Biological Aspects of Large Whitespotted Conger
(Conger myriaster) in the Akashi Strait,
Eastern Seto Inland Sea, Japan

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Abstract: This paper reports on various biological aspects of whitespotted conger (Conger myriaster) on the basis of a long-term pot survey conducted in the Akashi Strait from 1982 to 2009. The fish caught consisted of one or two major size groups, and large females (>500 mm total length) were predominant. Both the gonadosomatic index and condition factor of large females were higher in winter (January and February) than those in other seasons. Females appear to spend for up to four years in this strait and then begin a spawning migration by age-5 to other waters. While catch per unit effort (CPUE) in the pot survey showed considerably large annual and seasonal fluctuations, it was high from May to August and from November to January when bottom water temperature ranged from 10–25°C but low from September to October (>25°C) and from February to April (<10°C). The Akashi Strait is likely to be an important habitat of large whitespotted conger for their early maturation.

Key words: Conger myriaster; Length frequency distribution; Seto Inland Sea; Pot survey

The whitespotted conger (Conger myriaster) is a benthic, commercially important marine fish and is usually caught by the small trawl fishery in the eastern Seto Inland Sea. They migrate to this region as leptocephali and recruit to the fishery at about 250 mm in total length (TL) in October (Gorie and Ohtani 1998). The male-biased occurrence is known for young fish (<45 cm TL) (Takemori et al. 2004) and a sex-biased migratory habit has been suggested (Okamura et al. 2000). Large fish caught in this region are mostly females, some of which move from the Harima Nada Sea to both Osaka Bay and the Kii Channel from January to August: this movement appears to be the onset of their spawning migration (Gorie et al. 2010).

The Akashi Strait is part of the eastern Seto Inland Sea and located between Honshu (the main island of Japan) and Awaji Island (Fig. 1). This strait is small (only 4 km between the two islands) but has a strong tidal current (Kunishi 1976), and the maximum water depth is about 120 m (Kaseno 1976). While various fisheries have been conducted there using different types of fishing gear, such as small trawls, longlines, boat seines, gillnets, and angling, a pot fishery is not commonly operated because of the strong current (Uchihashi 1976). Furthermore, the pot fishery to catch whitespotted conger is strictly prohibited from December to May under the Hyogo Prefectural Fishery Adjustment Rules outside the common fishery areas off Hyogo Prefecture, and only a few fisheries cooperative associations are permitted to operate the fishery.

It is generally known that large whitespotted conger are commercially caught with longlines in the Akashi Strait, but we have little information on them. As those large fish have been...
thought to be a spawning stock (Gorie et al. 2010), it is important to collected their biological data for stock management and spawning stock conservation.

Since 1982, a monitoring survey of whitespotted conger has been conducted using pots in the Akashi Strait in order to clarify annual changes in their length frequency distribution and catch per unit effort (CPUE). Although this survey must be operated during the neap tide, it can be done regardless of fishing grounds and appears to be appropriate to examine the stock assessment in the Akashi Strait. In this paper, biological aspects of whitespotted conger caught through the pot survey are presented. Seasonal changes in gonadosomatic index, condition factor, and age composition are also discussed on the assumption that large females in the eastern Seto Inland Sea including this strait conduct a spawning migration.

**Materials and Methods**

*Fish collection*

The study area is located in the western Akashi Strait (Fig. 1). Water depth of the survey area ranged from 20–50 m. The bottom consisted of gravel and cobbles. A fishing survey was conducted almost every month from 1982 to 1999 and 2–5 times a year (usually twice: June and November) from 2000 to 2009, using commercially available pots (nominal mesh size, 18 setsu; mesh size of the upper and bottom parts, 18 and 15.9 mm, respectively) (Nabeshima et al. 1995). Sampling was done from evening to night. Deeply frozen sardines were thawed, cut in pieces, and then put as bait in the pots. Pots were usually put down to the sea before one hour of sunset and allowed the fish to trap for four hours. The effective number of pots in each fishing survey ranged from 60–110. The CPUE was expressed as a number of the fish caught per pot for four dipping hours.

Oceanographic data, such as bottom water temperature (WT), salinity, and depth, were taken with STD (JFE Advantech Co., Ltd., Nishinomiya, Japan) before fishing.

