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Protandrous Sex Reversal in *Cyclothone atraria* (Family Gonostomatidae)

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Kawaguchi and Marumo (1967) found protandrous sex reversal in *Gonostoma gracile* and suggested that this phenomenon might be observed in other gonostomatid fishes, especially in the genera *Gonostoma* and *Cyclothone*. Since then, *C. microdon* (see Badcock and Merrett, 1976) and *G. elongatum* (see Fisher, 1983) have been reported to be protandrous. Among thirteen species of the genus *Cyclothone*, examinations of gonads revealed no evidence of protandry in three species of *Cyclothone* except *C. microdon* from the eastern North Atlantic (Badcock and Merrett, 1976) and three species from the Hawaiian waters (Maynard, 1982).

During the course of a study on the life history of three dominant species of *Cyclothone* (*C. alba*, *C. pseudopallida* and *C. atraria*) in Sagami Bay, we found many hermaphrodites in *C. atraria* Gilbert, and this paper reports evidence of protandry in *C. atraria* from Sagami Bay.

Materials and methods

Samples were obtained during a series of eleven cruises of the R/V Tansei Maru of the Ocean Research Institute, University of Tokyo, between December 1982 and November 1983 from a fixed station in Sagami Bay (35°00′N, 139°20′E, ca. 1,500 m depth) in Japanese coastal waters. Collections were made using an ORI net with a mouth area of 2.0 m^2 and a mesh size of 0.69 mm (Omori, 1965). Two to four oblique tows were made during each cruise. Maximum depths reached by the nets varied from 600 to 1,350 m with a mean depth of 1,102 m.

The samples were preserved in 5–10% buffered formalin seawater. *C. atraria* was sorted out and all individuals were dissected. A smear of a pair of whole gonads were examined under a compound microscope for sex determination.

A total of 62 pairs of gonads from a wide range of fish sizes (11–56 mm SL) were sectioned at 5 μm and stained with hematoxylin-eosin for histological examination.

Fig. 1. Sagittal section of hermaphroditic gonad in *C. atraria*. Ripe testis (1) with early oocytes (2); hermaphrodite, 24 mm SL. Scale indicates 20 μm.

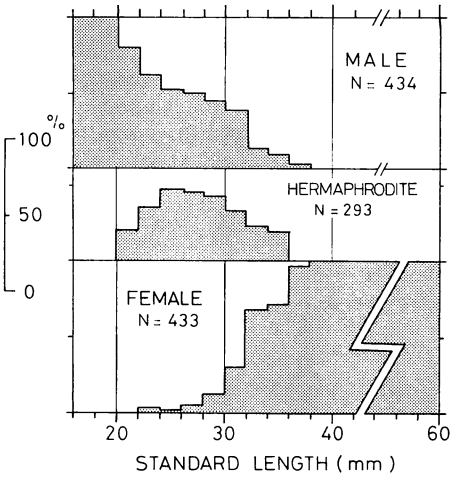

Fig. 2. Size specific ratios of male, hermaphrodite and female *C. atraria*.

Results

Many hermaphroditic gonads were found in individuals which appeared to be macrosmatic males (males with enlarged olfactory apparatus) externally. A band of small spherical ova (ca. 10–30 μm diameter) could be observed along the long axis of the gonads under a compound microscope. Histological observations showed that these gonads were hermaphrodite (Fig. 1). There were no individuals in which both testicular and ovarian tissues were mature. We could discern hermaphroditic gonads through examination of the smear of whole gonads.

Size specific ratios of males, females and

hermaphrodites are shown in Fig. 2. Individuals smaller than 20 mm SL are all males including individuals of indeterminate sex while those larger than 38 mm SL are all females. The ratio of males declines in proportion to increase in size, while that of females increases in proportion to increase in size. Hermaphroditic individuals occur in the intermediate size range from 20 to 36 mm SL and their ratio declines at both ends of size spectrum with a broad peak at 24–30 mm SL.

Discussion

Two criteria have been used to define protandry: sexual dimorphism in size and the presence of an intermediate hermaphroditic stage (Fisher, 1983). In *C. atraria*, males are smaller than females and hermaphrodites occur in the intermediate size ranges. Thus, the criteria are satisfied and *C. atraria* is protandrous in Sagami Bay. However, there remains the possibility that some females, especially smaller than 30 mm SL where more than 95% individuals are males and hermaphrodites, are primary females as suggested by Fisher (1983) for *G. elongatum*. Further histological studies are needed to confirm this possibility.

Badcock and Merrett (1976) found evidence of protandry in *C. microdon*. Therefore *C. atraria* is the second record of protandry in *Cyclothone*. Both species share many morphological and ecological characteristics: compared with other *Cyclothone*, they are deeper dwellers, dark colored, have a large body size, and have higher fecundity (Mukhacheva, 1954; Badcock and Merrett, 1976). As a result, they were provisionally considered to form a species group together with *C. acclinidens* and *C. obscura* (see Mukhacheva, 1967). The most noteworthy characteristic common to *C. atraria* and *C. microdon* is their higher fecundity compared with other shallow living congeners (cf. Maynard, 1982). Marshall (1979) recognized that deeper dwellers tend to be more fecund than those that live nearer the surface in midwater fishes. If *C. atraria* and *C. microdon* need to be more fecund than other shallow living congeners, protandrous sex reversal might be a means of boosting fecundity (Bone and Marshall, 1982). If so, there is a possibility of protandry in *C. obscura*, since it is the deepest dweller among *Cyclothone*.

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ヨコエソ科オニハダカ *Cyclothone atraria* の雄性先熟性転換

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相模湾における中層性オニハダカ属魚類3種，ユキ

オニハダカ，ハイイロオニハダカ，およびオニハダカの生活史を調査中そのうちの1種オニハダカにおいて，外見は嗅板が肥大した雄に類似するが，両性生殖巣をもつ個体が多数観察された．このような雌雄同体は体長の小さな雄 (17–37 mm SL) および体長の大きな雌 (23–59 mm SL) の中間的な体長 (20–36 mm SL) に認められたことから，本種は相模湾において雄性先熟性転換を行なっていると考えられた．

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