La mer 61 : 1–11, 2023, https://doi.org/10.32211/lamer.61.1-2_1
Société franco-japonaise d'Océanographie, Tokyo

Occurrence patterns and feeding habits of *Tridentiger obscurus* in Furuhama Park, Ota City, Tokyo, central Japan

Keita MARUYAMA[1, 2]*, Chihiro KANEKO[1] and Hiroshi KOHNO[1, 3]

Abstract: The occurrence patterns and feeding habits of the gobiid *Tridentiger obscurus* were investigated to clarify the habitat use in an urban seaside park constructed in the inner Tokyo Bay. Surveys were conducted using small seine nets and net cages on an artificial sandy beach, a tidal flat, and a seawall in Furuhama Park, Ota City, Tokyo. In total, 119 individuals (6.3–46.6 mm body length [BL], mode of BL was 5.0–9.9 mm) were collected from the sandy beach; 89 (6.2–42.6 mm, 10.0–14.9 mm) from the tidal flat; and 1,092 (8.0–73.7 mm, 40.0–44.9 mm) from the seawall. On the sandy beach and tidal flat, the goby fed mainly on zooplankton by 11.0 mm BL, and thereafter on small benthic and epibenthic crustaceans in addition to the zooplankton as they grew. On the seawall, *T. obscurus* fed on small benthic and epibenthic crustaceans with no ontogenetic diet shift. These results revealed that *T. obscurus* would grow by taking different prey resources among multiple environments in the urban seaside park during their early life history, implying the need for comprehensive conservation of the various environments to protect the fish species.

Keywords : *Gobiidae, Ontogenetic dietary shift, Artificial environment, Tokyo Bay*

1. Introduction

Tokyo Bay is a closed bay located near the center of Japan and opens to the Pacific Ocean. The bay is surrounded by Tokyo, Chiba, and Kanagawa prefectures, and one of the most developed sea areas in Japan. The inner Tokyo Bay is defined as the bay area of north side of the line connecting Futtsu in Chiba Prefecture and Kannonzaki in Kanagawa Prefecture (KOHNO *et al.*, 2011).

The inner Tokyo Bay with vast tidal flats had been one of the most productive fishing areas in Japan by the 1960s (SHIMIZU, 1990). However, as the economy began to develop, the pollution load to the inner bay began to increase in the 1950s, and water quality problem became more serious. Furthermore, the reclamation of many tidal flats and shallow areas from the 1960s led to a decrease in fish and shellfish catches, and the area became known as the "Sea of Death" (SHIMIZU,

1) Laboratory of Ichthyology, Tokyo University of Marine Science and Technology, 4–5–7 Konan, Minato-ku, Tokyo 108–8477, Japan
2) Graduate School of Science and Technology for Innovation, Yamaguchi University, 2–16–1 Tokiwadai, Ube, Yamaguchi, 755–8611, Japan
2) Nagao Natural Environment Foundation, 4–20–9 Midori, Sumida-ku, Tokyo 130–0021, Japan
*Corresponding author:
E-mail: bokuwamoku@gmail.com

1999). Thus, the area of tidal flats, which was estimated to be 136 km^2 before the 1940s, decreased to 10 km^2 in 1973 (OGURA, 1993). Since the 1970s, multiple administrative agencies along the coast of the Tokyo Bay have created artificial tidal flats to revitalize the area so that citizens can enjoy ecosystem services again (YAMANE *et al.*, 2004; KOHNO *et al.*, 2008). As a result, the area of tidal flats increased to 16.4 km^2 in 1997 (MINISTRY OF THE ENVIRONMENT OF JAPAN, 1997), but the vast mudflats and shallow areas in the past have been lost and much of the coastline have been replaced by seawalls and artificially placed rocky areas (SHIMIZU, 1999; ONODERA *et al.*, 2020).

Owing to the loss of these tidal flats and shallow areas, which served as important habitats for fish, there are only few natural tidal flats left to serve this function (KANOU *et al.*, 2000; HERMOSILLA *et al.*, 2012). Under this situation, comprehensive surveys have been conducted on artificial tidal flats in Tokyo Bay; for example, Kasai Marine Park (KUWABARA *et al.*, 2003; YAMANE *et al.*, 2004) and Furuhama Park in Tokyo (MURAI *et al.*, 2016; MARUYAMA *et al.*, 2021); Shinhama-ko Lagoon in Chiba Prefecture (KOHNO *et al.*, 2008); and Hakkei-jima Park in Kanagawa Prefecture (YAMANE *et al.*, 2004). These surveys revealed that artificial tidal flats would function as nursery grounds for various fish species.

