TOXICITY OF NEW MEXICO BRACKISH GROUNDWATERS TO FINGERLING CHANNEL CATFISH

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SUMMARY

A two phase experiment was conducted testing the tolerance of channel catfish to high-sulfate brackish waters. Fish were exposed to concentrations of 8,000; 10,000; 11,000; 12,000; 13,000 and 14,000 mg/l total dissolved solids (TDS) formulated from city and brackish well water available at the Roswell Test Facility. The brackish well water contains about 10.5 percent sulfate ion in solution. Sixty-two percent of the fish at 14,000 mg/l TDS died within 12 days while 17 percent died at 13,000 mg/l in the same time period. Only one other death was recorded at 8,000 mg/l during the experiment. It appears that no significant difference occurs between the toxicity of this brackish well water to channel catfish and the toxicity of waters formulated using sodium chloride or diluted sea water.

INTRODUCTION

Channel catfish (*Ictalurus punctatus*) production in the south central United States increased 43 percent from August 1982 to August 1983 (Anon. 1983). This increase follows a trend of expanding United States aquacultural production predicted to rise in value from $89 million in 1979 to $485 million in 1989 (International Resource Development, Inc., 1979). To keep domestic supply equal to demand, aquacultural production facilities must be increased. One method of doing this is to spread the catfish farming industry out from its focal point in the Mississippi Delta.

If commercial aquaculture in New Mexico is to contribute to this growth, two problems must be overcome. Because of New Mexico's arid climate and relatively short growing season, traditional warm water pond culture with fresh water (2,000 mg/l TDS) is not feasible, indicating a need for alternate production methods such as closed, recirculating systems. Also, most freshwater sources suitable for aquaculture are allocated to more conventional agricultural uses. This water could be reallocated. However, existing users may be reluctant to convert to aquaculture because of lack of experience, high initial investments for conversion, and lack of information relating to the best waters and production systems for New Mexico. An unused and possibly cheaper source of water for potential aquaculturists is the abundant brackish ground water (2,000 to 30,000 mg/l TDS) found throughout the state. However, New Mexico's ground waters contain high concentrations of sulfate ions (O'Connor 1980), which may be toxic to channel catfish (Lewis 1971) or other aquatic species.

Raising channel catfish in brackish waters could improve production efficiency. Catfish culture in brackish water 1,500 to 8,000 mg/l TDS has proved beneficial in reducing off-flavors in catfish flesh by controlling blue-green algae in warm water ponds and in controlling outbreaks of parasites, such as *Ichthiopthirius multifilis*, in high-density systems (Avault 1982). Adding sodium chloride to culture water alleviates stress from nitrite poisoning, the source of brown blood disease in high-density channel catfish production facilities (Tomasso et al. 1979). Fish may grow even better in more brackish environments because they expend less energy to maintain osmotic equilibrium (Canagaratnam 1959).

Results reported here are preliminary trials to determine short-term mortality of channel catfish at high concentrations of TDS and uppermost salinity tolerance without mortality. Further trials will determine long-term growth and survival at sublethal salinity levels established here.

METHODS

Fish were obtained from the Uvalde National Fish Hatchery, Uvalde, Texas. One month prior to this study, these fish were treated with 25 mg/l formalin every other day for five days to remove external parasites.

No death occurred after the formalin treatment and all fish appeared healthy. Microscopic checks of gill tissue and gross external examinations indicated no parasite or disease problems. Twenty fish were held in three tanks containing Roswell city water for three to four weeks prior to the tests. The purpose of this control group was to determine toxic effects of local tap water with no subsequent mortality.

The experiment was conducted in two phases, the first to estimate upper tolerance of channel catfish to brackish water and the second to estimate sublethal salinities.

Phase I

Twelve 60-l aquariums, each with 24-l of water at four different TDS concentrations (3 replicates at each level), were prepared for a 14-day bioassay at the Roswell Test Facility east of Roswell, New Mexico. Based on an estimated TDS of 14,000 mg/l for the brackish well water and 1,000 mg/l for the city water (Table 1), appropriate ratios of well water to city water were calculated to create approximate concentrations of 8,000; 10,000; 12,000 and 14,000 mg/l TDS (Table 2). Water was mixed into each aquarium and allowed to stand aerated for 24 hours. Water temperature was maintained at ambient room temperature and remained near 27^{o}C throughout the experiment.

