Research Technical Completion Report

FEASIBILITY OF DIRECT UTILIZATION OF SELECTED GEOTHERMAL WATER FOR AQUACULTURE OF *MACROBRACHIUM ROSENBERGII*

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ABSTRACT

The purpose of the study reported was to test the feasibility of direct utilization of geothermal water for the aquaculture of Malaysian freshwater prawns (Macrobrachium rosenbergii). A problem with using geothermal water for aquaculture is the chemical composition of the water with high flouride levels being a particular problem. Results from this study show that (1) some geothermal water in Idaho can be used directly for the aquaculture of Macrobrachium rosenbergii, (2) high flouride levels cannot be directly correlated with high mortality rates and (3) low flouride levels do not correlate with high growth rates.

INTRODUCTION

Idaho has abundant geothermal resources (Fig. 1) which generally are too low in temperature to be developed for electrical generation purposes, but which potentially have many other applications such as in space heating and agricultural purposes. Other applications and required temperatures are listed in Mitchell, 1976, p. 24. Some agricultural applications which have been attempted or which are already developed include utilization in greenhouses and alcohol plants. Some wells originally drilled for irrigation purposes may have geothermal development potential. Of some interest lately has been the application of geothermal water for aquaculture purposes. Idaho's interest in aquaculture originates from the fact that the state has been the leading U.S. producer of hatchery raised trout; this production represents over 90% of total U.S. production. In contrast to Idaho's domination of U.S. trout production, Idaho's share of warm water aquaculture is very small; the great geothermal water resource available for such an industry in Idaho, however, provides a large potential and much interest. There have been several attempts in Idaho to use geothermal water in aquaculture projects. The most successful of these has been the production of catfish and, to a lesser degree, production of ornamental fish in southern Idaho. During the last two to three years, scientists and potential producers in southern Idaho have become interested in the giant Malaysian freshwater prawn, Macrobrachium rosenbergii. Several attempts at commercial development have been planned or initiated in Ada and Owyhee Counties. Largely, much of the interest has developed from the observation that giant prawns, tiger prawns, freshwater prawns, or whatever the market name may be for large prawns, retail at

