Bull. Inst. Zool., Academia Sinica 13(2): 55-60 (1974)

SEX REVERSAL IN ONE SPARID FISH, *CHRYSOPHRYS MAJOR* (PERCIFORMES, SPARIDAE)

CHUNG-CHIA HUANG, CHU-FANG LO* AND KUN-HSIUNG CHANG

Institute of Zoology, Academia Sinica Taipei, Taiwan 115
Republic of China

Recived for publication, April 2, 1974

ABSTRACT

C. C. Huang, C. F. Lo and K. H. Chang (1974). *Sex reversal in one sparid fish, Chrysophrys major (Perciformes, sparidae).* Bull. Inst. Zool., Academia Sinica, 13(2): 55-60. Histological observations of the gonads were employed to study the growth and maturation of the red sea bream, *Chrysophrys major* Temmick & Schlegel. Thirteen monthly random samples consisting of 373 fish were examined. Three types of gonads were recognized. They were ovaries, testes, and ovotestes; the latter were invariably underdeveloped. The percentages of the female, male, and hermaphrodite were 53.9%, 19.3% and 26.8%, respectively. There were only females at the age below one year old. Hermaphroditic fish existed in ages from two to six. However, there were neither males below the age of two nor hermaphrodites at the age above seven. In view of the distributions of the female, hermaphroditic, and male fishes in different age groups, it seems that some of the female red sea breams undergo sex reversal, and the ovotestes are transitional gonads. The chronological appearance of the female, hermaphrodite, and then male would suggest that the amphosexuality in the red sea bream is a protogynous one. Seasonal changes were observed in fish at the age above five years old. Oocytes of the perinucleolar stage existed in all females. However, oocytes in the advanced secondary yolk stage appeared in females above five during the winter and disappeared in the following spring. It is suggested that the minimal age of the spawners is five, and the spawning season falls in early spring. Spermatogenesis in the testes is much vigorous in males above five during fall and winter.

The red sea bream, *Chrysophrys major* Temmick & Schlegel, is one of the most economically important species of fishes in Taiwan fisheries. A study on its population ecology has been undertaken since 1970 in the Laboratory of Fishery Biology of this Institute. A report on the age and growth of the red sea bream had been published[4]. The maturity and fecundity of this species are being studied in the same Laboratory.

Amphosexuality in fishes has recently been reviewed[2,8,11]. A complex hermaphroditism was found in the sparid fishes. There are protogynous, protandrous, synchronous, and rudimentary hermaphroditisms.

In the present histological study on the gonads of the red sea bream, it reveals that the red sea bream undergoes sex reversal and is a protogynous species. The minimal age of the

* Present address: Department of Biology, Fu-Ren catholic University, Hsin-Chuan, Taipei Hsien, Taiwan 242, R.O.C.

spawners is five years old, and the spawning season falls in early spring.

MATERIALS AND METHODS

The present investigation employed exclusively the red sea breams, *Chrysophrys major* Temmick & Schlegel. Thirteen monthly random samples consisting of 373 red sea breams were bought alive directly from the fishing boats based in Keelung, a northern sea port of Taiwan. The fishing ground was about 54 Km from the port. Morphometric measurements of the external characters of the individual fish were made (the data will be published separately). Their ages were determined by analyzing the annual rings of the scales. The paired gonads were dissected out and their fresh weights were recorded. The entire whitish, sexually undiscernible gonads, which were usually less than 3 mm in width, were fixed intact. The distal sections of the differentiated gonads were preserved for histological preparations. The ovary is of light orange color and of cylindrical shape; the testie is milk white color and elongated lobe.

The gonads were either fixed in Bouin or Carnoy fixatives and embedded in paraffin. Serial sections of 7 μ in thickness were prepared from the undifferentiated gonads. Consecutive thin sections were sampled separately from the distal, middle, and proximal sections of the gonads for histological studies. The preparations were stained with Delafield hematoxylin and eosin *Y*, and examined with the bright field compound microscope.

