EFFECTS OF SALINITY ON THE GROWTH OF *PARALICHTHYS LETHOSTIGMA* POSTLARVAE REARED UNDER AQUACULTURE CONDITIONS

Robert R. Stickney
and
David B. White
Skidaway Institute of Oceanography
P. O. Box 13687
Savannah, Georgia 31406

ABSTRACT

As a part of investigations into the feasibility of rearing flounders of the genus *Paralichthys* for use as an aquaculture product, the effects of salinity on the growth of advanced postlarval *Paralichthys lethostigma* were examined. Deubler (1960) and Deubler and White (1962) demonstrated that early postlarvae grew most rapidly at high salinity (30 o/oo). Data from the present study on two groups of advanced post-larvae indicate that these larger fish prefer low salinity water (5 to 15 o/oo). These results indicate that *P. lethostigma* is physiologically adapted to its normal seasonal distribution pattern. The fish are spawned offshore and migrate to inshore waters as postlarvae. They remain inshore during spring through fall and return offshore in winter. While this species is euryhaline, its physiological adaptation to salinity appears to change seasonally and with age, thus more rapid growth of the animal under aquaculture would be expected if the salinity in which it is reared is adjusted to meet optimum physiological requirements.

INTRODUCTION

Studies were initiated in Georgia during 1971 to determine the feasibility of rearing *Paralichthys dentatus* (summer flounder) and *P. lethostigma* (southern flounder) under aquaculture conditions. Initial work centered on the construction of suitable culture facilities and the preparation of a suitable salt water system (White, Stickney, Miller and Knight, 1973). These initial phases of the program were completed prior to collection of postlarval flounder during January and February, 1972.

The feasibility of stripping eggs from gravid female *Paralichthys* sp. and fertilizing the eggs has been demonstrated (Smith and Fahay, 1970), however, the availability of gravid fish appears to be restricted. Historically, postlarval *Paralichthys* sp. have been captured from the estuarine waters of North Carolina (Hildebrand and Cable, 1931; Deubler, 1958; Williams and Deubler, 1968), although a few postlarval *Paralichthys* sp. were obtained for our studies from Georgia estuarine waters during the winter of 1971, and several hundred were collected during the winter, 1973.

One of the major problems facing flounder aquaculture at the present time centers on the fact that postlarval fish are available for only a short period of time during the winter months. Juvenile and adult *Paralichthys* sp. occur along the Georgia coast, but are not readily available in quantities sufficient for even laboratory scale studies.

Previous work with *Paralichthys* sp. has been largely restricted to morphometric studies and studies of natural populations (Ginsburg, 1952; Poole, 1961, 1962, 1964, 1966; Williams and Deubler, 1968), although some laboratory studies into the effects of environmental parameters on growth and survival of *Paralichthys* sp. postlarvae have been undertaken (Deubler, 1960;

Deubler and White, 1962; Deubler and Posner, 1963). In addition, the feeding behavior of *Paralichthys* sp. and other Pleuronectiform fishes have been examined (Stevens, 1930; Olla, Wicklund and Wilk, 1969; Olla, Samet and Studholme, 1972; De Groot, 1970; Stickney, White and Miller, 1973).

More information is presently available on plaice, *Pleuronectes platessa*, than on *Paralichthys* sp. because of the extensive research effort which has been conducted over the past several decades both in Norway and the United Kingdom. For example, studies by Dannevig (1897), Dawes (1931a, 1931b), Shelbourne (1963a, 1963b, 1964), Shelbourne, Riley and Thacker (1963), Riley and Thacker (1963), Ryland and Nichols (1967), Blaxter (1968), Colman (1970), Cowey, Adron and Blair (1970), Cowey, Pope, Adron and Blair (1971), Nordeng and Bratland (1971), Wyatt (1972) and Cowey, Pope, Adron and Blair (1972) have added appreciably to our knowledge of *Pleuronectes platessa*. The work of these and other authors has also given indications as to the difficulty as well as the suitability of using Pleuronectiform fishes as aquaculture candidates. The present paper focuses on the effects of salinity on the growth of advanced postlarval *Paralichthys lethostigma*.

