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Spawning of the Silver Sea Bream, *Sparus sarba*, in Captivity

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Abstract Spawning of the silver sea bream, *Sparus sarba*, in captivity was studied at ambient temperature and photoperiod during one breeding season. Broodstock were divided to two groups (A and B) of 6 and 7 individuals, respectively. They were caught in the sea and acclimatized to laboratory conditions for about seven months prior to spawning. Spawning lasted 65 days from April 8 to June 11 in group A, and 43 days from April 10 to May 22 in group B, within the temperature range between 13.5 and 21.3°C. Numbers of buoyant and sunken eggs, fertilization rate of buoyant eggs and percentage of abnormally developed eggs were estimated daily. There was no correlation between water temperature at spawning and viable hatch, and between spawning period and viable hatch, at the same incubation temperature in all cases. The total number of eggs released during the spawning period was estimated at 18.1 million in group A and 10.8 million in group B. Mean egg diameter tended to decrease during the spawning season along with increasing water temperature. Mean egg diameter ranged from 0.952 to 1.001 mm and from 0.962 to 1.015 mm in groups A and B, respectively.

The silver or gold-line sea bream, *Sparus sarba*, is a widely distributed sparid species in the seas surrounding Japan, Korea, Ryukyu, and Taiwan, and in the East China Sea, Indo-West Pacific and Red Sea, in depths less than 50 m (Okada, 1966; Fowler, 1972). In Qatari waters, Arabian Gulf, *S. sarba* spawns from April to June, sexual maturity being attained by about 20% of the fish during their second year (El-Agamy, 1989).

The species has good potential for both culture and restocking (Tsukashima and Kitajima, 1982; Kitajima and Tsukashima, 1983). Juveniles used for culturing are usually collected from local coastal waters, but their supply is insufficient for mass production (Leu, 1994). Egg-production capability remains one of the most important limiting factors for this purpose. In Taiwan, spawning of *S. sarba* in captivity has been induced both with and without hormonal or other treatment (Lin et al., 1987, 1988, 1989, 1990; Leu, 1994). However, spawning of the species under captive conditions in Japan has not yet been reported.

The purpose of this study was to clarify the spawning period, daily periodicity of egg production, and egg quality and size variation in captive silver sea bream, without hormonal treatment or manipulation of temperature and/or photoperiod.

Materials and Methods

Broodstock were caught by set-net off Nomozaki, Nagasaki Prefecture, western Kyushu, during May and June 1991, and transported to the Fishery Research Laboratory, Kyushu University, in September of the same year, where they were acclimatized to laboratory conditions for about seven months prior to spawning. The broodstock consisted of two groups of fish, group A (6 individuals) and group B (7 individuals).

Because silver sea bream have no apparent external dimorphism, identification of sex was made soon after the end of the spawning season. The fish were anaesthetized with tricaine methanesulfonate (MS-222) and the remaining gonadal contents removed by aspiration into a polyethylene cannula inserted into the genital pore, and examined. Group A fish comprised 4 females and 2 males, and group B 3 females, 2 males, and 2 unresolved. Manipulation and stripping of broodstock before and during the spawning season were avoided owing to the possibility of undue stress and injuries resulting to the fish.

The fish were measured and weighed on December 12, 1991, and July 2, 1992. Total lengths (TL) were measured to the nearest 1 mm and body weights (BW) to the nearest 10 g. The fish were kept in outdoor concrete tanks (diameter 2.0 m; water depth 1.5 m) under natural photoperiods. Direct sunlight was intercepted by a roof 3.0 m above the surface of the tanks. Sand-filtered sea water, without thermal control, was supplied continuously to the tanks at the rate of about 50 *l*/min. Vigorous aeration was provided through diffuser stones.

The spawners were hand-fed to satiation once daily with a semi-purified diet (composition shown in Table 1). Water temperature was recorded daily to the nearest 0.2°C. Salinity was recorded weekly to the nearest 0.1‰.