Moreover, similar surveys have been performed on vertical seawalls and rocky shorelines, which make up the majority of the inner Tokyo Bay; for example, the ichthyofauna of vertical seawalls (SAKAI *et al.*, 2007; ONODERA *et al.*, 2020) and the occurrence patterns of gobies in rocky areas (MURASE *et al.*, 2007). However, these surveys have mainly focused on ichthyofauna, and there have been few studies on the detailed occurrence patterns and feeding habits of each fish species. Currently, while planning the restoration of lost tidal flats and shallow areas, the need to clarify environment preferences and food habits in each developmental stage in each fish species has been pointed out (MURAI *et al.*, 2016; MARUYAMA *et al.*, 2021).

The tripletooth goby *Tridentiger obscurus* is typical estuarine fish, widely distributed in brackish waters in Japan (KISHI, 2001). In this study, we investigated ecological information such as the occurrence patterns and feeding habits of the goby in an urban seaside park of the inner Tokyo Bay in order to clarify the habitat use of resident fish in several artificial environments in the bay area.

2. Materials and Methods

The survey site is Furuhama Park, located in Ota City, Tokyo, on the western shore of the inner Tokyo Bay (Fig. 1). Furuhama Park was opened in 2007 as a park with 1.2 ha of sandy beach (median particle size = 0.2 mm mountain sand from Kimitsu, Chiba Prefecture, hereinafter referred to as "sandy beach"); 1.0 ha of muddy tidal flat (a native tidal flat relocated 200 m offshore and covered with porous gravel and rocks, hereinafter referred to as "tidal flat"); and a 4.6 ha shallow area with water depth of 1.5 m between the sandy beach and tidal flat (TAKEYAMA *et al.*, 2018). Submerged dikes, approximately 4.0 m high from the seafloor, are located at the northern and southern ends of the shallow area that borders the surrounding canal. Submerged dikes control the discharge of sediment from shallow areas and the inflow of hypoxic oxygen water spreading to the bottom layer of the surrounding canals (OKAMURA *et al.*, 2004). Environmental and ichthyofaunal surveys have been conducted on this park since before its construction (e.g., OTA CITY, 2019; TAKEYAMA *et al.*, 2018) and there are many previously reported studies

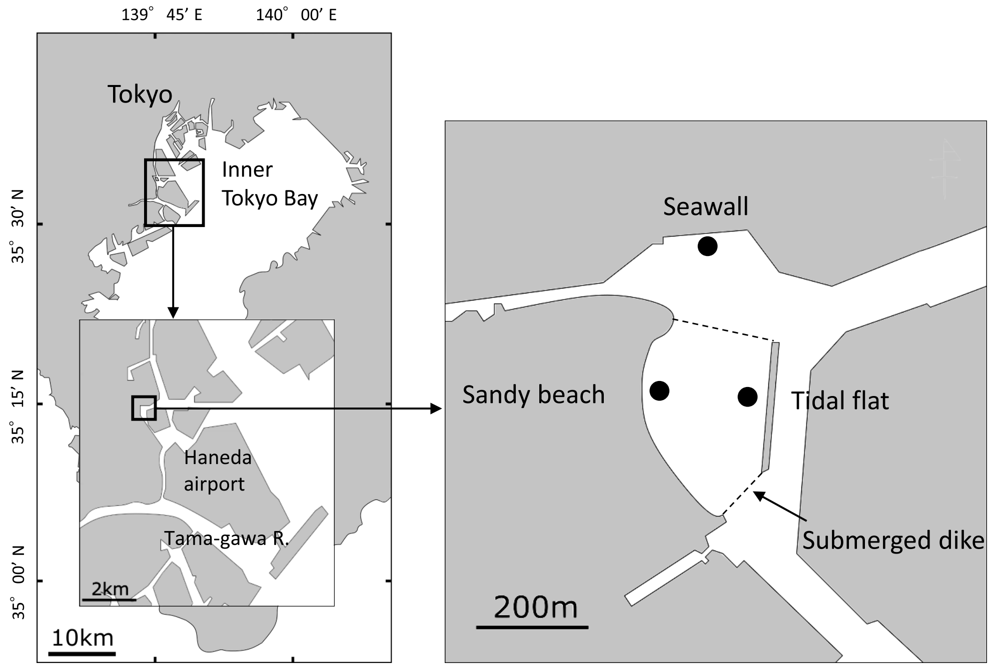

Fig. 1 Map showing the sampling sites in Furuhama Park located in inner Tokyo Bay. Fish were caught with a small seine net in the sandy beach and tidal flat and with net cages in the seawall.

on them, which are unusual for an urban waterfront park.

The study site and surrounding waters are brackish, and the annual mean salinity is 17.4 on the beach and 18.0 on the tidal flat (MARUYAMA *et al.*, 2021). The average dissolved oxygen (herelnafter DO) is more than 7.0 mg/L through years on sandy beach and tidal flat and have never been below 3.0 mg/L; however, the bottom layer of the surrounding canal area becomes hypoxic, causing the DO level to be below 3.0 mg/L during summer (TAKEYAMA *et al.*, 2018; ONODERA *et al.*, 2020). There are no *Sargassum* or *Zostera* beds, and many vertical seawalls made of concrete and rocky areas, which are characteristic of urban canal areas, exist in the surrounding area.