The authors would like to acknowledge the assistance in both the field and laboratory of Messrs. Daniel Perlmutter, Gary Taylor and Rodney Ziegler. This research is a result of studies sponsored by NOAA Office of Sea Grant, Department of Commerce, under Grant No. 1-36009.

MATERIALS AND METHODS

The effects of various salinities on the growth of *Paralichthys lethostigma* were demonstrated by experiments run on two groups of advanced postlarvae. Fish were collected from Bogue Sound near Morehead City, North Carolina, during January, 1973, and from the Skidaway River near Savannah, Georgia, during February, 1973. Specimens of *P. lethostigma* and *P. dentatus* were separated from the remainder of plankton samples obtained at night on rising tides in 1 m diameter plankton nets with 1 mm nylon mesh. Flounders were separated to species on the basis of pegmentation patterns (Deubler, 1958). Following completion of the experiments verifications of the original identifications were made by gill raker and fin ray counts (Hildebrand and Cable, 1931; Deubler, 1958; Gutherz, 1967).

Fishes collected in North Carolina were transported to the laboratory in plastic bags half filled with water and injected with pure oxygen. No mortality was noted during transportation. Skidaway River fish were carried directly to the laboratory after collection and placed in 50 l capacity opaque fiberglass culture tanks. North Carolina fish were placed in similar culture tanks upon receipt at the laboratory. All of the fish were initially maintained at 15 C and 15 o/oo salinity after capture. Beginning approximately one week after their arrival in the laboratory the water temperature was raised 2 C daily until a temperature of 25 C was obtained.

Postlarval flounder were fed twice daily *ad libitum* on living brine shrimp nauplii *(Artemia salina)*. When the fish reached an average weight of approximately 0.1 g, chopped frozen shrimp *(Penaeus setiferus)* was introduced along with the brine shrimp. Brine shrimp nauplii become too small for efficient ingestion as the flounders grow, thus the changeover from living to frozen food represents a critical stage in the culture of these animals. Once the transition from living to frozen food was affected, the salinity experiments were begun.

Approximately six weeks after capture, six *P. lethostigma* from the North Carolina collections were placed in each of eight 16 l capacity opaque fiberglass culture tanks. Duplicate tanks were set up at 5, 15, 25 and 35 o/oo salinity using synthetic sea salts (Instant Ocean, Aquarium Systems, Inc., Eastlake, Ohio).

After one week of acclimation the fish were weighed and the experiment was begun. Fish were initially weighed after one month, and thereafter at two week intervals. Because of the rapid growth of the North Carolina fish the culture tank area was expanded from 16 l to 50 l midway during the experiment.

Following completion of the first experiment, *P. lethostigma* from the Skidaway River were run in a similar experiment. About eight weeks following capture, eight fish were stocked in each of 12 opaque fiberglass tanks of 25 l capacity. Duplicate tanks at salinities of 5, 10, 15, 20, 25 and 30 o/oo were set up for this experiment with salinity control as described above.

Fish in both groups were maintained on a diet of frozen chopped shrimp for the duration of their respective experiments. The experiments were run until the most rapidly growing group approached or exceeded a 500 percent increase in weight over the weight at stocking. Feeding was twice daily, *ad libitum.*

Water temperature and salinity were determined daily. Temperature was controlled by placing the culture tanks in a running water bath. Salinity was adjusted daily as necessary. Ammonia was determined twice weekly through the utilization of an Orion ammonia electrode and Orion digital pH meter. When the ammonia concentration approached 1 part per million, the water was changed. Dissolved oxygen was maintained in excess of 5 mg/l with air stones suspended in each tank.

Light intensity was maintained at approximately 500 foot candles with fluorescent fixtures suspended over the culture tanks. The photoperiod was maintained at eight hours of light and 16 hours darkness daily. No substrates other than the fiberglass tank bottoms were provided, thus the animals were not able to bury as they might be expected to do in nature.

