FRESHWATER PRAWN(SHRIMP) CULTU
FOR JAMAICA

-an exploratory report

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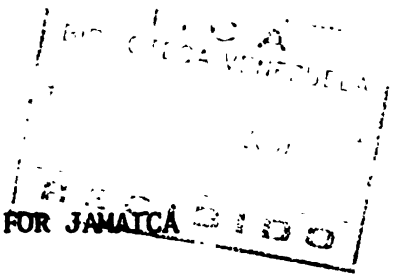


AN EXPLORATORY REPORT

JUNE 1982

MICHAEL WILES

INTRODUCTION

The freshwater crayfish, also known as prawn or shrimp is regarded as a local delicacy. Local "production" refers essentially to what has been generated under natural environmental conditions, without intervention by man, and results in the availability of relatively small catches which are sold at high unit prices. The potential production is largely unexploited.

Some attempts have been made through studies to provide information designed to reverse this position, but the results have not been very positive, have remained largely fragmentary and have not been pursued to finality. The necessity therefore exists for the development of a structured husbandry and production programme which could lead to the commercial exploitation of the potential.

The IICA/Jamaica Office in its awareness of this situation has given consideration to the possibility of undertaking a study for formulating and implementing a programme in view of the potential demand for crayfish not only for import substitution but also as a foreign exchange earner, for example in Spain. It has held discussions with the Permanent Secretary Ministry of Agriculture, and the Head of the Zoology Department of the University of the West Indies (Mona campus) and private sector interests. The Prime Minister of Jamaica has expressed a keen interest in this study.

The Pear Tree Bottom River which runs through the Belle Air Estate, St. Ann, a government-owned property, has species of crayfish which have a potential for commercial exploitation. The Permanent Secretary Ministry of Agriculture has made facilities and land available on this property and the collaboration of the Zoology Department of the UWI has been secured through its Head, Professor I. Goodbody. IICA/Jamaica was able to obtain the services of Dr. Michael Wiles, Professor of Biology and Chairman of the Biology Department of St. Mary's University, Halifax, Nova Scotia, on sabbatical leave to identify the project and undertake preliminary work necessary for providing some of the parameters required for undertaking the pre-feasibility study.

A number of preliminary investigations have been undertaken, the results of which provide useful inputs for the pre-feasibility study. A number of supportive investigations have been identified and it is the hope that the study when prepared will take Jamaica beyond the present stage of knowledge and will assist in the implementation of an appropriate programme for crayfish production in Jamaica.

The proposals include a research programme, and special studies on the cannibalistic nature of four (4) main freshwater shrimp species namely Macrobrachium acanthurus; M. carcinus, M. faustinum and M. rosenbergii.

The work will be carried out by selected University Graduate students under the direction of a Resident Research Director. The setting up of the project on government-owned land where adequate security at reasonable cost can be established and adequate environment (fresh and sea water) is available are distinct advantages.

It is proposed that the study be a joint GOJ/IDRC/IICA exercise, extending over a period of 3 years.

Percy Aitken-Soux
Director

FRESHWATER PRAWN (SHRIMP) CULTURE FOR JAMAICA

An Exploratory Report

THE POTENTIAL FOR COMMERCIAL FRESHWATER PRAWN CULTURE IN JAMAICA

IICA OFFICE IN JAMAICA

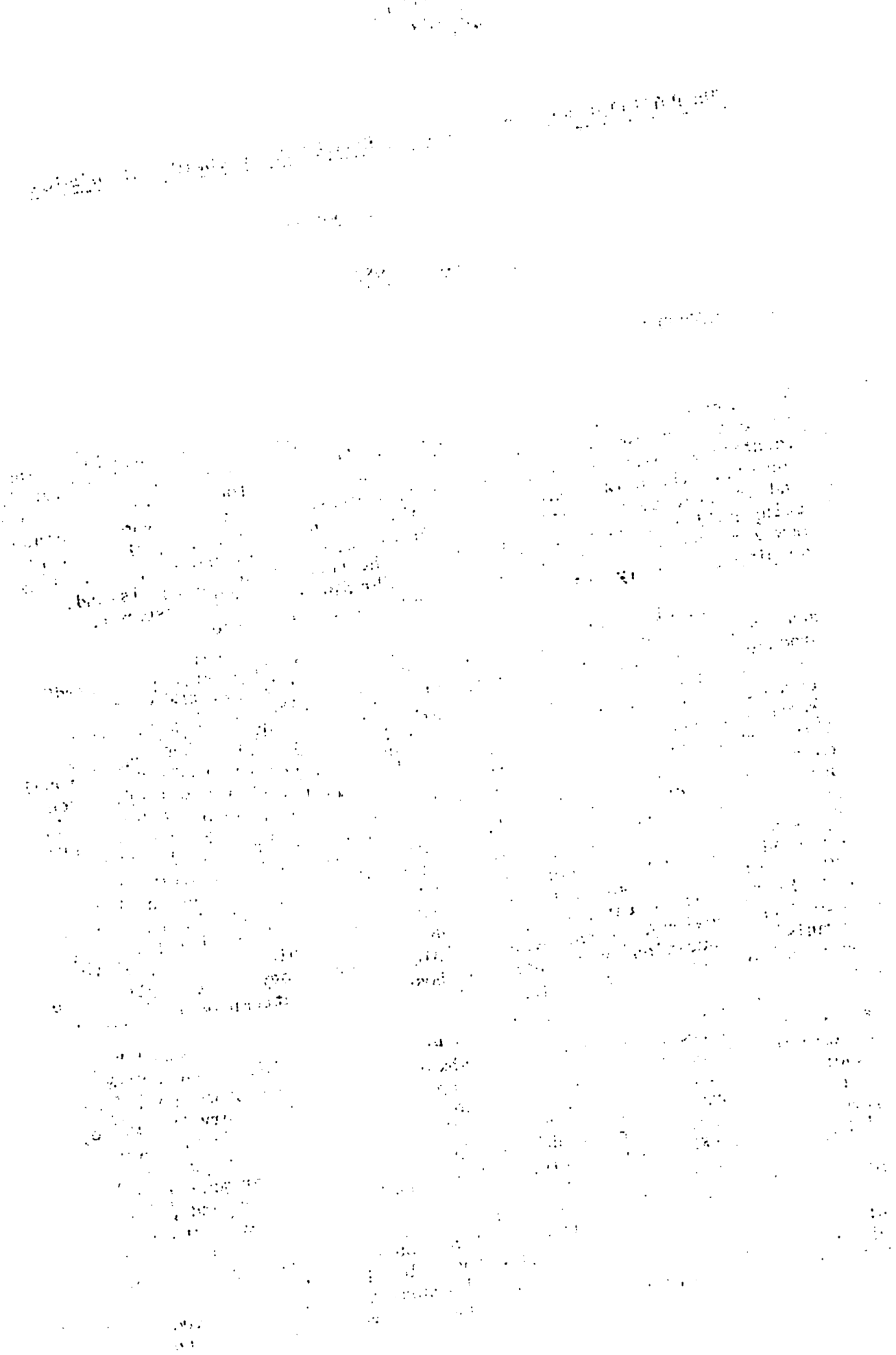
APRIL, 1982

I. INTRODUCTION

Jamaica's rivers abound the several species of freshwater prawns (or shrimps) of the genus Macrobrachium (L). Some refer to these animals as "crayfish" or even "lobsters", although they belong to neither of these identities, being zoologically, decapod crustaceans of the Family Palaeomonidae. The palaeomonid shrimps grow to a handsome size rather quickly and are sold by the roadside at various locations in Jamaica, as well as being sold by commercial fishermen to the hotel trade on the island. However, Jamaica is a net importer of shrimps for human consumption despite the bounty of them in her natural water-courses.

Worldwide, there is a strong market demand for "cocktail-sized" and "restaurant-sized" shrimps that cannot be met by all the shrimp producers combined. Consequently, the market price for this food commodity is high and stable. Predictably, the price for shrimp can only increase in the future if production increases significantly. Traditional "hunter-gatherer" fishermen cannot by any stretch of the imagination meet this market demand. Over the last 15 years, freshwater shrimp culture has emerged as an alternative to artisanal fisheries, using modern techniques, scientific knowledge and the rapidly developing concepts of the applied science known as aquaculture. This word, if literally translated, means farming of waters and is analogous to agriculture, which means farming the lands. In Jamaica, there are as yet no proven experts in freshwater shrimp culture, although some have tried to develop commercial farms but have failed. These failures are probably attributable to a lack of scientific knowledge of the general biology, physiology and ecology of the organisms in question on the part of those who have attempted to culture them commercially in this country.

Now IICA at the request of the Prime Minister, has commenced a scientific and technical study of freshwater shrimp farming with a view to implementation of commercial aquaculture when the necessary knowledge, experience and expertise have been acquired. Specifically, a site which comprises government-owned land on the north coast of Jamaica has been identified as having considerable potential as a future shrimp farm. Already, scientific investigations of the geology, hydrology and pedology at this location have been carried out, and primary biological studies have recently been conducted by a Canadian aquatic ecologist who has been in Jamaica for three months while on sabbatical leave from his home university. Results of these efforts show clearly that this site is suitable for development into an applied research facility for study of three indigenous Macrobrachium species and one exotic species of the genus.



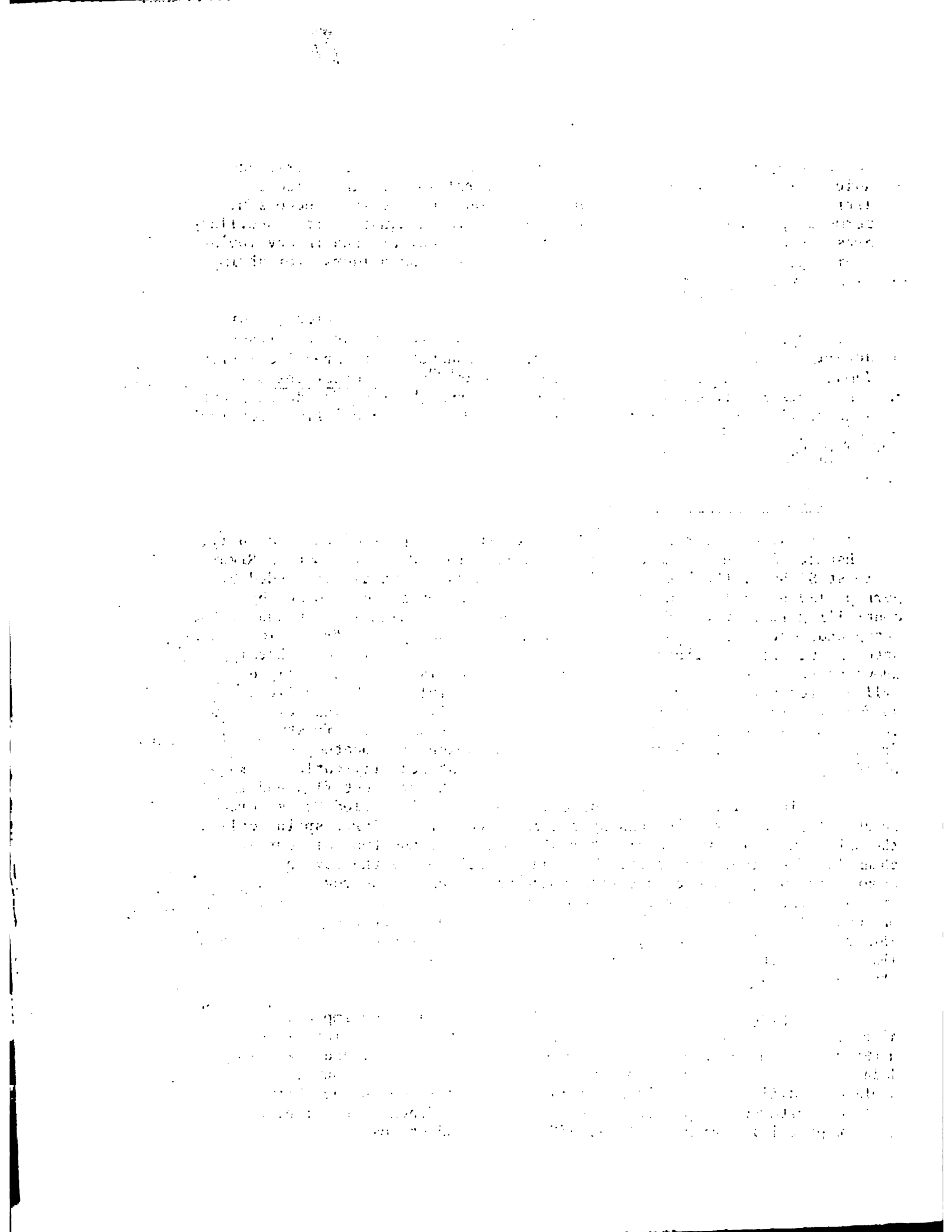
The purpose of the research facility is to carry out the scientific and technical trials needed to compare these several species under local conditions, in order to find out which one would be the most successful in terms of productivity at the commercial scale of aquaculture. Ancillary efforts would be in training of Jamaicans in aquaculture and in developing some arrangements, if possible, with local small land holders, for shrimp grow-out activities for the domestic market.

The purpose of this report is to summarise the geological, hydrological and pedological data on the proposed culture site and to present in detail the results of biological research conducted at three localities in Jamaica on the indigenous freshwater populations of Macrobrachium in rivers. This report culminates in several recommendations for development of a commercial shrimp farm in Jamaica based on sound scientific, technical and economic principles.

II. THE PROPOSED PROJECT SITE

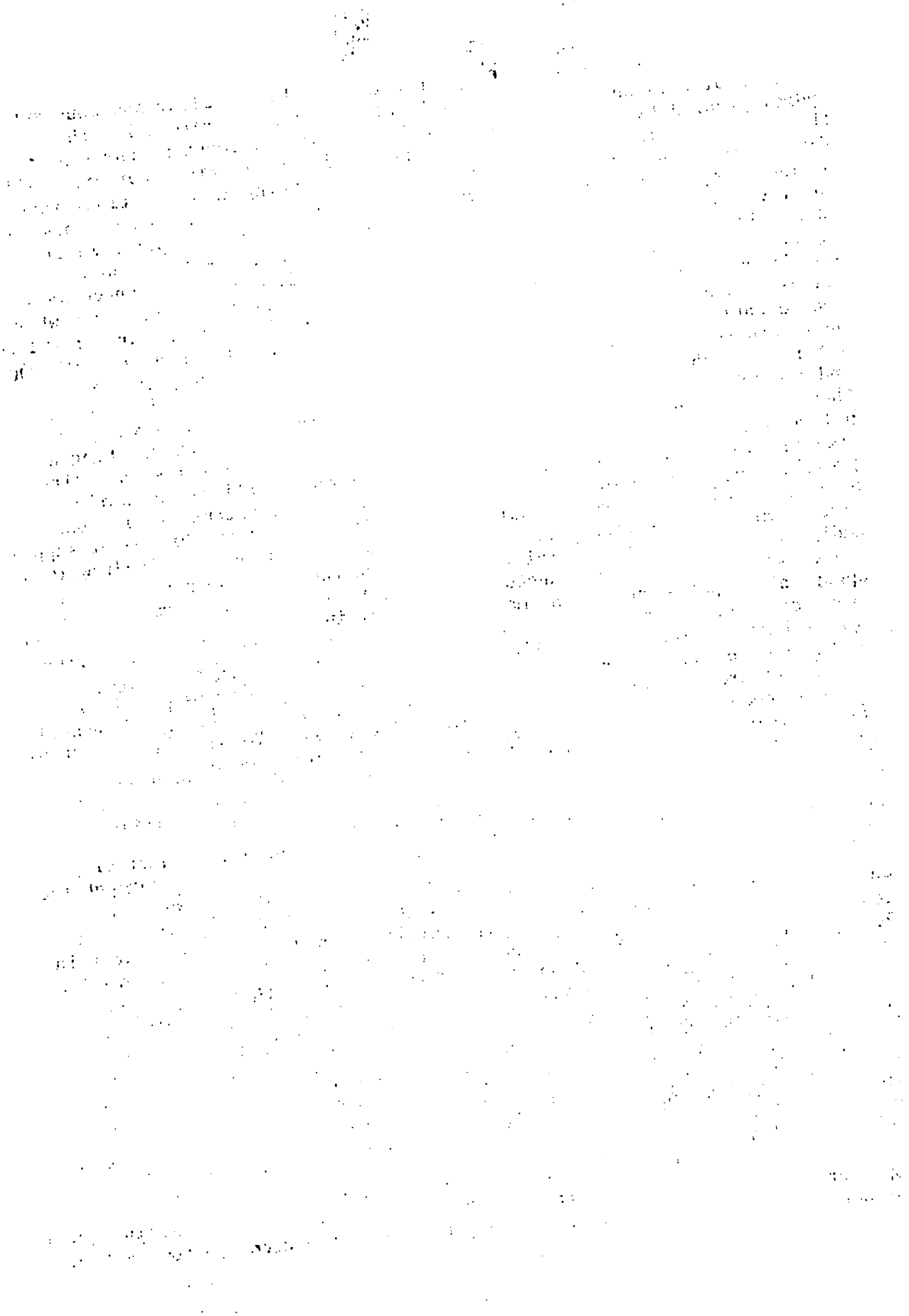
The site of interest for shrimp culture is part of the old "Belle Air" Estate, St. Ann, Jamaica, through which flows Pear Tree Bottom River. At least 50 ha of the bottom land is swamp (Class IV land) surrounded by perhaps 150 ha of flat (Class V) land which can readily be flooded by controlling river water flows through a network of channels. Inland of the swamp and bottom land, there rises a limestone escarpment, from which freshwater issues at 18 springs or "blue holes" to collectively form what is known as Pear Tree Bottom River. This river consists of a normally dry gulley through the lower part of the escarpment inland (which collects surface runoff after rainfall) and a series of ill-defined channels through the bottom land that converge to form a coastal swamp. The freshwaters drain to the sea through three main outflows which are located between Discovery Bay and Runaway Bay, St. Ann. The most westerly outlet is known locally as Parson's Creek, the central one has the greatest flow and is known as Main Outlet, and the most easterly outlet is called Grassy Creek. About 70% of the water in this system comes out of one large spring called the Main Blue Hole, with a diameter of about 15 m. and two main outlet channels of variable position. The land, purchased by the Government of Jamaica in 1978, was once a cattle ranch with coastal mangrove swamps on its shoreline. The mangroves were cleared out, the land partly drained and channelled, and coconuts planted on raised banks between the channels. This venture failed. Later, the coconuts became infected with a mycoplasma that causes lethal yellowing disease, and the plantation was virtually abandoned. Today the land is derelict.

The property is ideally located for freshwater shrimp culture for there is easy access to both freshwater and saltwater, the latter being required for the earlier larval phases in the life cycle, and the former being the medium for growth of juveniles and adults. The bottom land could be modified inexpensively to contain ponds in which the shrimps could be cultured and protected from predators. Fencing the property to prevent praedial larceny would be effected at modest cost.



The freshwater on the property is unpolluted, clear and abundant. As its source is underground it is little affected by rainfall. The hydrological data show that its flow is practically constant throughout the year at about 7 x $10^6 m^3$/month. The qualities of this water are ideal for shrimps, the total dissolved solids levels being in the optimal range of 150-22 mg/l, with highest amounts in the blue holes and lowest ones in the river channels themselves. The hardness range of the spring waters is 140-160 mg/l which is an ideal level for a domestic water supply because it is low enough for water softening equipment to be unnecessary. The freshwaters are affected by seawater influxes close to the coast where levels of sodium, chloride and sulphate are much higher than further inland. Consequently, total dissolved solids near the river outlets approach 1,000 mg/l, and total hardness levels exceed 300 mg/l. For shrimp culture, seawater encroachment like this provides an optimal environment for the growth and moulting of the first 6 or 7 larval phases in their life cycle, for these have an obligatory requirement for saline waters after hatching and before metamorphisis into juveniles. River water temperatures vary little over the year, the range being 22 to 25°C, which is optimal for shrimp growth. Thus, biological production proceeds on a constant, year-round basis in this system and so could shrimp culture based on this water supply. Ground water levels fluctuate, yet they do so in response to withdrawals or additions of water, not to rainfall (although the rainy season in April-May causes a general, pronounced rise). Heavy rains cause turbid water to appear at seepages and in the main surface drainage gulley, but at the same time spring water from the blue holes remains clear. Overall, the spring waters in this area are remarkably clear. Thus the freshwater supply is ample and dependable for drinking, domestic and laboratory use, and for shrimp culture. However, clearing out the vegetation in the swamp channels would be necessary to use this resource effectively. To maintain acceptable water levels in the swamp thereafter, a regular programme of vegetation removal would have to be carried out.

The Main Blue Hole is the obvious spring to use as a source of freshwater for the building (including laboratories and living quarters) and the shrimp culture facilities. Its discharge varies little through the year, the range being 13 to 17 m/sec. and the mean 15 m/sec., while the change in the height of a guage installed in it for about 3½ months was less than 3 mm in one day. This spring provides about 0.7 of the water in Pear Tree River Bottom system. The rest comes from at least 17 other blue holes, 9 of which have had their water flows measured (their flows are constant too), and from limestone seepage. The second largest blue hole has a constant discharge rate of 4.5 m/sec. Some water flow data for the three main discharge channels flowing into the sea (and subject to tidal backwater) have been collected. Mean values reported are 28.5 m/sec. in March, 30.3 m/sec. in June and 23.4 m/sec. in October. Impedence of freshwater flow into the sea by tidal seawater is overcome by an increased flow rate from the blue holes at high tide, the freshwater flow and tidal flow maxima co-inciding quite precisely. Whereas there is reason to think that the tidal rise reduces underground out-flow of freshwater into the sea, it apparently interferes little with the above surface flow so that saline water intrudes only a very short distance into the Pear Tree River Bottom system.



Infrared photography has revealed offshore discharge points for freshwater at Pear Tree Bottom River which carry away excess groundwaters from the system and probably contribute to the constancy of the above surface freshwater flows thrcugh the swamp.

III. PRESENT FACILITIES AT THE PROJECT SITE

The Pear Tree Bottom area of the Belle Air Property, having once been a livestock farm and coconut plantation, already has certain facilities, albeit in a state of disrepair. There are at present dirt access roads with gates and fencing so that motor vehicles can easily reach the swamp and plantation areas, as well as the existing buildings. There is a house that, after renovation, could serve as both an office facility and a residence for the Resident Research Director and his family. A long cement block building nearby that served as living quarters for several field hands could be converted into laboratories, dormitories and storage facilities.

A pumping and water distribution system once operated on this property. This system could be repaired and used as a water supply system for buildings and shrimp culture facilities.

The waterways on the property, after being cleared of vegetation, can be easily travelled by boat for conducting of in situ ecological research on spatial and temporal changes in the indigenous freshwater shrimp populations. In this way, an analysis of the structure of, and the rates of recruitment of juveniles into the natural population of each species of Macrobrachium in this system could be carried out. These studies would constitute valuable information usable for assessment of the biological productivity (the rate of formation of new biomass) of each species.

The land planted in coconut, or adjacent pasture lands, could be used for construction of the necessary nursery and culture ponds. The exact site for the ponds will be determined by characteristics of the soil and of the topography. There is probably sufficient diversity in the soil and in slope values to encompass a substrat of about 28% clay and a natural or man-made slope of 5°.

IV. SUGGESTIONS FOR ADDITIONAL FACILITIES AT THE PROJECT SITE

If it is not possible to accommodate hatchery facilities within an existing building, then it would be necessary to construct a hatchery building serviced by water, compressed air, electric power and drainage pipes.

It is imperative that the research and culture complex be effectively fenced off and the property protected from praedial larceny by guard dogs and handlers, who should be present all the time. Without such security, it would be impossible for the planned research and development work to develop satisfacotrily.

V. BIOLOGICAL RESEARCH CONDUCTED

1. Materials and methods

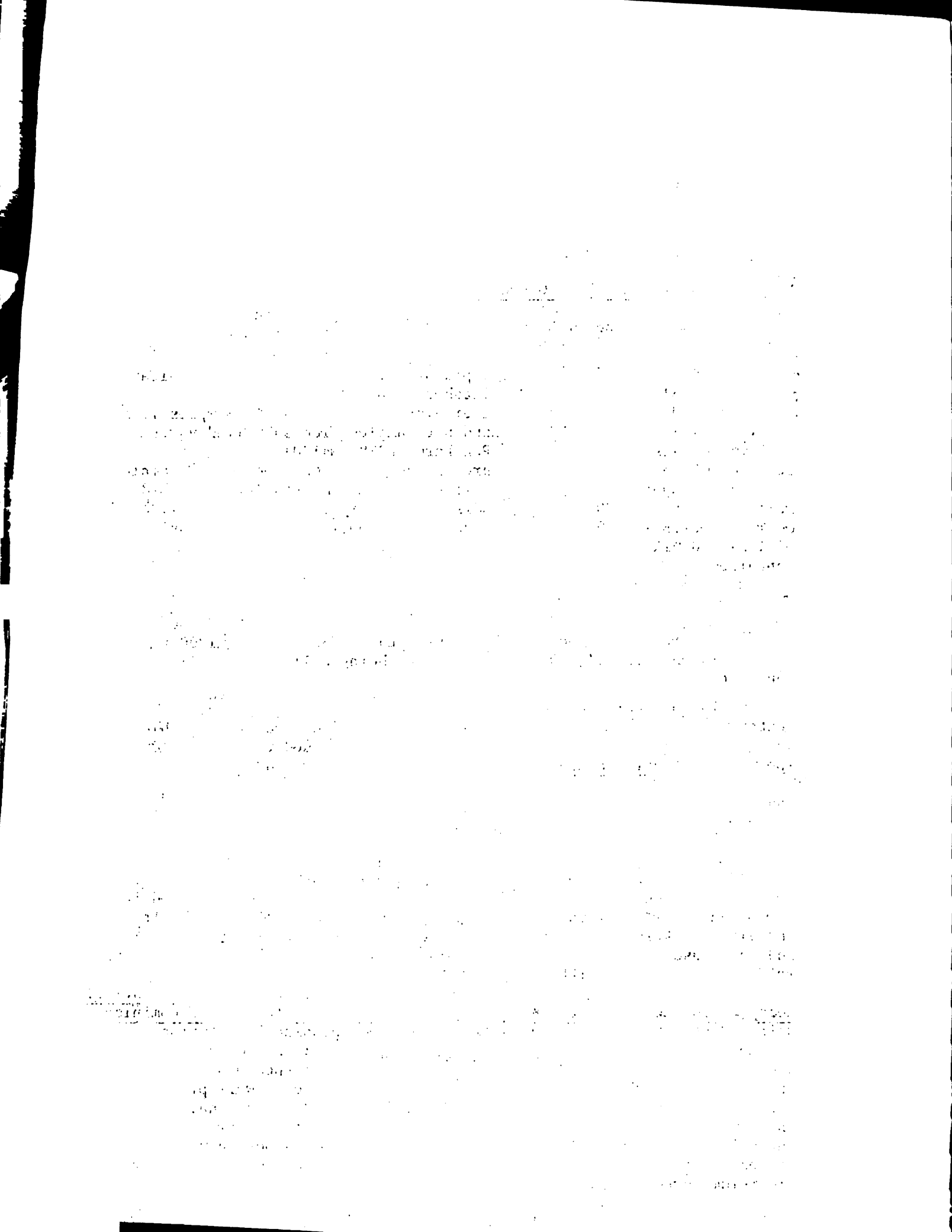
Collections of freshwater prawns were made from three Jamaican Rivers, the Black River in St. Elizabeth, the Martha Brae River in Trelawny, and Pear Tree Bottom River System in Saint Ann. Samples from Black River were of two kinds; hand net samples from submerged vegetation on the west bank at Pentio Pen Farm (E2580 N4120), collected between 0730 and 1000 hours on March 17 and 18, 1982; commercial samples of shrimp caught in pots by local fishermen and purchased live at Middle Quarters (E2620 N4370) at 1230 hours on February 23, 1982 and at 1100 hours on March 18, 1982. On both days the commercial samples consisted of 2lbs. (0.91kg.) of shrimp, all water removed; the February sample contained 90 animals, the March sample 70, the hand net samples consisted of 1,082 small specimens.

Shrimp were collected from the Martha Brae River, about 300 m. from its source near Windsor Great House (E3250 N5275), from 1200 to 1400 hours on March 14, 1982, 45 specimens being collected in all with hand nets.

In the Pear Tree Bottom River System (E4260 N5646) nine representative sampling sites were established at various locations (Table 1); Map 1. Both hand nets and small mesh seines were used to recover 120 specimens of Macrobrachium (Table 2). Collecting was done from 0700 to 1100 hours each day from February 16 to 20, 1982. Crustaceans other than Macrobrachium were also obtained (Table 2), for a total of 553 specimens.

All specimens were fixed in 10% formalin (4% formaldehyde) while still alive. After several days in fixative, the formalin was discarded and the specimens washed in 30% ethanol; the shrimp were then stored in 70% ethanol. Identification of species were carried out against white and black backgrounds by studying anatomy and morphology of the animals under a Bausch and Lomb stereoscopic microscope at magnifications ranging from 7 x to 30 x and with strong reflected illumination. The relevant dichotomus keys in Chace and Hobbs (1969) - 'The freshwater and terrestrial decapod crustaceans of the West Indies with special reference to Dominica United States National Museum Bulletin 292, Smithsonian Institution, Washington, D.C. (pp. 48-51, 56-57, 66-70, 76-79, 81-99 and 102-106) were used to determine the specific identification of all specimens in the collections. Specimens other than Macrobrachium species were present in the samples. These too were identified and included in the analyses of the compositions of the decapod shrimp populations of the three rivers investigated in this survey. Macrobrachium larvae and postlarvae were collected from a large blue hole (Crater Lake) on land owned by Kaiser Aluminium Corporation.

The earliest phases of the life cycle from this lake were examined with a compound microscope. Details of the results of the investigation of Crater Lake, as compiled by Dr. Donald McQueen, of York University, Toronto, Ontario, Canada as well as the author, are given in Table 3.



A search and review of the scientific and technical literature on the biology and culture of freshwater shrimp (prawns) have been carried out to establish a sound background of information on these potentially valuable organisms. Emphasis in this search has been on the scientific journals Aquaculture and Crustaceana, and the technical publications of the United Nations Food and Agricultural Organisation (FAO). However, relevant articles in several other organs have also been gathered together. A useful bibliography on freshwater prawns has been compiled and deposited in IICA files for future reference. It is also appended to this report (Appendix D).

All specimens collected in this investigation are preserved in 70% ethanol and stored in the Department of Zoology, University of the West Indies, Mona Campus, Kingston, Jamaica, under the custodianship of Professor Ivan Goodbody, Head of the Zoology Department.

2. RESULTS

(i) Relevant characteristics of the Pear Tree Bottom River System

Geologically, this short (5km) river system, which rises in a limestone plateau near Orange Valley, St. Ann, is dominated by

(a) the Montpelier Family of the Tertiary White Limestone Group with flints, dating from the late Miocene through mid-Eocene geological epochs, and located on the escarpment of the hinterland of the system, bounded to the south by the Duanvale Fault; and

(b) the Coastal Group of limestone, overlain by alluvial till composed of limestone debris, flint pebbles and boulders brought down from the plateau. The land on the coast is ex-mangrove swamp (remants of the mangrove trees are still present), and rises sharply immediately to the south of the swamp but less sharply further inland up to the limestone plateau.

The swamp itself extends over about 50 ha and surrounding it on three sides are about 150 ha of flat land that could serve as the pond construction area. The permanent freshwater flow comes from springs at the base of the limestone escarpment and from general seepage, so that there is very little variation in flow rates through the year. By the coastline the water is brackish so that a salinity gradient exists between the sea and the river proper. This constitutes an excellent environment for the completion of the life cycle and for the growth to adult sizes of freshwater Macrobrachium prawns.

(ii) Species compositions and relative abundance of crustaceans in samples collected

Table 1 gives samples site numbers and codes, names of sites and bottom types for Pear Tree Bottom River System and Crater Lake, while Table 2 gives specie compositions and relative abundance of species of crustaceans recovered during the sampling programme at the Black, Martha Brae and Pear Tree Bottom Rivers and Crater Lake. In Table 3 details of the sampling of plankton and benthos at Crater Lake are shown.