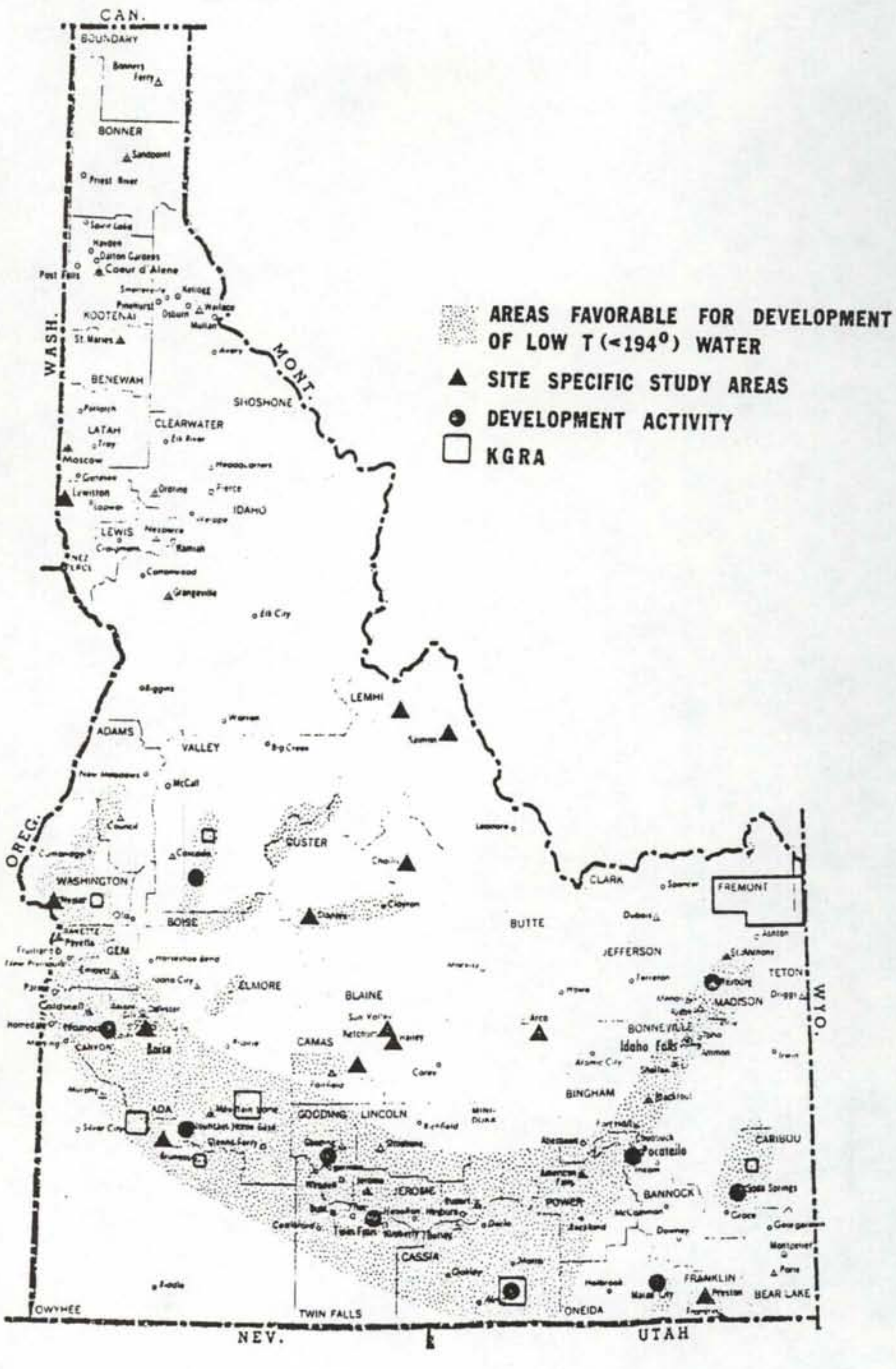

Figure 1. Summary Map. Geothermal potential in Idaho.

prices close to or over \$10.00/lb. Published data suggest that expectable production figures are close to 4000 lb./acre at a cost of \$1.54/lb. (Taylor, 1980). Idealized production figures such as these do not account for technical problems, processing and marketing problems, and hundreds of other problems which decrease producer profitability. These figures tend to provide a high expectation of the profit potential for freshwater prawn production. The potential for large profits, especially during times of generally depressed farm prices, creates a great deal of interest from potential producers. Many technical, biological, and marketing problems need to be addressed before a viable freshwater prawn industry is developed--especially in southern Idaho, employing geothermal water.

One basic question which generated this project and which was addressed by a committee of the Idaho Water and Energy Resources Research Institute was: "Will Macrobrachium rosenbergii survive in Idaho geothermal water?" The legitimacy of the question is underscored by the paucity of research data regarding aquaculture with geothermal water in temperate regions and by the fact that much of Idaho's geothermal water contains a great variety of dissolved material. One element of particular concern to biologists is flourine because fluoride is known to be harmful to many crustaceans and fluoride levels are high. The present study was developed in response to that question; to determine whether in fact geothermal water can be used directly for the aquaculture of the freshwater prawn Macrobrachium rosenbergii.

PREVIOUS WORK

Freshwater prawns belonging to Macrobrachium rosenbergii are indigenous to the equatorial western Pacific. Approximately one hundred species are reported to occur but M. rosenbergii is the only species used for commercial aquaculture purposes. Freshwater prawns have been cultured for centuries by inhabitants of those regions to which M. rosenbergii is indigenous. Until the 1960's, however, aquaculture efforts for Macrobrachium consisted of rearing in grow-out ponds specimens obtained from the wilds because larvae could not be maintained in captivity past the first few metamorphic stages. Aquaculture efforts were of necessity located in areas close to source of wild stock and limited in scope. In the early 1960's, however, the life cycle of M. rosenbergii was completed by S. W. Ling (Ling, 1961, 1962, 1967 etc.). The discovery that the last larval stages require brackish water enabled the production of larvae in captivity and the subsequent development of a freshwater prawn aquaculture industry. Significant hatchery and production research has been conducted in Hawaii, at the Anuenue Fisheries Research Station, Honolulu, formerly under the direction of Takuji Fugimura. Research conducted at these facilities has been responsible for the development of a prawn aquaculture industry in the United States, and the brood stock developed there probably represents the entire genetic stock available in the United States presently. Additional significant research in hatchery and production techniques has been carried on in South Carolina at the Marine Resources Research Institute, under the direction of Paul Sandifer.