RESULTS

The initial weight of fish stocked from North Carolina was about 0.5 g (Table 1). Ten weeks were required to reach the 500 percent weight increase desired. Survival was greatest (100 percent) in the group maintained at 15 o/oo salinity (Table 1). Final average weights were similar foı fishes reared at 5, 15, and 25 o/oo salinity, while the fish reared at 35 o/oo were considerably smaller at the end of 10 weeks. The growth curves for the North Carolina fish are presented in Figure 1. The figure demonstrates that the growth at all salinities was similar until the final weighing period, when the curve for fish reared at 35 o/oo leveled off, while curves for the other groups continued to increase.

Fish from the Skidaway River were collected from nature about one month later than those from North Carolina; however, when stocked on experiment after eight weeks in the laboratory (as compared with six weeks for the North Carolina fish) the Skidaway River postlarvae averaged only 0.15 g (Table 2). Survival was less than 100 percent in all groups, with the lowest survival levels occurring at the highest salinities (Table 2). A 500 percent weight increase was seen after six weeks in fish reared at the lowest salinity. Growth appeared to be more obviously salinity dependent in fish captured from the Skidaway River than in those from North Carolina. By the end of the experimental period the data were clustered in three groups at 50-10 o/oo, 15-20 o/oo and 25-30 o/oo (Figure 2).

DISCUSSION

More information is presently available on the spawning season and location as regards *P. dentatus* than that of *P. lethostigma*. Since the two species are available as postlarvae during the same period of time in the area from Beaufort, North Carolina to Savannah, Georgia, it may be assumed that their spawning

Table 1. Initial and final average weight and percentage survival after 10 weeks of *Paralichthys lethostigma* postlarvae from North Carolina reared at various salinities.

Salinity (o/oo)	Initial average weight (g)	Final average weight (g)	Percentage survival
5	0.53	2.9	83.3
15	0.47	2.7	100.0
25	0.48	2.6	58.3
35	0.47	1.7	66.7

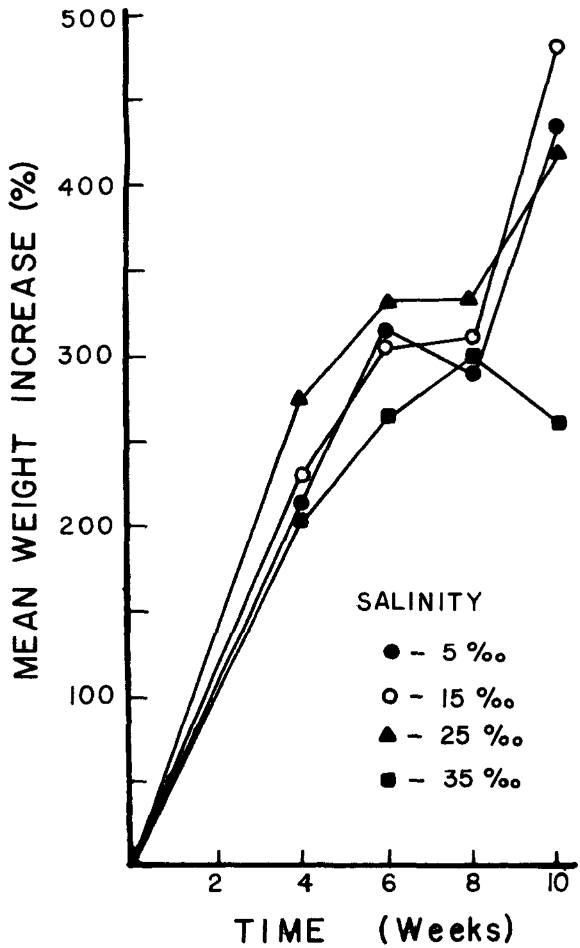

Figure 1. Mean weight increase (percent) of *Paralichthys lethostigma* postlarvae from North Carolina versus time (weeks).