Fish samples were collected at three stations: sandy beach, tidal flat, and seawall (Fig. 1). On the sandy beach and the tidal flat, surveys were conducted once a month from May 2014 to April 2019 using seine nets at low tide during the daytime around the spring tide. However, the tidal flat was not surveyed in September and October 2014, January and June 2015, and April 2019. In 2016 and 2017, the surveys could not be conducted in August; therefore, they were conducted twice in September. The number of tows of small seine nets was two (three in May and June 2014). A small seine net (sleeve net: 4.5 m long, 1.0 m high, mesh size 2.0 mm; body to bag net: 2.0 m wide, 1.0 m high, 5.5 m long, 0.8 mm mesh) (KANOU *et al.*, 2002) was used for the survey and towed 25 m along the shoreline at a depth of 1.0 m or less. The net was towed such that the width of the net opening was 4.0 m. In this case, 100 m^2 of fish was collected at a time.

Sampling surveys were conducted on the seawall from April 2016 to March 2019 using a fishing gear called a net cage. Three types of net cages were prepared by placing different internal materials (nylon net, bamboo shoot, and oyster shell) in a wire mesh cage (0.4 m in length and width, 0.5 m in height, 40 mm mesh size), as described by Takeyama *et al.* (2017). The net cages for each internal material were set with ropes at two points, one at the water surface and the other at the seafloor, and sampling was conducted once a month at low tide during the daytime around the spring tide. The water surface cages were anchored to a floating pier that moved with the tides, so that they were always positioned at the water surface. The net cages that had been collected were sunk in the same position and collected again the following month in the same manner. In collecting the fish, we hauled the fish with the rope, retrieved the net cage, and collected the fish in the cages. To prevent fish from escaping from the net cage, the bottom and surrounding areas of the net cage were covered with a scoop net (opening size 1.1 m, mesh size 1.0 × 1.0 mm). The differences in fish occurrence patterns by materials and depth are discussed in detail in Onodera *et al.* (2020) and Takeyama *et al.* (2017), so this paper treats all *Tridentiger obscurus* collected in the seawall together. At the study site, it has been shown that the hypoxic water occurs in the bottom layer during the summer months, making it difficult for fish to inhabit.

The samples were fixed in the field using 10% brackish water formalin and brought to the laboratory. *Tridentiger obscurus* specimens were sorted and identified from the samples in the laboratory, counted, measured for body length [BL], and their developmental stages were determined. The developmental stages of the samples were classified into three classes (larvae: when the number of fin rays had not completed; juvenile: when the number of fin rays had completed but the fish was still immature; adult: when the fish was sexually mature) based on Kanou *et al.* (2000). In this study, samples with 9.9 mm BL or less were classified as larva, 10.0–29.9 mm BL as juvenile, and 30.0 mm BL or more as adults.

A total of 218 individuals were used as samples for feeding habit analyses: 22 individuals (7.0–15.5 mm BL) collected on the sandy beach, 39 individuals (7.0–30.3 mm) on the tidal flat, and 157 individuals (11.2–68.3 mm) on the seawall. Volumetric analysis (Hyslop, 1980) was used to examine their gut contents, and the mean volume percentage (%V) was calculated according to Horinouchi and Sano (2000) and Kanou *et al.* (2004). The food items in the gut contents of each individual were identified as the lowest possible taxon. The anterior half of the gut was examined for larvae with a straight gut, and the gut contents up to the first bending were examined for individuals with a bent gut. The volume of gut contents was determined as follows: the gut contents of each individual were observed under a binocular microscope to assess the diet and the volume of each food item was determined on a glass slide with a 1.0 × 1.0 mm grid pattern, aligned with the thickness. In each individual, the volumes of all food items were added and the total volume of the gut contents was calculated. The percentage of the volume of each food item was calculated from the total calculated volume. Specimens with empty guts were excluded from the analyses. To determine whether the feeding habits changed with growth, the Mann-Whitney *U*-test was used to test whether there was a difference in the %V of major food items among several length ranges.