Nearly all research pertinent to production of the giant Malaysian prawn has been conducted in tropical or subtropical regions; very limited research has been conducted regarding aquaculture of Macrobrachium in geothermal water. Recent reports regarding aquaculture of Macrobrachium in geothermal water include Beleau and Woiwode, 1980; Campbell et. al., 1979; Christiansen, 1978; Smith, 1971; Taylor, 1980; Thompson, 1978. All the papers mentioned above are preliminary in scope and do not address the critical problems of prawn production in temperate regions.

OBJECTIVES

The main objective of this study was to test the feasibility of direct utilization of geothermal water for the aquaculture of Macrobrachium rosenbergii. A specific objective was to ascertain any deleterious effects which high fluoride levels and other dissolved material might have on prawns reared in geothermal water. Additionally, we wanted to obtain data regarding the effects that different geothermal waters might have on growth rates, fecundity and general health of specimens whose nearly entire life cycle occurred in geothermal water.

METHODS

Selection of water:

Initially we were planning to select water from ten different geothermal sites from southern Idaho. The plan was changed and only five sites were selected. One "site" was the control group employing domestic water provided to Boise State University by Boise Water Corp. Evaporation losses from the tanks were higher than expected (twenty gallons of water every three to four weeks). The logistics and expenses for procuring replacement water from ten sites across the state were beyond our budget capabilities and the added expenses, had additional funding been available, would not have been justified for any reasonable additional expectable return of data. The selection of sites was made on the basis of expected availability of water over the duration of our study and maximum geographic representation within the constraints of our budget. It was felt that four geothermal sites and

and one control group would provide adequate information and would meet the objectives of the project.

The four selected sites are: Zim's Hot Springs, New Meadows; Erwin Ranches, Bruneau; Magic Hot Springs Wells, Blaine County; Warm Springs Water, Boise. The latter was obtained from effluent in a cooling pond of the geothermal heating plant of the Idaho State Department of Agriculture Building in Boise. The Erwin and Zim's localities were selected because Mr. S. Erwin and Mr. B. Dixon, operators of the two facilities volunteered to make water available as needed during their frequent trips to Boise. The Magic Hot Springs locality was selected because the author had other reasons for going to that area during which time he could procure water at no cost to the project. Table 1 provides the chemical composition of water from the five selected sites.

Laboratory methods and techniques

Laboratory animals were selected at the post-larval stage and were obtained from Dr. Robert E. Lee Taylor of the Veterinary Medical Center at the University of Nevada, Reno. All laboratory animals were maintained in commercially available ten-gallon tanks with air lift-driven, reverse flow filters as illustrated in figures 2 and 3. Water was heated by means of commercially available aquarium heaters and temperature was maintained at approximately 26 degrees C (79^{o}F). Water quality was monitored on a regular basis (daily during the initial week and weekly thereafter). Testing was done with commercially available test kits for ammonia, nitrite and pH. Water quality deterioration was never a problem because of the low biomass level maintained in each

TABLE 1. CHEMICAL COMPOSITION OF WATER FROM FIVE LOCALITIES
(chemical constituents in milligrams per liter)

LOCALITIES	MEASURED SURFACE TEMPERATURE (°C)	SILICA (SiO_2)	CALCIUM (Ca)	MAGNESIUM (Mg)	SODIUM (Na)	POTASSIUM (K)	BICARBONATE (HCO_3)	CARBONATE (CO_3)	SULFATE (SO_4)	PHOSPHATE (PO_4)	PHOSPHORUS (P)	CHLORIDE (Cl)	FLUORIDE (F)	NITRATE (NO_3)	BORON (B)	AMMONIA (NH_3)	CONDUCTANCE (Field)	CONDUCTANCE (Lab)	pH (Field)	pH (Lab)	DISSOLVED SOLIDS (TDS)	SODIUM ABORPTION RATIO (SAR)	ALKALINITY ($CaCO_3$)
[1]MAGIC RESERVOIR	72	105	20	0.10	321	23	735	0	52	.01		85	10	0.56	0.08	0.10	1149		6.9		1213	19.6	
[2]BOISE WARM SPRINGS	29	79	2.7	0.01	86	1.5			27		<.01	8.1	19	0.11	100		398	382	9.1	8.0	296	14	120
[2]IRWEN RANCH - BRUNEAU	40	89	12	0.5	50	6.8	85	9	18	0	0.00	9.0	11	0.71	60		290		9.0		250	3.8	85
[3]ZIMS HOT SPRINGS		64	12	0.1	190	3.6	47	9	330	<.1		32	2.3	<0.1			940		8.5		666		54
[4]BOISE WATER COMPANY (Control)		13.2	10	3.2	5.8				5.4	0.68		0.85	0.31	1.46					7.2		71		94