Table 2. Initial and final average weight and percentage survival after six weeks of *Paralichthys lethostigma* postlarvae from Georgia reared at various salinities.

Salinity (o/oo)	Initial average weight (g)	Final average weight (g)	Percentage survival
5	0.15	0.89	87.5
10	0.15	0.82	87.5
15	0.14	0.60	87.5
20	0.16	0.70	87.5
25	0.14	0.36	68.8
30	0.14	0.39	75.0

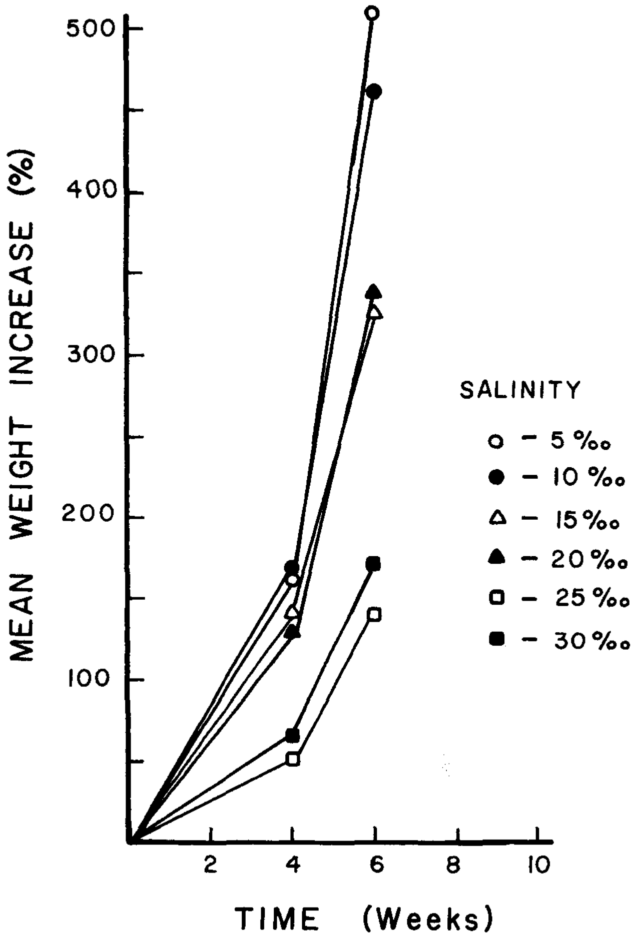

Figure 2. Mean weight increase (percent) of *Paralichthys lethostigma* postlarvae from Georgia versus time (weeks).

sites and seasons largely overlap. The spawning season of *P. dentatus* is during the fall and winter (Ginsberg, 1952). Gravid fish have been obtained from depths between 25 and 40 m (Smith and Fahay, 1970). Postlarvae of both species are found inshore during January and February; however, the absolute ages of these fish have not been determined. Smith and Fahay (1970) reared larvae for 96 hours after hatching and have provided drawings of these plus larvae and postlarvae of greater, but unspecified age since the latter were obtained from plankton tows and could not be precisely aged. The gravid female sapwned by Smith and Fahay (1970) was captured during October off New Jersey. If fish spawned in that area come inshore off the Carolinas and Georgia, they might be as much as three or four months old when caught during January and February. Gravid *Paralichthys* sp. have not been collected along the Georgia coast, but since the postlarvae appear inshore during the same period of the year throughout their range, it is probable that the spawning season varies little along the Atlantic coast of the United States.

The discussion as to the actual age of postlarval fishes collected in various areas becomes important in relation to the data presented above. Postlarvae from North Carolina were somewhat larger when stocked than those from Georgia waters although the North Carolina fish had been maintained in the laboratory longer than those from Georgia. Fish from the two areas were of identical size when captured. The two groups of fish may represent geographically distinct populations since their growth rates were shown to be dissimilar not only in this experiment, but also when groups of fish from the two areas were reared in running water culture over extended periods of time. After five months North Carolina *P. lethostigma* weighed an average of 28 g while those from Georgia weighed only 15 g average.

