GROWTH OF CHANNEL CATFISH IN SALINE GROUNDWATERS OF THE PECOS VALLEY OF NEW MEXICO

by

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DISCLAIMER

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ABSTRACT

This essentially unused 18.5 trillion m^3 of saline (> 3,000 mg/L) groundwater in New Mexico cannot be readily utilized by conventional water users. However, its use for production of euryhaline species offers potential opportunities in the state because of the rapid growth of aquaculture and increasing demand for fishery products in the United States.

The objective of this research was to evaluate the potential use of saline groundwater for culture of channel catfish, a species with high consumer acceptance. Laboratory studies in circular tanks at the Roswell Test Facility indicate that fingerling channel catfish can be grown efficiently in groundwaters with salinities $\leq$ 6,500 mg/L. Percent weight gain, food conversion, and survival of channel catfish at these salinities were comparable to results of other studies done in fresh water. Further evluation of the economic feasibility of the culture of channel catfish and other species should be made using specific criteria for potential sites and different production systems. Results of this study indicate there are no biological reasons why saline ground waters of the Pecos Valley cannot be used for aquaculture purposes.

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INTRODUCTION

There has been a rapid worldwide expansion in the importance of aquaculture during the last 20 years with various estimates indicating that aquaculture production has gone from 1 million metric tons (mmt) in 1966 to 12.43 mmt by 1985 (Joint Subcommittee on Aquaculture 1983a; Rhodes 1987; McIntyre 1987). In the United States fish imports and private aquaculture production have both expanded rapidly in the last 10 years. Total value of private aquaculture production in the United States increased from about $200 million in 1980 (Joint Subcommittee on Aquaculture 1983a) to about $448 million in 1985 (Personal communication, N. C. Parker, U.S. Fish and Wildlife Service). Estimated percent increases in private aquaculture production from 1980 to 1985 have been impressive with catfish increasing by 354%, clams increasing by 283%, crawfish increasing by 272%, freshwater prawns increasing by 196%, and salmon increasing by 1,109%, and total production increasing by 264.5% (Rhodes 1987). Imports of fish and fishery products also increased rapidly after 1980 and were valued at $7.6 billion in 1986 (Parker In Press). Annual per capita consumption of fish in the U.S. increased by 20% between 1975 and 1986 and is expected to double by 2020 (Parker In Press). The growing demand and consumption of fish products because of increased national advertising and better marketing, combined with the limited supply of fish from the world's capture fisheries, are expected to increase the financial profitability of private aquaculture in the future (Rhodes 1986; Parker In Press).

The passage of the National Aquaculture Act of 1980 and the completion of the National Aquaculture Development Plan in 1983 (Joint Subcommittee on Aquaculture 1983a; 1983b) has resulted in positive changes in private aquaculture in the United States. Although private aquaculture has expanded in most states (including Arizona and Texas) in the last 10 years, the high evaporation rates and limited availability of fresh water in New Mexico has discourged the development of conventional aquaculture on a commercial scale.

The potentially recoverable groundwater supply of New Mexico is about 24.7 trillon m^3 (Bureau of Reclamation 1976); of this total, about 3.7 trillon m^3 is fresh water (total dissolved solids (TDS) < 1,000 mg/L), whereas 1.7 trillon m^3 is slightly saline (TDS = 1,000-3,000 mg/L) and can be used for some forms of irrigation (Bureau of Reclamation 1976; Bahr and Herman 1981). The remaining 18.5 trillion m^3 of groundwater is more saline (> 3,000 mg/L) and has been rarely used for agricultural production or domestic supply in New Mexico (Hood and Kister 1962; O'Connor 1981). Hernandez (1986) and Lansford et al. (1986a) have evaluated the potential use of these groundwaters to either produce salt-tolerant crops or use in conjunction with fresh waters for irrigated crop production in New Mexico. In addition, the feasible production of microalgae (Spirulina spp.) over a wide range of salinities has been demonstrated (Goldstein 1986) and suitable sites identified in New Mexico for large scale microalgae production using saline waters (Lansford et al.

1986b). Although market demand for and economic feasibility of brackish water aquaculture has not been evaluated, aquaculture provides another potential direct use of either slightly saline or moderately saline (3,000-10,000 mg/L) groundwaters in New Mexico.

Some aquaculture species are relatively euryhaline, can be readily acclimated to brackish water, and grow well at salinities between 10 ppt and 50% seawater (17.5 ppt). For example, Stickney (1986) reviewed three papers where the growth of red hybrid tilapia (Tilapia spp.) was more rapid in either brackish water or full-strength seawater than in fresh water. Rainbow trout, Salmo gairdneri, can also be acclimated to salinities up to seawater strength (35 ppt) (Landless 1976) and have been grown in cages in brackish water in Alabama (Tatum 1973). Striped bass, Morone saxatilis, survived and grew better in water with salinities up to 60% sea water than in fresh water (Lal et al. 1977). Other aquaculture species like channel catfish, (Ictalurus punctatus) blue catfish (I. furcatus)· (Allen and Avault 1970), their hybrids (Stickney and Simco 1971), white catfish (I. catus) (Perry and Avault 1972), red swamp crayfish, Procambarus clarki, (Perry and LaCaze 1970), hybrid white bass, Morone chrysops X striped bass (Bayless 1972), and Macrobrachium rosenbergii (Perdue and Nakamura 1976) survive and grow in brackish waters at salinities ≤ 11 ppt.

When funds became available from the New Mexico legislature in 1983 for research on brackish water aquaculture, an evaluation was made of the species that had aquaculture potential in New

Mexico. The channel catfish was a logical test species because of its known tolerance for brackish waters (Allen and Avault 1970a; Perry and Avault 1972) and the rapid growth of catfish farming in the early 1980s (Joint Subcommittee on Aquaculture 1983b). For example, catfish production in the United States had grown from 145 metric tons (mt) in 1960 to 34,780 mt in 1980 and was estimated to have reached 90,719 mt in 1982 (Joint Subcommittee on Aquaculture 1983b). In addition, research on the potential for using low salinity ground water for production of channel catfish in West Texas had been identified as a need in an aquaculture status report and development plan for Texas (Stickney and Davis 1981). Techniques for the culture of channel catfish also were well known (Piper et al. 1982; Andrews et al. 1971) and the necessary tanks and channel catfish fingerlings for the research were readily available.

The main objective of this study was to determine what salinities of the brackish groundwater of the Pecos Valley near Roswell, New Mexico were satisfactory for optimal growth and efficient food conversion by fingerling channel catfish. A secondary objective was to review the literature in relation to what aquaculture species and production systems have potential for brackish water aquaculture in New Mexico.

METHODS

The effect of brackish groundwater on the growth of fingerling channel catfish was evaluated by growing fish in circular fiberglass tanks maintained inside a room at the Roswell Test Facility (RTF) located east of Roswell, New Mexico. The salinity of the inflowing water was regulated by mixing the relative proportion of water from the deep brackish well at the RTF and water from the Roswell city water system (Table 1). The latter water was dechlorinated by passing it through an activated charcoal filter before it was mixed with the brackish groundwater.

The channel catfish used in this study were obtained from the Uvalde National Fish Hatchery in Uvalde, Texas in October of 1983 and held in four fiberglass tanks supplied with 20 L per minute of Roswell city water to each tank. Fish were treated with formalin to eliminate ectoparasites every other day for 6 days after they arrived and at 14 and 10 days before the beginning of the acclimation period. Gross external checks of the fish made just before starting the acclimation process revealed no signs of ectoparasites or other diseases. However, all tanks were treated with 150 mg/L of formalin for 2 hours about 2 weeks after the start of the acclimation process.

The salinities used during the first phase of the study were selected after a review of the literature and a preliminary static bioassay in December of 1983 using water from the brackish well at RTF. This bioassay documented that undiluted water from the brackish well (TDS of 14,240 mg/L) was toxic to the

Table 1. Concentrations of various ions and total dissolved solids for Roswell city water and the brackish well at the Roswell Test Facility, New Mexico.

Constituent	Concentration (mg/L)			
	City water 12/20/83	Deep brackish well water[c]		
		Sample #1[a]	Sample #2[b]	Sample #3[b]
Sodium	67	4,449	4,420	4,570
Potassium	1	23	27.3	27.1
Calcium	184	525	541.1	532.4
Magnesium	51	156	148.5	148.2
Chloride	97	6,948	7,367	6,974
Sulfate	451	1,488	1,350	1,350
Bicarbonate	238	190	190.4	191.6
Total dissolved solids (Evaporated)	1,055	14,240	13,648	14,036
Total hardness ($CaCO_3$)	670	1,950	--	--
Conductivity (at 25°C, µmhos)	1,470	22,100	--	--

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[a] Concentrations determined by S. Isaacs, Chemist, Roswell Test Facility; Tested on December 20, 1983.

[b] Concentrations determined by Soil and Water Testing Laboratory, New Mexico State University, Las Cruces. New Mexico; Tested on December 22, 1983.

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

fingerling channel catfish (Turnbull 1984). Because the sublethal concentration was less than 13,000 mg/L, a salinity treatment level of 11,000 mg/L was chosen to reduce the likelihood of short-term mortalities caused by excessive salinity.

Design of Experimental System

Each of the 18 circular fiberglass tanks used during this study was plumbed with PVC pipes that delivered both water from the RTF brackish well and the Roswell city system. The salinity of the water injected into each tank was regulated by adjusting the gate valves on the two water lines that joined at each tank. The amount of water entering each tank was controlled by a flow regulator attached at the end of the common water line. Through May 19 of the Initial Experiment, a flow regulator was used that maintained water inflow at 5.7 L per minute into each tank. In July, a larger capacity flow regulator was installed that delivered 9.7 L per minute.

Each tank (1.52-m diameter) was equipped with a center overflow standpipe (7.6 cm, outside diameter) that maintained a center water depth of 50 cm and a total water volume of 760 L. The standpipe system included an outer, Venturi-type drain pipe (10.2 cm, outside diameter) to allow the continuous removal of fecal material and other settable solids that accumulated near the center of the tank. Inflowing water was injected into each tank at an angle to create a clockwise circular flow pattern in the tank and to provide aeration. Supplemental aeration was supplied to each tank during most of the study by a 3 by 12-cm air stone that was connected to either the RTF air compressor or a 3/4-H.P., regenerative air blower.

