INDUCTION OF SPAWNING IN THE WEAKFISH, *CYNOSCION REGALIS*

Reproductive activity in the weakfish, *Cynoscion regalis*, is associated with extensive, north-south migrations that result in spawning in the estuaries of the Middle Atlantic Bight during the late spring and early summer. Spawning is apparently related to increasing water temperature and day length, but there have been no experimental investigations of specific factors that control this process in the weakfish. In contrast, general aspects of the reproductive biology of the species are well known (reviewed by Mercer 1983). Both males and females become sexually mature at 1 year of age, and remain sexually active throughout their lifespan (10^+ years). Spawning involves external fertilization of eggs by pairs or small aggregations of fish.

There has been limited study of larval development in the laboratory, and descriptions of growth and development of larval weakfish come entirely from field investigations (Lippson and Moran 1974). Weakfish larvae resulting from gametes stripped from sexually mature adults captured in the field have been reared for a few days on natural zooplankton diets (Public Service Electric and Gas Company 1984), but no information is available on mortality or growth rates on prescribed diets and rations. In contrast, Houde and Taniguchi (1981) and Taniguchi (1981, 1982) have conducted extensive investigations of the effects of diet, ration, and temperature on growth and survival of larval spotted seatrout, *Cynoscion nebulosus*, under laboratory conditions. Similar studies have been conducted with other sciaenids including red drum, *Sciaenops ocellatus* (Holt and Arnold 1983; Holt et al. 1981), spot, *Leiostomus xanthurus* (Powell and Gordy 1980), and bairdiella, *Bairdiella icistia* (May 1974).

The present paper describes a technique for induction of spawning in a laboratory population of weakfish and provides preliminary information on early development and growth of weakfish larvae.

Methods

Sixteen adult weakfish, *C. regalis*, (approximately 30–45 cm and 0.5–1.5 kg) were captured in September 1984 in Delaware Bay by hook-and-line. Five of these fish were dissected and found to have regressed gonads. The remaining 11 fish were placed in two large tanks (2,000 L) connected to a 20,000 L recirculating system that delivered temperature-controlled seawater to each tank at 10 L/minute. Water in the recirculating system was replaced approximately monthly. Ordinary white room light was provided by two 1.25 m fluorescent lamps positioned 1 m above the surface of the water in each tank. Initial conditions in the tank were similar to ambient conditions in Delaware Bay in September: 18°–19°C, 30‰, and 12 hours light:12 hours dark. Temperature and salinity in the tanks were measured daily and pH approximately weekly. The pH was maintained between 7.0 and 7.6 by additions of new seawater to the system; this was accomplished by replacing 40% of the water in the system with new seawater approximately monthly.

Fish began to feed 5–7 days after capture. Diet consisted of an ad libitum ration of sliced squid with weekly additions of penaeid shrimp or fresh calf liver. After approximately one month in the laboratory, the fish were subjected to a prescribed regimen of temperature and photophase (Fig. 1). Temperatures were lowered and light phase shortened over a period of three weeks until conditions reached 8 hours light, 13°–14°C; this approximated winter conditions on the continental shelf off Cape Hatteras where adult fish are known to overwinter (Merriner 1976). Fish were held under these conditions for 11 weeks after which temperature was gradually raised and light phase increased until spring conditions of 14 hours light and 22°–23°C were reached. Fish were held at these conditions throughout a period of extended spawning activity. After spawning activity ceased, six newly captured fish were placed in the system to replace fish that had died during the previous year, and the process of gradually changing temperature and photoperiod to winter conditions was repeated (Fig. 1).

Fertilized eggs were buoyant and exited the tanks at the surface via stand pipes that emptied into a sump tank. The drain was located at the bottom of the sump tank allowing eggs to accumulate at the water surface. The presence or absence of eggs in the sump was determined daily with a fine-meshed dip net. After collection, eggs from each spawning were allowed to hatch in 20 L plastic aquaria filled with 5.0 μm filtered seawater at 30‰ and 23°C. Eggs exposed to gentle aeration under these conditions hatched in 24–36 hours.