Deubler (1960) demonstrated that *P. lethostigma* postlarvae are able to survive and grow at salinities ranging from 0 to 30 o/oo without prior acclimation. His studies also showed that growth rate increased with increasing salinity up to 30 o/oo. A second paper (Deubler and White, 1962) demonstrated the same relationships for *P. dentatus.*

The data presented above do not mirror those of the earlier work by Deubler (1960) and Deubler and White (1962). Our first experiment (Table 1, Figure 1) showed that little variability in growth rate occurred with salinity in the range 5-25 o/oo, although there was a slight trend toward more rapid growth with reduced salinity. The fact that growth leveled off after eight weeks in fish reared at 35 o/oo may be significant. A greater departure from the data of Deubler (1960) occurred in our experiment with Georgia *P. lethostigma* postlarvae. In the second experiment there was a definite trend toward increased growth rate with reduced salinity (Table 2, Figure 2). The fish used by Deubler were less than 100 mg in average weight following exposure to the various salinities, whereas the fish used in our experiments were initially heavier than 100 mg in both cases. Hickman (1968) demonstrated the occurrence of annual cycles in the average rate of glomerular filtration in *P. lethostigma* which were held at constant salinity for extended periods of time. Hickman's data support the hypothesis that *P. lethostigma* becomes physiologically adapted to waters of different salinities depending upon season of the year. The rate of glomerular filtration, as pointed out by Hickman, corresponded with the behavioral characteristics of the adult flounders which seek high salinity offshore water in the winter and come inshore during the rest of the year.

Postlarval *P. lethostigma* also seek lower salinity water during the spring, summer and fall. If the postlarvae are physiologically adapted to their migration pattern, they should be less stressed by lower salinity water shortly after their arrival inshore than by water of salinities in excess of those which they would seek in nature. Extending this thesis one step further, postlarvae which had just arrived inshore might be better suited to high salinity water (e.g., the fish studied by Deubler, 1960), while those which had been maintained in lower salinity water longer may have become physiologically adapted to inshore conditions.

It might be expected that the larger North Carolina fish would have shown a greater degree of adaptability toward low salinity water than the small Georgia fish. Among the possibilities which might explain this discrepancy are: 1) the Georgia fish may be older, although smaller, than those from North Carolina, 2) there may be physiological differences between the two geographically separated groups or, 3) the 100 to 500 mg fish may be more sensitive to salinity change than those larger than 500 mg.

Insofar as implications on aquaculture are concerned, it appears as though *Paralichthys lethostigma* postlarvae should be maintained in relatively high salinity water (25-30 o/oo) until they reach about 100 mg. At that time they can be transferred to lower salinity (5-15 o/oo). In the culture system currently in use at our institution, normal salinities fluctuate generally between 15 and 25 o/oo with lower salinity water often occurring during the spring and summer. Augmentation of natural salinity by addition of synthetic sea salts would only be necessary during the first few weeks of culture.

Some mortality was noted in fish from each salinity during both experiments with one exception (Tables 1 and 2). There did not seem to be a great deal of mortality associated with any particular salinity, although mortality was generally higher at the higher salinities in both studies. Water quality, aside from salinity, was nearly identical in all tanks during both experiments.

In conclusion, *Paralichthys lethostigma* is a euryhaline fish but shows some salinity preference depending upon season of the year. While this species is able to live and grow at various salinities, its growth rate can be improved if the proper salinity regime is applied. Since this is a dynamic situation, the advisability of changing salinity with time must lie with the individual fish culturist and the flexibility available to him in terms of his culture system and the number of animals with which he is working.

LITERATURE CITED

Blaxter, J. H. S. 1968. Light intensity, vision, and feeding in young plaice. J. Exp. Mar. Biol. Ecol. 2:293-307.