*Fish examination*

The fish caught were transferred to the laboratory, where they were measured for total length (TL, mm) and body weight (BW, g). In 1996 to 2009, they were sexed by the observation of the gonad (Gorie et al. 2004) and the gonad was weighed (GW, g).

For age determination, otoliths were removed, cleaned, dried, and stored in small sealable plastic bags until otolith structure analysis. They were heated at 200°C for several minutes on a hot plate until the color turned light brown. Burnt otoliths were embedded in polyester resin (Marumoto Struers K. K., Tokyo, Japan) and sectioned into 0.3 mm thick intervals using a diamond saw (Leica SP1600; Leica Microsystems GmbH, Wetzlar, Germany). Serial transverse sections were mounted on glass slides with sticky

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**Fig. 1.** The study area (hatched) for the pot survey in the Akashi Strait, eastern Seto Inland Sea, Japan.
Conger myriaster in the Akashi Strait

wax (Maruto Instrument Co., Ltd., Tokyo, Japan). Their surfaces were ground using abrasive-coated papers (Presi, Grenoble, France), etched with 0.2N HCl for several tens of seconds. Before observation, sections were covered with clear nail polish and then microscopically observed under transmitted light or UV light (Katayama et al. 2002, 2010).

**Fig. 2.** Monthly changes in length frequency distribution of whitespotted conger caught in the Akashi Strait based on the pot survey. Monthly data taken from 1982 to 2009 are combined. Vertical lines indicate 500 mm TL. Numerical values represent MTL ± SD mm and percentage proportion of large fish (>500 mm TL). n, sample size.
Since the spawning season was estimated to be from August through February (Tanaka et al. 1987; Lee and Byun 1996; Mochioka 2001; Kurogi et al. 2002), age is chronologically expressed, assuming that the fish hatch every January. Gonadosomatic index (GSI) and condition factor (CF) were calculated as follows: $GSI = \frac{GW}{BW} \cdot \frac{1}{100}$ and $CF = \frac{BW}{TL^3} \cdot 10^6$, respectively. In this paper, individuals of whitespotted conger are categorized into two groups: large fish (>500 mm TL) and small fish (≤500 mm TL).

**Statistical analysis**

In this paper, results are presented as mean and standard deviation (SD). Overall significant differences in TL, GSI, and CF between four seasons were determined by one-way analysis of variance (ANOVA). If the one-way ANOVA was significant, differences between each season were estimated using Tukey-Kramer method. The GSI of fish between the Akashi Strait and other region (Osaka Bay and the Kii Channel combined) was examined by Mann-Whitney's U test.

**Results**

**Total length distribution**

A total of 14,370 whitespotted conger were caught during this survey from 1982 to 2009, and 7,829 fish (54%) were larger than 500 mm TL. The overall TL and BW ranged from 217–953 (mean = 519, n = 14,370) mm and from 12–2,028 (283, 14,354) g. The males and females measured 390–506 (446, 17) and 314–950 (575, 773) mm TL, respectively. Of the 829 fish examined for the sex, the vast majority (n = 773, 93%) were females, but the remaining 17 and 39 fish were males and unsexed, respectively.

There were one or two major modes in length frequency distribution (Fig. 2). In October, fish smaller than 400 mm TL newly appeared. These fish gradually grew up in the following months. The percentages of large fish in January and February were about 40% and 20%, respectively. It then increased gradually and reached 76% in December. The overall seasonal mean TL (MTL) gradually increased from winter (Jan.–Mar.) to fall (Oct.–Dec.) and showed over 500 mm MTL during summer (July–Sep.) and fall. The fall MTL value was the biggest (Fig. 3). There was a significant difference in MTL between four seasons (ANOVA, $P<0.001$): $P$-value between winter and spring (Apr.–June) was 0.023, and others were less than 0.001 (Tukey-Kramer test).