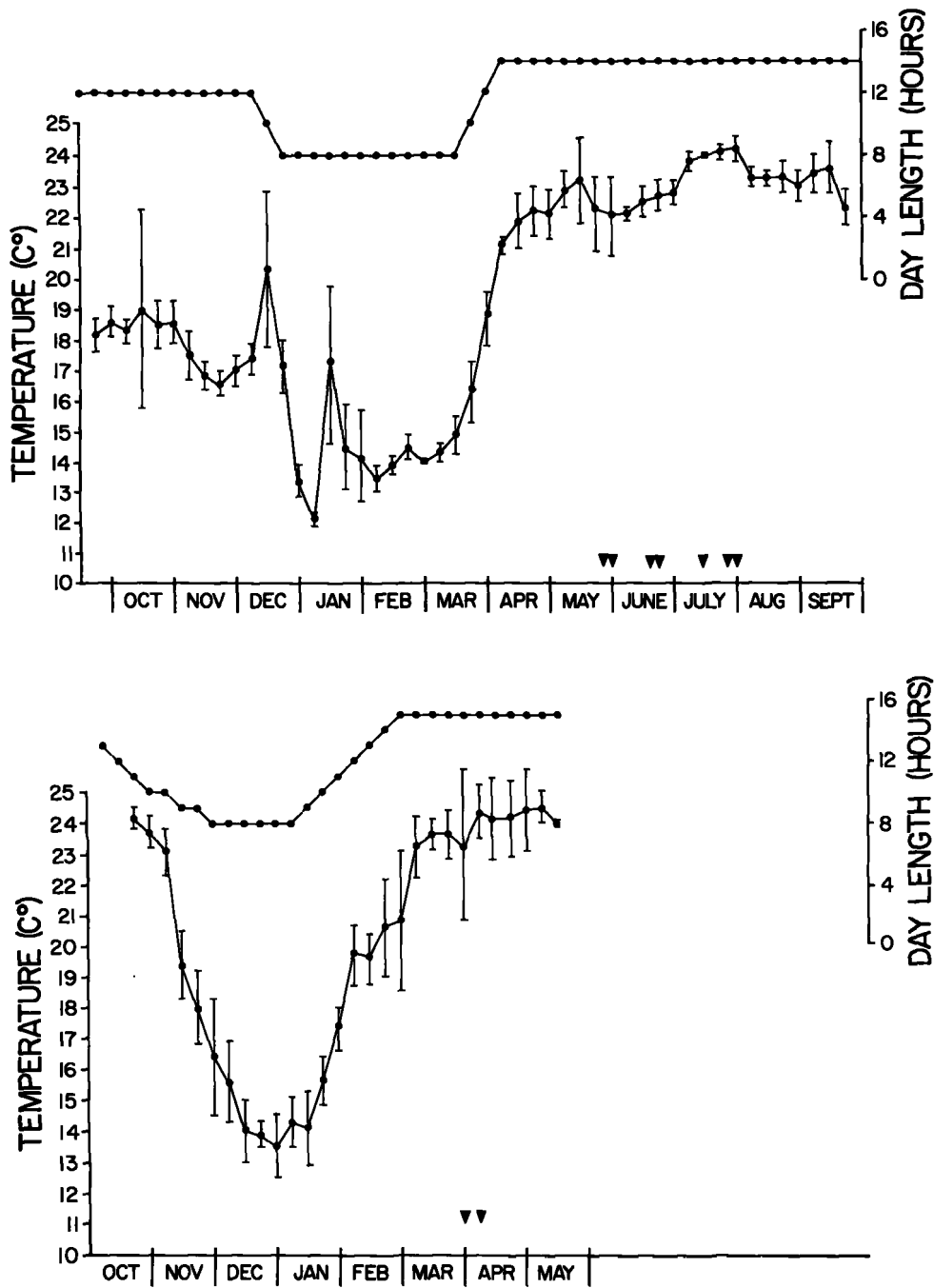Larvae were cultured in 2 L beakers filled with filtered seawater (25°C, 30‰, and 5 mg/liter

FIGURE 1.—Temperature-photophase regime used to condition northern weakfish, *Cynoscion regalis*, to spawn in the laboratory. Values are 7-d means. Standard deviations are plotted for temperature. Arrows on time axis indicate dates of spawning. A = 1984–85. B = 1985–1986.

chloramphenicol) at a density of 25 larvae/liter. Larvae were fed rotifers, *Brachionis plicatilis*, beginning two days after hatching; on the seventh day after hatching, brine shrimp *Artemia* sp. were added to the diet.