1. Idaho Dept. Water Resources, Water Information Bulletin No. 30
2. U.S.G.S. Data
3. Geothermal Resource Evaluation, New Meadows, prepared by Energy Services, Inc.
4. Boise Water Corp. Data, Northern Testing Laboratories analysis - average figures for two collectors (No. 1, 2) providing water to BSU

tank. Initially we maintained five post-larval animals in each tank with an average weight of approximately 1.5 grams. During the final stages of the project a single animal no larger than approximately 20 grams was kept in each tank. Each tank included small rocks and pieces of plastic to provide shelter for specimens undergoing ecdysis. Every attempt was made to maintain the same conditions in all tanks in as many aspects as possible. The only variable was the origin of the water.

All tanks were provided commercially available prawn diet donated by Rangen Inc. at no cost to the project. Five percent of total biomass was initially placed in each tank daily. Later, at the 125th day, it was found satisfactory to feed on alternate days. A summary of dates of duration of the feeding and measuring program for each water locality is provided in Table 2.

General observations were made on a daily basis; observations included general appearance, shedding, apparent hunger, aggressiveness, head count, water turbidity, and water temperature. Growth was recorded as body weight and telson length. Length was measured individually whereas weight was taken for the entire group (control number on Table 2) and an average weight was calculated. This approach provided adequate data while minimizing stress of handling. Early in the project, length and weight measurements were taken weekly; later it was felt that stress had to be decreased and measurements were taken at two week intervals.

Table 2. Summary of Duration and Results

CONTROL NO.	LOCALITY	DURATION OF WEIGHT & LENGTH MEASUREMENT	DURATION OF FEEDING	DURATION DAYS
1	Magic Reservoir	Aug 23 - Aug 31	Aug 23 - Sept 5	15
2	Magic Reservoir	Aug 23 - Aug 31	Aug 23 - Sept 5	15
3	Warm Springs	Aug 22 - Feb 20	Aug 23 - Feb 17	180
4	Warm Springs	Aug 22 - Feb 20	Aug 23 - Feb 17	180
5	Zims	Sept 29 - Mar 26	Sept 29 - Mar 23	180
6	Zims	Sept 29 - Mar 26	Sept 29 - Mar 25	180
7	Control Group	Sept 22 - Mar 20	Sept 22 - Mar 19	181
8	Control Group	Sept 22 - Mar 20	Sept 22 - Mar 19	181
9	Bruneau	Aug 26 - Feb 23	Aug 26 - Feb 22	180
10	Bruneau	Aug 26 - Feb 23	Aug 26 - Feb 22	180

CONTROL NO.	NUMBER OF SPECIMENS PLACED IN TANKS	MORTALITY RATE	DAILY GROWTH LENGTH(mm)	DAILY GROWTH WEIGHT(G)	TOTAL GROWTH ($\Sigma\bar{x}$/check) LENGTH(mm)	TOTAL GROWTH ($\Sigma\bar{x}$/check) WEIGHT(G)
1	7 (7) [0]	.46				
2	7 (7) [0]	.46				
3	21 (16) [14]	.011	.248	.070	44.9	12.68
4	20 (15) [12]	.016	.120	.026	21.8	4.68
5	7 (2) [1]	.006	.305	.134	55.0	24.1
6	9 (4) [3]	.006	.350	.193	63.0	34.8
7	10 (5) [5]	.000	.150	.044	27.2	7.90
8	10 (5) [4]	.006	.357	.130	64.6	23.6
9	14 (9) [7]	.011	.287	.102	52.0	18.45
10	9 (9) [5]	.022	.457	.218	81.8	39.16