OBSERVATIONS AND DISCUSSIONS

I. The Histology of the Gonads.

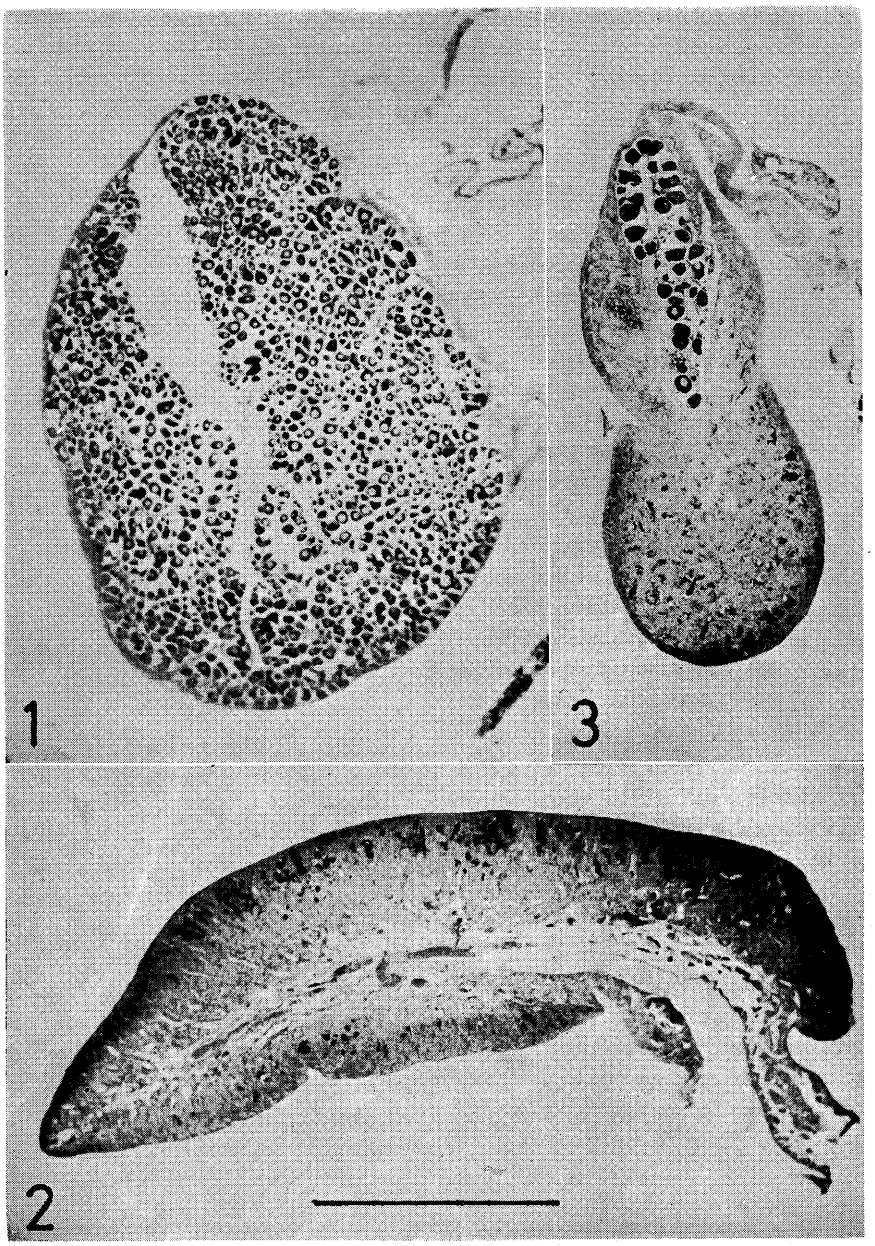
(a) The ovary (Fig. 1): The female red sea bream has a paired, elongated cystic ovaries. They run antero-posteriorly along the roof of the abdominal cavity. They are kept in place with the membranous mesovarium. The central ovocoel leads posteriorly into a short muscular oviduct which fuses with each other to form a common oviduct opening into the cloaca.