3. Results

3.1 Occurrence patterns

The number of *Tridentiger obscurus* collected

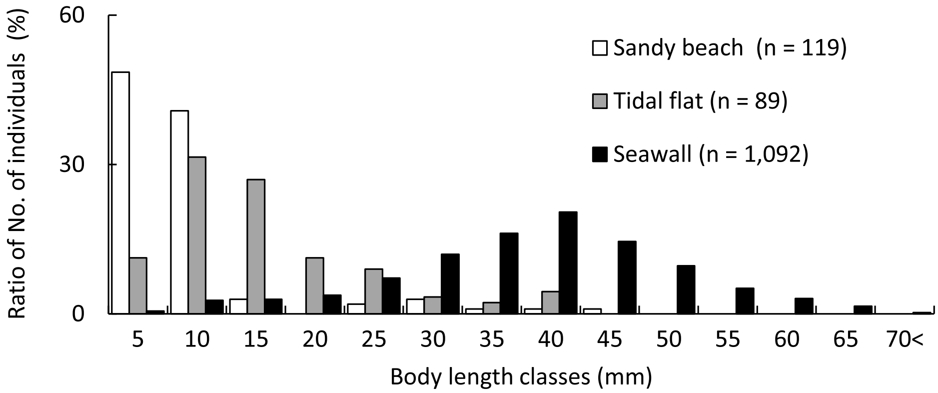

Fig. 2 Body length classes of *Tridentiger obscurus* collected from Furuhama Park during the study period from 2014 to 2019, shown by each collecting site.

was 119 individuals (6.3–46.6 mm in body length, BL) on the sandy beach, 89 individuals (6.2–42.6 mm BL) on the tidal flat, and 1,092 individuals (8.0–73.7 mm BL) on the vertical seawall (Fig. 2). The mode of body lengths classes from 5.0 to 9.9 mm for the sandy beach, 10.0 to 14.9 mm for the tidal flat, and 40.0 to 44.9 mm for the seawall. In addition, 40.0–44.9 mm were collected in abundance on three materials of the net cages. The goby occurred from March to October on the sandy beach, January to November on the tidal flat, and throughout the year on the seawall. The number of individuals collected on the sandy beach was high from July to October and low from January to June (Fig. 3). On the tidal flat, relatively large numbers of individuals were collected from April to June and few individuals throughout the year. On the vertical seawall, a certain number of individuals were collected throughout the year, but the number was particularly high from July to September.

In terms of developmental stages, larvae and juveniles appeared in the same proportion on the sandy beach from July to September, but more larvae were observed in October (Fig. 3). On the tidal flat, most fish were juveniles from January to June; however, adults were observed in addition to juveniles from July to September, and larvae and juveniles appeared in the same proportions in October and November. On the vertical seawall, adults were abundant throughout the year and almost no larvae were observed. Juveniles were also observed throughout the year and were abundant from July to September.

3.2 Feeding habits

Tridentiger obscurus on the sandy beach and tidal flat fed mainly on zooplankton, such as calanoid copepods (65.6% and 88.4%, respectively), followed by small benthic and epibenthic crustaceans, such as amphipods and mysids (Fig. 4). However, the %Vs of zooplankton were significantly different between the two stations after they attained 11.0 mm BL ($p<0.05$), with a mean percentage of 23.8% on the sandy beach and 48.4% on the tidal flat, indicating that *T. obscurus* larger than 11.0 mm BL shifted to and fed primarily on small benthic and epibenthic crustaceans. In contrast, *T. obscurus* on the seawall did not show a diet shift with growth; they mainly fed on small benthic and epibenthic crustaceans, such as amphipods, and polychaetes (Fig. 4). No individuals of *T. obscurus* feeding on fish includ-