Ten channel catfish (mean total length 62 mm) were placed in each aquarium after 24 hours. Fish were not fed for the 14-day duration of the experiment and tanks were checked for deaths twice daily for the first 3 days and daily thereafter. Death, assumed when fish showed no opercular movement, was ascribed strictly to experimental treatments because no signs of parasites or diseases were observed during the experiment.

Phase II

In phase II, tests were conducted for 12 days in waters mixed to produce estimated concentratios of 11,000; 12,000; 13,000 and 14,000 mg/l TDS. Actual salinities and calculated salinities for the 12 tanks are contrasted in Table 2. The water in tanks 14A through 14C in Phase II was from the same batch of water that was tested as Deep #1 and Deep #2 except that it had stood for 24 hours. The difference in TDS

Table 1. Concentrations of various ions and total dissolved solids in mg/l for Roswell city water and brackish well at the Roswell Test Facility.

Constituent	City Water[a]	Deep Well (Brackish) Water		
		12/20/83[a,c]	Deep Sample #1[b,c]	Deep Sample #2[b,c]
Sodium (Na)	67	4,449	4,420	4,570
Potassium (K)	1	23	27.3	27.1
Calcium (Ca)	184	525	541.1	532.4
Magnesium (Mg)	51	156	148.5	148.2
Chloride (Cl)	97	6,948	7,367	6,974
Sulfate (SO_4)	451	1,488	1,350	1,350
Bicarbonate (HCO_3)	238	190	190.4	191.6
Dissolved Solids (Evap)	1,055	14,240	13,648	14,036
Total Hardness ($CaCO_3$)	670	1,950	-	-
Conductivity (25°C)	1,470 μmhos	22,100 μmhos	-	-

[a]Source: S. Isaacs, Chemist, Roswell Test Facility; tested December 20, 1983.

[b]Source: A. L. Bristol, Dept. Crop and Soil Sciences, New Mexico State University, Las Cruces, N.M.; tested December 22, 1983.

[c]Waters are from the same brackish well, sampled 10 days apart.

Table 2. Actual versus calculated total dissolved solids concentrations for test waters in phase II and conductivity of test waters in phase I.

Tank	TDSc	Conductivity[a] (mhos) (phase I)	TDS (mg/l)[b] (phase II)
8 A	(8,000 mg/l)	11,200	-
8 B		11,100	-
8 C		11,200	-
10 A	(10,000 mg/l)	14,100	-
B		13,800	-
C		14,000	-
11 A	(11,000 mg/l)	-	11,036
B		-	10,492
C		-	10,940
12 A	(12,000 mg/l)	16,100	12,016
B		15,800	11,592
C		16,500	11,732
13 A	(13,000 mg/l)	-	12,456
B		-	12,700
C		-	12,512
14 A	(14,000 mg/l)	17,900	13,400
B		18,000	12,960
C		18,600	13,056

[a]Conductivity taken with YSI conductivity meter; results are unsubstantiated.

[b]Samples taken for 14 A, B and C and Deep Sample #1 and #2 are from the same batch of water. Source: A. L. Bristol, Dept. Crop and Soil Sciences, NMSU.

[c]Calculated TDS levels based on brackish well water at 14,000 mg/l and city water at 1000 mg/l TDS.

concentration may be due to precipitation of some of the constituents. This may be the reason all measured concentrations were slightly below the calculated concentrations.

RESULTS AND DISCUSSION

Phase I

No deaths occurred in any tank during the first 96 hours. On the fifth day, fish started dying in tanks at 14,000 mg/l and deaths occurred sporadically over the remainder of the experiment (figure 1 and 2). After 14 days, a total of 18 fish had died in water at 14,000 mg/l TDS. One other fish died during the experiment, on the fifth day, in a tank at 8,000 mg/l. Because this was the only fish from either experiment to die in water with less than 12,000 mg/l TDS, it is likely that it died from causes unrelated to toxicity, such as malnutrition or handling stresses.