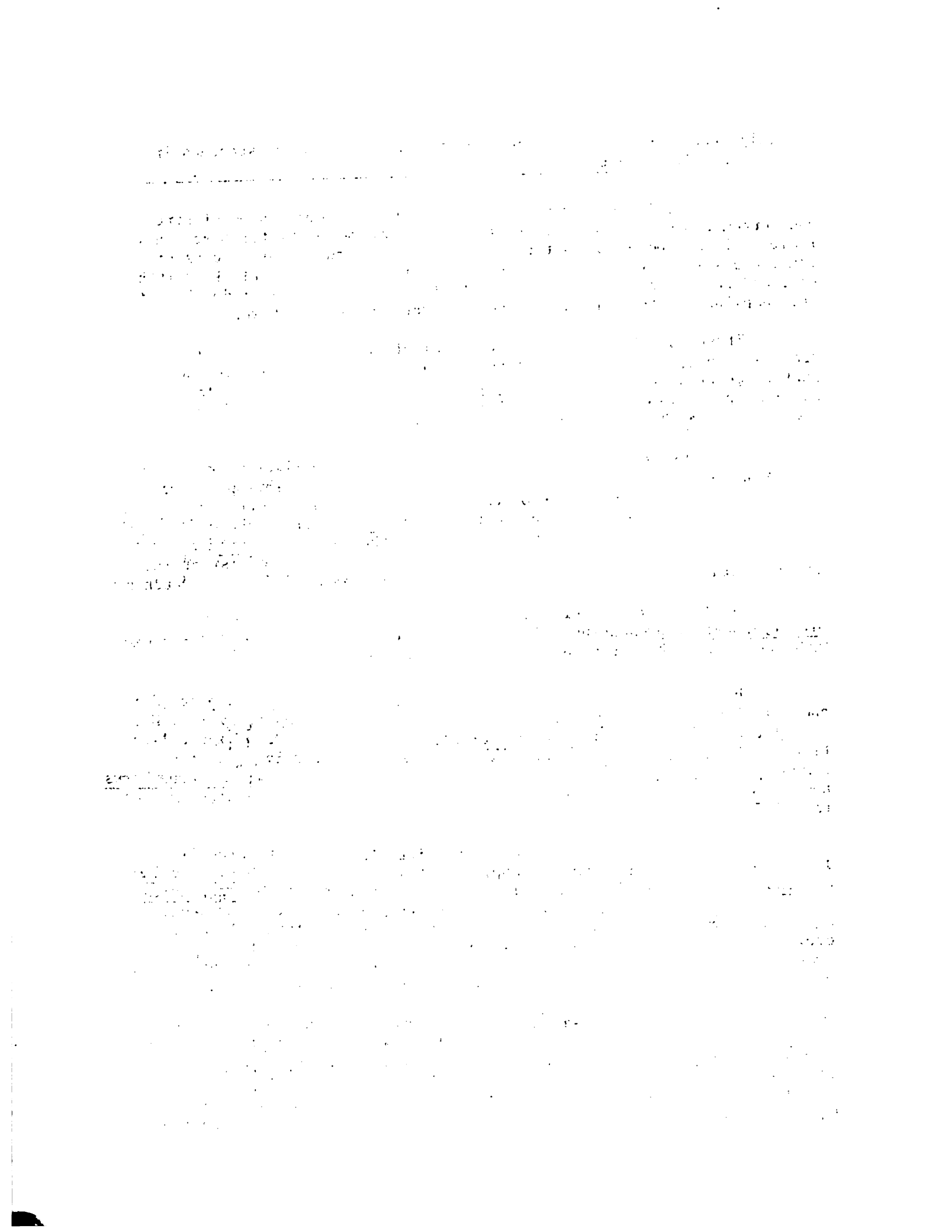
These data indicate that 0.89-0.91 of crustaceans at the lower reaches of Black River, St. Catherine (Pontio Pen Farm), amongst the bank vegetation as juveniles are Jonga serrei and only 0.075-0.112 of samples are of species of Macrobrachium. A mere 0.0055-0.010 of the decapods are Xiphocaris elongata in this part of the river.

In contrast to these specie proportions in the river bank vegetation samples, are the compositions of the two samples of shrimps, purchased at Middle Quarters, consisting of commercial fishermen's catches from lower Black River. In these shrimp pot catches, Macrobrachium is the only genus represented, M. acanthurus being 0.57-0.84 of the catch, M. carcinus 0.02-0.13 and M. faustinum 0.03-0.41 of the samples. The only consistent fact is the dominance of M. acanthurus in Black River commercial shrimp catches.

In Martha Brae River, the dominant crustacean in the sample is Micratyapoeyi, representing 0.56 of the collection. Macrobrachium species made up 0.33 of the catch and Potimirim mexicanan 0.11 of the total.

The Pear Tree Bottom River System collections yielded a preponderance of Xiphocaris elongata at 0.56 of the total specimens recovered. Next in relative abundance was Jonga serrei which comprised 0.22 of the collections. Of the Macrobrachium species represented, M. carcinus was most common, constituting 0.14 of the samples. Prevalances of both M. acanthurus and M. faustinum were low, being only 0.13 and 0.07 of the samples, respectively.

In Crater Lake a most interesting situation seems to prevail. A large proportion of the benthic samples (0.89) consisted of Macrobrachium carcinus, while only 0.01 and 0.01 of the collections were M. acanthurus and M. faustinum, respectively. These proportions by species are quite different from those in Pear Tree Bottom River System (Table 2). Benthic crustaceans other than Macrobrachium were quite insignificant in the Crater Lake samples. However, of greatest interest is the presence in the plankton of phase II and later phases of Macrobrachium larvae, and of juveniles. Even though the Macrobrachium larvae and juveniles were minor components in the samples (Table 3), being much less numerous than the copepods, and less common than both rotifers and ostracods, the existence of these early life cycle forms of Macrobrachium in the lake indicates that conditions are suitable for reproduction and growth of freshwater prawns. This is plausible because there is a surface layer of freshwater one to two meters deep (1.25 m near shore and deeper towards the middle),



below which there is water of a salinity of 19-21 ppt. which extends down to near the lake bottom (McQueen, 1982 MS report). Freshwater springs issue from the limestone bed of the lake. Thus a wide range of salinities is found in this system. The abundant copepod naupii could serve as a food source for developing Macrobrachium larvae.

(iii) Ecological details on crustaceans recovered in samples collected

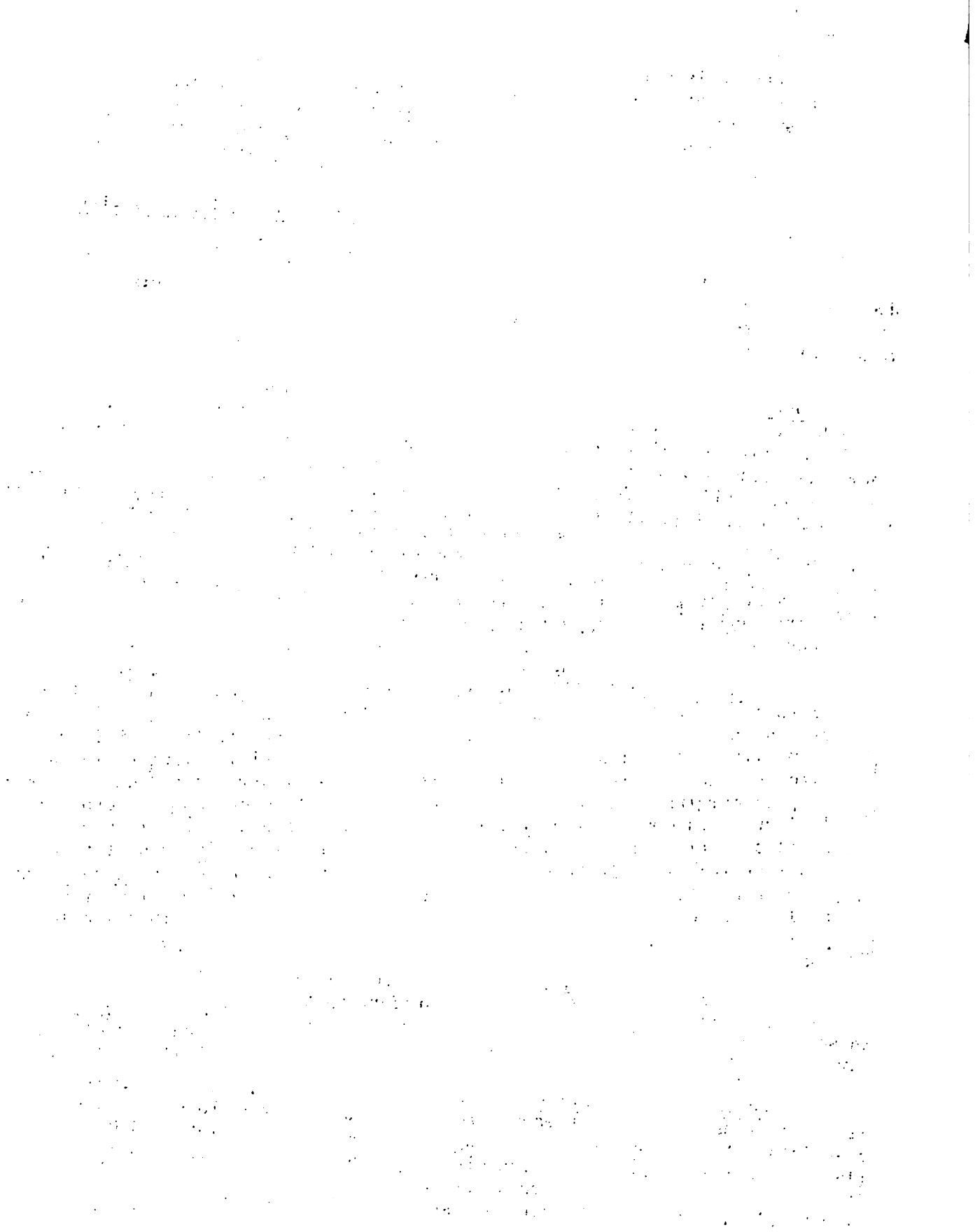
"The majority of the West Indian freshwater and terrestrial decapod crustaceans are known to be tolerant of salinities approaching that of seawater, many actually invading the ocean or having larval stages that typically occur in the sea". (Chace and Hobbs, 1969, p. 32.

Jonga serrei and Macrobrachium acanthurus are found in estuarine and subestuarine habitats, being restricted to sluggish waters near the mouths of streams. They are progressively less abundant as stream gradient increases, normally being restricted to above sea level elevations of less than 150 feet (45 m). They are normally absent in streams that reach the coast with their beds above high tide level. Macrobrachium acanthurus seems to be most abundant in sluggish streams over muddy bottoms. It is restricted to quiet pools near the mouths of streams and rivers at or below sea level and lacking riffles. During the day it can be found among debris and roots of shoreline plants exposed in the waters. After dark, they move to the tops of debris accumulation or into open water.

Macrobrachium carcinus ascends streams from the sea up to elevations of about 2,000 ft. (600 m) or more, living in pools or under large stones in larger rivers. In subestuarine conditions it finds shelter among littoral debris. It can also be found in rapidly flowing drainage ditches beneath large stones in swift portions of streams and under stones at pool margins of even the smallest creeks. It is basically nocturnal. It leaves its cover during the night and moves around, even crossing riffles in travelling from one pool to another. There is thought to be a direct relationship between size of a pool and the number of M.carcinus populating it. About 15 to 20 square feet of bottom is required by an adult M. carcinus as its territory. The largest speciment in a single pool containing several individuals is the master of that pool. Dominance is linked to size in this species.

Macrobrachium crenulatum is found from almost sea level up to elevations of about 1,300 ft. (390 m), preferring the stream bed of pools in smaller streams and quiet littoral microhabitats of shallow riffles in larger streams.

Macrobrachium faustinum is found in quiet pools and protected littoral areas of larger streams, from subestuarine conditions, where it co-exists with M. acanthurus and Jonga, to elevations as high as 500 ft. (150 m.), but is primarily an inhabitant of the lower reaches of streams. It shelters beneath stones, trunks of water-logged trees or larger pieces of debris. It is believed that this species seldom enters riffles.



Macrobrachium heterochirus appears to be confined to riffles from about 2,500 ft (750 m.) down almost to sea level.

Macrobrachium jelskii occurs in habitats similar to those of Jonga serrei and M. acanthurus, ranging quite far inland from the coast.

The usually epigean Potimirim mexicana, M. carcinus and M. faustinum have also been reported from caves, as has X. elongata in Puerto Rico. M. carcinus has been reported to be flushed out of underground passages into river pools, from which it was then recovered.

Xiphocaris elongata occurs from elevations of about 1,200 ft. (360) right down to sea level, preferring pools, though this species can move through the fastest currents as adults. Juveniles are mostly restricted to stream margins in moderate currents. Most specimens are to be found in pools at low elevations. Adults may be restricted to elevations about 150-200 ft. (45-60 m). M. faustinum and M. carcinus and X. elongata are the most widespread shrimp in Jamaica, according to Hunt (1976), having been collected by him from parishes bordering the four coasts of the island. M. acanthurus, J. serrei and P. mexicana were collected only from western and southwestern parishes. The eastern and northeastern parishes are mountainous, whereas the western and southwestern ones are relatively low lying and flat. The E and NE rivers tend to be high gradient streams, with shallow, clear, cold and fast-flowing waters with a high O_2 content and stony bottoms with little vegetation. The W and SW rivers are mostly low gradient water courses with deep, turbid, warm, slowflowing waters, low O_2 content and muddy bottoms with abundant vegetation.

The most important ecological factor in the successful completion of the life cycle, from fertilised egg to sexually mature adult, is the level of dissolved salts in the water at the different phases of this cycle. The larvae need to be hatched in relatively high salinity water. Optimum salinities for larval development have been investigated experimentally by several workers with the following results:

Species	Family	Dissolved salts Concentration	Reference
Atya innocuous	Atyidae	30 ppt[1]	Hunt(1976)
Atya lanipes	Atyidae	20 ppt	Hunt(1976)
Atya scabra	Atyidae	Not known	-
Jonga serrei	Atyidae	20 ppt	Hunt(1976)
Macrobrachium acanthurus	Palaeomonidae	15-20 ppt (66% sea water)	Choudhury (1976)
Macrobrachium carcinus	Palaeomonidae	(14-18 ppt)	Lewis & Ward(1965)
Macrobrachium faustinum	Palaeomonidae	19-20 ppt	Choudhury (1971)
Macrobrachium heterochirus	Palaeomonidae	32 ppt[3]	Hunt (1976)
Micratyapoeyi	Atyidae	32 ppt[3]	Hunt (1976)
Potimirim mexicana	Atyidae	14 ppt	Hunt (1976)
Xiphocaris elongata	Atyidae	Not known	Hunt (1976)

NOTE: 1 ppt - dissolved salts level as parts per thousand of water e.g. 30 ppt = 3 per cent salts, or 3g per 100g of water = 30g per 1000g (=1 liter).

2. These species are flexible in their salinity requirements for the larvae

3. These concentrations are approximately full strength coastal seawater

3. DISCUSSION

There is no doubt that the relevant characteristics of the Pear Tree Bottom River System constitute a most suitable situation for a research, testing and development facility for freshwater prawn investigations. Without repeating evidence for this conclusion, which is given in other parts of this report, suffice it to say here that it is hard to conceive of another location in Jamaica that would be better for aquacultural research than the Belle Air property. In addition to the desirability of the site itself for the proposed facility, another advantage is the proximity of the Discovery Bay Marine Laboratory of the University of the West Indies, Mona Campus. Cooperation in research and development with the University could be easily effected in the form of post-graduate student research on the site and use of some Discovery Bay facilities.

The results of analysing the species' compositions and relative abundance of shrimp from the three rivers and one lake sampled, indicate several encouraging possibilities with respect to the current proposal. First, all three of the indigenous Jamaican species of Macrobrachium which are of interest for testing, occur naturally in both Pear Tree Bottom and Crater Lake so that we know conditions are suitable for maintenance of their life cycles there. It has been shown for the first time that M. acanthurus is established in these two systems, although it is uncommon. Second, M. carcinus is relatively uncommon in Pear Tree samples, but strongly dominates the Crater Lake populations, whereas M. faustinum is rare in the lake but dominant in the river system. Thus brood stock of both species is readily available in the region, while abundant berried females of M. acanthurus could easily be obtained from lower Black River, where this species is the dominant type, and transferred to the culture ponds at Pear Tree Bottom, if necessary. Brood stock for experiments on the exotic but widely cultured species, M. rosenbergii, would have to be imported, but this is an inexpensive procedure. Third, M. carcinus is present near the source of the Martha Brae River, which is not far from Pear Tree Bottom, and is found in unpolluted water. Mature males and females and/or berried famales could be transferred from Martha Brae River at moderate cost, if required. Fourth, the occurrence of several different life cycle phases of Macrobrachium in Crater Lake suggests that the life history is completed within the lake. This raises the possibility of culturing it by providing suitable holding facilities for adults along the lake's edge, such as meshed boxes to provide a refuge and exclude predators. With proper planning, this lake could be made into a huge incubator - grow out complex using the abundant, clean, constantly replenished lake water. Augmentation of the currently established wild copepod population with copepod eggs might provide an abundant food supply for the Macrobrachium larvae. At the very least, these ideas should be kept in mind if expansion becomes necessary.

Appendix B provides an analysis of the available water chemistry, water quality and water flow rates data for Pear Tree Bottom by presenting ranges of values, where appropriate, arithmetic means, standard deviations and standard errors. An examination of these statistics indicates the excellent water chemistry and water quality characteristics of the system with respect to aquaculture of Macrobrachium shrimp. The springs providing good, soft freshwater for adults and the lower channels, where tidal seawater intrudes, offering saline waters for newly-hatched larval development. The water flow rates data on rain recharges, rain outflows and subsurface flows are remarkable for their large standard deviations, due to high variability, and large standard errors caused by small samples. In contrast, spring discharges have low variability, while the constancy of the river system outflow is very striking indeed. Both spring and river flows ensure a reliable water supply of known flow rate.

The ecological information on crustaceans collected in this study which is presented in the results section is of interest to the current proposal because it emphasises the different requirements for living conditions of the individual species in the samples. Amongst the species of Macrobrachium, specificially, we note different physiological optima with respect to salinity, stream bottom type, water current speed and altitude of the three main species under consideration in the present proposal, i.e. acanthurus, carcinus and faustinum. This not only tells us that these species are segregated in nature, so that they do not compete against each other for food and living space, but also that we must be careful to provide each species with the particular condition required for its optimal performance.

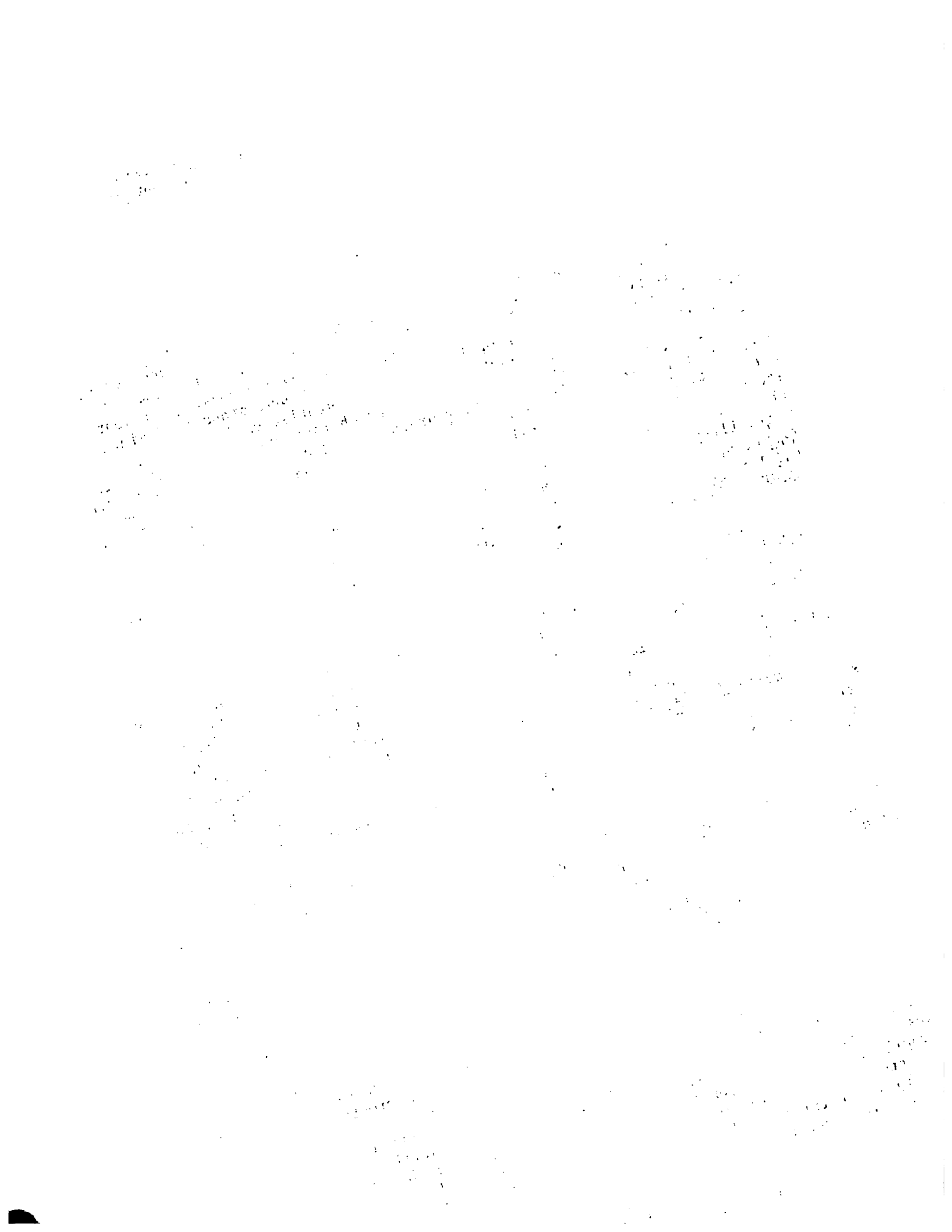
There are some relevant points to be raised concerning ecological conditions in the exploitation and rational conservation of aquatic resources at an aquaculture facility. There will co-exist under these conditions two paramount conflicting aspects:

(1) exploitation, usage and dissipation of resources and energy, leading to losses; and

(2) conservation, husbandry and rational channeling of energy, leading to maintenance of the integrity of the system, where common effects are thus stability and recycling of nutrients

The cost of (2) is reduced energy utilization rates and economic return rates. Clearly, these conflicts have to be resolved by striking an appropriate balance between them. This can obviously only be done in the context of the objectives which are established in advance for the particular enterprise. The following objectives for an aquaculture facility are proposed here:

(1) to utilize rationally a natural resource at the same rate that it can replenish itself or at a rate consistent with economically viable, but non-disruptive, subsidy inputs that aid replenishment,



(2) to avoid environmental degradation in order to prevent the eventual destruction of the resources;

(3) to avoid pollution, destabilizing nutrient enrichment rates, water flow modifications on a scale conducive to resource deterioration, and harmful stresses resulting from the application of technology,

(4) to generate information useful for continuing research and development, and that can be basis for advice to governmental and private sector institutions;

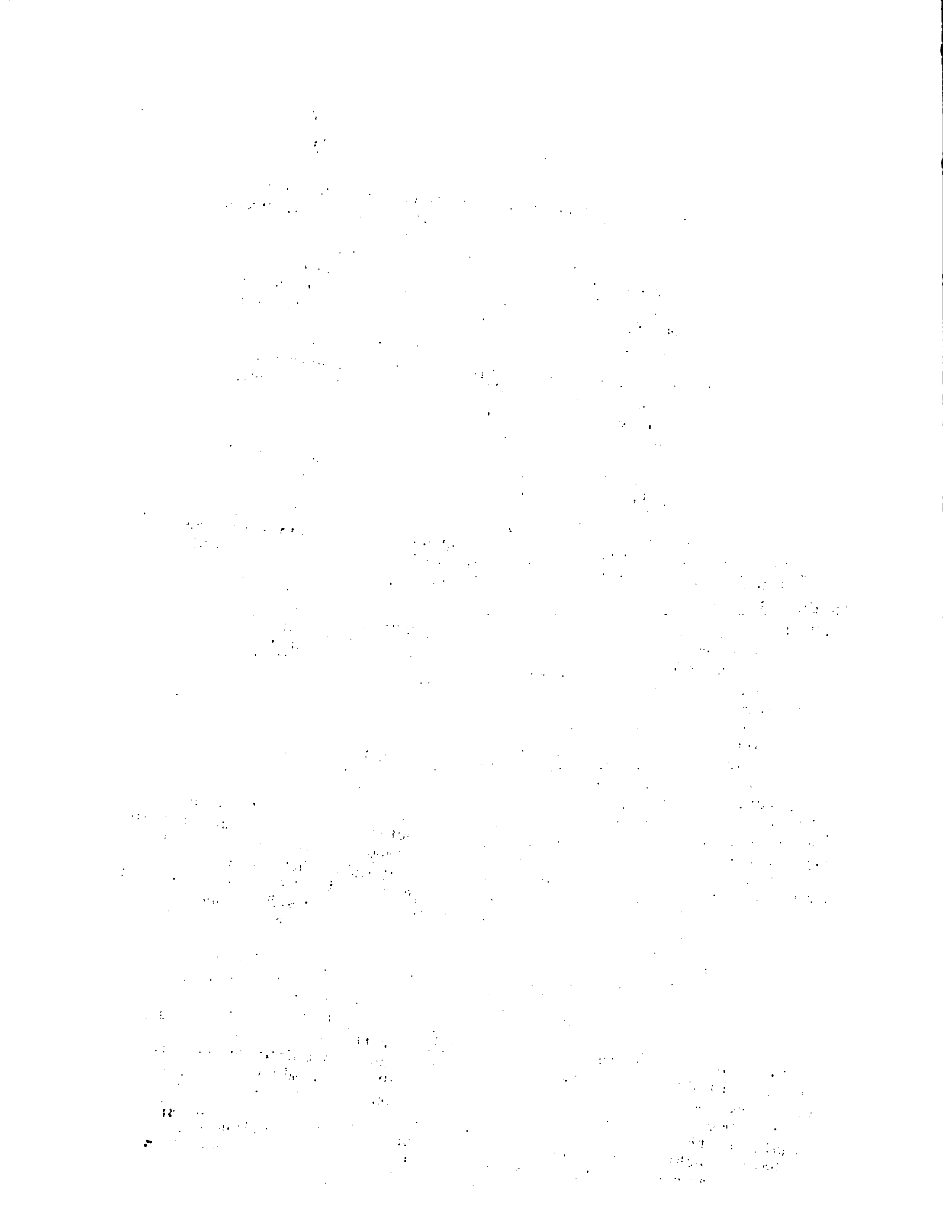
(5) to fulfill practical ends that increase economic well-being, social wealth and the quality of human life.

What is the relative position of aquaculture production of crustaceans when compared to other types of animals that are utilized in this way? In 1975, the level of world aquaculture production was as follows, in round figures.

Animal type	Production (tons)	Percentage of total
1. Finfishes	3,980,000	66.0
2. Seaweeds	1,055,000	17.5
3. Molluscs (oysters, mussels, clams, scallops, cockles etc.)	978,000	16.2
4. crustaceans (shrimps and prawns)	16,000	0.3

We see from these figures that crustaceans constituted an insignificant proportion of world aquacultural production in 1975. This situation is typical of world output of the 1970's and 1980's. However, although crustaceans are a minor component in terms of weight, they are much more important in terms of value because they command a high price in the market per unit of weight. Cultured crustaceans are characteristically a high value commodity of which the price trend is strongly upwards. It is this strong market price that makes prawn acquaculture an attractive and potentially profitable proposition.

Today, freshwater prawn culture around the world is strongly concentrated on Macrobrachium rosenbergii (de Man, 1879) because it is hardy, adaptable and fast-growing. Culture of this species was first achieved in 1962 in Malaysia by Ling (1962) and mass culturing techniques were developed by 1970 in Hawaii (Fujimura, 1966, Fujimura and Okamoto, 1970). Over 20 organizations in the United States alone are involved in studies on the culture of this species. Improvements in larval rearing techniques achieved in Hawaii have made possible the establishment of several commercial shrimp farms there and in various parts of southeast Asia, especially Thailand, in Puerto Rico, Taiwan and Central America



(Costa Rica and Honduras), by 1980 (Shang 1981). Over 2 million postlarvae were produced in Hawaii by 1974 and annual production capacity at the state hatchery was projected to be 25-30 million postlarvae by 1975 (Shang 1981). Today 27 countries have experimental hatcheries. Emphasis in developed countries is on intensive culture systems, where major economic problems are high cost of formula feeds, and to a lesser extent expensive land and labour.

The costs of Macrobrachium culture using different species constitute one of the most critical factors in this kind of activity. Yet there are few data available which compare different species on a cost basis, so that this matter is still to some extent an open question, one that needs to be investigated further. According to Alston (1981), in I.M.A. (1981) (bibliographic reference No. 83, App. D), an effort has been made in Florida to look at the relative success of a variety of species of Macrobrachium shrimps from several points of view, including the economics of culture under controlled conditions. Some results of this work follow. In Florida, research is on-going on M. acanthurus, M. carcinus, M. rosenbergii and M. ohione, the last-named being considered for production as bait and for polyculture with crayfish (Sic). A very condensed version of the results is shown below:

Comparison of costs of rearing acanthurus and rosenbergii reveals the following

Species	Cost to rear 1,000 larvae to metamorphosis
	US$
acanthurus	13.42
rosenbergii	3.56

Drawbacks of acanthurus in culture were found to be the following:

(1) it was less hardy than rosenbergii;

(2) it did not readily accept ground fish as food;

(3) it consumed 4 times as much Artemia nauplii as rosenbergii to achieve metamorphosis (nauplii are expensive);

(4) there was no selected out brood stock available for purchase in starting a culture, non-selected or wild brood stock had to be used; and

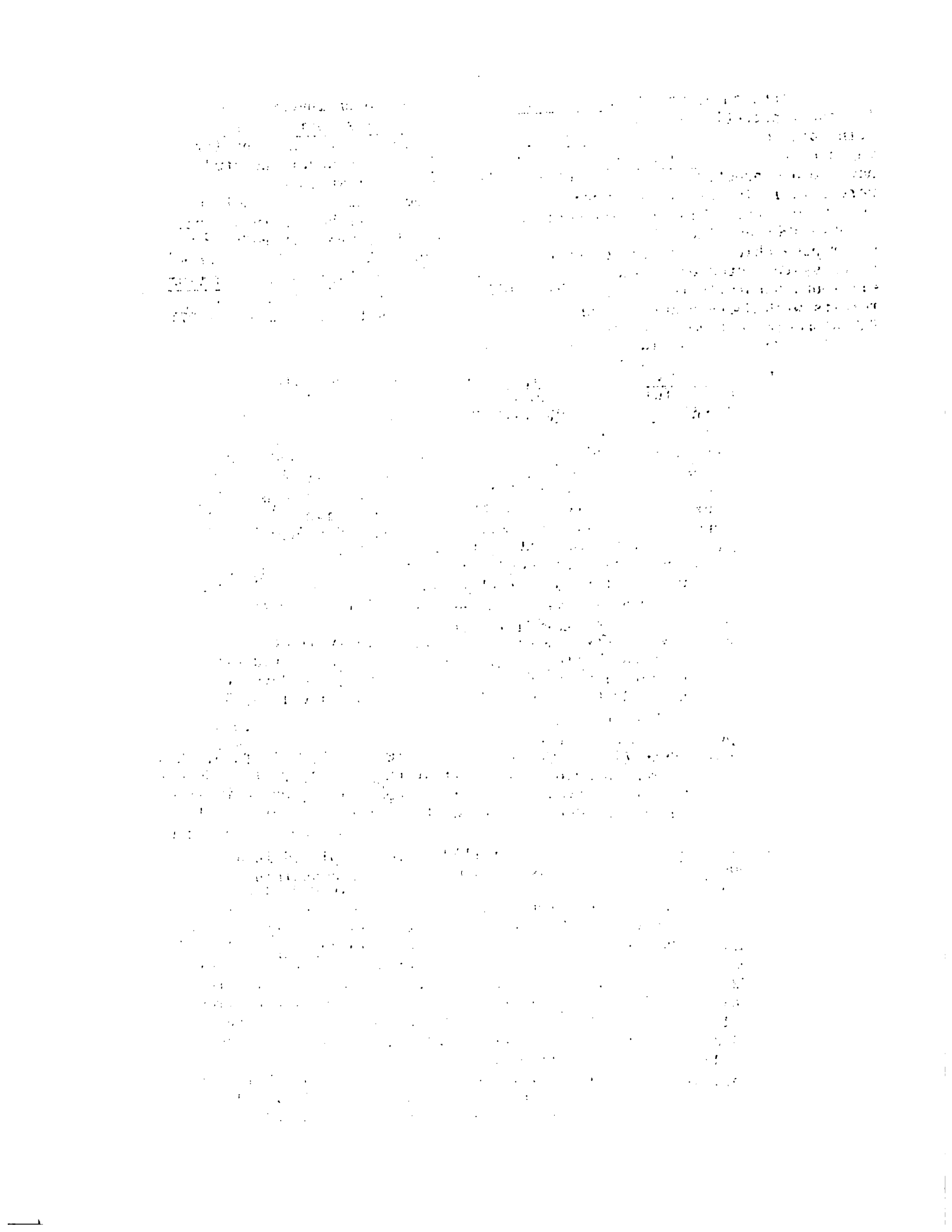
(5) it grew more slowly than rosenbergii

Although about 12 Macrobrachium species have been investigated for their potential for aquaculture, by 1982 only M. rosenbergii was being produced on a large scale. The only other species to show any farming potential are M. lanchesteri and M. malcolmsonii. However, no studies have been conducted in Jamaica, where conditions for prawn culture are particularly favourable and several species of Macrobrachium are indigenous and are the basis of small scale commercial prawn fisheries in several rivers, such as Black River, Wag Water River and Rio Cobre. Therefore, we propose that in addition to tests of M. rosenbergii in Pear Tree Bottom River system, studies be made of M. acanthurus, M. carcinus and M. faustium, all found naturally in Jamaica. Some examples of culture practices and results with Macrobrachium prawns are given below. Reference: Anon. (1977). FAO Aquacult. Bull 8(2):11.