For estimation of the number of eggs released daily, a collecting net was fixed under the outlet pipe of each spawning tank. The nets were fixed every evening (16:00) and removed the following morning (09:00) for as long as fish continued to spawn. To avoid loosing eggs from the first spawning, the procedure was established earlier than the expected onset of spawning. The collected eggs were washed and transfered to measuring cylinders, filled with the same sea water as that supplying the spawning tanks. Egg numbers were estimated volumetrically using the mean number per aliquot (two aliquots of 0.5 m*l* each). The eggs were classed as viable if they were buoyant, fertilized and appeared to be developing normally.

A sample of 100 buoyant eggs of average appearance was taken daily to estimate the fertilization percentage and the percentage of those developing abnormally (eggs with two or more oil droplets and/or with apparently abnormal embryonic development).

The hatching percentage was determined six times for group A and four times for group B during the spawning period. A sample of 100 fertilized eggs was transferred to a 1000 m*l* Pyrex beaker and incubated at 22.0±0.2°C, thus providing optimum conditions for viable hatching (Lin et al., 1988; Mihelakakis and Kitajima, 1994). To minimise evaporation, incubators were covered with a loose-fitting plastic lid. No aeration was provided inside the incubators. The numbers of successfully hatched larvae and larvae with normal appearance and behaviour were recorded as total hatch and viable hatch, respectively.

Table 1. Percentage composition of the experimental broodstock diet

Ingredients	Composition (%)
Cuttlfish meal	34.8
White fish meal	30.0
α-Starch	10.0
Active gluten	5.0
Mineral mixture	5.0
Tuna oil[1]	5.0
Vitamin mixture	3.0
C.M.C.[2]	2.0
Astaxanthine	5.0
Vitamin E	0.2

[1] Extracted from orbit; [2] carboxymethylcellulose.

Fifty fertilized eggs were sampled each 5–7 days and their diameters measured to the nearest 0.001 mm using a profile projector. Mean egg diameter and standard deviation were computed for each sample. Preserved eggs were not used for measurements owing to their possible distortion (Fukuhara, 1979; Hislop and Bell, 1987).

Results

Size of broodstock

The fish were measured on December 6, 1991, mean TL and BW in group A being 30.4±1.4 (SD) cm and 1228±172 g, respectively. After the spawning period, these had increased to 32.9±3.2 cm and 1723±163 g, respectively (measured on July 2, 1992), average gains of 2.5 cm (8.1% TL) and 496 g (40.4% BW). Over the same period, mean TL and BW of group B fish increased from 31.4±1.2 cm and 1337±152 g to 36.0±4.8 cm and 1875±117 g, respectively, average gains of 4.6 cm (14.7% TL) and 538 g (40.2% BW).

Duration and periodicity of spawning

Silver sea bream began to spawn successfully in captivity in spring 1992. No spawning was observed until the temperature had risen to 14.5°C. Spawning in group A lasted 65 days from April 8 to June 11. Throughout this period the water temperature fluctuated between 13.5 and 21.3°C (Fig. 1). Salinity varied between 30.5 and 32.0‰. Spawning in group B lasted 43 days from April 10 to May 22. In all, group A and B fish released 59 and 35 batches of eggs during the spawning period, respectively. It was unclear whether or not all of the females released eggs simultaneously on the spawning days. On such days the first batch of eggs was released between 18:00 and 23:00 hours. Daily spawning occurred for 51 days (from April 20 to June 8) in group A,

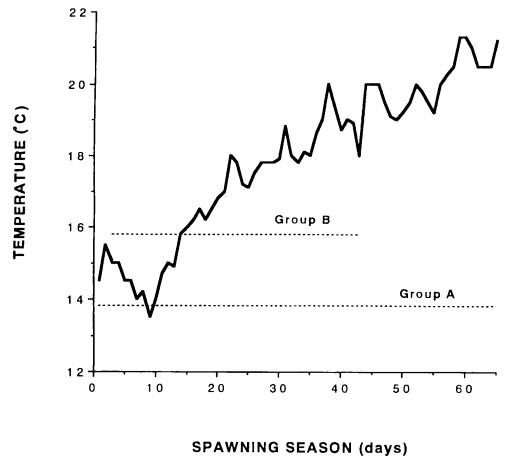

Fig. 1. Variations in water temperature during the spawning season and spawning period (dotted lines) of each group.

and 29 days (from April 20 to May 19) in group B.

