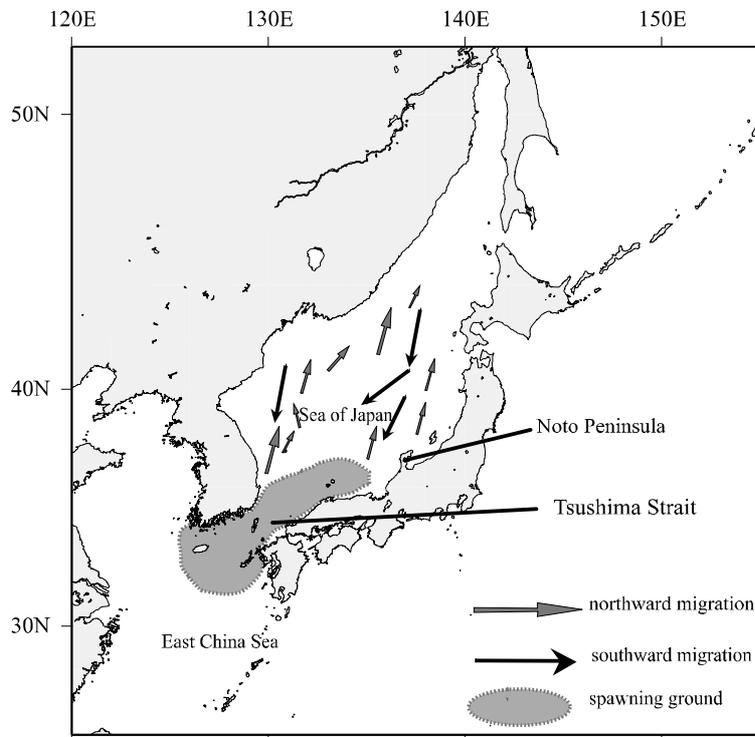
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## INTRODUCTION

*Todarodes pacificus* is a commercially important squid in Japan. Three populations that have different peaks of spawning seasons (fall, winter and summer) seasonally migrate in Sea of Japan and the Pacific Ocean (Okutani, 1983). The main spawning area is located in the north East China Sea during fall (Okutani and Watanabe, 1983; Murata, 1989; Murata, 1990) (Fig. 1). Therefore, mature squids and paralarvae are surveyed annually between Noto Peninsula and Tsushima Strait. In addition, since recent studies have indicated that the potential spawning area is located on the continental shelf where the temperature is from 15°C to 23°C (Sakurai *et al.*, 2000), the spawning area could also be found at Yamato Rise during fall. However, the simultaneous survey of mature adult squid and paralarva *Todarodes pacificus* has not been carried out in the area yet. The present study attempts to confirm whether Yamato Rise can be a possible spawning area by considering the maturity of squids and the paralarvae distribution.

## MATERIALS AND METHOD

A survey in Sea of Japan was carried out during the cruise of the T/S Hokusei-Maru of Hokkaido University (892ton) from September to October 2000. Adult squids were collected at 13 stations with automatic or hand jigging machines after sunset (Fig. 2). Samples were sexed, and the dorsal mantle length (ML) and the body weight were measured on the vessel. Then, the gonads were dissected and weighed. The maturity is expressed as gonad somatic index (*GSI*: ovary and oviduct weight as a percentage of body weight) introduced by Ikeda *et al.* (1991a). Ikeda *et al.* (1993a; 1993b) reported that *Todarodes pacificus* place their spermatophores on the buccal membrane of females, and spermatozoa are stored in the female's seminal receptacles for up to several weeks until spawning. Therefore, the buccal membrane and inner mantle wall of each female were investigated to find evidence of mating. The paralarvae samples were collected at 12



**Figure 1.** The typical migration and main spawning ground of *Todarodes pacificus* (autumn spawning group) are shown by arrows and region style (Murata, 1990).

stations with paired Bongo nets (70 cm in mouth diameter) with 0.335 mm mesh and equipped with paired flowmeters (Fig. 2). One 15-min double-oblique tow was conducted at each station to about 100m in depth. In the field, plankton samples were fixed in a 4% buffered formaldehyde-seawater solution immediately after the collection. In the laboratory, those paralarvae were removed from the catches and identified (Okiyama, 1965; Okutani, 1965). The dorsal mantle length of paralarvae was measured to the nearest 0.1 mm with an ocular micrometer in a stereomicroscope.