**Gonadosomatic index (GSI)**

As stated above, the majority of the fish examined for sex were females. The overall GSI ranged from 0.02–5.06 (mean = 1.59, n = 245) and 0.14–0.44 (0.25, 6) in females and males, respectively. Also, GSI ranged from 0.18–5.06 (1.65, 233) in large females, while it from 0.02–0.86 (0.46, 12) in small ones. In most of large females, GSI was less than 4, and mean monthly GSI values were 1.5 in April to December and 2.7 in January to February (Fig. 4). Although only a small number (n = 4) of large females were examined in February, their GSI values were clearly separated into two (high and low) groups.

In large females, there was a significant difference in GSI between four seasons (ANOVA, $P<0.001$): GSI was the highest in winter (Jan.–Feb.) (Tukey-Kramer test, $P<0.001$), decreased markedly in spring (Apr.–June), but increased

![Fig. 3.](image-url) Seasonal changes in mean total length of whitespotted conger caught in the Akashi Strait based on the pot survey. Seasonal data taken from 1982 to 2009 are combined. Vertical bars represent standard deviation. Sample size is given for each sampling season.
gradually in July to December (Fig. 5). $P$-values between fall (Oct.–Dec.) and spring and between fall and summer (July–Sep.) were 0.003 and 0.01, respectively.

**Condition factor (CF)**

The overall CF ranged from 1.3–2.8 (mean = 1.8, $n = 772$) and 1.5–2.2 (1.8, 17) in females and males, respectively. CF values ranged from 1.3–2.8 (1.9, 599) and 1.3–2.2 (1.7, 173) in large and small females, respectively. Male’s CF was 1.6 in one large fish (506 mm TL) and ranged from 1.5–2.2 (1.8, 16) in small fish.

In large females, a significant difference was found in CF, like GSI, between four seasons (ANOVA, $P<0.001$): CF was the highest in winter (Jan.–Feb.) (Tukey-Kramer test, $P<0.001$) but decreased in spring (Apr.–June). In small females, on the other hand, there was no significant difference in CF between four seasons (Fig. 6).

**Age composition**

Of the 291 fish examined for age, 276 (95%) were females, but the remaining one and 14 fish were a male and unsexed, respectively. This single male was age-2 (395 mm TL). The females were age-1 to 4 but did not contain any fish of age-5 and more (Fig. 7). There was a wide TL variation in females of such ages.

**CPUE**

CPUE was high from May to August and from November to January (highest in June) but low from September to October and from February to April (lowest in March) (Fig. 8).
These monthly changes in CPUE well coincided with those of WT: CPUE values were usually high when WT ranged from 10–25°C but low when WT was very high (over 25°C) or very low (under 10°C).

While CPUE showed considerably large annual and seasonal fluctuations, it showed a decreasing trend from 1982 to 1999 but a gradual recovery after 2000 (Fig. 9). Although annual commercial catches of the species in the eastern Seto Inland Sea off Hyogo Prefecture were correlated with annual CPUE values from 1982 to 1999, no significant correlative relationship was detected from 2000 to 2008: commercial catch continued to show a decreasing trend, but annual CPUE had an increasing trend.

Discussion

The Akashi Strait is considered to be an important region for whitespotted conger before the onset of their spawning migration. Unlike those in the nearby Osaka Bay and the northeastern Harima Nada Sea (Gorie and Ohtani 1998; Tanda et al. 1998), individuals caught in the Akashi Strait are mostly large females, implying that the fish over 400 mm TL aggregate and/or grow there.

The present study also supports our previous hypothesis (Gorie et al. 2010) that large females move from the Akashi Strait to other regions for spawning during January to August and the remaining other individuals continue to grow in the strait. After recruitment in

Fig. 7. Total length of female whitespotted conger of various ages caught in the Akashi Strait during the pot survey from 1996 to 2009.

Fig. 8. Monthly changes in mean CPUE (a number of the fish caught in a pot per four dipping hours) of whitespotted conger and bottom water temperature in the Akashi Strait based on the pot survey. Monthly data taken from 1982 to 2009 are combined. Closed circles, CPUE; open circles, bottom water temperature (WT, °C).