Normal System Operation

Inflowing tank water was heated until July 18, 1984 by counter-current steamlines in two commerical heat exchangers. Separate systems were required for both the brackish and Roswell city water lines in order to maintain similar water temperatures at all treatment salinities. A temperature-sensitive probe in each water supply line was connected to a steam control valve that regulated the temperature of inflowing water by controlling the amount of steam passing through the heat exchanger. Mean water temperatures in circular tanks were normally maintained at 25.5 to 28.5°C between March 24 and July 18 by the heated inflow water. Channel catfish have optimal growth between 26 and 30°C (Andrews and Stickeny 1972; Stickney 1986) with an optimum of 29.4°C recommended by the National Research Council (Piper et al. 1982). Because of mechanical failures of the heat exchanger on the brackish water line, heat was shut off twice for short periods. This caused gradual reductions in the water temperature of the tanks to the temperature of the incoming water from the brackish well.

Fish were weighed after the first 3-week acclimation period and then at the end of each 2-week growth period in order to determine weight gains and to allow periodic adjustments of feeding rates. During the Initial Experiment, the 100 catfish in each tank were weighed together in a large plastic container with slotted openings that allowed water to drain off quickly. After allowing water to drain out of the container for about 30 seconds, the total weight of fish and container (known weight) was measured to the nearest 10 g on an Ohaus triple-beam balance provided by the RTF. After the fish biomass in a tank reached 8 kg, the fish were divided into two lots during weighings to reduce the likelihood of injuries to the fish. After weighing was complete, fish were examined for general condition and any signs of disease before returning them to the appropriate tank.

Checks for any dead fish were normally made twice daily when checking water quality. During the first 3-week period, any dead fish were counted and weighed and then replaced with fish of comparable weight from a group of fish being held at 26°C in Roswell city water. After this period, dead fish were counted and weighed, but not replaced; only eleven fish died after the first 3-week period and all but one of these fish were in the treatment maintained at the highest TDS level.

The walls of the tanks were cleaned with a brush at 4 to 10-day intervals when bacteria and algal growth became noticeable. Any uneaten feed and fecal material that wasn't removed by the Venturi drain pipe were flushed by removing the inner standpipe for a few minutes every 2 to 5 days.

Initial Experiment

Growth of channel catfish fingerlings was compared between fish maintained in circular tanks receiving six different proportions of brackish and Roswell city water. Target salinities were 11,000, 9,000, 7,000, 5,000, 3,000 mg/L and undiluted Roswell city water (about 1,055 mg/L, TDS). The three replicates of each salinity were randomly distributed in the room to minimize the impact of any differences between tanks in human activity and lighting.

Acclimation period procedures. On March 3, 1984, 100 channel catfish with a mean total length of 157 mm and a mean weight of 35.6 g were placed into each of the 18 circular tanks. All tanks were receiving 5.7 L per minute of Roswell city water and water temperatures averaged 13.2°C. Beginning the next day, water temperatures in all tanks were gradually increased by raising the temperature of the inflowing water by using the heat exchangers. By March 13, water in the circular tanks averaged 27.6°C. During the same 10-day period, the salinity of the water in the tanks was gradually raised to the planned treatment concentrations by adjusting the proportion of brackish to city water that was delivered through the flow regulators. Salinity levels were adjusted during the acclimation period and subsequently by comparing the conductivity of each tank to the conductivity of prepared sodium chloride standards with salinities of 3,000, 5,000, 7,000, 9,000, and 11,000 mg/L; based on initial readings with a conductivity meter, the conductivities of the standards were 5,500, 9,000, 12,200, 15,100, and 18,000 micromhos. Conductivity readings of each tank were usually taken twice a day with a Yellow Springs Instrument Co. (YSI) Model 33 conductivity meter and appropriate adjustments were made to the proportion of brackish to city water in the inflow water. Water temperatures were determined at the same time as conductivity readings and adjustments made to the heating system when necessary. Oxygen concentrations in the tanks were determined occasionally with a YSI Model 57 portable oxygen meter.

During this study, the channel catfish were fed Silver Cup trout pellets produced by Sterling H. Nelson and Sons, Inc. of Murray, Utah. These sinking pellets (either 2.4, 3.2, or 4.0-mm diameter) had a guaranteed minimum protein content of 38%, a minimum fat content of 10%, and 3,100 Kilocalories per kilogram of digestible energy. During the first 3 weeks, fish in all tanks were fed identical amounts of food each day. The catfish did not consume all of the feed fed (1.5% of total fish weight) during the single feeding the first two days they were fed, so they were fed a reduced ration twice per day for the fifth through tenth day when water temperature and salinity reached the target values. For the remainder of the first 3 weeks, fish in all tanks were fed two equal feedings per day as recommended for channel catfish reared at temperatures >26 C(Lovell et al. 1980) at a rate equal to 3% per day of their total weight on March 3. This rate is generally recommended for fingerling channel catfish cultured at optimal temperatures (Stickney 1979; Stickney and McGeach 1984), but the size of the fish and water temperature must be considered when selecting the optimal feeding rate (Foltz 1982).

Two-week growth periods. Beginning on March 24, fish in all tanks were weighed every 2 weeks and the amount of food to be fed was recalculated. Fish were not fed the morning of the day they were weighed. After each weighing, the daily food ration was adjusted and half of the new ration was fed late that same evening. During the 2-week period ending April 7, fish were fed a daily ration equivalent to 3.0% of their weight at the beginning of the period (ration was not increased during the period). The daily ration was divided into two equal portions and fed at morning and evening feedings that were normally 10-14 hours apart.

Feeding rate of trout pellets fed during this study was determined as the percent fish body weight fed per day (Piper et al. 1982). The actual percent body weight that was fed daily during each growth period (% BWF_i) was determined for each tank by the following formula:

$$\%\ BWF_i = \frac{\text{Total feed fed } \underline{\text{(dry weight)}}}{\text{No. of days in period}} \div \frac{\text{Initial + Ending fish weight}}{2} \times 100.$$

The feed was kept inside an air-conditioned room during the study period, but the moisture content of the feed was not determined. At the end of each growth period the Food Conversion Ratio (FCR) was determined for each tank by dividing the total weight of food fed by the wet weight gain of fish in that tank. During the growth periods that ended on April 21, May 5 and 19, and June 2, the intital daily ration fed was 3% of the total fish weight at the start of the 2-week period. For these periods the daily ration in each tank was increased every 3 to 5 days by 3% of the projected weight increase based on the previous FCR value for that tank. Feeding rates were not adjusted in a standardized manner during June and July because of problems with maintaining satisfactory dissolved oxygen and salinity levels. Mean differences in the percent weight gains and food conversion ratios (FCR) fish grown at different salinites were compared ratios of for the April 7-21 period by the general linear models procedure (SAS 1987). T tests (Least Significant Difference) were used to determine whether significant (alpha = 0.05). differences occurred between mean gains and FCRs of fish grown at different salinities. In addition, a stepwise regression procedure (SAS 1987) was used to describe the relationshps between percent weight gain and mean salinity of the 18 culture tanks and between FCR and the mean salinity of the 15 tanks at the lowest salinities; fish in the three tanks at about 11,000 mg/L were excluded from the stepwise regression analysis because FCR could not be estimated due to decreases in fish weights.

Second (August) Experiment

The effect of extended acclimation at salinities of about 3,000 and 5,000 mg/L on the subsequent growth of advanced fingerlings (mean initial weight of 271 g) of channel catfish was tested by stocking each circular tank with an average of 8.01 kg of fish on August 4, 1984. For catfish previously grown at 3,000 mg/L, two tanks each were maintained at salinities of about 3,000, 5,000, 6,500 and 8,500 mg/L through September 1, 1984. The same experimental design was used for fish that had been previously grown at 5,000 mg/L except that only one tank was maintained at 3,000 mg/L.

Fish in all tanks were fed 200 g per day (2.5% of initial weights) of trout pellets on 10 days (in two equal feedings) and 100 g per day on 2 days (one feeding only) during the August 4-17 period; fish were not fed on August 4 and 5 to allow them to acclimate to their new treatment conditions. Fish in all tanks were weighed the morning of August 18 and then fed 100 g per tank that evening. Fish were then fed at a rate equivalent to about 2.5% of their weights on August 18 from August 19-26 in two equal feedings per day. Because all pellets weren't being eaten, the amount fed per day was reduced to a mean of 1.88% of their initial total weight for August 27-30. The fish were fed only once on August 31 and were then weighed on September 1.

During the August growth experiment, conductivity and salinity of each tank and the NaCl standards were regularly measured with a YSI Model 33 conductivity meter. Adjustments to the proportion of brackish to city water were made as necessary. Water temperatures were also measured twice per day, but no adjustments were necessary because the heat exchangers were not being used. Concentrations of dissolved oxygen were measured periodically with YSI Model 57 oxygen meter.

Calculations of percent weight gains, food conversion ratios, and percent of fish weight fed per day were made as described for the Initial Experiment. A two-way analysis of variance was used to test the effects of acclimation salinity, salinity during the August periods (treatments), and the interaction of acclimation salinity and treatment on the percent weight gains and FCR values (only for the August 18-31 period).

RESULTS

The mean starting weights of fish (35.6 g), amount of food fed (1485 g), and mean water temperatures (24.8 - 25.0°C) were nearly identical for all tanks during the 3-week acclimation period when water temperatures and salinities were being increased (Tables 2-7). Mean percent weight gain during the first 3-week period ranged from 19.8% for fish in the three tanks being acclimated to a salinity of 11,000 mg/L, TDS to 36.7% for fish in tanks being acclimated to 3,000 mg/L (Table 8). No statistical comparisons were made during the acclimation period between tanks being acclimated to different salinity levels because of problems encountered in maintaining salinity values at the desired levels and because of the variation in salinity between tanks that should have been at the same salinity level. For example, the range in mean conductivity of different tanks being acclimated to 9,000 mg/L was 8,500 to 9,000 micromhos during the first 3 weeks, whereas the range was 8,800 to 11,130 micromhos for tanks targeted for 11,000 mg/L, TDS (Tables 5 and 6).

