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Evidence of Sexual Maturation in Young Adult Shiner Perch, *Cymatogaster aggregata* Gibbons (Perciformes, Embiotocidae)

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ABSTRACT

Examination of *Cymatogaster aggregata* collected in Bodega Bay, California revealed that many young males, 5.0 to 6.0 cm. in length, become sexually mature during the first summer after birth and that females, 4.0 to 5.0 cm. in length, receive spermatozoa that can be found in their ovaries. The males are not sexually mature at birth.

Fertilization in the adults occurs during the summer; all females in the collection made in late October were found to harbor spermatozoa in their ovaries.

The implications of these findings are discussed.

INTRODUCTION

Cymatogaster aggregata Gibbons (shiner perch) belongs to the Embiotocidae, a family of viviparous perches, found mainly in the eastern Pacific, particularly in inshore and intertidal waters. There are, according to De Martini (1969), 23 species, and in two of these, *Micrometrus aurora* (Jordan and Gilbert)[2] and *Micrometrus minimus* (Gibbons), the males clearly are sexually mature at birth. At one time, *C. aggregata* was also considered to show natal maturity (Hubbs, 1921) but in 1954, after their

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[2] Referred to as *Amphigonopterus aurora* (Jordan and Gilbert) (De Martini, 1969).

examination of late embryos and young born in nature and aquariums, Hubbs and Hubbs stated that this assumption was incorrect. According to Hubbs and Hubbs (1954), Triplett (1960), Gordon (1965), and De Martini (1969), the fish do not mature before the end of the first year of life. On the other hand, Turner (1938), in his studies of gestation, had reported that the spermary (testis) of *C. aggregata* developed precociously and that the females received sperm the same summer they were born. Sperm are stored in the ovary until November or December when fertilization takes place. The young are born the following May to July (Eigenmann, 1894).

The findings, reported below, made during the summer of 1970 at the University of California's Bodega Marine Laboratory, Bodega Bay, California, demonstrate that males of *C. aggregata* become sexually mature not long after birth and that the females are inseminated soon after birth. In addition to those findings, notes on other aspects of the reproductive biology of *C. aggregata* are presented.

MATERIALS AND METHODS

The main collections of *C. aggregata* were made in Bodega Bay in shallow water, 2 to 5 feet in depth, primarily at two locations, Gaffney Point and Spud Point, which are separated by approximately 1 mile (fig. 1). A 100-foot seine, of ½-inch mesh, was dragged along the bottom, close to, and parallel with, the shore for a distance of up to 200 feet. Collections were made on July 6, 15, 31, August 8, 24, and October 23, 1970. Seining operations were carried out December 16 through December 22 in the same areas but no perch was caught. During the summer at Spud Point, the water temperature hovered around 16° C., at Gaffney Point, around 14° C. Gaffney Point is closer to the ocean inlet. The bottom of each area was sandy-muddy with a few rocks scattered about. *Enteromorpha*, the fine threadlike alga, and *Ulva*, the lettuce-like alga, was considerably more dense at Spud Point.

The water was murky, with a maximum vertical visibility of 3 feet, but generally 1 or 2 feet. The specific gravity of the sea water was 1.33, essentially the same at both points.

The most abundant species was *C. aggregata*. Other embiotocid species taken in the same hauls were *Hyperprosopon argenteum* Gibbons and *Phanerodon furcatus* Girard. From the many hundreds of *C. aggregata* brought in with each sweep, approximately 250 were brought to the laboratory for examination. They ranged in size from 3.4 cm. to 12.0 cm. (S.L.).

In the laboratory, the fish were measured and the sex was determined.