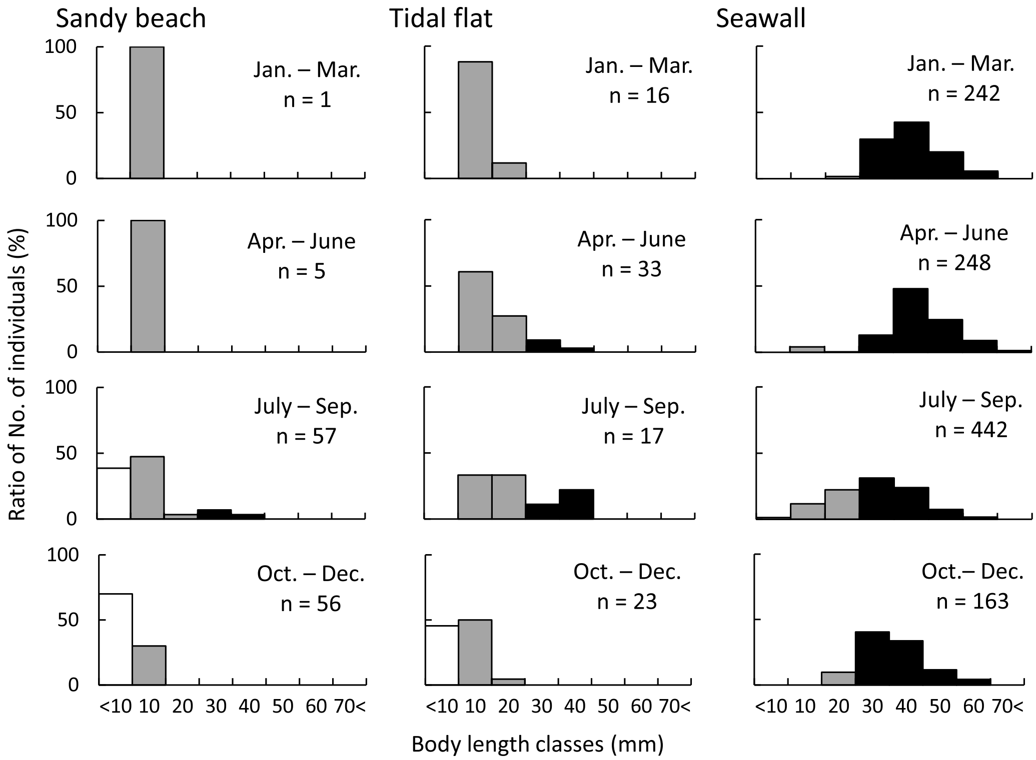

Fig. 3 Body length classes of *Tridentiger obscurus* collected at each habitat for every three months from May 2014 to April 2019. Open bars indicate the larva, gray bars indicate the juvenile, and solid bars indicate the adult.

ing this species were observed.

The percentage of empty gut was 0% on the sandy beach, 2.6% (1 individual) on the tidal flat, and 4.0% (6 individuals) on the vertical seawall.

4. Discussion

4.1 Habitat shifts with growth

The number of *Tridentiger obscurus* larvae smaller than 9.9 mm BL collected in this study was 59 out of 119 individuals (49.6%) at the sandy beach and 10 out of 89 (11.2%) at the tidal flat. NAKAMURA (1942) reported that *T. obscurus* up to 9.35 mm BL is considered to be pelagic larvae. Many gobiid species in Tokyo Bay have a pelagic life during the larval stage, and such larvae have been shown to have poor swimming abilities (ANGMALISANG *et al.*, 2020; NAKAIMUKI *et al.*, 2022). Therefore, the sandy beach and tidal flat in Furuhama Park, which are less affected by waves, may provide pelagic life area for the *T. obscurus* larvae.

Although *Tridentiger obscurus* rarely appeared on the sandy beach after reaching 15.0 mm BL (11 individuals occupying 9.2%), they appeared in some numbers on the tidal flat (51 individuals occupying 57.3%) and were abundant on the seawall (1,059 individuals occupying 97.0%). In Furuhama Park, hand net sampling was conducted twice a year (in June, September, or October) as a post-construction environmental survey in Ota City. Among them, results from a rocky area approximately 50 m west of

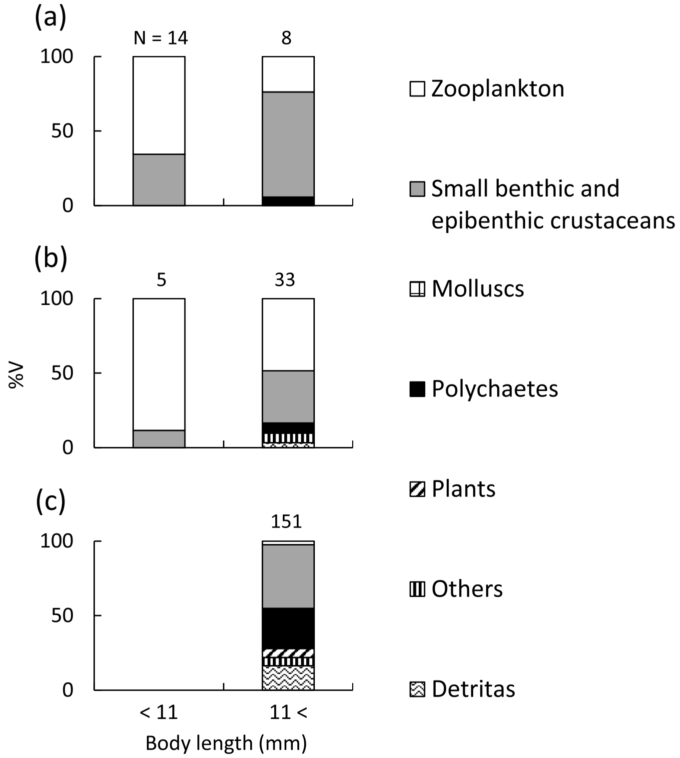

Fig. 4 Percentage volume (%V) of food items in the guts of *Tridentiger obscurus* in each habitat (a: sandy beach; b: tidal flat; c: seawall) from May 2014 to April 2019. Numerical characters on top of each column indicate the number of fish with food examined.

the seawall in the present study site showed that *T. obscurus* of 7–90 mm BL were collected, and the mode was 45.1–50.0 mm BL (Ota City, 2015–2019). *T. obscurus* generally congregate in estuarine areas where there are gravels, boulders, and artificial dumping sites (Kishi, 2001; Kohno *et al*., 2011). Recently, *T. obscurus* was reported to be abundant on seawalls in urban canal areas (Takeyama *et al*., 2017; Onodera *et al*., 2020). Therefore, *T. obscurus* select habitats according to their developmental stages, such that they initially grow on sandy beach and tidal flat up to 15.0 mm BL and then change habitat to seawall and/or rocky areas where they grow to 15.0 mm BL and larger.

