Reproductive biology of konoshiro gizzard shad, Konosirus punctatus, in Tokyo Bay

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REPRODUCTIVE BIOLOGY OF KONOSHIRO GIZZARD SHAD, *KONOSIRUS PUNCTATUS*, IN TOKYO BAY*

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Reproductive biology, including the establishment of maturation phase of ovary based on histological study, seasonal changes of the maturation phase and gonadosomatic index (GSI), sex ratio and sexual size dimorphism, was examined on the konoshiro gizzard shad, *Konosirus punctatus*, in Tokyo Bay. The phase III (spawning) of ovaries occurred from March to July, although most ovaries sampled from June and July were considered to be spent. Values of GSI were also high from March to June in both sexes, the mean value ranging from 6.9–14.8 and from 5.1–15.1 in females and males, respectively. These results indicate that the spawning season of the konoshiro gizzard shad in Tokyo Bay is from March to June. Ovaries sampled during the spawning season possessed various maturation stages of ova. Furthermore, in these ovaries, three egg size groups were recognized, and empty follicles were observed in ovaries collected from April to July. Based on these results, individual konoshiro were considered to spawn several times, two or more, in one spawning season. A minimum mature size was 196.5 and 140.2 mm SL in females and males, respectively. Number of females was much larger than males, the sex ratio being 0.53 in an average. Sexual size dimorphism, in which females are larger than males, was recognized.

Key words: Tokyo Bay, *Konosirus punctatus*, Maturation, Gonadosomatic index, Sexual dimorphism

Introduction

Konoshiro gizzard shad, *Konosirus punctatus*, is distributed in coasts and rivers of northwestern Pacific from Japanese coasts and Sea of Japan southward from about 38° N to Yellow Sea and East China Sea south to Taiwan and Hong Kong (Whitehead, 1985). Although individual catches of this species have not been recorded by FAO (Whitehead, 1985), this species occupies an important position in the fisheries of Japanese coasts (Ochiai and Tanaka, 1986). Therefore, the reproductive biology of the species has been studied well by such Japanese researchers in various places as Takita (1978a, 1978 b: seasonal changes of gonadosomatic index (GSI) and egg diameter and histological observations of gonad maturation in Ariake Sound, Kyushu), Yoshida *et al.* (1978: sex ratio and spawning season and ground in Osaka Bay), Kuwatani *et al.* (1956: seasonal change of GSI in Kumihama Bay and Yosanaikai, Kyoto) and Matsushita and Nose (1974: seasonal changes of GSI and egg diameter in Lake Hamana, central Honshu). Also in Tokyo Bay, the species has been a target fish for fisheries; however, the information of reproductive biology is limited to the study of Kamiya (1916), in which the occurrence and development of eggs were revealed in Tateyama Bay, the southeastern part of Tokyo Bay. The purpose of the present study was to elucidate the reproductive biology of the konoshiro gizzard shad, including the histological study of gonad maturation, seasonal changes of GSI and egg diameter, and sexual dimorphism, in Tokyo Bay.

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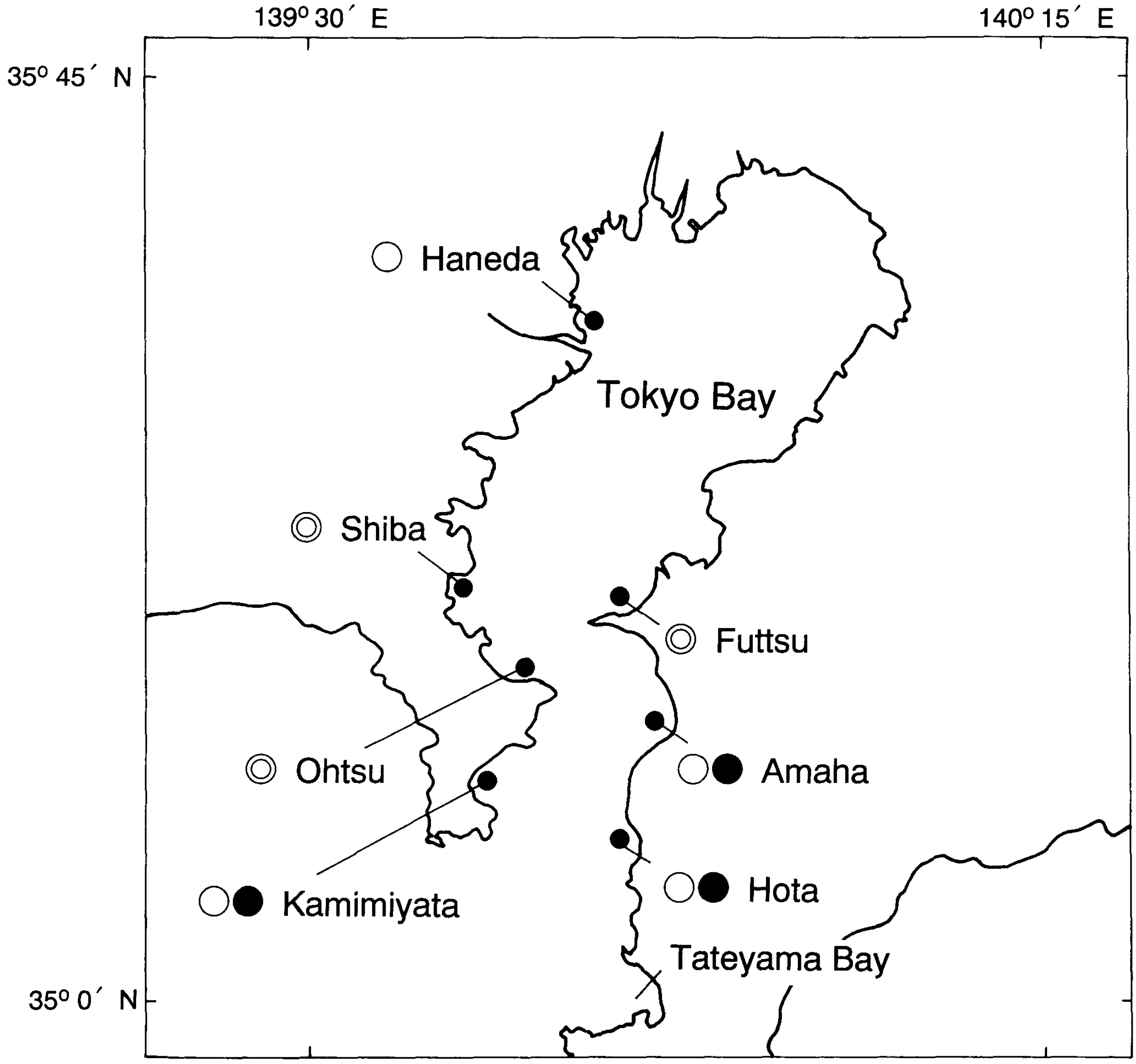