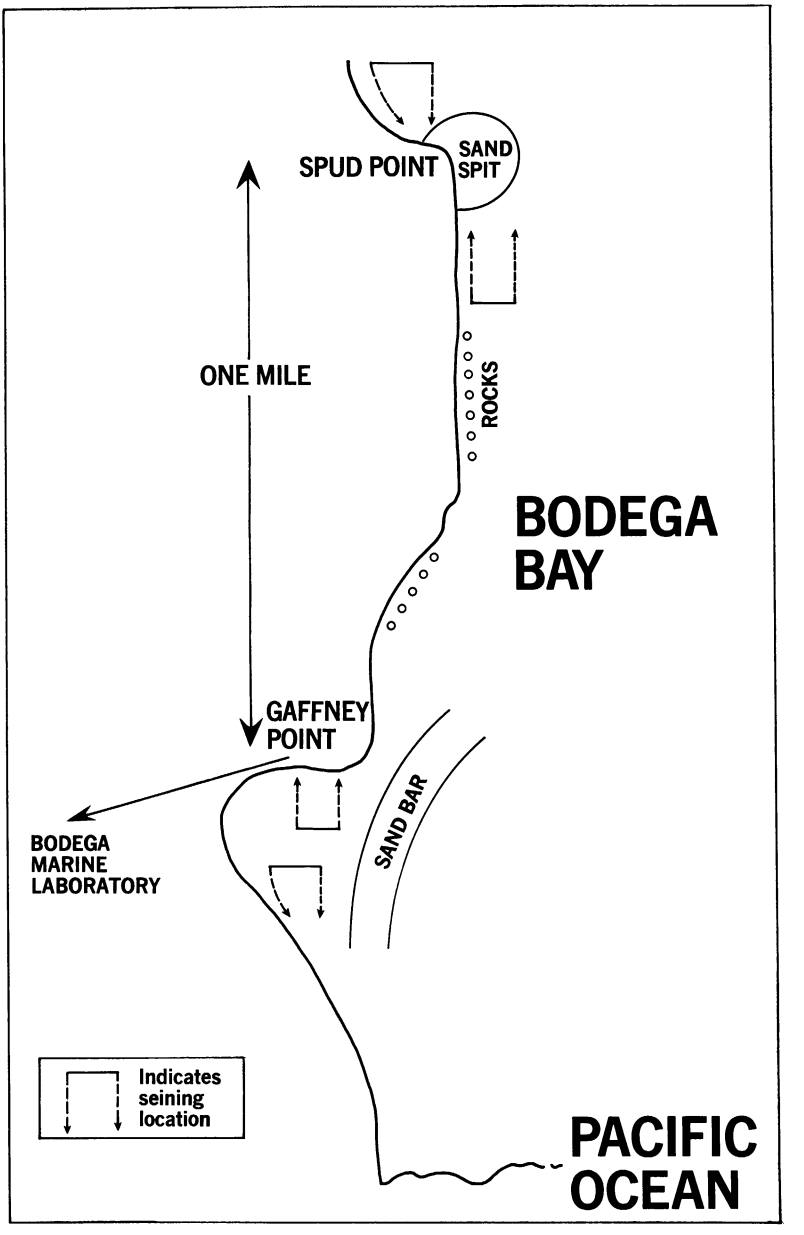

FIG. 1. Collecting locations.

During the reproductive season, *C. aggregata* is sexually dimorphic, the males exhibiting a modification of the anal fin in which the anterior anal fin rays are clumped together. They are flanked on each side by a bulbous gland and its tubular appendage (fig. 2). The function of the gland and appendage is unknown. A fluid is secreted from the gland. In all the collections, the abdomens of the males were squeezed gently to see if spermatozoa could be obtained from the genital papilla. The spermatozoa are contained in spermatophores. If spermatozoa were not freely running, the testes were excised and examined for the presence of spermatozoa.

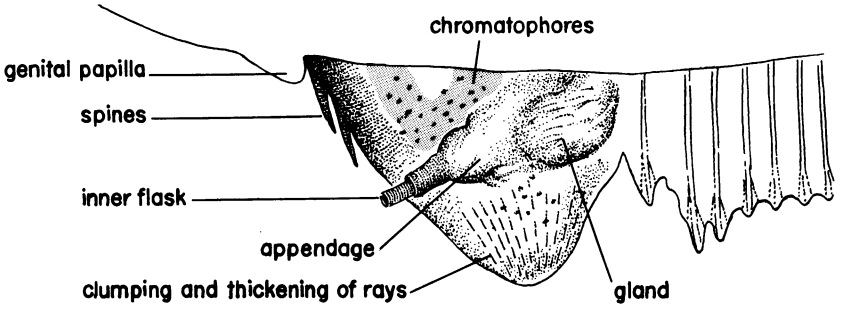

FIG. 2. Diagram of secondary sexual apparatus of the male. Inner flask is usually retracted. When gland is pressed, fluid is secreted.

In later collections, beginning July 31, in addition to looking for spermatozoa in the males, smears were taken from the genital opening of the female by inserting a fine pipette into the genital aperture and also by inserting the pipette into a deep pocket found just posterior to the genital opening. The smears were examined for the presence of spermatozoa. In cases in which they were not recovered from either the pocket or the genital aperture, the ovary was excised and crushed, and the ovarian fluid was inspected for spermatozoa. Smears were also taken from gravid females, easily recognized by the distention of the ventral body wall.