Egg production

Daily egg production and numbers of sinking and buoyant eggs are shown in Figures 2 and 3. The total numbers of eggs released during the spawning period were estimated at 18.1 million in group A (mean number per female approx. 4.5 million) and 10.8 million in group B. Because of the method used for egg collection (surface overflow), the number of sunken eggs may have been underestimated. The number of eggs spawned in one day varied greatly from 11,500 (May 26, June 10) to 948,700 (April 30) in group A, and from 18,900 (April 20) to 711,000 (April 30) in group B. Peak egg production in group A occurred at temperatures ranging from 17 to 20°C.

Egg quality

In group A, the total number of buoyant eggs collected during the spawning season was estimated at 10.1 million, representing 55.4% of all eggs spawned. The daily percentage of buoyant eggs varied greatly, from 5% (April 27) to 83.5% (April 30). In group B, the number of buoyant eggs was estimated at 3.7 million, representing 34.1% of the total spawned. The daily percentage of buoyant eggs varied from 8.3% (May 22) to 93.9% (April 17). Buoyant eggs were not always fertilized, the proportion of fertilized eggs being quite low during the first 18 days in group A and the first 28 days in group B (Fig. 4). The percentages of buoyant, normally developing eggs (as opposed to abnormally developing) were usually high, fluctuating between 95 and 100% on most spawning days (Fig. 5).

The hatching percentage of buoyant fertilized eggs was recorded as both total and viable hatch (Table

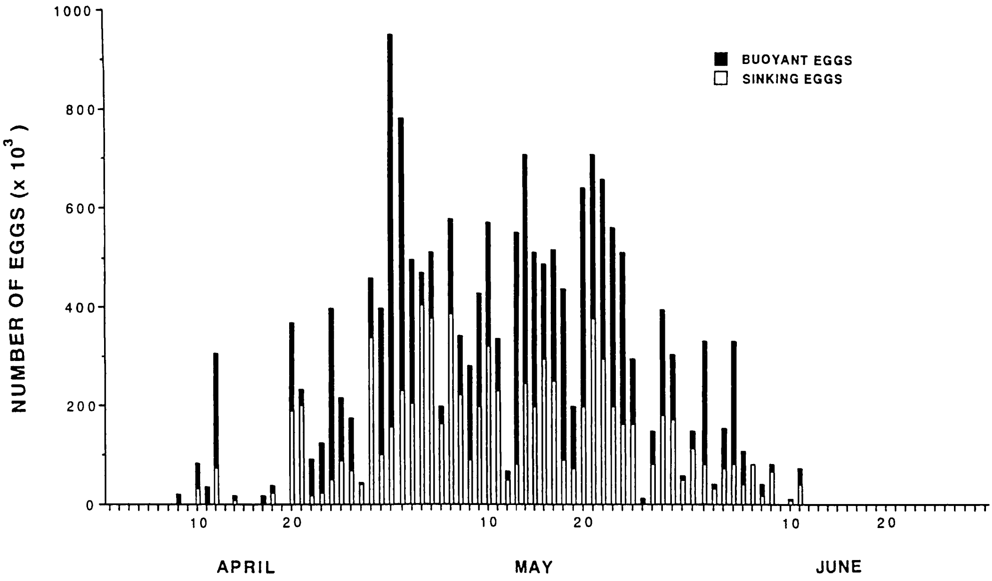

Fig. 2. Spawning frequency and numbers of eggs produced by group A.

