LITERATURE CITED

Buntz, Jon, and Charles S. Manooch, III. 1968. *Tilapia aurea* (Steindacher), a rapidly spreading exotic in south central Florida. Proc. Ann, Conf. S. E. Game and Fish Comm., 22:495-501.

Crittenden, Edward, 1962. Status of *Tilapia nilotica* Linneaus in Florida. Proc. Ann. Conf. S. E. Game and Fish Comm., 16: 257-262.

McBay, Luther G., 1961. The Biology of *Tilapia nilotica* Linneaus. Proc. Ann. Conf. S. E. Game and Fish Comm., 15: 208-218.

Smith-Vaniz, William F., 1968. Freshwater fishes of Alabama. Auburn University, Agr. Exp. Sta., Auburn, Alabama.

EFFECTS OF SALINITY ON GROWTH AND SURVIVAL OF CHANNEL CATFISH, Ictalurus punctatus *

By KENNETH O. ALLEN and JAMES W. AVAULT, JR

School of Forestry and Wildlife Management
Louisiana State University
Baton Rouge, Louisiana

ABSTRACT

Laboratory tests were conducted to determine the effect of salinity on growth and survival of channel catfish, *Ictalurus punctatus*.

Three-day old or older eggs tolerated up to 16 ppt total salinity. However, at the time of hatching there was a sharp drop in tolerance to about 8 ppt. This level of tolerance was maintained during the period of yolk absorption. Following yolk absorption there was an increase in tolerance to about 9 or 10 ppt.

By five months of age tolerance had increased to 11 ppt and to 12 ppt by six months. The level of tolerance was about the same at 11-14 months.

Nine days acclimation to 5 ppt increased growth and food conversion slightly but did not increase survival. Forty days of acclimation to 5 ppt increased tolerance about 0.5 ppt. Fish failed to maintain themselves at salinities greater than 12 ppt, even with extended acclimation to 10 ppt salinity.

In long-term studies, starting at an age of 42 days and continuing through an age of 148 days, fingerlings in freshwater had the best indexes for food consumption, growth, food conversion and survival. Fingerlings in 5 ppt salinity did almost as well. Fingerlings in 10 ppt salinity were a poor third.

In long-term studies with 11 through 14 month-old yearlings, when fish were acclimated to 5 ppt, indexes were similar at all test salinities of 0 ppt through 11 ppt. Fish acclimated to 10 ppt gave similar results at 0 ppt through 12 ppt.

INTRODUCTION

Vast areas of marshland along the coast of Louisiana and other states offer a great potential for culture of fish. Perry and Avault (1968, 1969) reported that channel (*Ictalurus punctatus*), blue (*I. furcatus*), and white catfish (*I. catus*) were successfully grown in brackish water. Since salinity in these areas may vary widely, specific salinity tolerances are needed for each species of fish being considered for culture.

* This study was supported by the National Science Foundation through the Sea Grant Program, by the Louisiana Wild Life and Fisheries Commission and by the L. S. U. Agricultural Experiment Station.

This study was designed to delineate specific effects of salinity level on channel catfish eggs, fry, fingerlings, and yearlings under laboratory conditions. Eggs and fry were tested for survival. Fingerlings and yearlings were tested for food consumption, growth, food conversion, and survival.

Three lots of fish, all originating from fresh waters were studied over a two-year period.

MATERIALS AND METHODS

Eggs and yolk fry

In 1968 a spawn estimated to be one day old was obtained from a pond near Baton Rouge, Louisiana. The spawn was divided into masses of approximately 50 eggs each. One egg mass was placed in each of 19-liter aquaria at salinities of 0 (control), 5, 9, 10, 11, 12, 13, and 14 ppt (two replicates each). The eggs were suspended in a fine-mesh seine. Air stones, lying on the bottom of each aquarium, provided air from squarium pumps. Air was permitted to bubble around the egg mass. Extra eggs from the remainder of the spawn were hatched in other acquaria for future experiments.

Eggs were checked daily. From gross appearance they were designated as healthy (o) or dead or dying eggs (x). Dead egg masses were replaced with fresh egg masses from the supply of extra eggs.

In 1969, a two-day-old spawn was obtained from Anderson Farms, Yazoo City, Mississippi. Experiments with these eggs were conducted as outlined previously, except salinities of 0, 2.5, 5.0, 7.5, 10.0, 12.5, 15.0, and 17.5 ppt. (two replicates each) were used.