From the juvenile stage, *Tridentiger obscurus* has a habit of getting under cover and prefers areas with boulders and artificial dumping rather than open areas (Kohno et al, 2011). Some individuals larger than 15.0 mm BL were observed on the tidal flat, probably because of the presence of boulders of various sizes (10–50 cm in diameter) scattered on the tidal flat. Although these boulder areas have been shown to be feeding areas for birds, such as *Arenaria interpres* and *Numenius phaeopus* (Ota City, 2018), they may provide important microhabitats for other organisms such as fish.

4.2 Ontogenetic dietary shift

At both the sandy beach and tidal flat, *Tridentiger obscurus* fed mainly on zooplankton such as calanoid copepods when they were up to 11.0 mm BL, but when they grew to a size larger than 11.0 mm BL as juveniles, the proportion of zooplankton in their gut contents decreased and they started feeding on small benthic or epibenthic crustaceans such as amphipods and mysids. These results indicate that these two stations function as ontogenetic dietary shift areas.

The timing of these diet shift has been studied in other gobiids; for example, *Acanthogobius flavimanus*, which are dominant species on tidal flats in the inner Tokyo Bay, change their main food items from zooplankton such as calanoid and cyclopoid copepods and cladocerans to small benthic and epibenthic crustaceans such as harpacticoid copepods and gammaridean amphipods and polychaetes when juvenile fish settle on the bottom (KANOU *et al*., 2004). Although *Tridentiger obscurus* entered the juvenile stage at 10.0 mm BL in this study, HWANG *et al*. (2006) mentioned that the size format which they change from larval to juvenile was 11.6–14.3 mm BL. NAKAMURA (1942) indicated that *T. obscurus* shifted to a benthic lifestyle at 9.35 mm BL. From these results, it is clear that *T. obscurus* change their main food items as they settle on the bottom during transformation period from larvae to juveniles.

The present study revealed that *Tridentiger obscurus* on the seawall at Furuhama Park fed mainly on small benthic or epibenthic crustaceans such as amphipods and polychaetes. Therefore, food habits of *T. obscurus* after the juvenile were common; however, they expand their habitat from sandy beach and tidal flat to seawall and rocky areas after changing their main food items from zooplankton to small benthic and epibenthic crustaceans in the former nurseries. Although it has been reported that *T. obscurus* in the inner Tokyo Bay fed heavily on algae (KANOU *et al*., 2004; MURASE *et al*., 2013), the %V of algae in this study was low (6.1 %). In Lake Hinuma, Ibaraki Prefecture, the main prey of 31–52 mm BL *T. obscurus* was mysids (KANEKO *et al*., 2016). During sampling in the present study, many amphipods were observed to be attached to net cages and on boulders in the tidal flat. In addition, it has been reported that many amphipods inhabit seawalls and boulder areas, which are the research locations in this study (OGAWA, 2011), and it is possible that *T. obscurus* used to prefer to feed on amphipods in Furuhama Park. This supports the idea that the feeding habit of *T. obscurus* varies according to environmental conditions (MURASE *et al*., 2013); thus, the species is classified as a miscellaneous/opportunist, rather than an omnivore.

4.3 Spawning ground and seasons

The smallest specimen of *Tridentiger obscurus* captured in this study was a 6.2 mm BL and was collected on the tidal flat, and hatching larvae have been reported to be 3.1 mm BL (NAKAMURA, 1942). HWANG *et al*. (2018), who bred *T. obscurus* in aquaria and observed the larvae and juveniles, reported that *T. obscurus* grew to 2.83–4.07 mm in total length [TL] at 8 days after hatching, 3.63–4.93 mm TL at 17 days, and 7.18–8.73 mm TL at 28 days. NAKAMURA (1942) reported that the TL of *T. obscurus* larvae is 105.1 to 118.9% of BL. Thus, the smallest specimen collected in this study was estimated to be 6.5–7.4 mm TL, indicating that the specimen was between 17 and 28 days post-hatching.

