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A Phenological Study on Surfperch (*Ditrema temminckii*) at the Eastern Coast in Suo Nada Area

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Abstract : We recorded the phenological observation on the surfperch (*Ditrema temminckii*) whose recruitment, development and maturing aspects on the quasi population were examined. The specimens were collected in spring tide periods from 12th January 1994 to 21st December 2010 except the duration of suspension of operation due to diking in February-May 2002. We equipped two kinds of cod hoop net. The monthly total length (TL) arrangement of all the fishes illustrated that this species recruits every May and gaining larger body size within several months, they contains developed gonads, which continue to mature until next April. We perceived them as likely to be the UNDERYEARING and introduced a formula on their growth such as, $L_t = 232.6\{1\text{-}e^{-0.06471(t+4.557)}\}$ where L_t denotes the TL size (mm) at monthly age t under the condition that $t = 0$ in May, which approved the somatic alteration of multi generation of this species. On the other hand, CPUE (N/haul) at t was represented as, $\log C_t = -0.1223t + 1.536$, which demonstrated how their rather small litter size creates the sustainable population in this area.

Key words : surfperch, phenology, pauciparous, seasonable recruitment, sustainable generation

Introduction

A large number of fisheries, targeting over 200 species, exploit the resources in the Seto Naikai (Inland Sea of Japan). The high level of productivity in this area is sustained by the aquatic plant beds, the intertidal zones, and mud flats.[1, 2] A number of studies have documented the fish assemblage in this region, of which the surfperch (*Ditrema temminckii*) is an integral component. This species occupies the near shore areas all over the Japanese archipelago, with the exception of the far northern districts.[3] A number of studies have documented its life history, in part because it is a typical pauciparous fish that produces viviparous offspring. In addition to general research into growth, dietary requirements, and the ethological properties of this species,[4, 5] there have been a number of studies documenting pregnancy, embryogenesis, and parturition.[6-12] Despite this, the demography of the population is poorly understood.

To address this, we documented the fish assemblage on mud flats near the Tana Biological Laboratory (TBL), located on the eastern coast of Suo Nada (Fig. 1) . The

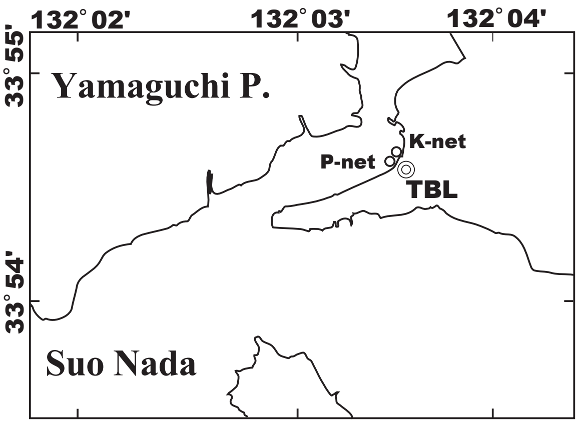

Fig. 1. Sampling location.
TBL : Tana Biological Laboratory.
Refer to text on K-net and P-net.

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contribution of surfperch to the assemblage appears to have increased, though there was considerable fluctuation in CPUE (N/haul) (Fig. 2). Interestingly, the monthly variation in CPUE was similar among years (Fig. 3), suggesting that this species has adapted to the area and is maintaining a self-sustaining population. However, it is not feasible to collect sufficient specimens on an annual basis to quantify the population structure of each year class. Therefore, we developed a theoretical model based on empirical data to represent the change in population demography throughout the year.