The visceral peritonium of the ovary is simple squamous epithelium. The thin underlying connective tissue constitutes the tunica albuginea which lies on a muscular layer. This is divided into an outer longitudinal and an inner circumferential musculatures. The inner most layer, the oviparous layer, varies in thickness and appearance depending on the development of the gonad. It is composed of the connective tissue and the germ cells. The ovocoel is enclosed by a simple squamous epithelium of the oviparous layer. In young fish (one year old and under) the oviparous layer has a number of papillae protruded into the ovocoel. In elder fishes (two years old and older), these protuberances develop into tall, thick lobes—the ovarian lamellae, which have a highly vasculated stroma and are rich in germ cells. The oogonia lie beneath the thin epithelium and the developing oocytes are in the stroma of the lamellae.

Seasonal changes are recognized in the ovary. Proliferation of the oogonia occurs throughout the year. However it is more active in 4-year old and younger fishes. Growth of the gonial cells into mature ova is divided into two periods. Development of the primary oocytes invariably comes to a pause at the perinucleolar stage. Further development of these oocytes resumes only in 5-year old and older fishes in fall and reaches the secondary yolk stage in samples gathered in December. Fully matured-oocytes had been observed in one specimen collected in March. Oocytes in 4-year old and younger fish never develop beyound the perinucleolar stage. During the first four years of the females, oocytes in the perinucleolar stage are gradually accumnlated in the ovary.

It is suggested that the minimal age of the spawners would be five years old. Advanced oocytes has been observed in some, but not all of the adult females during the spawning season. It seems that the potential spawners would not produce mature ova in every spawning season.

(b) The Testis (Fig. 2): The male red sea bream has a paired testes suspended from the roof of the abdominal cavity with a membranous mesoarchium along the entire length of the



Legends of Figures

Fig. 1. The cross section of the ovary of a 3 years old female red sea bream.

Fig. 2. The cross section of the testis of a 3 years old male red sea dream.

Fig. 3. The cross section of the ovotestis of a 4 years old hermaphroditic red sea bream. Scale indicates lmm.

individual testis. The vas deferens runs within the mesoarchium. The simple squamous epithelium, an extension of the coelomic peritonsion of the coelomic peritonium, encloses the testis. A thin dense connective tissue lies beneath the epithelium. The entire testis is permeated with tubular structures of various diameters and arrangements. The tubules are densely packed and with the connective tissue and the smooth muscle fibers in between.

The seminiferous tubules are blind tubules and located at the cortex of the testis. They are arranged in parallel and perpendicular to the longitudinal axis of the testis. The central lumen is limited by a simple squamous epithelium. The cuboidal primary spermatogonia form a complete layer outside the thin epithelium. Nurse cells are located irregularly between the germ cells. Based on histochemical studies of the rockfish testis, Moser (1967)[7] considered the pale staining cuboidal cells of the seminiferous tubule to be the tubule boundary cells rather than the germ cells. They were suggested to function as Leydig cells and sartoli cells. However, in the red sea bream the disappearance of the cuboidal cells in the seminiferous tubules occurred concurrently with the proliferation of the spermatozoon. It would suggest that the cuboidal cells should be primordial germ cells rather than the endocrine and/or nutritional cells.

Cysts of germ cells in various mitotic and meiotic stages locate along the seminiferous tubules. The cell division in the individual cyst is synchronous. Mature spermatozoa are released from the cysts into the lumen, collected into the efferent ductules which are convoluted and located in the medulla. The wall of these ductules is consisted of an inner epithelium, the connective tissue sheath and the muscular layer. The wall of the vas deferens is similar to that of the ductule except that the muscular layer is much developed.

Spermatogenesis occurs throughout the year. However, it is less active in spring and summer and becomes vigorous in fall and winter. Young males of 4-year old and under are not as active in spermatogenesis as the aged ones.