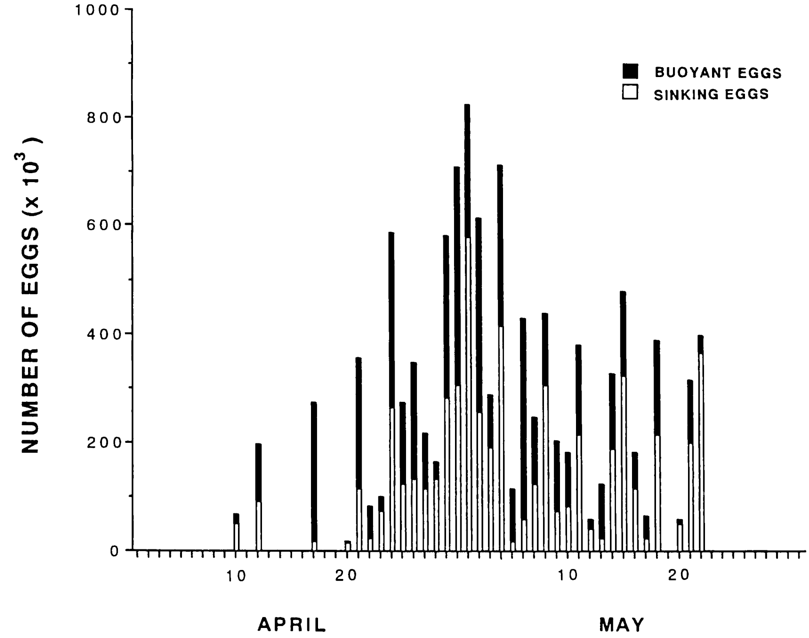

Fig. 3. Spawning frequency and numbers of eggs produced by group B.

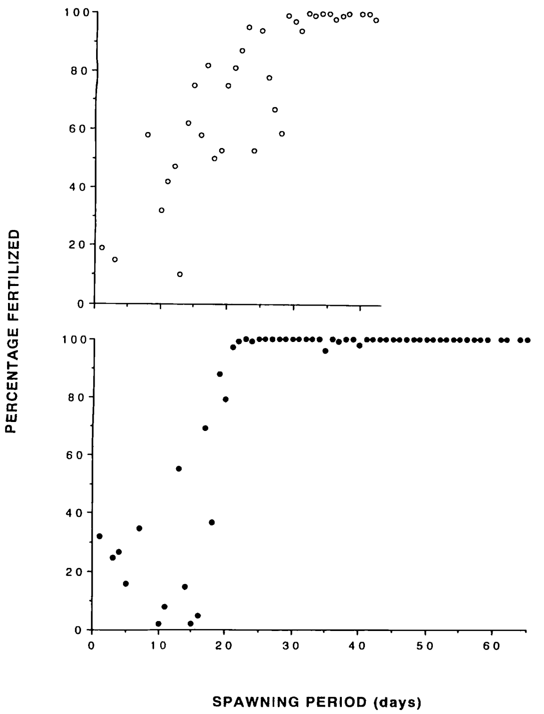

Fig. 4. Fraction of fertilized buoyant eggs of groups A (●) and B (○) during the spawning period.

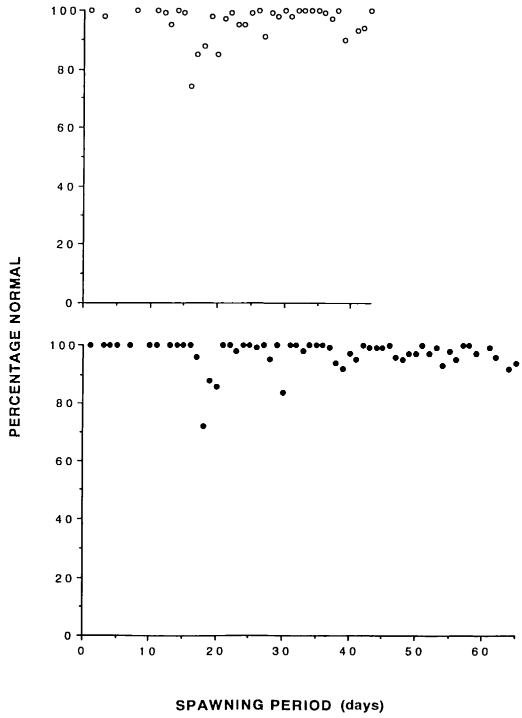

Fig. 5. Fraction of normally-developed, buoyant eggs of groups A (●) and B (○) during the spawning period.