Early larval development from spawning to first feeding was determined for larvae from three separate spawnings. Newly hatched larvae (6–15 hours old) were pipetted into an aquarium and 10–15 removed immediately and preserved in 70% ethanol. Additional larvae were sacrificed daily for nine days. These samples were examined to relate early development and age.

Results and Discussion

Three adult fish died of undermined causes during the period of winter conditions in 1984–85. Four additional fish died after jumping from the tanks. The initial spawning by the remaining population of four fish occurred five weeks after spring conditions were achieved. This was followed the next day by another spawning. Spawning continued for nine weeks at 10–14 d intervals. Spawning episodes usually consisted of production of fertilized eggs over 2 successive days. While actual spawning was never observed, it always occurred between sunset and 08:00 the following day.

After cessation of spawning, the four fish were removed from the tanks and their sex determined. Two of the fish drummed when handled and were clearly males. At least one (and probably both) of the two remaining fish were females. The fish were returned to the system after examination.

The temporal sequence of the spawning events (two successive days at 10–14 d intervals) suggests that each female may have spawned as many as four times during the 9-wk period. This is in contrast to reports for natural populations of *C. regalis* (e.g., Merriner 1976), but has been reported for laboratory populations of other sciaenid fishes. For example, Arnold (1984) observed 82 spawning events in a laboratory population of 12 *C. nebulosus* over a 27-mo period and 52 spawning events in a similar population of six *S. ocellatus* over a 3-mo period. It is not clear why the *C. regalis* in our investigation ceased spawning after several months of long days and high temperatures while the *C. nebulosus* in Arnold's system continued to spawn over a much longer period. Perhaps this is related to the smaller annual variation in photophase and temperature

typical of *C. nebulosus* habitats. However, gonadal resorption has been reported for at least one other sciaenid species (*B. icistia*) held in the laboratory for extended periods of long day-length (May 1974).

Spawning from the 1985–86 conditioning period first occurred four weeks after spring conditions were reached with a second spawning nine days later. Further spawning in the 1985–86 population did not occur because of an unidentified infection resulting in the death of all 10 fish in the system over a period of a few weeks. Autopsies revealed that all fish had highly developed ovaries or testes at the time of death.

Newly hatched larvae (6–15 hours old) had a yolk sac, no mouth, and little development of the eyes. By 24–36 hours after hatching, the yolk sac had been virtually absorbed, the mouth was just beginning to form, and the eyes were not yet pigmented. By 48–60 hours, larvae had a completely formed mouth and digestive system, and the eyes were pigmented. Larvae were capable of feeding at this stage.

Chloramphenicol improved larval survival, which was as high as 24% over 11 days. This survival is comparable to that reported for other sciaenid larvae (Holt et al. 1981; Houde and Taniguchi 1981; Holt and Arnold 1983). However, growth was less than the maximum seen in the laboratory for *C. nebulosus*. After 11 days *C. regalis* larvae in the present experiments had grown from a mean, posthatching size of 2.7 mm (36 µg dry weight) to 4.5 mm (235 µg dry weight). In contrast Houde and Taniguchi (1981) found that one group of *C. nebulosus* larvae reached a size of 13.6 mm (7,082 µg dry weight) in 12 days when reared on a concentrated ration of natural zooplankton at very low stocking density and high temperature (32°C). However, when fed a rotifer diet at comparable temperatures and stocking densities, growth of *C. nebulosus* larvae was somewhat less than that of *C. regalis* larvae in the present experiments.

Our results show that the spawning cycle of weakfish can be manipulated to produce repeated spawnings without the aid of hormone injections. While the fish appear to resorb their gonadal tissue after several months of exposure to long day length and high temperature, the differential manipulation of several groups of fish could allow year-round production of fertilized eggs. Furthermore, survival and growth of larvae produced in this manner appear comparable to survival and

growth of other sciaenids reared in the laboratory.

Acknowledgments

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