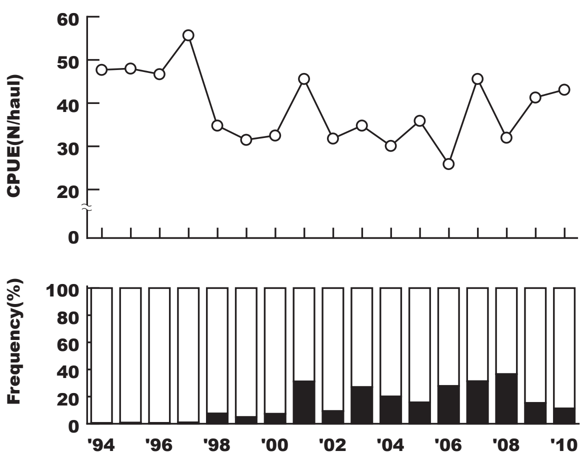

Fig. 2. Annual record of CPUE (N/haul) of all the fishes which cod hoop net harvested in 1994–2010 (upper), and those of proportion surfperch accounted for in the composition of the individuals (lower).
closed square : surfperch ; open square : others.

Materials and Methods

We collected surfperch during the spring tides between 12 January, 1994 and 21 December, 2010, with a break in collection between February-May, 2002. We used two kinds of cod hoop nets (Fig. 4),[13-15] both of which were framed similarly and constructed of chemical fiber fabrics (2 mm mesh size). The first net type ("K-net") had a

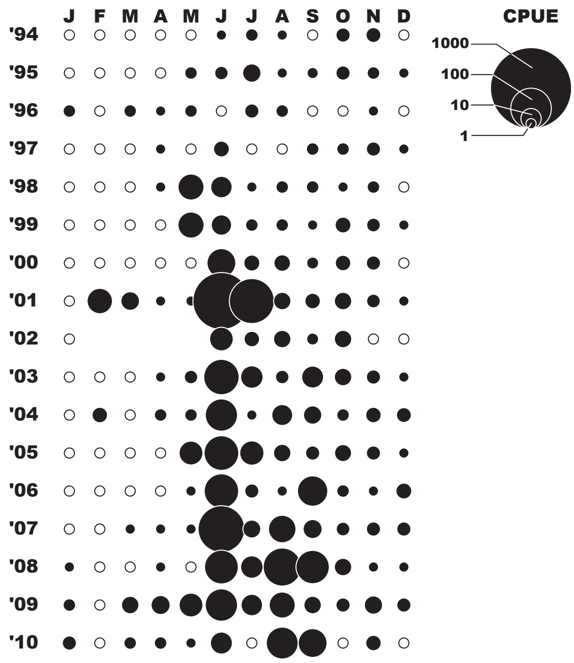

Fig. 3. Monthly arrangement of CPUE (N/haul) which surfperch occurred in 1994–2010.
Reffer to the numerical index on closed circle. Open circle indicates no yield. There is no haul in February-May in 2002.

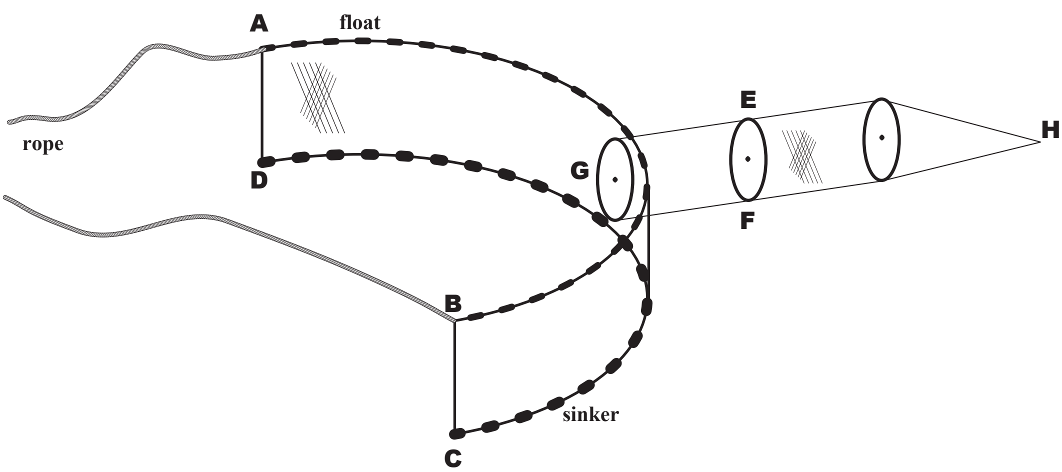

Fig. 4. Scheme of the sampling gear cod hoop net (*fukuro-machi-ami*).
Refer to text on structure in detail and characters.