March 24 - April 7

As planned, the mean water temperatures of the tanks (26.3 - 27.9°C) and actual mean feeding rates (2.44 - 2.72% of fish weight fed per day) were greater during this period than during the acclimation period. Percent weight gains of fish ranged from 28.5 to 41.4% for tanks where mean conductivities were less than 11,000 micromhos (salinity of about 6,200 mg/L) (Tables 2-5). In contrast, percent weight gains of fish were less and food

Table 2. Mean conductivities, percent weight gains, food conversion ratios, mean percent of total fish weight fed per day and mean temperatures in tanks of channel catfish maintained at a salinity of about 1,055 mg/L at the Roswell Test Facility, New Mexico from March 3 - July 29, 1984.

End of period	Mean conductivity (µmhos)	Percent weight gain	Total fish weight (kg)	Weight gain of fish (kg)	Weight of feed fed (kg)	Food conversion ratio	Mean% of fish weight fed/day	Mean temperature (°C)
<u>Tank 4</u>			3.569[b]					
Mar 24	950	37.0	4.890	1.321	1.485	1.12	1.67	24.8
Apr 7	700	41.6	6.926	2.036	2.025	0.99	2.45	27.4
Apr 21	1200	41.7	9.813	2.887	3.000	1.04	2.56	26.7
May 5	1300	16.1	11.390	1.577	5.070	3.21	3.41	25.4
May 19	1120	17.0	13.325	1.935	5.025	2.60	2.90	27.4
Jun 2	–[a]	21.1	16.130	2.805	6.170	2.20	2.99	27.7
Jun 16	1150	18.3	19.085	2.955	6.960	2.36	2.82	28.3
Jun 29	1190	6.4	20.311	1.226	3.250	2.65	1.27	28.3
Jul 15	1260	12.7	22.885	2.574	9.055	3.52	2.62	28.6
Jul 29	–[a]	8.4	24.800	1.915	7.190	3.75	2.16	25.7
<u>Tank 10</u>			3.593[b]					
Mar 24	930	36.7	4.875	1.282	1.485	1.16	1.67	25.1
Apr 7	740	39.3	6.790	1.915	2.025	1.06	2.48	27.1
Apr 21	1200	44.6	9.820	3.030	2.870	0.95	2.47	26.6
May 5	1300	15.6	11.350	1.530	5.070	3.31	3.42	25.3
May 19	1120	15.0	13.050	1.700	5.025	2.96	2.94	27.4
Jun 2	–[a]	23.7	16.140	3.090	5.995	1.94	2.93	27.6
Jun 16	1150	8.6	17.520	1.380	6.960	5.04	2.95	28.3
Jun 29	1190	8.2	18.956	1.436	3.020	2.10	1.18	28.2
Jul 15	1280	13.8	21.580	2.624	8.495	3.24	2.62	28.4
Jul 29	–[a]	14.3	24.660	3.080	6.755	2.19	2.09	25.4
<u>Tank 18</u>			3.548[b]					
Mar 24	900	36.7	4.850	1.302	1.485	1.14	1.68	25.1
Apr 7	730	39.7	6.775	1.925	2.025	1.05	2.49	27.8
Apr 21	1200	44.7	9.806	3.031	2.870	0.95	2.47	27.0
May 5	1300	16.1	11.385	1.579	5.070	3.21	3.42	25.7
May 19	1130	18.0	13.435	2.050	5.195	2.53	2.99	27.4
Jun 2	–[a]	20.8	16.235	2.800	6.170	2.20	2.97	28.1
Jun 16	1140	15.3	18.720	2.485	7.105	2.86	2.90	28.6
Jun 29	1190	5.6	19.770	1.050	3.220	3.07	1.29	28.3
Jul 15	1290	17.8	23.290	3.520	8.785	2.50	2.55	28.7
Jul 29	–[a]	11.1	25.870	2.580	7.345	2.85	2.13	25.6

[a] Meter used to measure conductivity was giving inaccurate readings during at least part of the period.

[b] Total weight of the 100 fish on March 3, 1984 when the acclimation process was started.

Table 3. Mean conductivities, percent weight gains, food conversion ratios, mean percent of total fish weight fed per day and mean temperatures in tanks of channel catfish maintained at a salinity of about 3,000 mg/L at the Roswell Test Facility, New Mexico from March 3 - July 29, 1984.

End of period	Mean conductivity (µmhos)	Percent weight gain	Total weight of (kg)	Weight gain of fish (kg)	Weight of feed fed (kg)	Food conversion ratio	Mean % of fish wt. fed/day	Mean temperature (°C)
Tank 1			3.583[b]					
Mar 24	3220	38.3	4.955	1.372	1.485	1.08	1.66	25.2
Apr 7	3650	38.0	6.838	1.883	2.025	1.08	2.45	27.0
Apr 21	7500	44.6	9.890	3.052	2.870	0.94	2.45	26.6
May 5	6200	18.9	11.755	1.865	5.070	2.72	3.34	25.5
May 19	5420	13.7	13.360	1.605	5.195	3.24	2.95	27.4
Jun 2	-[a]	17.0	15.630	2.270	6.170	2.72	3.04	28.3
Jun 16	6160	11.8	17.470	1.840	6.815	3.70	2.94	28.7
Jun 29	5550	11.1	19.415	1.945	2.990	1.54	1.25	28.6
Jul 15	5310	17.2	22.755	3.340	8.630	2.58	2.56	29.0
Jul 29	-[a]	8.3	24.650	1.895	7.095	3.74	2.14	25.9
Tank 6			3.570[b]					
Mar 24	4260	37.3	4.900	1.330	1.485	1.12	1.67	25.0
Apr 7	6980	37.6	6.740	1.840	2.025	1.10	2.49	26.8
Apr 21	7400	45.4	9.800	3.060	2.870	0.94	2.48	26.5
May 5	6000	15.4	11.310	1.510	5.070	3.36	3.43	25.4
May 19	5580	9.5	12.390	1.080	5.025	4.65	3.03	27.5
Jun 2	-[a]	22.7	15.200	2.810	5.725	2.04	2.96	27.8
Jun 16	5770	11.8	17.000	1.800	6.670	3.71	2.96	28.4
Jun 29	5450	13.6	19.311	2.311	2.905	1.26	1.23	28.4
Jul 15	5360	15.6	22.325	3.014	8.620	2.86	2.57	28.6
Jul 29	-[a]	9.8	24.510	2.185	6.960	3.19	2.12	25.6
Tank 7			3.560[b]					
Mar 24	3990	34.6	4.790	1.230	1.485	1.21	1.69	24.9
Apr 7	4340	37.9	6.605	1.815	1.890	1.04	2.37	27.1
Apr 21	5100	43.2	9.460	2.855	2.870	1.01	2.55	26.8
May 5	6600	14.6	10.840	1.380	4.845	3.51	3.41	25.5
May 19	5140	14.8	12.440	1.600	4.830	3.02	2.96	27.5
Jun 2	-[a]	16.1	14.440	2.000	5.725	2.86	3.04	28.1
Jun 16	5700	16.8	16.865	2.425	6.235	2.57	2.84	28.5
Jun 29	5500	12.5	18.981	2.116	2.905	1.37	1.24	28.5
Jul 15	5580	19.7	22.725	3.744	8.485	2.27	2.54	28.7
Jul 29	-[a]	10.1	25.030	2.305	7.095	3.08	2.12	25.6

[a] Meter used to measure conductivity was giving inaccurate readings during at least part of the period.

[b] Total weight of the 100 fish on March 3, 1984 when the acclimation period was started.

Table 4. Mean conductivities, percent weight gains, food conversion ratios, mean percent of total fish weight fed per day and mean temperatures in tanks of channel catfish maintained at a salinity of about 5,000 mg/L at the Roswell Test Facility, New Mexico from March 3 - July 29, 1984.

End of period	Mean conductivity (µmhos)	Percent weight gain	Total wt. of fish (kg)	Weight gain of fish (kg)	Weight of feed fed (kg)	Food conversion ratio	Mean % of fish weight fed/day	Mean temperature (°C)
Tank 8			3.548[b]					
Mar 24	5380	36.1	4.830	1.282	1.485	1.16	1.69	25.0
Apr 7	6750	40.2	6.770	1.940	2.025	1.04	2.49	27.1
Apr 21	9800	42.2	9.630	2.860	2.870	1.00	2.50	26.4
May 5	9900	18.8	11.440	1.810	4.545	2.51	3.08	25.4
May 19	9400	12.5	12.870	1.430	5.315	3.72	3.12	27.1
Jun 2	–[a]	19.9	15.430	2.560	5.995	2.34	3.02	28.1
Jun 16	8990	23.8	19.100	3.670	6.670	1.82	2.76	28.6
Jun 29	9220	10.7	21.135	2.035	3.250	1.58	1.24	28.7
Jul 15	8290	15.4	24.390	3.255	9.325	2.86	2.56	28.7
Jul 29	–[a]	6.4	25.950	1.560	7.630	4.89	2.17	25.6
Tank 12			3.588[b]					
Mar 24	8950	24.0	4.450	0.862	1.485	1.72	1.76	24.6
Apr 7	10100	30.4	5.805	1.355	1.755	1.30	2.44	26.6
Apr 21	8700	45.5	8.445	2.640	2.480	0.94	2.48	26.5
May 5	10900	19.0	10.050	1.605	4.260	2.65	3.29	25.2
May 19	8570	24.3	12.490	2.440	4.200	1.72	2.66	27.2
Jun 2	–[a]	11.4	13.920	1.430	5.860	4.10	3.17	28.1
Jun 16	10170	22.6	17.060	3.140	6.090	1.94	3.29	28.5
Jun 29	9050	12.7	19.230	2.170	2.905	1.34	1.23	28.6
Jul 15	9370	17.4	22.580	3.350	8.620	2.57	2.58	28.7
Jul 29	–[a]	10.2	24.880	2.300	7.095	3.08	2.14	25.5
Tank 16			3.610[b]					
Mar 24	7220	32.1	4.770	1.160	1.485	1.28	1.69	24.9
Apr 7	9320	37.5	6.560	1.790	1.890	1.06	2.38	27.1
Apr 21	8500	42.1	9.320	2.760	2.810	1.02	2.53	26.6
May 5	8700	17.8	10.975	1.655	4.650	2.81	3.27	25.5
May 19	8660	15.3	12.650	1.675	4.830	2.88	2.92	27.2
Jun 2	–[a]	13.4	14.350	1.700	5.860	3.45	3.10	28.0
Jun 16	10020	18.8	17.050	2.700	6.235	2.31	2.84	28.4
Jun 29	9100	9.9	18.739	1.689	2.905	1.72	1.25	28.4
Jul 15	9310	25.6	23.540	4.801	8.350	1.74	2.47	28.5
Jul 29	–[a]	10.0	25.890	2.350	7.440	3.17	2.15	25.5

[a] Meter used to measure conductivity was giving inaccurate readings during at least part of the period.