Fry

Studies were continued with fry obtained from the egg experiments. General observations and specific studies were conducted with lots hatched and maintained at 0, 5, and 8-10 ppt.

Two-day-old Yazoo City fry hatched in fresh water were tested in 19-liter aquaria for effects of salinity on survival. Salinities of 0, 2, 4, 6, 8, 10, 12, and 14 ppt (two replicates each) were used. Each aquarium contained 10 fish. Mortality was checked daily for 11 days.

Five-day-old Baton Rouge fry were tested in 3.8 liter jars for effects of salinity and prior acclimation on survival. Fry hatched at 0 and 5 ppt salinity were each tested at salinities of 0, 5, 9, 10, 11, 12, 13, and 14 ppt (unreplicated). Each jar contained 10 fish. Mortality was checked daily for six days.

Fingerlings

Forty-day-old Baton Rouge fingerlings were tested for effects of salinity and prior acclimation on growth and survival. Fish that had been hatched and reared in 0 and 5 ppt were each tested in 19-liter aquaria at salinities of 9, 10, 11, 12, 13, and 14 ppt (unreplicated). One control at each acclimation level was used (o and 5 ppt). Each aquarium contained 10 fish. Fish were measured for total length initially and at termination of the experiment. Mortality was checked daily for 22 days.

Beginning at an age of 42 days and continuing through an age of 148 days, a long-term growth and survival study was conducted. Fish from lots that had been hatched and reared at 0, 5, and 8-10 ppt were placed in 19-liter aquaria at salinities of 0, 5, and 10 ppt respectively. Two replicates at each salinity were maintained. Each aquarium contained 30 to 35 fish. Fish were measured for total length initially and after 4, 47, 74, and 106 days. Mortailties were recorded daily.

In addition to the two lots of fish previously discussed, a third lot of fish was used in the fingerling studies. Four-month-old fingerlings were obtained in 1967 from the Meridian, Mississippi National Fish Hatchery. At an age of five months these fingerlings were tested for effects of salinity and prior acclimation on food consumption, growth, food conversion, and survival. Fish acclimated to 0 ppt and 5 ppt for

9 days were placed in opposite sides of 38-liter aquaria that contained a glass partition. This partition divided the container into two equal halves and prevented the exchange of fish between the two halves. However, it was not water tight and there was an exchange of water along the sides and bottom. Thus fish from two different acclimations could be kept separate but tested in a common medium. Five fish from 0 ppt acclimation were placed in one side and five fish from 5 ppt acclimation were placed in the other side. The fish were tested for 22 days at salinities of 0, 4, 8, 12, 14, 15, and 16 ppt (unreplicated). Mortalities were recorded daily. Determination of food consumption, growth, and food conversion will be discussed separately.

One month after the preceeding experiment, samples of fish from the same two lots were again tested. They were now 6 months of age and the fish at 5 ppt had now been acclimated for 40 days. The chief purpose of this test was to see if additional acclimation time affected the results. The experiment was conducted similarly to the preceeding one, except that a salinity of 13 ppt was added and levels of 14, 15 and 16 ppt were not used.

The survival and growth of 5-month-old Baton Rouge fingerlings were tested for 22 days at salinities of 12 ppt (four replicates) two were tested for 2 days at salinities of 12 ppt (four replicates) and 13 ppt. (two replicates). Each aquarium contained five fish.

Yearlings

In 1968, Meridian fish now 11 months old were tested for long-term effects of salinity and prior acclimation on food consumption, growth, food conversion, and survival. Methods were similar to earlier tests with Meridian fish at 5 and 6 months of age. However, fish were tested that had been acclimated to either 5 or 10 ppt for 154 days, to see if additional acclimation affected results. Salinities of 8, 9, 10, 11, 12, 13, and 14 ppt (unreplicated) were used. Fish acclimated to freshwater were maintained as controls in two aquaria at 0 ppt. This experiment was conducted for 45 days with all the test salinities and in addition, salinities of 11-14 ppt were tested an additional 71 days.

