Some Biological Aspects of the Deep Sea Squaloid Shark
Centroscymnus from Suruga Bay, Japan

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Specimens of the deep sea sharks, Centroscymnus coelolepis and C. owstoni, were caught with bottom drop line, bottom longline, and bottom gillnet in Suruga Bay, Japan. The catch rates of males were higher than catch rates of females on the bottom drop lines. In both species, the females were distributed in deeper layers than the males, but the distribution of C. owstoni seemed to extend to shallower layers than that of C. coelolepis. The smaller individuals of both species, those below 600 mm in total length (T.L.), were thought to inhabit separate areas such as the waters outside of the bay. The stomach contents of both species consisted mainly of fish and squid. Empty stomachs were more frequently found during the daytime than at night. The proportion of the weight of the intestinal contents to the weight of the intestine was found to be higher during the night than during the day.

Several kinds of deep sea sharks inhabit Suruga Bay, which is located on the Pacific side of central Japan. Since World War II, these sharks have been taken by fishermen for the purpose of extracting squalene from their liver oil. Most of them belong to three genera, Centroscymnus, Centrophorus, and Deania, of the family Squalidae.

The genus Centroscymnus can be distinguished from the other genera of Squalidae by the concave, crown-shaped dermal denticles and the broadly rounded inner corner of the pectoral fins. Two species of Centroscymnus, C. coelolepis and C. owstoni, have been found in the seas around Japan. There have been very few biological studies carried out on these sharks. This paper presents results of a study on the distribution, food habits, and certain biological characteristics of the sharks belonging to Centroscymnus, which is one of the most important genera in Japan’s deep sea shark fishery.

Materials and Methods

The sharks studied were the C. owstoni GARMAN, 1906, which had long been known to inhabit Suruga Bay, and the C. coelolepis BOCAGE et CAPELLO, 1864, which was newly discovered in the Pacific Ocean during our recent investigation of Suruga Bay. We examined 40 males and 24 females of C. coelolepis whose total lengths ranged from 637 mm to 1085 mm, and 144 males and 192 females of C. owstoni, from 376 mm to 1168 mm. Most of the specimens for this study were caught in Suruga Bay, either by our research vessels or...
Fig. 2. Construction details of the bottom drop line used on the research vessels. (GB: glass buoy; NB: noctilucent beads; S: sinker; and Sw: swivel.)

Fig. 3. Construction details of the bottom longline gear. (GB: glass buoy; NB: noctilucent beads; S: sinker; and Sw: swivel.)
by commercial fishing vessels, during the period from June 1980 to January 1983. Four additional specimens were provided by fishermen who caught them in waters outside of the bay at Kanesu-no-se on July 30, 1981. All of the samples were taken from depths between 150 m and 1500 m (Fig. 1).

The principal fishing gear used on our vessels was the vertical drop line which consisted of 20 hooks per line, evenly spaced as shown in Fig. 2. The distance between each hook and the sinker on the sea bottom ranged from 1.5 m to 30 m (=1.5 × 20). Another gear used was the bottom longline which was set in waters between 400 m and 687 m in depth. The bottom longline gear consisted of 40 branch lines, each with 5 hooks, thus totalling 200 hooks (Fig. 3). Commercial fishermen use longer bottom longline, consisting of 300 branch lines of 3 to 5 hooks, or a total of 900 to 1500 hooks. The gear is set at depths of 400 m to 700 m. Some fishermen have also used bottom gill nets which were set at depths of 150 m to 350 m.

**Results and Discussion**

**Distribution**

The adults*1 and subadults*2 of both *C. coelolepis* and *C. owstoni* were caught almost all the deeper layers of Suruga Bay, while the adults and subadults of *C. owstoni* were sometimes also caught around Kanesu-no-se, a bank located outside of the bay (Fig. 1). The juveniles*3 of

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*1 The adult possesses mature reproductive organ.
*2 The subadult attains about the same size as the adult but its reproductive organ is not yet mature.
*3 The young and the juvenile both have immature reproductive organ; the difference between them is based on shape of dermal denticles (YANO and TANAKA1)).
C. owstoni were caught only around Seno Umi in the central region of Suruga Bay, and off Omaezaki at the entrance to the bay (Fig. 1).

