A LAYMAN'S GUIDE TO GEOTHERMAL AQUACULTURE

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INTRODUCTION

The following paper is designed as an aid to anyone contemplating a venture into commercially raising giant freshwater prawns, *Macrobrachium rosenbergii*.

Oregon Institute of Technology has been actively involved in a research program to determine the feasibility of such a venture and results to date have been very encouraging.

This aquaculture research was initiated in 1975 and was developed as an effort to utilize excess energy from the school's geothermal heating system. Therefore, most of the information gathered here, will apply to flow-through systems which use geothermal water to maintain a suitable environment for the animals.

A study of the market potential for freshwater prawns has been conducted and a favorable response received from wholesale distributors in the Pacific Northwest. Not only is a good market available, but distributors have suggested paying from $4.50 to $5.00 per pound for whole prawns in the size category of 16 to 20 tails to the pound, for a constant fresh supply. By maintaining constant temperatures of 27°C (80°F) ± 1°C in our research ponds, we have been able to produce this size prawn in 6 to 8 months.

BACKGROUND INFORMATION

Giant freshwater prawns, *Macrobrachium rosenbergii*, are a crustacean which normally inhabit streams and estuaries in the tropical climates of the South Pacific and Indonesian areas. Research conducted by the Anuenue Fisheries, Hawaii Department of Fish and Game, show that these aquatic animals can exist in water which fluctuate seasonably from 13°C (55°F) to 35°C (95°F), but that optimum growth occurs, when the animals are reared in a thermal environment of from 27°C (80°F) to 29°C (84°F).

When maintained in an optimum thermal environment, the continuous growth of the prawns results in a molting process which occurs about once every three weeks. Due to the existence of exoskeleton, these structures are shed and replaced with new shells to accommodate their increase in size.

Under controlled-environmental conditions, prawns are able to reach sexual maturity in six months. The males and females can be differentiated at this age by the contrasting size of their pincher claws (chela). The male claws are much longer and thicker than those of females of equal age and body size. Males fertilize the eggs of a newly molted female, and approximately two days later, the female attaches them to swimmeretes on the ventral side of her tail. The eggs remain on her swimmeretes until they hatch, about four weeks later, and have changed from a bright orange to a gray color.

In their natural environment, larvae hatch out in a free-swimming state and are carried into bays and estuaries where they feed on zooplankton which consists of copepods, cladocerans, and other small, free-floating flora and fauna.

The larvae molt through eleven distinct stages in thirty to forty-five days until they reach a post-larval stage. At this stage, they are similar in appearance, but much smaller than the adult prawns. After the eleventh molt, they have developed walking appendages, and are able to "settle out," and begin their migration back upstream, and into a freshwater environment.

WATER RESOURCES

As with any aquaculture project, the venture will be highly dependent upon the quantity and quality of water available. In order to obtain the optimum growth for a prawn crop, a thermal environment of 27°C (80°F) must be maintained. Therefore, an initial projection of the amount of water needed per half-acre pond should be calculated for that area's coldest month with its average daily temperatures and wind velocities.

As an example, if January were the coldest month for an area with average daily temperatures of -3°C (27°F) and assumed wind velocities of 14 km/h (9 mph), it would take 567.8 L/m (150 gpm) of 66°C (150°F) water to keep an open 0.2-ha (1/2-acre) pond heated to 27°C (80°F). This required volume would be greatly decreased in the event the ponds were covered or insulated from the ambient air condition, especially wind, but the economics of protecting the ponds in some manner would need to be projected in a feasibility study.

Another way of meeting a deficit of hot water supplies would be to cut back operations during the colder months and expanding when the weather conditions permit it. Since it is possible to have 1-1/2 crops per year, it might be more advantageous for a grower to concentrate on producing a crop for the spring through fall months, and to decrease the amount of ponds used during the winter months, or to use these ponds for other crops which are tolerant to colder environments (i.e., *Salmo gairdeni* - rainbow trout).

Once the requirements of water quantity have been determined and fulfilled, it is necessary to conduct both a bioassay and chemical analysis of the water. The chemical analysis is performed to assure that the water is low in chemicals such as arsenic, boron, fluoride, and other elements which could be detrimental to the survival of the aquatic organisms.

