Smith, R. R. 1971. A method for measuring digestibility and metabolizable energy of fish feeds. Prog. Fish Cult. 33(3):132-134.
Snedecor, G. W. and W. G. Cochran. 1967. Statistical methods. Iowa State University Press, Ames, Iowa. 593 p.
Tunnison, A. V., D. R. Brockway, J. M. Maxwell, A. L. Dorr, and C. M. McCay. 1942. Cortland Hatchery Rep. 11: 52.
Windell, T. 1966. Rate of digestion in the bluegill sunfish. Invest. Indiana Lakes and Streams 7: 185-214.

EFFECT OF SELECTED CONCENTRATIONS OF SODIUM CHLORIDE ON THE GROWTH OF CHANNEL CATFISH [1]

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ABSTRACT

A number of studies have been done on the tolerance of fish to salt, but there is little information on the effect of salt on growth of fish. In the present study, repeated trials in tanks indicated that selected concentrations of salt have a significant effect on the growth of channel catfish. Subsequent trials in ponds showed a similar effect. The increased growth resulting from selected concentrations of salt is of such magnitude as to be of practical significance in some situations. An explanation for this effect is postulated.

INTRODUCTION

The ionic content of fresh water varies greatly. As of now the fishery scientist does not possess the necessary information to advise inland fish farmers on the significance of the different materials commonly occurring in water. Among the dissolved salts, the carbonates, sulphates and sodium chloride are especially important since they occur at high and varying concentrations. It is true that the mineral constituents of water have been studied, particularly as they relate to primary productivity, but their direct effect on fish in connection with the commercial production of food fishes has not been considered.

For at least two reasons the need for pertinent information on the effects of sodium chloride on fish is especially pressing. There are numerous water supplies that contain high concentrations of sodium chloride. Such water is of limited value for many uses but may be superior for at least some types of fish farming. Freshwater fishes must constantly osmoregulate in order to maintain a required level of salts in the body. Since there is an expenditure of energy in osmoregulation, it is quite possible that the growth of freshwater fishes can be improved if the work involved in osmoregulation can be reduced. The addition of a suitable concentration of sodium chloride, the principal salt involved in maintaining osmotic balance, to fresh water may give this result.

It was the purpose of the present study to investigate the effect of selected concentrations of sodium chloride on the growth of channel catfish.

PROCEDURE

Both laboratory and field tests were conducted. In ten laboratory experiments channel catfish were held in a series of fiberglass tanks containing 60 liters of water. These tanks were located in water baths designed to hold the temperature at a level which favored channel catfish growth. One experiment (Exp. 4) was set up in the field using plastic-lined redwood tanks containing 230 gallons of water. In this one experi-

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TABLE 1. Effect of salt on mortality, growth and food conversion of channel catfish held in tanks.

Exp. no	Days	Fish per tank	Mean wt. of fish (grams)	Experimental conditions	Mortality (%)	Weight gain (%)	Food conversion (food fed/wt. gain)
1	52	10	20	H_2O	40	50	1.19
				0.5% NaCl	0	50	1.44
2	25	6	12	H_2O	100	..	...
				0.17% NaCl	0	..	...
				Ca added	6	..	...
3	28	5	14.5	H_2O	93	..	...
				0.17% NaCl	0	14	...
				Ca added	60	..	...
4 (well water)	38	25	22	H_2O	11	40	2.60
				0.17% NaCl	7	58	1.70
				Ca removed	3	33	2.50
5	41	4	15	H_2O	54	29	2.10
				0.17% NaCl	14	40	2.10
6	38	4	13	H_20	0	24	2.80
				0.17% NaCl	0	22	2.40
7	32	4	14.3	H_2O	0	24	1.49
				0.17% NaCl	0	33	1.23
				0.085% NaCl	0	37	1.47
8	20	10	13.8	H_2O	0	39	1.42
				0.085% NaCl	0	46	1.40
10	25	4	13.8	H_2O	14	9	3.50
				0.17% NaCl	0	12	2.20
				Na_2SO_4	54	33	1.22
11	37	4	17.6	H_2O	50	29	...
				0.17% NaCl	0	27	...
				Na_2SO_4	75	..	...
				KC1	0	39	...

ment temperatures were stabilized at a suitable level by floating the tanks in a pond receiving a flow of well water.