(1) Macrobrachium rosenbergii. This species was cultured successfully, for example, at the Prawn-breeding Unit of the Central Inland Fisheries Research Institute, Kakinadam, Andhra Pradesh, India, and described as "the giant freshwater prawn". Newly-hatched larvae were released into earthernware pots holding 30 litres of aged seawater, diluted by 20% and containing a dense plankton component. At larval phase VI, larvae were transferred to round, flat-bottom 10 litre troughs with continuous aeration and water circulation. Larvae of phase VI were fed Artemia nauplii plus minced algae for 7 days, thereafter on nauplii only for another 3 days. After that, the feed was finely-sliced and cleaned Tubifex. Larval rearing was completed with the attainment of larval phase X after 38 days at about 30°C, and with dissolved oxygen levels at 3.95 to 6.55 p.p.m.

(2) Macrobrachium carcinus. Research on the culture of this species commenced at the Instituto Oceanografico, University of Sao Paulo, Brasil, in April 1975, where it lives in small mountain streams at water temperatures of 17° to 23°C. At the time of reporting this species had not been found in the estuarine zone.

(3) Procedure. A 92 mm long berried female was placed in a 500 litre concrete tank, 100x60x80 cm, and containing freshwater. On the 5th and 6th days after the female was confined, 5,000 newly-hatched larvae were released from the animal. These were transferred to seawater aerated by compressed air. Larvae were fed Artemia nauplii. Experimental water temperature ranged from 22.7° to 28.9°C, with an average of 26°C, average salinity was 33.5 ppt. Newly-hatched larvae measured 2.1 to 2.2 mm from rostral tip to telson tip. By 20 days larvae averaged 5.8 mm in the phase VIII, by 35 days were 7.6 to 7.8 mm long. Morphology and physiology of this species were being studied.



SUMMARY OF CHARACTERISTICS DESIRABLE IN AQUATIC ORGANISMS CULTURE FOR COMMERCIAL SALE

(1) Successful reproduction in captivity, high hatching success.

(2) Availability of proven techniques for rearing of larvae; short larval life.

(3) High growth rate; adaptability to a wide range of temperatures.

(4) High survival rate, especially amongst juveniles and adults.

(5) Absence of, or immunity to, major diseases.

(6) Wide consumer acceptability; high quality meat in terms of taste and texture.

(7) High market value.

(8) Technically feasible culture procedures adaptable to the species in question at different locations or in moderately varying conditions.

(9) Economic feasibility under the local conditions of the venture, using the species of choice.

Of concern in the development of a concept such as is the subject of this report is the maintaining of the momentum established in the early phases of planning into later phases. To help ensure that the idea that a viable freshwater prawn research and culture facility could be functional in the Pear Tree Bottom River System, there follow some lists which should prove useful as the project takes shape. The main value of these lists is that they provide access to relevant information and facilitate the implementation of remedies for problems that may occur in the future as the aquaculture facility goes through its step by step phases of development.

EXPERTS ON CULTURE OF FRESHWATER PRAWNS (SHRIMPS)

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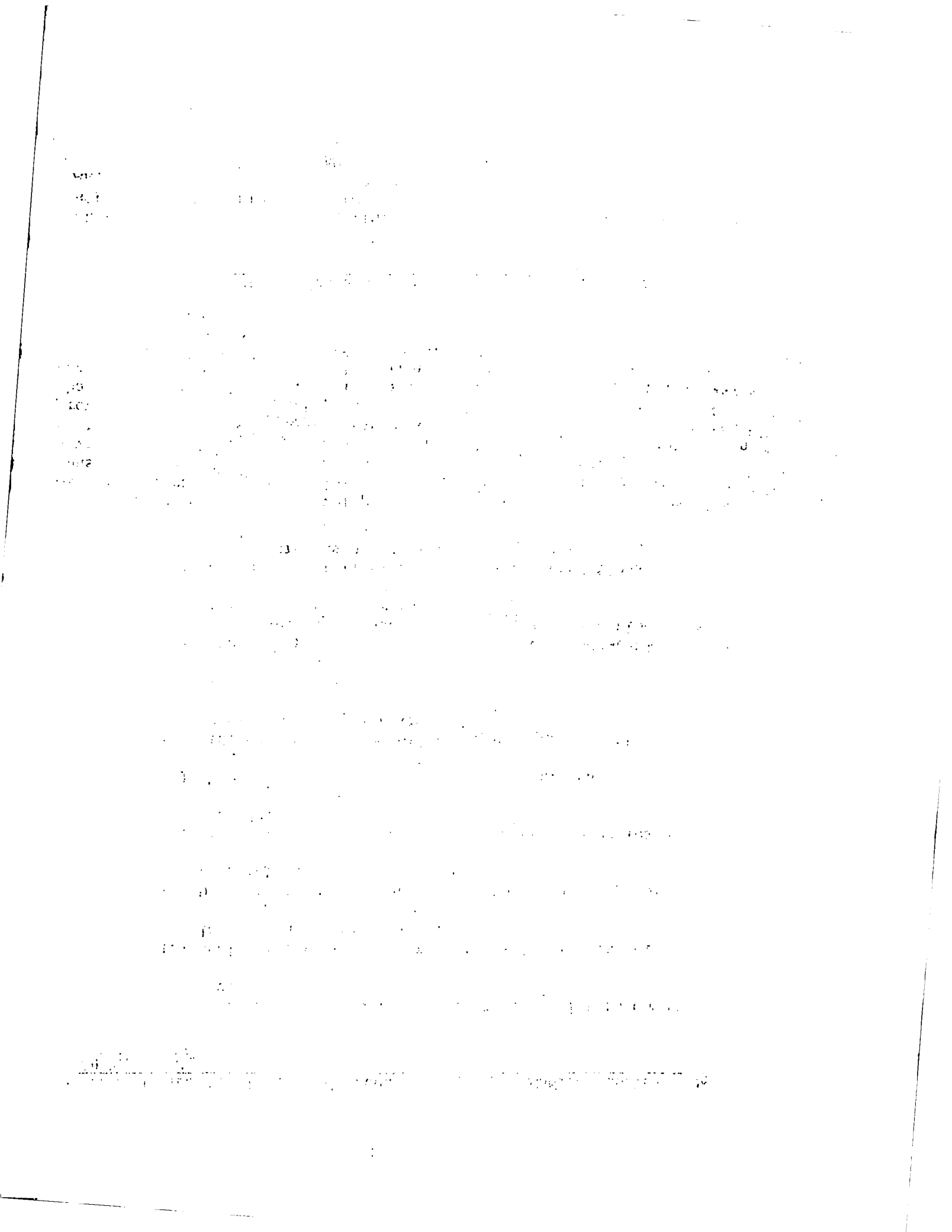

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Two sources of literature abstracts on parasites

(1) Helminthological Abstracts

(2) Protozoological Abstracts

Published by: Commonwealth Agricultural Bureau
Central Sales Branch
Farham Royal
Slough SL2 3BN England

For control of fungal infestations in aquatic animals - some chemicals and their effective concentrations

Crystal violet	0.002%
Formalin	0.01%
Hydroquinone	0.04%
Malachite Green	0.5 ppm
Merbronin	0.25%
Neutral red	0.01-0.05%

$K_2Cr\ 0_4$	0.20% (potassium chromate)
$K_2Cr_2\ 0_7$	0.1% (potassium dichromate)
$K\ Mn\ 0_4$	0.02% (potassium permanganate)
NaCl	1.0% (Sodium chloride)
'Teepol'	0.04% (a disinfectant and detergent)

An example of a prepared shrimp food

Experimental Marine Ration 25, Ralston Purina Company, St.Louis, Missouri. This is a water stable high density flake, containing soy meal and soy oil; it is rich in 18:2w6 (linoleic acid), with a crude protein content not less than 25% and fat not less than 7%. However, it contains no shrimp, which some workers would see as a disadvantage.

Proximate analysis

Protein 25.5%; Fiber 4.1%;

Fat 7.3%; Ash 6.7%;

Moisture 11.0%; N-free extract 40.2%

Summary of General Objectives of Aquaculture Development & Coordination for the purposes of Planning and Community Integration

(1) Provision of multidisciplinary help;

(2) Strengthening of indigenous research efforts;

(3) Training of senior aquaculturists,

(4) Promotion of cooperation at various political unit levels;

(5) Stimulation of investment;

(6) Assistance in releases of extra financial help;

(7) Promoting participation by lower socio-economic persons, e.g. labourers.

Characteristics of small-scale undertakings

(1) Tropical climate

(2) Good water supply

(3) Adequate available land area of non-agricultural value

(4) Labour intensive, in an area of high unemployment

(5) Competitive price for the finished product

Infrastructure needed

(1) Public works for excavations, construction, drainage, etc.

(2) Joint service for feeds, fertilisers, chemotherapeutics, etc., if required

(3) Marketing integrated and traditional fisheries, if possible

(4) Inspectors to regularly check the physical components such as screens, etc.

Possible physical preparations needed

(1) Installation of screens to keep culture organisms in, competitors out

(2) Vegetation removal and/or bottom clearing

(3) Elimination of predators to the extent that that is feasible

(4) Propagation of natural food, or its protection (e.g. planktonic food)

ALTERNATIVES IN DEVELOPMENT AND USING AN AQUATIC RESOURCE FOLLOWING THE CONDUCTING OF SCIENTIFIC STUDIES

The following methods are feasible options in the exploitation of an aquatic resource

(1) STOCKING (controversial) and INTRODUCTIONS OF EXOTICS (even more controversial)

(2) AQUACULTURE:

(i) capture fisheries based on cultured young;

(ii) capture fisheries based on wild young;

(iii) husbandary fisheries

(3) COMMUNITY DEVELOPMENT

(4) ENVIRONMENT ENGINEERING:

(i) weeding and brush clearance;

(ii) selective poisoning;

(iii) water aeration;

(iv) nutrient enrichment;

(v) dredging

(vi) artificial cover;

(vii) artificial environment

(5) CONSERVATION OF INDIGENOUS SPECIES AND NATURAL ENVIRONMENTS, WITH USE OF SUITABLE INDIGENOUS TYPE IN CULTURE

SUMMARY OF REQUIREMENTS FOR INTENSIVE AQUACULTURE

(1) High water quality

(2) Plentiful amounts of water

(3) Industrially prepared feeds

(4) Effective disease control

(5) High value per unit weight of marketed product

(6) Absence of pollution

NOTE World finfish production from aquaculture was estimated by Pillay (1973) to be about 3.6×10^6 tons, 65% of which came from inland or brackish waters. Of this total, only 20,000 tons were produced in the whole of Latin America. Thus, there would appear to be considerable scope for the initiation and rapid expansion of aquacultural activities in Jamaica.

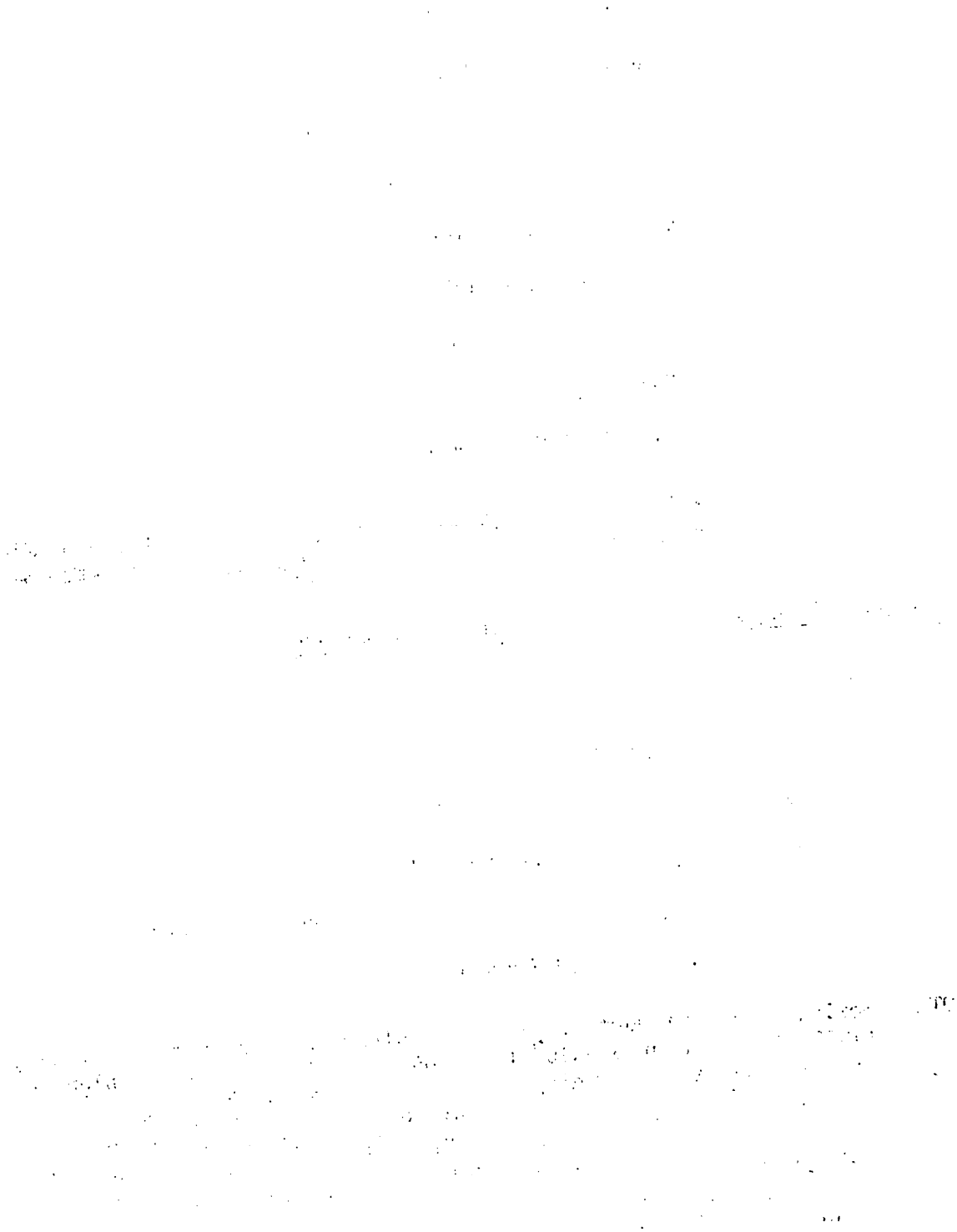


TABLE: 1 Sample sites established at Pear Tree Bottom River System and vicinity

Site No.	Name of Site	Code	Bottom type
1	Parson's creek, at bridge No. 3	PRSB	Sand
2	Grassy creek, at bridge No. 1	GCSW	Grey mud
3	Swamp Pool A	SPA	Grey mud
4	Lock-Spillway	LS	White mud
5	Rowe's Canal, Coconut Grove	RCCF	Black mud
6	Pear Tree River Main Outlet, at bridge No. 2	PTRMO	Mud, sand
7.	Roger Clarke's Ditch	RCD	Black mud
8	Crater Lake, Kaiser Aluminum	CL	Limestone, mud
9	Pear Tree Bottom River Proper, Lower Reaches	PTBRPLR	Mud sand
10	Row's Canal, Upper Site	RCUS	Black mud

NOTE: Refer to May 1 for the geographic locations of the sample sites

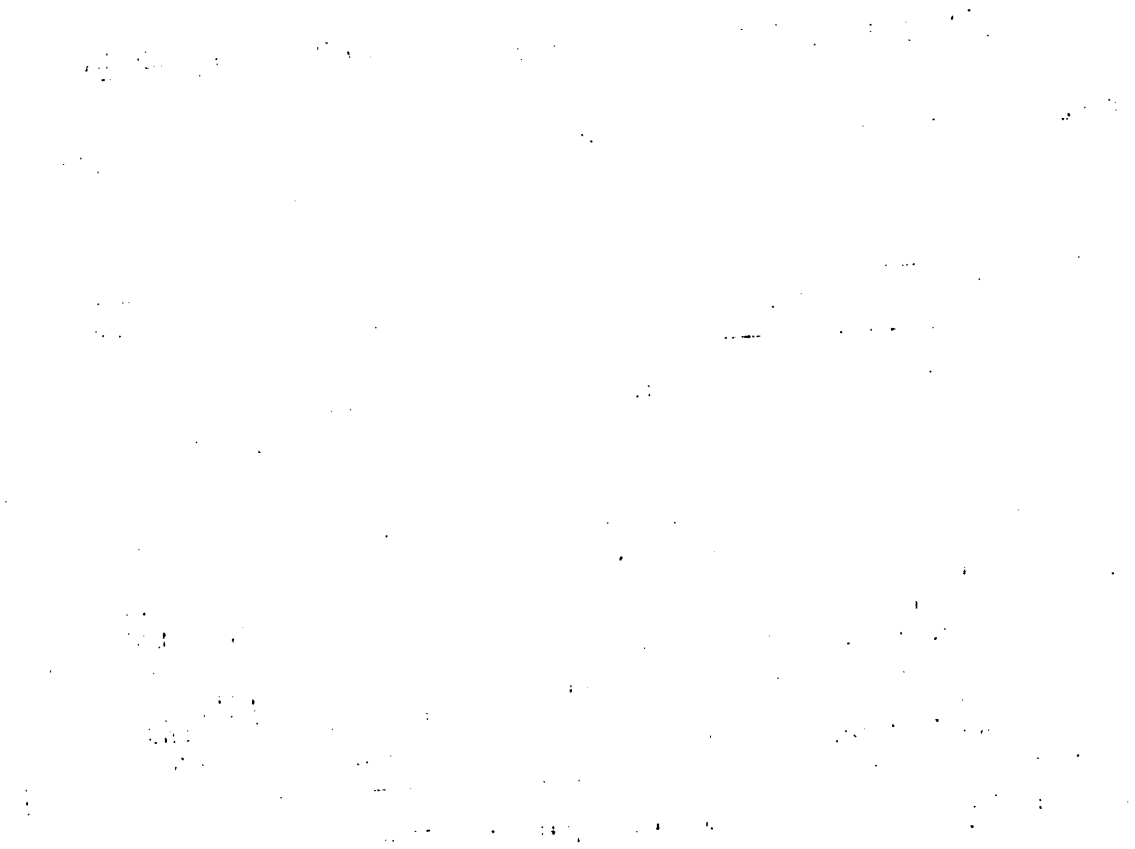


TABLE: 2 Compositions by species and relative abundance of crustaceans in samples from Black River, Martha Brae River, Pear Tree Bottom River and Crater Lake, Kaiser Aluminum property, Jamaica, February-March 1982

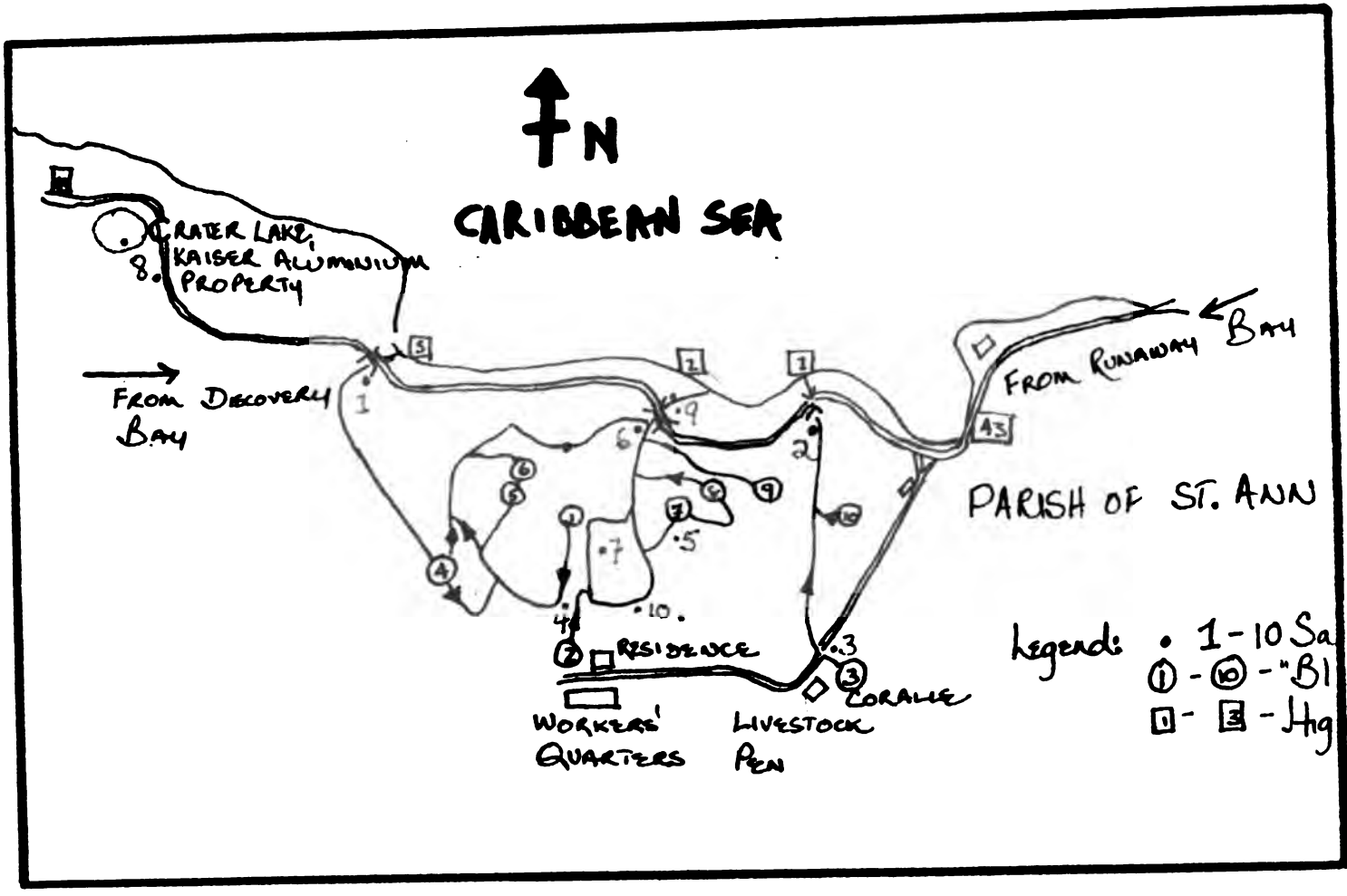
Side Code	Specimen Code	System	Species	Number in Sample	Propora-tion in Sample	Total in Sample
PPFPI	PPFPI-82-1-ABH	Black R.	Jonga Serrei	443	0.890	
PPFPI	PPFPI-82-1-D	Black R.	Macrobrachium Acanthurus	25	0.050	
PPFPI	PPFPI-81-E	Black R.	Macrobrachium Carcinus	30	0.060	
PPFPI	PPFPI-82-1-F	Black R.	Macrobrachium Faustinum	1	0.002	499
PPFPI	PPFPI-82-3BC	Black R.	Jonga Serrei	532	0.911	
PPFPI	PPFPI-82-3-A	Black R.	Macrobrachium Acanthurus	24	0.045	
PPFPI	PPFPI-82-3-D	Black R.	Macrobrachium Carcinus	22	0.038	
PPFPI	PPFPI-82-3-E	Black R.	Xiphocaris Elongata	6	0.010	584
PPFPI	PPFPI-82-13-ABHBA	Black R.	Jonga Serrei	975	0.9003	
PPFIP	PPFPI-82-13-DA	Black R.	Macrobrachium Acanthurus	49	0.0452	
PPFPI	PPFPI-82-13-ED	Black R.	Macrobrachium Carcinus	52	0.0480	
PPFPI	PPFPI-82-1-F	Black R.	Macrobrachium Faustinum	1	0.0009	
PPFPI	PPFPI-82-3-E	Black R.	Xiphocaris Elongata	6	0.0005	1,083
BRCS-1	BRCS-82-1-BCDG	Black R.	Macrobrachium Acanthurus	51	0.5667	
BRCS-1	BRCS-82-1-A	Black R.	Macrobrachium Carcinus	2	0.0222	
BRCS-1	BRCS-82-1-EFH	Black R.	Macrobrachium Faustinum	37	0.4111	45
BRCS-2	BRCS-82-2-I	Black R.	Macrobrachium Acanthurus	59	0.8429	
	BRCS-82-2-II	Black R.	Macrobrachium Carcinus	9	0.1286	
	BRCS-92-2-III	Black R.	Macrobrachium Faustinum	2	0.0386	70
MBRWGH	MBRWGH-82-1	Martha Brae R.	Macrobrachium Carcinus	10	0.2222	
MBRWGH	MBRWGH-82-II	Martha Brae R.	Macrobrachium Faustinum	5	0.1111	
MBRWGH	MBRWGH-82-III	Martha Brae R.	Potimirim Mexicana	5	0.1111	
MBRWGH	MBRWGH-82-IV	Martha Brae R.	Micratya Poeyi	25	0.5555	45
PTBRS	PTBRS-82-I	Pear Tree R.	Macrobrachium Acanthurus	7	0.0127	
PTBRS	PTBRS-82-II	Pear Tree R.	Macrobrachium Carcinus	76	0.1374	
PTBRS	PTBRS-82-III	Pear Tree R.	Macrobrachium Faustinum	37	0.0669	
PTBRS	PTBRS-82-IV	Pear Tree R.	Jonga Serrei	122	0.2206	
PTBRS	PTBRS-82-V	Pear Tree R.	Potimirim Mexicana	0	0.0000	
PTBRS	PTBRS-82-VI	Pear Tree R.	Xiphocaris Elongata	310	0.5606	
PTBRS	PTBRS-82-VII	Pear Tree R.	Unidentified	1	0.0018	553
CL	CLDM-1-IV-82	Crater Lake	Macrobrachium Acanthurus	2	0.0132	
CL	CLDM-8-1-82	Crater Lake	Macrobrachium Carcinus	135	0.8940	
CL	CLDM-1-1-82	Crater Lake	Macrobrachium Faustinum	2	0.0132	
CL	CLDM-1-111-82	Crater Lake	Potimirim Mexicana	1	0.0066	
CL	CLDM-28-1-82	Crater Lake	Macrobrachium sp.Larvae	11	0.0728	151

TABLE: 3 Identities and distribution of crustaceans recovered from Crater Lake, Kaiser Aluminum property in February, 1982

Depth below water surface (m)	Copedods (Cyclops spp) [1,2,4] Number per L of Lake water					Macrobrachium juveniles[3]	Macrobrachium larvae[2]	Ostracods[2]	Rotifers (Brachionus sp.)[2]
	Males	Females	Copepods - lids	Nauplii	Eggs[5]				
0.1	0	0	0	0	0	139	0	0	0
1.0	0	0	1	1	0	0	0	0	0
2.0	17	45	75	183	2(15)	0	0	0	0
3.0	17	37	137	462	2(7)	0	1	0	0
4.0	30	38	168	418	10(27)	0 0	1	0	0
5.0	103	120	445	517	20(50)	0	4	0	0
6.0	25	55	215	493	13(37)	0	0	0	0
9.0	38	83	182	497	32(97)	0	1	5	25
12.0	78	87	203	517	25(70)	0	1	8	28
15.0	23	58	112	282	5(15)	0	1	0	0
20.0	30	85	138	237	22(70)	0	2	8	5
30.0	35	73	67	125	23(52)	0	0	0	5
± 35.0	40	40	112	228	7(22)	0	0	3	2
Total	436	721	1,855	3,960	162(462)	139	11	24	65

NOTES:
1. The cyclopid copepods have not been identified yet, but they are all one species
2. Planktonic forms of life caught by a 201 Schindler trap attached to a 75 um mesh plankton net
3. Benthic form of life caught by long-handled dip net from around a floating dock
4. All counts except those for Macrobrachium juveniles are number per liter of lake water. The number of juveniles caught at 0.1 m is the total caught by dip net (139)
5. Egg counts are expressed as number of females with eggs, with the number of actual eggs counted in parentheses.

Map. 1. Pear Tree Bottom River System and Vicinity showing Location of Sample Sites 'Blue Holes', waterways and main highway, and Crater Lake, Kaiser Aluminum property.



VI. Review of relevant scientific and technical literature

The following review is not comprehensive. It selects certain articles that together present the state of the art in freshwater prawn biology and culture. It focuses down on certain cardinal aspects of the scientific and technical literature on freshwater shrimp (prawns). It also deals with the information available on the Pear Tree Bottom River System that has been collected by other workers.

When Ling (1962) first successfully completed in the laboratory the life cycle of Macrobrachium rosenbergii (de Man), the "giant" Mayaysian freshwater prawn, the stage was set for commercial aquaculture of this, and possibly other, species of Macrobrachium shrimp. Within a few years of this break-through Ling (1969) was able to report that the culture methods for the Malaysian prawn were standardized and reliable. In the meantime mass culture methods were being developed so that commercial scale culture might become a reality (Fujimara, 1966) and soon thereafter mass culture was a practical proposition whose results were replicatable (Fujimara and Okamoto, 1970). Many studies have been made of M. rosenbergii since these earlier developments. Just a few examples are discussed here.

Wickins and Beard (1974) saw the need for a fast-growing species that would mature and reproduce in captivity. Their study was based on certain observations made on 3 males and 20 females reared from eggs to sexual maturity in captivity, so that conditions required for maturation, mating and production of viable larvae of M. rosenbergii would be known, with measured yields as added information. Newly-hatched larvae were recovered, counted and measured. Adults were measured too and the following details were recorded: frequency of molts; number of times mated; number of times spawning; fate of eggs; and first signs of femal maturity. Mating occurred within 24 hours of the pre-spawning female's molt if a male was left with her 1-4 hours. Some results of their experiments were as follows:

(1) No. of larvae hatching from each brood ranged from 50 to 98,100 (mean 24,000)

(2) There was a correlation ($r = +0.480$, $df. = 21$, $p < 0.05$) between larval size at hatching and size of the female parent.

(3) There was a trend, once experimental conditions were under control and more suitable, for there to be a relationship between no. of larvae hatched and size of the female parent.

(4) Growth of the females was arithmetic rather than geometric, males grew faster than the females, which is to be expected.

