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Mariculture of the Toadfish *Opsanus tau*

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In response to declining stocks of toadfish in local waters around Cape Cod, Massachusetts, a toadfish mariculture program was initiated in the summer of 1998 (1); the aims were to provide researchers at the Marine Biological Laboratory (MBL) with sufficient numbers (approximately 400 per year) of this valuable biomedical research model (2, 3) while lessening pressure on native stocks. The goal was to raise fish to the target size of 25 cm and 500 gm within three years. In the first year of the program, culture methods were developed, and the effects of temperature and stocking density on toadfish growth were monitored; a preliminary report was published in 1999 (1). We continued to observe and monitor this captive population through the summer of 2001. This paper summarizes the growth rates and mortalities of these three-year fish.

Briefly, two toadfish nests (with guardian males) were transported to the Marine Resources Center of the MBL from Waquoit Bay, Massachusetts in July 1998. Approximately 400 juvenile fish

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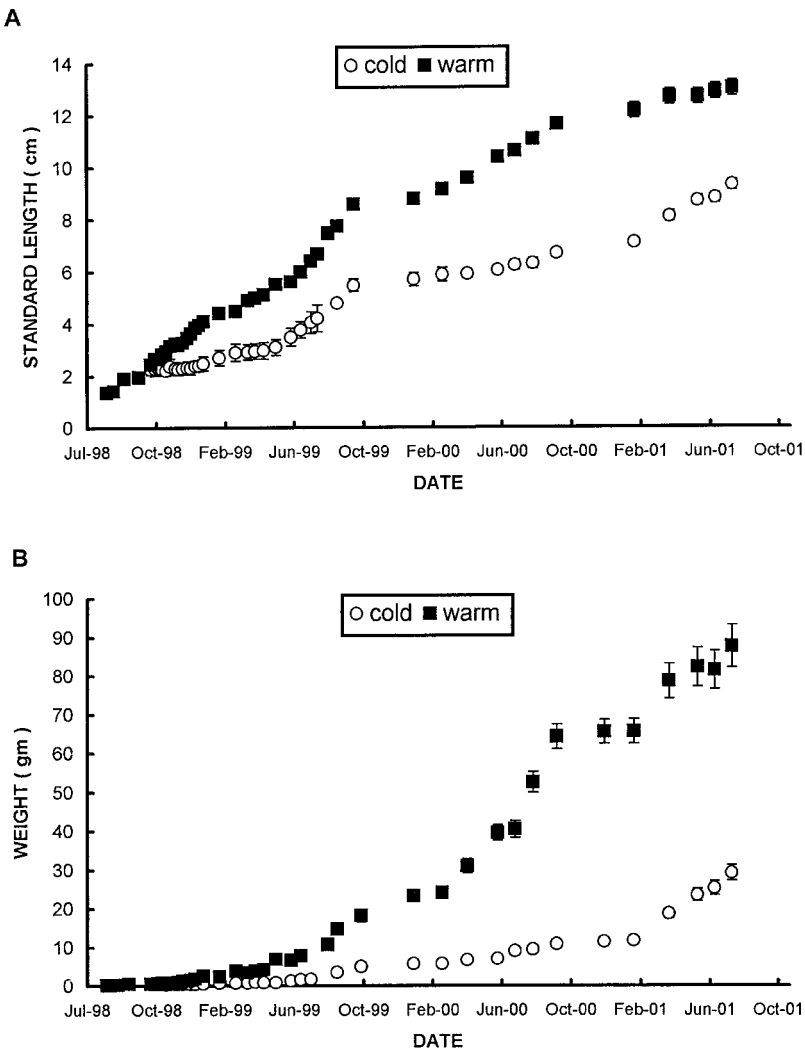