The water was recirculated individually in all tanks, including those used in Experiment 4 above, by means of an air lift system and was filtered through a bed of glass wool. The tanks were covered to reduce evaporation and disturbance of the fish. Test fish ranged in weight from 12 to 22 grams (Table 1), but fish in any one experiment were of a similar size. The fish were stocked at low density to avoid confusing effects resulting from pollution. All tests were run in triplicate.

Water for the laboratory experiments was obtained from a municipal supply and was run through a charcoal filter to remove chlorine. The source of this water was a large artificial lake receiving surface run-off. In the field test (Exp. 4) well water was used. This gave an opportunity to observe the effect of initial differences in the water used. Water was added to the tanks in the first four experiments to maintain the water level, but this practice was discontinued in later experiments, and changes in water quality during the course of these tests could be attributed either to evaporation or to the presence of the fish.

The field studies were conducted in two locations. At Reservoir Road four 1/7-acre ponds supplied with water from a watershed reservoir were stocked with 12,000 and 6,000 catfish per acre (Table 2). The average weight of these fish was 48.7 grams. At the Gorham location two 1/3-acre ponds supplied with water from a deep well were stocked at a rate of 1,800 per acre with the fish being confined in two cages (6 x 3 x 4 feet deep) in each pond. One cage in each pond was stocked with fish having an average weight of 43.8 grams and one with fish that averaged 25.5 grams. In both study areas ponds were set up in pairs, and salt was added to one pond of the pair.

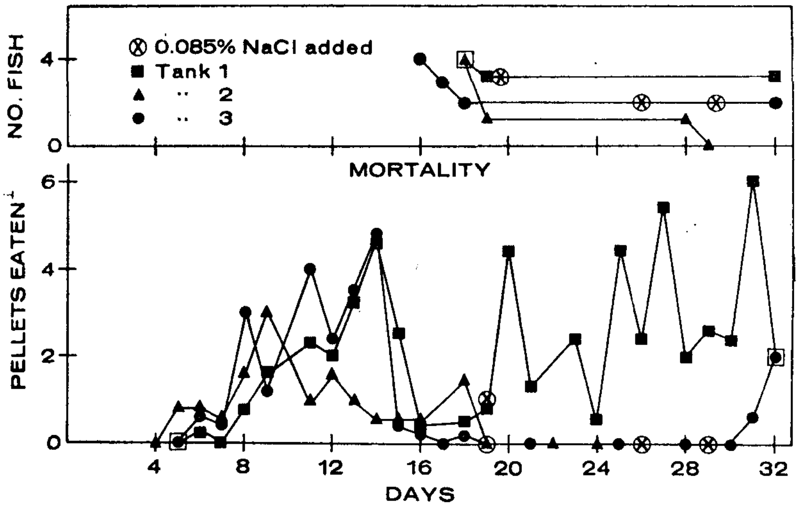
In an earlier study (Lewis, unpubl.) it was established that the golden shiner (*Notemigonus crysoleucas*) tolerates extended exposure to 0.2 to 0.3% sodium chloride and is benefited by this level of salt, but a concentration of 0.7% sodium chloride produces evidence of toxicity. Perry (1967) observed that in brackish water channel catfish occurred most abundantly at a concentration of 0.17% salt. On the basis of these observations, 0.17% sodium chloride was accepted as the principal concentration to be investigated, although lower and higher values were also considered (Table 1). In addition to sodium chloride, sodium sulphate and potassium chloride were tested at concentrations calculated to supply a number of cations equivalent to the sodium ions present in a 0.17% sodium chloride solution. Thus, sodium sulphate provided a different source of sodium, while potassium chloride substituted a potassium ion for the sodium ion.

Culinox 999, a feed grade salt sold by Morton Salt Company, was the source of sodium chloride. Culinox 999 is 99.9% pure, but the impurities which it contains include some trace minerals. In Experiment 11 reagent grade sodium chloride was used. Although this product also contained impurities, a complete analysis of the material was available. The sodium sulphate and potassium chloride were also reagent grade chemicals and contained impurities of a similar nature.

