

## Spawning Behavior and Social Organization of the Flounder *Crossorhombus kobensis* (Bothidae) at Miyake-jima, Japan

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Although Pleuronectiformes are important food fishes, knowledge of their reproductive biology is largely concerned with descriptions of sexual dimorphism and aspects of life history strategies; e.g., differential growth rates, fecundity, breeding seasonality, etc. (Matsuura, 1962; Breder and Rosen 1966; Ochiai, 1966; DeGroot, 1969; Roff, 1982, etc.). An extensive literature search failed to disclose any information about social organization within the entire order, and descriptions of spawning behavior were few and limited entirely to aquarium observations (Thresher's 1984 survey of reef fish reproduction did not include Pleuronectiformes).

Between August, 1983 and September, 1984, we studied the social organization and spawning behavior of the bothid flounder *Crossorhombus kobensis* (Jordan et Starks) at Miyake-jima, (34° 05'N, 139°30'E), one of the Izu Islands of southern Japan. Observations amounted to slightly more than 60 man-h. Data were taken selectively at various times of day between early morning and sunset in order to determine (a) sex ratio, (b) social organization, (c) spawning times, and (d) aspects of spawning behavior.

### Results

*Crossorhombus kobensis* is a small bothid flounder (80–90 mm in standard length) from southern Japan. Like most flounders, body coloration is cryptic and subject to a variety of changes to match background shades and hues; however, the basic pattern is relatively stable, including large and small darkened blotches and an orange to yellow "crucifix" marking on the ocular side. Subtle variations in this pattern made individual recognition of most of the study animals possible. Sexual identity was conspicuous; the interorbital width of males considerably exceeds that of females (see Amaoka, 1969).

**1. Study site and habitat.** *C. kobensis* is rare at Miyake-jima. Our study population was found on a strip of relatively coarse coral and volcanic sand running parallel to a heavily eroded cliff that forms the east side of a lava flow estimated to be at least 300 years old (Hamada, pers. comm.). The sand strip varies in width from roughly 30–50 m and extends seaward for about 250 m from depths of 15–26 m, varying in distance from the cliff from 5 m to more than 30 m. Rocks and boulders of varying sizes separate the cliff from the sand strip. This solid substratum is covered with dense algae (mainly *Gelidium*). To the east of the sand habitat the substratum consists of a vast plain of volcanic rubble, rocks and sand, with a lush covering of benthic algae (*Padina*, *Gelidium*, *Codium*, etc.).

The algal covering on both sides of the sand strip becomes greatly reduced from surge associated with the annual typhoon season in late summer and autumn (Aug.–Oct.).

*C. kobensis* occupied mainly the sand strip, where its mottled grey and white coloration blended well with the substratum. Foraging on benthic organisms was also observed in the cobble zone to the east of the sand strip.

Our study site included the shallow portion of the sand and associated cobble between depths of 15–23 m and covering an area of approximately 100 m × 30 m of substratum.

**2. Population density and sex ratio.** A total of 12 census dives in Aug.–Sept., 1983, and 14 between June–Sept., 1984, was carried out in the study site. Cryptic coloration and behavior of *C. kobensis* made exact counts difficult, but fairly accurate estimates were possible, based on consistency of counts, site attachment of females, and characteristic body markings. Four males and five females resided in the study site in 1983 (in addition to at least three sexually non-functional juveniles). Unusually low water temperatures in the spring and early summer of 1984 (Moyer, in press) seemed to have an adverse effect on the study population, and only three males and three females could be located in 1984. Totals for the two seasons equalled seven males and eight females, indicating a sex ratio of 1:1.14, not significantly biased from unity ( $\chi^2=0.07$ ,  $df=1$ ,  $p<0.5$ ).

**3. Social organization.** In summer, females could be found daily feeding solitarily within small, non-overlapping home ranges (about 15 m ×

15 m maximum), and can thus be described as site-attached. Three of four males in 1983 and all three males under observation in 1984 defended territories which encompassed the feeding ranges of 1-2 females. The single non-territorial male in 1983 frequently invaded territories of successful males, resulting in considerable aggressive behavior, including chases and lightening fast biting attacks by the territorial males. Seventeen such fights were observed, all of which resulted in the departure of the invading male. In two summers of observations, six male territories were recognized, two of which overlapped feeding ranges of two females. Single males were observed to spawn with both females in their territories on two occasions. Thus, observations of female site attachment, male territoriality, and polygynous spawnings indicate a harem social system of *C. kobensis* at Miyake-jima. The largest male territory under observation included two females and measured about 35 m × 30 m, while the smallest (occurring at the shallow end of the study site) measured 15 m × 30 m and included one female.