Determination of food consumption, growth, and food conversion

Diet for all fish up to 5 months of age consisted of a commercial trout food. In all of the tests involving fish of 5 months or greater age, commercial floating catfish pellets were fed. The daily diet consisted of one pellet per fish, but occasionally when the fish were feeding well, more pellets were offered. The number of pellets placed in the water was recorded and then approximately one-half hour later the uneaten pellets were removed and the number recorded. The pellets were fairly uniform in size and from sample counts the average weight of each pellet was determined to be 0.087 grams.

Food consumed was determined by adding all pellets offered, subtracting pellets removed, and multiplying the answer by 0.087.

Weight gain or loss was determined from weights obtained at the beginning of experiments, at intervals during the experiments, and at the conclusion of the experiments. Food conversion was determined by dividing the food fed by the weight gain.

Salinity and other chemical-physical factors

Water for the experiments was prepared by diluting sea water from Grand Isle, Louisiana with tap water. Salinity was determined by the mercuric nitrate method (American Public Health Association, Inc. *et al.*, 1965, pp. 370-371).

The dissolved oxygen was usually 5.0 to 6.0 ppm but extremes of 3.8 to 7.5 were recorded. Carbon dioxide was never present in more than trace amounts. The pH ranged from 7.9 to 8.1. Total hardness for the fresh water controls averaged about 40 ppm. Temperature in egg and fry studies ranged from 23.5° to 25.0°C. During the fingerling studies it usually ranged from 23.5° to 25.0° but extremes of 19.0° to 27.0° were recorded.

RESULTS

Eggs and yolk fry

Very similar results were obtained with the two lots of eggs (Tables 1 and 2). Eggs apparently increased in tolerance as they aged until the 3rd day, at which time the tolerance leveled off at about 16 ppt. However, upon hatching there was a drastic reduction in tolerance to about 8 ppt. Close observation revealed this mortality started as soon as the egg membrane ruptured.

Fry

After yolk absorption there appeared to be a small increase in tolerance to about 9 or 10 ppt (Tables 3 and 4). One or more days were usually required for salinities of 10 through 12 ppt to kill fry. However, only 8 to 16 hours were required for a salinity of 14 ppt to kill fry. There was no significant difference in tolerance of fry acclimated to fresh water and 5 ppt salinity.

Fingerlings

There did not appear to be an appreciable increase in tolerance from post-yolk-absorption Tables 3 and 4, to 40 or 60 days of age (Tables 5 and 6). In the study utilizing Baton Rouge fish, 42 to 148 days of age (Table 6), fish in fresh water had the best growth and survival. Fish at 5 ppt did not do as well at first, but by the termination of the experiment had practically caught the 0 ppt fish in growth. Fish at 10 ppt had poor growth and very poor survival. A gill infestation of a marine dinoflagellate tentatively identified as *Oodenium* sp. did, however, adversely effect growth and survival of fish in the 5 and 10 ppt aquaria before it was controlled.

In the experiment with 5-month-old Meridian fish, similar food consumption, growth, food conversion, and survival were obtained at 0, 4, and 8 ppt (Figure 1). Fish acclimated 9 days to 5 ppt achieved slightly better growth and food conversion than fish acclimated to fresh water. Results indicated the fish could not survive indefinitely at 12 ppt or greater salinities. The limited tests with Baton Rouge fish at 5 months of age (Table 7) indicated their tolerance was similar to the Meridian fish.

At 6 months of age the Meridian fish had increased their tolerance and were able to survive and grow slowly at 12 ppt (Figure 2). Food consumption, growth, and food conversion indexes were best for fish at 4 ppt, followed by 8 ppt, and then 0 ppt. Fish given 40 days of acclimation to 5 ppt did better than fish acclimated to fresh water. Neither group were able to maintain themselves at 13 ppt.

Yearlings

Eleven-fourteen months old Meridian fish acclimated to 5 ppt, had about the same tolerance (Table 8) as they did at 6 months, acclimated to 5 ppt. Fish acclimated to 10 ppt had a slightly greater tolerance, but again the fish could not maintain themselves at salinities greater than 12 ppt. In this test, fish in fresh water controls did slightly better than fish in 8-12 ppt water.

In most of the tests with fingerlings and yearlings, it was noted that fish at the higher salinities were more sluggish and easily netted. This was true even with fish that attained good growth and survival.