Influence of the calcium ion was tested by adding calcium to municipal water having an initially low methyl orange alkalinity and removing it from well water having high methyl orange alkalinity. This treated water was then tested against untreated water for its effect on fish. Calcium was added to the water by bubbling carbon dioxide into a solution of calcium carbonate and was removed by filtering the water through an ion exchange resin. Thus, in Experiments 2 and 3, methyl orange alkalinity was increased from 40 to 150 ppm, and in Experiment 4 it was reduced from 180 to 40 ppm.

In Experiment 9 in which the fish did not feed well in fresh water, sodium chloride was added to some tanks several weeks after the experiment was started (Figure 1).

Tank trials lasted 20 to 52 days (Table 1). In Reservoir Road tests, a sample of approximately one-third of the fish was taken from the



[1]Average number of pellets eaten per fish per day.

FIGURE 1. Effect of periodic addition of NaCl on mortality and feeding of channel catfish held in recirculated fresh water in tanks.

ponds after 33 days, a similar sample was removed after 60 days and the remaining fish were harvested after 105 days. Water was added after the first sampling to maintain the volume of water in the pond. The Gorham study was terminated after 50 days.

All fish were fed floating Purina Trout Chow. In the tank trials the fish were fed once a day six days a week. A counted number of food pellets was added to each tank, and uneaten pellets were removed after 20 minutes. The fish were thus allowed to consume the amount of food they desired during the feeding period. Since the pellets were graded to a uniform size, the weight of food consumed could be calculated from the number of pellets eaten.

Fish in the pond experiments were fed daily. For the first 33 days the fish in Reservoir Road ponds were fed all that they would eat in 20 minutes, but after the first sampling, ponds stocked at the same rate received an equal quantity of food. After 60 days dissolved oxygen became low in some ponds and feeding was discontinued. The fish fed poorly thereafter and received a trivial quantity of food during the last 45 days of testing. In the Gorham tests fish of the same size were given an equal amount of food.

Although the temperature of the water in the tanks varied from one test to another, it did not change more than three degrees C during any one experiment. In Experiment 6 water temperature was maintained at 17 to 20 C, while in all other tests the temperature was held between 24 and 31 C. Dissolved oxygen remained above 5 ppm, pH ranged from 6.8 to 7.8 and carbon dioxide remained below 10 ppm in both salt and water. Atomic absorption analysis showed that the concentration of the specific ions Na^{+}, Ca^{++} and K^{+} increased slightly during an experiment as water evaporated from the tanks. Salt concentrations in both tank and field tests were checked with an osmometer. Osmotic values increased slightly in tanks to which no water was added, but it was necessary to occasionally add salt to the ponds during the experimental period to maintain the desired concentration.

RESULTS

Channel catfish showed better growth in 0.17% sodium chloride than in fresh water in both laboratory and field studies (Tables 1 and 2). In the tank experiments weight gain was also greater in 0.085% sodium chloride, sodium sulphate and potassium chloride, but growth was not improved when the fish were held in 0.5% sodium chloride.

Although all of the fish grew well at Reservoir Road, they weighed 15% more after 60 days in ponds containing 0.17% sodium chloride than in ponds containing fresh water. Caged fish at Gorham weighed 23% more after 50 days in the pond containing salt. After feeding was discontinued at Reservoir Road, the fish in ponds containing salt gained 7 to 8% in weight in 45 days. Those in the heavily stocked freshwater pond lost weight, and in the lightly stocked freshwater pond, weight gain was 3%.

At the 60 day sampling time, the heavily stocked Reservoir Road ponds contained 2,250 and 2,650 pounds of fish per acre, and the lightly stocked ponds contained 1,500 and 1,750 pounds of fish per acre.

Food conversion was better for fish held in a 0.17% sodium chloride solution than for fish held in fresh water (Tables 1 and 2). However, these was little difference in food conversion between fish in 0.085% sodium chloride and those in water, and food conversion was poorer when a 0.5% sodium chloride concentration was used.

In most tank experiments mortality occurred in some or all tanks in which channel catfish were held in recirculated fresh water or in sodium sulphate (Table 1), but there was little or no mortality of fish held in 0.5, 0.17 or 0.085% sodium chloride or in potassium chloride. A 0.022 percent solution of sodium chloride gave results similar to those obtained when the fish were held in fresh water.