The bioassay is conducted by obtaining a few of the young organisms which are to be grown in the ponds and rearing them in 15 L - 20 L aquariums filled with the source water. Observations of the animals are conducted for a period of two weeks to 60 days to determine that they can live and grow in the water. The bioassay is then continued to determine if aquatic organisms are able to reproduce in the source water. This can be accomplished by placing a live-bearing tropical fish, such as *Poecilia* sp. (guppies), or *Mollienesia* sp. (mollies), in the aquarium and observing them to see if the animals can go through a complete reproductive cycle.

If the results of these tests show the water to be of inferior quality for rearing prawns, the developer has a few options available to him. One might be utilization of a heat exchanger system where a colder water resource of purer quality is used but heated by the geothermal water. Another option could be the rearing of other organisms which are more tolerant to the adverse chemical conditions of the geothermal resource.

SOIL CONDITIONS

In an effort to reduce the cost of construction of an aquaculture venture, the location of the ponds should be in a rather flat or gently sloping area. When excavation of the ponds begins, the excavated material can be used to build up the banks of berms of each pond, thereby limiting the excavation time and equipment.

Size of each pond is related to heating supply and harvesting efficiency (Figure 1). Preliminary reports and experimentation suggest that ponds from 0.1 to 0.2 ha (1/4 to ½ acre) in size usually are easiest to harvest. With dimension of the ponds being from 15.2 m to 30.5 m (50 ft to 100 ft) wide by 64 m (210 ft) long and 1.2 m (4 ft) deep, it is relatively easy for four people to seine harvest the crop.

