EFFECTS OF PUGHEADEDNESS ON GROWTH AND SURVIVAL OF STRIPED BASS, *MORONE SAXATILIS* (WALBAUM), INTRODUCED INTO CANTON RESERVOIR, OKLAHOMA[1]

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High percentages of hatchery-reared striped bass, *Morone saxatilis* (Walbaum), have been observed to be pugheaded. Samples collected from Canton Reservoir during the summers of 1969 and 1970 gave evidence that pugheaded striped bass had a shorter total length than normal fish of the same age. The growth rate of pugheaded striped bass was slower than that of normal fish during the 1970 sample period, but no such difference was observed in 1969 samples. Incidence of pugheaded striped bass decreased as the season progressed, presumably due to a higher mortality rate for pugheaded striped bass than for normal fish.

Pugheadedness, an abnormality in teleost fish, is characterized by a pronounced shortening of the upper jaw, a steepening of the forehead, an abnormal projection of the lower jaw, and a marked bulging of the eyes. Accounts of individual fish with this anomaly are common in the literature and an extensive list of both marine and fresh-water species that have been affected by this condition is presented by Dawson (1, 2). Pugheadedness in adult striped bass, *Morone saxatilis*, has been reported by Sutton (3), Gudger (4), Lyman (5), and Alperin (6). Both Sutton and Gudger presented detailed accounts of the osteological modifications in the skull of these fish. Mansuetti (7, 8) made a comprehensive review of pugheadedness in both adult and young-of-the-year striped bass. He noted that laboratory-reared striped bass were especially prone to develop pugheaded characteristics and reported that, in Maryland, approximately 33% of laboratory-reared striped bass which survived during the summer of 1956 were pugheaded. Oklahoma hatchery-reared striped bass have also been observed to have an exceptionally high incidence of pugheadedness.

The effects of pughearedness upon the fish's ability to compete has not been fully resolved. Both Cheek (9) and Issacson (10) have reported that the growth of pugheaded American shad, *Alosa sapidissima*, and the black perch, *Embiotoca jacksoni*, was slower than that of normal fish from comparable samples. Mansuetti (8) indicated that, in Maryland, the total length of an adult pugheaded striped bass was less than that of a normal, or non-pugheaded, individual at each comparable age-group. Alperin (6) reported that a 5-year-old female striped bass with excessive pugheadedness was well below the average size of normal fish of comparable age and was not well nourished. However, Leggett (11) found that a reduced growth rate was not apparent in a pugheaded Atlantic salmon, *Salmo salar*. He concluded that the only indication of any hardship resulting from this anomaly was an observed reduction in the length-weight relationship of this fish. Mortality rates of pugheaded fish and/or comparisons with normal fish were not available in the literature.

This investigation was initiated to determine the percentage of occurrence of pugheadedness in the young-of-the-year, hatchery-reared striped bass stocked in Canton Reservoir, and to measure effects of this condition on growth and survival.

All striped bass examined in this investigation were hatched at the Santee-Cooper Fish Hatchery in South Carolina and were transported to Oklahoma as prolarvae. They were reared in culture ponds until they reached a total length of approximately 50 mm, when they were stocked in Canton Reservoir. A total of 56,000 striped bass was stocked June 16, 1969, and 44,200 were stocked June 22 and 23, 1970. Culture techniques have been detailed by Jarman and Harper (12). A description of Canton Reservoir has been given by Bross (13).

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METHODS AND MATERIALS

This investigation was conducted as a segment of a study designed to determine the effects of an introduced striped bass population upon the existing fish populations and upon the sport fishery of Canton Reservoir. Young-of-the-year striped bass were collected with a 40 x 6-foot x ¼-inch mesh bag seine which had a cheese-cloth liner in the bag. Fish were collected from six locations and a latin-square sampling schedule described by Gennings (14) was followed. All samples were taken at night. Sampling periods extended from June 20 to September 10, 1969, and from June 23 to September 25, 1970.

