

Protogynous Hermaphroditism in the Parrotfish, *Calotomus japonicus*

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Abstract Sexual patterns of the parrotfish, *Calotomus japonicus*, were studied using fifteen specimens collected in February and April, 1990, near Makurazaki, Kagoshima Prefecture. The males ranged from 265 to 345 mm SL, and were larger than the females on average. Most females ranged from 202 to 260 mm SL, but a female of 305 mm SL was obtained. Sexual dichromatism was conspicuous. Histological examination of the gonads and low values of gonado-somatic indices of both males and females indicated that they were not in spawning season. It was concluded that *C. japonicus* is a protogynous hermaphrodite, because all male specimens had secondary testes. It was pointed out that the present species has a weak size-sex relationship. Because the specimens examined did not include primary males, it is suggested that primary males are relatively rare, if they occur at all.

The parrotfish, *Calotomus japonicus*, subfamily Sparisomatinae, is distributed from the Hawaiian Islands to the western Pacific Ocean (Schultz, 1969). It is one of the prominent members of reef fish communities from central Honshu to Kyushu, Japan. The fish is moderately large, reaching 45 cm in standard length (Masuda et al., 1975), and is most often caught by gill-net as a commercially important reef fish in the coastal waters of southern Japan. No aspects of the reproductive biology of this species have been reported, since Seno et al. (1926) studied the development of the ova.

Most species of parrotfishes are considered to be protogynous hermaphrodites (Choat and Robertson, 1975; Robertson and Warner, 1978; Yogo et al., 1980). However, many species are yet to be examined. Because parrotfishes are not only a major component of shallow reef fish communities from tropical to temperate regions but are also commercially important, it is necessary to elucidate sexual patterns of species which have not been studied to date. In this report, we describe the scarid, *C. japonicus*, as a protogynous hermaphrodite. In addition, we describe the size-sex relationship and sexual dichromatism in *C. japonicus*.

Materials and methods

Fifteen specimens of the parrotfish, *Calotomus japonicus*, were caught by shallow water gill-net from

Makurazaki coast of Kagoshima Prefecture, in February (n=6) and April (n=9), 1990. Just after the specimens were purchased from a fish market, the abdomen of each individual was injected with 40% formalin solution and the whole body was preserved in 10% formalin-seawater for several days. Subsequently, standard length (SL) of all specimens was measured to the nearest 1 mm, and the gonads were weighed wet to the nearest 0.1 g. A gonado-somatic index ($GSI = GW(g) \times 100 / BW(g)$) was calculated for each individual to compare gonadal status and maturity. All gonads were then washed in an ethanol series and embedded in Paraplast. Transverse sections were cut nearly at the central part of the gonad, at a thickness of 5 to 9 μ m. The sections were mounted on slides and stained with Mayer's haematoxylin and eosin (Humason, 1979). Slides were examined under a compound microscope for confirmation of sex and testes structure, i.e. primary or secondary. Based upon histological data, the size-sex relationship of the specimens was studied.

Results

Size-sex relationship and sexual dichromatism.

The raw data, calculated GSI, gonadal status, and body color of fifteen specimens of *Calotomus japonicus* are presented in Table 1. Female specimens averaged 240.3 mm SL (SD=30.3, range 202–305, n=7), while males were moderately larger, averag-

ing 294.3 mm SL (SD=30.2, range 265–345, n=8). Although one female reached 305 mm SL, the others ranged from 202 to 260 mm SL. Occurrence of a female within the same size range as males suggested that *C. japonicus* has a weak size-sex relationship.

Body color of *C. japonicus* differed between the sexes. The body was reddish brown in females, but light bluish in males with red coloration between the mouth and eyes. Scales of females had numerous tiny light spots, but these were almost absent in males. Females also had several larger white spots on the upper area of the body, which were lacking in males. Males were colored red on the caudal fin with the margin of the peduncle being dark brown. Such coloration could hardly be seen in females.

Gonadal morphology and sex change. Gonadal shape of both sexes was similar, being composed of two lobes, triangular in cross-section. The two lobes were joined posteriorly.

Ovary: Spawning of *Calotomus japonicus* takes place in summer (Zaiser, pers. comm.). Female GSI of the present specimens was as low as 0.228 ± 0.078 (mean \pm SD, n=7), indicating that the fish were not in spawning season when they were caught. As is shown in Fig. 1A, ovarian tissue of *C. japonicus* also indicated that the fish were reproductively inactive. Oocytes present were in stages 1 and 2 (Moe, 1969), with no sign of vitellogenesis (Shapiro, 1981a). However, the large number of oocytes in early developmental stages suggested that these specimens would have become reproductively active in the ensuing spawning season.

Atretic eggs or brown bodies were not seen in these ovaries. The ovarian lamellae were pressed closely together, and the ovarian lumen was narrow.