DISCUSSION

This study agrees with field studies of Perry and Avault (1968, 1969) that channel catfish can be grown in brackish water. In the present study older fingerlings and yearlings at salinities up to 11 or 12 ppt had food consumption, growth, food conversion, and survival comparable to fresh water controls.

Unanswered is the question of whether or not channel catfish will reproduce in brackish water. This study did indicate that 3 day-old-plus

eggs had a tolerance of about 16 ppt. At the time of hatching, however, there was a drop in tolerance to about 8 ppt. After yolk absorption the tolerance increased to about 9-10 ppt, leveled off and then increased again at about 5-6 months of age to about 11-12 ppt. Beyond 6 months there did not appear to be a further increase in tolerance.

Adaption to changes in salinity appeared to be very slow. Fingerlings acclimated to 5 ppt salinity for 9 days did not have a greater tolerance than did fingerlings acclimated to fresh water. Forty days of acclimation to 5 ppt salinity, however, did increase tolerance. On an average, longterm acclimation to brackish water increased tolerance about 0.5 ppt. It does not appear that channel catfish up to 14 months of age can be indefinitely maintained at salinities greater than 12 ppt, even with increased acclimation time. General effects of age and acclimation on tolerance are schematically shown in Figure 3.

These studies indicate that a potential catfish farmer with waters less than 8 ppt salinity could start with eggs, fry, or fingerlings. In waters of salinities of 8-12 ppt he would have to start with older fingerlings or yearlings. Waters in excess of 12 ppt would not be suitable for channel catfish culture.

Perry and Avault (1968, 1969) noted substantial losses from predation in brackish water ponds. Sluggishness of fish as noted in the present study could account, in part, for this loss. In aquaria, this sluggishness did not appear to adversely affect the fish. However, in a natural or semi-natural environment this could be an important factor.

All three lots of fish used in this study originated from fresh water populations. Channel catfish native to brackish water may have a greater tolerance to high salinities. Also, catfish with higher tolerance could possibly be developed genetically.

ACKNOWLEDGMENTS

The authors wish to express their appreciation to managers of Anderson Farms, Yazoo City, Mississippi and National Fish Hatchery, Meridian, Mississippi for furnishing eggs and fish used in this study.

LITERATURE CITED

American Public Health Association *et al.* 1965. Standard methods for the examination of water and wastewater. 12th ed., American Public Health Association, New York, N. Y. 769 p.

Perry, W. Guthrie, Jr. and James W. Avault, Jr. 1968. Preliminary experiment on the culture of blue, channel, and white catfish in brackish water ponds. Proceeding 22nd Annual Conference Southeastern Association of Game and Fish Commissioners, 22:397-406.

————. 1969. Experiments on the culture of blue, channel, and white catfish in brackish water ponds. Proceedings 23rd Annual Conference Southeastern Association of Game and Fish Commissioners, 1969 (in press).

TABLE 1. Effect of salinity on survival of Baton Rouge channel catfish eggs and larvae.

Salinity level (ppt)	Mortality 2 days	3 days	4 days	5 days	6 days	7 days	8 days*	9 days
0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	X
9	0	0	0	0	0	0	0	X
10	X	0	0	0	0	0	0	X
10	X	0	0	0	0	0	0	X
11	X	0	0	0	0	0	0	X
11	X	0	0	0	0	0	0	X
12	X	0	0	0	0	0	0	X
12	X	0	0	0	0	0	0	X
13	X	0	0	0	0	0	0	X
13	X	0	0	0	0	0	0	X
14	X	0	0	0	0	0	0	X
14	X	0	0	0	0	0	0	X

Eggs were one day old at start of experiment.
Dead egg masses were replaced with fresh egg masses.
0=2% or less mortality
X=complete mortality

* Eggs started hatching on 8th day and hatching was completed during the 9th day.

TABLE 2. Effect of salinity or survival of Yazoo City channel catfish eggs and larvae.