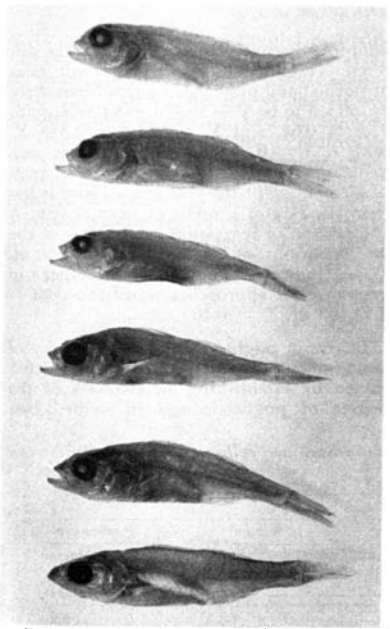

FIGURE 1. A series of young-of-the-year striped bass illustrating the variation in degree of pugheadedness. (See TABLE 1.)

A total of 226 striped bass was examined for pugheadedness in 1969 and 84 were examined in 1970. A wide variation occurred in these striped bass collected from Canton Reservoir (Figure 1). Therefore, a system was devised to quantitate degree of pugheadedness in each fish. As is indicated in Table 1, a value of 0, 1, or 2 was assigned to each of four conditions which characterize pugheadedness, i.e., a pronounced shortening of the upper jaw, a steepening of the forehead, an abnormal projection of the lower jaw, and a marked bulging of the eyes. A higher value was given to indicate a higher degree of pugheadedness. This numerical system of measuring the degree of pugheadedness was utilized in calculations to determine the effects of pugheadedness upon the growth and mortality rate of striped bass in Canton Reservoir.

TABLE 1. *Code used to establish a numerical classification for the degree of pugheadedness in striped bass.*

Characteristic		Code
Upper jaw	Normal	0
	Moderately shortened	1
	Greatly shortened	2
Forehead	Normal	0
	Moderately sloped	1
	Greatly sloped	2
Lower jaw	Normal	0
	Moderately extended	1
	Greatly extended	2
Eyes	Normal	0
	Moderately bulged	1
	Greatly bulged	2

To calculate effects of pugheadedness on growth of striped bass, individual fish were classified as pugheaded if a value of at least one was assigned to any of the four characteristics which denotes pugheadedness. This system of classification would therefore result in biased data toward a type-two error, *i.e.*, if, in fact, pugheadedness did have an effect upon growth, and if all the marginal individuals were classified as pugheaded, a significant difference in growth would be less likely than if only the more extremely pugheaded individuals were classified as pugheaded.

RESULTS

The percentage of occurrence of pugheadedness in striped bass introduced into Canton Reservoir was determined by examining those fish which were collected during the first four weeks of the sampling period. In 1969, 74 of 152 striped bass (48.7 percent) were to some degree pugheaded, whereas 11 of 29 striped bass (37.9 percent) were found to be pugheaded in

1970. Occurrence of pugheadedness in striped bass stocked in Canton Reservoir was, therefore, estimated to range between these two values. Mean total lengths of normal and pugheaded striped bass, collected during 14-week periods following introductions in 1969 and 1970, were compared according to data obtained from biweekly samples (Table 2). In only one instance, *i.e.*, 10 weeks after introduction in 1969, was the mean length of normal fish not greater than that of pugheaded fish. A non-parametric sign test was used to determine the significance of the differences in the total lengths of these two groups. Dixon and Massey (15) indicate a probability of less than 0.01 for a distribution of 1 minus in a total of 14 individual comparisons. These data indicate that the total length of pugheaded young-of-the-year striped bass was significantly less than the total length of normal fish collected from Canton Reservoir in 1969 and 1970.

Growth rates of normal and pugheaded striped bass were compared during the sample period by expressing growth as a linear function of age. A linear relationship was assumed because of the short sampling period. Growth of normal fish during the study period of 1969 was estimated to be $Y = 54.71 + 2.918\ X$, with $r_{xy}^2 = 0.49$, where Y equals total length in mm and X equals weeks since introduction. Pugheaded fish had a growth rate estimated as $Y = 50.49 + 2.941\ X$, with $r_{xy}^2 = 0.37$. Although the total length of pugheaded fish was less than that of normal fish, the rate of growth during the 1969 sampling period was not significantly different (Figure 2). In 1970, growth rates of normal and pugheaded striped bass were estimated to be $Y = 56.478 + 3.598\ X$, with $r_{xy}^2 = 0.68$, and $Y = 52.02 + 2.316\ X$, with $r_{xy}^2 = 0.54$ (Figure 3). These estimates indicate that rate of growth of pugheaded young-of-the-year striped bass is less than the rate of growth of normal fish. A comparison of regression coefficients of the two equations, as described by Crow et al. (16), indicates that this difference in growth rates approaches significance ($t = 1.52$, 80 df, $P = 0.10$).