(c) The Ovotestis (Fig. 3): The ovotestes are invariably underdeveloped. They appear as two thin, slender organs in the abdominal cavity. The ovarian and testicular tissues are well separated from each other with the connective tissue. In cross sections, the ovarian tissue locates dorsally to the testicular tissue.

The histology of both the testicular and ovarian tissues are similar to that of normal ones. Individuals with ovotestes are considered to be hermaphrodites.

II. Sex Reversal.

The numbers of the male, female, and hermaphroditic red sea breams in different age groups are listed in Table 1.

TABLE 1

The Numbers of the Male, Female, and Hermaphroditic Red Sea Bream in Different Age Groups

Sex / age	Female	Hermaphrodite	Male
0	1	—	—
1	5	—	—
2	50	40	—
3	35	20	6
4	44	25	21
5	27	14	14
6	11	1	4
7	8	—	12
8	10	—	7
9	7	—	7
10	3	—	1
Total	201 (53.9%)	100 (26.8%)	72 (19.3%)

As shown in Table 1, there are only females at ages of one-year old and under. Hermaphrodites appear first in two-year old fish, however, the existence of males is delayed until the age of three. No hermaphrodites are observed at the ages of seven and above.

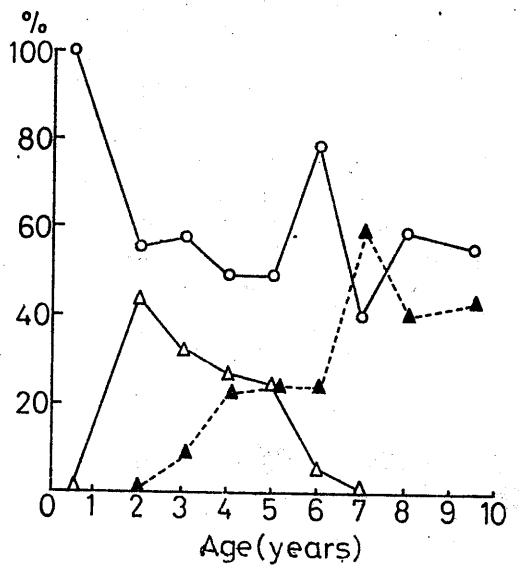


Fig. 4. The frequencies of the male (▲), female (○), and hermaphroditic (△) red sea breams in different age groups.

The percentages of the male, female, and hermaphrodite in different age groups are depicted in Fig. 4. Since the young fish (one year old and under) and the aged ones (nine-year old and above) are few in number, they are combined, respectively, for the preparation of this figue. The curve for the female has an initial drop at 2nd year of age, and levels around 50% from 4th to 5th year. Irregularity of the curve is evident from 6th through 10th year. It is suggested that the sample sizes of these groups could be accounted for. The curve for the hermaphrodite comes to its peak at 2nd year, and decreases gradually thereafter. The curve for the male increases gradually from 3rd year and reaches its peck at 7th year.

The chronological appearance of the female, hermaphrodite, and male in that sequence indicates that the red sea bream undergoes sexual reversal and is protogynous. It is proposed that the primitive gonad develops initially into the ovary and finally evolves into the complete testis through a transitional organ, the ovotestis. The percentages of the female, from the ages of 2 through 10, remain fairly constant, while the increase of the percentages of the male, from the ages of 3 through 6, is at the expense of that of the hermaphrodite. It seems justify to combine the number of hermaphrodite to that of the male, hence the sex ratio of the female and male comes to an unity. It is suggested that sex reversal in the red sea bream involves about 50% of the original population of the young female. However, sex reversal in a complete population has been reported for other fishes[1,3,5,6]

The sexual reversal is not uncommon in other teleosts. It occurs natually and could be induced artificially. Sex reversal could be induced in both male and female medaka by feeding the appropriate steroid hormones at definite developmental stages[10]. A social control of sexual reversal had been reported in a coralreef fish[9]. It seems that the sex transformation is mediated through the action of male and female steroid hormones.