rectangular shaped leader (A-B-C-D) and was 8.0 m long and 2.0 m high. The cylindrical bag was 1.0 m in diameter (E-F) and 4.5 m long (G-H). The net was set at the mouth of Kutanabe-gawa brook to collect fish as they moved out on the ebb tides.[14] The second net ("P-net") had a leader that was 16.0 m long and 2.0 m high, and a bag that was 1.2 m in diameter and 5.0 m long. This net was set along the shore line to capture fish moving in with the flood tide (Fig. 1). The nets were set for <24 h at a time and water temperature was recorded to the nearest 0.1°C during the P-net sets (Fig. 5).

All the specimens were fixed in 10% formalin immediately after capture. After preservation, the fish were measured to the nearest millimeter (total length: TL), weighed to the nearest milligram and visually inspected to determine the sex. The gonads were removed and weighed to the nearest 0.1 mg to calculate the gonadosomatic index (GSI=[gonad weight] / [body weight]).

In 2007 Katafuchi and Nakabo[16] reviewed the species and subspecies of genus *Ditrema* and they recognized *Ditrema jordani*, *D. viridis*, *D. temminckii temmincki*, and *D. t. pacificum*. Note that the surfperch we have collected since 1994 were formed by either *Ditrema temminckii temminckii* or *D. t. pacificum*, or both of them, therefore, in the case of their issue accepted.

Results and Discussion

We captured 213 surfperch in 44 sets of the K-net and 2,965 perch in 201 sets of the P-net. Of these, 87 were identified as females, 90 as males, and the remainder could not be distinguished visually. The monthly frequency distribution of TL for all years is given in Fig. 6. The smallest, immature fish (47 mm TL) was captured in May 1998 although the majority of fish were <80 mm TL at this time. In addition, we observed several individuals that were >130 mm TL in May, the majority of which were mature. However, there were no individuals between 80 and 130 mm TL. Our data suggest that the immature cohort subsequently increased their body size and a subset developed precociously as water temperatures decreased (Fig. 5).

Abe[6] noted the length of surfperch embryos at hatch (52.0-59.0 mm TL) and immediately prior to hatch (48.2-59.5 mm TL) in female fish captured over algal and/or grassy vegetation in Uraga Suido Strait (35° 15'N, 139° 44'E). Similarly, Sakurai and Nakazono[8] recorded the length of embryos (51.4-58.2 mm TL) soon after hatch in an aquarium. Sakurai *et al.*[10] reported that surfperch commence gonad development several months after hatch. Ochiai and Tanaka[17] noted that Japanese surfperch of both sexes (~12 cm SL) were able to copulate, leading to conception and parturition.

These observations suggest that the immature fish mentioned above were recent recruits to this area, and the onset of gonad development occurred prior to reaching the yearling stage. Among the fish that were <140 mm TL between September-December, gonad maturation was only observed in the larger individuals. In males, this corresponded to those >102 mm TL (0.34% GSI) whereas in females this corresponded those >112

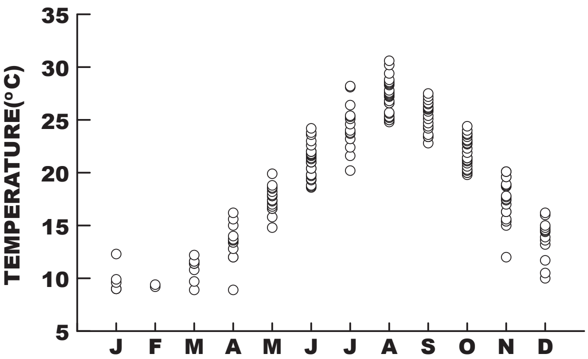

Fig. 5. Monthly arrangement of water temperature at which surfperch was sampled.