Explanation for Table 2

LOCALITY identifies source of water; see methods, selection of water, for details. DURATION OF WEIGHT AND LENGTH MEASUREMENT indicates the initial and final dates of measurements, as does DURATION OF FEEDING for initial and final days of feeding. DURATION DAYS indicates the total duration of the experiment in number of days. NUMBER OF SPECIMENS indicates the total number of specimens used in each tank for each locality; in parenthesis () is indicated the number of specimens that were found dead in the tank. In brackets is indicated the total number of specimens which were found dead with evidences of cannibalism. A significant measure of water "inhospitability" would be suggested by calculating the difference between the two values. Magic Reservoir water would be most inhospitable since all deaths occurred without evidence of cannibalism--either as a cause of death or after death. This suggests that death was caused by water chemistry connected with the source because other water quality parameters such as dissolved oxygen, ammonia, pH, etc. were maintained nearly equal in all tanks. MORTALITY RATE was calculated by dividing non-cannibalized deaths by total duration in days; this should give an indication of daily mortality rate directly attributable to water chemistry, or at least attributable to causes other than cannibalism. DAILY GROWTH was calculated by dividing TOTAL GROWTH (next column) by duration in days. TOTAL GROWTH is a summary of all measured growth increments. This was calculated by adding all averaged individual weight increases and individual telson length increases. Total growth and daily growth were not calculated for control groups 1 and 2 because of the short (15 days) duration for that experiment.

DISCUSSION AND CONCLUSIONS

Several conclusions seem appropriate from the data presented in Table 2:

--Some geothermal water in Idaho can be utilized directly for the aquaculture of Macrobrachium rosenbergii

--High fluoride levels cannot be directly correlated with high mortality rates

--Low fluoride levels do not correlate with high growth rates

A comparison of Table 1 and Table 2 suggests that low fluoride levels are associated with low mortality rates and generally with good health. The Boise Water Company domestic water tanks (control group, control numbers 7, 8) maintained specimens with high growth rates, but not appreciably higher than control numbers 5 and 6, which have moderately low (2.3) fluoride levels. The Erwin Ranches (Bruneau) water (control numbers 9 and 10) with high fluoride levels (11 milligrams per liter) sustained high fluoride levels (11 milligrams per liter) sustained high growth rates which were generally higher than the control group. The Bruneau water tanks did, however, sustain higher mortality rates than the control group. Since the deaths were in part due to cannibalism, the mortality rate difference cannot be attributed to differences in fluoride levels exclusively or partially. Our experimental tanks were subjected to high rates of cannibalism. So high, in fact, that we had to decrease the number of specimens in each tank to two. We are presently maintaining the tanks and continuing some of the data-gathering presently but were forced to place only a single specimen in each tank. Small numbers of specimens such as we were forced to use do not provide a statistically valid sample.

Additional tanks with large display and brood stock also experienced death due to cannibalism, especially during the vulnerable time of shedding. In each of four large (100 gallon) display tanks only one specimen remains after as many as five specimens were placed in each tank. The author's conclusion from over six months of direct observation is that Macrobrachium rosenbergii cannot be regarded as a good candidate for intensive aquaculture efforts in areas where large ponds and low population densities cannot be accommodated. M. rosenbergii is territorial, aggressive and generally cantankerous. Published data suggest that this species is the least aggressive and cannibalistic of all the Macrobrachium species and that it will require a maximum of one square foot of pond space per animal. Our observations in aquarium tanks suggest that each specimen requires much larger territory. One large male 40 cm in length (22 cm rostrum to telson) has eaten every other former cohabitant of a 150 gallon tank and demonstrates continuously aggressive behavior towards a specimen of Tilapia equal to his size.

The question of the effects of fluoride levels on growth and mortality cannot be answered quantitatively because of the small samples with which we were forced to work. We are reasonably confident, however, that fluoride levels as high as in control numbers 3 and 4 are not significantly deleterious to growth of Macrobrachium rosenbergii. The unanswered question which remains is to explain such high mortality rates for the water in control numbers 1 and 2. Water from the Magic Reservoir well was depleting our stock of post-larval animals and it