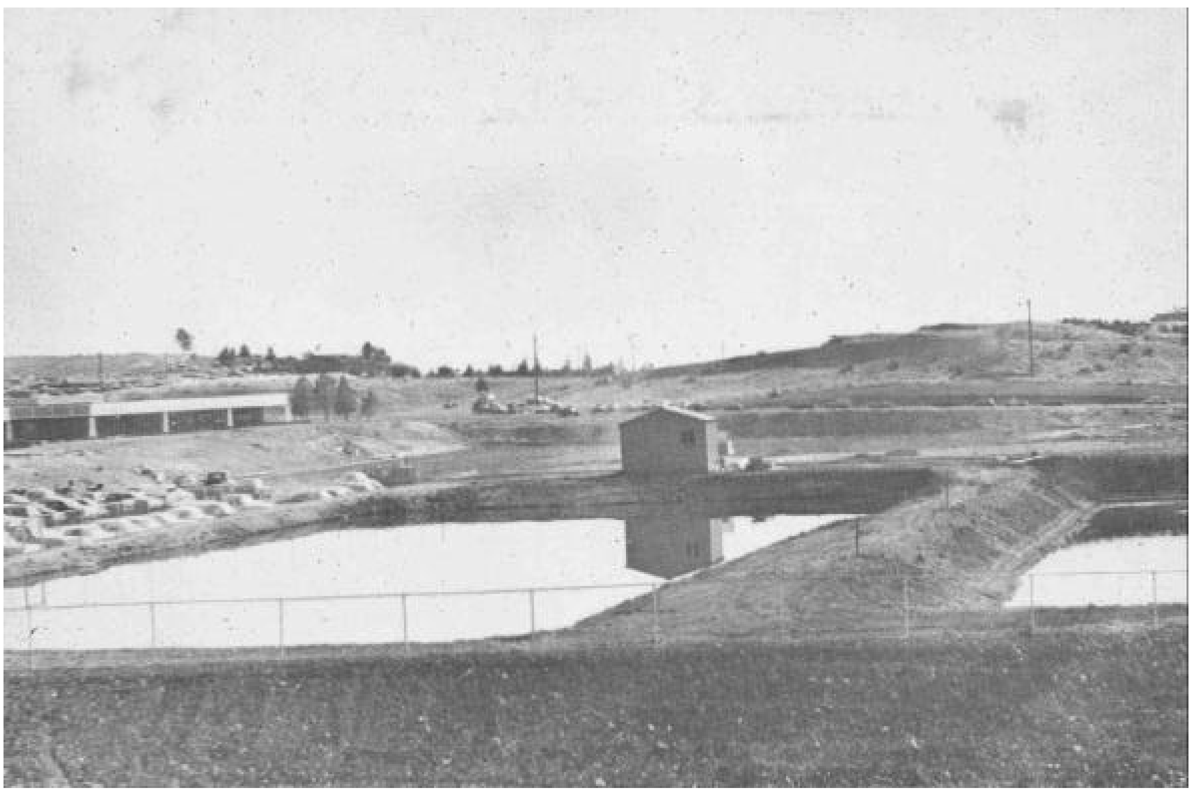

Figure 1. Research ponds at OIT.

The discharge water from each pond can be regulated either through a sluice box, which can regulate depth of the water, or by means of an overflow pipe which maintains a 4 ft depth of water in the ponds. If the overflow pipe is used, then another discharge pipe and gate should be placed in the pond to allow for complete drainage when necessary. Each discharge system should also be screened to prevent the escape of stocked PL prawns.

Distribution of water into the pond should be designed to allow for an even flow of water and thus, temperature regulation. The system designed for the 0.2-ha (1/2-acre) ponds at Oregon Institute of Technology uses five sets of 38.1 mm (1-1/2 in.) black iron pipe that lay across the bottom of the pond. Each line has 3.175 mm (1/8 in.) holes drilled into the pipe at 0.6 m (2 ft) intervals. Water flowing into the pipes is ejected from each hole and supplies heat to the pond water. This type of distribution system also provides one the least amounts of obstruction for seining and harvesting.

Temperature regulation of the ponds is accomplished by using 38.1 mm (1-1/2 in.) solenoid valves which are operated by means of Honeywell Temperature Controllers. The valves are normally closed but are actuated when the temperature sensors indicate the water temperature in the pond has dropped to 26°C (78°F). The solenoid, at that time, is opened to allow geothermal water into the distribution system until pond temperature reaches 27°C (80°F) and the valve is automatically closed again (Figures 2 and 3).