Fig. 1. Sampling sites for the konoshiro gizzard shad, *Konosirus punctatus*, in Tokyo Bay. ○: gill net; ●: set net; ◎: purse seine.

Materials and Methods

Fish were collected from seven sites in Tokyo Bay by various commercial fishing gear such as set net, purse seine and gill net (Fig. 1) in the period from June 1996 to May 1998. The number of fish used in this study was 5,252 specimens (3,440 females, 106.9–265.4 mm in standard length [SL]; 1,812 males, 107.0–242.5 mm SL). For all the specimens, standard length nearest to 0.1 mm and wet body and gonad weights (BW and GW, respectively) nearest to 0.1 g were measured, their sexes being determined by dissection of gonad. Gonadosomatic index (GSI) was calculated as $GSI = 10^2 (GW/BW)$ and the sex ratio as (No. of males)/(No. of females). The egg diameter frequency was examined on 28 specimens taken from several classes of GSI, the diameter of about 500 eggs sampled from a well-mixed solution of whole the left ovary being measured for each specimen. For histological observations of ovary, around ten specimens were taken monthly from Haneda samples in the period

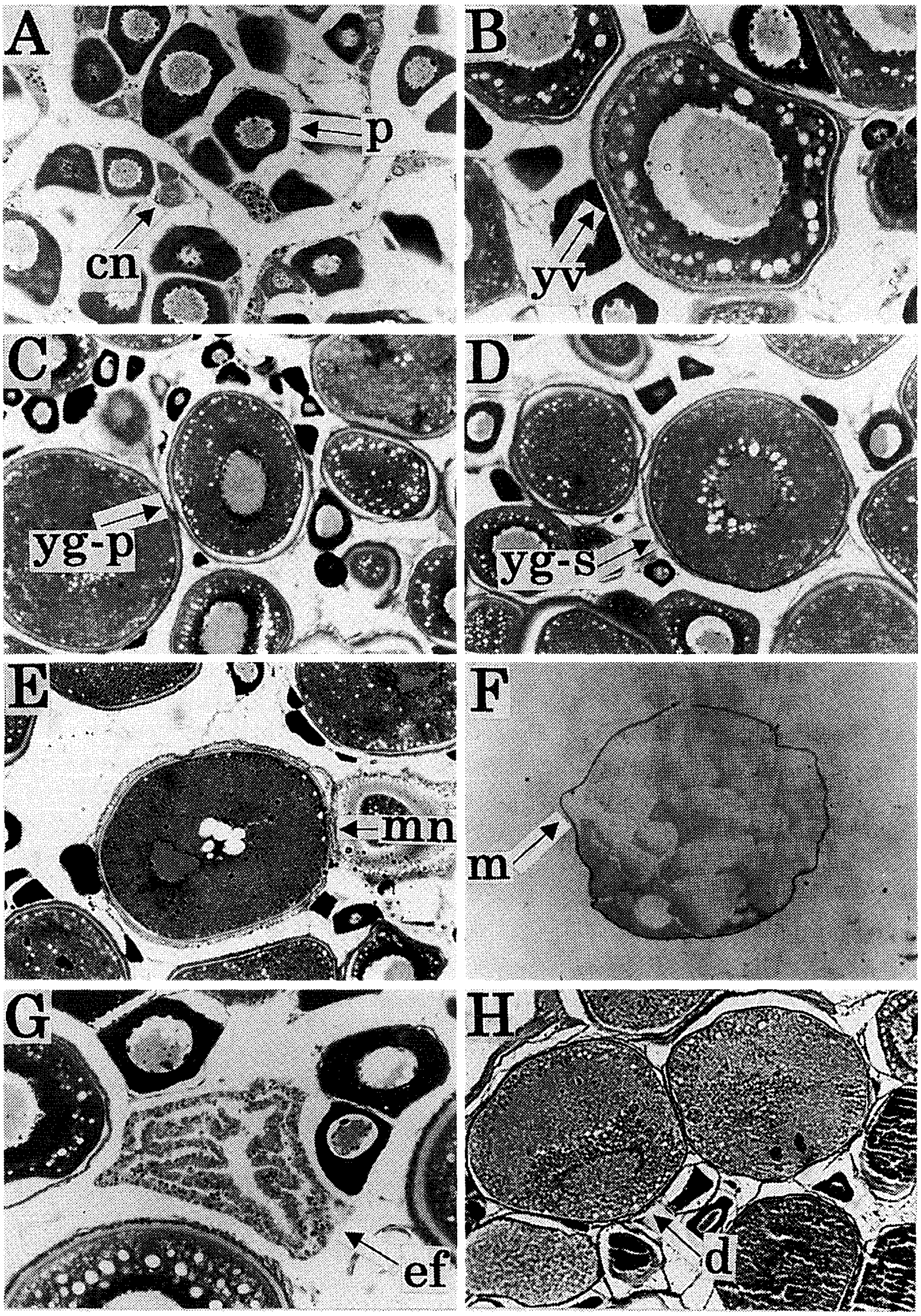

Fig. 2. Histological sections of ovary of the konoshiro gizzard shad, *Konosirus punctatus*, showing the maturation stages. A: chromatin-nucleolus (cn) and peri-nucleolus (p) stages; B: yolk vesicle stage (yv); C: primary yolk globule stage (yg-p); D: secondary yolk globule stage (yg-s); E: migratory nucleus stage (mn); F: maturation stage (m); G: empty follicle (ef); H: decaying ova (d).

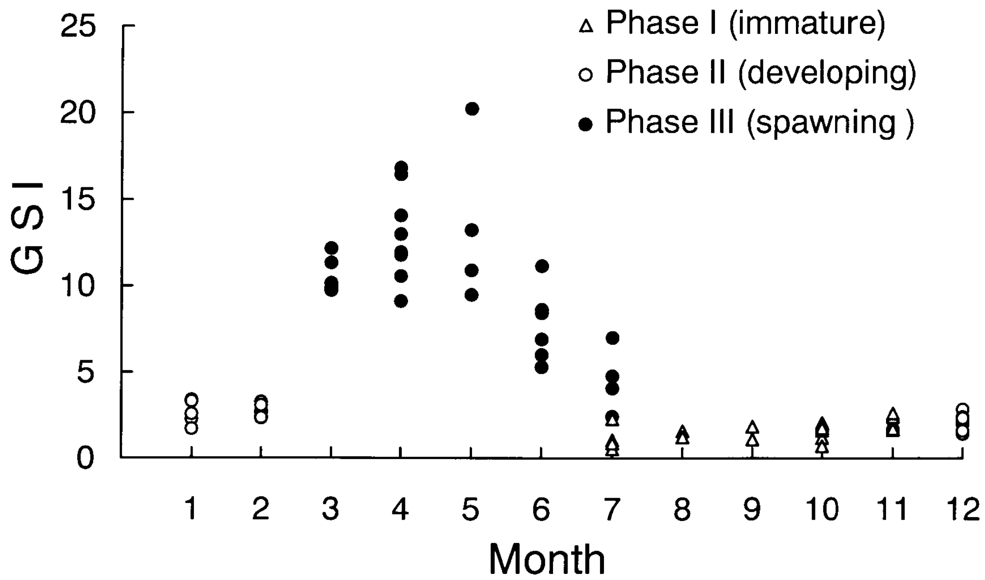