[b] Total weight of the 100 fish on March 3, 1984 when the acclimation period was started.

Table 5. Mean conductivities, percent weight gains, food conversion ratios, mean percent of total fish weight fed per day and mean temperatures in tanks of channel catfish maintained at a salinity of about 7,000 mg/L at the Roswell Test Facility, New Mexico from March 3 - July 29, 1984.

End of period	Mean conductivity (µmhos)	Percent weight gain	Total fish weight (kg)	Weight gain of fish (kg)	Weight of feed fed (kg)	Food conversion ratio	Mean% of fish wt. fed/day	Mean temperature (°C)
Tank 3			3.564[b]					
Mar 24	8820	33.3	4.750	1.186	1.485	1.25	1.70	25.0
Apr 7	10230	34.9	6.410	1.660	1.890	1.14	2.42	26.7
Apr 21	13100	30.3	8.350	1.940	2.740	1.41	2.65	26.4
May 5	12800	22.2	10.200	1.850	4.225	2.28	3.26	25.2
May 19	11950	18.2	12.060	1.860	4.200	2.26	2.70	27.0
Jun 2	-[a]	1.3	12.220	0.160	5.390	33.69	3.17	28.2
Jun 16	12420	32.8	16.230	4.010	5.365	1.34	2.69	28.6
Jun 29	12470	12.1	18.190	1.960	2.790	1.42	1.25	28.7
Jul 15	11510	29.8	23.610	5.420	8.115	1.50	2.43	28.7
Jul 29	-[a]	6.2	25.070	1.460	7.610	5.21	2.23	25.6
Tank 13			3.544[b]					
Mar 24	8500	27.3	4.510	0.966	1.485	1.54	1.76	24.9
Apr 7	10770	28.5	5.795	1.285	1.755	1.37	2.43	26.4
Apr 21	13100	32.6	7.685	1.890	2.480	1.31	2.63	26.4
May 5	12100	21.9	9.370	1.685	3.900	2.31	3.27	25.1
May 19	11910	17.5	11.010	1.640	3.955	2.41	2.77	26.9
Jun 2	-[a]	7.9	11.880	0.870	4.975	5.72	3.11	28.0
Jun 16	12580	29.2	15.350	3.470	5.220	1.50	2.74	28.6
Jun 29	12440	16.7	17.912	2.562	2.645	1.03	1.22	28.7
Jul 15	11880	24.6	22.310	4.398	7.970	1.81	2.48	28.7
Jul 29	-[a]	6.6	23.790	1.480	7.190	4.86	2.23	25.6
Tank 15			3.595[b]					
Mar 24	7660	32.7	4.770	1.175	1.485	1.26	1.69	24.9
Apr 7	10620	33.4	6.365	1.595	1.890	1.18	2.42	26.6
Apr 21	12600	34.6	8.570	2.205	2.740	1.24	2.62	26.5
May 5	12200	18.6	10.160	1.590	4.260	2.68	3.25	25.2
May 19	11870	8.2	10.995	0.835	4.450	5.33	3.01	27.3
Jun 2	-[a]	7.3	11.800	0.805	4.975	6.18	3.12	28.0
Jun 16	12940	31.4	15.500	3.700	5.220	1.41	2.73	28.3
Jun 29	12400	8.4	16.802	1.302	2.675	2.05	1.27	28.5
Jul 15	12220	34.1	22.530	5.728	7.340	1.28	2.33	28.6
Jul 29	-[a]	3.2	23.260	0.730	7.285	9.98	2.27	25.6

[a] Meter used to measure conductivity was giving inaccurate readings during at least part of the period.

[b] Total weight of the 100 fish on March 3, 1984 when the acclimation period was started.

Table 6. Mean conductivities, percent weight gains, food conversion ratios, mean percent of total fish weight fed per day and mean temperatures in tanks of channel catfish maintained at a salinity of about 9,000 mg/L at the Roswell Test Facility, New Mexico from March 3 - July 29, 1984.

End of period	Mean conductivity (µmhos)	Percent wt. gain	Total fish weight (kg)	Weight gain of fish (kg)	Weight of feed fed (kg)	Food conversion ratio	Mean % of fish wt. fed	Mean temperature (°C)
<u>Tank 2</u>			3.598[b]					
Mar 24	8500	27.1	4.572	0.974	1.485	1.52	1.73	25.1
Apr 7	13220	16.0	5.305	0.733	1.890	2.52	2.73	26.5
Apr 21	15700	16.5	6.182	0.877	1.820	2.08	2.26	26.1
May 5	15400	23.0	7.605	1.423	2.275	1.60	2.36	25.2
May 19	13880	1.4	7.708	0.103	3.190	30.97	2.98	27.0
Jun 2	-[a]	-1.9	7.560	-0.148	3.315	--	3.10	28.3
Jun 16	15120	35.8	10.270	2.710	3.335	1.23	2.67	28.7
Jun 29	14840	4.4	10.727	0.457	2.255	4.93	1.65	28.8
Jul 15	14230	31.0	14.055	3.328	4.165	1.25	2.10	28.9
Jul 29	-[a]	-4.3	13.450	-0.605	4.535	--	2.36	25.7
<u>Tank 9</u>			3.491[b]					
Mar 24	9620	28.1	4.480	0.982	1.485	1.51	1.77	24.8
Apr 7	11900	19.0	5.330	0.850	1.755	2.06	2.56	26.7
Apr 21	15200	14.3	6.090	0.760	1.820	2.39	2.28	26.1
May 5	15600	15.4	7.025	0.935	2.275	2.43	2.48	25.1
May 19	14600	7.3	7.540	0.515	3.215	6.24	3.15	27.0
Jun 2	-[a]	9.7	8.270	0.730	3.315	4.54	3.00	27.9
Jul 16	15120	37.0	11.330	3.060	3.625	1.18	2.64	28.3
Jun 29	15080	8.4	12.280	0.950	1.955	2.06	1.27	28.5
Jul 15	14160	22.6	15.060	2.780	4.910	1.77	2.25	28.5
Jul 29	-[a]	-2.7	14.660	-0.400	4.820	--	2.32	25.5
<u>Tank 17</u>			3.533[b]					
Mar 24	9900	21.7	4.300	0.767	1.485	1.93	1.81	25.2
Apr 7	13740	8.9	4.685	0.385	1.485	3.86	2.36	26.9
Apr 21	15500	15.9	5.430	0.745	1.820	2.44	2.57	26.4
May 5	15600	19.0	6.460	1.030	2.235	2.17	2.68	25.4
May 19	15100	8.4	7.000	0.540	2.830	5.24	3.00	27.0
Jun 2	-[a]	-4.3	6.700	-0.300	3.045	--	3.18	28.3
Jun 16	15450	39.3	9.330	2.630	2.900	1.10	2.58	28.5
Jun 29	15450	12.4	10.490	1.160	2.010	1.73	1.56	28.6
Jul 15	14400	39.1	14.590	4.100	4.035	0.98	2.01	28.6
Jul 29	-[a]	-3.9	14.020	-0.570	4.725	--	2.36	25.5

[a] Meter used to measure condcutivity was giving inaccurate readings during at least part of the period.

[b] Total weight of the 100 fish on March 3, 1984 when the acclimation period was started.

Table 7. Mean conductivities, percent weight gains, food conversion ratios, mean percent of total fish weight fed per day and mean temperatures in tanks of channel catfish maintained at a salinity of about 11,000 mg/L at the Roswell Test Facility, New Mexico from March 3 - May 5, 1984.

End of period	Mean conductivity (µmhos)	Percent weight gain	Total fish weight (kg)	Weight gain of fish (kg)	Weight of feed fed (kg)	Food conversion ratio	Mean % of fish wt. fed/ day	Mean temperature (°C)
<u>Tank 5</u>			3.578[a]					
Mar 24	9590	22.0	4.364	0.786	1.485	1.89	2.67	25.1
Apr 7	15070	8.7	4.745	0.381	1.755	4.61	2.75	26.5
Apr 21	18700	-6.1	4.456	-0.289	1.670	--	2.59	26.2
May 5	18300	-0.2	4.310	-0.011	1.560	--	2.54	25.3
<u>Tank 11</u>			3.531[a]					
Mar 24	11130	15.0	4.060	0.529	1.485	2.81	2.79	24.9
Apr 7	16550	5.8	4.295	0.235	1.620	6.89	2.77	26.4
Apr 21	18800	0.3	4.310	0.015	1.560	104.0	2.59	26.0
May 5	18800	1.2	4.360	0.050	1.560	31.2	2.57	25.2
<u>Tank 14</u>			3.514[a]					
Mar 24	8800	22.4	4.300	0.786	1.485	1.89	2.71	25.0
Apr 7	16190	4.7	4.500	0.200	1.620	8.10	2.63	26.4
Apr 21	19000	-1.4	4.350	-0.064[b]	1.560	--	2.52	26.0
May 5	18500	8.6	4.680	0.375	1.560	4.16	2.47	25.2

[a] Total weight of the 100 fish on March 3, 1984 when the acclimation period was started.

[b] Two fish that weighed a total of 86g died on April 19.

Table 8. Mean total weights of fish, percent weight gains, food conversion ratios, and percent of fish weight fed per day for channel catfish grown in water of different salinities at the Roswell Test Facility, March 3 - July 29, 1984.