Phase II

No deaths occurred for the first 96 hours and none occurred in tanks at 11,000 or 12,000 mg/l TDS over the course of the experiment. Fish began dying in waters with 14,000 mg/l TDS on day 5, and 20 of 30 were dead by day 12. In one tank with 13,000 mg/l TDS 5 fish died, starting on day 8 (figure 1).

A chi-square test comparing 12-day mortalities between Phases I and II at 14,000 mg/l TDS showed no significant difference at the 5 percent level. The waters were taken from the same well about two months apart and TDS levels should not have varied greatly over that time.

The deaths occurring in one of three replicates at 13,000 mg/l TDS may have been due to the slightly higher TDS concentration in that tank (Table 2). This finding indicates that water about 13,000 mg/l TDS may be the sublethal threshold.

The results of this experiment show that at 27°C fingerling channel catfish cannot survive long-term exposure to high-sulfate, brackish ground waters above 14,000 mg/l TDS and that the sublethal, short-term tolerance is at or slightly higher than 13,000 mg/l TDS. Internal osmotic pressure of body fluids is maintained in fish at about 10,000 mg/l

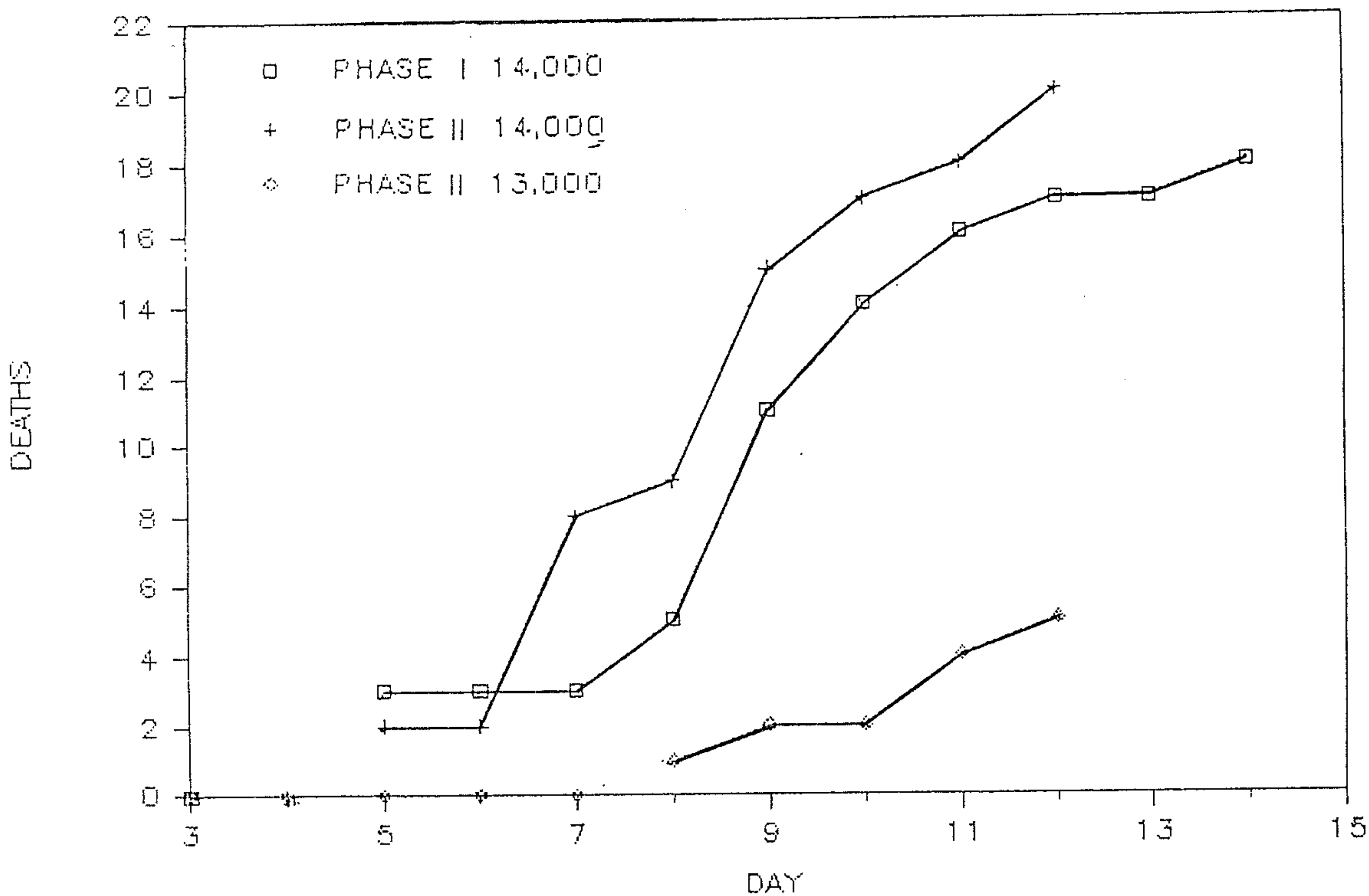

Figure 1. Cumulative deaths of channel catfish fingerlings (phases I and II) in waters at concentrations of 13,000 and 14,000 mg/l total dissolved solids.