A total of 111 bottom drop lines were set at depths between 300 m and 1500 m, and these caught 52 C. coelolepis and 89 C. owstoni. The former was not taken at the shallower depths between 300 m and 700 m, while the latter began to be taken at 500 m (Fig. 4). Both species were caught in rather large numbers at depths greater than 800 m. The catch rates (catch in numbers per 100 hooks fished) on the bottom drop lines were 1.59% in males and 0.72% in females of C. coelolepis, and 2.30% in males and 1.44% in females of C. owstoni. Thus, the catch rates were higher for the males of both species. The catch rates at the various depths are shown in Fig. 4. The peak catch rates for the males of both species occurred between 800 m and 900 m. On the other hand, the catch rates of the female C. coelolepis were about the same at the depth ranges of 900–1000 m, 1100–1200 m, and 1200–1300 m, whereas the catch rate for female C. owstoni peaked at the depth range of 1000–1100 m (Fig. 4). These results lead us to conclude that the females tend to be distributed in deeper layers than the males in both species, and that the distribution of C. owstoni seems to extend to shallower depths than that of C. coelolepis. The shallower extension in the distribution of C. owstoni seems to be supported by data obtained from the commercial bottom longline fishery (1500 hooks; one operation), in which only 5 C. coelolepis were caught in the total catch of fish which included 156 C. owstoni when the gear was set at depths of 400 m and 450 m. In other commercial bottom longline sets made at depths around 500 m or 600 m (900 hooks; 12 operations), more than 300 C. owstoni were caught but no C. coelolepis were taken. Our research vessel bottom longlines set at depths between 400 m and 687 m (200 hooks, 5 operations) resulted in catches of 3 C. coelolepis and 40 C. owstoni.

The bottom gill net sets made during the spring at depths of 150 m and 350 m (23 operations) resulted in catches of 1 C. coelolepis and 33 C. owstoni. The single C. coelolepis was a pregnant female while the C. owstoni catches included 3 mature males, 2 subadult females and 28 mature females. The mature females consisted of 9 in the stage just preceding ovulation, 2 that had just ovulated, 2 that were pregnant, and 6 following parturition. These sharks appear to inhabit shallow waters during the breeding period. Seasonal segregation seems to exist between the two sexes and also between mature and immature individuals.

The catches of C. coelolepis and C. owstoni on the bottom drop line, in relation to the distance of the hooks from the bottom sinker, are shown in Fig. 5. The distance was estimated from the sinker to the snood attached to the line. The catches of the two species tended to fluctuate but exhibited no noticeable trend in relation to hook depths. FORSTER et al. reported that the deep sea elasmobranchs showed a marked decrease in catch rates with increased distance of the hook from the bottom. In our drop line investigations, however, fewer sharks were caught at heights of 1.5 m to 3.0 m from the bottom as compared to
the higher hooks (Fig. 5).

Size Composition

The *C. coelolepis* specimens ranged in size from a minimum of 637 mm to a maximum of 924 mm in males and 662 mm to 1085 mm in females, while the specimens of *C. owstoni* ranged from 337 mm to 820 mm in males and 506 mm to 1220 mm in females. The length-frequency distributions for the two species are shown in Fig. 6. Even when smaller hooks (2.5 cm in maximum length) were used, *Centroscymnus* specimens smaller than 600 mm T.L. were not caught, although we have information that smaller specimens of other types of sharks are often taken of hooks of the ordinary size (3.5 cm in maximum length; see Fig. 2). Accordingly, we may conclude that the absence of smaller sharks in our samples is not due to any size selectivity of the fishing gear. The smaller individuals (below 600 mm T.L.) of the two species of *Centroscymnus* are therefore thought to inhabit other areas, such as possibly the waters outside of the bay.

Sex Ratio

The sex ratio (male/female) of *C. coelolepis* caught with the drop line was 2.19. The sex ratio of *C. owstoni* caught by drop line was 1.59, by bottom longline, 0.65, and by bottom gillnets, 0.10. The large catch of mature females of *C. owstoni* in the bottom gill nets may be indicative of the fact that these sharks move into shallower waters during the breeding period.