Fig. 3. Monthly changes of the maturation phases of ovaries and gonadosomatic index (GSI) in the konoshiro gizzard shad, *Konosirus punctatus*.

from June 1996 to July 1997, except for February 1997 when specimens from Ohtsu being used, a total number of fish used being 73. The ovaries, fixed with Bouin's solution and transferred to 70% ethyl alcohol for preservation, were embedded in paraffin wax, sectioned at 6 micrometers, and stained with hematoxylin and eosin. The classification of ovary maturation followed Yamamoto (1954), Yamamoto *et al.* (1965) and Matsuura (1972).

Results

Based on the histological observations of ovaries, the following six maturation stages of ova were recognized: chromatin-nucleolus (Fig. 2A), peri-nucleolus (Fig. 2A), yolk vesicle (Fig. 2B), yolk globule (Fig. 2C, D), migratory nucleus (Fig. 2E), and maturation (Fig. 2F). The chromatin-nucleolus and peri-nucleolus stages occurred all the year round, although these two stages did not appear separately. The yolk vesicle stage was observed from December to July, the yolk globule, migratory nucleus and maturation stages from March to July. Empty follicles (Fig. 2G) were observed from April to July. In addition to these stages, the "decaying" ova (Fig. 2H) were observed from December to July.

Based on these ova stages, ovaries were classified into the following three developmental phases: Phase I (immature), only chromatin-nucleolus and peri-nucleolus stages of ova appeared; Phase II (developing), yolk vesicle stage of ova was added to the preceding two stages; Phase III (spawning), in addition to the preceding three stages, yolk globule, migratory nucleus, maturation and/or empty follicles were observed.