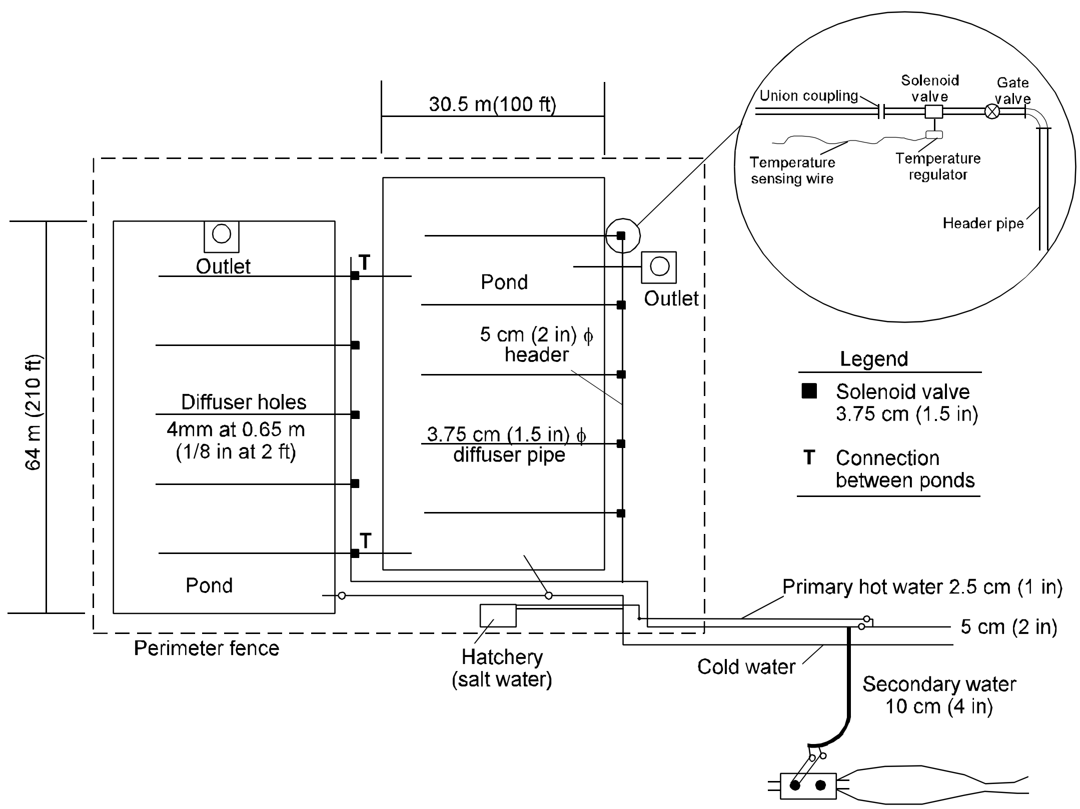

Figure 2. Aquaculture distribution system.

The question of whether or not the ponds should be lined with plastic or diatomaceous earth or clay is dependent upon the characteristics of the soil itself. If pond excavation is in a topsoil with a high clay content and the ponds are able to seal themselves, then no liners would be necessary; but, if a porous soil condition exists, then liners or diatomaceous earth might be required to seal the ponds.

Once the ponds have been completed and filled with water to temperature, they should be fertilized with natural fertilizers in amounts of about 90 k (200 lbs.) of cattle manure per 0.2 ha (1/2 acre) of ponds. Temperatures should be maintained and the ponds aged for approximately two weeks before the introduction of the preliminary test animals. Since prawns are sensitive to ultraviolet radiation, this fertilization and aging allows time for a growth of algae and a “green water” condition which filters out the ultraviolet radiation.

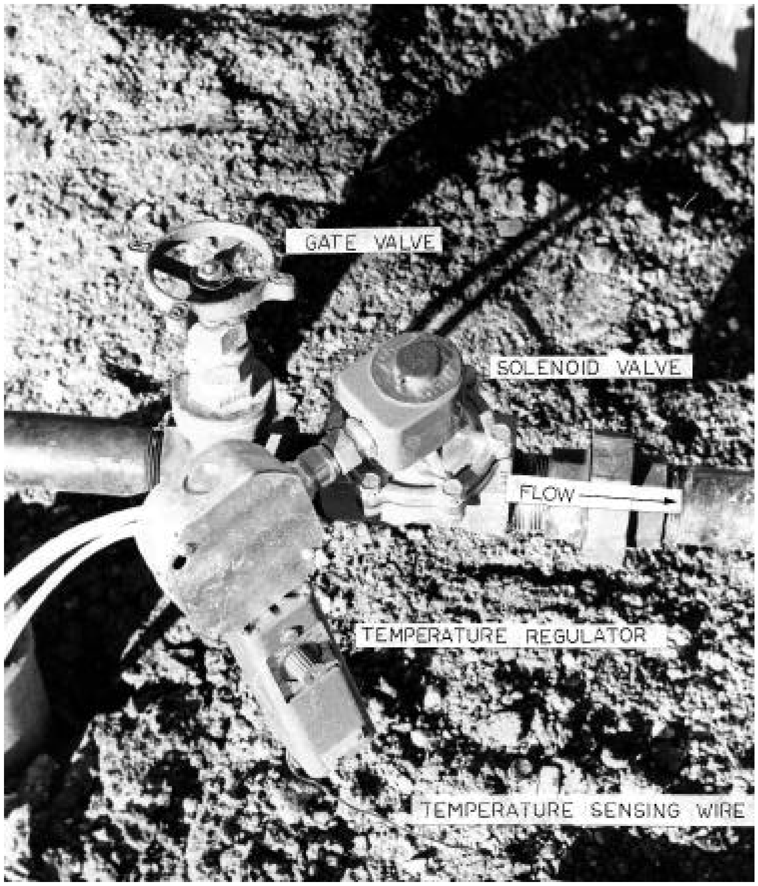

Figure 3. Valves in distribution sytem.