Fig. 9. Seasonal changes (12-month moving average) in CPUE (a number of the fish caught in a pot per four dipping hours) of whitespotted conger in the Akashi Strait based on the pot survey from June 1982 to November 2009.
October as individuals smaller than 400 mm TL, they grew, gradually replaced large fish, and were more abundant than small fish from July to December. The percentage of such large fish dropped in between December and February and thereafter increased gradually (Figs. 2, 3). Their GSI and CF values peaked in January to February, dropped in April to June, but then gradually increased (Figs. 4–6). In particular, GSI values of the majority of large females caught in the Akashi Strait in January to February remained less than 4 (2.7 ± 1.21, n = 31) which were significantly lower (U test, \( P = 0.005 \)) than those in tag-released and recaptured females in Osaka Bay and the Kii Channel (4.2 ± 0.97, n = 8, Gorie et al. 2010). Also, GSI values of large females from the Akashi Strait were significantly lower (U test, \( P < 0.001 \)) than those of individuals commercially caught in Osaka Bay in the same season (5.1 ± 1.16, n = 10, Gorie unpublished). Moreover, females caught in the Akashi Strait were less than age-5 (Fig. 7). These results suggest that large whitespotted conger occurring in the Akashi Strait are a spawning stock and spend a certain period in preparation for their spawning migration. Especially, females with high GSI (>4) may be just about to begin the spawning migration in January to February. Okamura et al. (2000) also suggested that whitespotted conger spend a certain period off the Pacific coast of the Atsumi Peninsula, central Japan, and move to a deeper area with maturation.

The migration of males, on the other hand, is still yet unknown because of the small sample size in this study. More information on the age composition and other biological aspects of males in the Akashi Strait is necessary to clarify the trigger to launch their spawning migration.

Monthly changes in CPUE in the Akashi Strait were closely related to those in WT, and high CPUEs were observed when WT ranged from 10–25°C (Fig. 8). This is probably because the feeding of whitespotted conger is dependent on water temperature (Gorie and Ohtani 1997).

A significant correlation between commercial catch of whitespotted conger and CPUE of the pot survey in the Akashi Strait can help us to estimate their stock abundance if no fishery statistic is provided. In 1982 to 1999, annual commercial catches of the species in the eastern Seto Inland Sea off Hyogo Prefecture were correlated with annual changes in CPUE, but such correlative relationship disappeared from 2000 to 2008. Although it is not easy to explain this reason, one of the possible explanations is that the observed, non-correlative relationship during the latter period might be due to the reduction in sampling effort: the survey was conducted at almost monthly intervals from 1982 to 1999, but it was done only 2–5 times a year from 2000 to 2008. It is thus desirable to analyze in details a relationship between commercial fisheries and catch data from the pot survey.

To summarize, length frequency distribution of whitespotted conger caught in the Akashi Strait through the pot survey showed the presence of two major size groups, and large females were dominant there. The Akashi Strait is likely to be an important region for the early maturation of such large females before conducting the spawning migration. They may stay in the strait for up to four years. Considering the importance of the Akashi Strait for the life cycle of whitespotted conger, we must consider conservation of individuals in this area: this species has been targeted by only a few fisheries there, which might have contributed to the conservation of the spawning stock. Further study through the pot survey is desirable to collect more information on the biology and abundance of whitespotted conger in the Akashi Strait.

**References**


**明石海峡における大型マアナゴの資源生物学的特徴**

五利江重昭・長澤和也

明石海峡におけるマアナゴの資源生物学的情報を明らかにするため、1982－2009年にかけて、あらゆる種を用いた試験操作を実施し、当海域におけるマアナゴの月別CPUE、全長組成の推移、GSIおよび肥満度の変化を調べた。マアナゴの全長組成には1－2個の大きなモードが存在し、毎年10月頃に全長40cm以下の新規加入者群が認められ、この群は1年かけて、より大きなモードへと移行していく様子がみられた。CPUEは、水温変動期である春と秋に高く（底層水温：10－25℃）、夏と冬に低くかった（25℃以上および10℃以下）。明石海峡には主に大型の個体が分布し、全長50cm以上の雌の占める割合が多かったため、明石海峡は産卵回遊に向かうまでの集積地の一つであると考えられた。雌のGISおよび肥満度は、冬（1－2月）に高く、春（4月）になると低下し、年齢は0－4歳であった。マアナゴの雌は、5歳までの冬以降に産卵回遊を行うと考えられた。