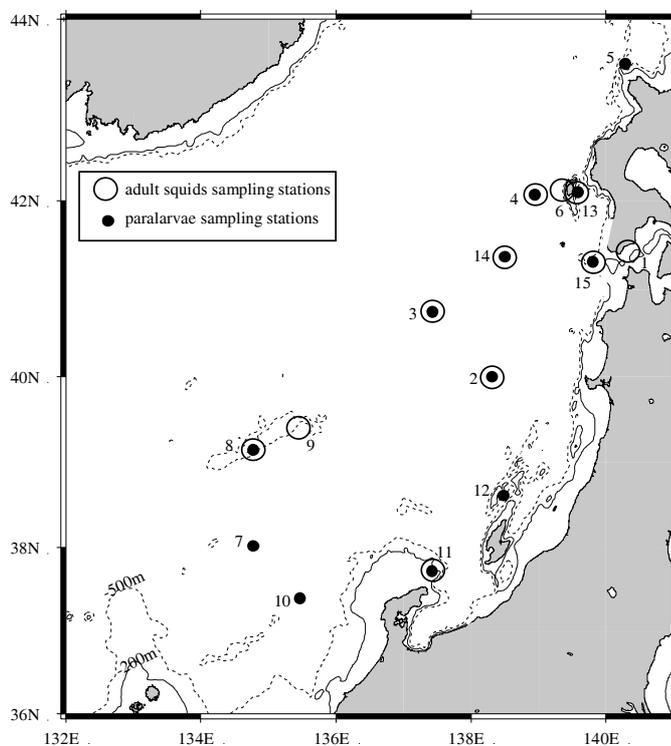
The temperature through the water column was measured near the sampling station with CTD.

## RESULTS

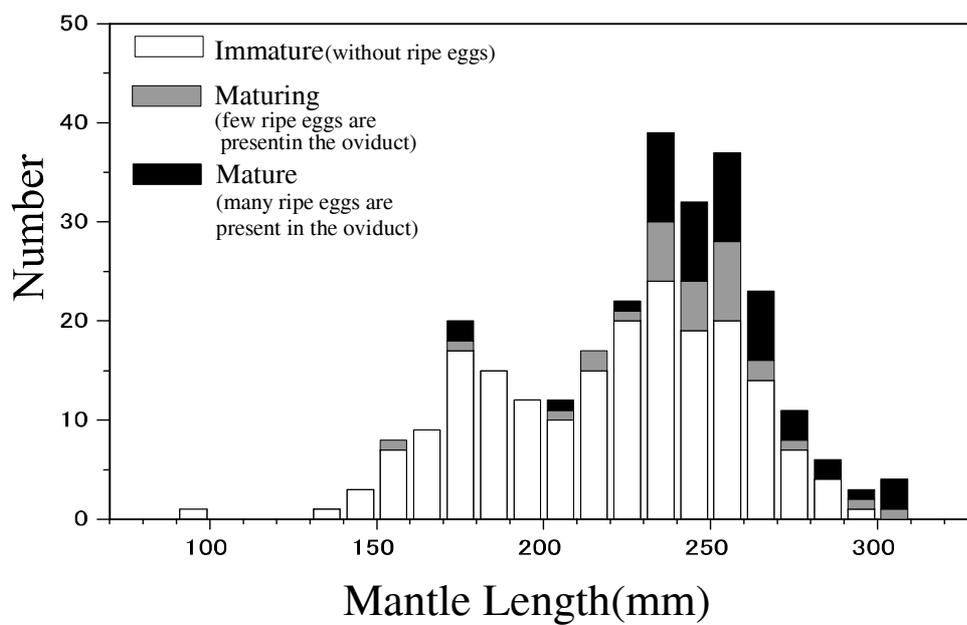
### Female squids

In total, 2793 adults of *Todarodes pacificus* were collected. The mantle length of female squids ranged between 90 and 314 mm (mean and