Length-Weight Relationship

The relationships between body weight (W in kg) and total length (L in mm) in *C. coelolepis* and *C. owstoni* are shown in Figs. 7 and 8, respectively. The equations were calculated by the least square method. Each curve was fitted to the data by the following formulas:

For *C. coelolepis*:
- Females: $W=6.06 \times 10^{-11} \times L^{3.71}$ (n=21)
- Males: $W=2.31 \times 10^{-8} \times L^{2.61}$ (n=33)

For *C. owstoni*:
- Females: $W=1.02 \times 10^{-10} \times L^{3.01}$ (n=83)
- Males: $W=4.63 \times 10^{-8} \times L^{2.38}$ (n=85)

The minimum and maximum weight of male *C. coelolepis* used for the above calculations were 1.64 kg (633 mm) and 5.51 kg (924 mm) and those of the females were 1.59 kg (662 mm) and 11.75 kg (1085 mm), while the minimum and maximum weight used for male *C. owstoni* were 1.10 kg (574 mm) and 4.2 kg (833 mm) and those for females were 0.75 kg (506 mm) and 12.55 kg (1091 mm).
Liver Weight–Body Weight Relationship

The liver is used as the raw material from which squalene ($C_{30}H_{50}$) is extracted. The relationships between the liver weight ($L_w$ in kg) and the body weight ($W$ in kg) in $C. coelolepis$ and $C. owstoni$ are shown in Figs. 9 and 10, respectively. The equations were calculated by the least square method. Females with ovaries weighing more than 1000 g or those with embryos, were excluded from the equations. Each line was fitted to the data by the following formulas:

$C. coelolepis$:
- Females,
  \[ L_w = 0.31 \times W - 0.16 \quad (n=15) \]
- Males,
  \[ L_w = 0.32W - 0.10 \quad (n=25) \]

$C. owstoni$:
- Females,
  \[ L_w = 0.25W - 0.08 \quad (n=70) \]
- Males,
  \[ L_w = 0.29W - 0.11 \quad (n=81) \]

The average proportion of liver weight to body weight (hepatosomatic index: $L_w/W \times 100$) was 26.6% in males and 26.2% in females of $C. coelolepis$. In the $C. owstoni$, the average proportion was 24.5% in males and 23.1% in females. The hepatosomatic index of $C. owstoni$ in our samples is similar to that found by Higashi et al.\(^3\)\(^4\). The large livers in both species appear to be useful in regulating bouyancy as already reported by Corner et al.\(^5\)
Food

The stomach contents of both species are shown in Fig. 11. Although empty stomachs with fully digested food remains, or chyme, were encountered most frequently, the stomachs of both species contained such varied items as skulls, vertebrae and fin skeletons of teleosts, fish muscles, gills and lenses, squid beaks and tentacles, sea weed and mud. The identified stomach contents of C. owstoni, included Brama japonica, Coelorhynchus sp., Mugil cephalus, Myctophidae and Ommastrephidae. The sharks seem to thrive on fish and squid. As shown in Fig. 11, the empty stomachs were found in higher percentage during the day than at night. The intestinal contents were mostly black, purple and mud-yellow in appearance and sometimes included fish lenses, vertebrae and skin. The proportion of the weight of intestinal contents to the weight of the intestine is shown in Fig. 12 in the form of a frequency distribution. During the day, there is a decreasing tendency in the proportions while the opposite holds true at night. The fact that there is a tendency for both the stomach and intestinal contents to increase at night suggests that these sharks are preying on food more actively during the night.

BIGELOW and SCHROEDER\(^5\) suggested that C. coelolepis subsist primarily on a fish diet, on the basis of an Argentine (Argentia silus) found in the stomach of one C. coelolepis. FORSTER\(^7\) described a C. coelolepis with an octopus in its stomach. CLARK and MERRETT\(^8\) reported that

![Fig. 10. The relationship between liver weight and body weight in C. owstoni.](image)

![Fig. 11. The stomach contents (percentages) of C. coelolepis and C. owstoni, by type of fishing gear and by time of day.](image)
Cephalopods, fish, cetaceans and bottom-living invertebrates were found in the stomachs of *C. coelolepis* and postulated that the high incidence of empty stomachs (90%) may be due to frequent loss of food during their ascent from great depths. We have observed water in the stomachs of these sharks, suggesting the possibility that food are forced out of their stomachs by the pressure of sea water swallowed when they are being hauled up from the depths.

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**References**