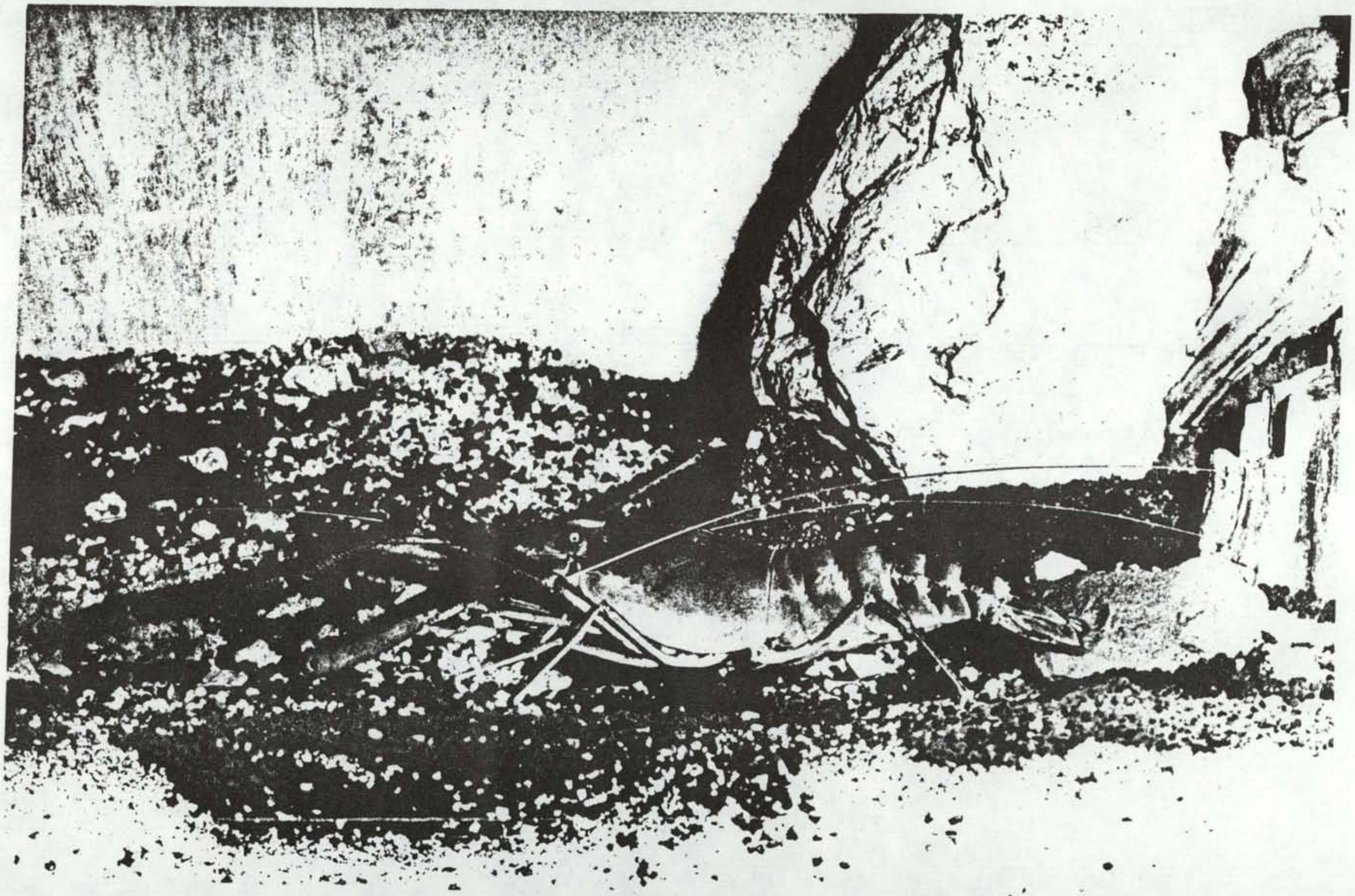

Figure 2. Large male specimen Macrobrachium rosenbergii, 20 cm length telson to rostrum.