Testis: Males also had small testes. GSI was 0.079 ± 0.032 (mean \pm SD, n=7), significantly smaller than that of females ($P < 0.01$, Mann-Whitney's U-Test, 2 sided). Histological examination of the testes indicated that the males were also reproductively inactive. Testicular tissue was small in volume and had a large central cavity (Fig. 1B). However, spermatozoa were already formed in the testicular lobule, suggesting that the testis would have become functional in the ensuing spawning season.

The male gonads of protogynous labrids (Reinboth, 1962) and scarids (Robertson and Warner, 1978) are characterized by the presence of a residual ovarian structure. Such testes are referred to as secondary testes and are characterized by the presence of a central lumen covered with a thin membrane. It has been shown that the secondary structure is a result of gonadal transformation from ovary to testis (Reinboth, 1962). All eight testes of *C. japonicus* examined in the present study exhibited a typical secondary structure (Fig. 1B and Table 1), strongly indicating that they were derived from ovaries. In these secondary testes, the vasa deferentia occurred within the former ovarian wall as a series of sinuses. It was also noted that brown bodies, which were not seen in the ovary, were usually found in the testicular tissue. No primary testes (testes of innate males, Reinboth, 1962) were

Table 1. Sexual pattern of *Calotomus japonicus*. SL=Standard length; BW=Body weight; GW=Gonad weight; GSI=Gonado-somatic index; IP=Initial phase; TP=Terminal phase; 2°M=Secondary male.

No.	SL (mm)	BW (g)	GW (g)	GSI	Sex	Body color
0208-1	204	325.9	0.95	0.291	F	IP
-2	237	522.9	1.33	0.254	F	IP
-3	202	315.7	0.83	0.263	F	IP
-4	235	478.3	1.28	0.268	F	IP
-5	275	794.0	1.10	0.139	2°M	TP
-6	285	1,015.6	0.82	0.080	2°M	TP
0424-1	305	1,020.0	2.65	0.260	F	IP
-2	265	660.0	0.60	0.090	2°M	TP
-3	265	580.0	0.24	0.041	2°M	TP
-4	290	680.0	0.69	0.101	2°M	TP
-5	345	1,610.0	0.96	0.060	2°M	TP
-6	295	950.0	0.40	0.042	2°M	TP
-7	335	1,520.0	1.16	0.076	2°M	TP
-8	260	460.0	0.29	0.063	F	IP
-9	240	480.0	0.93	0.194	F	IP