(5) In females when conditions were not under control mean intermolt period was significantly longer in oviferous than in non-oviferous specimens, as shown below:

Water Conditions State of female	Length of intermolt period (days)	S.E.	d.f	p for ts
Not Controlled Oviferous	38	±1.63	43	<0.05*
Not Controlled Non-oviferous	31	±1.64	60	
Controlled Ovigerous	43	±2.799	14	<0.05
Controlled Non-oviferous	46	±3.200	13	n.s.

When water conditions were under control, there was no difference between the mean lengths of the intermolt periods of oviferous and non-oviferous individuals.

(6) For females producing larvae, time interval between hatching and the next moult ranged from 9 to 37 days, being longer when eggs were spawned at the following molt than when spawning did not occur, as shown below:

State of female	Interval between hatching and next moult (days)	S.E.	d.f.	p for ts
Eggs spawned at following molt	38	±1.26	3	<0.05*
Eggs <u>not</u> spawned at following	16	±3.13	5	

The moulting delay may be due to oocyte development in the ovaries.

(7) Incubation period ranged from 19 to 22 days ($\bar{x}$=19.0±0.134 S.E., d.f=31); 18 brood hatched in 1 night, 13 others took 2 nights for completion; larvae ranged in size 1.9-2.1 mm ($\bar{x}$=2.0 mm) total length of hatching, mean no. of larvae (brood was c.2,600), the range being 100 to 79,852

(8) Successful matings resulted in viable larvae about 20 days after copulation.

(9) Growth of males was arithmetic, with no significant correlation of increment and total length; the mean length increment over the period of the experiment was 13 mm during each moult.

(10) Growth of females was arithmetic, with a mean increment of 13.89 mm during each moult, which is not significantly different from the mean increment of the males.

(11) Mean intermoult period was 41.9 days ± 9.89 S.E., d.f. = 17, and was independent of prawn size ($r=\pm 0.0408$, d.f. = 1b; p 0.1).

(12) Mean brood size increased signficantly after environmental conditions were brougt under control, as was the no. of times females spawned; also the rate of egg loss by females declined after the controls were effected.

(13) Females could lay eggs twice within five months, and probably can spawn 3 to 4 times in one year in nature.

(14) Control of the environment improved growth rate and mean length increment at moult values (7.2 of 13.6 mm; P 0.05*).

(15) Log_{10} no. of larvae = 3.01036=3.34477 $\log_{10}$ female length; e.g. a 200 mm female produces 48,530 (hatched) eggs and a 160 mm female 23,010 eggs (larvae).

(16) Females grew from 115 to 205 mm and males from 145 to 250 mm total length.

(17) 3 females spawned more than 4 times in successive intermoult period and 1 female five times in succession.

(18) 2 males sired viable larvae 4 and 7 times respectively during one intermoult period.

There are various techniques for raising prawn larvae to juveniles. Problems in doing this commercially are failure to ensure a constant production of juveniles and operational management mistakes. For an example of the latter, many hatcheries use a static water system with replacement and require large amounts of sea water, so that if the site is far from the sea, operational costs are high due to sea-water transportation charges.

Three culture techniques were compared by Menasvata and Piyatiratitivokul (1980) with respect to survival of prawn larvae; effects on water quality; effect of stocking density on survival of juveniles; economics. The three techniques are:

(1) static system with partial replacement;

(2) closed recirculator with separate subsand filter; and

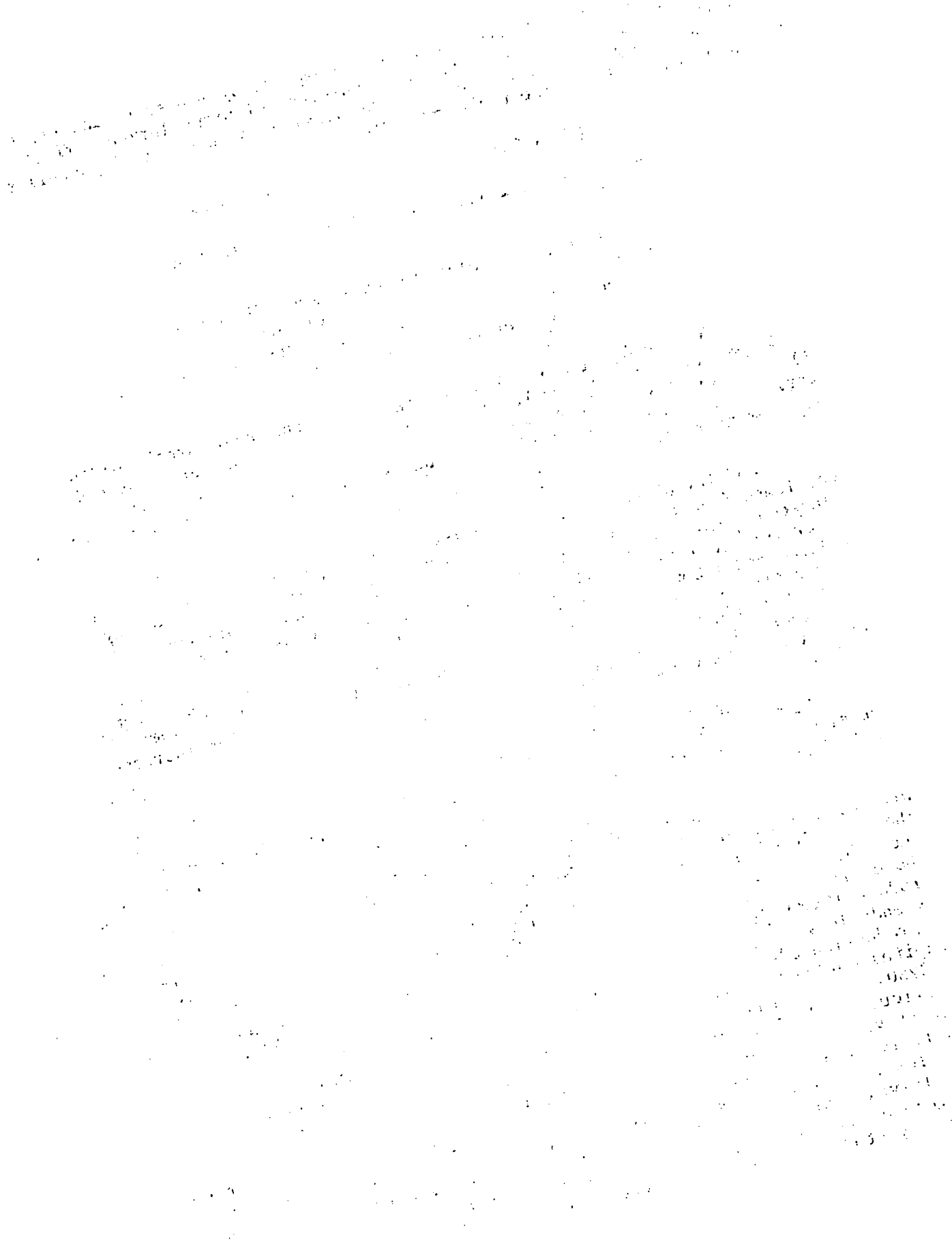
(3) closed recirculator with subsand filter in the rearing tank. Brood stock for the experiment were reared in an earthern pond and in cement tanks inside a shed.

Selected berried females were taken from the brood stock holding tanks and put in larval hatching tanks. Hatched larvae were placed in 20.L plastic buckets for counting to get brood size of each female. Larvae were counted in 10x100 ml aliquots. Larvae were then transferred to rearing tanks.

Density showed a linear inverse relationship with survival. It was found that the recirculators keep nitrite levels down because phytoplanktons grow well in such systems. Labour and operational costs are lower for recirculators than for static systems because water use is reduced and labour in changing water is elimated. System (3) is cheaper to run than system (2) because there is no need to use labour to clean up food residues and wastes, and it also had a larger rearing volume than system (2). Fujimura and Okamoto (1970) reported that an increase in rearing tank volume from 1,000 to 18,000 L. cut production costs by 0.71.

Survival is not a good indicator of larviculture success. A better datum is postlarval yield/l. Best stocking density was found to be 20 larvae/l.

Limpadanai and Tansakul (1980) conducted larviculture experiments with M. rosenbergii in a small reservoir in Thailand. They pointed out that larval survival rates vary widely from facility to facility. Further their growth is dependent on Artemia nauplii. Another problem is the capital investment required. For example, in Thailand, in 1976, to produce $16x10^6$ juveniles per annum, fixed cost input was US$20,350, non-expendable supplies cost US$13,200 and running costs were US$32,150, for a production costs of US$2.50/1000 juveniles. This is low, but the capital outlay is high for a country with a per capita income in 1976 of US$250. Thus expansion of prawn farming among small fish farmers is difficult. However, the advantage of the freshwater prawn is its high market value. The paper investigates semi-controlled prawn culture in small reservoirs, where the life cycle is completed by returning berried females to a hatchery using controlled salinity for spawning, hatching and larval rearing. Postlarvae are released into the reservoirs. Also considered is the support for subsistence fishermen in the reservoir basin by studying cost effectiveness of this system.



Juveniles were stocked in the reservoir in 5x5 and 10x10 m pens made of polyethylene netting of 2 cm and 0.5 cm mesh sizes, respectively. Stocking rates were as follows:

Pen No.	Pen size (m)	Mesh size (cm)	Stocking density prawns/m^2	Characteristics of stock		Prawns Age (days)
				Avg.1 (cm)	Av. Wt. (g)	
1 and 2	5x5	2.0	10.0	11.24	19.42	150
3 and 4	5x5	2.0	10.0	3.94	5.51	90
5 and 6	10x10	0.5	10.0	2.45	-	70

Natural conditions were simulated in the pens in terms of hiding places and prey-predators, in order to examine the effect of stocking the reservoir with prawns, and not of intensive pen culture. No food supplement was given.

Some of the conditions in the water during these experiments were:

Water quality: T°=26-30°C; dis. 0_2=6-8,g/1, diss CO_2=0-5 mg/1, pH=7-8;

Biota: Fish - Puntius sp.; Rasbora sp.; Tilapid sp.; Cyprinus sp., Clarius sp., Ophiocephalus striatus; Trichogaster sp.

Invertebrates - Macrobrachium lanchesteri, chironomid larvae. Prawns stocked at a mean length of 2.45 cm had total mortality. Those at 11.24 cm reached 14.30 cm in 7 months and matured in the 8th month; those at 3.94 cm reached 11.20 cm in 8 months and matured in the 9th month. This growth rate is slow compared to what can be reached in intensive prawn culture (e.g. from 4.37 to 15.0 cm in 6 months (Piyatisatitivokul, 1978), but this requires more labour and capital input.

Prawns stocked at length 3.94 cm grew faster than those started off at 11.24 cm. It seems that prawns of 2.45 cm and 11.24 cm are not suitable for stocking in natural waters. The former suffer predator attack and cannot tolerate certain environmental changes; the latter require too long in nursery ponds. Prawns 3-5 cm long are appropriate for natural waters because nursery time is shorter and subsequent growth is faster.

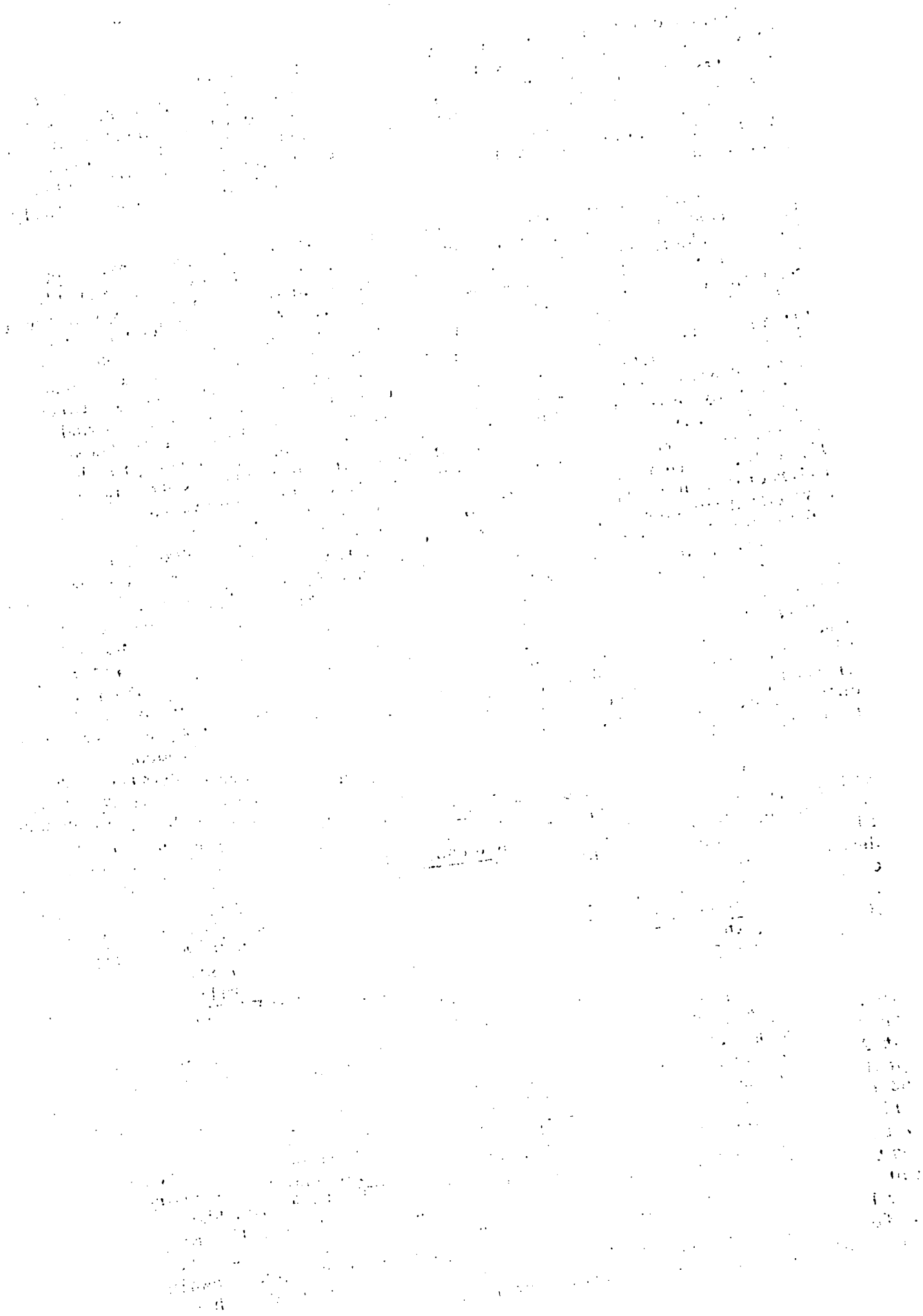
Survival rates for 11.24 cm prawns at a density of 10/m^2 were, an average, 0.48, and for 3.94 cm animals at 20/m^2 were 0.22. These results suggest that prawn density under certain natural water conditions adjusts itself to not more than 5/m^2, a level high enough for extensive, successful culture practices. It would be appropriate to stock juveniles at a density 5/m^2. If 1,000 juveniles cost US$2.50, these animals, being equivalent to 300g. of market-size prawns (about 3 whole animals), leads

to the calculation that, if survival is 0.01, 10 will grow to market size, and if 0.60 of these (i.e. 6 prawns) reach the fisherman's gear at market-size, then 100% profit will be achieved (at a market price of US$5.00/lb). In the experiments, survival was at least 0.22, which would provide a handsome profit if achieved by commercial culturists. Funds for juvenile production from public expenditure are, thus, easily justified.

Dense phytoplankton populations (100-500 $mg.m^{-3}$ Chl.) are kept up in Hawaiian prawn ponds to shade out benthic macrophytons, assimilate waste products from pond animals and help maintain desirable oxygen levels yet a problem arises if many of the plants die because of decompositon reducing 0_2 levels. Dense populations can also be problematic on calm nights because of their respiratory demand for oxygen. We need a quantitative understanding of the relationship between algal density, rates of oxygen production and consumption, nutrient assimilation rates and algal physiological state. Laws and Malecha (1981) looked into these problems by using a growth model to investigate phytoplankton growth, which was mainly controlled by light under the prevailing conditions because the water was saturated with dissolved plant nutrients. The light levels in turn can be affected by water clarity and mixing, so indirectly controlling phytoplankton growth. This study showed that phytoplankton populations in prawn ponds should be kept between 150 and 400 $mg./m^3$ chlorophyll in order to prevent anoxia in worse case situations, should they occur, such as calm nights. There was a negative correlation between light-limited growth rates and chloraphyl as levels are raised about $2g./m^3$. There was also, actually, a negative correlation between photosynthesis and chlorophyl a concentration at values greater than $5g./m^3$. This ideally, even 1 meter deep ponds should be operated with chlorophyl a concentrations less $2g./m^3$. Success of this light-limited model in describing data from both momo specific continuous culture systems and from diverse populations in prawn ponds suggests that the model may have wide applicability in mass algal culture systems.

Much of the literature on Macrobrachium is concerned with larviculture. Some of the earliest work was actually carried out in Jamaica, by Choudhury (1970; 1971c), on M.acanthurus (whose larval development was also studied) and by Chouldhury (1971a; 1971b), on M. carcinus (again, development was also described). Larval development in M. carcinus had earlier been investigated by Lewis and Ward (1965), whereas Dobkin (1971) looked at M. acanthurus development. Lee and Fielder (1981) studied the effect of salinity and temperature on the larvae of M. australiense in Australia, and found them to be important for proper development.

Monaco (1974) was the first to rear larvae of M. americanum in the laboratory. He used a self-contained life support system based on "Instant Ocean" sea salts at a salinity of 15 ppt and a temperature of 29.5°C. Diet was sifted fish (see Ling (1969) and Artemia nauplii prefed for 48 hours on Chlamydomonas coccoides. Postlarvae appeared 53 days into the experiment and eleven distinct larval phases were noted prior to metamorphosis. Further details on M. americanum life history were given by Monaco (1975). A breeding pair was obtained from the Syntex facility in Mazatlan, Mexico, consisting of one male, 155 mm., 140., and one female, 125 mm., 110g. The male was introduced to the female's aquarium three hours after the completion of her pre-spawning oviferous molt. He responded instantly to her and copulated with her within 45 sec. pause, and another lasting 12 secs. Egg laying was



then completed within 24 hours, the extruded eggs being fertilised in the brood pouch. Hatching occurred after 15 days incubation, about 80,000 larvae being collected; eggs hatched in freshwater of 27±0.°C and pH=6.70. Larvae were acclimatised slowly to 15±0.1 ppt salinity, and 29.5±0.5°C with a pH of 8.29, over a 2 hour period in a water bath to regulate temperature. These conditions were maintained until metamorphosis, with the pH ranging from 8.01 to 8.31.

Postlarvae were transferred to a self-contained, life support-system designed by Monaco and MCarty of Syntex, using Instant Ocean salts. Daily readings were taken of temperature, pH and salinity and weekly readings of NH_4^+-N, NO_2-N and NO_3-N.

Larvae were fed 3 times daily on sieved fish flesh and live Artemia nauplii. The fish were sprayed with hot water to wash away lipids and denature the protein to render it less water-soluble. Then the flesh was forced through a #12 mesh sieve with cold water to produce an appropriate food particle size. Nauplii were prefed for 48 hours on Chlamydomonas coocodies .

Newly-hatched larvae measured 1.99 mm total length, on average. Eleven larval phases before metamorphosis were recognised. Development to metamorphosis required 53 days at 29±0.5°C. The first juvenile postlarvae measured 15.6 mm., on average. Larvae swim backwards with ventral surfaces up and are positively phototatic. Postlarvae swim forward with dorsal surface up and are negatively phototactic. Their movements are less random, and more directed, then those of larvae. Evasion is effected by a very rapid backwards movement powered by the telson.

Larval deaths occurred from phase VI on, with high mortalities from phase VII on, possibly because of nutritional insufficiences for ecdysis.

The 15 ppt. salinity chosen may not be optimal for M. americanum. This value was selected because it is a known optimum for M. rosenbergii. The role of both algae and Artemia in M. rosenbergii larviculture were investigated by Cohen, Finkel and Sussman (1976), using ^{14}C labelled algal cells. Radioactivity counts of larvae were negative, so negligible amounts of algae are directly ingested. Experiments with Artemia nauplii, on the other hand, showed they assimilated and digested considerable quantities of algae.

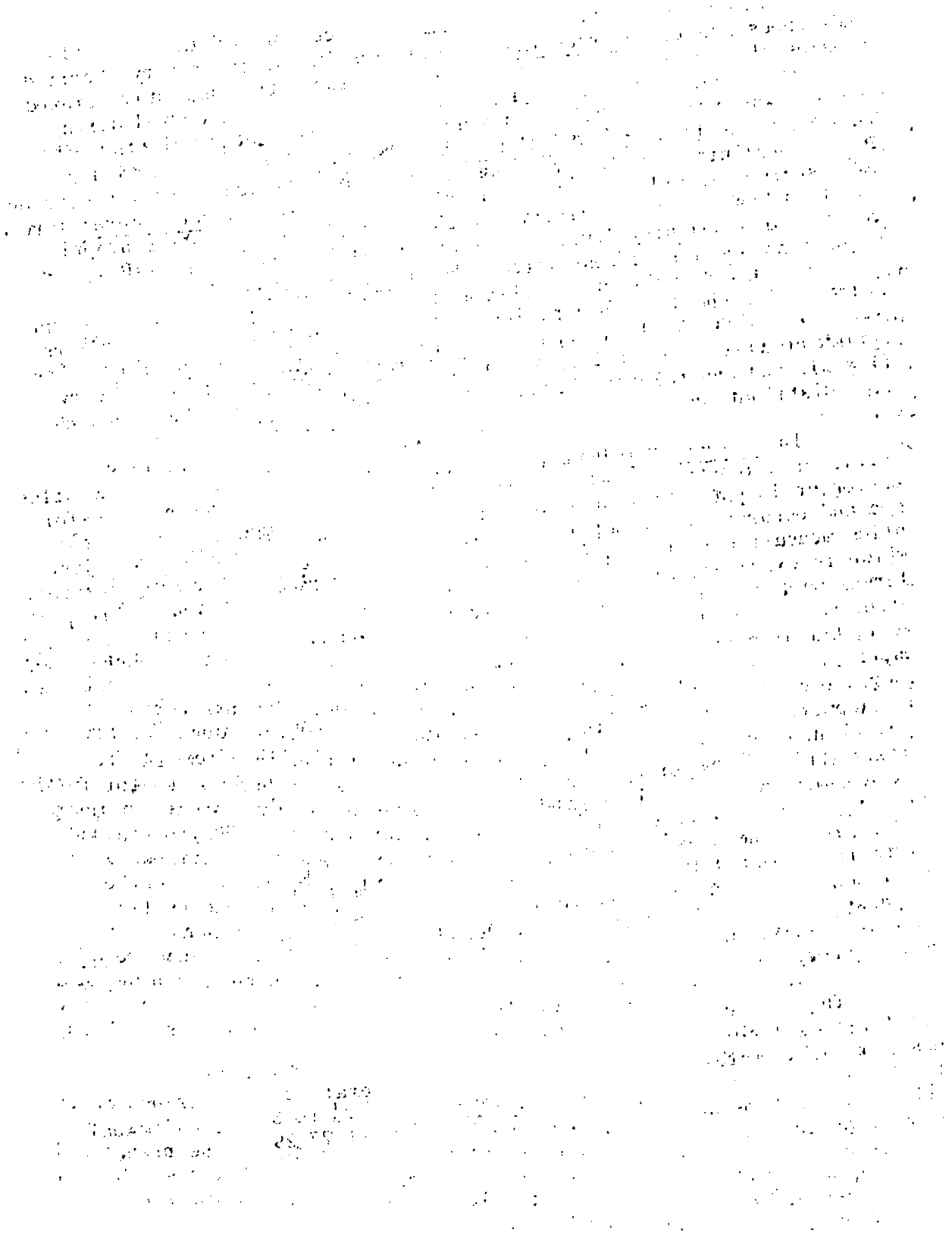
Algae quickly removed ammonia added to the medium even at levels toxic to the shrimp larvae 10.6 mg/1. Yet high density (20/ml/) population of Artemia caused ammonia accumulation even when algae were present, because of an increase in their metabolic rate when agal-fed. Removal of Artemia resulted in a drop in ammonia levels.

Tilapia was seen to be beneficial in shrimp larviculture only if algae were present and, in fact, larval mortality increased in water that had supported Tilapia growth in the absence of algae. Thus algae enhance shrimp growth indirectly by removing toxic ammonia. If ammonia can be removed by other means, the algae can be dispensed with.

In Jamaica, Hunt (1976) studied the culture of larvae of the indigenous species M. faustinum. Mating was in the laboratory, berried females then being isolated one to an aquarium with constantly aerated freshwater, and fed chopped fish and oats. Hatching occurred during early night hours, usually in two batches on consecutive nights. The best diet was found to be Artemia nauplii and "Tetramin" particles. Optimum salinity was 20 ppt. Cannibalism was infrequent, only occurring with starved animals. Hunt (1976) also worked with M. heterochrus larvae, and found the optimum salinity for them was 30 ppt., which is adaptive for the high salinity levels in river mouths in E and NE parishes, to which this species is restricted. For M. acanthurus, restricted more or less towards SW parishes, the larvae have optimal response at 15-20 ppt., adaptive for the lower salinities of the large estuaries of the rivers in the W and SW of the island. M. carcinus and M. faustinum larvae have optima at 14-18, and 19-20 ppt., respectively, but both spp. are very flexible and can tolerate higher levels, which fits with their island-wide distribution.

In M. faustinum Hunt (1976) found that metamorphosis to juveniles occurs at a length of 9--1.5 mm at 19-20 pptl but there was no transformation at 18 ppt. This suggests that larval development occurs in the sea and esturaries but not in the rivers themselves. Specimens of juveniles measuring 10-13 mm are found at river mouths and migrating upstream, which is extra evidence that the river is the habitat for the entire post-larval part of the life cycle. The smallest berried females are 26-28 mm, after about 6 months of postlarval growth. Spawning occurs throughout the year, but is heavier in January and February and between June and November, especially. These peaks precede or coincide with heavy rainfall, to increase changes of newly-hatched larvae being swept out to sea for further development. They also coincide with periods of maximum diurnal temperature changes around a 9°C range, an observation also made by Dugan and Frakes (1972). Temperature range experiments shows that berried females are non-migratory. Their fecundity is directly proportional to their weight, there is a heavy incubation mortality in brood pouches (18.2%) and there are no seasonal changes in either fecundity or incubation mortality. Most larvae are produced by 38-44 mm females at an age of about 1½ years. Juvenile recruitment peaks between about September and February, and usually especially in December, these animals being derived from the sprawning peak of June to November, the larval life span being about ninety days.

There is evidence that M. faustinum juveniles can survive in the sea for long periods before they contact their river water and migrate upstream. The males then grow faster than the females in the rivers and reach adult size sooner. The total life span is 2½ to 3 years. Sexual differences become detectable at a length of about 27-29 mm. when the animals avarage about 7 months old.



Growth follows a sigmoid curve for length, and an asymmetrical sigmoid for weight. Instantaneous growth rates tend to decline with age, although irregularities occur, due to the discontinuous nature of the growth process in molting organisms. The growth data fit the van Bertalantty equation well, with L.O. values for males of 79.5, and for females 55.4, mm., with respective K values of 0.027 and 0.019.

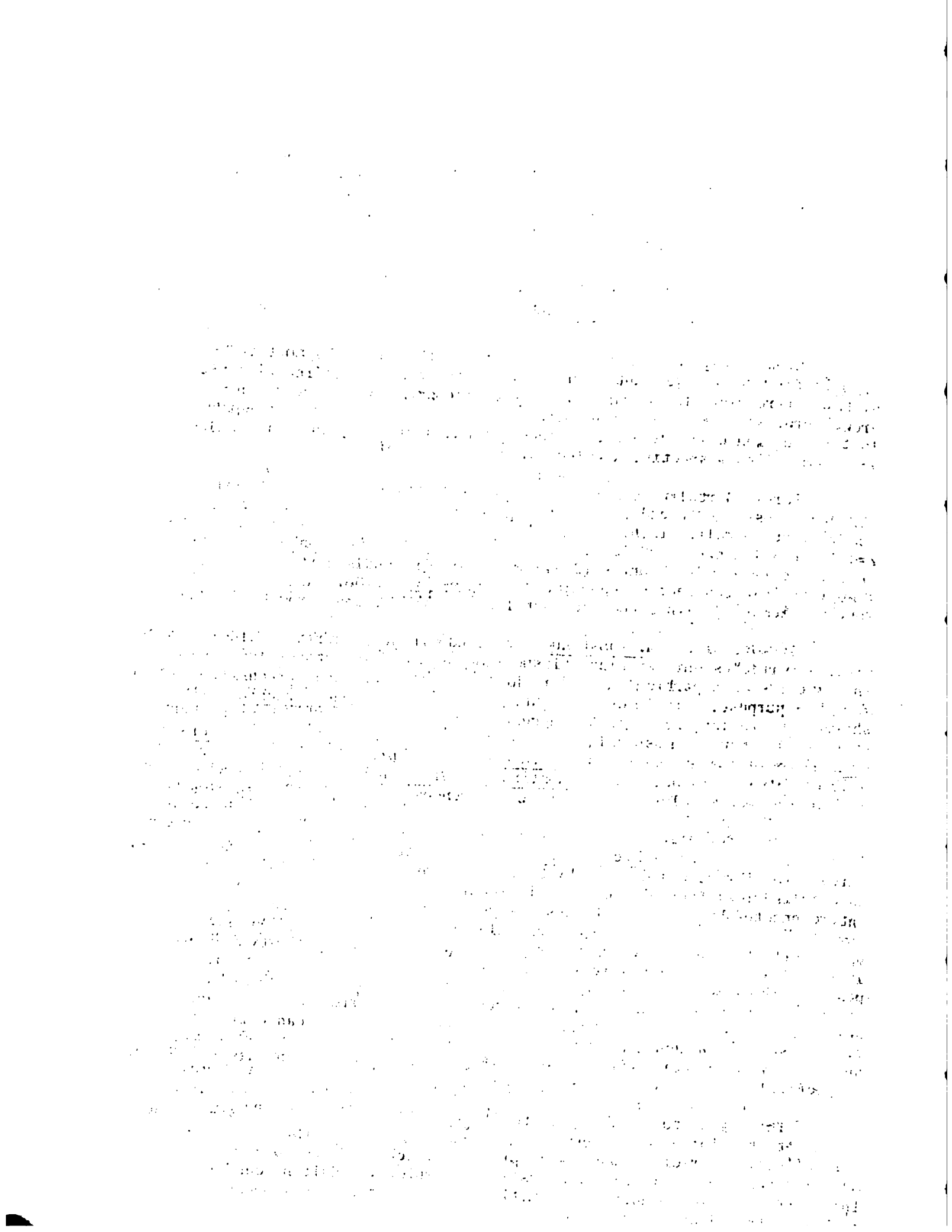
Larval mortality consists of general mortality plus net larval migratory loss and it added up to the very high level of 99.8%. Post-recruitment mortality is high at early ages z=0.13 at age 2-3 months, z=0.14 at 3-4 months, z=0.13 at 4-5 months, z=0.09 at 5-6 months, etc). In the age range 7-22 months (28-46 mm.), growth equals mortality resulting in a constant sub-population biomass over time. After 22 months, biomass declines because mortality is greater than growth.

In Cave River, M. faustinum eats predominantly detritus, plus mineral particles, higher plant tissue remains and filamentous algae. This species is a particular feeder which uses its chelipeds extensively for this purpose. It feeds at night. In his work on Macrobrachium shrimps in Jamaica, Hunt (1976) suggested that the following ecological niche separation of nonspecifics on the island occurs commonly. M.heterochirus prefers high altitudes; M. carcinus has a predilection for intermediate altitudes; and both M. faustinum and M. acanthurus choose low altitudes. Nevertheless, there are concurrences amongst these species.