Colman, J. A. 1970. On the efficiency of food conversion of young plaice (*Pleuronectes platessa*). J. Mar. Biol. Assoc. U. K. 50:113-120.

Cowey, C. B., J. Adron and A. Blair. 1970. Studies on the nutrition of marine flatfish. The essential amino acid requirements of plaice and sole. J. Mar. Biol. Assoc. U. K. 50:87-95.

Cowey, C. B., J. A. Pope, J. W. Adron and A. Blair. 1971. Studies on the nutrition of marine flatfish. Growth of the plaice *Pleuronectes platessa* on diets containing proteins derived from plants and other sources. Mar. Biol. 10:145-153.

Cowey, C. B., J. A. Pope, J. W. Adron and A. Blair. 1972. Studies on the nutrition of marine flatfish. The protein requirement of plaice (*Pleuronectes platessa*). Br. J. Nutr. 28:447-456.

Dannevig, H. 1897. On the rearing of the larval and post-larval stages of the plaice and other flatfishes. Fish. Bd. Scotland. 15th Ann. Report, 1896. Part III: 175-193.

Dawes, B. 1931a. Growth and maintenance in the plaice (*Pleuronectes platessa* L.). Part I. J. Mar. Biol. Assoc. U. K. 17:103-172.

Dawes, B. 1931b. Growth and maintenance in the plaice (*P. platessa*, L.). Part II. J. Mar. Biol. Assoc. U. K. 17:877-947.

De Groot, S. J. 1970. Some notes on an ambient behavior of the Greenland halibut. *Reinhardtius hippoglossoides* (Walb.) Pisces: Pleuronectiformes. J. Fish. Biol. 2:275-279.

Deubler, E. E. 1958. A comparative study of the postlarvae of three flounders (*Paralichthys*) in North Carolina. Copeia, 1958:112-116.

Deubler, E. E. 1960. Salinity as a factor in the control of growth and survival of post-larvae of the southern flounder, *Paralichthys lethostigma*. Bull. Mar. Sci. Gulf & Carib. 10:338-345.

Deubler, E. E., and J. C. White. 1962. Influence of salinity on growth of post-larvae of the summer flounder, *Paralichthys dentatus*. Copeia, 1962:468-469.

Deubler, E. E. and G. S. Posner. 1963. Response of postlarval flounders, *Paralichthys lethostigma*, to water of low oxygen concentrations. Copeia, 1963:312-317.

Ginsburg, I. 1952. Flounders of the genus *Paralichthys* and related genera in American waters. Fish. Bull. 52:276-351.

Gutherz, E. J. 1967. Field guide to the flatfishes of the family Bothidae in the Western North Atlantic. U.S. Dept. of the Interior, Fish and Wildlife Serv. Circular No. 263. 47 p.

Hickman, C. P. 1968. Glomerular filration and urine flow in the euryhaline southern flounder, *Paralichthys lethostigma*, in seawater. Can. J. Zool. 46:427-437.

Hildebrand, S. F. and L. E. Cable. 1931. Development and life history of fourteen teleostean fishes at Beaufort, North Carolina. U.S. Bureau of Fisheries Bulletin, 46:383-488.

Nordeng, H. and P. Bratland. 1971. Feeding of plaice (*Pleuronectes platessa* L.) and cod (*Gadus morhua* L.) larvae. J. Cons. Int. Explor. Mer. 34:51-57.

Olla, B. L., R. Wicklund and S. Wilk. 1969. Behavior of winter flounder in a natural habitat. Trans. Am. Fish. Soc. 98:717-720.

Olla, B. L., C. E. Samet, and A. L. Studholme. 1972. Activity and feeding behavior of the summer flounder (*Paralichthys dentatus*) under controlled laboratory conditions. Fish. Bull. 70:1127-1136.

Poole, J. C. 1961. Age and growth of the fluke in Great South Bay and their significance to the sport fishery. New York Fish and Game J. 8:1-18.