Phase I ovaries were observed from July to November, their GSI being limited to the range between 0.5 and 2.6 (mean 1.7, $n=26$) (Fig. 3). Phase II occurred from December to February, and their GSI ranging from 1.4 to 3.4 (mean 2.5, $n=19$) (Fig. 3). The GSI of Phase III ovaries, which occurred from March to July (Fig. 3), varied from 2.4 to 20.2 (mean 10.2, $n=28$), the values increasing from March (10.5, 6) to May (13.5, 4) through April (13.0, 8) and decreasing from May to July (4.6, 4) through June (7.7, 6). Because most of the Phase III ovaries sampled in June and July possessed many decaying ova, these ovaries were determined to be "spent". Out of six June specimens,

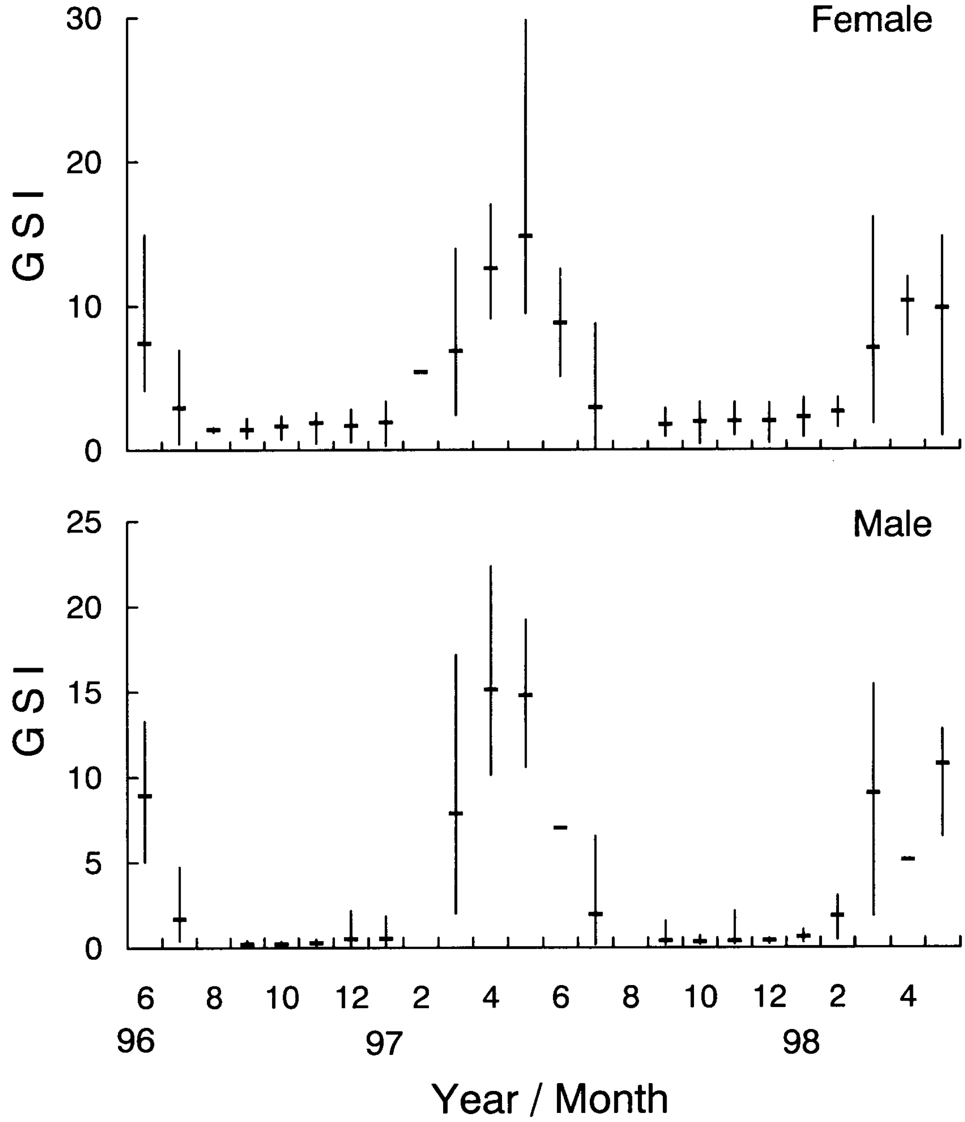

Fig. 4. Monthly changes of gonadosomatic index (GSI) in the konoshiro gizzard shad, *Konosirus punctatus*, shown by sex.

five were determined to be spent, whereas all the July specimens, four in number, were considered to be spent.

Seasonal changes of GSI of Haneda samples are shown in Figure 4. In the periods from August or September to February in 1996/1997 and 1997/1998, respectively, GSI values were low in both females and males (Fig. 4), ranging from 0.3 to 5.4 (mean 1.8, $n=480$) in 1996/1997, 0.4 to 3.6 (2.0, 810) in 1997/1998 in females, and from 0.1 to 2.2 (0.4, 267) in 1996/1997, 0.2 to 3.1 (0.4, 232) in 1997/1998 in males. On the other hand, higher values of GSI were observed from March to May in both females and males (Fig. 4), the mean GSI values of females in 1997 and 1998 being 6.9 and 7.0 in March, 12.6 and 10.3 in April and 14.8 and 9.8 in May, and those of males 7.9 and 9.0 in March, 15.1 and 5.1 in April and 14.8 and 10.7 in May. Mean GSI values decreased from June to July 1996 and 1997 in both sexes, the values in females being from 7.4 and 8.8 in June to 2.9 and 2.9 in July, and those in males from 8.9 and 7.5 in June to 1.7 and 2.0 in July.