**4. Courtship and spawning.** Five spawnings were observed, all in mid-afternoon just prior to high tide (Fig. 1). Males were observed courting females by mid-morning of the days when spawnings were observed. Courtship consisted of circling of the female by the male, while flagging

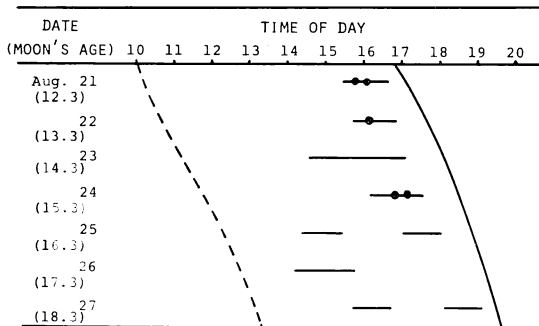


Fig. 1. Spawning times of *Crossorhombus kobensis* at Igaya Bay, Miyake-jima, August, 1983, showing the relationship between spawnings and tidal rhythm. The lateral bar shows the period of observations, and each closed circle represents one observed spawning. Dashed and unbroken lines represent the times of low and high tides. "Moon's age" = moon phase in days; e.g., 1 = new moon, 15 = full moon.

the elongated pectoral fin repeatedly. Periodically the male arched his body so as to rest only on the long dorsal and anal fins. Usually this posture was followed by a slight rise above the

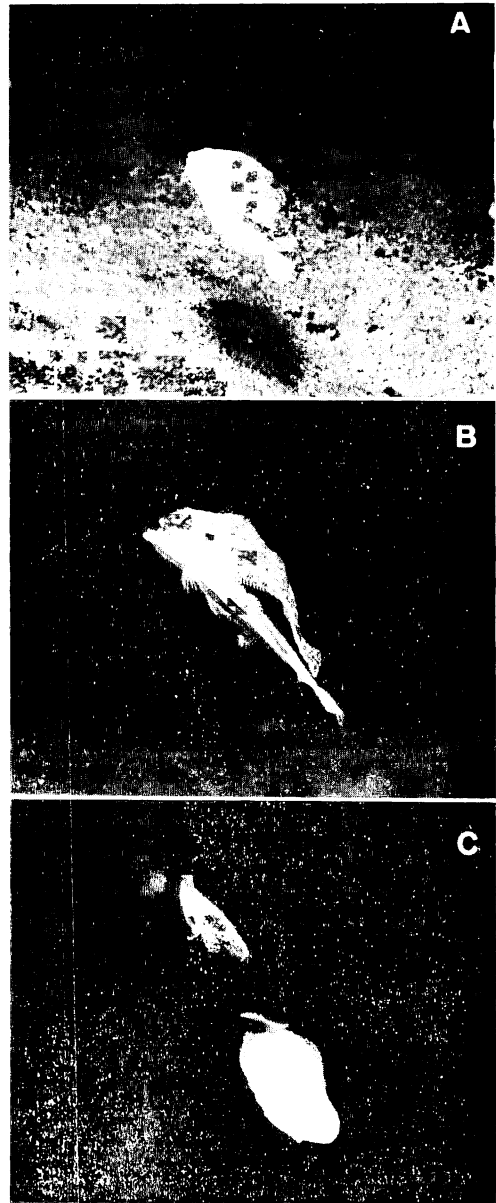


Fig. 2. Spawning of *Crossorhombus kobensis*. A, beginning of spawning rise (male above female); B, male (above) rests blind side of head on female during spawning rise; C, downward dash just after spawning. Note gamete cloud above descending fish. (From color transparencies by J. T. Moyer).

substratum and an attempt to settle on the ocular side of the female. Usually the female avoided such contact by fleeing 1–2 m from the male. After several minutes of courtship, the male moved away to locate another female, and repeated the courtship sequence.

Courtship was often interrupted by interference from invading males, both territorial neighbors and the single non-territorial “bachelor” male in the study site. During a single 1 h watch on 24 Aug. 1983, Male A fought with the bachelor male two times and with Male C once. Male A spawned with both of the females in his territory on this occasion.