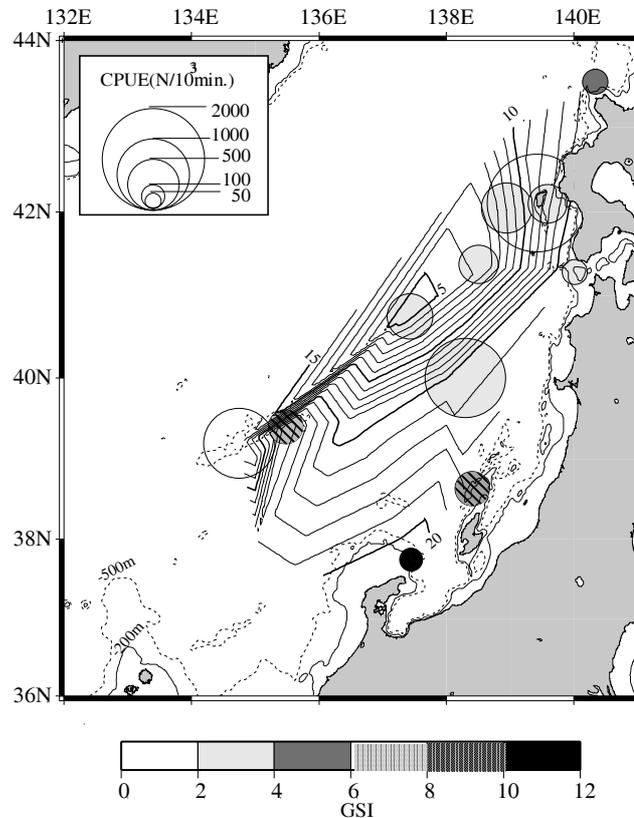
$SD=215.8\pm38.2$ mm). Females with mature eggs were more than 160 mm ML (Fig. 3). Two fully mature females were collected near the Yamato Rise (St.8, 166 mm ML), and off Noto Peninsula (St.11, 294 mm ML). Two spent females (218 and 234 mm ML) were collected at Yamato Rise (St.9). The ovaries of these females could no longer be divided into proximal and distal portions, and the mantle wall was very thin. Fig. 4 shows the distribution, the standing stock densities and *GSI* of female *Todarodes pacificus*. The highest value of *GSI*  $11\pm11$ (mean and SD) was off Noto Peninsula (St.11). The second highest was  $9.3\pm3.5$ (mean and SD) at Yamato Rise (St.9). The lowest was  $1.0\pm0.2$  near Okushiri Island (St.6). There were significant correlations between female squid *GSI* and the temperatures at 5 m, 50 m and 100 m depth ( $p<0.001$ ; Student's *t*-test). A number of immature females are collected near the Okushiri Island. Maturing females were more abundant at the southern stations than at the northern stations.

Possible spawning by the Japanese common squid, *Todarodes pacificus*

**Figure 2.** Map of sampling stations(St.1~15). White circles: adult squids sampling stations; black circles: paralarvae sampling stations.



**Figure 3.** Length frequency and maturity by size of female of *Todarodes pacificus*.



**Figure 4.** Distribution and abundance of female squids. Size of the circle indicates CPUE(N/10<sup>3</sup>min.) and pattern of the circle indicates GSI(ovary and oviduct weight as a percentage of body weight). The contour line indicates the 50-m depth temperature.

The mating rate of *Todarodes pacificus* slightly varied during cruises (Table 1). The mating rate was higher at the southern stations than at the northern stations. The highest mating rate was observed at Yamato Rise (St.9). On the other hand, Okushiri Island squid (St.4 and 6) had a lower mating rate (0~8.0%) than the other stations.

#### Paralarvae spatial distribution

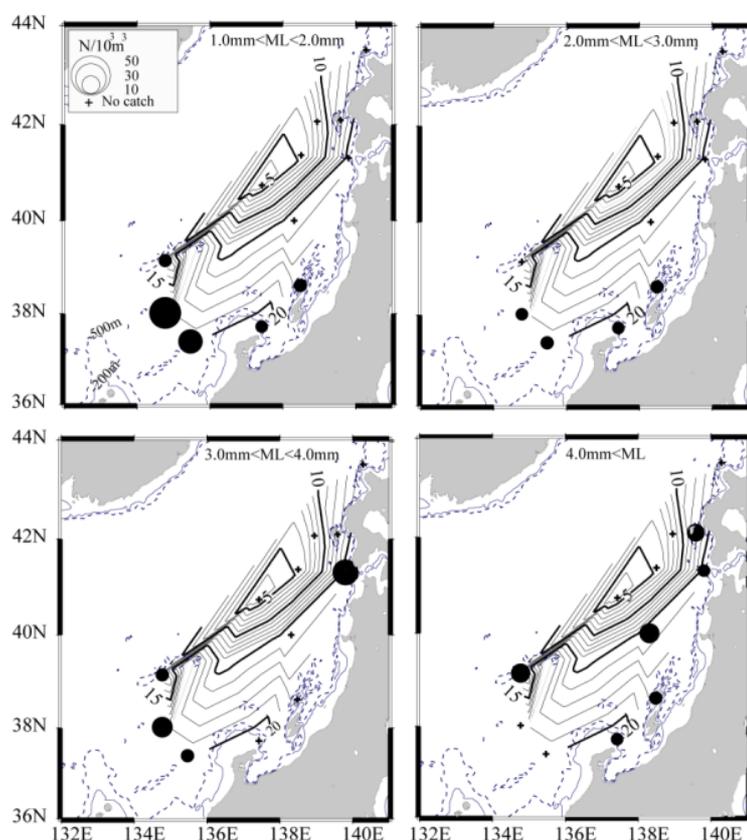
We collected 35 *Todarodes pacificus* paralarvae at 8 of the 12 sampling stations. The catch densities at positive stations ranged between 10 and 52 ind./10<sup>3</sup> m<sup>3</sup>. The largest catches occurred at St.7 (52 ind./10<sup>3</sup> m<sup>3</sup>). Fig.5 shows the distribution and standing stock densities of *Todarodes pacificus* paralarvae that were less than 1 mm ML. The stations where we caught no *Todarodes pacificus* paralarvae were located in the northern waters where temperatures at 50 m depth