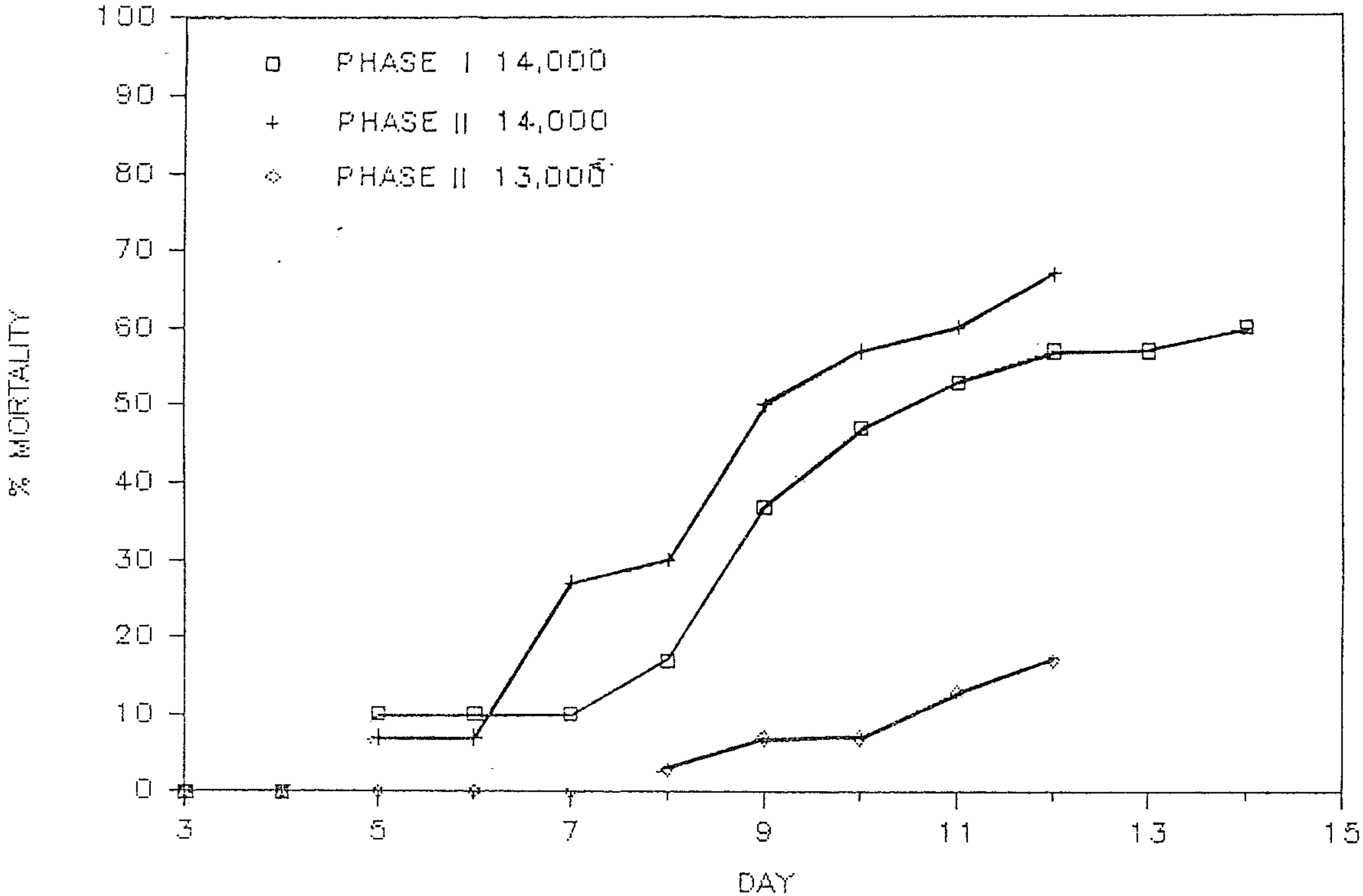

Figure 2. Cumulative percent mortality of channel catfish fingerlings (phases I and II) in waters at concentrations of 13,000 and 14,000 mg/l total dissolved solids.

salinity (± 2,000) by regulation of plasma ions (Brett 1979). Growth, a function of energy storage, drops off rapidly after the isotonic point in stenohaline freshwater fish. This suggests that a great deal of energy is put into maintenance of internal osmotic pressure during exposure to high salinities. It would appear that stress caused by excess energy demand and osmoregulatory problems were the cause of death of fish in waters with TDS concentrations above 12,000 mg/l.

Channel catfish have survived TDS concentrations up to 15,000 mg/l for two to three days (Stickney and Simco 1971) in brackish waters formulated using diluted sea water or sodium chloride, however, long term survival limits are closer to 12,000 mg/l (Allen and Avault 1971). As channel catfish get larger, their tolerance to brackish water increases (Allen and Avault 1969) although the difference between fingerlings and one-year-old fish is only 1,000 to 2,000 mg/l TDS. Allen and Avault (1971) found that some fingerling channel catfish (30-45 grams) could survive 14,000 mg/l TDS for up to eight days but most fingerlings died between days four and six. In another experiment (Stickney and Simco 1971), some fingerlings (50-70 mm TDS, 2-6 g) survived for 96 hours in water with salinities up to 15,000 mg/l, but most tests at 14,000 to 14,500 mg/l TDS resulted in fingerlings dying within the first 40 hours.