Figure 5 shows the frequency distribution of egg diameter in some specimens. Based on the egg

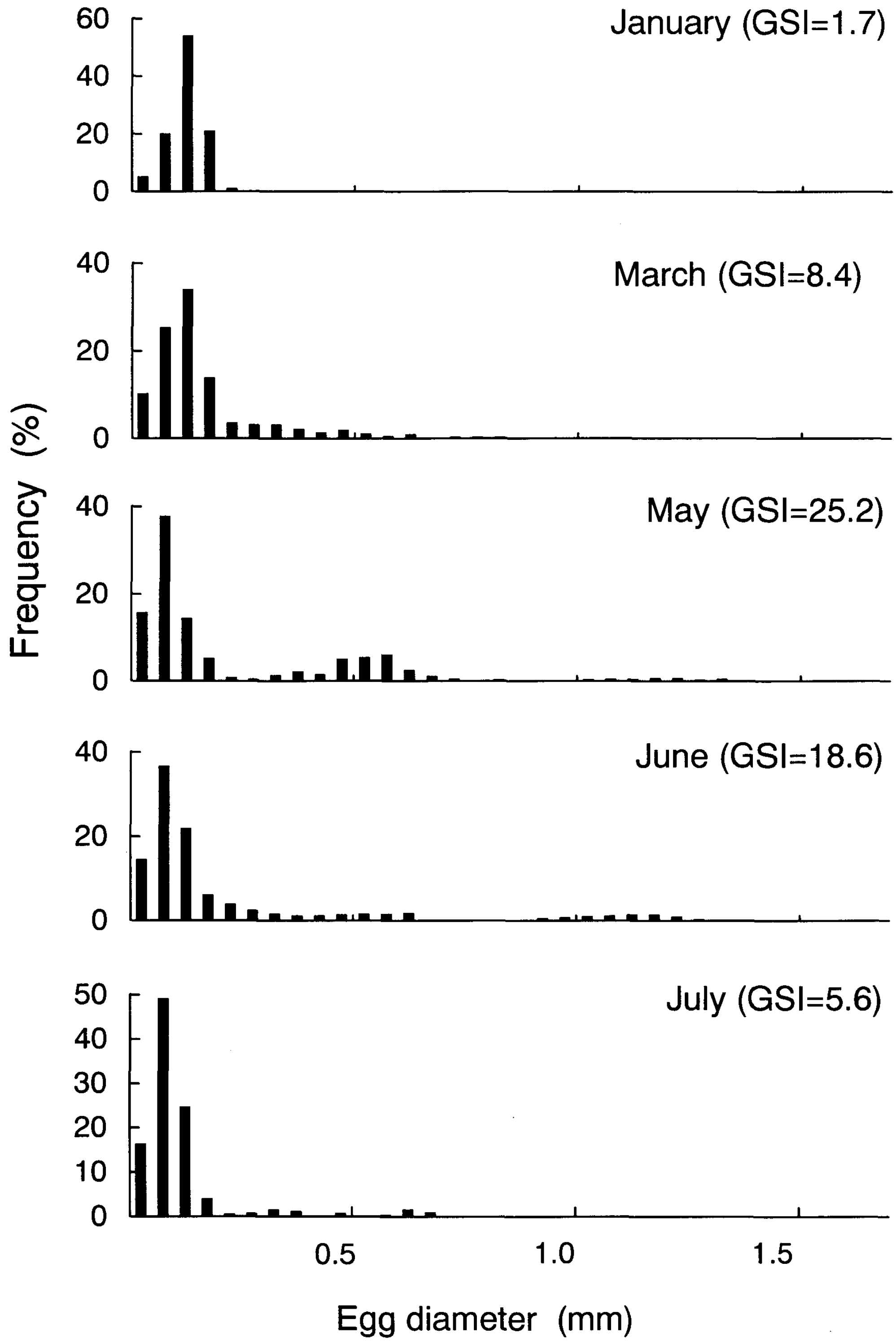

Fig. 5. Frequencies of egg diameter in the konoshiro gizzard shad, *Konosirus punctatus*, shown by several gonadosomatic index (GSI) values.