Once the algae has been established in the water column, a daily record of the dissolved oxygen content should be made. If over-fertilization occurs, the algae will overproduce and actually cause depletion of oxygen in the pond water. For ponds constructed at elevations of 4,000 to 5,000 ft and pond temperatures at 27ºC (80ºF), a dissolved oxygen concentration of 4-6 mg/L is ideal. It has been shown that prawns can survive and do well, down to dissolved oxygen concentrations of 2.0 mg/L. If it appears that maintaining sufficient oxygen levels could be a problem, it would be advisable to have backup aeration equipment. This type of equipment is commonly used for other fish farming ventures.

After the ponds have aged and acquired a “green water” condition, adult test animals, such as guppies or mosquito fish should be placed in the ponds and observed. These live-bearing tropical fish will not only give bioassay results on the pond water, but will ultimately be a source of food for larger prawns. When no detrimental effects are observed with the test animals in a 30-day period and pond waters can be maintained with no problems, it is time to stock the ponds with juvenile or post-larval (PL) prawns.

STOCKING AND HARVESTING

With any new aquaculture venture, the initial stock must be ordered from a commercial hatchery. For prawns, post-larvae can be ordered from several companies. A list of some of the distributors is included in the Appendix of this report.

The amount of PLs ordered is related to the size of the ponds. Stocking density should be about 14 prawns per square meter (1.5 per ft^2) of pond area. Therefore, a 0.2-ha (0.5-acre) pond should be stocked with approximately 31,500 PLs. If a continuous harvesting technique is employed, then restocking at a rate of about 20% every two months should occur so a continuous crop is available year round.

The restocking operation may be delayed until results of the initial stocking are obtained along with the harvesting of natural brood stock from the ponds. These brood stock can then be used in a hatchery operation and the developer can stock his ponds with PLs reared at his own facility.

After the initial stocking, it will take approximately seven months before the first seine harvest of commercial-size prawns can be accomplished. This is done by dragging a seine net with 38.1 mm (1-1/2 in.) openings through the pond. The net should be long enough to completely cover the width of the pond, be equipped with a lead line at the bottom to insure that prawns cannot slip under it, and be provided with sufficient floats to keep the top of the net at the surface of the pond. By pulling the seine through the water, the larger harvest-able prawns are captured; while, the smaller prawns are able to swim through the openings and remain in the ponds until they are of a harvest-able size.

From the first harvest, the operator may want to keep some of the faster growing males and females as brood stock for his own hatchery operations. These animals can be separated and placed in special brood tanks or smaller ponds.

HATCHERY OPERATIONS

The size of a hatchery will be directly related to the size and requirements of the prawn operation. If the prawn operation were to require a restocking rate of 15,000 PLs every two months, this amount could be supplied from one 950-L (250-gal) hatchery tank. For each additional 15,000 PLs, another 950-L (250-gal) tank and the necessary room to accommodate it will be required. Room should also be available in the hatchery for a small brood tank setup, a lab area, storage area, and refrigerator. The building should be heated to 28ºC (82ºF) to maintain the aquarium tanks at optimum temperatures or a separate heating system should be supplied to each tank. Larval prawns have been known to hatch out in freshwater, but will die within three to four days unless they are introduced into a saline environment of 12 - 13% ppt. Because of this, the aquarium or hatch-out tanks will need to be closed systems using artificial sea salt to maintain the saline environment. As a closed system, each hatchery tank will need filtration and aeration equipment. The aeration is needed to provide oxygen and a boiling action in the tanks that keeps food particles suspended and available to the larvae. The filtration system will remove toxic waste materials from the water and maintain the pH at a slightly alkaline condition, through a buffering action. The most efficient filter we have found, simply bubbles water over a sand, gravel, charcoal, and oyster shell mixture, and then reinjects it back into the tank. The intake for this system is covered with foam rubber pad to prevent larvae from being sucked into the filter. Once the larvae have hatched, they should be placed on a consistently-regimented feeding schedule and sufficient food should be available in the hatchery. This would require that several cans of brine shrimp eggs and some frozen fish meat be on hand.