The smallest mature BL of *Tridentiger obscurus* is 27 mm for males and 30 mm for females (NAKAMURA, 1942). Many larger adult individuals were observed in this study, particularly on the seawall station. In addition, many adults have been found on the rocky areas in Furuhama Park (Ota City, 2015–2019). The spawning season of *T. obscurus* in Tokyo Bay is from May to September (Kishi, 2001), and larvae were observed from July to November on the sandy beach and tidal flat. In May 2017, during the period of this study, *T. obscurus* were observed to spawn and protect their eggs on the inner surface of dead oyster shell (*Crassostrea gigas*) attached to the seawall. Based on these reports, the area around Furuhama Park, including the seawall, may be a spawning ground for *T. obscurus,* and the spawning season is estimated to be from May to October. These findings indicate that artificial environments may not only provide habitats for each developmental stage but also have the potential to become important spawning grounds for the next generation of *T. obscurus.*

Acknowledgments

The authors are grateful to the staff of Division of Urban Infrastructure Improvement, Ota City, and to the chairman Mr. Masahiro Iijima and his staff of the Tokyo Bay Recreational Fishing Boat Cooperative for granting the permission to conduct our surveys and charter boats. We thank Dr. Kana Takeyama and Mr. Kota Nakase of Penta-Ocean Construction Co., Ltd. for their useful contribution in this survey. We also thank the students of the Laboratory of Ichthyology, Tokyo University of Marine Science and Technology for their cooperation during the monthly surveys. This study was supported by JSPS KAKENHI Grant Numbers 24310028 and 15K00654 and Sasagawa Scientific Research Grant Number 2019–4094 from the Japan Science Society.

References

Angmalisang, D. E., K. Maruyama, A. Hihara and H. Kohno (2020): Occurrence patterns and ontogenetic intervals of *Eutaeniichthys gilli* (Gobiidae) in Obitsu-gawa river estuary, Tokyo Bay, central Japan. *La mer*, **58**, 83–99.

Hermosilla, J. J., Y. Tamura, M. Moteki and H. Kohno (2012): Distribution and community structure of fish in Obitsu-gawa River Estuary of inner Tokyo Bay, central Japan. *AACL Bioflux*, **5**, 197–222.

Hwang, S. Y., K. H. Han, W. K. Lee, S. M. Yoon, C. C. Kim, S. H. Lee, W. I. Seo and S. S. Roh (2006): Early life history of the *Tridentiger obscurus* (Pisces, Gobiidae). *Dev. Reprod*, **10**, 47–54.

Hwang, S. Y., J. M. Park, S. H. Lee and K. H. Han (2018): Osteological development of the larvae and juvenile of trident goby, *Tridentiger obscurus. Dev. Reprod*, **22**, 205–212.

Horinouchi, M. and M. Sano (2000): Food habits of fishes in a *Zostera* marina bed at Aburatsubo, central Japan. *Ichthyol. Res.*, **47**, 163–173.

Hyslop, E. J. (1980): Stomach contents analysis: a review of method and their application. *J. Fish. Biol.*, **17**, 411–429.

Kaneko, S., K. Kanou and M. Sano (2016): Food habits of salt marsh fishes in Lake Hinuma, Ibaraki Prefecture, central Japan. *Fish. Sci.*, **82**, 631–637.

Kanou, K., T. Koike and H. Kohno (2000): Ichthyofauna of tidelands in the inner Tokyo Bay, and its diversity. *Japan. J. Ichthyol.*, **47**, 115–129. (in Japanese with English abstract)

Kanou, K., H. Kohno, P. Tongnunui and H. Kurokura (2002): Larvae and juveniles of two engraulid species, *Thryssa setirostris* and *T. hamiltomi*, occurring in the surf zone at Trang, southern Thailand. *Ichthyol. Res.*, **49**, 401–405.

Kanou, K., M. Sano and H. Kohno (2004): Food habits of fishes on unvegetated mud flat in Tokyo Bay, central Japan. *Fish. Sci.*, **70**, 978–987.

Kishi, Y. (2001): *Tridentiger obscurus.* In "*Freshwater Fishes of Japan 3rd edition*" (ed. by Kawanabe, H., N. Mizuno and K. Hosoya), Yama-Kei Publishers Co., Ltd., Tokyo, Japan, p. 605. (in Japanese)

Kohno, H., K. Kanou and T. Yokoo (2011): A Photographic Guide to the Fishes in Tokyo Bay. Heibonsya, Tokyo, Japan, 374 pp. (in Japanese)

KOHNO, H., T. YOKOO, M. MOTEKI and K. KANOU (2008): Ichthyofauna of the artificial lagoon, Shinhama-ko, located along the northernmost shore of Tokyo Bay. *Bull. Biogeogr. Soc. Japan*, **63**, 133–142. (in Japanese with English abstract)

KUWABARA, Y., N. TSUCHIDA, T. MOTOYAMA, H. KOHNO, K. KANOU, Y. SHIMADA and R. MIMORI (2003): Ichthyofauna of artificial tideland in Kasai Marine Park, Tokyo Bay. *La mer*, **41**, 28–36. (in Japanese with English abstract)