Allen and Avault (1969) reported that channel catfish fry survived poorly at 10,000 mg/l TDS, fingerlings died within 100 days at 12,000 mg/l, and six-month-old fish could survive and grow indefinitely at 12,000 mg/l.

Lewis (1971) found higher mortality of channel catfish in waters containing 1,700 mg/l sodium sulfate than in waters containing 1,700 mg/l sodium chloride, indicating a toxic effect of the sulfate ion. Trama (1954) found sodium sulfate to be more toxic than sodium chloride to bluegills (<u>Lepomis machrochirus</u>), although a saturated solution of calcium sulfate (2,980 mg/l) showed no significant mortality.

My experiments were not designed to test the relative toxicity of sulfate ions and other ions, but mortality and lethal limits (12,000 to 14,000 mg/l TDS) for brackish ground waters in New Mexico are similar to those expressed elsewhere for channel catfish exposed to waters formulated using sodium chloride or diluted sea water. The results of this experiment have been used to select an upper limit for subsequent evaluation of long-term effects of New Mexico brackish ground waters on channel catfish.

This subsequent research has been designed to determine growth and survival of channel cafish in high-sulfate, brackish ground water from 1,000 mg/l to 11,000 mg/l TDS over a six-month period, about the time required to raise 150 mm channel catfish to market size (450-500 g). The results should show any difference between growth and survival of channel catfish cultured in New Mexico's ground water and channel catfish cultured in brackish waters formulated using sodium chloride or dilute sea water.

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