Better survival occurred in water to which calcium had been added than in the original water, but survival was best in a 0.17% sodium chloride solution. Although fish lived well in water from which some of the calcium had been removed, they made a somewhat smaller weight gain. In this experiment (Exp. 4) a small amount of mortality occurred under all conditions immediately after the fish were handled in setting up the experiment. When the test was terminated, some fish were found trapped behind the plastic liner of one tank containing salt, which accounted for most of the mortality of fish held in sodium chloride. The only mortality noted during the course of the experiment was in the tanks containing water and occurred during the fourth week of testing.

In Experiment 3 considerable mortality of fish occurred in fresh water when dissolved oxygen became low following a power failure which shut off the air compressor. Although fish held in water to which calcium had been added and in a 0.17% sodium chloride solution were subjected to the same low oxygen stress, there was no mortality among these fish at this time.

All of the mortality of fish in 0.17% sodium chloride in Experiment 5 was caused by a protozoan parasite, *Ichthyophthirius*, in one tank.

Mortality of fish held in fresh water followed a definite pattern. Fish began to die approximately 20 days after an experiment was initiated. In some cases all fish in a tank died over a period of a week, while in other cases one or two fish died, and the rest survived until the test was terminated. Some tanks in a triplicate series showed no mortality. A period during which the fish in fresh water failed to feed preceded mortality, and the intestinal tract of dead fish was always empty. When sodium chloride was added to the water of tanks in which fish had ceased to feed, feeding was resumed (Figure 1), and the fish survived. However, mortality occurred in tanks in which the fish stopped feeding but which did not receive salt.

There was no period of poor feeding associated with mortality of fish in sodium sulphate.

Although no mortality was noted in the Reservoir Road ponds during the course of the study, only 87% of the fish were recovered at harvest

TABLE 2. Effect of sodium chloride on the growth and food conversion of channel catfish stocked at three densities in ponds.

Pond Number	NaCl level (%)	Wt. gain (% of initial)[5]			Food conversion (food fed/wt. gain) at 60 days
		33 days	60 days	105 days	
Res. Rd. 1[1]	0.17	124	210	233	1.28
Res. Rd. 16	0.0	83	179	171	1.41
Res. Rd. 17[2]	0.17	144	284	314	1.38
Res. Rd. 18	0.0	151	230	240	1.69
		50 days			
Gor. 5 Cage 1[3]	0.0	225			1.08
Gor. 6 Cage 2	0.0	149			1.59
Gor. 5 Cage 3[4]	0.17	301			1.06
Gor. 6 Cage 4	0.0	241			1.33

1 12,000 fish per acre. Aver. wt. 48.7 g.
2 6,000 fish per acre. Aver. wt. 48.7 g.
3 1,800 fish per acre. Aver. wt. 43.8 g.
4 1,800 fish per acre. Aver. wt. 25.5 g.
5 All differences between salt and water are significant at the 0.05 probability level except for Res. Rd. ponds 17 and 18 at 33 days.

from the heavily stocked pond containing salt. Survival was better than 95% in the other three ponds. There was no mortality in the cages at Gorham.

DISCUSSION

Sodium chloride concentrations up to 3% have been shown to alter the metabolic rate of salmonids 10 to 15% (Brett, 1970). In the present study the increase in rate of growth and improvement in food conversion of the channel catfish when cultured in 0.17% sodium chloride solution indicates a relationship between reduced metabolic rate and improved growth and food conversion. The magnitude of the improvement and the fact that some salts in addition to sodium chloride produce beneficial effects suggest the effect to be a result of reduction in expenditure of energy in osmoregulation.

Improved growth in 0.17% sodium chloride was demonstrated in three different water supplies: surface run-off, surface water modified by municipal treatment and water from a deep well. This indicates an effect of salt on the fish rather than addition of a specific ion to the water and is further evidence of an influence of salt on osmoregulation.