Poole, J. C. 1962. The fluke population of Great South Bay in relation to the sport fishery. New York Fish and Game J. 9:93-117.

Poole, J. C. 1964. Feeding habits of the summer flounder in Great South Bay. New York Fish and Game J. 11:28-34.

Poole, J. C. 1966. A review of research concerning summer flounder and needs for further study. New York Fish and Game J. 13:226-231.

Riley, J. D. and G. T. Thacker. 1963. Marine fish culture in Britain. III. Plaice (*Pleuronectes platessa* L.) rearing in closed circulation at Lowestoft, 1961. J. Cons. Int. Explor. Mer. 28:80-90.

Ryland, J. S. and J. H. Nichols. 1967. Effect of temperature on the efficiency of growth of plaice prolarvae. Nature, 214:529-530.

Shelbourne, J. E. 1963a. Marine fish culture in Britain. II. A plaice rearing experiment at Port Erin, Isle of Man, during 1960, in open sea water circulation. J. Cons. Int. Explor. Mer. 28:70-79.

Shelbourne, J. E. 1963b. Marine fish culture in Britain. IV. High survivals of metamorphosed plaice during salinity experiments in open circulation at Port Erin, Isle of Man, 1961. J. Cons. Int. Explor. Mer. 28:246-261.

Shelbourne, J. E. 1964. The artificial propagation of marine fish. Adv. Mar. Biol. 2:1-83.

Shelbourne, J. E., J. D. Riley and G. T. Thacker. 1963. Marine fish culture in Britain. I. Plaice rearing in closed circulation at Lowestoft, 1957-1960. J. Cons. Int. Explor. Mer. 28:50-69.
Smith, W. G. and M. P. Fahay. 1970. Description of eggs and larvae of the summer flounder, *Paralichthys dentatus*. Bureau of Sport Fisheries and Wild. Research Report 75. 21 p.
Stevens, G. A. 1930. Bottom fauna and the food of fishes. J. Mar. Biol. Assoc. U. K. 16:677-698.
Stickney, R. R., D. B. White and D. Miller. 1973. Observations of fin use in relation to feeding and resting behavior in flatfishes (Pleuronectiformes). Copeia, 1973:154-156.
White, D. B., R. R. Stickney, D. Miller and L. H. Knight. 1973. Sea water system for aquaculture of estuarine organisms at the Skidaway Institute of Oceanography. Georgia Marine Science Center Technical Report Series No. 73-1. 18 p.
Williams, A. B. and E. E. Deubler. 1968. A ten-year study of meroplankton in North Carolina estuaries: assessment of environmental factors and sampling success among Bothid flounders and Penaeid shrimps. Ches. Sci. 9:27-41.
Wyatt, T. 1972. Some effects of food density on the growth and behaviour of plaice larvae. Mar. Biol. 14:210-216.

EFFECTS OF FEEDING REGIMES AND SOURCES OF FISH ON PRODUCTION OF ADVANCE FINGERLING STRIPED BASS

by
*William C. Reeves**
Division of Game and Fish
Alabama Department of Conservation and Natural Resources
Montgomery, Alabama

ABSTRACT

Research on the production of advanced fingerling striped bass, *Morone saxatilis* (Walbaum), was conducted in ponds at Auburn University Fisheries Research Unit in the summer and winter of 1971. Investigations were conducted to determine the effects of two feeding regimes and two sources of small fingerlings on the survival and production of advanced fingerling striped bass.

Fingerling striped bass from the Cooper River, South Carolina, and the Savannah River, Georgia, were studied. Higher survival and greater production were obtained from the Cooper River fish. One feeding regime fed hourly, 15 hours per day; the other fed at 3-hour intervals, 15 hours per day. The two feeding regimes were not significantly different.

*This paper is based on a thesis submitted to the Graduate Faculty of Auburn University in partial fulfillment of requirements for the Degree of Master of Science in Fishery Management. This research was funded in part by Anadromous Fish Project (71), Contract Grant No. 14-17-0002-572.