End of period	March	April		May		June			July	
	24	7	21	5	19	2	16	29	15	29
Roswell city water - (about 1,055 mg/L)										
Mean total tank weight, kg	4.9	6.8	9.8	11.4	13.3	16.2	18.4	19.7	22.6	25.1
Mean percent weight gain	36.5	40.2	43.7	15.9	16.7	21.9	14.1	6.7	14.8	11.3
Mean FC ratio	1.14	1.03	0.98	3.24	2.70	2.11	3.42	2.61	3.09	2.93
Mean % of fish weight fed/day	1.67	2.47	2.50	3.42	2.94	2.96	2.89	1.25	2.60	2.13
Target salinity of 3,000 mg/L										
Mean total tank weight, kg	4.9	6.7	9.7	11.3	12.7	15.1	17.1	19.2	22.6	24.7
Mean percent weight gain	36.7	37.8	44.4	16.3	12.7	18.6	13.5	12.4	17.5	9.4
Mean FC ratio	1.14	1.13	0.96	3.20	3.64	2.54	3.33	1.39	2.57	3.34
Mean % of fish weight fed/day	1.67	2.44	2.49	3.39	2.98	3.01	2.91	1.24	2.56	2.13
Target salinity of 5,000 mg/L										
Mean tank weight, kg	4.7	6.4	9.1	10.8	12.7	14.6	17.7	19.7	23.5	25.6
Mean percent weight gain	30.7	36.0	43.3	18.5	17.4	14.9	21.7	11.1	19.5	8.9
Mean FC ratio	1.39	1.13	0.99	2.66	2.77	3.30	2.02	1.55	2.39	3.71
Mean % of fish weight fed/day	1.71	2.44	2.50	3.21	2.90	3.10	2.96	1.24	2.54	2.15
Target salinity of 7,000 mg/L										
Mean total tank weight, kg	4.7	6.2	8.2	9.9	11.4	12.0	15.7	17.6	22.8	24.0
Mean percent weight gain	31.1	32.3	32.5	20.9	14.6	5.5	31.1	12.4	29.5	5.3
Mean FC ratio	1.35	1.23	1.32	2.42	3.33	15.2	1.42	1.50	1.53	6.68
Mean % of fish weight fed/day	1.72	2.42	2.63	3.26	2.83	3.13	2.72	1.25	2.41	2.24
Target salinity of 9,000 mg/L										
Mean total tank weight, kg	4.5	5.1	5.9	7.0	7.4	7.5	10.3	11.2	14.6	14.0
Mean percent weight gain	25.6	14.6	15.6	19.1	5.7	1.2	37.4	8.4	30.9	-3.6
Mean FC ratio	1.65	2.83	2.30	2.07	14.15	--[a]	1.17	2.91	1.33	--[a]
Mean % of fish weight fed/day	1.77	2.55	2.37	2.51	3.04	3.0	2.63	1.49	2.12	2.35
Target salinity of 11,000 mg/L[b]										
Mean total tank weight,kg	4.2	4.5	4.4	4.4	--[b]	--	--	--	--	--
Mean percent weight gain	19.8	6.05	-2.4	3.2	--[b]	--	--	--	--	--
Mean FC ratio	2.20	6.53	---[a]	--[a]	--[b]	--	--	--	--	--
Mean % of fish weight fed/day	2.72	2.72	2.57	2.53	--[b]	--	--	--	--	--

[a] Fish in one or more tanks lost weight during this period.

[b] Experiment was stopped for fish at this total dissolved solids on May 5, 1984.

conversion ratios greater in tanks where mean conductivity was greater, especially when it was> 15,000 micromhos (about 9,000 mg/L) (Tables 6 and 7). Continuing problems with regulating the proportion of brackish to city water caused the mean conductivities of tanks to still be less than the target treatment levels during this 2-week period. Except for tanks receiving only Roswell city water, the mean conductivities of the 18 tanks varied in more of an irregularly spaced continuum than in an experiment with an equal number of replicates at each treatment level (Tables 2-7). The best fit for the relationship between mean conductivity (X) and percent weight gain (Y) of a given tank of fish was described by the equation, $Y = 39.12 + 0.780X - 0.0985X^2 - 0.00524X^3$ ($R^2 = 0.939$), where X was conductivity in 1000s of micromhos. Dissolved oxygen concentrations in the tanks ranged from 5.5 to 6.5 mg/L on April 6.

<u>April 7-21</u>

Except for tanks meant to be maintained at a salinity of 3000 mg/L, the mean salinities of the three tanks designated for a given treatment were similar to each other and also close to the desired treatment levels during this 2-week growth period (Table 9). Mean water temperatures (26.3 - 27.0°C) and the actual mean percent of fish weight fed per day (2.26 - 2.65%) were also similar. Poorer growth of fish during the previous 5 weeks caused the mean starting weights of fish in tanks at the two highest salinity levels (45 and 51 g) to be less than the mean fish weights (62 - 67 g) for the other salinity levels

Table 9. Mean total dissolved solids percent weight gains, food conversion ratios, mean percent of fish weight fed per day and mean temperatures for tanks used to grow channel catfish for April 7-20, 1984 at the Roswell Test Facility, New Mexico.

Mean TDS (mg/L)	95% confidence limits	Percent weight gain	Food conversion ratio	Mean % of fish weight fed/ day	Mean water temperature (°C)	Tank number
680	631-729	44.6	0.95	2.47	26.7	10
690	652-728	44.7	0.95	2.47	27.0	18
700	661-739	41.7	1.04	2.56	26.8	4
2,730	2,104-3,356	43.2	1.01	2.55	26.8	7
3,960	3,437-4,283	45.4	0.94	2.48	26.5	6
4,260	3,584-4,936	44.6	0.94	2.45	26.6	1
4,620	3,979-5,261	45.5	0.94	2.48	26.7	12
4,720	4,395-5,045	42.1	1.02	2.53	26.8	16
5,510	5,140-5,880	42.2	1.00	2.50	26.6	8
7,380	7,115-7,645	34.6	1.24	2.62	26.5	15
7,670	7,323-8,017	30.3	1.41	2.65	26.4	3
7,630	7,374-7,886	32.6	1.31	2.63	26.4	13
9,160	8,839-9,481	14.3	2.39	2.28	26.4	9
9,280	9,063-9,497	15.9	2.44	2.57	26.6	17
9,440	9,170-9,710	16.5	2.08	2.26	26.4	2
9,920	10,597-11,243	-6.1	-[a]	2.59	26.5	5
10,990	10,715-11,265	0.3	104.0	2.59	26.4	11
10,990	10,688-11,292	-1.4	-[a]	2.52	26.3	14

[a] The fish lost weight in this tank so the food conversion ratio was meaningless.

(Table 8).

Mean percent gains (43.3 - 44.4%) and mean food conversion ratios (0.96 - 0.99) of fish in tanks, that were maintained at the three lowest salinity levels, were not significantly different between treatments ($P > 0.05$). In contrast, mean percent weight gains of fish grown in tanks with mean salinities of 7,560, 9,293, and 10,633 mg/L (mean weight gains of 32.5, 15.6, and -2.4%, respectively) were significantly different from each other and from fish grown at lower salinity levels. Mean food conversion ratios (FCR) showed a similar pattern in significant differences between treatments as observed for mean weight gains; FCR could not be determined for the highest salinity level because fish in two of the three tanks lost weight during this period. (Table 8).

For this period the relationship between percent weight gain (Y) and mean salinity (X) of the test tank was best described by the equation, $Y = 43.155 + 0.09809X - 0.00004330X^3$ ($R^2 = 0.986$) where X was salinity in 100-mg/L units (Figure 1). The relationship between food conversion ratio (Y) and salinity was best described by the equation, $Y = 1.038 - 0.0002532X^2 + 0.00000423X^3$ ($R^2 = 0.943$), where X was salinity in 100-mg/L units (Figure 1).

April 21 - May 5

Although mean conductivities of all tanks remained similar to those measured during the preceding period (Tables 2-7), the mean percent weight gains for all four treatments $\leq$ 7,000 mg/L decreased from mean weight gains of 32.5 - 44.4% during the April

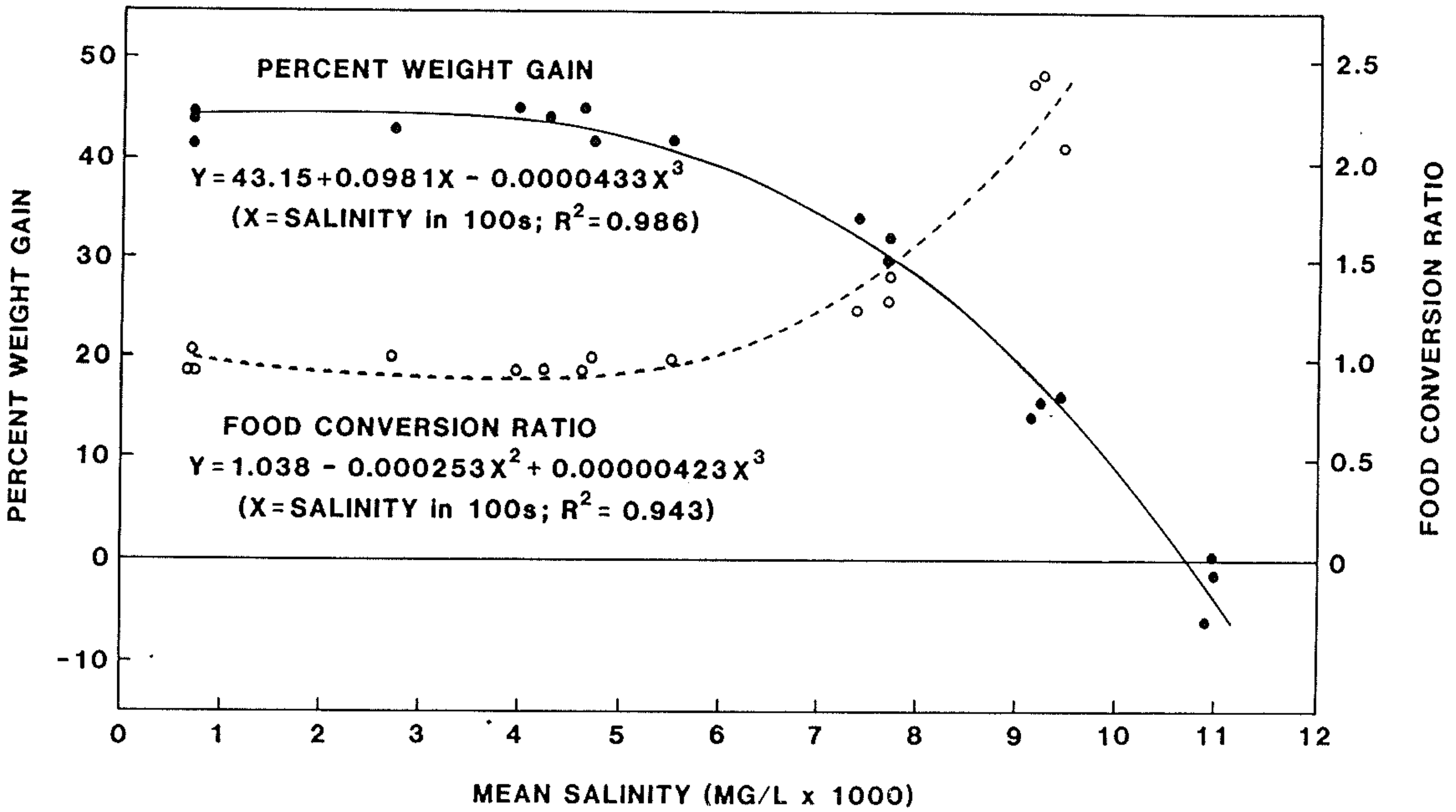

Figure 1. Effect of salinity on the percent weight gain and food conversion ratio of channel catfish raised in circular tanks at the Roswell Test Facility, New Mexico, April 7-21, 1984.