2). Total hatch varied between 62 and 92%, and 47 and 92% in groups A and B, respectively and viable hatch between 55 and 90%, and 31 and 78%, respectively. The most common larval abnormalities were body curvature and tail flexure. There was no relationship between percentage viable hatch and water temperature at spawning ($r=0.106$, $n=6$, $p>0.05$ for group A; $r=0.114$, $n=4$, $p>0.05$ for group B), nor between percentage viable hatch and spawning day ($r=0.224$, $n=6$, $p>0.05$ for group A; $r=0.521$, $n=4$, $p>0.05$ for group B).

Changes of the size in eggs

The average diameter of viable eggs in the various batches declined during the spawning season (Fig. 6), there being a high negative correlation between mean egg diameter and water temperature in the spawning tank (Fig. 6; $r=0.900$, $n=9$, $p<0.001$ for group A; $r=0.881$, $n=7$, $p<0.001$ for group B). Mean egg diameter ranged from 0.952 to 1.001 mm (overall range throughout spawning season 0.900–1.040 mm) and from 0.962 to 1.015 mm (overall range 0.900–1.060 mm) in groups A and B, respectively.

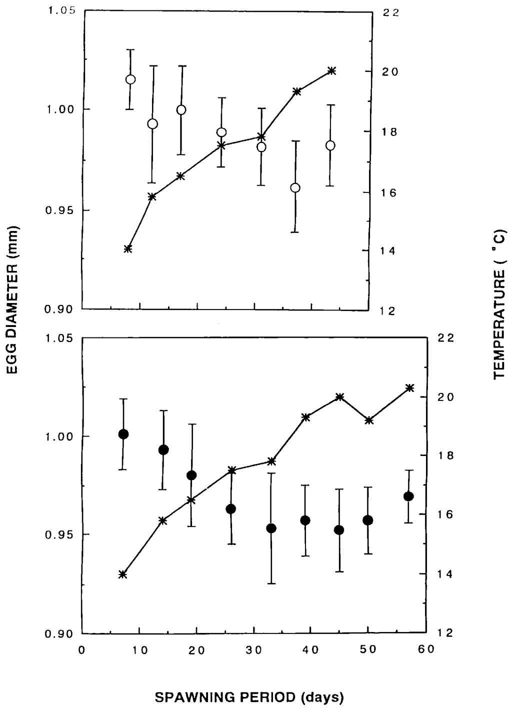

Fig. 6. Relationship between mean egg diameter of groups A (●) and B (○) and water temperature (✳) at spawning. Spawning period was taken as time from the commencement of spawning. Vertical bars indicate standard deviations.

Discussion

In Taiwan, the spawning period of a 4-year-old female *Sparus sarba* maintained in captivity without hormonal treatment or manipulation of temperature and/or photoperiod, lasted 120 days from November 27 to March 26, during which it spawned on 94 days (Lin et al., 1990). The water temperature during this period fluctuated between 14.0 and 22.4°C. A group of 3-year-old *S. sarba* (4 females and 12 males) was reported as spawning for 96 days from December 24 to March 29, in water temperatures ranging from 13.8 to 23.5°C (Leu, 1994). The above water temperature ranges overlapped those of the present study. However, the spawning season in Taiwan was prolonged and quite different from that in the present study (from April 8 to June 11). Since spawning occurred within similar temperature ranges in both Taiwan and Japan, the differences in the spawning seasons may reflect the differing temperature patterns in these geographical areas. However, Kinoshita (1986) reported that during semi-monthly collections from May 1981 to June 1984 in the surf zones of Tosa Bay, Shikoku Island, Japan, larvae and juveniles of *S. sarba* appeared from late March to late May, and from late November to late January, being most abundant in April and May, indicating

Table 2. Fraction of hatched eggs in groups A and B, in relation to water temperature and spawning date

Date	Spawning day	Spawning temp. (°C)	Incubating temp. (°C)	Hatching percentage	
				Total	Viable
Group A					
1 May	24	17.2	22.0	75	66
8 May	31	18.8	22.0	62	56
14 May	37	19.0	22.0	66	55
22 May	45	20.0	22.0	81	68
28 May	51	19.5	22.0	92	90
8 June	62	20.0	22.0	85	57
Group B					
1 May	22	17.2	22.0	47	31
8 May	29	18.8	22.0	57	46
14 May	35	18.0	22.0	92	78
22 May	43	20.0	22.0	66	49

that in nature the species may have two spawning seasons. Nevertheless, captive *S. sarba* are serial spawners with a single spawning season per year.