Salinity level (ppt)	Mortality 3 days	4 days	5 days	6 days	7 days	8 days	9 days*	10 days
0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0
2.5	0	0	0	0	0	0	0	0
2.5	0	0	0	0	0	0	0	0
5.0	0	0	0	0	0	0	0	0
5.0	0	0	0	0	0	0	0	0
7.5	0	0	0	0	0	0	0	0
7.5	0	0	0	0	0	0	0	0
10.0	0	0	0	0	X	--	--	--
10.0	0	0	0	0	X	--	--	--
12.5	0	0	0	0	X	--	--	--
12.5	0	0	0	0	X	--	--	--
15.0	0	0	0	0	X	--	--	--
15.0	0	0	0	0	X	--	--	--
17.5	X	--	--	--	--	--	--	--
17.5	X	--	--	--	--	--	--	--

Eggs were two days old at start of experiment.
0=2% or less mortality
X=total mortality

* Eggs started hatching on 7th day and hatching was completed during the 8th day.

TABLE 3. Effect of salinity on survival of 2-day-old Yazoo City channel catfish fry hatched in fresh water.

Salinity level (ppt)	Percent survival 1 day	2 days	4 days	6 days	11 days
0	100	100	100	100	100
0	100	100	100	100	100
2	100	100	100	100	100
2	100	100	100	100	90
4	100	90	90	90	90
4	100	100	100	100	100
6	100	100	100	100	100
6	100	100	100	100	100
8	100	100	100	80	60
8	100	100	100	100	100
10	100	100	60	40	30
10	90	90	80	60	50
12	90	0	--	--	--
12	90	30	--	--	--
14	0	--	--	--	--
14	0	--	--	--	--

Ten fish were tested in each 19-liter aquarium.

TABLE 4. Effect of salinity on survival of 5-day-old Baton Rouge channel catfish fry hatched and held in 0 ppt and 5 ppt salinity

Salinity level (ppt)	Acclimation level (ppt)	Percent survival 1 day	2 days	4 days	6 days
0 (control)	0	100	100	100	100
0 (control)	0	100	100	100	100
5 (control)	5	100	100	100	100
5 (control)	5	100	100	100	100
9	0	100	100	100	100
9	5	100	100	100	100
10	0	90	70	70	70
10	5	80	80	70	70
11	0	100	100	100	10
11	5	80	80	80	80
12	0	70	20	10	0
12	5	70	60	10	0
13	0	0	0	0	0
13	5	70	40	0	0
14	0	0	0	0	0
14	5	0	0	0	0

Ten fish were tested in each 3.8 liter jar.

TABLE 5. Effect of salinity on growth and survival of 40-day-old Baton Rouge channel catfish fingerlings hatched and reared at 0 ppt and 5 ppt salinity

Salinity level (ppt)	Acclimation level (ppt)	Percent survival						Average increase in-length (mm)	Average percent increase in length
		1 days	2 days	4 days	6 days	17 days	22 days		
0 (control)	0	100	100	100	100	100	100	3.44	14.6
5 (control)	5	100	100	100	100	100	100	6.00	26.6
9	0	100	60	50	50	40	40	2.75	11.7
9	5	100	80	70	60	60	60	4.66	20.7
10	0	100	50	30	0*	--	--	--	--
10	5	100	100	80	80*	10	0	--	--
11	0	80	70	60	60	50	0	--	--
11	5	80	80	80	80	70	70	2.50	11.1
12	0	30	20	20	20	0	--	--	--
12	5	30	20	0	--	--	--	--	--
13	0	30	0	--	--	--	--	--	--
13	5	40	10	0	--	--	--	--	--
14	0	0	--	--	--	--	--	--	--
14	5	0	--	--	--	--	--	--	--

Ten fish were tested in each 19-liter aquarium.

* Water fouling was suspected in both these lots.

TABLE 6. Effect of salinities of 0, 5, and 10 ppt on growth and survival of Baton Rouge channel catfish fingerlings (Tested from age 42 days to 148 days)

Salinity level (ppt)	Percent survival				Average total length				Average increase in length (mm)
	4 days	48 days	74* days	106 days	4 days	48 days	74* days	106 days	
0	91.2	70.6	65.2	65.2	23.5	35.4	41.9	47.5	27.5
0	68.6	68.6	68.6	68.6	23.2	35.4	41.7	47.5	27.5
5	90.0	83.6	>		22.5	32.8	>		
			41.4	41.4			39.8	46.7	26.7
5	74.3	69.0			22.3	33.3			
10	23.5	12.7	4.1	>	21.7	28.0	>		
				1.7			32.6	35.5	15.5
10	26.7	16.7	2.8		21.7	27.8			

> Indicates fish consolidated into one aquarium.