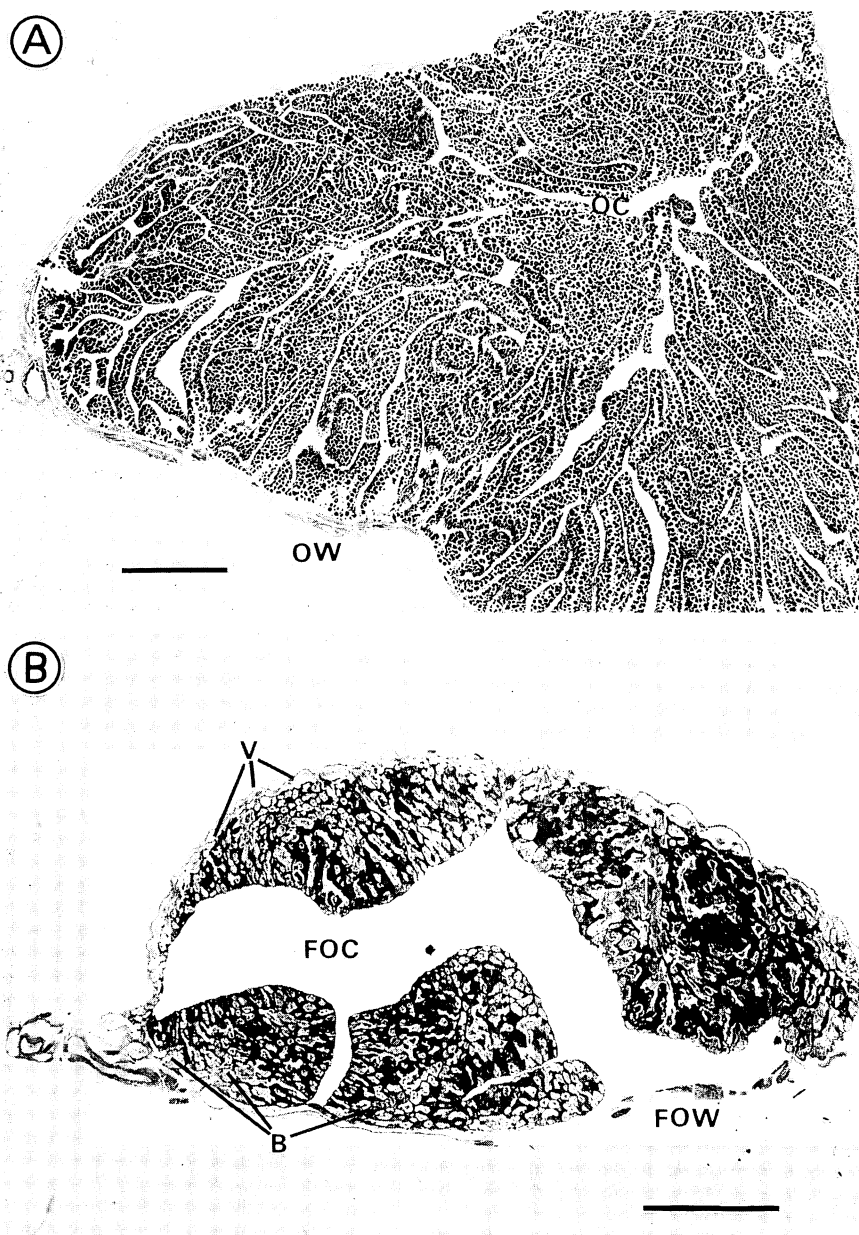


Fig. 1. A: Photomicrograph of a transverse section of ovary of *Calotomus japonicus*. 305 mm SL. Date 900424. OW=Ovarian wall; OC=Ovarian cavity. Scale bar represents 1 mm. B: Photomicrograph of transverse section of secondary testis of *Calotomus japonicus*. 285 mm SL. Date 900208. FOW=Former ovarian wall; FOC=Former ovarian cavity; B=Brown body; V=Vas deferens. Scale bar represents 1 mm.

seen in the present specimens.

Discussion

Although there have been several previous studies

on *Calotomus japonicus*, such as development of ova (Seno et al., 1926) or age and growth (Kawajiri, 1975), no studies have been conducted on its sexual pattern.

The present histological study of the gonads of *C.*

japonicus showed that all eight males had secondary testes, in which the tubular structure of the ovary remained. It was also shown that the males are generally larger than females. According to Sadovy and Shapiro (1987), secondary structure of the gonad is one of the reliable features for diagnosis of sex change in fishes, but bimodal size distribution between males and females cannot be a reliable feature, because such a distribution can also be found in non-hermaphroditic fishes and crabs due to several other reasons. In *C. japonicus*, it is clear that size difference between males and females is related to protogynous sex change, because all males had secondary testes. Occurrence of a female, however, within the same size range as males shows that size and sex of *C. japonicus* are but weakly related. It is highly probable that sex change in the present species takes place within a relatively wide range of body size. The same is known for several other hermaphroditic species (Warner, 1975; Moyer and Nakazono, 1978; Shapiro, 1981b).

The present specimens were collected only in January and April. Low GSI values of both males and females indicated that they were not in spawning season. However, the large number of oocytes in the ovary and occurrence of spermatozoa in the testes suggested that the fish will become functional in the ensuing spawning season. A difference of GSI between males and females is usual in labrid and scarid fishes (Robertson and Warner, 1978; Nakazono, 1979).

No transforming gonads were observed during the present study, due to the fact that the fish were collected only just before the summer spawning season (Zaiser, pers. comm.). Further investigation is needed to know when and at what body size sex changes in *C. japonicus* occur.

Sexual dimorphism and dichromatism are commonly found in many protogynous scarids (Robertson and Warner, 1978; Yogo et al., 1980), wherein the gaudy and conspicuous body color of larger males is referred to as the terminal phase, compared with that of females, called the initial phase. As Table 1 shows, all males were differently colored from females, suggesting that the body color of male *C. japonicus* is associated with sex change.

In some other scarid species, diandry has been reported (Choat and Robertson, 1975; Robertson and Warner, 1978; Yogo et al., 1980). Moyer observed spawning behavior of *C. japonicus* (Zaiser, pers. comm.) and suggested the occurrence of pri-

mary males in the species. Because all males of the specimens examined here had secondary testes, it is suggested that primary males are relatively rare, if they occur at all, in *C. japonicus*.

Acknowledgments

The authors are deeply indebted to Prof. T. Okuda of Kyushu University for his encouragement and advice through the study. We are also grateful to anonymous reviewer(s) for critical reading of the manuscript.

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(Received September 14, 1990; accepted December 12, 1990)

ブダイの雌性先熟雌雄同体性について

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鹿児島県枕崎産の標本 15 尾を用いて、ブダイ *Calotomus japonicus* の雌雄性を検討した。雌は雄より小形で、多くの個体 (n=6) の体長は 202-260 mm SL の範囲にあったが、305 mm SL の個体も 1 尾出現した。雄 (n=8) は雌より大形で、体長範囲は 263-345 mm SL であった。雌雄による体色の相違が顕著であった。生殖腺の組織学的検討により、今回の標本の雄はすべて二次精巣を持つことが明らかになった。すなわち、本種も他の多くのブダイ科魚類と同様に雌性先熟の雌雄同体であることが分かった。今回の標本では一次雄が出現しなかったため、一次雄が居てもその割合は低いと推定した。

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