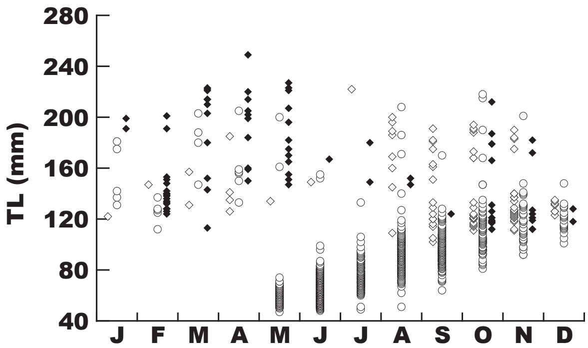

Fig. 6. Monthly arrangement of total length (TL) of surfperch.
open circle : sex undetermined ; open square : male ; closed square : female.

mm TL (of which there were two individuals with a GSI of 0.35 and 0.66%) (Figs. 6, 7). Sakurai *et al.*[10] collected 'yearling' specimens that were 117-165 mm SL between March-July in the coastal zones of the Fukushima Prefecture. Similarly, we captured several individuals that were <160 mm TL between January-April (Fig. 6). These included several females (159 mm TL) that contained up to ten embryos. Although the GSI of the specimens collected in February was <1%, those in March and April were generally above this level (Fig. 7) .

We evaluated the temporal change in the size of recently hatched surfperch. Their body size was <130 mm TL between May-August, 150 mm TL between September-December, and 160 mm TL between January-April (Fig. 6) , and we labeled them as UNDERYEARLING.[18, 19] Using these data, we estimated the von Bertalanffy's growth curve of the virtual population which was represented by the following:

$$L_{t+1} = 0.9373L_t + 14.57 \quad (1)$$

where L_{t+1} denotes the average size at monthly age $t+1$, L_t represents the size at t when $t=0$ occurs in May. The Durbin-Watson test for Eq. (1) supported the use of linear regression to explain the relationship between L_t and L_{t+1} (p=26.52%) , and Breusch and Pagan's χ^2-test demonstrated that Eq. (1) is a homoscedastic model (p =27.76%).[20] There was a significant correlation between L_t and L_{t+1} (p<0.01%, t-test). Given these, Eq. (1) can be transformed to the following :

$$L_t = 232.6\,\{1 - e^{-0.06471(t+4.557)}\} \quad (2)$$

where the notation is the same as in Eq. (1), but Eq. (2) is arranged to fit the initial mean size. Using Eq. (2), the mean size of age 1 surfperch UNDERYEARLING is 157.9 mm TL, and based on an extrapolation from Eq. (2), the mean size of age 3 individuals is 215.7 mm TL, which ranges 159.5-230 mm TL.[6, 17]

Examination of Fig. 6 and Eq. (1) or (2) indicates that the total length distribution in each month is derived from at least two year classes, suggesting that surfperch remain in the area throughout their life history. The monthly change in CPUE (N/haul) between May and the following April is given in Fig. 8. These data were fit with the following linear regression model :

$$\log C_t = -0.1140\, t + 1.464 \quad (3)$$

where C_t denotes the CPUE (N/haul) at t (defined in Eq. (1)). Durbin-Watson's test (p=49.40%) and the χ^2

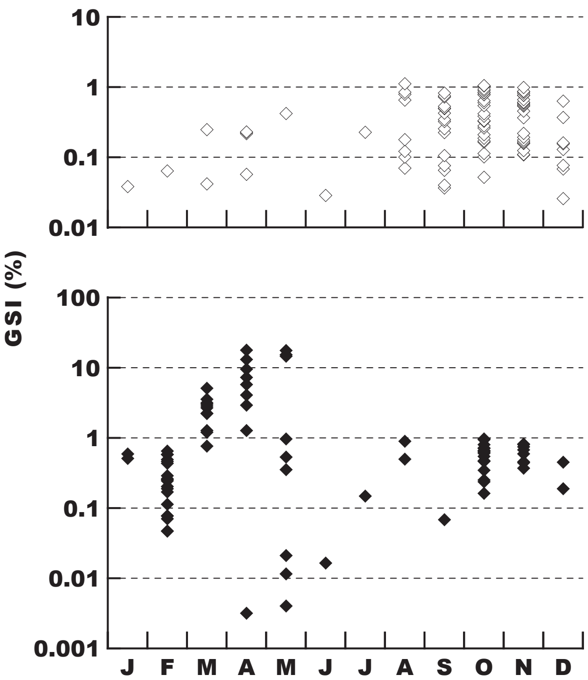

Fig. 7. Monthly arrangement of GSI.
open square : male ; closed square : female.