May 5-19

Percent weight gains and food conversion ratios of fish at the three lower salinity levels remained similar during this period to values during the previous period (Table 8). Dissolved oxygen concentrations of tanks measured on May 13 (3.4 - 4.2 mg/L) indicated that the poorer growth of fish during the periods ending on May 5 and May 19 was related to low dissolved oxygen levels. Another possible problem during this growth period was a systematic error in the conductivity readings used to adjust the proportion of brackish to city at the different salinities levels. Although the mean conductivities of tanks measured during the May 5-19 period were slightly less than the means for the previous period (Tables 2-7), the actual mean conductivity may have been somewhat higher because the conductivity meter may have been reading too low. The conductivity meter was reading 30-40% too low on May 28 because the probe was fouled. If the meter was also reading too low during May 5-19, the salinity levels in the tanks would have been adjusted higher than the planned treatment levels. Mean percent weight gains of tanks meant to be at a salinity of 9,000 mg/L decreased from 19.1% (period ending May 5) to 5.7% for the period ending May 19 (Table 8).

May 19 - June 2

The resumption of supplemental aeration during this period using a low pressure, high volume air compressor partially alleviated the problem of low dissolved oxygen in the tanks, but dissolved oxygen was still less than desirable (3.7 - 5.0 mg/L) on June 1. However, the most serious problem during this growth period was the error in conductivity readings first confirmed on May 28 and corrected on May 30. After the probe of the conductivity meter was cleaned, the meter measurements taken before adjusting the valves on the brackish and city water lines indicated that tanks meant to be at salinity levels of 5,000, 7,000, and 9,000 mg/L were actually closer to concentrations of 6,000, 9,500, and 12,000 mg/L, respectively. Although the salinities of these tanks may not have been this high throughout the 2-week period, the decreases in mean percent weight gains from the previous period of fish in tanks targeted for 7,000 mg/L (14.6 to 5.5%) and 9,000 mg/L (5.7 to 1.2%) were not surprising (Table 8). In contrast, mean percent weight gains of fish in tanks being maintained at the two lower salinity levels were greater than the two previous growth periods (Table 8).

June 2-16

After salinity levels in the tanks were adjusted back to target levels on May 30, mean percent weight gains during June 2-16 increased to 37.4% for fish at 9,000 mg/L and to 31.1% for fish at 7,000 mg/L (Table 8). Because of relatively lower total fish weights, dissolved oxygen concentrations in tanks at salinities levels of 7,000 and 9,000 mg/L were 4.1 - 4.6 mg/L on June 3 and mean food conversion ratios ranged from 1.10 to 1.50. In contrast, oxygen levels were 3.2 - 3.6 mg/L in tanks at about 5,000 mg/L. These tanks had a mean weight gain of 21.7% and a mean FCR in tanks at about 1,000 and 3,000 mg/L of 2.02 (Table 8). Although total fish weights in tanks at about 1,000 and

3,000 mg/L were only slightly greater than in tanks at 5,000 mg/L, the oxygen concentrations on June 3 (2.4 - 3.1 mg/L) and mean percent weight gains during the period (13.5 and 14.1%) were less than for fish in tanks at higher salinities (Table 8).

June 16 - July 29

Because of problems with maintaining satisfactory dissolved oxygen concentrations, the percent of fish weight fed per day was reduced to 1.24 - 1.49% during the period ending June 29. Mean percent weight gains (6.7 - 12.4%) were similar between tanks at the different salinities. After installing larger capacity flow regulators in early July, the amount of water injected into the tanks was increased from 5.7 to 9.7 L per minute. Mean percent weight gains during the period ending July 15 were inversely related to salinity with a range in mean weight gains from 14.8% for the lowest salinity (city water) to 30.9% for fish at a salinity of about 9,000 mg/L (Table 8). Renewed problems with the conductivity meter caused the TDS levels during the period ending July 29 to exceed the target salinities. Except for fish at the highest salinity level, where fish lost weight, the mean percent weight gains ranged from 5.3% for fish at the next to highest salinity to 11.3% for fish grown in city water. Mean temperatures of the tanks during the period ending July 29 were about 3°C lower than the previous 2-week period because the heating system was turned off.

Second (August) Experiment

For channel catfish acclimated at salinities of about 3,000 and 5,000 mg/L, mean percent weight gains of fish (mean starting weights of 271 g) ranged from 21.02 to 26.64% and were not significantly different between treatments for fish in tanks at the three lower salinities during the period ending August 17 (Table 10). However, mean percent weight gains (16.86 and 15.33%) were significantly different ($P < 0.01$) from other treatment means for fish that were maintained at about 8,200 mg/L. The two-way analysis of variance comparing the effect of treatment (salinity) and acclimation salinity found no signficant acclimation or acclimation X salinity treatment effect on either percent weight gain or food conversion ratio (FCR) of catfish grown at four different salinities during August 18-31 (Table 11). However, mean percent weight gain and mean FCR of fish grown at about 8,800 mg/L. During August 18-31 were significantly poorer ($P < 0.001$) than for means at lower salinities. For fish grown at the three lower salinities, FCR ranged from 1.60 to 2.01 and percent of fish weight fed per day ranged from 1.90 to 1.97%.

Mean salinity of tanks at the same treatment and acclimation condition varied <200 mg/L during the growth periods ending on August 17 and 31 (Tables 10 and 12). As was the case during both 2-week periods, the only significant difference between salinity treatments and acclimation conditions throughout the August 4 - 31 period was the lower mean percent weight gains at the highest salinity. Mean weight gains during August 4-31 ranged from 41.66 to 47.12% for fish at the three lower salinities, whereas gains were 22.77 and 24.14% for fish grown at 8,500 mg/L (Table 11).

Table 10. Percent weight gains of channel catfish grown in water of different salinities at the Roswell Test Facility, New Mexico, August 4-17, 1984[a].

Acclimated at about 3,000 mg/L				Acclimated at about 5,000 mg/L			
Mean salinity (mg/L)	Mean salinity (mg/L) of two tanks	Percent weight gain for tank	Mean % weight gain of two tanks	Mean salinity (mg/L)	Mean salinity (mg/L) of two tanks	Percent weight gain for tank	Mean % weight gain of two tanks
2820	2860	18.02	21.02	2750		23.00	--[b]
2900		24.02		--		--	
4720	4745	25.72	26.64	4700	4720	20.57	21.98
4770		27.56		4740		23.38	
6400	6400	22.20	23.86	6430	6445	24.70	23.52
6400		25.51		6460		22.34	
8120	8195	18.66	16.86[c]	8220	8240	13.73	15.33[c]
8270		15.05		8260		16.93	

[a] Mean water temperatures of tanks were 24.3-24.5°C.

[b] Only one tank was tested for this salinity and acclimation salinity.

[c] Mean percent weight gain is significantly different ($P<0.01$) from the mean of the other treatments after they were adjusted for acclimation condition.

Table 11. Mean percent weight gains and food conversion ratios of channel catfish grown in water of different salinities at the Roswell Test Facility, New Mexico, August 4-31, 1984.

August 4 - 17		August 18 -31			August 4 - 31	
Mean salinity (mg/L)	Mean weight gain	Mean salinity (mg/L)	Mean % weight gain	Food conversion ratio	Mean salinity (mg/L)	Mean % weight gain
Acclimated at about 3,000 mg/L						
2860	21.02	3210	17.16	1.74	3035	41.66
4745	26.64	4810	16.18	1.72	4778	47.12
6400	23.86	6555	15.94	1.92	6478	42.84
8195	16.86[b]	8765	5.07[b]	4.81[b]	8480	22.77[b]
Acclimated at about 5,000 mg/L						
2750[a]	23.00	3070[a]	16.97	1.75	2910[a]	43.88
4720	20.57	4935	16.80	1.82	4828	42.44
6445	24.70	6615	17.35	1.78	6530	44.94
8240	15.33[b]	8810	7.68[b]	3.38[b]	8525	24.14[b]

[a] Only one tank was tested for this salinity level and acclimation condition; all other values are means for two tanks.

[b] Mean was significantly different ($P < 0.001$) from the means of other treatments after they were adjusted for acclimation condition.

Table 12. Percent weight gains and food conversion ratios of channel catfish grown in water of different salinities from August 18-31, 1984 at the Roswell Test Facility, New Mexico[a].

Acclimated at about 3,000 mg/L				Acclimated at about 5,000 mg/L			
Mean salinity (mg/L)	Mean salinity (mg/L) of two tanks	Percent weight gain for tank	Food conversion ratio	Mean salinity (mg/L)	Mean salinity (mg/L) of two tanks	Percent weight gain for tank	Food conversion ratio
3140	3210	16.00	1.88	3070	_[b]	16.97	1.75
3280		18.33	1.60	_[b]		-	-
4770	4810	15.19	1.80	4890	4935	18.49	1.62
4850		17.18	1.65	4980		15.10	2.01
6450	6555	14.89	1.95	6590	6615	18.26	1.79
6660		16.98	1.88	6640		16.44	1.78
8750	8765	4.53	4.90	8780	8810	7.86	4.15
8780		5.61	4.72	8840		7.51	2.61

[a] Mean water temperatures of tanks were 25.6-25.8°C.