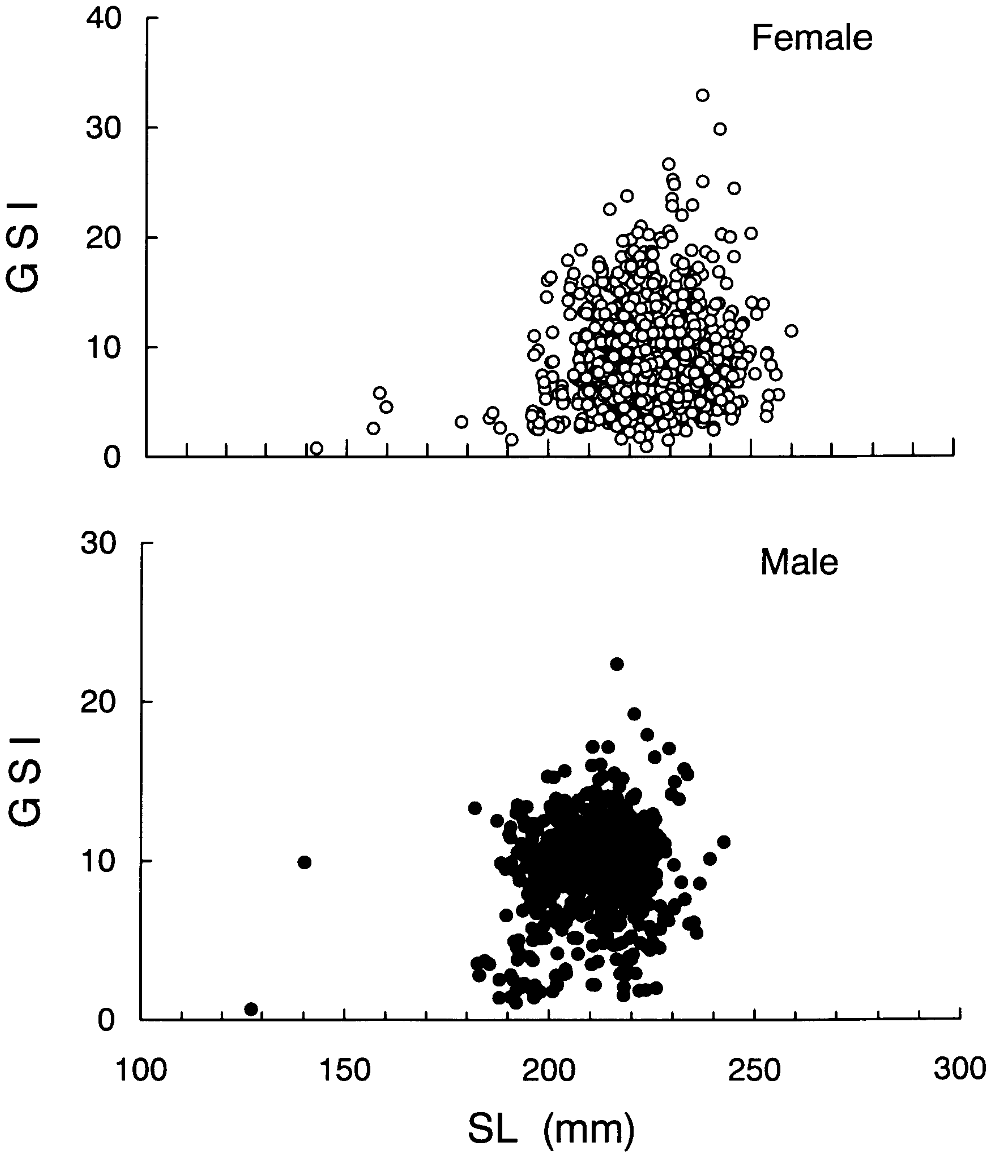

Fig. 6. Relationships between the gonadosomatic index (GSI) and standard length (SL) in the konoshiro gizzard shad, *Konosirus punctatus*, shown by sex.

diameter of May and June specimens, three egg size groups were recognized: the first group being smaller than about 0.3 mm, the second group ranging from about 0.3 to 0.7 mm and the last group being larger than about 1 mm (Fig. 5). Although the January specimens possessed only the first group eggs, intermediate eggs between the first and second groups appeared in the March specimens (Fig. 5). In the July specimens, in addition to the first group eggs, a small number of the second group eggs was found (Fig. 5).

Relationships between GSI and SL in specimens collected from March to June are shown in Figure 6 by sex. In females, specimens of 191.0 mm SL and smaller possessed low GSI values ranging from 0.8 to 5.8. The smallest specimens having higher GSI values, 9.3 and 11.0, were two specimens of 196.5 mm SL. GSI values of specimens of 196.5 mm SL and larger varied from 0.9 to 32.9 (Fig. 6). Although no specimens were examined in males between 140.2 and 181.9 mm SL, GSI value of the 140.2 mm SL specimen was a relatively high, 9.9. The smallest specimen of 127.4 mm SL had the GSI

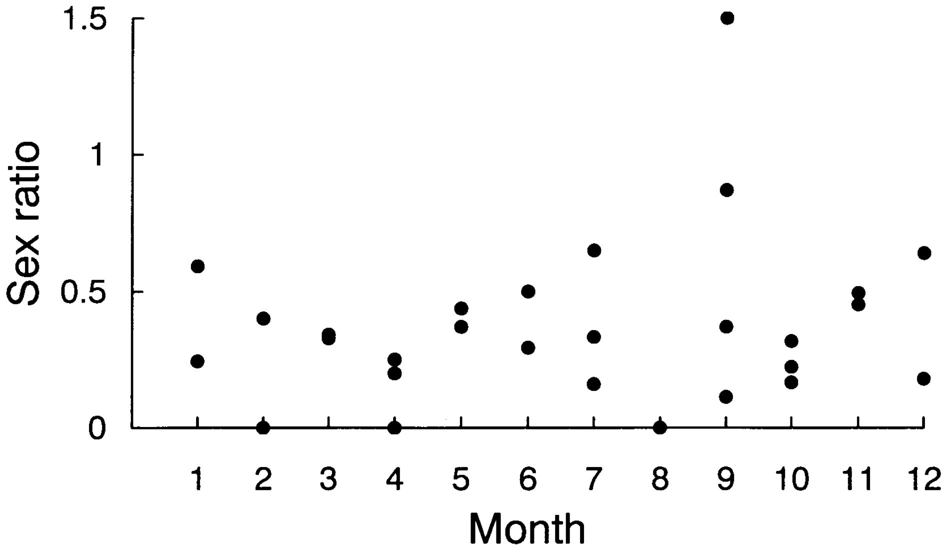

Fig. 7. Seasonal changes of sex ratio in the konoshiro gizzard shad, *Konosirus punctatus*, in Haneda, shown by month.

value of 0.7 (Fig. 6). Values of GSI varied from 1.1 to 22.4 in specimens of 181.9 mm SL and larger (Fig. 6).