Some interesting special apparatus has been developed for use in larviculture studies of Macrobrachium. An apparatus to separate post-larvae from larvae was devised by Smith and Hopkins (1977). The apparatus is a cylindrical tank with concentric inner and outer water chambers, interconnected by narrow slit passageways. From a centre drain water is pumped in the outer chamber and a circular flow pattern is thereby set-up in both outer and inner chambers. The latter contains the mixed population of larvae and postlarvae. The postlarvae, which exhibit a strong positive rheotaxis, swim through the passageways to become concentrated in the outer chamber. In contrast, larvae are planktonic and hence weak swimmers, and so they are retained in the inner chamber. Mean efficiencies of separation achieved were 0.79 over an operation time of 30 mins., and 0.93 after 60 mins, with 8,400-13,800 and 14,800-16,600 animals, respectively.

This apparatus is designed to allow rapid harvesting of post-larvae at any time. Maintenance of individual larval rearing tanks is a relatively inefficient management practice which involves costly manual separation of larvae from postlarvae, which in additon, can injure these delicate animals, resulting in a decreased development rate for several days after handling.

The main tank was 45 cm deep x 117 cm diam., with a 62 cm diameter polyethylene cylinder, attached to its centre, but modified by having cut in it 3 evenly-spaced vertical openings 5 mm wide along its sides and a 5 mm wide opening around its base, serving as water and postlarvae passageways. Water is pumped from the bottom of the drain below and injected at the surface of the outer chamber to produce a circular flow pattern. Curved sections of 13 mm internal diameter PVC pipe act as



water deflectors to enhance movement of water into the inner chamber. Water is also injected into the water surface of the inner chamber to strengthen the circular water flow. Prevention of re-entry of postlarvae into the inner chamber is prevented by a 30 mm high polyethlene barrier ring attached on the bottom of the circular tank 5 mm from the outside of the bottom horizontal passageway. A circular air line around the base of the screened drain cover causes larval dispersion away from the centre drain. Cost of construction of this apparatus in 1977 was US$170.

Peebles (1974) developed an elegant method for molt staging of M. rosenbergii. Examinations causing little or no stress to the animals were needed to determine their phase of the ecdysial cycle. The technique involves microscopic examination of an exopodite of one of pleopod once every 7 days for 6 weeks. The exopodite is cut at the base mounted in freshwater for microscopy, for examination of external pigmentation changes in the pleopod. These external changes in pigment correlate well with internal pleopod morphology changes. States A and B are postmolt, C is intermolt and late D is premolt. These stages are readily distinguishable by degree of hardness of exoskeleton. Transition phases are difficult to identify, histology being needed for this. Other pointers help identify transitions, namely:

(1) State A - animals cannot raise their chelae if held out of water;

(2) State A - rostrum is easily bent;

(3) State A - pleopods setae lack an internal cone;

(4) State B - Chelae are operative;

(5) State B - rostrum cannot be bend, exoskeleton is pliable;

(6) States A and B - pigment retraction from rostral and abominal plates margins has not started;

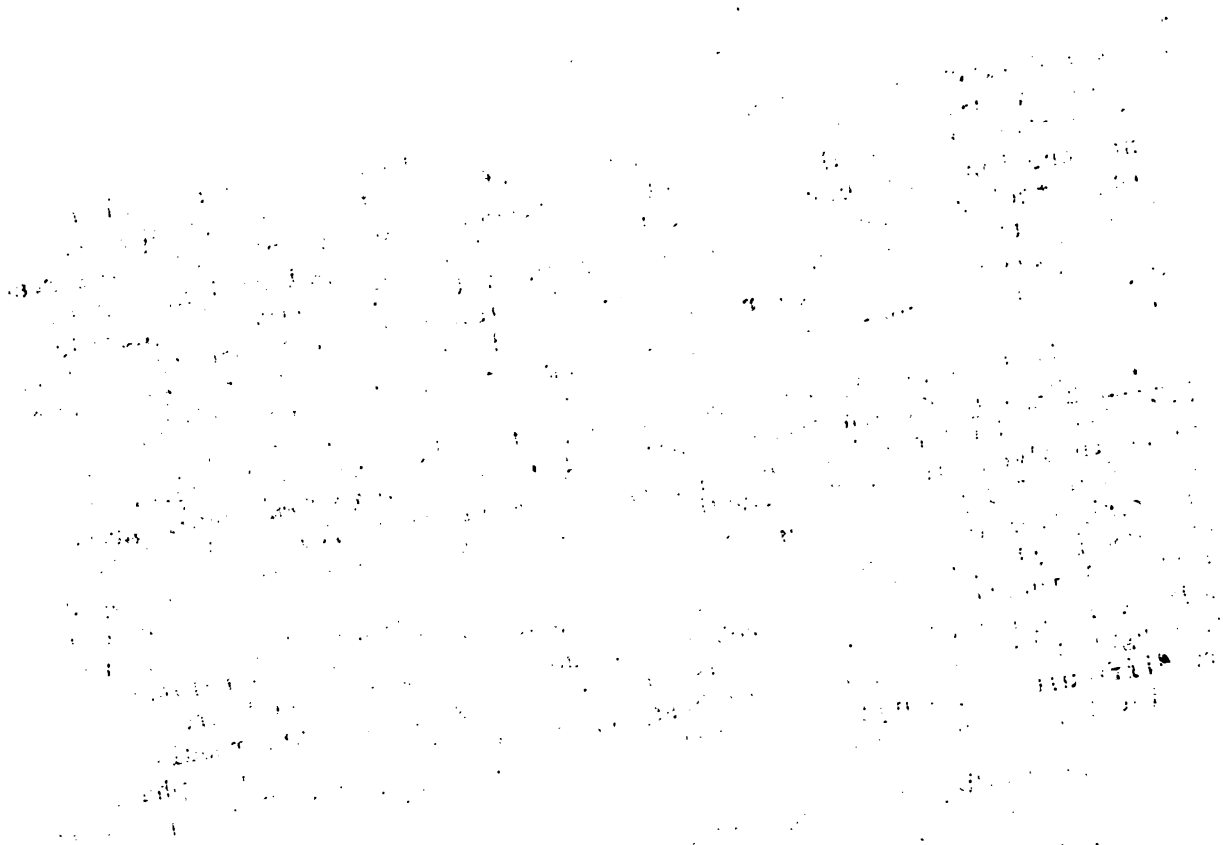
(7) State C - exoskeleton is hard, there is little pigment retraction;

(8) Early State C - most pleopod setae have an internal cone, no epidermal pigment retraction from the exoskeleton;

(9) Later State C - pigment retraction begins, being observable first at margins of dorsal surface of abdominal somites;

(10) Early state D - epidermal pigment retraction in pleopods (apolysis) - phase D_0;

(11) Early premolt (states D_0 and D_1) - extensive pigment retraction, at lateral margins of exoskeletal abdominal somites;



(11) State D - complete pigment retraction at margins of lateral abdominal plates (pleura);

(12) Substates D_1^{1-11} and D_2^{1-111} requires microscopy with unstained and stained pleopods, as does differentiation of D_0 from D_1, because pigment retraction is variable;

(13) State D_1 - new setae start to develop and appear as a "tube within a tube";

(14) State D_2 - secretion of new cuticle begins, accompanied by extensive pigment retraction on both lateral and dorsal abdominal surface, and lack of visible setae development within antennal scales;

(15) Early state D_3 - barbel development on pleopod setae and an epicuticle or exocuticle layer over the epidermi also setal development in the internal scale begins and pigment retraction starts along the margin of the dorsal surface of the rostrum; later, the exoskeleton becomes flexible ($D_3$111).

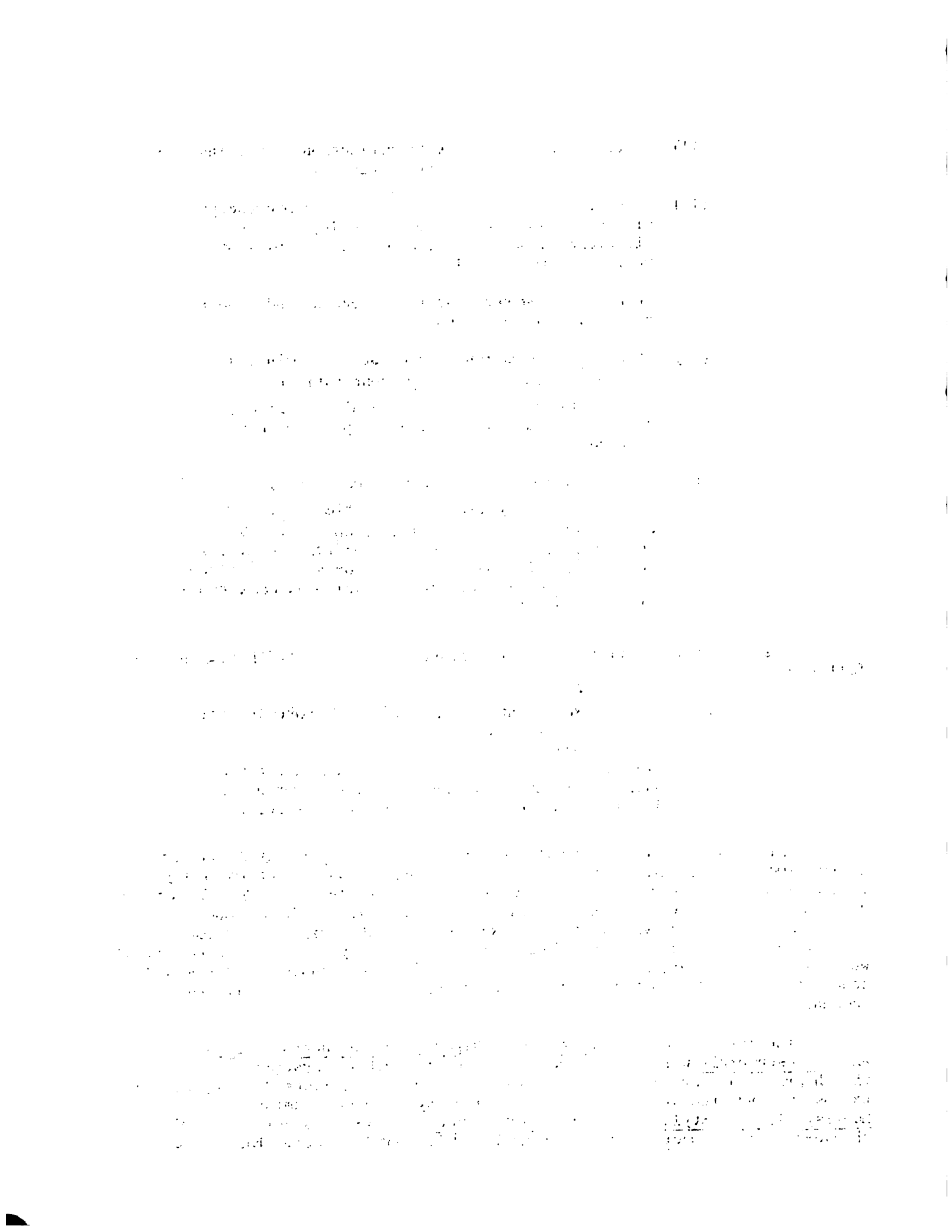
Possible factors which affect the length of the molt cycle are as follows:

(1) Size, sex and water chemistry are knowasifnificant factors;

(2) Density, food type and quantity, shelter and temperature are other candidates for effects but they have not been studied directly.

A common failure of aquaculture ventures is unpreparedness for dealing with pests, parasites and diseases. Often the sheer inability to recognise the causative organism is enough to cause loss of all cultured animals. In recent years these agents of disaster have been taken much more seriously than previously. Some examples of both unexpected effects of contamination of culture facilities with the lowly hydrozoan coelenterate were made by Sandifer, Smith and Colder (1974). These authors uncovered some interesting information on these pests, as is shown by the following account of this work.

The larval prawns Palaeomonetes vulgaris, Macrobrachium ohione and M. rosenbergii were brood stock and juveniles Closed systems, though promising, are not "problem-free". The paper describes population explosions of three brackish-water and marine hydrozoan contaminants, Moerisia lyonis, Stylactisarge and Clytia gracilis, which established themselves on the Macrobrachium prawns in their larval phases. These



coelenterates are both predators on the larval prawns and competitors of them for food. Clytia gracilis is a common colonial hydroid of the west Altantic coast from New England to Argentina, Gulf of Mexico and South Pacific, which release small medusae. Iylactisarge is a mesocond polyhaline species recorded from Chesapeake Bay and Woods Hole, whose degenerate medusae live for only one day and do not feed. Moerisia lyonsi medusae grow up to 8.4 mm diameter, but can have gonads when as small as 1.1. mm. Fertilized egg develops into a planula which later settles to become a polyp-polyps, produce medusae or can reproduce sexually by producing frustules that transform into new polypo which are oligoor meso-haline, reported from Egypt (Lake Qurum), Virginia, Maryland and Delaware Bay, besides the South Carolina records in the present study. M. lyonsi was the most troublesome of the three hydrozoan species encountered.

The coelanterates were probably introduced on detritus mixed in with live prawn collections. Within a month, their populations soared from a few medusae to 25/1 in several 120-1,800 1 culture tanks, on their bottoms and sides, but especially in the filter beds of calcareous gravel. In one instance the top few mm of the gravel filter beds were covered with a mass of brownish-red M. lyonsi polyps, budding off medusae. M. lyonsi and S. arge thrived at 25-28.5°C and 1b ppt., while C. gracilis required 35 ppt. salinity so was not present in Macrobrachium tanks. These hydrozoans competed with prawn larvae for Artemia nauplii food, but they ate the larvae too, especially M. lyonsi medusae as small even as 1-2 mm diameter, which devoured up to stage IV larvae. In one 1,800 1 tank, these medusae ate several thousand M. rosenbergii larvae in a few days. In another tank, medusae stung to death with nematocysts over 90% of the phase IX-XI M. rosenbergii larvae over three days.

Two hydrozoan groups were identified; polyps on filter beds and medusae with polyps in culture tanks. Chemical treatment would probably adversely affect the filter's bacterial flora and its water quality maintenance ability, and retention of chemicals might subsequently affect larvae, which after all, are human food organisms. However, some trials with chomotherapy were ran. Treatment with 50-100 ppm formalin for 30-60 mins. stopped medusae swimming with subsequent settling out. However, >50% revovered within 24 hours in clean, brackish water. None recuperated within 24 hours of a 60 minutes treatment with 250 ppm formalin, and prawn larvae were not adversely affected.

The best control is prophylaxis, by use of treated or artifical seawater, and exclusion of all hydroid-carrying material, or their sterilisation. Once hydroids invade, the best course of action is sacrifice of infected cultures by draining, scrubbing with hot water, and rinsing of tanks and materials with very hot water. Following these treatments with complete drying for several days, back flush infected filter beds and treat as were the tanks.

This paper shows how organisms harmless in nature can wreak havoc in a culture system. Therefore, the golden rules are:

(1) Set and maintain rigid water quality control,

(2) Prevent introduction of parasites, diseases, predators and competitors;

(3) Maintain vigilance over the matter of good water management,

(4) Treat culture water by an appropriate anti-pathogen method, such as UV irradication, to effect prevention of contamination

Agriculturalists have learned not only to detect and identify diseases and pests but also to fight back. Chemical control of a protozoan ciliate pest on M. acanthurus, for example, was investigated by Roegge, Rutledge and Guest (1977). These workers made the following observations:

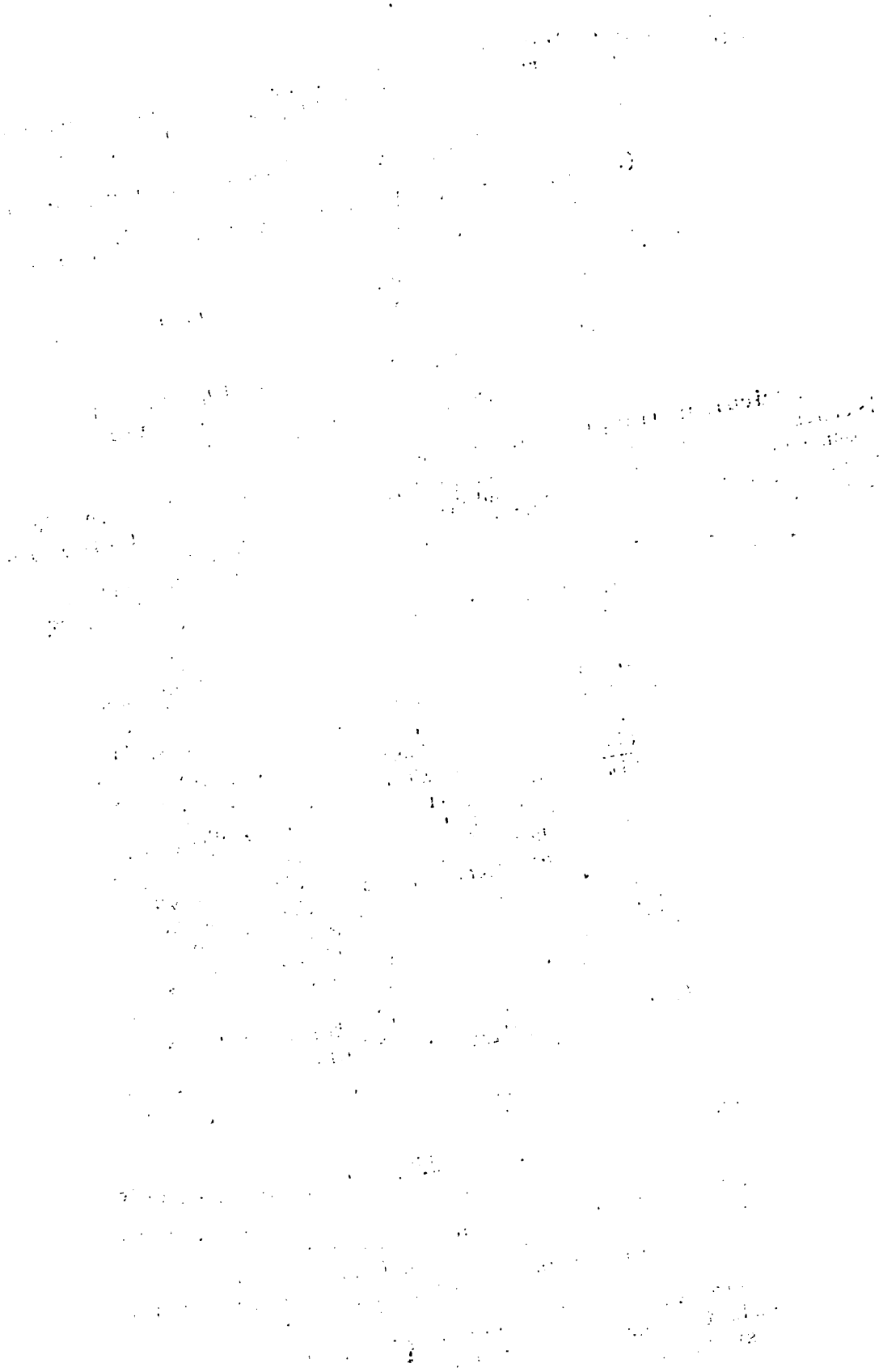
- This stalked ciliate caused heavy mortalities on larval shrimps in a 40L tank lacking filtration, with a stocking density of 300/1. Although shed with larval exuviae during the molting, reinfection occurred. Ten preparations were used to test efficacy against Zoothamnium, using 10 infected larvae per treatment with replicates, and 20 infected ones as the control, with 10 in each of 2 batches. There was a minimum of 2 replicates per treatment, with the exception of malachite green at 0.5 ppm where 10 replicates were used. Tests were run in 0.5L containers in aerated, artificial sea water of 15 ppt salinity.

  Compounds tested were: nitro-furazone - no effect on Zoothamnium or the ciliate but billed of the larvae.

  $CuSO_4$, Dylox, methylene blue and Combiotic had little effect on Zoothamnium but larvae were in poor condition;

  Roccal killed the ciliate, but 40% of larvae too; 0.5 ppm Malachite green killed 90-100% of the parasite and 10-80% of the larvae;

  Terramycin and $KMnO_4$ killed <5% of the ciliates but wiped out 100 and 80%, respectively, of the larvae;



> Formalin at both 50 and 67 ppm killed all the parasites but none of the larvae, which remained in good condition at the end of the experiments.

Biological filtration prevents the entry of these parasites into culture facilities. However, any outbreaks of it on M. acanthurus can be treated effectively with 50 ppm formalin for 24 hours.

Rather detailed and sophisticated studies have emerged recently on surface pests of M. rosenbergii. In South Carolina, Smith, Sandifer and Manzi (1979) dealt with some epibionts of the Malaysian prawn, as follows:

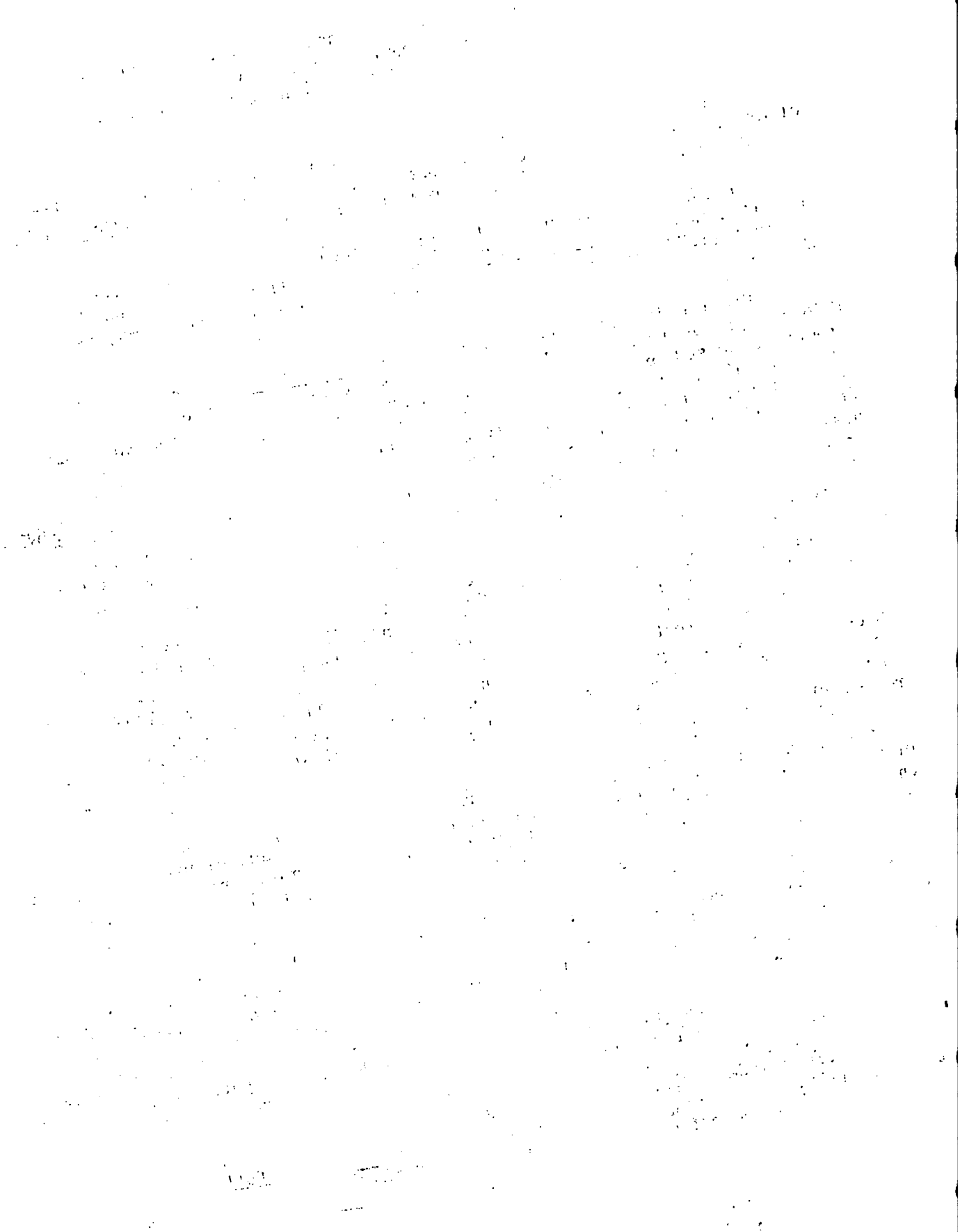
Previously unreported epibionts on M. rosenbergii were noted in 1976 for prawns reared in an out door brood stock pond. Dense algal growths composed of about 90% of the chlorophyte Cedogonium crassiusculum and about 10% by the cyanophyte Lynabua, were observed on the carapace in 58.3% of the males in the tanks (mean weight 47.1 g.), but were absent from all the females. Infected prawns are sluggish, and some cases of blindness were recorded where the eyestalks were physically covered by the growths. When infested animals were moved to indoor culture tanks the algae were lost and the behavior of the previously infested animals returned to normal.

Eggs of the water boat man Samphocouxa acuminata, were recorded on 52.5% of the females in the brood stock pond, their mean wt. being 78.0 g, and were observed on 5.9% of the males at harvest. Distribution of these eggs was restricted to the carapace and/or the 1st. and/or 2nd abdominal somites. Eggs were not seen on 84,000 smaller prawns distributed amongst six adjacent rearing ponds. They appeared to do no harm to their "hosts", and they disappeared just after infested animals were returned to indoor laboratory tanks.

Studies have advanced to consideration of disease proper and one of the earlier considerations of this important aspect of aquaculture was that of Delves-Broughton and Poupard (1976), who were particularly concerned with British recirculation systems. These workers took the following apprach.

Whenever possible, moribund prawns were examined alive, or were fixed in 10% formol-saline or Bouins, or kept on ice for bacteriological examination. Live animals were killed in ice-cold water and examined under a stereoscope for gross symptoms. Presence of parasites was checked from smears of haemolymph, hepatopancreas, gut, gills, muscles and exoskeleton. By these means, some valuable information was gathered and presented in this publication on the diseases of culture prawns.

Sometimes sudden disaster due to disaese can overwhelm an aquaculture facility. For example, a sudden mass-kill of M. rosenbergii reared in ponds was reported by Green, Richards and Singh (1977).



A trial culture was involved which resulted in death en masse of 45% of the prawns in a 0.19 ha. pond fed by a stream carrying waste water from a dormitory building in Malaysia. The pond had a slope of 2% and a depth of 1.5 m at the outlet end. At its inlet was a sand-gravel filter to prevent entry of fish eggs and fish. The pond was dried out and limed with 10 kg of $Ca(OH)_2$ and 10 cm water added. The pond was redrained and dried for 4 weeks till grass covered the bottom, and then it was re-filled and left to stabilise for 2 weeks. This pond was stocked with 200 juvenile prawns, mean 1.23.9±5.4 mm. A food supplement at a rate of 5% of dry weight was added each day, starting 2 weeks after stocking. Stocking density was $4/m^2$.

Some 36 days after stocking the massive kill occurred. Water was murky and there was a bloom of phytoplankton. Dead prawns were recovered over the next 3 days and refrigerated. On the first day of mass die-off, pH, diss. O_2, temperature, conductivity and light penetration were measured from 0630 to 170 hours.

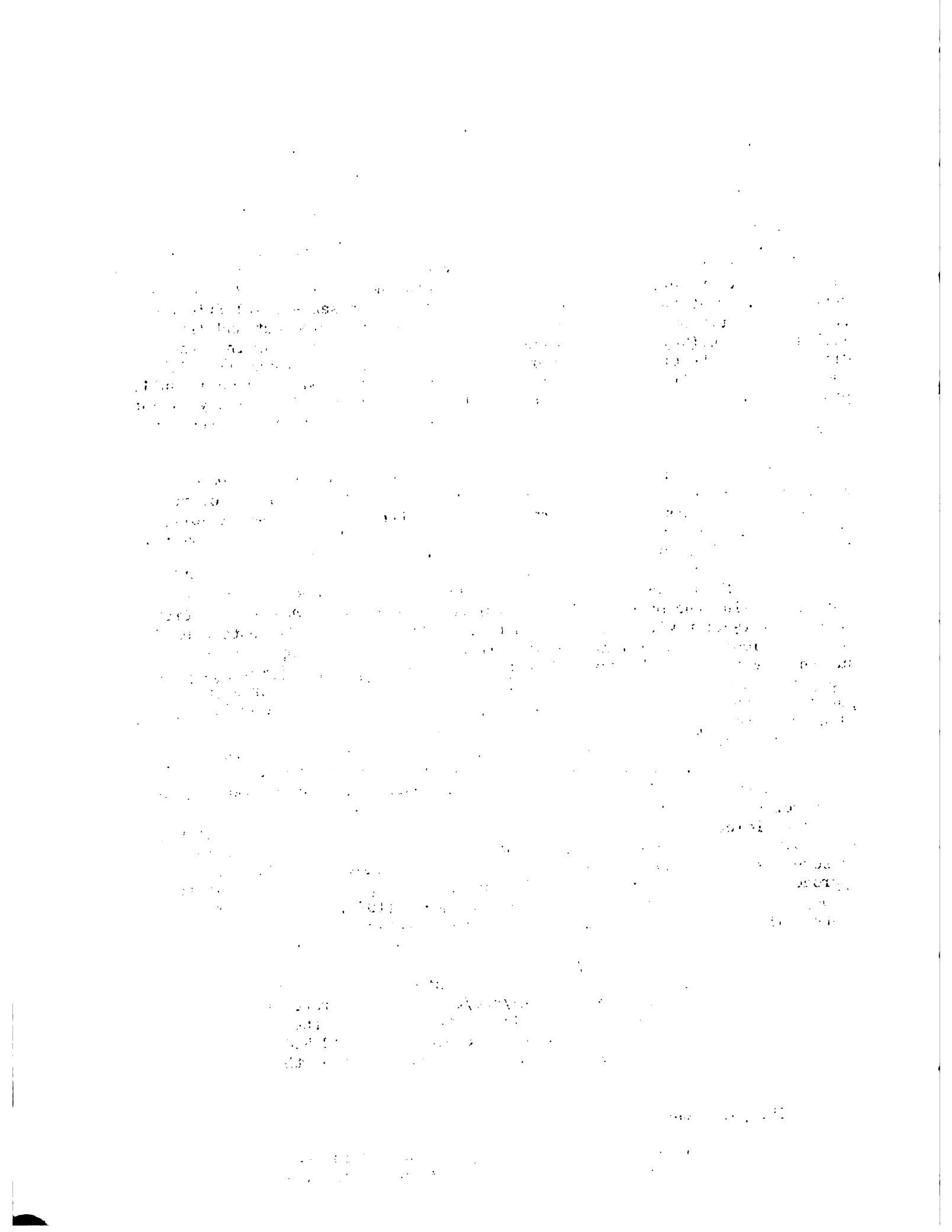
The pH was 7.5-9.8, diss. O_2 0.5-16.7 mg/1. and T°27-32.6°C. Factors causing the mass kill were surmised to be as follows. These were over fertilisation with phosphate, nitrate and additional nutrients caused an algal bloom, lack of rain resulted in a reduced water supply; then a sudden, severe storm the day before the kill caused a rush of water into the pond, which stirred up the organic material from the sediments and put them into suspension. This encouraged bacterial growth. Combined algal and bacterial respiration that night reduced dissolved oxygen levels drastically even down to 0-0 mg/1. This killed the prawns.

Another form of fighting back against disease is disinfection, and an effective way of doing this in aquatic environments involves the use of ultra-violet irradiation (UVR). For filtered water, this is effective, with 99.9% or more reduction in viable bacterial cells being on record in some instances. Fungi are also killed by UV irradiation. The best approach is to filter the culture facility water supply and then pass it through the UVR emitting unit. Brown and Russo (1979) conducted experiments. They give some specifications on their set-up.

(a) 2 μ orlan filter
(b) aqualine Aluminum SL-1 steriliser, producing up to 30,000 μW/sec/cm^2 at a flow rate of 321/min. At a flow rate of 4L/min. the radiation dosage rate becomes 93.312.520 uW/sec/cm^2, depending on the power of the UV lamp

The pathogens were:

(1) Twenty pseudomonad types: seeded in the experiments to a level of 10^5 cells/ml at 26°C



(2) Three vibrio types: seeded in the experiments to a level of 10^5 cells/ml. at 26°C

They found that sea water contaminated with any of the test bacteria at 10^5 cells/ml. was detremental to the development of fertilised oyster eggs.