Acknowledgements: The authors wish to express their sincere appreciation to Dr. Irene Tan Wie, Department of Zoology, National Taiwan University for her critical reading of this manuscript. This work was financially supported to one of us (CCH) from National Science Council, R. O. C.

REFERENCES

1. Coyama, T., T. Kitajima and K. Mizue (1963). Study of the sex reversal of Inegochi, *Cociella crocodila* (Jilesius). *Bull. Seikai Region. Fish. Res. Lab.* **29**: 11-33.
2. Atz, W.J. (1969). Intersexuality in Fishes. In "Intersexuality in Vertebrates including Man." 145-232. Eds. C. N. Armstrong and A. J. Marshall. Academic Press, New York.
3. Chan, S. T. H. and J. G. Phillips (1967). The structure of the gonad during natural sex reversal in *Monopterus albus* (Pisces: Teleostei). *J. Zool., Lond.* **151**: 129-141.
4. Chang, K. H. and S. Chen (1972). The age and growth of red sea bream in Pescadores Island. *Bull. Inst. Zool., Academia Sinica* **11**: 11-19.
5. Fujii, Taketo (1970). Hermaphroditism and sex reversal in the fishes of the Platycephalidae-I. Sex reversal of *Onigocia macrolepis* (Bleeker). *Japan, J. Ichthyol.* **17**(1): 14-20.

6. Fujii, Taketo (1971). Hermaphroditism and sex reversal in the fishes of the Platycephalidae-II. *Kumocoius detruses* and *Inegocia japonica*. *Japan. J. Ichyol.* **18**(3): 109–117.
7. Moser, H. Geoffrey (1967). Seasonal histolgical changes in the gonads of *Sebastodes paucispinis* Ayres, an ovoviviparous teleost (Family Scorpaenidae). *J. Morph.* **123**: 329–354.
8. Reinboth, R. (1971). Intersexuality in fishes. In "Hormones and Environment." Eds. G. K. Benson and J. G. Phillips. Men. Soc. Endocrinol. **18**: 515–543.
9. Robertson, D. R. (1972). Social control of sex reversal in a coralreef fish. *Science* **177**: 1007–1009.
10. Yamamoto, Toki-O (1959). A further study on induction of functional sex reversal in genotypic males of the medaka (*Oryzias latipes*) and progenies of sex reversals. *Genetics* **44**: 739–757.
11. Yamamoto, Toki-O (1969). Sex differentiation. In "Fish Physiology." Vol. 3, 117–175. Eds. W. S. Hoar and D. J. Randall. Academic Press, New York.

嘉鱲魚的性轉變

黃仲嘉 羅竹芳 張崑雄

從十三次逐月的嘉鱲魚標本共尾373，發現其生殖腺的組織有三種不同的型式：(1)卵巢，(2)睾丸及(3)兩性腺。因此嘉鱲魚的性別可區分爲雌魚、雄魚及雌雄同體魚。它們的性比百分組成分別爲 53.9%，19.3% 及 26.8%。兩性腺的發育常不發達。

一齡以下之個體（共 7 尾）全爲雌魚，雌雄同體魚則出現於二至六齡之魚羣，而二齡以下之魚羣中（共 103 尾）不曾發現雄魚，七齡以上之魚羣中（共 55 尾）則祇有雌魚及雄魚，不曾發現雌雄同體魚。由各魚齡中雄魚、雌魚及雌雄同體魚之性比及先有雌魚再有雌雄同體魚及雄魚的次序，嘉鱲魚顯然有進行性轉變之現象：部分之雌魚轉變爲雄魚，兩性腺爲過渡性之器官。

五齡以上之魚羣其卵巢及睾丸有季節性之變化。睾丸在秋冬兩季有顯著的精子成熟活動，而卵巢中的卵細胞成熟則見於冬季及越年之春季。