Seasonal changes of sex ratio of Haneda samples are shown in Figure 7. Out of 28 samples, three samples were composed solely of females (sex ratio 0), and one sample contained nine males and six females (sex ratio 1.5) (Fig. 7). In the remaining 24 samples, the number of females was much more than males, the sex ratio being lower than 1, ranging from 0.11 to 0.87. No seasonal trends were observed in the sex ratio (Fig. 7). In 35 other samples collected from several sampling sites, in which more than 30 fish were collected at one time, the sex ratio was lower than 1 in 25 samples, higher than 1 in 8 samples and 1 in 2 samples. No particular trends were observed in the sex ratio by sampling sites. The sex ratio in all the samples used in this study was 0.53.

Figure 8 shows differences of body size between females and males collected from Haneda in July and December 1996 and March 1997. Out of 23 samples, females were larger than males in 20 samples, body sizes being significantly different at 1% level in 17 samples (Fig. 8C: mean 227.9 mm SL, range 203.9–256.8 mm, $n = 290$, in females; 215.9, 185.5–235.9, 95, in males) and at 5% level in three samples (Fig. 8B: 212.3, 171.2–245.7, 20, in females; 199.8, 177.8–218.1, 13, in males), whereas no significant differences were detected in the remaining three samples (Fig. 8A: 219.6, 201.0–239.0, 25, in females; 214.1, 195.0–238.0, 16, in males). A significant difference between females and males larger than 170 mm SL of all the specimens examined in this study was also detected at 1% level (Fig. 9) (females: mean 225.5, range 171.2–265.4, $n = 2{,}654$; males: 209.8, 171.9–242.5, 1,635).

Discussion

Based on the developmental phase of ovary and GSI presented in this study, the konoshiro gizzard shad, *Konosirus punctatus*, in Tokyo Bay spawned from March to June; this result agrees with Kamiya (1916), in which the spawning season of konoshiro was reported to be from mid-March to mid-June, based on the occurrence of eggs, in Tateyama Bay, the southeastern part of Tokyo Bay. In Japanese waters, no regional differences of the spawning season of konoshiro fish are observed as follows: April and May in Ariake Sound, Kyushu (Takita, 1978a); from late-April to early-August in Osaka Bay (Yoshida *et al.*, 1978); from mid-April to mid-June in Kumihama Bay, Kyoto (Kuwatani *et al.*, 1956);

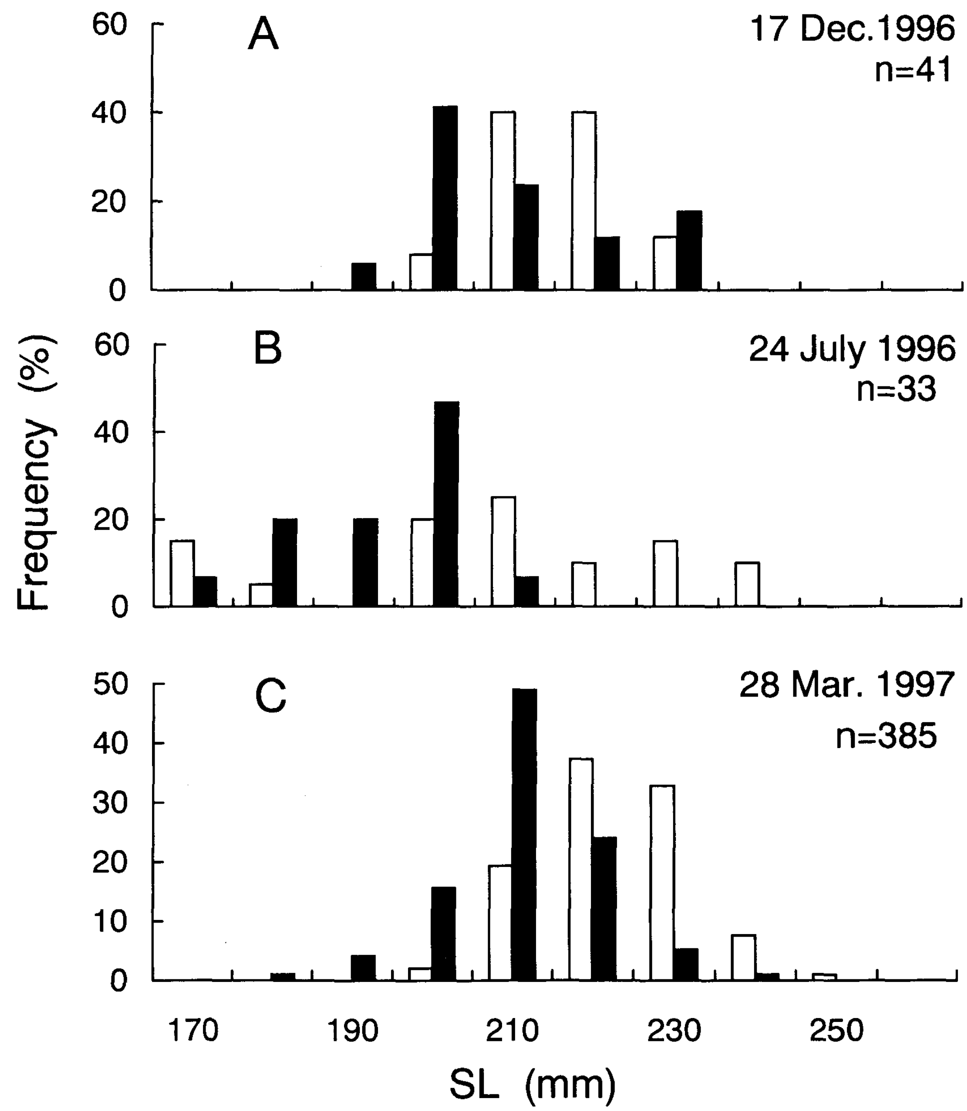

Fig. 8. Frequency distribution of standard length (SL) of males (black bars) and females (open bars) in the konoshiro gizzard shad, *Konosirus punctatus*, shown by three sampling dates.

from mid-April to mid-June in Hamana Lake, central Honshu (Matsushita and Nose, 1974).