The mortality of fish held in recirculated fresh water cannot be explained by the data obtained in these experiments. The fact that it occurred three weeks after the fish were added to the tanks indicates a reduction or depletion of some necessary material from the water, to accumulation of a harmful substance in the water or to a physiological stress. Depletion of a specific ion, such as a trace mineral, which was initially in short supply could be lethal, but such a possibility was not tested. There was no evidence of oxygen shortage or accumulation of metabolites to a level lethal to fish. In any case, salt prevented mortality whether it was included in the water from the beginning of the tests or was added to the tanks after the fish stopped feeding. Salt was especially helpful in preventing mortality when the fish were subjected to low oxygen. If the metabolic rate of channel catfish is reduced when they are held in low concentrations of salt, as is indicated by the present study, oxygen requirements for fish in salt would be lower than for fish in fresh water. Such a difference would account for better survival of fish held in salt solutions when dissolved oxygen became low.

Since in all cases mortality of fish in recirculated fresh water was preceded by a loss of appetite and failure to feed, starvation might be assumed to be the cause of death. However, similar fish which were held in flowing fresh water survived several months without food, while fish in the present study died within a few days after they ceased to feed.

Although there was considerable mortality of fish in sodium sulphate, the mortality pattern was different from that of fish held in fresh water, and death was probably due to a different cause.

Conditions which led to mortality in the tanks were obviously not present in the ponds since there was good survival in all ponds containing fresh water.

It has been suggested (Holliday, 1969) that the effect of salinity on specific gravity, osmoregulation and activity of fish may have important implication to the fish culturist. Results of the present experiments indicate that use of water having a low salt content may be desirable in commercial fish production. It would be entirely practical to mix salt water obtained from wells or coastal waters with fresh water to make a solution of a similar salinity to those tested. It may also be feasible to use dry salt since an inexpensive commercial grade product would be satisfactory for this purpose. The increase in growth and improved food conversion of fish in low concentrations of sodium chloride appear to be great enough to warrant such a procedure.

CONCLUSION

(1) In both laboratory and field tests, the use of a 0.17% sodium chloride solution in rearing channel catfish increased weight gain 15 to 20% over that of fish reared in water. Food conversion was also better.

(2) Channel catfish exhibited similar growth and food conversion when held in potassium chloride at a concentration which provided a number of potassium ions similar to the number of sodium ions in a 0.17% sodium chloride solution.

(3) Sodium chloride at a concentration of 0.085% improved growth but did not improve food conversion.

(4) Sodium chloride at a concentration of 0.5% did not improve growth or food conversion.

(5) Sodium sulphate at a concentration calculated to provide a number of sodium ions similar to that in 0.17% sodium chloride gave good growth but resulted in mortality after three or four weeks.

(6) Mortality was greater for fish held in recirculated fresh water than for fish held in salt solutions.

(7) The beneficial effects of salt are thought to result from a reduction in the work required for the fish to maintain a suitable osmotic balance in fresh water.

(8) It would be entirely practical to mix salt water obtained from wells or coastal waters with fresh water to make a salt solution similar to those tested. An inexpensive commercial grade dry salt might also be used. Results of the present study indicate that such a procedure would be profitable.

LITERATURE CITED

Brett, J. R. 1970. Fish—The energy cost of living. pp. 37-52. *In* W. S. McNeil (ed.) Marine Aquaculture. Oregon State Univ. Press, Corvallis.

Holliday, F. G. T. 1969. The effects of salinity on the eggs and larvae of teleosts. pp. 293-312. *In* W. S. Hoar and D. J. Randall (ed.) Fish Physiology. Vol. 1. Academic Press, New York.

Lewis, Sue D. Unpublished.

Perry, W. Guthrie. 1967. Distribution and relative abundance of blue catfish, *Ictalurus furcatus,* and channel catfish, *Ictalurus punctatus,* with relation to salinity. Proc. 21st Ann. Conf. S. E. Assoc. Game and Fish Comm. 21:436-444.

POLYCULTURE STUDIES WITH BLUE, WHITE AND CHANNEL CATFISH IN BRACKISH WATER PONDS [1]

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ABSTRACT

This paper includes a discussion of a catfish polyculture experiment conducted in brackish water ponds at the Rockefeller Wildlife Refuge, Grand Chenier, Louisiana. Ponds containing channel catfish (*Ictalurus punctatus*) only served as controls and were compared to other ponds containing various stocking ratios of blue (*I. furcatus*), channel and white catfish (*I. catus*) to determine if production could be increased. Length-weight relationships, coefficients of condition, food conversions, survival and growth data were compared in an analysis of the various stocking combinations.

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