It was not possible to determine the sex of the smallest fish from external characteristics and it was necessary to inspect the state of the gonads directly through abdominal incisions.

The fish are referred to as follows: under 5.0 cm., juveniles; 5.0 to 7.9 cm., young adults; 8.0 to 12.0 cm., adults.

The term young adults is used here as the general morphological characteristics of these fish are more similar to those of juveniles than they are to those of adults, yet males of this size often have well-developed secondary sexual characteristics, as will be shown in the results.

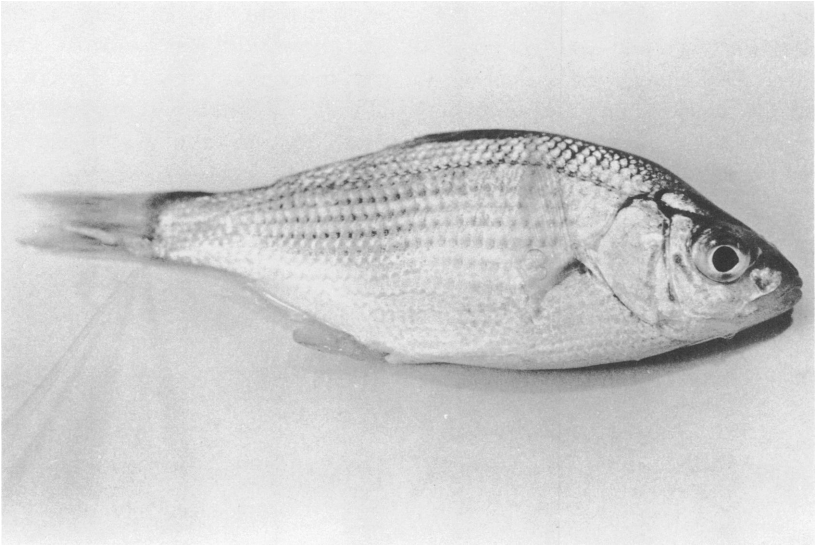

FIG. 3. Adult male *Cymatogaster aggregata*, 10.3 cm.

RESULTS

Juveniles and young adults were found at Spud Point as were a few gravid females. At Gaffney Point, the collections were composed of adult males (fig. 3) and adult gravid (fig. 4) and non-gravid females.

A. THE MALES: In the July 6 and 15 collections, approximately one-half the adult males had freely running seminal fluid, invariably containing spermatophores. In the July 31 and August 8 collections, all the males exuded freely running seminal fluid. In the August 24 collection, 12 of the 24 males exuded seminal fluid. In the October 23 collection at Gaffney Point, the secondary sexual characteristics had regressed almost completely in the five males examined. The gland and tubular appendages were absent; the anal fin rays remained clumped. Spermatozoa were seen in the crushed testes of one male only.

B. SIZE AT WHICH MALE SEXUAL CHARACTERISTICS APPEAR: In order to determine the size of the fish when secondary sexual characteristics appear, a sample of 100 fish, juvenile and young adult males from the Spud Point collections of July 15, August 8, and August 24 were examined. Forty ranged from 3.4 to 4.0 cm., 40 from 4.1 to 5.0 cm., and 20 from 5.1 to 6.0 cm. The anal fins were examined for the appearance of the secondary sexual modifications, such as the bulbous glands, tubular appendages, and

the thickening and clumping of the anterior anal fin rays. In addition, the testes were crushed and examined for the presence of spermatozoa. The first signs of change in the anal fin occurred in the clumping of the fin rays and the development of a flap where the bulbous glands and appendages would appear. Subsequently, the bulbous glands and tubular appendages appeared.