[b] Only one tank was tested for this TDS level and acclimation condition.

DISCUSSION

The third growth period (April 7-21) was the best period during the Initial Experiment for determining the effect of salinity on the growth and food conversion ratio (FCR) of fingerling channel catfish. During other growth periods, salinity was either less than desired treatment levels or could not be accurately determined during all days of the period. In addition, low dissolved oxygen concentrations apparently reduced growth rates of fish after April 21 and confounded meaningful comparisons between tanks at different salinities. Percent weight gains (41.7-45.5%) and FCRs (0.94-1.04) were not significantly different for fish grown in tanks with mean salinities of ≤ 5,500 mg/L. However, both mean percent weight gain (32.5%) and mean FCR (1.32) were significantly different for fish grown in tanks with a mean salinity of 7,560 mg/L than for fish grown in tanks at lower or higher salinities.

Acclimation of channel catfish in tanks maintained at salinities of about 3,000 and 5,000 mg/L for an additional 3 1/2 months at the RTF had no apparent impact on the effect of salinity on fish growth. Percent weight gain of fish (mean starting weight of 271 g) during August 4-17 was not significantly different for fish grown in tanks with mean salinities of 2,805, 4,732, and 6,422 mg/L. However, growth was significantly poorer for fish grown in tanks with a mean salinity of 8,217 mg/L. During the next 2-week period (August 18-31), mean percent weight gain and mean FCR were similar for fish grown in tanks with mean salinities of 3,140, 4,872 and 6,585 mg/L. Again fish grown at the highest mean salinity level (8,787 mg/L) had significantly poorer weight gain and FCR.

In contrast to my findings, mean percent weight gain (30.6%) and FCR (1.58) for yearling channel catfish (mean initial weights of 8-9 g) grown in fresh water were similar to values (28.0% and 1.64) of fish grown for 45 days in sea water diluted to 8 ppt; fish had been accliminated at salinities of 5 and 10 ppt for 154 days (Allen and Avault 1970a). Percent weight gains were slightly less for fish at salinities of 9, 10, and 11 ppt (17.6-28.6% increases). Allen and Avault (1970a) concluded that yearling channel catfish acclimated at 5 and 10 ppt for 154 days had similar weight gains, survival, and FCR after 45 days at test salinities of 0, 8, 9, 10, and 11 ppt. However, their test salinites were unreplicated and no statistical tests were made. Another serious problem that probably affected the validity of their conclusions was the low percent of fish body weight fed per day (% BWF) during the experiment. Analysis of their data indicated that fish in one freshwater tank was fed 0.83% per day and fish grown at 8, 9, and 10 ppt were fed 0.89-0.97% per day. These feeding rates were less than one-third the currently recommended % BWF for the appropriate size of channel catfish and water temperature (Foltz 1982; Stickney and McGeachin 1984; Westers 1987). Thus, the low feeding rates and lack of replication potentially masked significant differences in weight gain and FCR of fish grown at different test salinities. Because of the low % BWF, fish grown at salinities of 0, 8, 9, 10, and 11 ppt gained only 17.6-30.6% of their initial weights in 45 days (Allen and Avault 1970a). In contrast, mean weight gains of catfish after 49 days in the RTF study ranged from 67% at the target salinity of 9,000 mg/L to 175% for fish grown in 100% city water.

In the RTF study, fish maintained at a mean salinity of 10,633 mg/L during April 7-21 lost weight, whereas fish in aquaria at 11 ppt gained weight in the study of Allen and Avault (1970a). In the latter study, yearling channel catfish acclimated for 154 days at 10 ppt also gained weight at a test salinity of 12 ppt, but lost weight at 13 ppt. The inability of fish at the RTF to gain weight at a salinity of about 11 ppt may be related to the differences in either acclimation conditions or chemical composition of the groundwater used at the RTF versus the diluted seawater used by Allen and Avault (1970a). Sulfate was a major constituent of the groundwaters near Roswell, New Mexico, whereas it would be a minor constituent of seawater. Lewis (1972) reported fingerling channel catfish had high mortality rates within 3-4 weeks when grown in tanks where 2,066 mg/L of sodium sulfate was added to city water of Carbondale, Illinois. However, no fish mortalities occurred in the same experiments in tanks where 1,700 mg/L of sodium chloride had been added. In contrast, percent weight gain and FCR in one experiment were much better in the tanks where sodium sulfate had been added than in tanks with only city water and tanks where sodium chloride was added.

Sodium sulfate was more toxic to bluegill, Lepomis macrochirus, than sodium chloride or sodium nitrate when considering their molar concentrations, but was either slightly less toxic (sodium nitrate) or had similar toxicity (sodium chloride) when considering total concentration in mg/L (Trama 1954).

Percent weight gains and food conversion ratios of fish at the three lower salinities in the RTF study were similar to values in other tank studies with channel catfish when the influence of water temperature, dissolved oxygen concentrations, and feeding rate were considered (Andrews et al. 1971; Stickney et al. 1972; Andrews et al. 1973; Carter and Allen 1976; and Stickney and McGeachin 1984). For example, channel catfish fed at 3% and 4% of body weight (% BWF) gained 199% and 227%, respectively, and had FCR values of 0.9-1.3 (Stickney and McGeachin 1984). Catfish of similar size and grown at similar temperatures at the RTF gained 154-175% and had FCRs of 1.0-1.1 after 49 days for fish in tanks at the three lower TDS levels. The slightly lower weight gains at the RTF were probably related to the lower % BWF during the first 10 days of the acclimation period. The actual mean % BWF during the first 49 days in the RTF study was 2.4%.

Channel catfish fed ad libitum three times per day for 42 days gained 265, 207, and 108% and had FCRs of 1.12, 1.18, and 1.47 when grown in tanks where dissolved oxygen (DO) was maintained at 100, 60, and 36% of saturation,respectively (Andrews et al. 1973). It was likely that low DO concentrations reduced the growth of fish at the three lower salinities during the 7th-11th weeks of the RTF study because supplemental aeration was not used. Mean weight gains during this 4-week period were less than half previous weight gains and FCRs were 2-3 times greater than during the first 7 weeks. Growth of fish during the period of no supplemental aeration at the RTF was similar to weight gains of fish maintained at 36% of oxygen saturation (Andrews et al. 1973). DO concentrations in tanks at the RTF were 3.4-4.2 mg/L near the end of the 4-week period (April 21-May 19) of no supplemental aeration. Carter and Allen (1976) found significantly reduced growth and poorer FCR of channel catfish (mean initial weight of 64 g) when DO dropped below 4 mg/L in tanks that reached temperatures up to 34.5 C. Carlson et al. (1980) found growth of channel catfish, that reached mean weights of 4.5-9.6 g after 69 days at 25°C, was significantly poorer for fish grown in tanks with a mean DO of 3.4 mg/L than in tanks with a mean DO of 7.65 mg/L; weight gains of fish grown at mean DOs of 5.0, 3.4, and 2.0 mg/L were 86, 61, and 46%, respectively, of the gains of fish at 7.65 mg/L. Although a minimum DO of 5 mg/L is normally recommended for production of warmwater fishes (Piper et al. 1982), channel catfish are more tolerant to low DO (Stickney 1986). In the RTF study, weight gains and FCR of channel catfish at salinities < 7,000 mg/L were excellent through the first 7 weeks when DOs were 4-6 mg/L, but were negatively affected during subsequent periods when DO was < 4mg/L at mean water temperatures of 25-28°C.

Weight gains and FCR of fish at salinities < 7,000 mg/L in the RTF study were much better through 7 weeks than reported for channel catfish grown in tanks with either freshwater (Lewis 1973; Carter and Allen 1976) or brackish water (Allen and Avault 1970a; Lewis 1973); the feeding practices used in the other studies were at least partially responsible for the differences in weight gains. Results of the RTF study indicate that fingerling channel catfish grow and survive well in tanks receiving brackish groundwater with salinities < 7,000 mg/L. The FCR values of fish (35-100 g) grown at < 7,000 mg/L during the first 7 weeks of the RTF study were either better than or similar to FCRs and survival rates of channel catfish grown in tank studies (Andrews et al. 1971; Stickney et al. 1972; Andrews et al. 1973; Stickney and McGeachin 1984) and were better than values for monoculture and polyculture tests using channel catfish in brackish water ponds (Perry and Avault 1972; Perry 1975). With the exception of fish at about 11,000 mg/L only seven fish died during the RTF study. Six of these mortalities occurred within 24 hours of a static formalin treatment during the second week of the acclimation period.

High-density culture of channel catfish in brackish waters has several potential advantages over culture in fresh water (Avault 1982; Stickney 1986). Control of serious parasites like Ichthyophthirius multifilis by the elimimation of the infective trophozoites was documented for channel catfish maintained in brackish water of 1 to 9 ppt (Allen and Avault 1970b). Avault (1982) indicated that no problems with off-flavor, brown-blood disease and infectious diseases occurred in 10 years of research on channel catfish in brackish water ponds in Louisiana. He felt off-flavor problems were avoided at salinities of 1.5 to 8 ppt by the control of blue-green algae that cause off-flavor problems when ingested by fish. Brown-blood disease, which is caused by elevated nitrite concentrations in high-density culture of channel catfish, can be controlled by the addition of chloride ions (Tomasso et al. 1979; Huey et al. 1980).

Another potential advantage of brackish-water aquaculture is the reduction in the toxicity of ammonia to fish (Alabaster et al. 1979; Harader and Allen 1983). Atlantic salmon, Salmo salar, were more tolerant to ammonia when salinities of the culture water was similar to salinity of body fluids (Alabaster et al. 1979). Likewise, the toxicity of ammonia was lowest in brackish water of 9.6 ppt for chinook salmon, Oncorhynchus tshawytscha, and toxicity was greatest in freshwater when compared to waters of greater or lesser salinity than 9.6 ppt (Harader and Allen 1983). Sheehan and Lewis (1986) theorized that the ammonia tolerance of channel catfish may be influenced more by salinity or certain ions than for the more euryhaline salmonids. They also concluded that the apparent increase in NH_3 toxicity of channel catfish at lower pH was caused by the osmotic effects of toxicant formulations and not by NH_4, which they considered essentially nontoxic. Because ammonia and nitrite concentrations can become serious problems when rearing channel catfish (Piper et al. 1982), growth in brackish water may offer advantages by reducing apparent toxicities of these substances in high-density culture systems, especially in recycle systems.