were less than 15°C. The mantle length of *Todarodes pacificus* paralarvae slightly varied during cruise. It ranged from 1.0 to 6.5 mm ML, and the most common size was 1.5 and 2.0 mm ML. The smaller paralarvae were more abundant at the southern stations than at the northeastern stations. We collected small paralarvae of 1.0 mm ML only off Yamato Rise (St.7).

#### DISCUSSION

The present study describes the distribution patterns of mature females and paralarvae of *Todarodes pacificus* off northwestern Japan during fall spawning seasons. The results showed that spawning occurred at Yamato Rise during fall.

Ikeda *et al.* (1991) reported that the GSI is less than 1.0 in immature squids, between 1.0 and 2.6 in maturing squids, and more than 2.6 in

Possible spawning by the Japanese common squid, *Todarodes pacificus*

**Figure 5.** Distribution and mean abundance of 1.0-mm size group of *Todarodes pacificus*. The contour line indicates the 50-m depth temperature.

**Table 1.** The mating rate of *Todarodes pacificus*.

St.	location		mating rate (%)
	Latitude (°N)	Longitude (°E)	
1	41-27.8	140-17.8	14.7
2	40	138-18.1	15.8
3	40-44.8	137-25.9	67.6
4	42-03.0	138-56.8	8.0
5	43-31.6	140-20.4	24.2
6	42-06.4	139-25.2	0.0
8	39-11.8	134-44.8	55.2
9	39-24.1	135-28.9	94.7
11	37-44.8	137-26.9	63.2
12	38-38.2	138-24.3	73.8
13	42-05.9	139-35.3	10.3
14	41-22.6	138-30.5	44.9
15	41-17.2	140-01.0	52.4

mature squids. In this study, the highest *GSI* was  $11 \pm 11$  (mean and SD) off the Noto Peninsula (St.11), and the second was  $9.3 \pm 3.5$  at Yamato Rise (St.9). These results indicate that as they become sexually mature, the squids migrate from the northern area to Yamato Rise for spawning. Moreover, post-spawning (spent) female squids were found at Yamato Rise. The spawning of *Todarodes pacificus* is assumed to occur in the continental shelf around Japan because the captive females regularly sit on the bottom of the tank right before spawning (Bower and Sakurai, 1996). Also many post-spawning females are often collected on the shelf and slope at 100–500 m depth by bottom trawls (Hamabe and Shimizu, 1966). Nesis (1993) suggested that other oceanic squids (*Todarodes sagittatus*) similarly migrate to seamounts to spawn.

Temperature at 50 m depth was used to estimate the range of spawning grounds of *Todarodes pacificus* because most paralarvae are found at 25–50 m depth (Watanabe, 1965). The optimal range of temperature for normal embryonic development is from 15 to 23°C (Sakurai *et al.*, 1996). The temperature of the station near Yamato Rise was more than 15°C at a depth of 50 m during cruise, supporting a possibility of spawning at Yamato Rise.

Most paralarvae with less than 2 mm ML were caught at Yamato Rise. In conclusion, since maturing females, post spawning females and small

paralarvae were more abundant at Yamato Rise than at the other areas, spawning is likely to have occurred at Yamato Rise during fall.

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*Possible spawning by the Japanese common squid, *Todarodes pacificus**

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