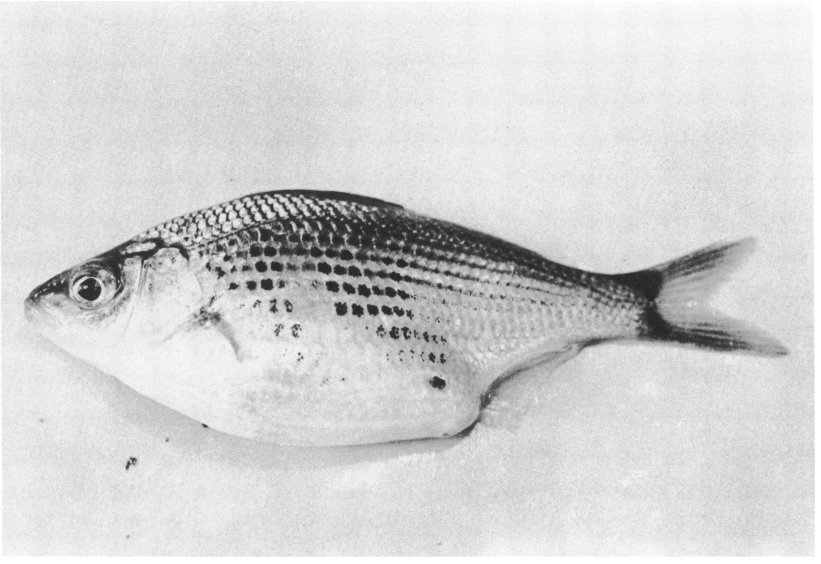

FIG. 4. Gravid female *Cymatogaster aggregata*, 10.5 cm.

Among fish less than 4.0 cm. long, the testes were small and transparent. There were no appendages although there was occasionally an incipient thickening of the rays. Spermatozoa were not seen in the crushed testes. No spermatozoa were found in the testes of the males born in the laboratory.

When the fish reached a length of 4.0 to 4.9 cm., the anal fin began to change. The rays clumped and thickened and small bulges appeared at the site of the bulbous glands. Mature spermatozoa, mostly inactive, were occasionally seen in the crushed testes. However, one fish 4.5 cm. long had active spermatozoa and another fish of 4.3 cm. contained fully formed spermatophores in the seminal fluid. Interestingly, the latter had no modifications of the fin. When the fish were between 5.0 cm. and 5.9 cm. in length, 15 had fully developed secondary sexual modifications. In the

August 24 collection, three males 5.1 to 5.7 cm. long did not have secondary sexual characteristics.

Spermatophores were obtained from a number of young adults in the July 31 and August 8 collections but not on August 24. The spermatozoa in the spermatophores were active in some males, inactive in others. It was found that nonmotile spermatozoa, taken from the testes or found in the seminal fluid of young adults and adults, became active in Ringers solution and could be inactivated by sea water, an entirely reversible procedure occurring almost upon instant contact with either solution. Spermatozoa removed from ovaries of some females were inactive, from others, highly active. Ovarian fluid activated sperm that had been immobilized by sea water.

C. The Females: As discussed, females were not examined for the spermatozoa in the ovary until the collections beginning on July 31. Spermatozoa were recovered from the deep pocket found just posterior to the genital opening in one female only and none at all were recovered from the genital aperture. In a number of cases, the ovaries of gravid females (8.0–11.9 cm. in length) were excised, and the ovarian fluid was examined for the presence of spermatozoa. None were recovered. Other adult females (8–11 cm. in length), were found to carry spermatozoa in the ovary in the July 31 and August 8 collections. In the August 24 collection, several adults did not carry sperm in the ovary. In the October 23 collection all the adult females harbored sperm.

Young adult females with and without sperm were taken in the August 8 collection. In the August 24 collection all the young adult females carried sperm in the ovary.

Spermatozoa were never recovered from juvenile females less than 4.0 cm. In the August 8 collection eight females, 4.0 to 4.8 cm. in length, carried sperm in the ovary. Five of these fish were less than 4.4 cm. in length. In the August 24 collection all the females, ranging in length from 4.3 to 5.0 cm., carried sperm. Their ovaries ranged from 1.5 to 2.5 mm. in length.

DISCUSSION

As mentioned in the introduction, there has been confusion about whether *C. aggregata* is sexually mature at birth or matures at the end of the first year of life. The investigation carried out during the summer of 1970 in Bodega Bay, California shows that the fish mature between these two periods. *Cymatogaster aggregata* develops sexually within a short period of time during the first summer after birth. The males are evidently capa-

ble of inseminating the females during August when they are 5.0 cm. in length. The females are receptive when they are even smaller.

According to Gordon (1965), who carried out age determinations of *C. aggregata* in British Columbia, the fish at one year are 7 to 8 cm., at two years 9 to 10 cm., and at three years 11 to 12 cm. in length.

Female *Micrometrus aurora* (Jordan and Gilbert) at one year ranged in length from 7.6 cm. to 10.8 cm. (Hubbs, 1921). Yearling *Brachyistius frenatus* Gill ranged in size from 5.8 to 10.5 cm. The young of the year were mostly between 5.0 and 7.5 cm. in length (Hubbs and Hubbs, 1954).