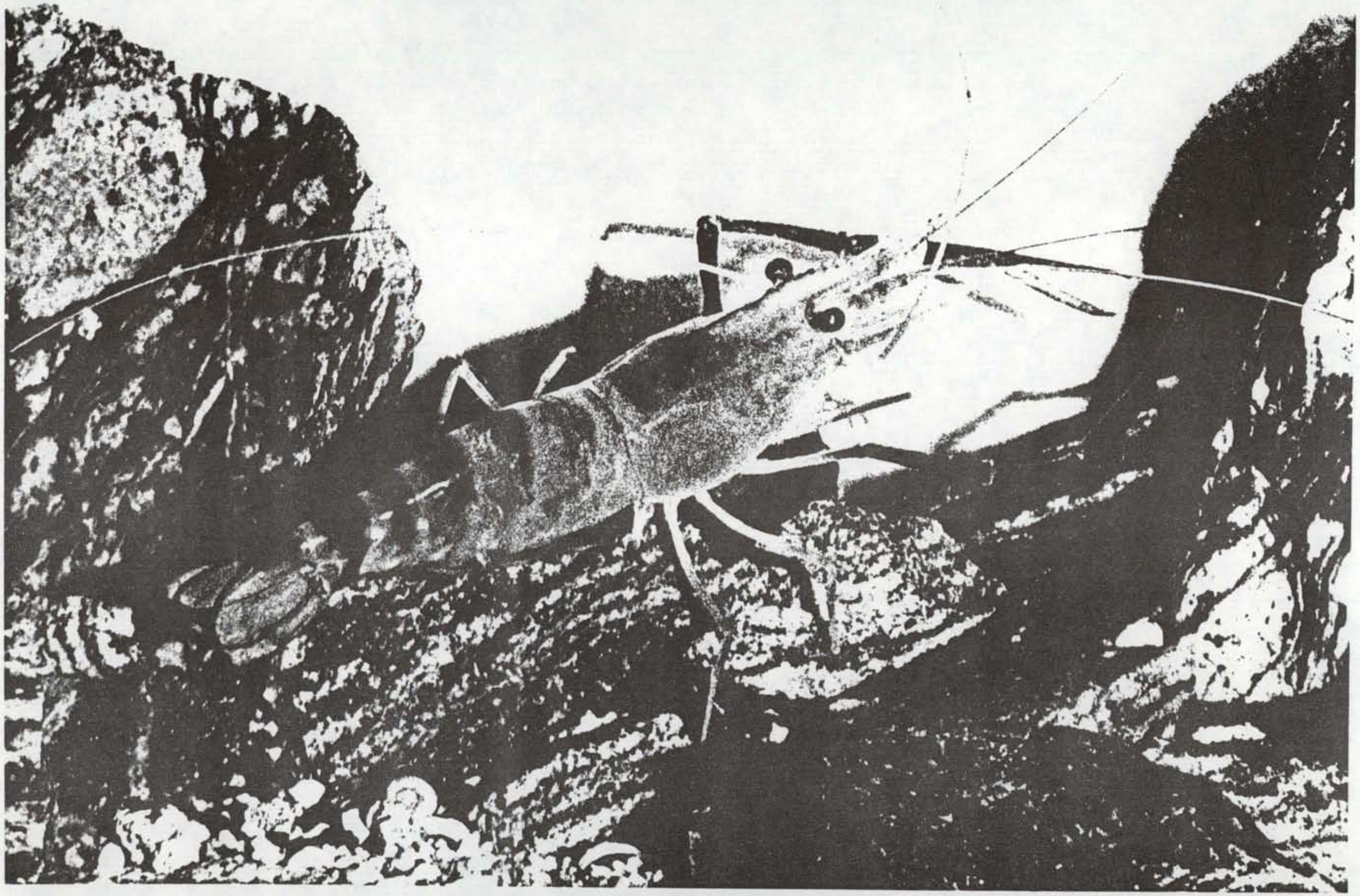

Figure 3. Female specimen of <u>Macrobrachium</u> <u>rosenbergii</u>, approximately 12 cm length telson to rostrum,

was decided to discontinue replacing dead animals. The significantly higher constituents present in the Magic Reservoir water which are not present in other water we used include silica, calcium, sodium, bicarbonate, chloride, and total dissolved solids. Ammonia is also listed in Table 1 but our tests prior to placing animals in the tanks indicated no measurable ammonia levels. Mitchell, 1976, Table 3 indicates the presence of trace metal concentrations which could be of concern but comparable data for other water used in our study are not available. Mitchell lists the following chemical constituents (in milligrams per liter): scandium: .45 x 10-8; iron: 2.3 x 10-4; zinc: .18 x 10-5; rubidium: 11 x 10-5; strontium: 7.7 x 10-4; antimony: 1.5 x 10-5; barium: 11 x 10-5; and cesium: 40 x 10-7.

Fecundity studies were not conducted because specimens had not reached sexual maturity and appropriate size to enable us to place test females in the same tank with large male stock. Similar attempts with non-test females terminated in cannibalism. Fecundity tests and taste tests will be conducted at a later time.

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