UV treated seawater proved satisfactory for rearing fertilised oyster eggs. Oyster larvae reared in irradiated water had a significantly higher survival rate during their first seven days of life larvae raised in non-irradiated seawater; in the irradiated trials, survival was 78% compare to 60% in non-irradiated trials, although there was no significant difference in mean size of larvae in the two treatments. Spontaneous disease occurred in 6 out of 10 non-irradiated cultures and in only 2 of the irradiated ones.

It was determined that UVR was bactericidal to the strains of bacteria used in this study. A dosage of about 80,000 uW/sec/m^2 is required to effect reliable efficacy in destruction of pathogenic bacteria at a flow rate of 4L/min.

Sources of bacterial contamination were seawater, fertilised eggs, and food. Another study of note that has added to the armoury of prevention against disease is that of Burns, Berrigan and Henderson (1979), who looked at the fungus Fusarium in M. rosenbergii, and described this so thatculturalistscould be aware of this affliction if they encounter it in their facilities.

One approach to deal with disease is chemotherapy. Just two studies will be considered here. A new class of synthetic compounds effective in treatment of a wide variety of diseases of aquatic organisms has been invented in recent years. Delves-Broughton (1974) undertook some exploratory work of the effectiveness of one of these compounds, Furanace, in the cure of prawn diseases.

Furanace, a brood specturum chemotherapeutic for fish diseases is also called p-7138, nifurpirinol or 6-hydroxymlthyl-2(2) (5-nitro-2-furyl) vinyl) pyridine. Effective against a wide range of Gram-positive and Gram-negative bacteria pathogenic to fish and shellfish, and against Saprolegnia (a fungus) this compound is now coming into common use in the battle against disease in aquaculture facilities.

Absorption by tissues and excretion of the drug are rapid. Administerable orally or by bathing, in the latter case absorption is through gills and skin. It inhibits macromolecular synthesis of DNA and is non-toxic at bactericidal concentrations. Delves-Broughton (1974), did some careful work on this drug. He used a 10% active ingredient preparation of Furance. Minimum inhibitory concentrations (M.I.C.) from 25 to 0.003 mg/l were determined against bacteria by the tube dilution method, using 0.1% yeast extract, 0.1% peptone and 0.5% NaCl broths, although the NaCl level was raised to 2% for Vibrio

anguillarum and to 7% for V. parachaemolyticus. Gaffkya hamari was tested in tryptone soy broth. M.I.C. against fungal zoospores was tested by the plate dilution method using the following medium: 1% glucose, 0.5% soluble starch, 0.3% yeast extract, 0.6% Na_2 (HP)4.12H_2O, 0.2% KH_2 PO_4, 1.5% algae, incubated at 25°C, to produce zoospore cultures by inoculum. Water-autoclared hemp seeds were then added and the culture left for 2 days, by which time the hemp seeds were covered by the mycelium of the fungus. The seeds were then transferred to sterile water in plastic dishes, where the hyphae developed sporangia and release zoospores. The fungal media, in a series containing a range of concentrations of Furance from 25 to 0.003 mg./l, were inoculated with zoospores, incubated at 25°C and fungal growth recorded daily.

Toxicity of Furanaceto M. rosenbergii was tested by baths of both high concentration-short exposure and low concentration-long exposure regimes, using 5 or 6 prawns each time, and holding the prawns in bath at 27°C in 45L tanks fitted with their own gravel biological filters. Prawns were fed daily and checked for deaths, stress and ecdysis. The experimental design was as follows:

High concentration-short exposure regime

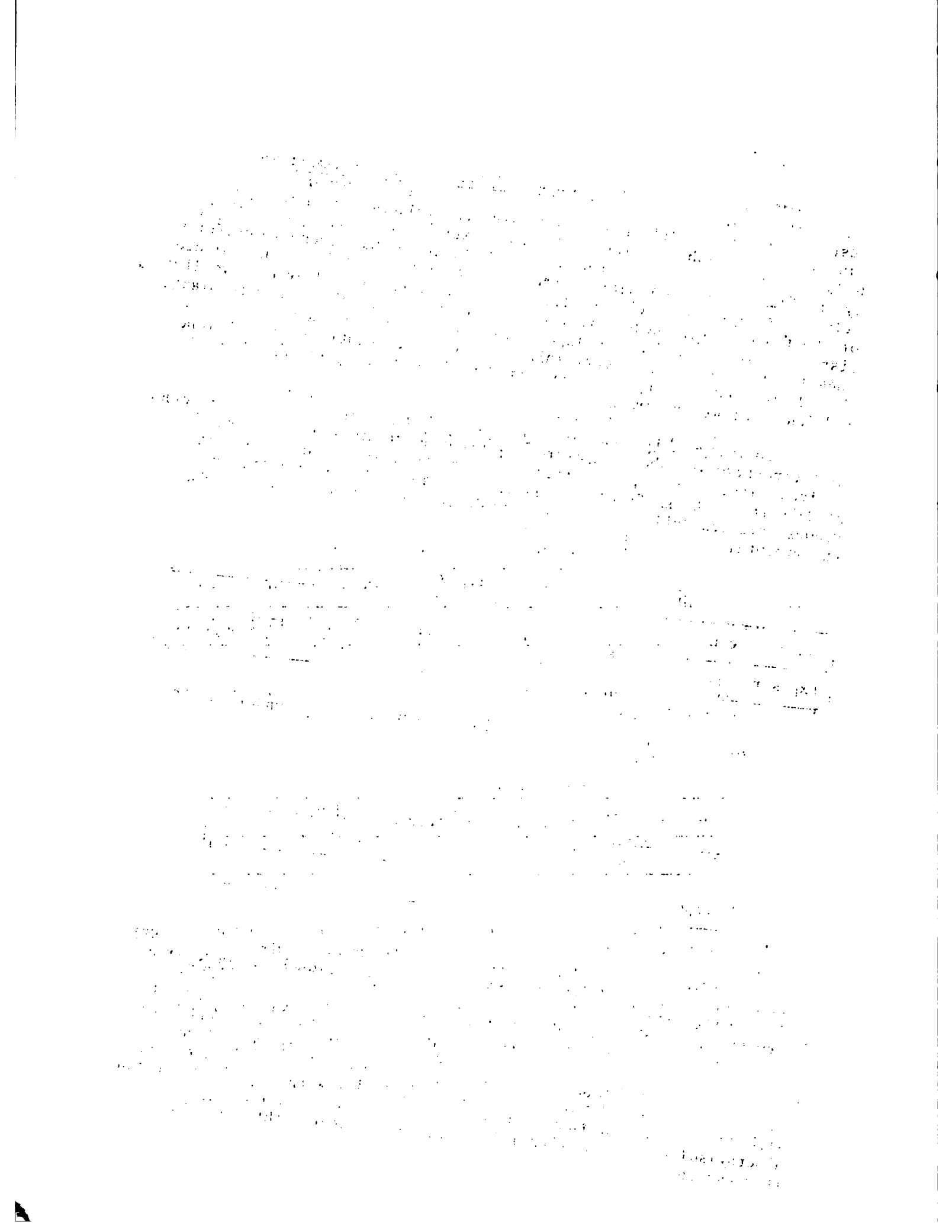
Furanace conc. (mg/l)	5			10			15			20			0
Exposure time (min.)	5	10	15	5	10	15	5	10	15	5	10	15	5 Control

After treatment in this regime, prawns were kept under observation for seven days.

Low concentration-long exposure regime

Furanace conc (mg/l)	1.33	2.5	5.0
Exposure time (days)	7	7	7

Ammonia levels were monitored in all prawn tests to assess any effect of Furanace on nitrification by the Nitrosamonas-Nitrobacter complex in the biological filters. Haemolymph, gill tissue, abdominal segment and exoskeleton levels were measured by the cup-plate method using Bacillus Subtilis as indicator organism. Prawns were killed in ice-cold water, haemolymph was collected by breaking haemocoel and transferred to McCartney bottles coated with tri-sodium citrate to prevent coagulation. To extract Furanace from tissues, organs were frozen with dry ice acetone then ground tissue was treated with 0.5 ml dimethylsul toxide and then 1.5 ml distilled water. This fluid was then assayed.



For the study of the uptake of Furanace by prawn tissue the following experimental design was used. The experiments were run at 25°C. Furance levels in haemolymph, gills abdominal segment and exoskeleton were measured immediately after bathing.

Furanace conc. (mg/l)	10			20		
Exposure time (min.)	10	20	30	10	20	30

In order to investigate excretion of Furanace from prawn tissue the experimental desing was as follows: The concentration of furance used was 20 mg./1 at 25°C.

Exposure time to furanace (min.)	30	30	30	30	30	30	30
Bathing time in fresh water, no furanace (hr)	0	0.5	1.0	1.5	2.0	2.5	3.0

After treatment, prawns were killed in ice-cold water and furanace levels were then assayed.

The results of the experiments on invitro antimicrobial activity showed that vibrios were all inhibited by <1mg/1 (0.1-0.4 mg/1) concentrations. Aeromonads and Cytophaga spp. were inhibited by 3.1 and 0.4-3.1 mg/1 levels, respectively. Beneckea spp. succumbed to 3.1, 6.2 and 12.5 mg/1 values, for each sp., respectively. Pseudomanads and Gaffkya homari did not succumb even to levels> 25.0 mg/1 and so can be said to be resistant to furanace. All Sparolegnia spp. tested succumbed to 0.8-1.55 mg/1 levels, except S. ferax which was resistant even at >25 mg./1.

Achyla diffusa succumbed at M.I.C. 3.1 mg./1. In investigating the invivotixicity of furanace, the high concentration-short exposure tests showed 3-5 g prawns could tolerate 20 mg./1 furanace for 20 minutes with no deaths in 7 days. A 20 mg/1 treatment for 30 minutes caused stress in 4 out of 7 animals tested. The low concentration-long exposure regime indicated that 3.5 g animals could tolerate 1.33 and 2.5 mg./1 levels for 7 days. At 5 mg./1, all 5 prawns in the test died on the 4th day.

Nitrifying bacteria were inhibited as ammonia levels in the 1.33 and 2.5 mg./1 tests went up significantly.

The uptake and excretion of furanace by prawn tissue was studied for prawns treated with 10 mg./l for 20 minutes and 20 mg./l for 30 minute. The furanace levels in several tissues was as follows: (nd means not detectable)

Furanace level (mg./l		10	20
Exposure time (min.)		20	30
Tissue (Haemolymph		0.4-0.5	0.5-0.68
Levels (Gill		0.1-0.25	0.45
(mg./l (Abdominal segment		0.5-0.7	0.6
	(Exoskeleton	nd	nd

Results of experiments involving "self-washing" in pure water after treatment in furanace baths of 20 mg./l for 30 minutes are shown below.

Time after bathing (h)	Furanace levels (mg./l) Haemolymph	Gill	Abdominal segment
0	0.68	0.45	0.60
0.5	0.092	nd	0.12
1.0	0.047	nd	0.075
1.5	0.043	nd	nd
2.0	0.013	nd	nd
2.5	0.011	nd	nd
3.0	nd	nd	nd

Thus, M. rosenbergii both rapidly takes up and rapidly excretes Furanace. Advantages of Furanace are:

(1) non-toxic,
(2) water soluble;
(3) absorbed inactive form;
(4) is rapidly excreted;
(5) has wide-spectrum anti-pathogen activity;
(6) has low antinitrifying bacteria activity in low concentrations, and
(7) is degradable

The best treatment is a long exposure-low concentration regime, which not only kills the pathogens in the animals but also eradicates it from their environment.

The danger with Furanace is its suppression of the nitrifying bacteria complex in biological filters. Recommended is 2.0 mg.1 in a constant bath. The Furanace will degrade with a half life of c. 3 days, under 40w illumination.

Further information on chemotherapeutics actions in crustaceans is given by Hanks (1976), for penaeid shrimps.

Another extremely important aspect of prawn aquaculture is nutrition and diet. A consideration of a few selected publications on the topic will be presented here. One of the earliest studies was that of Lewis, Ward and McIvor (1966) on reproductive behaviour, growth and feeding in M.carcinus. However, it remained for Balazs, Olbrich and Tumbleson (1974) to do a biochemical analysis of the effects of diet in Shrimp, by investigation of their serum constituents. M. rosenbergii was studied by these workers. The following were measured: Cl^-, Ca^{++}, Pi, glucose, cholesterol, urea N, total bilirubin, creatinine lactic dehydrogenase, alkaline phosphate and glutamic-oxaloacetic transaminase. Baseline serum values were determined by sequential multiple autoanalysis. Male prawns were found to have higher cholesterol levels than females, while females had higher urea N, creatinine and lactic dehydrogenase values than males. Females were smaller, on average, in both total weight and corapace length than males. Feeding habits of M. rosenbergii in nature and in captivity were studied by Balazs and Ross (1976). They pointed out that, in the wild, this species appears to be omnivorous, taking grass roots, detritus, insect nymphs and fishes. In captivity the Macrobrachium prawns that have been studied accept a vareity of foods. Best growth results from use of molluscan and crustacean flesh, although in most places such foodstuffs would be too costly, often unavailable and difficult to store. According to nutrition research that has been conducted, protein is likely the most limiting nutrient for growth, and feed costs are directly proportional to their protein content.

Feeding was at a level of 5% of prawns body weight, once daily after noon initially, and thereafter adjusted according to the amount uneaten after 24 hours. Eventually, the animals were being fed as much as they would consume. Dead animals were removed. Feeding and controls were continued for 244 days. Water temperatures ranged from 22 to 27.6°C.

Growth rates, feed conversion ratios and survival rates were determined. Water stable diets were used at 15, 25 and 35% levels. Principal protein source combinations were either soybean and tuna meal, or soybean, tuna and shrimp meal. Higher protein content produced larger prawns ($p < 0.01$), but differences between feed conversion ratios (range 1.36-1.72) or survival rates (range 90.3-93.6%). Trials with soybean and Tilapia meal and copra and Tilapia meal combination (25% protein) showed that growth rate was lower on these diets than on those mentioned above, although conversion ratios and the survival rates were the same.

For the controls, which received no formulated diet, growth and survival seemed dependent on natural algae being consumed by the prawns.

Mean prawn length after 244 days on 35% protein soybean and tuna meal (the best diet) was 73 mm.

An interesting diet study was carried out on M. rosenbergii by Sandifer and Joseph (1976). Experimental Marine Ration 25, Ralston Purina Company was impregnated with 3% by weight oil extracted from head of Penaeus setiferus, resulting in reduction of level of 26 fatty acids and an increase in the proportion of W3 and of saturated acids.

The diet complex was fed for 12 weeks to juveniles, the unmodified ration 25 being used as a control. Prawns fed on the augmented ration grew significantly larger than those on the control feed, this being apparent by the 6th week of the study. Final mean biomass/unit area and food utilisation efficiency were both also significantly higher than in the control group, by a factor of about two in each case, in fact. Survival rates differed little - 71% in augmented diet group and 60% in control group.

Results indicate the prawns conserve or synthesize W3 fatty acids and catabolise 18.2W6 (linoleic acid) as an energy source. Augmented diet animals also had about 15 times more carotenoid pigments than the controls. A main conclusion is that W3 fatty acids are important to M. rosenbergii and so prawn diets should benefit from adding waste shrimp head oil to their diet as a good, cheap source of W3 and pigments.

A most valuable review paper of diet and nutrition studies on shrimps was published by New (1976). This article is so useful to the present proposal for shrimp culture that is described here at some length, as follows:

Commercial rearing as an industry is predicted to expand in both developed and developing countries, e.g. in the U.S., consumption of farmed shrimp was 2×10^6 lbs in 1973 and this expected to expand to 245×10^6 lbs/yr by 1982 with a projected value of $> US\$134 \times 10^7$ at 1975 prices (US$5.47/lb). At a food conversion ration of 2%, the annual shrimp feed demand could exceed 220,000 metric tonnes.

This paper collates papers on feed and nutrition for both marine and freshwater shrimp, but excludes publications on use of live feed for shrimp larvae, effect of environmental factors upon ingestion, use of compounded diets in pond culture, use of fertilisation and natural feeding in ponds, and stomach contents of wild animals. The review is restricted to studies of diets under controlled laboratory conditions.

The review contains the following main sections:

(1) palatability and physical dietary structure;
(2) lipids and sterols;
(3) protein;
(4) carbohydrate;
(5) minerals;
(6) vitamins;
(7) larval foods
(8) discussion;
(9) conclusions

Only direct references to Macrobrachium are noted here:

1. Palatability and physical dietary structure

Pioneer Ling (1969) simply cut fresh animal material into pieces and supplemented this with pre-soaked for ½ hour, dired animal material

to achieve a suitable final moisture content in the compounded preparations which he used in culture of M. rosenbergii.

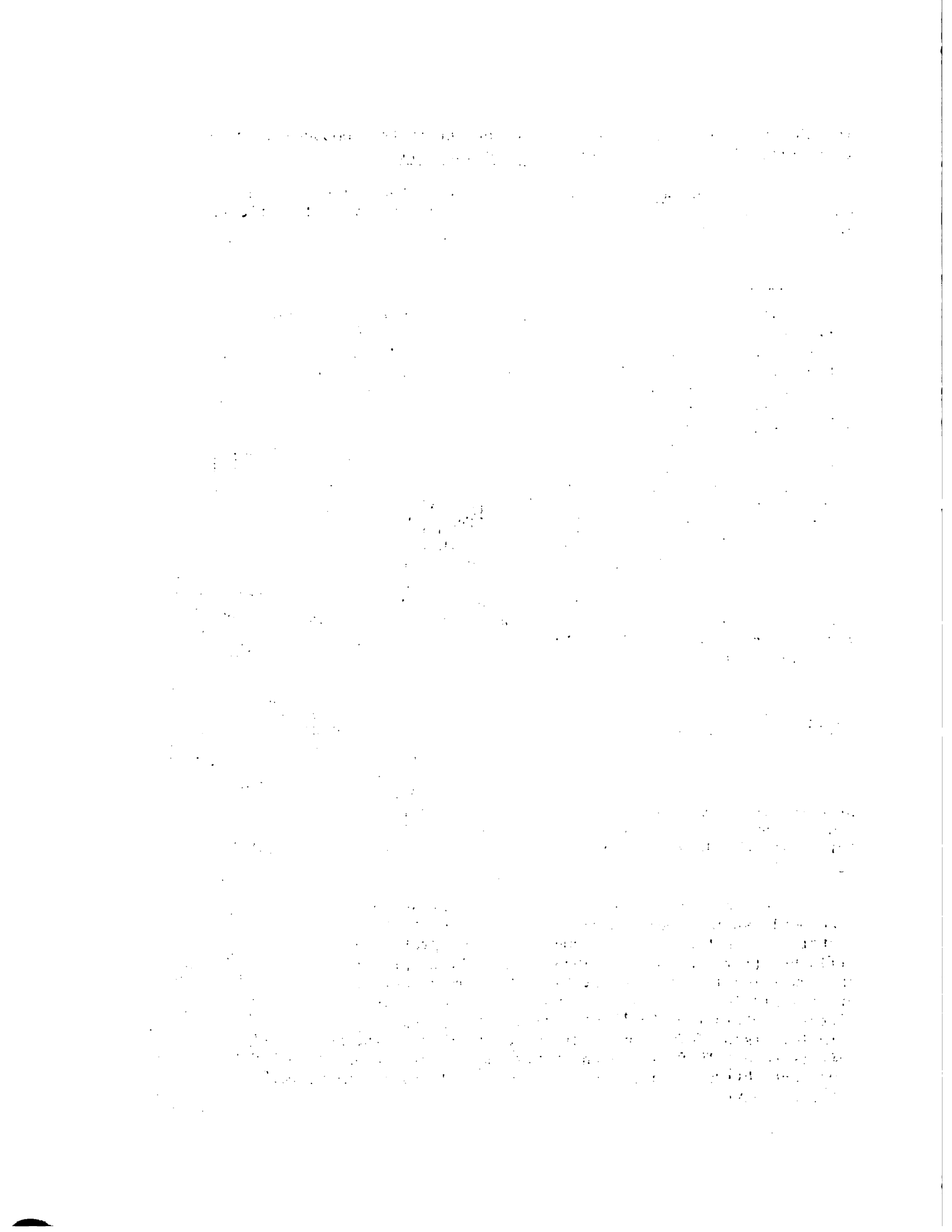
Macrobrachium zoea are able to rupture the walls of food microcapsules with cross-linked nylon-protein walls by physical mastication (Jones et al 1974).

2. Lipids and sterols

The biochemical composition of M. rosenbergii juveniles was worked out by Sze (1973), who reported that the dry weight lipid level was 15.8% of the body composition. It is thought, based on the work of others, that shrimp require a specific fatty acid composition in the diet, W6 being inhibitory and W3 types being stimulatory, so that diet lipids with a high W3: W6 fatty acid ratio are required by these animals. Shrimp head oil is an excellent source of W3 polyunsaturated fatty acids. Joseph and Williams (1975) found that M. rosenbergii fed for 3 weeks on a commercial shrimp chow containing 7.3% lipid, mainly from linoleic acid-rich (18.2W6) soy oil, but with 3% shrimp head oil, contained 6% more W3 and 6% less W6 fatty acids than control animals which were fed a diet not supplemented with shrimp head oil. Although levels of W3 fatty acids paralleled those in the diet in both groups, significantly lower levels of W6 fatty acids were found in tissue than in dietary lipid. The conclusion from these results is that W3 fatty acid are annabolished and therefore retained, while W6 fatty acids are catabolised for release of energy. Sandifer and Joseph (1976) confirmed these results. Those shrimp fed diets augmented with 3% shrimp head oil had 15 times more corotenoid pigment than the control animals.

Sick and Beaty (1974) determined the caloric budgets of M. rosenbergii. Balazs et al (1973), in initial trials with M. rosenbergii (where algae may also have been injested), an all soy bean protein source diet gave better results than a fish-soy bean diet, but was inferior to a fish-soy bean-shrimp based diet, even though all 3 diets were 35% protein. Shrimp of different ages, however, require different protein levels and sources in their diet, higher protein levels being required at earlier growth phases, early juveniles requiring $>35\%$ protein, although lower proportions may be optimal with a favourable amino acid balance.

Suitable major sources of protein for shrimps are squid, soy bean meal, shrimp meal and fish meal, but the most promising are chitin - containing crustacean wastes such as shrimp protein derived from cannery effluents (Toma and Meyers, 1975), the optimum protein level being 27-35%, the lower levels being acceptable if the amino acid balance is favourable, or if lipid levels are raised, where lipid may substitute for some of the dietary protein (the W6 fractions) in energy supply, so sparing the protein for tissue formation (Andrews et al, 1972). The most important task is to determine the quantitative amino acid needs of each commercially important shrimp species, in order to be able to formulate economically efficient diets.



4. Carbohydrate

Crustaceans digest carbohydrates and have carbohydrases including α and β amylase, maltase, saccharase, chitinase and cellulase, the last 2 originating in bacterial gut flora. Carbohydrates are important in the kreb's cycle, glycogen storage, chitin synthesis and steroid and fatty acid anabolism. There is strong carbohydrase activity in the herbivore, M. dayarum (Tyagi and Prakash, 1967).

Efficiency of utilisation of carbohydrates by shrimp varies according to source. Partial digestion of cellulose is carried out, and extra cellular chitinases digest chitin in the diet or in the shrimps' own cast exoskeletons. Ability to digest specific carbohydrate sources varies between species, starch in general protein from chitin synthesis to permit a shunt of the protein into tissue synthesis.

5. Minerals

Literature references to minerals in shrimp nutrition are sparse. Sze (1973) reported ash content of M. rosenbergii to be as high as its lipid level at 15.9% dry weight. There have been some studies on Ca^{+}-$PO_4^{=}$ ratios in shrimp but their overall mineral requirements are poorly known. Some species can presumably acquire Ca^{++}, K^{+}, Na^{+} and Cl^{-} from seawater by active osmo-regulation, but they cannot get $PO_4^{=}$ in this manner.

6. Vitamins

Vitamin requirements of shrimp are virtually unknown. There is a little information on vitamins A and C. Most of the B group vitamins are needed by crustaceans, plus C and E. Vitamin D may be partly injested but can also be synthesised from ergosterol, while K may even be inhabitory. The precursors of A may be needed but not the vitamin itself, e.g. β carotene in phytoplankton can serve as a source of synthesis of A. Vitamin C supplements speed penaeid growth rates, but in excess can inhibit growth, the optimum inclusion level being about 0.2%. Yet application of vitamin mixes to diets without knowledge on requirements may not only waste money but may also be dangerous as excess levels may be given.

7. Larval food

Few papers on artificial larval foods are published. In developing such diets the main problems are to devise food in a form and particle size acceptable to larvae. Further, the food must be in the same part of the water column as the larvae, and protected from leaching. Microencapsulation is a promising answer to these difficulties.

Respiration and injestion of larval M. rosenbergii was studied by Sick and Beaty (1975) to measure the amount of food needed for growth sustenance at each larval phase, using several compounded diets, as well as Artemia naupii. The 20% alginate gel and freeze-dried foods were very porous and therefore floated, though near-neutral buoyancy was attained

by extrusion followed by rolling into flakes. Six diets with different combinations of fish, soy bean and shrimp meals, with cellulose as a filler plus vitamin and mineral supplements, soaked in a linseed-menhaden oil mixture. Two rations had 15% or 30% Artemia meat added, two had 5% and 15% of albumin, Diets were prepared alternatively in freeze-dried, gel and dry flake forms. For all forms, diets with Artemia were incorporated at higher rates than others. Highest ingestion by phase VII-VIII larvae was a freeze-dried diet with 15% Artemia. With a 4:1 starch: albumin ratio larvae ingested more food than those fed any other diet except those containing Artemia. Only larvae fed 5.5 mm rather than 0.7 mm nauplii, or freeze-dried catfish, or the freeze-dried diet with Artemia, injested sufficient calories to provide for growth plus respiration. Artemia nauplii, and freeze-dried catfish diets were more efficient than the formula feed plus Artemia meat, and they produced stage VII larvae in the shortest time. Yet, combination of a diet of 5.5 mm nauplii plus freeze-dried catfish, and a diet of freeze-dried formula feed plus Artemia meat both gave an excellent result of 57% survival to stage VIII larvae in 19 days.

8. Discussion

Balazs and Koss (1975) reported a food conversion ratio of 1.46: 1.00 over 244 days for a soy-tuna shrimp diet fed to M. rosenbergii. This ratio must be used in calculation of feed costs.

The great importance of nutrition in shrimp maturation was stressed by Clark (1976). Basic studies linking actual rather than calculated chemical composition of diets with parameters like respiration, blood chemistry and tissue analyses are essential for success in culture that is other than empirical.

A standard measure of performance should be adopted such as specific growth rate, where $S.G.R. = \frac{\log_{10} \text{final wt.} - \log_{10} \text{initial wt.}}{t \text{ (days)}}$

Research must take into account and standardise the following variables:

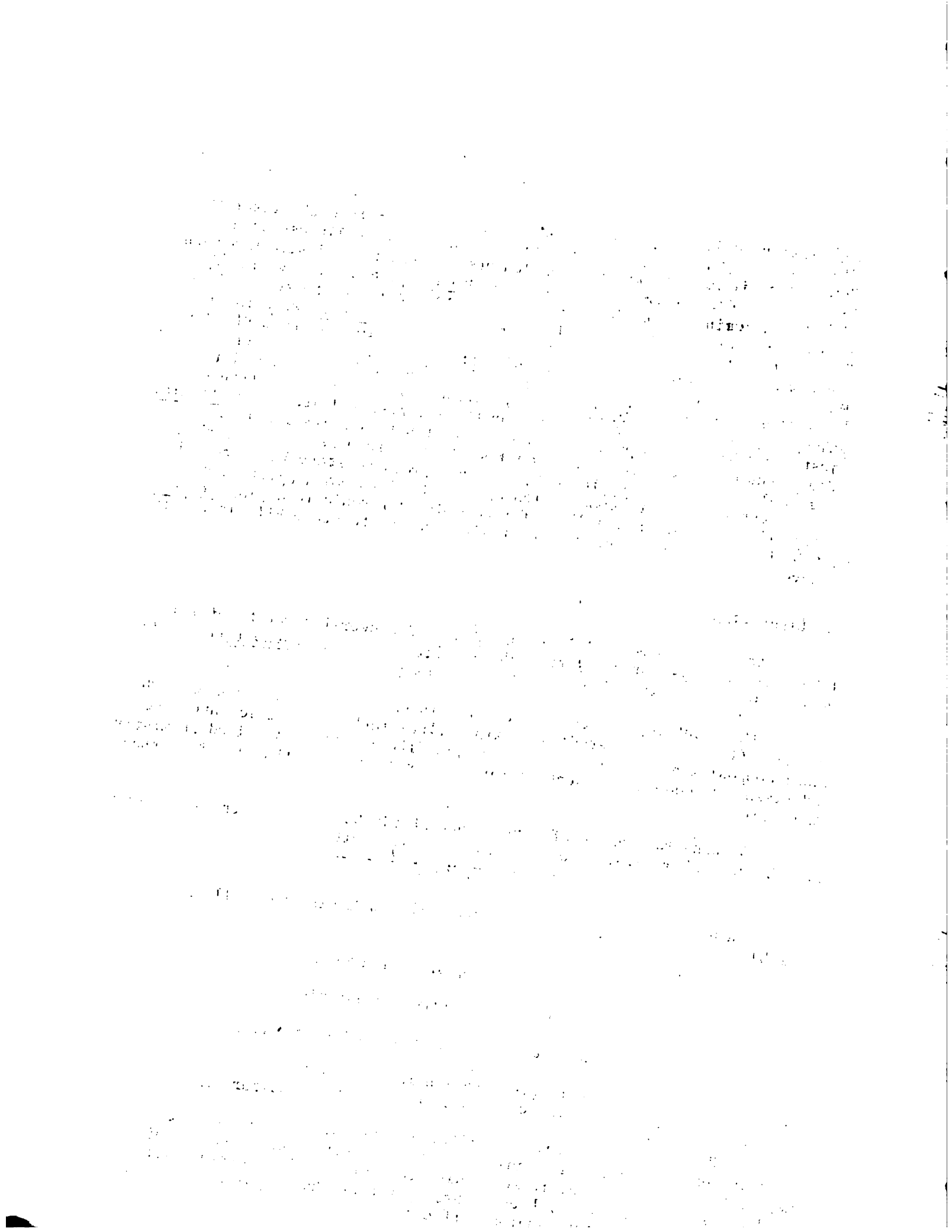
(1) selection of optimum environment;

(2) inherent variability in animals;

(3) selection of feed form and ingredients;

(4) data presentation in a suitable form for both scientists and commercial culturalists

Shrimp are aggressive, territorial and competitive, so stocking density bears on growth and survival rates. Interactions between animals may either increase or decrease feeding intensity. When testing diets, replicates of individually housed shrimp, rather than populations should be used to eliminate inter-animal effects.



9. Conclusions

Proposal for standardisation of experimental conditions for dietary trials with Macrobrachium rosenbergii

Aspect of expt.	Recommendations
Origin of animals	From defined strain reared in standard conditions; at least known parental and larval history; larval life 30 d., initial experiment wt. 0.2 g.
Trial length	Min. 98.3., preferred is 350 d., or until animals of 1 treatment average 35 g.
Measurement technique	Individual wt. by standardised blotting total and carapace lengths, using post margin eye orbit.
Measurement frequency	Approximately 21 days.
Pre-trial maintenance	House communally 7 d. at trial, environment conditions, select by wt. randomise to individual tanks; feed control diet a further 5 d.; gradual, complete, water change and starve 48 hours before trial; weigh and measure 1 d. before experiment diets given.
Trial environment	28±0.2°C; 2% S, 75% Diss O_2; pH 7-08.5; 16hL fluorescent light at 108 lux water surface: 8hD
Replication	Diets randomised to give 6 replicates on each of 2 recirculation systems, reverse treatments during trials
Food	Make 1 batch, store in bulk at 15°C, weigh enough for 7 days for each individual tank, and keep at 0_2, reweigh and discard unused; % of biomass feed daily, fr. of feeding, coll. and measurement of unused food, faeces and exuviae will vary acc. to experiment.
Data Collection	Maintain records on and report parameters of relevance

A very detailed study of the effect of using formulated feeds on the productivity of M. rosenbergii in culture was undertaken by Fair and Fortner (1981). What is the power for growth of supplemental feeds, compared to pond fertilization is the question they posed. Intense organic and inorganic pond fertilization increases fish yields and in many cases has replaced conventional feeds, but the extent to which this is effective in

prawn culture was unknown. What are the direct and indirect roles of formula feed in the growth of prawns? Are the nutrients in these feeds directly available and utilised by the prawns, or do the feeds disintegrate and mostly just fertilise the water medium, so stimulating the primary productivity of the system? What is the role of an organic fertiliser used to supplement a pelletised feed? A Purina Marine Ration (33% protein, 5% nitrogen, 11% fat, 11.5% ash, 3% calcium and 1.5% phosphorus was compared with a commercially composted cow manure (no pretein 1%N, no fat, 51% ash, 1% Ca and 0.2%P). Postlarvae were acclimated for thirteen weeks on Purina Marine Ration plus forzen, minced fish. The experiments used four treatments, no feed, no manure (NF NM), formula feed (AF), supplementation with non-available, pulverised formula feed (NAF) and manure (M).