Thirty to thirty-five fish were tested in each 19-liter aquarium.

TABLE 7. Effect of salinities of 12 and 13 ppt on weight loss and survival of 5-months-old Baton Rouge channel catfish fingerlings hatched and reared in 0 ppt and 5 ppt salinity

Salinity level (ppt)	Acclimation level (ppt)	Percent survival						Percent weight loss in 22 days	Percent weight loss per day
		1 day	2 days	4 days	6 days	17 days	22 days		
12	0	100	100	100	100	100	100	4,96	0.22
12	0	100	100	100	100	100	100	15.52	0.71
12	0	100	100	100	100	100	100	5.01	0.23
12	0	100	100	100	100	100	100	8.39	0.38
13	0	100	100	80	80	80	0	--	--
13	5	100	100	100	100	100	80	16.78	0.76

Five fish were tested in each 38-liter aquarium.

* During the period between 74 and 106 days a marine dinoflagellate, Oodenium sp., caused mortalities to the 5 and 10 ppt lots before it was controlled. This epizootic probably affected growth temporarily.

TABLE 8. Effect of salinity on food consumption, growth, conversion and survival of Meridian channel catfish yearlings acclimated to 5 and 10 ppt for 154 days.
(Tested from age 11-months to 15-months.)

Salinity level (ppt)	Acclimation level (ppt)	Percent survival 45 days	90 days	116 days	Food consumed (grams)	Food consumed per fish per day (grams)	Overall weight gain or loss (grams)	Percent increase or decrease in weight 45 days	90 days	116 days	Food conversion
0	0	100*	--	--	19.57	.081	11.9	25.7	--	--	1.64
0	0	100	0†	--	26.70	.088	16.5	35.6	--	--	1.52
8	5	100*	--	--	19.32	.086	11.3	27.0	--	--	1.71
8	10	100*	--	--	19.22	.085	12.0	29.0	--	--	1.60
9	5	100*	--	--	19.75	.088	10.1	22.7	--	--	1.96
9	10	100*	--	--	19.75	.088	8.3	20.1	--	--	2.38
10	5	100*	--	--	19.58	.087	9.3	21.6	--	--	2.11
10	10	100*	--	--	19.58	.088	7.6	17.6	--	--	2.61
11	5	100	80	80	38.92	.078	17.6	23.1	46.5	46.6	2.21
11	10	100	100	100	40.09	.080	21.6	28.6	52.5	52.9	1.85
12	5	80	20	20	24.36	.061	-1.3	4.3	-2.7	-3.0	0
12	10	100	100	80	35.40	.065	18.4	25.3	44.1	39.6	1.92
13	5	60	20	20	16.61	.052	-1.1	2.5	-6.2	-3.0	0
13	10	80	20	20	17.40	.050	-1.5	-4.5	-5.0	-4.0	0
14	5	0‡	0	0	0.09	.003	-4.4	--	--	--	0
14	10	20	0	0	5.40	.031	-8.4	-22.6	-30.8	--	0

Five fish were tested in each half of partitioned 38-liter aquarium.

* Terminated at 45 days.
† Died from accidental shut off of air supply at 57 days.
‡ Fish were all dead by 11 days.