Another potential advantage of growing freshwater fish in brackish waters, that are closer to the osmotic concentration of their body fluids, could be a reduction in the energy needed for osmoregulation (Canagarathnam 1959; Lewis 1972; Stickney 1979). Freshwater fish normally maintain the total dissolved solids of their body fluids between 8,000 and 12,000 mg/L by osmoregulation (Brett 1979). The effect of increasing salinities on the respiratory oxygen consumption of channel catfish is unknown, however oxygen consumption can either increase or decrease with increasing salinities, depending on the species (Maceina et al. 1980; Woo and Tong 1982). Lewis (1972) found weight gains and FCRs of fingerling channel catfish were generally better for fish grown in tanks where salinities were increased by adding either 850 or 1,7000 mg/L of sodium chloride or sodium sulfate than for fish grown in freshwater without salts added. Although Lewis (1972) assumed the beneficial effect of added salts was related to reduction in energy needed to maintain osmotic balance, the actual variation in energy requirements over a range of salinities has not been evaluated.

Recent increases in catfish production and sale for food use and sale for stocking in private and public fishing waters (Parker In Press) indicate that the potential for starting commercial catfish production in New Mexico has probably improved since 1983. Production of farm-raised catfish processed by the major processors increased from 13,687 metric tons (mt) in 1978 (Rhodes 1987) to 127,231 mt in 1987 (Anon. 1988). Parker (In Press) estimated that about 182,000 mt of farm-raised catfish were processed as food fish in the United States in 1987. Expansion in the sales and marketing of processed channel catfish to restaurants and super markets during the last 5 years has made channel catfish well known to the public (Rhodes 1986). At the present time, high national demand for processed channel catfish and relatively low supplies (Jones 1988) have resulted in the average price paid to the producer by the major processors increasing from $0.59 per pound (live weight) in March of 1987 (Anon. 1987) to $0.75 per pound (Anon. 1988) 12 months later.

A review of the scientific literature and the results of the present study suggests that the growth of channel catfish in brackish groundwaters of the Pecos Valley with salinities < 7,000 mg/L is possible. Although vaiations in the chemical compostition of the water supply from values used in the RTF study could have negative effects on growth, it appears that culture in waters with salinities of 1-6 ppt may offer some advantages over culture in fresh water.

A decision on the best culture system for production of channel catfish or other species in brackish water in southern New Mexico would have to be based on a thorough evaluation of the construction and operational costs of the various systems. In the United States most channel catfish are produced in large ponds in southern states with good groundwater supplies and a growing season of at least 150-210 days; the length of the optimal growing season is the number of days when water temperatures exceed 23.9°C (75°F) (Huner and Dupree 1984b). Because of high evaporation rates in southern New Mexico, pond culture of species that prefer high water temperatures may be less feasible than in other southern states due to a restricted growing season. Alternative culture systems using containers (e.g. raceways, tanks) may have potential, but most require pumping of water from springs, wells or surface waters through the container to maintain satisfactory water quality. Unless geothermal waters are available to maintain optimal water temperature for channel catfish growth, groundwaters would be too cool for efficient production. In Idaho the mixing of water from artesian geothermal wells and colder water provides optimal water temperatures for production of channel catfish year-around at densities of 80-160 kg/m^3 (5-10 pounds/ft^3); yearly production was three to four times the carrying capacity (Ray 1981). Production of 112 kg/m^3 (7 pounds/ft^3) was obtained for channel catfish grown experimentally in shallow raceways receiving 23 L per minute of fresh water during a 198-day growing period; production was relatively low (1.7 kg per liter per minute of inflow water), but the raceways were too short (3.05 m) to maximize production per unit of inflow (Tackett 1974).

If geothermal water is not available, the only viable alternatives are to use either surface water sources or water reuse systems that permit the pumping of water with satisfactory water temperatures for optimal growth either year-around or during an extended growing season. From an economic standpoint, the cost of constantly pumping relatively high volumes of water through the containers in water reuse systems can become prohibitive for private aquaculture (Huner and Dupree 1984a).

Water reuse systems, that conserve both water and heat, have become common in research facilities (Stickney 1986), however Huner and Dupree (1984a) questioned their use in private aquaculture. Although many private small-scale reuse systems have been either built or proposed, there are no known private water reuse systems (with ≥ 90% reuse) that have been able to economically produce food fish in the United States for an extended time period; it would be more economically feasible to use water reuse systems for production of either tropical fish or fingerling fishes with high value per unit weight produced (Personal Communication, N. C. Parker). Water reuse systems are generally more costly and complex to construct and operate than other fish culture systems, but a good understanding of their efficient design and operation has developed in the last 10 years (Piper et al. 1982; Wheaton 1982). Continued interest in the refinement of reuse systems and increasing costs of water pumping are expected to result in greater use of reuse systems in the future (Joint Subcomittee on Aquaculture 1983a). A key elements in the use of water reuse systems is the efficient operation of the biofilter that converts ammonia to nitrite and then to nitrate via bacterial nitrification (Piper et al. 1982). Research done in conjunction with the RTF study indicated that the nitrification process was optimized at salinities of 3,000 to 5,000 mg/L TDS when using water from the RTF at 30°C (Jacquez et al. 1987).

Several water reuse systems designed to grow channel catfish have been tried in New Mexico without commerical success. The high cost of construction and operation of water reuse systems makes it mandatory that the species grown in them should be maintained at optimal water temperatures for maximum growth rates on a year-around basis. Thus, the need for either cheap geothermal waters or waste heat to economically increase water temperature is extremely important when growing euryhaline species like channel catfish, tilapia, and striped bass that need warm water (26-30°C) for optimum growth. The only alternative to maintaining warm water temperatures year-around in New Mexico is to grow other species that grow well at cooler temperatures (e.g. salmonids) during part of the year. Although current demand for rainbow trout to stock in private or fee-fishing waters is fairly good in New Mexico, any potential aquaculture producer would need a dependable long-term market to justify the capital expenses of starting a high-density aquaculture operation. The key questions that should be asked by any potential aquaculture producer are whether the available resources (e.g. water, energy) and regional market demand make it economically feasible to produce the proposed product in a specific locality in New Mexico. An evaulation of potential sites for the development of large-scale microalgae production using specific criteria for Spirulina spp. identified several likely sites in southern New Mexico (Lansford et al. 1986b). Of these sites, Site B in the Tularosa Basin and the Crow Flats area also have features that would be suitable for channel catfish production. However, many other potential sites (e.g. Pecos Valley) with slightly to moderately saline groundwaters might be suitable for aquaculture of euryhaline fishes. Decisions on potential sites for aquaculture development are strongly influenced by the species and production system that would be used. Although the availability of large quantities of shallow brackish groundwaters offers some advantages, a thorough economic analysis of the production and shipping costs and future market demand for any aquaculture species should precede facility development in New Mexico.

SUMMARY AND CONCLUSIONS

Summary

Aquaculture development in New Mexico has lagged behind that of surrounding states because of the lack of suitable fresh water sources for production of conventional species. With the rapid growth of aquaculture and increasing demand for fishery products in the United States, a reassessment of the state's water resources for aquaculture is now appropriate. The large reserves of unutilized saline groundwaters are relatively well known, but their potential use for aquaculture development using either conventional or non-conventional species and production systems have not been thoroughly evaluated.

The main objective of this study was to evaluate what salinities of the groundwaters of the Pecos Valley near Roswell, New Mexico were suitable for optimal growth and efficient food conversion by channel catfish. After preliminary on-site tests of the salinity tolerance of fingerling channel catfish, salinities of about 1,000, 3,000, 5,000, 7,000, 9,000 and 11,000 mg/L were evaluated by growing fish indoors in circular tanks at the Roswell Test Facility (RTF). Appropriate salinities were maintained by mixing Roswell city water and brackish well water from the RTF in the inflow water delivered to the 1.52-m (diameter) tanks. Water temperatures were maintained at near optimum growing temperatures (25-29°C) and fish were fed trout pellets at recommended levels.

After a short acclimation period, percent weight gains and food conversion ratios (FCRs) were excellent for fingerling channel catfish grown at salinities $\leq$ 5,500 mg/L during the first 7 weeks of the study. Growth and FCR were significantly poorer for fish grown in tanks with a mean salinity of 7,560 mg/L. Weight gains and FCR values of fish were poorer in all tanks when dissolved oxygen levels were <4 mg/L.

After being grown at salinities of abut 3,000 and 5,000 mg/L for 4 months, channel catfish (mean starting weight of 271 g) were grown in tanks at salinities of about 3,000, 5,000, 7,000, and 9,000 mg/L for another 4 weeks at 24-27°C. There was no significant difference in percent weight gains and FCRs for fish grown at mean salinities of about 2,800, 4,700, and 6,400 mg/L. Growth and FCR was significantly poorer for fish grown at a mean salinity of about 8,5000 mg/L. There was no significant effect on subsequent growth and FCR of fish that had been acclimated for 4 months at 3,000 versus 5,000 mg/L.

Conclusions

1. Channel catfish fingerlings (mean initial weight of 36 g) grew well and efficiently converted food to flesh at salinities of 1,000 to 5,500 mg/L when using saline groundwaters from the Roswell Test Facility.
2. After growth for 4 months at salinities of about 3,000 and 5,000 mg/L, growth and FCR of advanced fingerlings were similar at salinities of about 2,800, 4,700 and 6,400 mg/L, but significantly less at 8,500 mg/L.
3. Growth, FCR, and survival of channel catfish in circular tanks receiving saline groundwaters of the Pecos Valley were either greater than or similar to published values for fish raised in experimental tanks in fresh water.
4. Saline groundwaters of the Pecos Valley that are $\leq$ 6,500 mg/L can be used for production of channel catfish, but the economic feasiblity of potential sites and culture systems needs further analysis.

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