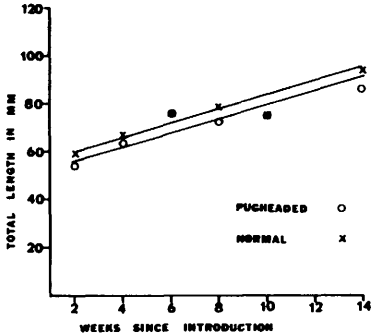

FIGURE 2. Total length of normal and pugheaded striped bass at various times during a 14-week period in 1969.

Effects of pugheadedness on mortality of young-of-the-year striped bass were determined by establishing an estimate of the degree of pugheadedness in striped bass

TABLE 2. *Mean total length of normal and pugheaded striped bass collected from Canton Reservoir during the summer of 1969 and 1970.*

	1969				1970			
	Normal		Pugheaded		Normal		Pugheaded	
Weeks since introduction	Number	Mean total length (mm)	Number	Mean total length (mm)	Number	Mean total length (mm)	Number	Mean total length (mm)
2	29	59.9	32	54.0	7	58.4	9	55.2
4	49	66.0	42	63.9	11	77.8	2	66.5
6	10	76.5	7	75.9	4	80.8	3	63.7
8	32	78.7	20	72.3	10	81.8	5	70.8
10	1	75.0	1	75.0	5	81.2	1	72.0
12	—	—	—	—	4	102.3	3	78.3
14	2	88.0	1	83.0	14	109.0	6	89.3

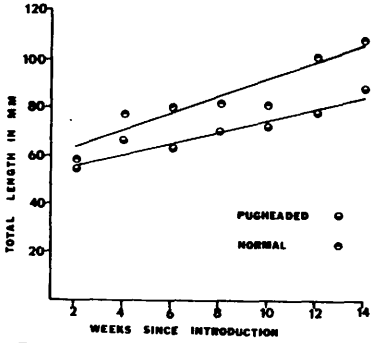

FIGURE 3. Total length of normal and pugheaded striped bass at various times during a 14-week period in 1970.

combined into bi-weekly samples by dividing the sum of the numerical values given for pugheadedness in each bi-weekly sample by the maximum numerical value that was possible for that sample, *i.e.*, the number of individuals in that sample multiplied by 8, the maximum value given to an individual with complete pugheaded characteristics. Reduction in the degree of pugheadedness as the season progresses is graphically illustrated as Figure 4. A linear

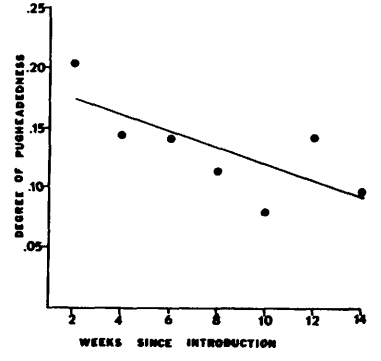

FIGURE 4. The degree of pugheadedness in collections of striped bass made at various times during 14-week periods in 1969 and 1970.

relationship was calculated from these data as $Y = 18.68 - 0.673\ X$, with $r_{xy}^2 = 0.55$, where Y equals weeks since introduction of striped bass. The correlation coefficient, $r_{xy}^2 = 0.74$, is significant at the 5% level, indicating that there are fewer instances of pugheaded characteristics in samples taken later in the season. This reduction could result from a higher mortality rate of pugheaded striped bass, or it could reflect a change in the appearance of pugheaded fish. Apparently this abnormality is irreversible; therefore, it is assumed that the occurrence of fewer pugheaded characteristics in later samples results from a higher mortality rate of pugheaded individuals.

DISCUSSION

Since the occurrence of pugheadedness is relatively high in hatchery-reared striped bass, and since these data indicate that pugheadedness in young-of-the-year striped bass does have a detrimental effect on growth and survival, an effort should be made to control this abnormality. Although the cause of pugheadedness has not been established, Mansuetti (8) has reviewed the theories postulating its cause. He concluded that the condition probably results from a germinal defect in the embryo, and that its course is directed by adverse conditions, especially an oxygen deficiency in the micro-environment of the early developmental stages. The results of this report indicate a need for an investigation to determine causes and control of pugheadedness in hatchery-reared striped bass.

ACKNOWLEDGMENT

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