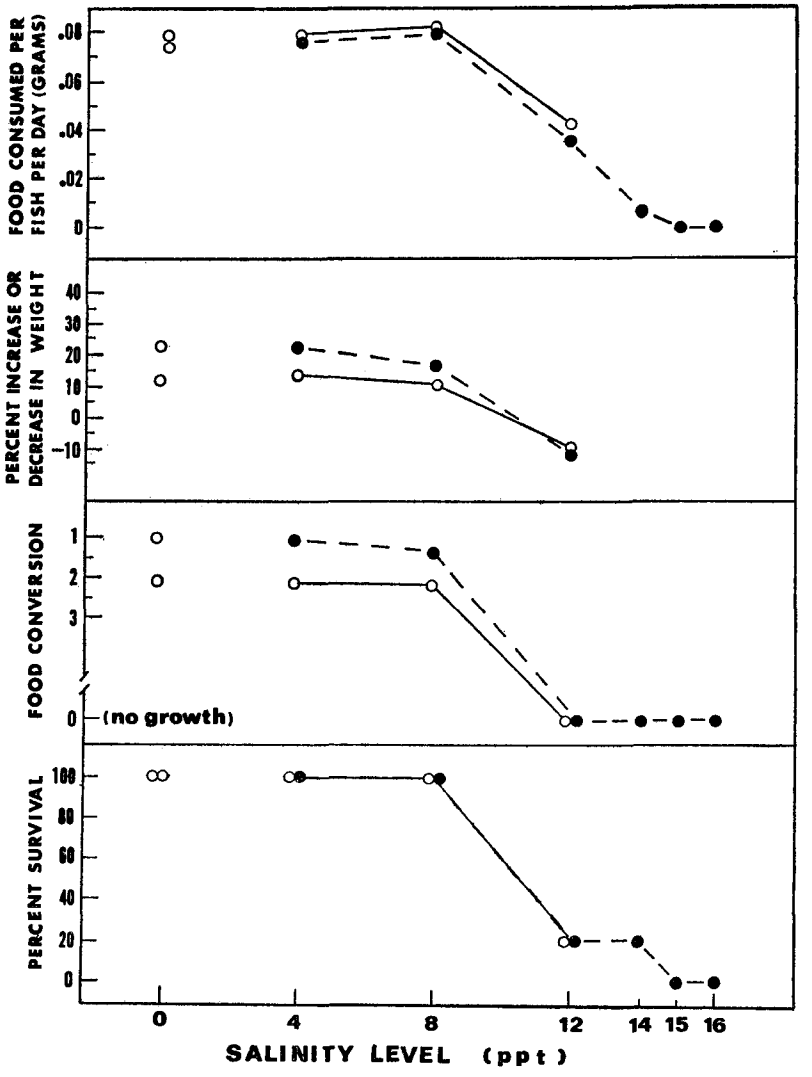

FIGURE 1. Effect of salinity and prior acclimation on food consumption, weight change, food conversion, and percent survival of 5-months-old Meridian channel catfish fingerlings. (Solid line indicates acclimation to fresh water, broken line indicates acclimation to 5 ppt. salinity for 9 days.)