The formula feed was found to be directly available to, and was used for growth by the prawns. Prawns in the AF treatment grew significantly ($P < 0.05$) faster than those in the NAF, M and NF, NM treatments. After 12 weeks, the highest mean weight gain (4.8 g) was achieved by prawns 1.5 g. The mean weight gain for NM, NF prawns was only 0.2 g. Survival after 12 weeks in the M treatment ponds was 0.53, that in AF treatment 0.54, whereas the figure for NAF ponds was 0.84 and that for NF, NM ponds was 0.79.

Total dry wt. feed offered: total wet wt. increase in biomass ratios for AF treatment averaged 1.7±0.11 compared with a NAF mean of 1.3±0.13 and an M mean of 192±22.5. These ratios are not directly comparable because of physical and chemical differences between formulated feeds and manure. If one uses instead the utilisation of available nitrogen to make a comparison, one finds that manure is at least 38 times less efficient than either the AF or NAF treatments. General pond productivity in the NM treatment was lower than in the other treatment groups. Pelagic and benthic organisms were present in all treatments, especially numerous capepods of Cyclops sp., rotifers, paramecia, cladocerans, ostracods and ceriodaphnia. The macro benthos was poorly represented in all pools, but there were some dipteran larvae of Chisonmus sp. and Chacoborus sp.

Apparent direct ingestion of formula diet resulted in growth rates by week 12 twice those of prawns fed pulverised, relatively unavailable feed, and three times those cultured under a natural productivity regime fertilised with manure.

Concerning the relation between growth rates and survival rates, AF and M treatments had low survival figures 10.54 and 0.53, respectively, while NAF and NM treatments had higher values (0.84 and 0.79. respectively). As survival rate was not related to final prawn biomass, density effect on growth was not a major factor in determining prawn growth. Although survival rates were low for both AF and M treatments, significantly higher growth rates were attained by prawns fed formula feed, indicating an independent effect of feed on growth rate. Cannibalism may have caused the higher mortality rates seen in the AF and M treatments. Further, lower growth rates in the M treatment might have been due to starvation.

Feed conversion ratios, based on total N, show that manure fertilisation is less effective for prawn growth than is pulverised formula feed. It is assumed that a major portion of pulverised feed is not ingested directly by prawns, then it follows that pulverised feed is a better pond fertilizer than manure. Yet the relation between fertilization with formula feed and manure is a function of nitrogen composition and rate of application of both feed and manure, qualities in the pond (especially resident flora and fauna), chemistry and physics of the pond water, and the type and number of the species cultured.

Other evidence suggests that natural foods in either fertilised or non-fertilised ponds are nutritionally as beneficial as pelleted formula feeds. Yet the current study shows that ponds not supplemented with formula feed, pulverised feed, or manure, produced insufficient food either directly or via natural productivity, to promote substantial growth among juvenile prawns.

The differental factor may be a micronutrient, rather than available energy level. Probably, both dietary energy and essential nutrients are equally important for optimal freshwater prawn growth. Growth rates of Macrobrachium could be improved by supplementation of high feed conversion diets in pellet form. However, feed costs constitute the larger single operating expense in prawn culture, so what is the importance of applied feeds as a direct source of nutrition? To what extent can natural productivity be augmented by indirect, additive stimulation of naturally occurring pond organisms? If formula feed is not merely an expensive fertilizer, but is directly ingested, as Fair and Fortner (1981) showed, it should become an important component in commercial prawn culture. However, these questions have not yet been answered definitively and more research is needed.

In recent years, some much-needed physiological studies have been conducted on Macrobrachium. Sandifer, Hopkins and Smith (1975) reared M. rosenbergii from eggs hatched in the laboratory and used these to study their salinity tolerance and osmoregulation. Larvae were cultured in a recirculating system using artificial seawater at c. 16‰ (Instant Ocean), and a temperature of c. 28°C in a controlled environment room; feeding was on Artemia nauplii and chopped fish daily, postlarval development required 30-40 days; after metamorphosis, postlarvae measured 8-10 mm, at which time they were transferred to 40L glass aquaria at selected salinities, postlarvae were fed a Ralston Purina experimental ration.

Mortalities occured at salinities around 25 ppt., increasing rapidly at levels $\geq$ 30 ppt., acclimation increased survival time at 36 ppt., significantly.

Freezing point depressions of blood in postlarvae and juveniles at various salinities from 0‰ to c. 35‰, showed blood values hyperosmotic to the medium for the range 0 to 17-18‰, and hypoosmotic at salinities higher than 18‰. Postlarvae kept blood concentration constant at a freezing point depression of -0.89±0.13°C over the salinity range 0 to 27-30‰, the osmoregulation falling at values $\geq$ 30‰. Juvenile blood

concentrations (FPD=0.88±07°C) at 0 to c. 15% resemble those of post-larvae. Osmoregulation in M. rosenbergii resembles generally that of other brackish water species, yet as it can hyperosmoregulate effectively in freshwater, it comes close to resembling freshwater species. It seems that M. rosenbergii can conserve salt in dilute media by producing blood-hypoosmotic urine.

Osmotic work and energy consumption should be minimal for an organism is an iso-osmotic medium and the maximum number of organisms should be culturable per unit of volume of work. Singh (1980) investigated some of the literature on growth at various salinities and the osmoregulation physiology of M. rosenbergii.

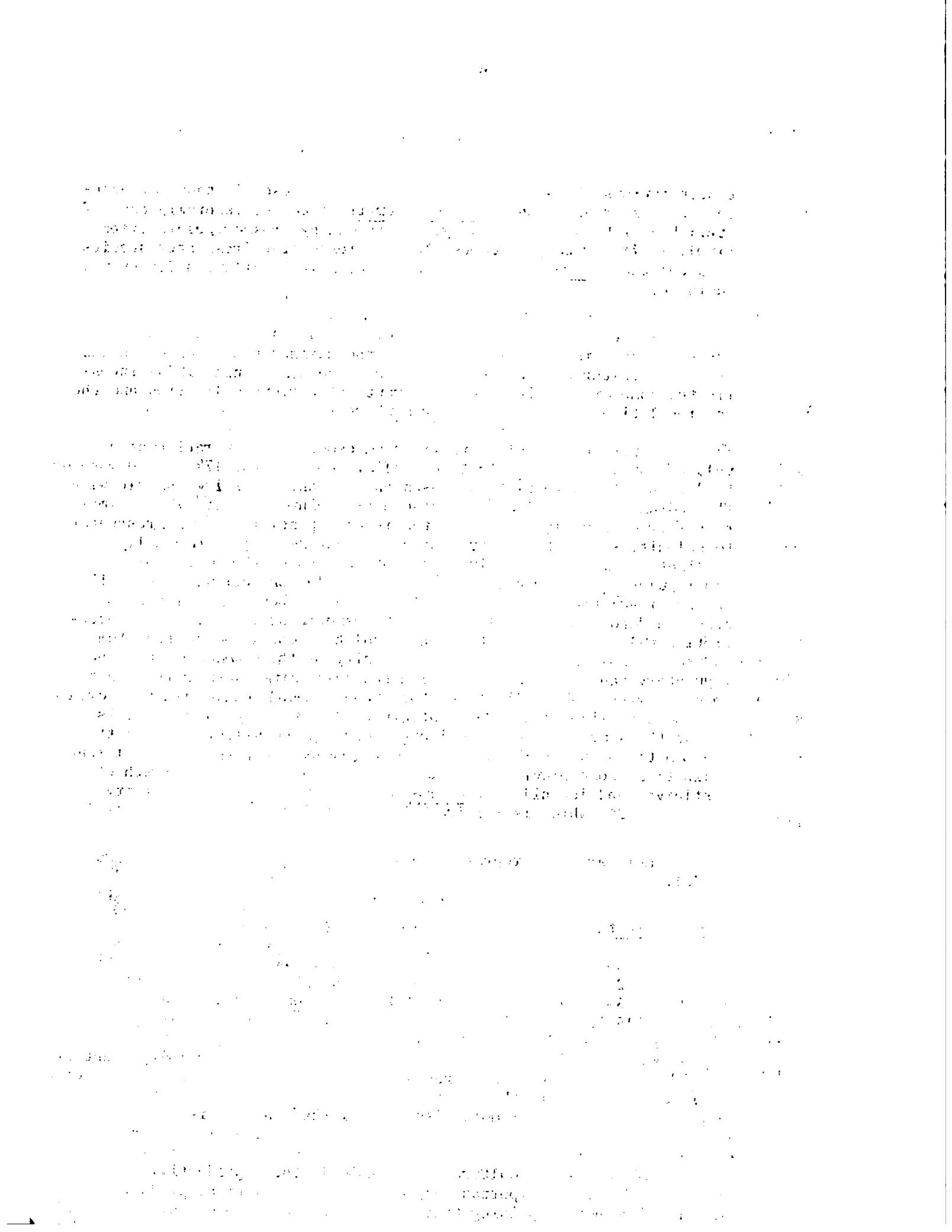
Adults hyperegulate their serum osmotic concentration at a value of 397±43 mosm dm^{-3} between salinities of 0 and 17% (0.440 mosm dm dm^{-3}). Above 17% regulation ceases and the animal is iso-osmotic with the medium so we conclude the iso-osmotic point is about 17%. Animals transferred abruptly as newly metamorphosed postlarvae from freshwater to salinities $>$ 18% survive for only about 24 hours. Gradually acclimated larvae can survive values higher than 18%, being able to osmoregulate in the range 0 to 27% hyperegulation occurring below 17.5% and hyporegulation in the range 17.5 to 27%. Above 27%, regulation ceases and postlarvae conform in a hypoosmotic state. Osmotic concentration value of haemolymph in the regulatory condition ranged from 330 to 490 mosm dm^{-3} according to salinity of the medium. Thus, the regulatory range is wider in acclimated postlarvae than in the adult. However, with slow acclimation, the range of adults can also be increased, to almost as wide as that of postlarvae. So, salinity tolerance is almost the same in slowly acclimated postlarvae and adults as is the iso-osmotic point at 17 to 17.5%. With respect to growth at different salinities, some previous studies have shown that maximum growth of postlarvae and juveniles of M. rosenbergii occurs in the salinity range 0 to 2%, which is far from the iso-osmotic range of 17 to 17.5%.

Here are some representative results from Perdue and Nakamura (1976).

Treatment	Growth rate (over 49 days)
0%	0.47
2%	0.47
8.5%	0.39
15%	0.25

Thus, the iso-osmotic growth concept does not hold for M. rosenbergii, probably because, in the range 0 to 2%, the prawns can more readily take into their tissues the large amount of water needed at ecdysis to stretch the new shell, this water later being replaced by tissue in the intermolt phase. In fact, prawns reared in freshwater contain 4.5% more tissue water than those raised in salinity of 15% and higher.

In commercial culture of any animal, the reproductive behaviour of the adults is an important aspect of their biological production. It is therefore not surprising that there have been a number of studies of this aspect of Macrobrachium biology (Lewis, Ward and McIvor, 1966; Wickins



and Bread, 1974, for example) A particularly interesting publication on breeding behaviour is that of Smith and Sandifer (1979), an account of which is given below. These workers described the construction and use of breeding depression on the bottom of the culture ponds by M. rosenbergii.

This is the first published report on the occurrence of such depressions among cultured M. rosenbergii stock, although they have not been reported for wild populations. They were constructed by males in eastern culture ponds in South Carolina at 4 widely separated locations in the state. Detailed observations and measurements were taken at 150x 17 m (0.25 ha) ponds at one location. Males here were of mean weight 147.1g, females, mean wt. 78.0 g. Before drainage, depressions were seen along dikes and in shallows, there being 1 male in each at night plus up to 4 ripe females within or on the periphery of depressions. Ten were observed and measured after drainage. All were elliptical or circular and deepest at their centres. Size range was 38x38 to 94x53 cm depths 7 to 15 cm. Maximum ratio of diameter to depth was 8:1, and ratio of major to minor axes ranged 1.1 to 1.8.1 (Sic). (i.e some were ellipses, some circles).

Differences in water quality and in soil type had no influence on the establishment of breeding depressions at various localities in South Carolina. Major factors controlling size and number of depressions are size and density of the male prawns. The larger the prawn, the larger its depression. Shallow and middle centre sections of ponds contained most depressions, with least being found at shallow ends of lateral sections (dykes) and an intermediate number occurring in deeper parts of the dykes.

Depressions may result in lowered productivity as they are made and occupied by large, dominant males that no longer grow rapidly and that utilise feed less efficiently. Further, during selective harvesting with seines, males in depressions can escape capture. The importance of these breeding depressions to the species is unknown. In indoor tanks, males readily mate with females in absence of depressions.

One problem that arises in culture facilities is predation on the stock by wild species, but surprisingly this phenomenon is little reported in the literature. When it is discussed, it tends to be in the context of some other aspect of aquaculture, so it seems there is a need for some careful studies of this potentially serious effect on cultured animals. At the same time, freshwater prawns are themselves predators in their own right. However, again this aspect of their biology has not been subjected to detailed studies. One article on predation by prawns was discovered during the carrying out of this literature review, that of Sukumaran and Kutty (1979) who investigated prey vulnerability to Macrobrachium malcolmsonii, a large south Indian species with good potential for polyculture and mass culture. Vulnerability of four pre-species was studied - a weed minnow, Aplochilus lineatus, fry of 2 exotics, Tilapia mossambica and Cyprinus carpio (Bangkok strain), and tadpoles of a frog, Rana cayanophyctis. All prey individuals tested were selected in the size range 1.1.1.6 g; these were placed in a glass tank

24x15x15 in. or 61x38x38 cm., with continuously recirculated water via a subsand gravel filter, at a temperature of 26.5° to 29°C. In each test 20 prey individuals of a given species were offered to one prawn, and the number consumed per day noted until only one remained uneaten. Then 19 of the same sp. were added to bring the number back to 20 for a second test. In this way starvation became impossible. Several prawns were tested in this way, and their 0.5 and 0.95 mean predation time were calculated at PT_{50} and PT_{95}, also calculated were mean weight of prey consumed by species per prawn and mean number of prey consumed by species per prawn. These three indices constituted measures of vulnerability.

Results were that the vulnerability scale was as follows in order of decreasing susceptibility to predation:

V frog tadpole > V minnow > V carp fry > V Tilapia fry

Taking V frog tadpole = 1.0, then using 0.5 predation times:

V minnow = 0.59; V carp fry = 0.77; V Tilapia fry = 0.36

Changes in prey density and satiation levels render all these indices imperfect, but serve as guides. For example, using weight of prey consumed per day and setting the index of Vf. tadpole = 1.0, then V minnow = 0.45, V.c. fry = 0.48 and V Tilapia fry = 0.23

Vulnerability may be determined by behaviour and form of the prey and predator's inate inclinations. Tadpoles are sluggish, soft and non-spinous, so their high vulnerability is not surprising. Previous conditioning did play a role because these prawns had been raised on Tilapia fry, and yet they proved to be the least vulnerable in the experiments.

Most aquaculture facilities have to filter their culture water and the most common type of filter in use is the biological one.

A biological filter's most important function is to oxidise NH_4OH to NO_2^- by use of nitrifying bacteria because NH_4OH is the main excretory product of aquatic organisms, and it is toxic at low concentrations. Forster (1974) described experiments on nitrification in biological filters using seawater. Factors affecting nitrification were investigated in laboratory-scale biological filters supplied with dilute (1-2 mg./l. ammonia nitrogen) solutions of ammonium sulfate water at 26±2°C. Increase of hydraulic loads from 10-25 to 246 $m^3/m^3/$ day caused the total quantity of NH_4OH oxidised by the filter to increase, although the proportion oxidised relative to influent concentration decreased. Decreased pH adversely affected nitrification, which stopped altogether at pH 5.5. Nitrification was inhibited at diss. O_2 values below 0.6-0.7 mg./l. Percolating (downflow) filters performed about as well as media submerged (upflow) filters. Time to onset of nitrification varied, but allowing at least 4 weeks at 26±2°C before the filter is assumed to be fully active is recommended. (Note: Hydraulic load is

the flow rate measured as m^3 water/m^3 filter volume per day). Failure of biological filters can be quite serious for when oxidation of ammonia is faulty nitrite is often the by product and this is very toxic to aquatic animals too. Armstrong, Stephenson and Knight (1976) reported the acute toxicity of nitrite to M. rosenbergii larvae and observed heavy mortalities because of it. Thus it is important to maintain any biological filters in the culture carefully.

Filters become particularly important in recirculation type systems. A very elegant system was built and described by New, Scholl, McCarty and Bennett (1974). This system is potentially of great value for the Pear Tree Bottom project as the basis for the experimental aquaria that we propose be included in the facility, and so it will be described here in some detail.

The compact, self-contained recirculation unit consists of 36 10 gal. acrylic sheet (1/8" on bottom and three sides, 3/16" on back, sides strengthened with 4"x3/16" across top rear, with side strips 1½" wide, top front being unstrengthened so as not to interfere with animal handling) tanks, measuring 12"x18"12", manufactured by View-Rite Aquariums, Burlingame, Calif. A 1" diameter water inlet hole is bored centrally in a top-mounted back plate, 3/4" from back of tank; air inlet hole, 1/8" diameter, in back plate accepts air supply tubing, outlet hole, 1" diameter, is bored high in front of tank to give 10" depth of water. Low-level outlet with stopcock can be fitted if varying water depth is required. Tanks are covered by a 13"x14" piece of ½" acrylic sheet. Tanks are mounted on a Dexion 225/S angle iron and ½" plywood shelf unit, with each 96"x40" shelf supporting 12 tanks, 6 on each side; there are three such tiered double shelves, with shelf heights at 14", 38" and 62" above ground level. Angle iron legs are extended up to 84" to support air and water systems with temperature and flow rate controls. A pump, filter and heater are located on the end of the rack. Total floor area needed is 36 ft^2. Pumped water pipes are not permanently attached, to permit tank substitutions etc.

A low pressure, high volume (Cyclonair #CHE-2, Rostron Inc., Woodstock, N.Y.) blower pump is used and can supply over 400 tanks. A pressure drop in the air system is sensed and activates a switch to turn on an emergency blower automatically. Blowers' capacity is 42 ft^3/min at 0 "water pressure, with 28 ft^3/min. flowing at 12" pressure. A 3/4" PVC pipe controlled by a ball valve takes air from the main air supply to a 1½" PVC pipe controlled by a ball valve takes air from the main air supply to a 1½" PVC header pipe (schedule 80). Needle valves are present in the header supply pipe for each pair of tanks, mounted above and between each tank row. Tygon tubing (1/8" and 3/16" I.D) connects each needle value to a glass aeration tube (3/16" O.D.) inserted through the top of each tank.

Water flows by gravity from filter to 2" PVC water header pipes mounted above and between the 2 rows of tanks on each shelf and controlled by threaded gate valves. A constant 4" head of water is supplied to each tank by a 2" semi-circular weir cut from acrylic sheet and bonded with silicone cement into the levelled header pipe at the opposite end to

the gate valve. A 1" hole is drilled on top of the elbow, downstream of the weir to allow observation of the water flow and its control with its gate valve. A ½" PVC pipe, threaded into the 2" header pipe, supplies each pair of tanks with water via a T-piece, two elbows and threaded end caps with orifices drilled in them. Water flow rates to each tank can be varied by putting on end caps with different orifice diameters. Average flow with a 1/8" orifice is about 500 ml/min, giving an 85% turnover in each tank per hour.

Water leaves each tank via a male nylon hose adapter, 3/4" diameter, attached to the tank with a PVC nut and sealed with silicone cement. Polyethylene mesh in the adaptor will prevent loss of small organisms. A flexible 3/4" vinyl tube connects the adaptor with a second hose adaptor screwed into an ABS/2" collection pipe (schedule 80). Two waste water collection pipes, one for each tank row, are needed on each shelf. One of the waste pipes also carries overflow from the header-pipe weir. At the end of each side of the rack, all waste pipes from each shelf join into one vartical pipe which empties into a control pump at floor level at the end side of the rack.

The pump is a 18" 24"12" high #R10M (J.T. Reyerson and Sons, Emeryville Calif.) polyethylene tank. Evaporation and siphoning losses are replaced via a 1/8" PVC float value rated at 80 p.s.i. (1 p.s.i. = 0.070 kg/cm^2), connected to domestic water supply. Water is pumped from pump to filter by a Model # 4E-34NR submersible pump (Little Giant Pump Co., Oklahoma City, Ok.), which can deliver 725 gal/hr. (1 gal. US=3.785 L.) at a head of 6½. A PVC, ½" supply pipe (Schedule 40) to the filter has a ball check valve in it immediately above the pump, to prevent water draining from the filter into the pump in the event of pump or power failure. A ½" ball valve reduces flow rate to about 450 gal./hr., to provide complete turnover of all the water in the 36 tank system every hour.

The filter vessel is a 30 gal., circular, Nalge #54100, polyethylene tank. Entering water is distributed throughout the whole cross section of the filter media via a Schedule 40, ½" PVC pipe grid, which has 3/16" holes drilled in its horizontal surfaces at 1" intervals. The 15 gals of filter media consist of:

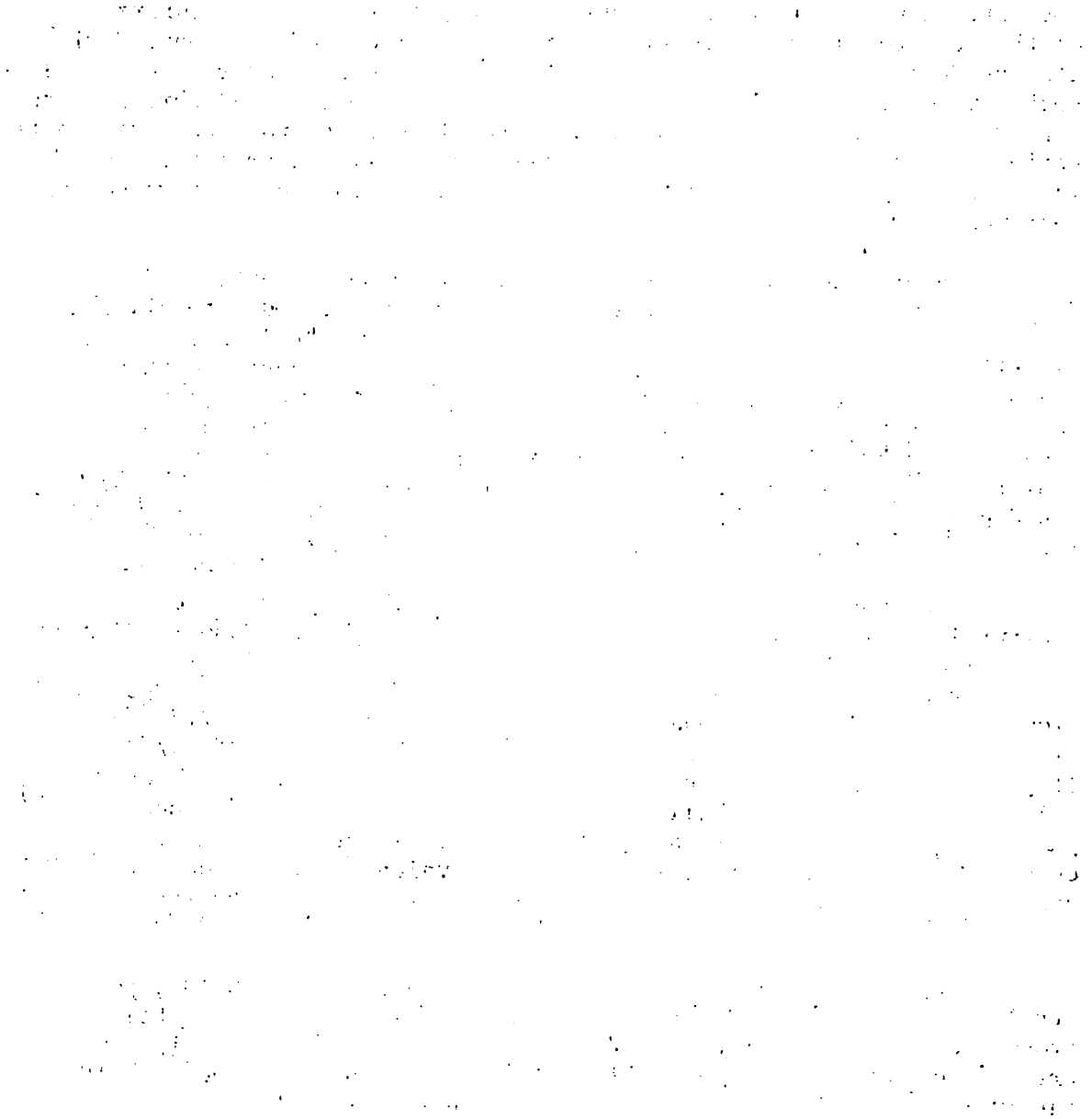
(1) 4" layer of 3/4"-1" crushed rock at the bottom;

(2) 8" layer of 1/8"-½" pea gravel in middle;

(3) 2" layer of #2 (0.05-1.0 mm) fine sand; and

(4) 1" layer of ½" Dolomite

Water leaves the top of the filter vessel through a 2" overflow and distributed through the water supply header by gravity. The filter vessel is 18" in diameter and 29" high. The water exist is 24" from the bottom of the vessel. The filter can be flushed with an air-water mixture supplied via a T-piece inserted in the pipe between pump and



filter, just above the control valve, which connects up to a separate air supply system. This air line is protected by a ½", threaded ball check valve, controlled by ½" PVC needle valve, and connected to a mobile diaphragm pump (Duraise pump; Bell and Gossett-Leiman Bors., Monsoe, Louisiana), producing 1.1 ft^3/min. at 5 p.s.i. Upward flow filtration requires no manual attention because flushing with a water-air mixture makes the filter media lift slightly and dislodges accumulated debris. Seed new filters with gravel from an old filter, and allow some food to decompose in the system. If this is done, you can stock with animals after three days.

If salinity changes are needed, set up a second set of supply and waste pipes for each shelf, supplied by a separate filter and recirculation unit to carry seawater while the first supply set carries fresh water. Each tank should be fitted with two water inlet pipes, one of which is always sealed. To change salinity, cap the freshwater inlet and place an end cap with an orifice on the seawater inlet; detach the flexible outlet pipe from the freshwater waste pipe and connect it to the brackish water waste pipe. If a constant salinity level is required, regulate the freshwater and saltwater flow rates accordingly until the required salinity value is achieved.

For siphoning waste food and faeces, use a peristaltic tubing pump, e.g. Master flex #6005-015; Cole-Parmer, Chicago, III., capable of removing 880 ml./min.

In the final analysis, economics exerts the iron laws that determine success or failure of commercial aquaculture enterprises, although in modern society these rules are "tempered" by socio-culture consideration and political overiders. Just one example of the economic approach will be given in this review, to illustrate what can be included in the analysis. Shang and Fujimura (1977) highlighted the main components of concern in farming Hawaiian freshwater prawns. Their study embodied three sections, cost of production, realities of production and profit.

Under costs they emphasized that site selection and pond construction are the most critical factors in prawn farming, the crucial aspects thereof being water quality and water quantity, soil type and topography. Soil for earthern ponds needs to be quite impermeable to water, and pond bottoms should be fertile and productive, flat land being ideal.

Pond design is important for ease of harvesting and pond control. Use of selective seining harvesting requires ponds of 1-2 acres (0.4-0.8 ha), with a well compacted bottom and a slope of about 0.5% (6"/100)[1]. A depth of 3 to 4 ft. (1.0 to 1.3 m) is ideal, with an elevation of 1.0 to 1.5 ft. above the water for the pond berm and a width of 10-12 ft. An outflow slince gate is required for rapid water discharge as needed for water level control and easy maintenance. Pond banks should have terrestrial vegetation to reduce erosion, give shelter and a habitat for macroscopic organisms.

Construction cost varies with slope, soil and clearing-out required. Average cost in Hawaii in 1977 was US$4,750/acre, including design, access road and drainage system. In additon, about 10.5×10^6 gals. of water/acre/year are required. Water pumped from a well at about 700 gals. per minute with a 10 H.P. motor can supply about 10 acres, and a 1,500 gpm, 20 H.P. motor 25 acres.

Equipment cost includes pumps, nets, truck and freezer, Equipment cost per acre decreased from about 6,100 for a 1 acre farm to about $600 for a 100 acre farm.

Operating cost mainly involves labour, feed, cost of juvenile prawns and interest payments, which can add up to 0.7 of the total operating expenses. Labour and feed can be 0.5 of the total. Annual operating cost per acre decreases with increase in farm size, especially the labour costs.

Labour cost is high because harvesting and feeding are manual operations. In Hawaii, labour accounts for 0.42 of total operating costs for a 1 acre farm and 0.23 for a 100 acre farm as labour efficiency increases with farm size. About 0.25 man years per acre is needed for a 1 acre farm and 0.1 man years per acre on a 100 acre set-up. Harvesting takes about 0.48 of the total labour time and feeding about 0.23 of it. Other tasks were weeding, bank repairs and silt pumping, accounting for, respectively, 0.17, 0.07 and 0.05 of labour time. In Hawaii, feed costs account for about 0.13 of total annual cost for a 1 acre (Cf) relates to production per acre (Q), conversion ratio of feed to prawn (R) and feed price, by the expression:

$$Cf = Q.R.Pf$$

Chicken broiler starter has been the basic prawn food in Hawaii, its price being 12¢ a lb. in 1977. With a current feed conversion ratio of 3.3:1, feed cost is 40¢ per lb. of prawn harvested. Broiler starter is optimal neither in nutritive value for prawns nor in cost effectiveness, so that a feed formulated on the basis of knowledge of prawn nutritional needs is very desirable for more efficient prawn farming.

The cost of juveniles is an extra cost to those farmers who buy juveniles from a hatchery. The cost of production of the juveniles at a hatchery is about $6.00 per 1,000. A good juvenile stocking rate is about 2 per ft^2 of water surface area. With continuous harvesting and stocking, with a mortality of 0.5, about 70,000 juveniles are needed per acre per year.

The electricity cost consists of costs for light, power tools, machines and pumps. About 10.5×10^6 gals. of water/acre/year are required. In Hawaii in 1977, cost of electricity was 7¢/KWH.

Other operating costs will include about 9% interest on construction costs in 1977, depreciation costs based on physical life of facilities and equipment, and miscellaneous costs.

Production mainly affected by stocking, survival, growth and harvesting rate. About 0.03-0.05 of the pond's prawn population reaches market size (c. 10 animals/lg.) about 7 to 8 months after stocking. Harvesting can be undertaken every 3 weeks, yielding about 175 lbs./acre/harvest. Restocking is done as the population decreases. Total production of about 3,000-3,500 lbs marketable prawns/acre/year can be attained, the common mortality rate being about 0.5.

Profit depends on production, operation costs and market price. Production level and costs depend on management skill, farm size and level of technology applied. Price is determined by demand.

Market segments for prawns:

(1) wholesale market

(2) restaurants and hotels

(3) retail markets (stores, supermarkets)

Farm price is US$3.00/lb (whole) to wholesalers and US$3.50/lb. to restaurants and retailers. Profit and rate of return increase with increase farm size and with increase in level of production. Rate of return on investment ranges from 0.6% for a 1-acre farm to 75% for a 100-acre farm when annual production reaches 3,000 lbs/acre, but increases to 11% and 96%, respectively, at 3,500 lbs/acre. A fairly economical starting size appears to be a 10-20 acre farm. When enough experience has been gained at this level, expansion to 100 or more acres becomes desirable.