MARUYAMA, K., H. KOHNO, K. TAKEYAMA and K. NAKASE (2021): Fish assemblages and diversities in the artificial sandy beach and tidal mud flat in the inner Tokyo Bay, central Japan. *J. Tokyo Univ. Mar. Sci. Technol.*, **17**, 1–17. (in Japanese with English abstract)

MINISTRY OF THE ENVIRONMENT OF JAPAN (1997): Tidal Flats, Algal and Sea-Grass Beds and Coral Reefs in Japan. Marine parks journal, Tokyo, Japan, 291 pp. (in Japanese)

MURAI, S., A. MURASE, H. KOHNO, K. TAKEYAMA, K. NAKASE and T. IWAKAMI (2016): Fish assemblage and diversity in the developed tidal flat and sandy beach at the Furuhama Park, Ota City, Tokyo, central Japan. *La mer*, **54**, 11–27. (in Japanese with English abstract)

MURASE, A., Y. NEMOTO and H. MAEDA (2007): Gobiid fishes from Shioirino-ike, Hama-rikyu garden and Takahama canal, Tokyo Bay. *Natural History Report of Kanagawa*, **28**, 75–83. (in Japanese with English abstract)

MURASE, A., H. MAEDA and Y. NEMOTO (2013): Diet of the goby, *Tridentiger obscurus* (Teleostei: Gobiidae), inhabiting Takahama canal, the inner part of Tokyo Bay. *Bull. biogeogr. Soc. Japan*, **68**, 93–98. (in Japanese with English abstract)

NAKAIMUKI, A., D. E. ANGMALISANG, K. MARUYAMA and H. KOHNO (2022): Occurrence patterns and ontogenetic intervals based on osteological and morphometric characters of larval and juvenile gluttonous goby (C*haenogobius gulosus*) in Furuhama Park, innermost Tokyo Bay, central Japan. *La mer*, **59**, 113–129.

NAKAMURA, N. (1942): Note on the life history of a gobioid fish, *Tridentiger obscurus* (Temminck et Schlegel). *Botany and zoology*, **10**, 115–119. (in Japanese)

OGAWA, Y (2011): A Guidebook of Gammarids in Tokyo Bay. The Faculty of Science, Toho University. http://marine1.bio.sci.toho-u.ac.jp/tokyobay/gammaridea_guide/gammaridea_tokyobay_2.0.pdf, accessed on 11 Nov. 2022. (in Japanese)

OGURA, N (1993): Tokyo Bay – Its Environmental Changes. Kouseisya-kouseikaku, Tokyo, Japan, 193 pp. (in Japanese)

OKAMURA, T., K. NAKASE, M. SATO and K. KOTERA (2004): Transition in environmental conditions of the tidal flat through its improvement and development. *Proceedings of civil engineering in the ocean*, **20**, 419–424. (in Japanese with English abstract)

ONODERA, A., K. MARUYAMA, K. TAKEYAMA and H. KOHNO (2020): Occurrence patterns of fishes collected by net cages placed at surface and bottom layers along a seawall at the Furuhama Park in innermost Tokyo Bay. *La mer*, **58**, 59–69. (in Japanese with English abstract)

OTA CITY (2015–2019): Report of the Environmental Survey at Heiwajima Canal. Division of Urban Infrastructure Development, Ota City. (in Japanese)

SAKAI, Y., M. MOTEKI and H. KOHNO (2007): Seasonal occurrence of fishes gathered with an aquatic lamp in the inner part of Tokyo Bay. *J. Tokyo Univ. Mar. Sci. Technol.*, **3**, 45–50. (in Japanese with English abstract)

SHIMIZU, M. (1990): Fishes and shellfishes in Tokyo Bay (6). *Aquabiology*, **68**, 183–189. (in Japanese with English abstract)

SHIMIZU, M. (1999): Impact of coastal development on biological environment. *Bulletin on Coastal Oceanography*, **36**, 121–130. (in Japanese)

TAKEYAMA, K., R. YAMANAKA, H. KOHNO, H. IWAMOTO, K. MIYAMOTO, R. HIRAKAWA and Y. KOZUKI (2017): Experimental study on the habitable seawall for fish in urban canal area. *Journal of JSCE, ser. B3 ocean engineering*, **73**, I_845–I_850. (in Japanese with English abstract)

TAKEYAMA, K., K. TANAKA, H. KOHNO, K. KIMURA, K.

NAKASE and T. IWAKAMI (2018): The environmental changes of tidal flats constructed in Tokyo Bay. *Journal of JSCE, ser. B3 ocean engineering*, **74**, I_510–I_515. (in Japanese with English abstract)

YAMANE, T., M. KISHIDA, I. HARAGUCHI, R. ABE, M. DAITO, H. KOHNO and K. KANOU (2004): Larval and juvenile ichthyofauna in artificial beaches facing Tokyo Bay. *La mer*, **42**, 35–42. (in Japanese with English abstract)

Received: January 16, 2023
Accepted: June 2, 2023