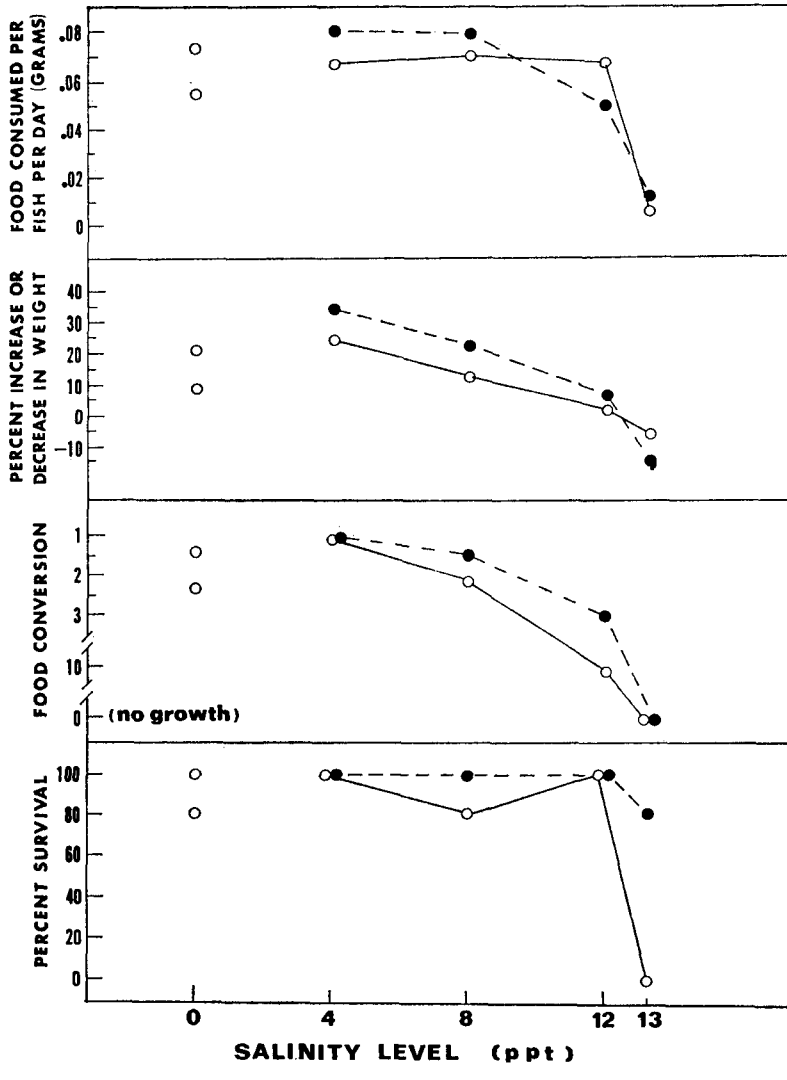

FIGURE 2. Effect of salinity and prior acclimation on food consumption, weight change, food conversion, and percent survival of 6-months-old Meridian channel catfish fingerlings. (Solid line indicates acclimation to fresh water, broken line indicates acclimation to 5 ppt salinity for 40 days.)

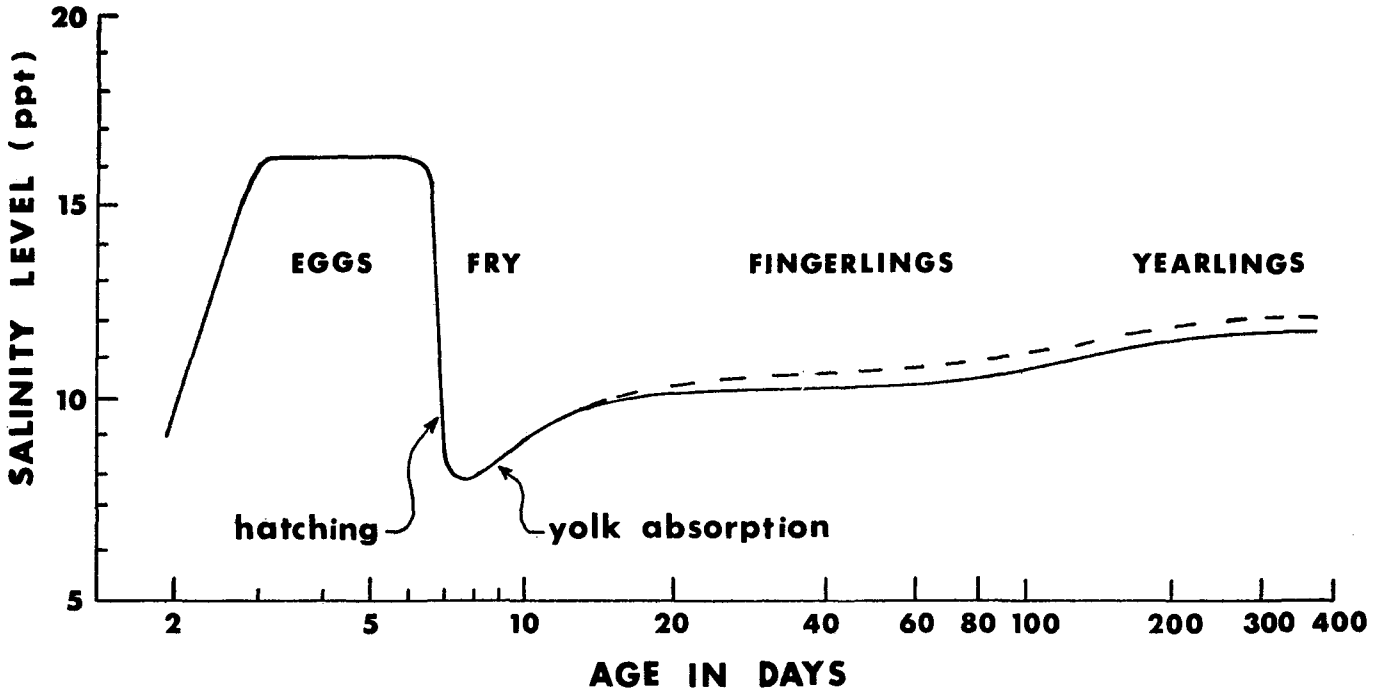

FIGURE 3. A schematic illustration of the effect of age and acclimation on salinity tolerance of channel catfish. (Solid line indicates upper tolerance of fish acclimated to fresh water and broken line indicates upper tolerance of fish acclimated to 5-10 ppt salinity.)