Figure 1. *Standard length (A) and weight (B) of maricultured toadfish plotted as a function of time for about three years. Data points represent mean values of fish raised at cold (circle) and warm (square) temperatures (see the text for specific temperatures). Error bars = 1 SE.*

detached from both nests in August 1998. In October 1998, 100 of the juvenile fish were selected for mariculture and placed in shallow fiberglass tanks (130 × 70 × 10 cm). Fish were raised at two different temperatures, and their growth was monitored. Half the fish were maintained at "cold" temperatures (15.8° ± 0.4 °C average weekly temperature), which have proven successful for maintaining adult toadfish in captivity. The remaining fish were maintained at "warm" (19.6° ± 0.8 °C) temperatures in an effort to increase growth rate. Stocking densities ranged from 10 to 40 toadfish m^{-2}. Fish initially were fed live adult *Artemia* that had been bathed in a nutritional supplement (Super Selco). After six months of culture, the diet was switched to chopped pieces of squid and butterfish. At the conclusion of the first year, the warm-water fish averaged 6.4 ± 0.1 cm in length and weighed 13.0 ± 0.3 g, and the cold-water fish averaged 4.0 ± 0.5 cm and 1.7 ± 0.0 g (1). Survival rate was 78%, with many of the mortalities attributed to the cannibalistic nature of batrachadoids (4).

At the conclusion of year one, the juvenile fish were transferred to large, fiberglass tanks measuring either 3.7 × 2.4 m or 3.7 × 1.8 m. The water level in each tank was maintained at 13 cm. Pieces of PVC pipe (diameter 7 to 10 cm) were provided as shelters for the fish. The temperature regimes were maintained (warm and cold), but fish from the different densities were combined after being sorted by size to prevent cannibalism. The fish were distributed to the tanks at a density of 1.8 to 2.4 fish m^{-2}. The two- and three-year age classes were maintained on a prepared diet consisting mainly of chopped squid and butterfish and were fed three times per week.

During the second year of culture, the average weekly temperatures were 19.4 °C (warm) and 16.9 °C (cold). In year three, the average warm-water temperature was 20.2 °C. Because the cold-water fish continued to be small, they were switched to the "warm" water in February of 2001; as a result, the average weekly temperature for these fish was 19.2 °C during year three.

After 24 months of culturing, the warm-water fish averaged 10.6 ± 0.2 cm and weighed 40.5 ± 2.1 g, and the cold-water fish averaged 6.2 ± 0.7 cm and 9.0 ± 0.6 g. By the end of the third year, the warm fish had grown to an average standard length of 13.0 ± 0.3 cm (range 9.5 to 15.5 cm) and average weight of 87.7 ± 5.5 g (25 to 136 g). The cold-water population continued to display slower growth, with the average fish measuring 9.3 ± 0.2 cm (8.4 to 10.8 cm) and 29.2 ± 2.0 g (15 to 45 g) in year three (Fig. 1).

Survival rates remained high, following the initial 78% rate in year one. Approximately two-thirds of the original fish remained alive after 24 months, and 60% survived through July 2001. The size segregation instituted in the summer of 1999 greatly reduced cannibalism.

Our eventual goal is to eliminate field collection through the successful spawning and rearing of captive fish. However, the age of sexual maturity among the Cape Cod population has never been firmly established. Five females in the warm-water tanks became gravid in the spring of 2001, and at least one successfully deposited scores of eggs inside a PVC pipe, suggesting that the onset of sexual maturity for female toadfish is less than three years. Unfortunately, for unknown reasons, these eggs failed to develop. The onset of sexual maturity in the males remains to be determined.

In summary, we have demonstrated that toadfish can be raised in captivity for at least three years. At the current maximal growth rate of 5 cm/year, we estimate that the fish will need at least five to six years to attain the desired size range of 25 to 30 cm, thus making the project impractical in terms of cost and time.

One of the main impediments to faster growth is the virtual cessation of growth during the winter (Fig. 1). Previous observations led us to hypothesize that keeping the fish at temperatures about 15 °C above ambient during the winter would circumvent this "hibernation." Because this expectation has proved incorrect, future attempts will focus on temperature and photoperiod. Preliminary evidence shows that newly detached juvenile toadfish raised at 26° to 29 °C grow significantly faster than fish raised at 20 °C (5). We also plan to manipulate the photoperiod during the winter to stimulate year-round growth.

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Strategies for Increasing Growth of Juvenile Toadfish

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A toadfish mariculture program was initiated in the summer of 1998 at the Marine Biological Laboratory, Woods Hole, Massachusetts. The purpose of this program was to reduce pressure on the native toadfish population while providing researchers with a year-round supply of appropriately sized animals. Although the toadfish have proven to be amenable to year-round culturing (survival rates were 60% to 70% during the initial three years (1, 2)), their growth was slower than that of conspecifics inhabiting

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