The konoshiro ovaries, especially those during the spawning season from March to June, included various stages of ova, which coincided with three egg groups regarding their diameter, and empty follicles were observed in ovaries from April to July. These results indicate that individual konoshiro fish would spawn serially, at least two to three times, in one spawning season. Takita (1978b) also reported that individual konoshiro would spawn twice or more in a spawning season in Ariake Sound, although Kuwatani *et al.* (1956) mentioned that individual konoshiro spawn one time only in one spawning season in Kumihama Bay and Yosanaikai, Kyoto.

A minimum mature size of konoshiro was 196.5 and 140.2 mm SL in female and male, respectively, in this study, although a few specimens smaller than about 190 and 180 mm SL in females and males, respectively, were examined, because of a bias of sampling gear. Matsushita and Nose (1974) mentioned that individuals less than 150 mm in length did not mature during the spawning season. Yoshida *et al.* (1978) reported a 129 mm in fork length specimen as a minimum mature size,

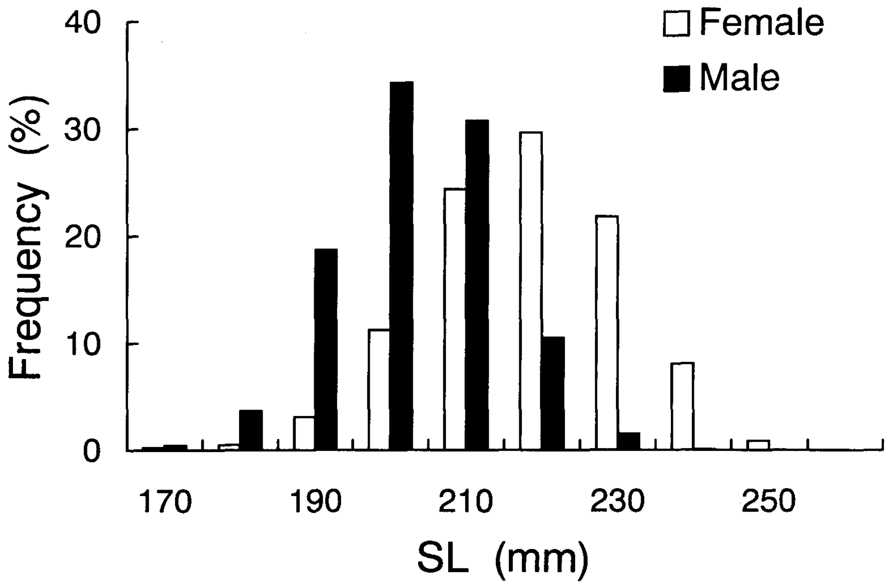

Fig. 9. Frequency distribution of standard length (SL) of males (black bars) and females (open bars) in the konoshiro gizzard shad, *Konosirus punctatus*.

the specimen being collected in June and having a 5.79 GSI value.

The sex ratio of konoshiro is generally lower than 1, indicating that females are much larger in number than males: 0.53 in this study; 0.70 in Tateyama Bay (Kamiya, 1916); 0.65 in Osaka Bay (Yoshida *et al.*, 1978); 0.24 in Yosanaikai, Kyoto (Kuwatani *et al.*, 1956).

Sexual size dimorphism of konoshiro was observed in this study, females being larger than males. Takita (1978a) reported that every age-group spawned and age one began and ended spawning slightly later than older ones. Matsushita and Nose (1974) indicated a possibility that age one konoshiro would take part in spawning, although no fully matured ovaries were observed in age one fish. No reports are available on the difference of growth between females and males, although some researchers investigated the growth of konoshiro (Takita, 1978a; Yoshida *et al.*, 1978). Therefore, further study is needed to elucidate the meanings of size differences between females and males on konoshiro fish.

Acknowledgments

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東京湾産コノシロの産卵生態

孔　立波・河野　博・藤田　清

東京湾産コノシロについて，組織学的観察に基づく卵巣の成熟段階を設定し，さらに成熟段階や生殖腺体指数の季節的変化，性比，大きさの性的二型を調べた。産卵可能と考えられる成熟段階の卵巣をもつ個体は 3 月から 6 月に出現し，また 6 月と 7 月には産卵後と思われる卵巣が見られた。さらに 3 月から 6 月にかけては生殖腺体指数も高く，雌で平均が 6.9～14.8，雄では 5.1～15.1 であった。これらのことから，東京湾におけるコノシロの産卵期は 3 月から 6 月であると判断された。産卵期に採集された卵巣にはさまざまな成熟段階の卵が見られ，さらにこれらの卵巣から得られた卵には，卵径から，少なくとも 3 卵群が認められた。したがって，1 個体のコノシロが 1 産卵期に 2～3 回の産卵を行っていると考えられた。最小成熟体長は雌で 196.5 mm，雄で 140.2 mm であった。性比は平均 0.53 で，雌の方が雄よりも多かった。また，雌の方が雄よりも体長が大きいという性的二型が認められた。

キーワード：東京湾，コノシロ，成熟，生殖腺体指数，性的二型