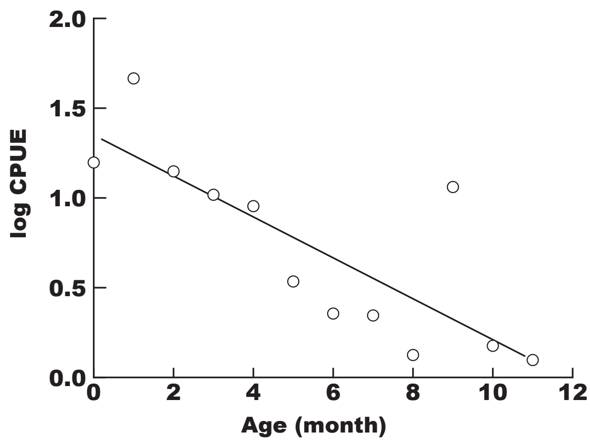

Fig. 8. Relationship between the monthly age of UNDERYEARLING and log CPUE.
Solid line indicates the regression between them. Refer to text on UNDERYEARLING.

-test (p=39.47%) respectively rejected autocorrelative and heteroscedastic disturbances in Eq. (3), and a t-test (p=0.18%) showed the correlation between log C_t and t was significant. The regression coefficient (-0.1140 per month) and its upper level within the 95% confidence limit of -0.05348 per month accounted for 4.291% and 22.82% survival, respectively, of the new recruits after a year.

The number of adults available to produce progeny of the next generation is highly dependent on the clutch or litter size and the mortality rate.[21] Female fish conceive 64 embryos at most, or ten neonates.[8, 11] Based on these observations, we modeled the demography using a mathematical model. When the annual mortality rate was approximated based on the embryo count, the minimum estimate annual mortality was ~3.13% (=2/64), which was consistent with the value obtained using Eq. (3). In other words, the model accurately predicts that this species possesses the potential fecundity to obtain a sustainable generation number. Conversely, if we estimate annual mortality based on the neonate count, we obtain a value of 20.0%, a considerable underestimate. However, when given the iteroparous nature of this species, the annual mortality rate estimated here may still allow a sustainable multigenerational population structure. The accuracy of these analytical approaches would be improved by including data describing age specific litter sizes and mortality rates.

In summary, we modeled the demography of surfperch in the mud flat areas of the eastern edge of the Suo Nada. Our model characterized the phenological modality and demonstrated how this species was able to sustain the population size despite having a small litter size. The accuracy of our estimates should be validated by determining the age of individuals in the population. However, there is no plausible explanation for the seasonable influx of surfperch neonates in this area. Given the recent deterioration in the fishery in the Seto Naikai region,[22-24] our observations highlight the need to document the development and reproduction of this species in situ to prevent over exploitation and extirpation.

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周防灘東部内湾域に棲息するウミタナゴ（*Ditrema temminckii*）の成長と成熟の季節変化について

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山口県熊毛郡平生町の水産大学校田名臨海実験実習場近辺水域で1994-2010年に敷設した袋待網で採集されたウミタナゴ（*Ditrema temminckii*）の成長と成熟の月変化について調べた。本種はほぼ通年にわたって棲息していること，また毎年５月には顕著な新規加入群が出現することがわかった。この小型個体群は，８月には生殖腺の発現がみられ，９月以降翌年４月までの期間にわたって雌雄ともに生殖腺の成熟する様子が観察された。この個体群について，成長方程式および生残方程式をもとめて解析したところ，本水域がウミタナゴの産仔場・育成場として機能していることが示唆された。