In the present study the exact length of individual spawning periods was not apparent, there being no evidence of onset and termination of overall spawning by each fish.

The mean number of eggs spawned per female in group A was estimated at 4.5 million, considerably fewer than the 7.5 million eggs collected from one female *S. sarba* (pre-spawning BW 0.9 kg) reported by Lin et al. (1990). The latter female spawned over a period of 94 days compared to the 59 and 35 spawning days of the present study. On the other hand, two groups of *S. sarba* (average pre-spawning BW 0.5 kg) produced mean total numbers of 1.6 and 2.0 million eggs per female (Leu and Wu, 1990), while other females (0.7–1.2 kg BW) were estimated to produce an average of 2.6 million eggs each (Leu, 1994). Such differences in fecundity among spawning groups may be attributable to differences in spawning duration and, consequently in the numbers of egg batches, although tank size, stocking density, sex ratio, broodstock size and age, and nutritional quality of diet are important factors that may also affect fecundity.

The fractions of fertilized eggs in the buoyant eggs collected during the first days of spawning were inconsistent. A similar case has been reported for wild broodstock of pink dentex, *Dentex gibbosus*, spawned in captivity: from a total of 22 natural spawnings obtained over 32 days, egg fertility was very low for the first 12 days of spawning, but thereafter improved (Fernandez-Palacios et al., 1994). It is not known if this is a natural phenomenon or a result of some behavioural/courtship problem affecting males in a tank environment.

Mean egg diameter decreased during the spawning season along with increasing water temperature. This was consistent with the report of Lin et al. (1990), that the mean egg diameter of a single silver sea bream decreased from 1.034 to 1.004 mm over the spawning period, concurrent with increasing water temperature. The decline in egg size in a red sea bream, *Pagrus major*, during the spawning season (Matsuura et al., 1988), as well as in a number of non-sparid marine fishes of communal populations spawned in captivity (Hislop, 1975; Houghton et al., 1985; Kimura and Aritaki, 1985; Bromley et al., 1986; Kashiwagi et al., 1987; Devauchelle et al., 1987; Kimura and Kiriyama, 1992), corresponded to water temperature increases. Clarke (1989) suggested the seasonal decline in egg size with increasing temperatures as being either ecophenotypic or genetic responses to the changing prey or predator spectra confronting larvae.

The results of the present study indicated that spawning of silver sea bream in captivity without hormonal treatment or manipulation of temperature and/or photoperiod can be used to regularly provide eggs for mass production of juveniles. However further investigations are needed for the improvement of egg quality, primarily by minimizing the proportion of non-viabl eggs collected.

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ヘダイの水槽内産卵

Apostolos Mihelakakis・北島　力

漁獲後，3 m^3 水槽で7カ月飼育した2群のヘダイ（A: ♀4個体，♂2個体；B: ♀3個体，♂2個体，性別不明2個体；実験終了時の体重は1.7–1.9 kg）の産卵経過を観察した．A群は4月8日から6月11日までの65日間，B群は4月10日から5月22日までの43日間，ほぼ毎日産卵を継続した．産卵は18時から23時の間に行われた．産卵期の水温は13.5–21.3°Cであった．A群の総産卵数は約1810万，B群は1080万，平均浮上卵率はA群55.4%，B群34.1%であったが，両群とも産卵中・後期に良質卵を産んだ．卵径はA群で0.952–1.001 mm，B群で0.962–1.015 mmであったが，水温の上昇に伴って減少する傾向がみられた．

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