One can be fairly certain that *C. aggregata* of 5.0 cm. are the young born during the spring and summer of that year. In fact, Triplett (1960) reported that the young he examined, at birth, were 4.0 cm. in length. Assuming that fertilization occurs at the appropriate time in the winter, females at one year should drop broods. Of course, one cannot conclude that because insemination has occurred, fertilization is a certainty. However, in Bodega Bay, a number of females, between 8.0 and 8.5 cm. were gravid. In contrast, Gordon (1965) did not find yearling females to be gravid in British Columbia. The smallest gravid females he collected were between 9 and 10 cm., the size of the two-year-olds. The fact that he did not find gravid yearling females could have resulted from differences in his collecting locations. Gordon's collections were made at greater depths than were those of Bodega Bay. Otherwise there do not seem to be great differences in the ecology of the two areas; temperature and light are similar. Perhaps, the fish, for unknown reasons, do not mature during their first summer in British Columbia.

In their 1954 paper, Hubbs and Hubbs put *C. aggregata* in close relationship to *Brachyistius* because it takes both species one year to reach sexual maturity. A new look at this relationship, based on the above results, may be in order.

A number of points about the reproductive biology of the fish require further investigation. For example, Weibe (1968b, 1968c) reported the height of reproductive activities as occurring in June and July. Yet he stated that sperm are not found in the ovaries during that time. Sperm are first recovered in August. Does this mean that the sperm are held elsewhere, such as in an undiscovered pocket in the ovarian wall, or does it mean that the courtship behavior results in insemination only in August?

During July, the juvenile males are developing sexually. During August, many become fully mature. This is a time of decreasing day length, although the days are still long. Weibe's (1968a, 1968b) experiments show that the maturation of the testes is under gonadotrophic control as a function of photoperiod with increasing day length. What are the mech-

anisms that operate in the development of sexual behavior in the young males during decreasing day length? That they inseminate the young females is obvious. They are found together at Spud Point where adults have not been found.

The fact that the adults and juveniles are located in different areas, separated by approximately one mile, leads to inquiries on the distribution of these age groups and the cues involved in the segregation of one age group from another.

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LITERATURE CITED

De Martini, E. E.
1969. A correlative study of the ecology and comparative feeding mechanism morphology of the Embiotocidae (Surf-fishes) as evidence of the family's adaptive radiation into available ecological niches. Wassman Jour. Biol., vol. 27, no. 2, pp. 177–247.

Eigenmann, C. H.
1894. On the viviparous fishes of the Pacific coast of North America. Bull. U. S. Fish Comm., art. 9, pp. 381–478.

Gordon, C. D.
1965. Aspects of the life history of *Cymatogaster aggregata*. Unpublished Master's thesis. University of British Columbia.

Hubbs, C. L.
1921. The ecological life-history of *Amphigonopterus aurora* and of other viviparous perches of California. Biol. Bull., vol. 40, no. 4, pp. 181–209.

Hubbs, C. L., and L. C. Hubbs
1954. Data on the life history, variation, ecology, and relationships of the kelp perch, *Brachyistius frenatus*, an embiotocid fish of the Californias. California Fish Game, vol. 40, no. 2, pp. 183–198.

Shaw, E.
1970. Schooling in fishes: critique and review. *In* Aronson, Lester R. et. al. (eds.), Development and evolution of behavior: essays in memory of T. C. Schneirla. San Francisco, W. H. Freeman. pp. 452–480.

Triplett, E. L.
1960. Notes on the life history of the barred surf perch, *Amphistichus argenteus* Agassiz, and a technique for culturing embiotocid embryos. California

Fish Game, vol. 46, no. 4, pp. 433–439.

TURNER, C. L.

1938. Histological and cytological changes in the ovary of *Cymatogaster aggregatus* during gestation. Jour. Morph., vol. 62, pp. 351–373.

WEIBE, J. P.

1968a. Inhibition of pituitary gonadotropic activity in the viviparous seaperch *Cymatogaster aggregata* Gibbons by a dithiocarbamoylhydrozine derivative (I.C. I33828). Canadian Jour. Zool., vol. 46, no. 6, pp. 751–758.

1968b. The effects of temperature and daylength on the reproductive physiology of the viviparous seaperch, *Cymatogaster aggregata* Gibbons. *Ibid.*, vol. 46, no. 6, pp. 1207–1219.

1968c. The reproductive cycle of the viviparous seaperch *Cymatogaster aggregata* Gibbons. *Ibid.*, vol. 46, no. 6, pp. 1221–1234.