Once the tanks have been filled and aged, one or two gravid (egg bearing) females are introduced into the tank. These brood animals should be maintained on a high protein diet to insure that they do not eat their own eggs and the tanks should be cleaned daily. They should be placed in the tanks with a low salinity content which is adjusted gradually to 12 or 13% ppt over a two-day period. The color of the eggs will slowly turn from a bright orange to a gray color just before hatching. This change and length of incubation usually ranges from three to four weeks in duration. Once the larvae have hatched, the females are removed to the brood tank and the larvae are put on a regular feeding schedule.

When the eggs have turned to a gray color, the operator should initiate the hatching of live brine shrimp in some 38- to 76-L (10- to 20-gal) aquariums. Instructions for hatching brine shrimp are usually printed on the egg containers. For a 950-L (250-gal) hatchery tank, it will take approximately one 38-L (10-gal) tank of live brine shrimp per day to feed the larval prawns.

The feeding schedule used at OIT was as follow:

> 8:00 a.m. - Three gallons of brine shrimp water are collected and the brine shrimp are separated from the egg shells and water. The live brine shrimp are then placed in the hatchery tank.
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> 1:00 p.m. - Two gallons of brine shrimp water are collected and live brine shrimp are separated from the eggs and placed in the hatchery tank. Two grams of fish meat are passed through a #60 fine mesh screen and fed to larvae. This amount is increased or decreased so that only enough is introduced into the tank to last for 30 to 45 minutes.
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> 6:00 p.m. - Five gallons of brine shrimp water are collected and live brine shrimp are separated and placed in the hatchery tank.

The amount of food in the water should be continuously monitored so that adjustments can be made if too much or too little is available.

When the larvae are about three weeks old, they begin to “settle out” and the majority have “settled out” when four weeks old. It is at this stage when the salinity in the water is gradually returned to a freshwater state, and the larvae have metamorphosized into the post-larval (PL) stage. The PLs should be observed for approximately one week to make sure they are adjusting to the freshwater and then placed in preliminary ponds or directly into the grow-out ponds.

Some research shows that the majority of mortality occurs during the young PL stage; therefore, some growers prefer to stock the PLs in small ponds for a one-month grow-out period to an early juvenile stage, and then to stock their grow-out ponds with these early juveniles.

With the limited amount of knowledge available on geothermal aquaculture, in reference to prawn rearing, it should be noted that each resource and each pond is a unique ecosystem. Therefore, a certain amount of variability will exist between any two ponds that are treated in the same manner. Due to this variability, the yields from pond-to-pond will also differ. The long-range crop harvest from ponds in Hawaii, show that an average of 3,500 to 4,000 pounds of prawns, per acre, per year, can be obtained with proper pond management. Although it is expected that a higher yield is obtainable from thermally-controlled ponds, the investors should not expect to receive significant profits with anything less than four to five acres of ponds.

Due to high initial costs for this size operation, it might be more advantageous to do a feasibility analysis on a smaller operation for the first year. If the venture looks successful after the first year, an expansion program could be initiated.

Although this paper has been concerned with prawn aquaculture, it should be noted that other aquatic crops should not be ruled out for geothermal aquaculture. Other organisms that could be cultured, include food fish, such as Channel catfish, Tilapia, or Bass; hobby animals, such as goldfish, tropical, and aquarium stock; or ornamental plants, such as water lilies, and aquarium plants.

It should also be noted at this point, that, as with any type of fish farming, this type of venture will be a very demanding one. Physical labor may be limited at times, but a constant vigil of the ponds and animals must be maintained.

ACKNOWLEDGMENT

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APPENDIX - Suppliers of Post-Larval Prawns

1. A.R.E.A., PO Box 1303, Homestead, FL 33030
2. Aquatic Farms Ltd., 49-139 Kamehameha Highway, Kaneohe, HI 96744
3. Aquafarms Int. Inc., PO Box 157, Mecca, CA 92254
4. C.S.C.I., PO Box AK, Port Isabel, TX 78578
5. Florida Aquaculture Inc., Rt. #1 Box 433X, Arcadia, FL 33821
6. The Shrimpery Inc., 240 Alden Road, Fairhaven, MA 02719
7. Shrimps Unlimited Inc., PO Box 759, Sabana Grande, P.R. 00747