Females announced readiness to spawn by rapidly raising and lowering their heads. Immediately the male rushed to such a displaying female, hovered over her, dropped down on top of her (establishing body contact), and then circled around her, flagging with the pectoral fin as described. The female then began a slow upward rise, the male on top with the blind side of his head in contact with the female’s operculum (Fig. 2). The male’s body was flexed, placing his genital pore close to that of the female (Fig. 2B). Gametes were released after a slow upward rise of 1.3–1.5 m, and both fish rushed rapidly to the substratum (Fig. 2C).

After spawning, the female resumed feeding while the male searched for the other female in his territory. Males also resumed feeding after spawning with the female(s) in their territories.

The apparent relationship between spawning times and high tide (Fig. 1) and the lack of courtship behavior during repeated observations at different times of day throughout the study suggest a lunar/tidal periodicity in spawnings of *C. kobensis*, however this possibility must remain speculative until more data are available.

### Discussion

Data on reproduction of Pleuronectiformes are surprisingly scarce. Some deep-water temperate flounders appear to engage in seasonal spawning migrations. The witch flounder (*Glyptocephalus cynoglossus*) of the Atlantic Ocean aggregates in waters 500–700 m in depth to spawn in the spring off Newfoundland, moving to shallow waters in the Gulf of St. Lawrence during the summer months (Bowering, 1976). Similar migrations

are not uncommon in flatfishes from temperate waters (e.g., Otterlind, 1967; DeGroot, 1969; Roff, 1982). Such seasonal movements in cold water habitats are probably related to annual temperature fluctuations in a dramatically seasonal environment (Moyle and Cech, Jr., 1982). Shallow water flounders in warm temperate and tropical environments probably do not migrate over such great distances, however short range spawning migrations such as those recorded by Johannes (1978) for some scarids, acanthurids, serranids, etc., are possible. At Miyake-jima, *Crossorhombus kobensis* occurs in the same habitat annually during the summer months (winter observations were not attempted). Males are territorial and a harem mating system is maintained.

Actual accounts of spawning behavior within the Pleuronectiformes are limited to a few often contradictory reports from aquarium observations (e.g., Butler, 1897; Künne, 1930; Forster, 1953; Riley, cited in Beverton, 1964; Flüchter, 1965). For example, both Butler (1897) and Flüchter (1965) reported considerable swimming of the common sole *Solea solea* by both males and females over the substratum prior to spawning; however, Flüchter described spawning with the fish’s head out of the aquarium water, while Butler reported them to move to the substratum to spawn. Riley (cited in Beverton, 1964) and Forster (1953) described considerable swimming above the substratum by *Pleuronectus plastessa* prior to spawning. It is unlikely that such conspicuous, exposed swimming behavior associated with courtship is common in nature, and such observations probably reflect abnormal behavior associated with confinement in the aquarium; e.g., females cannot reject male courtship in the manner described above when confined in an aquarium.

Künne (1930) reported considerable body contact between the sexes, with the male attempting to lie over the body of the female, similar to our observations of courtship in *C. kobensis*. All of the above aquarium observations reported spawnings to occur at night. Mito *et al.* (1969) also reported spawning at night by a right-eyed flounder, *Kareius bicoloratus*, in fish ponds, but from observations of embryonic development, they estimated that this species spawns in the Seto Inland Sea between 14:00–19:00 h. Ferraro (1980), estimating time required for embryonic development of planktonic eggs, reported spawn-

ing of the soleid *Trinectes maculatus* to occur between 12:00–18:00 h, and that of the bothid *Scophthalmus aquosus* between 12:00–24:00 h. Clearly, the literature available on social organization and reproduction within the Pleuronectiformes is scanty and inadequate.

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#### 三宅島における コウベダルマガレイの産卵行動と社会構造

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伊豆諸島の三宅島伊ヶ谷湾において、コウベダルマガレイの産卵行動と雌雄の構成を潜水調査した。本種は全長 10 cm 程度の小型魚で、水深 15～25 m の砂質底に生

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息しており、観察区域における成魚の性比はほぼ 1 対 1 であった。産卵期には、雌はそれぞれ約 200 m<sup>2</sup> の行動圏に定住し、雄は 1~2 尾の雌の行動圏を含む 400~1000 m<sup>2</sup> ほどの繁殖なわばりを持っていた。一方、なわばりを持たないあぶれ雄も認められ、これは他の雄のなわばりからしばしば追われていた。なわばりを持つ雄はそのなわばり内の雌に求愛し、雄が雌の上に重なる態勢で海

底より 1.5 m ほどゆっくりと上昇してペアで放卵、放精を行った。産卵は 1983 年 8 月に 5 例観察されたが、いずれも午後の満潮約 1 時間前であった。

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