Areas for which improvement and further research are needed:

(1) Pond design;

(2) Harvesting techniques

(3) Pond management;

(4) Cost-effective feed;

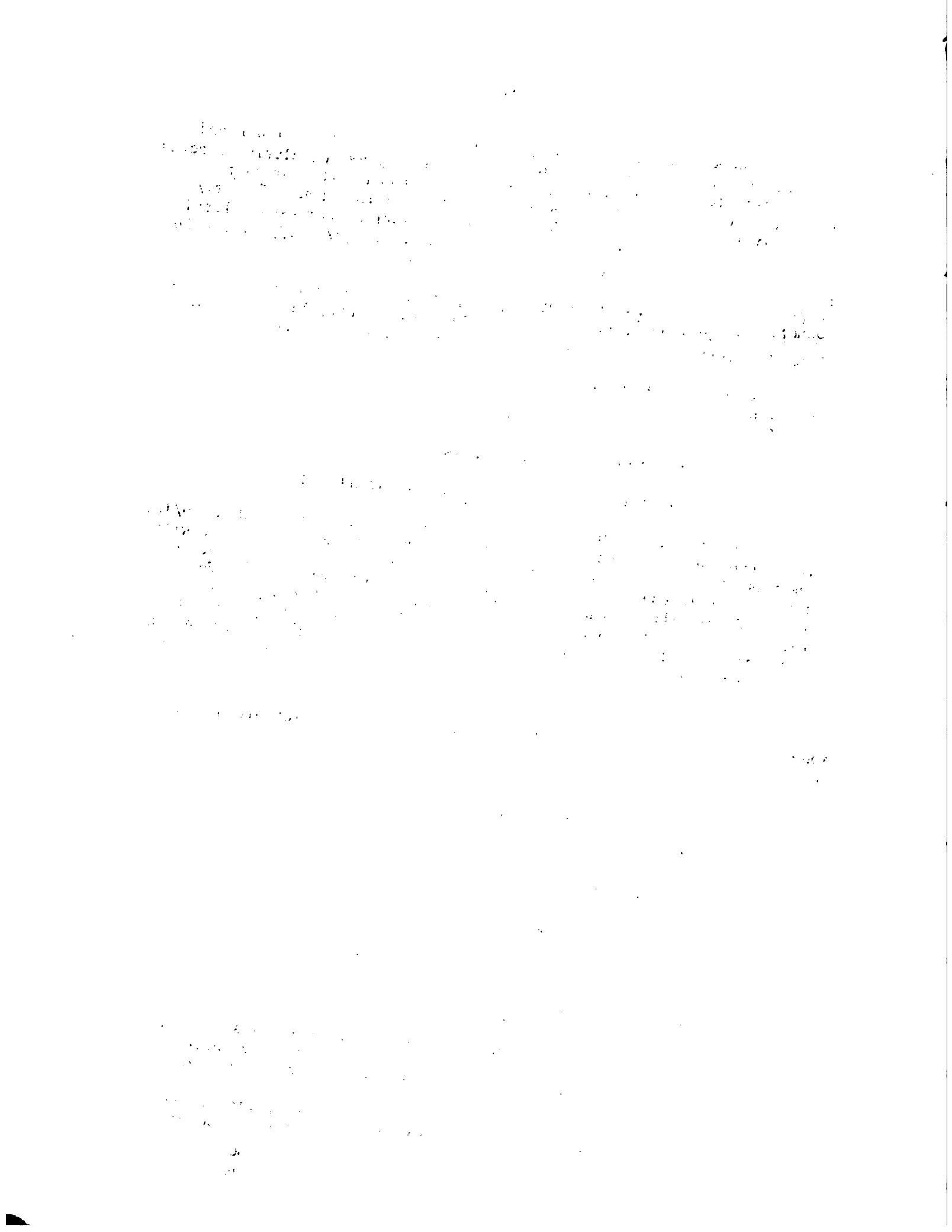
(5) Genetic improvement;

(6) Processing of market product

Some other general figures:

(1) Given an annual market demand of 10^6 lbs., about 330 acres of ponds would be needed, and 23x10^6 juveniles must be available to stock these ponds

(2) A country would gain an edge in competing in the world market if it had access to the following:



consistently warm weather year round, inexpensive land and cheap labour.

(3) Hawaii is faced with very expensive land costs, unavailability of land for production, and high labour costs, and because of these disadvantages is facing cost difficulties for world market penetration. Consequently, Hawaii's production in 1977 was all sold in the State.

These general characteristics of Hawaiian freshwater prawn farming for profit had not changed much by 1980. Shang (1981) summarized the situation there and concluded that profit still related to farm size and that small (1-5 acres) farm could be viable only as family ventures with virtually free labour. In addition, Hawaii has experienced inordinate inflation rates, raised energy costs and wage increases, inflated land prices and water use restrictions by government. Suffice it to say here that Jamaica is favourably situated, in comparison on all these counts except the last-mentioned. However, at Pear Tree Bottom River, water shortage is non-existent. Also, Hawaii recently has experienced a cost-prize squeeze where production costs in 1976-1980 increased 37% and prawn farm prices rose by only 30%. Of interest here is that even into 1981, in Hawaii climate, labour and land costs combined to exclude the State from the world export market. Jamaica feeds none of these restrictions so prawn aquaculture should support a valuable export industry.

On this note, Alston (1981) noted the advantages of the Caribbean area for Macrobrachium culture, which he listed as year round ideal climate and proximity to the markets of North and South America. For Jamaica we could add the attributes of clean water and cheap land and labour.

This concludes the survey of the scientific and technical literature that is relevant to the substance of this report.

However, for specific information on Pear Tree Bottom River System, limited as this is, please consult Anon. 1973; Barber, 1968; Donaldson, 1970; FAO-UNDP, 1974; and Inv. Bull., 1978/1979.

VII. Recommendations on Developing an Aquaculture Research Complex

The goal is to use a flowing freshwater and pumped seawater system as a research tool to investigate relative reproduction and production rates of four species of Macrobrachium shrimps.

It is important to plan requirements for types of materials, seawater distribution and filtering, freshwater supplies, services like compressed air and nutrient supply, and quality control testing. The scale of the experiments also has to be decided upon. To be taken into consideration as well are legal, marketing, political and regulatory aspects of the operation of the complex. Later if success is achieved,

an economic analysis of scaled-up systems has to be conducted. Finally, serious thought should be given to the possibility of developing a multi-species, multi-tropic level system rather than a separated species, single tropic level system.

Much of the basic biological knowledge required for setting up an aquaculture system is unavailable and some design variables have not been adequately investigated or documented. Thus we should test rather small systems first and scale up later, the design process and the scientific programme necessarily proceeding in parallel. The development approach should include:

(i) collection of information on previous similar endeavours carried out by others

(ii) small scale testing; and

(iii) careful, step-by-step refinement of design; the research and the development of the actual facilities must proceed hand-in-hand, with planning horizons at 12-15 months

Some specific design features:

(1) For flexibility of modification and low cost, keep as much piping as possible above ground level. Centralise the water supply and provide easy access to it wherever possible by passing it through raised channels fitted with removable covers. Cross connections can easily be added, as needed. Thus pipes carrying raw seawater, filtered seawater, freshwater, nutrient supply, electric power, drainage waters, oil-less low pressure air, and sewage will be easy to check, service and repair.

(2) Design the outdoor ponds to hold a variable depth of water to accommodate changing needs.

(3) Have drains at both ends of any raceways, and install removable wall baffles so that they can be operated in series as well as in parallel.

(4) Indoor wet laboratories should be designed for flexibility, with all services overhead. Use plenty of spot drains to keep the floor dry, with a handling capacity sufficient to deal with maximum flow rates, such as occur when the drain plugs of all tanks are pulled open at the same time.

(5) There should be two, not one, seawater intakes; only one of these should be in operation at any given time, while the other is either being serviced or cleaned, or is simply shut down. The pump station should have two self-priming, non-clog pumps. Install a chlorinator on the discharge line to prevent fouling.

(6) A continuously operating, biological sand filter that automatically backflushes itself at regular intervals, and consisting of layers of rocks, oyster shells and sand, can be readily installed. Turbidity sensors can be included that switch on the back-flushing mechanism more frequently if the incoming water should become more cloudy.

(7) If possible, use a gravity flow system where water elevations are controlled with standpipes and overflows. Flow rates can be controlled with calibrated orifices or valves.

(8) Take discrete water samples and test the water quality regularly.

(9) Consider the installation of a comprehensive alarm system to monitor water flows, electric power currents, air supply pressures and the like, so that any interruption of normal operating services will result in signals being sent to an alarm panel or to a telephone line attended by a staff member.

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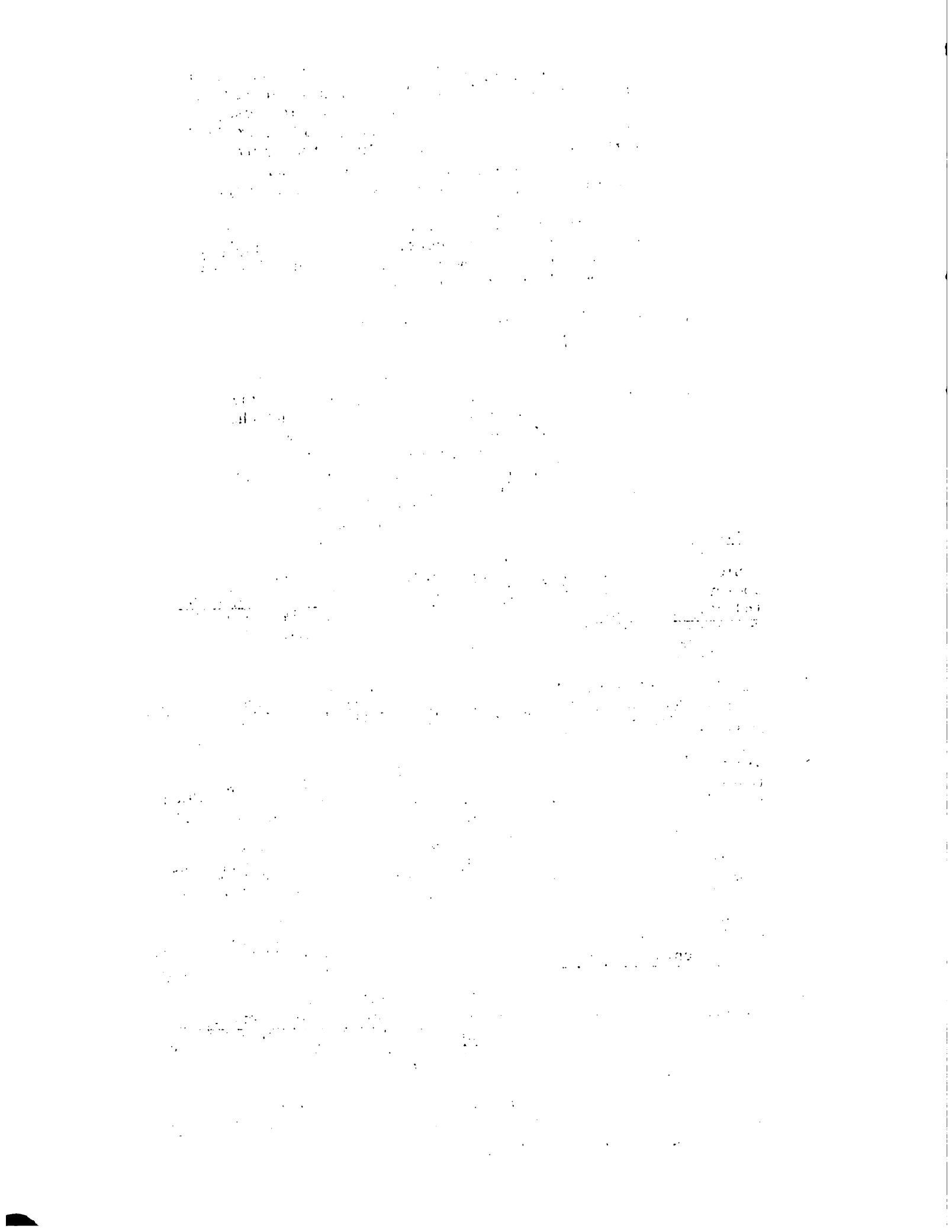

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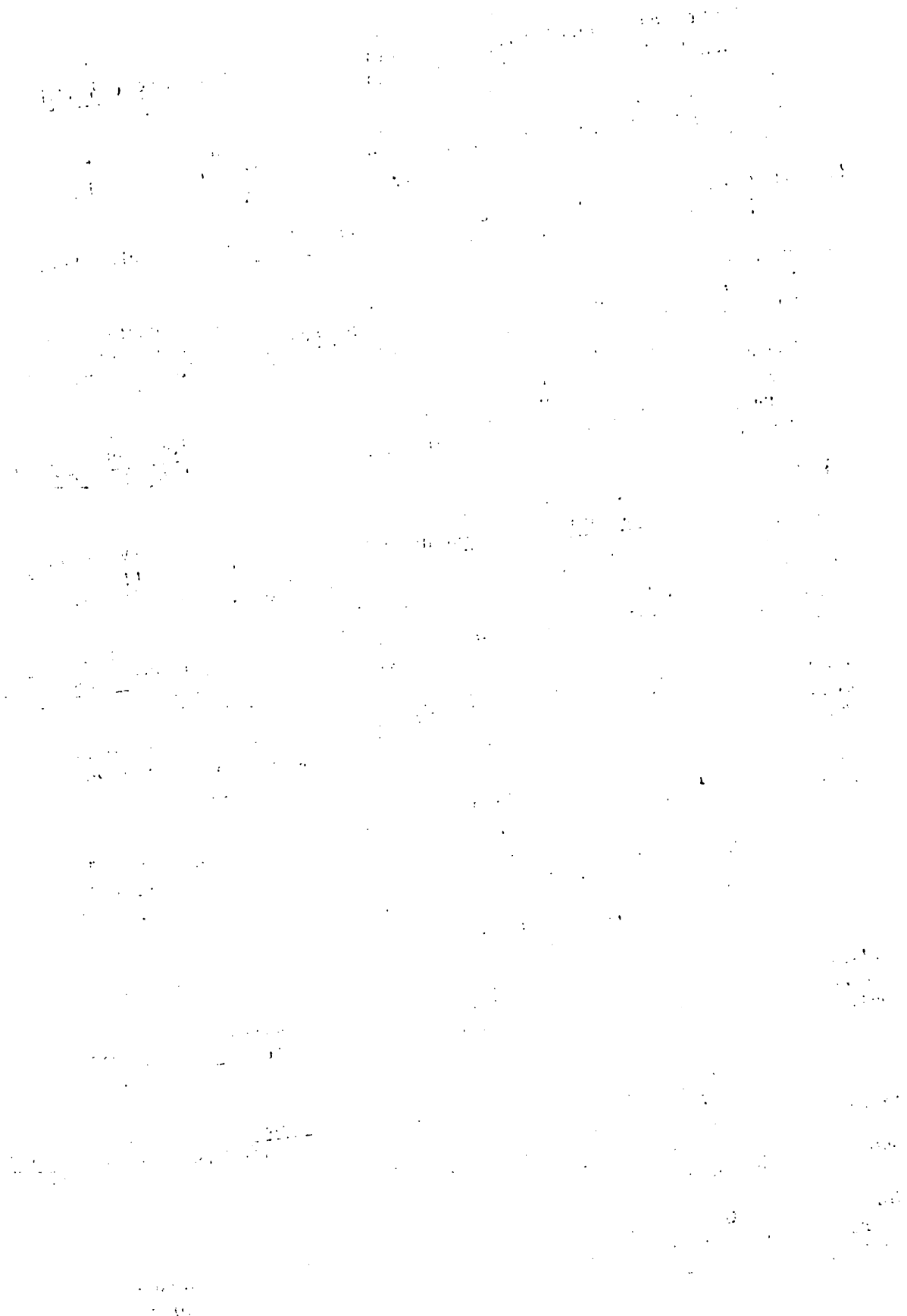

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APPENDIX A

REPORT ON PEAR TREE RIVER BELLE AIR

To: The Director of Inter-American Institute for Co-operation on Agriculture, Jamaica Office

As instructed by Dr. Aitken I visited the Belle Air property and carried out the survey of that part of the property which has been stated as the site of the Crayfish Farm Project.

The turn off to the site is on a stone/dirt road on the left of the main road to Discovery Bay about 1½ (one and a half mile) from the Brown's Town crossing. There is no visible sign pointing out the turn.

The stone/dirt road is for most of its length on solid ground on the top side of the spring line. After about half (½) a mile it crosses the swamps via a long culvert. At the end of the culvert it makes a right turn through a large wooden gate opposite some old milking sheds. The road enters the compound after about twenty chains.

The compound as shown on the site plan, sheet 1, is on a sloping ground with the swamp line approximately on the upper neat line. There are two large houses and three(3) support buildings. The main project building, No. 1, is on the left and the caretaker's cottage, No. 5, is on the right. The pump house No. 2 is straight ahead. The kitchen/store-room No. 4 and toilet is off to the right. Fruit trees over hang the compound. Most of the space in between the buildings has been compacted by usage and the addition of stony material over the years. Farm animals - cows, goats, chickens, and pigs move freely from water trough to pasture and so on. They are government caretaker's stock. Elsewhere on the property outsiders graze and water their cattle. There is talk that wild hogs also roam the swamps.

THE BUILDINGS

The main building No. 1, see floor Plan Sheet No. 2, consist of nine (9) rooms. A large utility room R1-1, 51 ft by 22 ft 6 ins; six (6) rooms R1-2A to R1-2F, 14 ft by 11 ft 6 ins; a small room R1-3 6 ft by 10 ft; and the bath/toilet area R1-4A 11 ft by 7 ft, R1-4B 14 ft by 10 ft and R1-4C 10 ft by 18 ft.

This building is approached using a 7 ft long two (2) tred step cut into a concrete landing 11 ft by 90 ft. From the landing one steps unto a verandah area 7 ft 6 ins by 78 ft. The roof of the verandah area is an extension of the main roof and is supported by a 21 in. deep beam with 8 ft 6 ins. 2 in. diameter steel pipes 12 ft on centers. Doors lead the verandah into the rooms. These doors are veneer ply doors 3 ft wide 7 ft high with a fan light 1 foot on top. One steps up five (5) inches into the rooms.

Room R1-1 is ventilated by five sets of windows as shown on plan and cross-sections. A 'bar' counter 2 ft 6 ins high by 2 ft 6 ins wide, 11 ft from the rear wall spans the room. There is a kitchen style twin sink with 2 ft standing cupboards as well as hanging cabinets at the rear of the room. Two exit doors are also shown. The rest of the room is open. The height of the room slopes evenly from 12 ft at the front to 7 ft 8 ins at the back.

Room R1-2A is entered through a centre door, as before described. They are completely enclosed with a rear window 3 ft 6 ins, 3 ft from the right and a 3 ft Vee jointed door at the left.

Room R1-3 is small, one enters through a centre door as before described. Facing the door is a 2 ft 6 ins louvre window the only glass window, all the rest being metal jalousies.

The bath/toilet area is entered via a small alcove. Room R1-4A contains space and plumbing for five wash basin one of which is missing. Head high walls separates it from R1-4B where there are three (3) water closets cubicles (low wall W.C.) served by a wide L shaped passage.

A two (2) inch step down takes one into R1-4C onto a landing. There is a 2 ft wide shower stall 5 ins below the surface of the 7 ft landing. There is plumbing for a six (6) showers in this open stall. Rear exit is provided by a 3 ft door at the right.

Through this door one steps four inches onto a 10 ft rear landing where all the rear doors from R1-2A to R1-2F and a side door from R1-1 opens. On the outside rear of R1-4C there are four 2 ft by 2 ft wash tubs.

The floor of Building 1 is good concrete slab float finished with cement mortar and blocked. The walls are of concrete blocks reinforced with steel and rendered in and out with cement mortar.

The walls are plated with 2"x4" sills, rafters are 2"x4" spaced 2 ft 6 ins on centers. In R1-1 there are two 8"x12" concrete beams and three (3) 3"x6" wooden beams helping to support the rafters. On the rafters there is 1"x10" sarking onto which a mixture of aluminium and galvanized iron sheets are nailed to complete the roof.

The caretakers cottage No. 5 has two bed rooms. It has wide enclosed verandahs and a shed to the left. It is in need of repairs to walls, roof and floor. The out buildings No. 3 and No. 4 are in good repairs. Building No. 2 is the old pump house - it is derelict. And as it stands, it can only be rebuilt not repaired.

ELECTRICITY

The compound is served by both 120 and 240 volts power lines. The 240 volts goes to the pump house, the 120 to the other buildings. On Building #1 R1-1 is supplied with overhead bulbs 7 ft 6 ins on centres. It has twin wall plugs over 14 ft 20 ins from floor. The main breaker panel is also in the room:

Room R1-2S all have a central roof bulb and twin outlets on the rear wall five (5) ft from the right. Room R1-3 is similarly lit. The bath/toilet areas are also lighted. Switches are on the inside of the entrance doors. The wiring is 'in house' through pipes. It should be possible to increase coverage by rewiring.

WATER

Water is supplied by pump from the well in No. 2. The pumps are not now working. In times past the pumps supplied all the property, it was drinkable, now it can only be used to water cows and land. A new well has been sunk about three (3) chains from the main building. The water has been tested found good and only needs to be harnessed.

The sink in R1-1 the bath rooms in R1-4 and the wash tubs are all supplied by 3/4" pipe from the water tank at the back. It has a head of over 10 ft, when full, it will supply the building adequately.

There is a 4 ft cube water tank for the caretaker area by the kitchen. At the time of the survey there was no water for testing. The plumbing is in place and the pipes take off the water.

There are no telephone services on the compound.

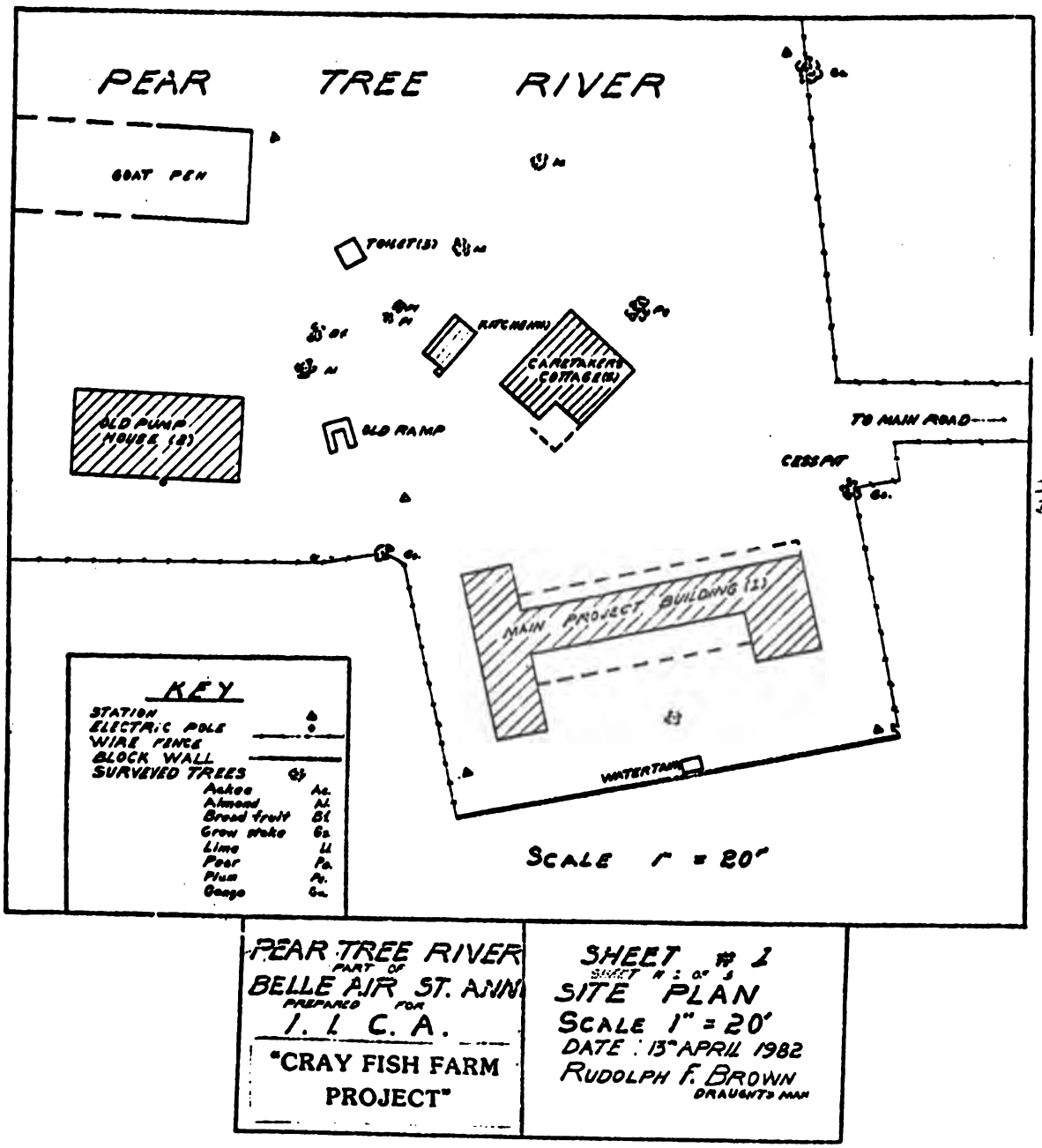
CONCLUSION AND RECOMMENDATIONS

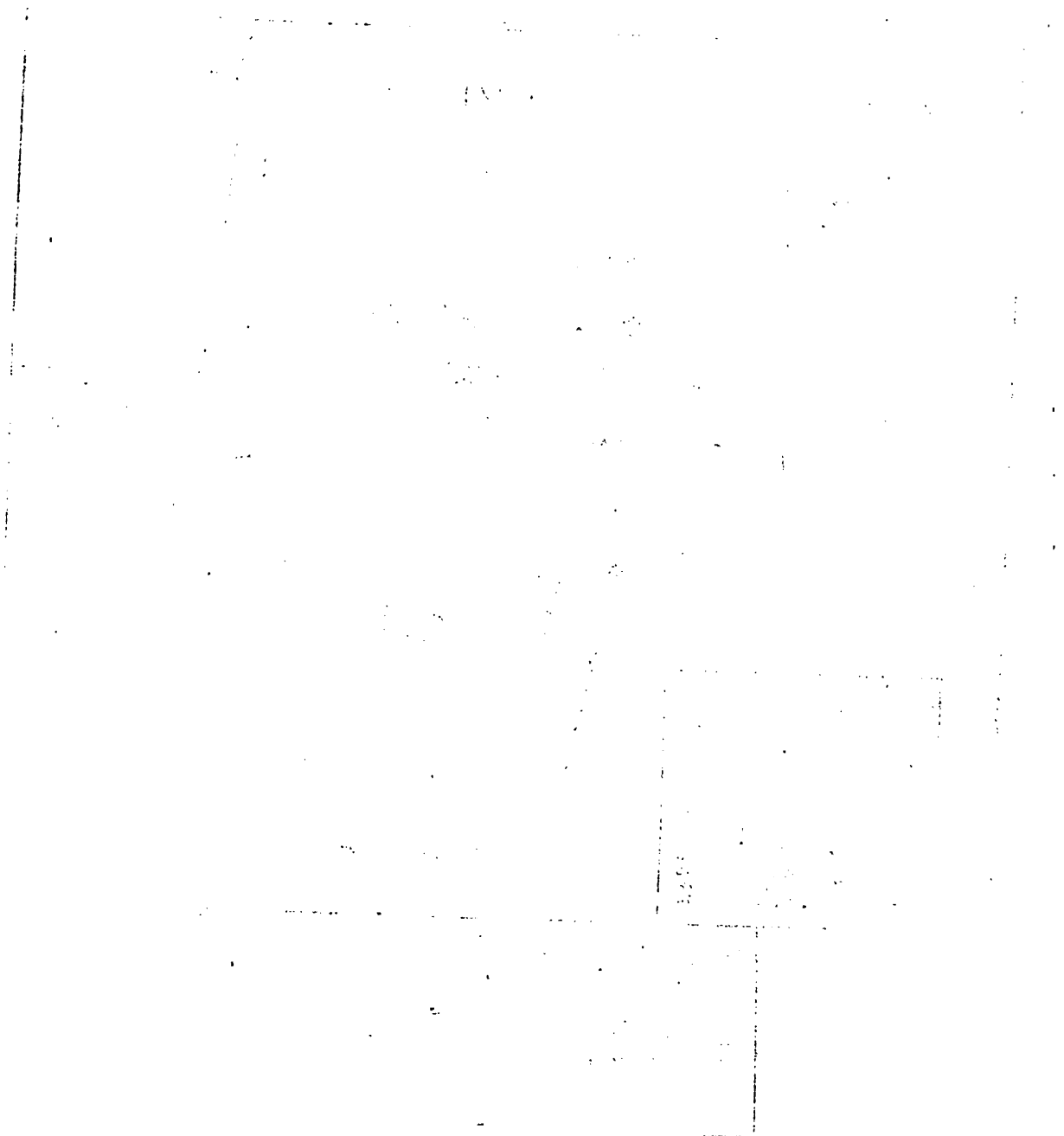
The Building No. 1 is in very good repairs. With modification it can be used for the stated project. Walls can be knocked out or added. More plumbing can be added by cutting walls and or floors. The electrical fittings and supplies can be improved by refishing new wires in and additional ones where needed.

The area between the Buildings could be paved and a chain link fence at least, is a must around the needed perimeter.

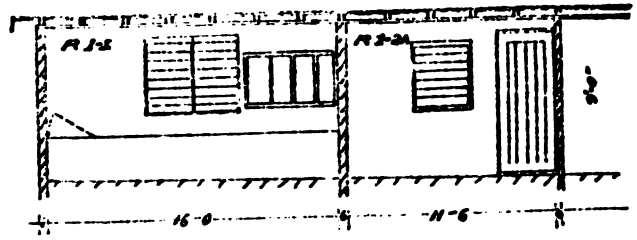
Rudloph Brown

APPENDIX A


PEAR TREE RIVER
GOAT PEN
TOILET(S)
CARETAKERS COTTAGE(1)
OLD PUMP HOUSE (2)
OLD RAMP
TO MAIN ROAD
CESS PIT
MAIN PROJECT BUILDING (1)
WATER TANK
KEY
STATION
ELECTRIC POLE
WIRE FENCE
BLOCK WALL
SURVEYED TREES
Ackee Ac.
Almond Al.
Bread fruit Bf
Crow stake Cs
Lime Li
Pear Pe.
Plum Pl.
Gauge Ga.
SCALE 1" = 20'
PEAR TREE RIVER
PART OF
BELLE AIR ST. ANN
PREPARED FOR
I. I. C. A.
"CRAY FISH FARM PROJECT"
SHEET # 1
SHEET # : OF :
SITE PLAN
SCALE 1" = 20'
DATE : 13th APRIL 1982
RUDOLPH F. BROWN
DRAUGHTS MAN



APPENDIX A



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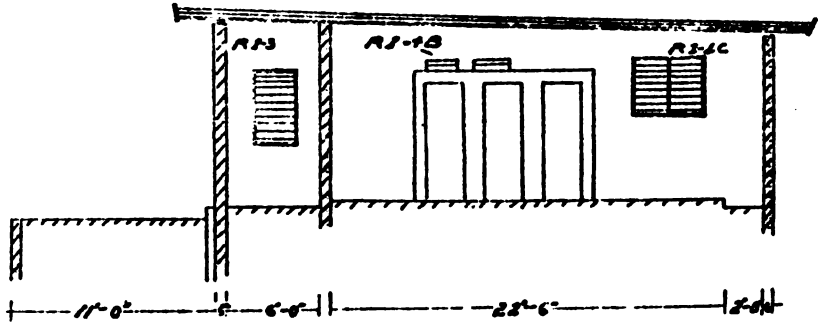
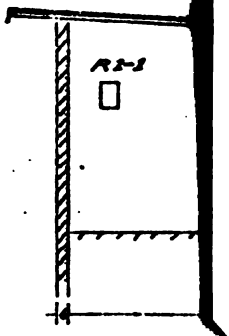
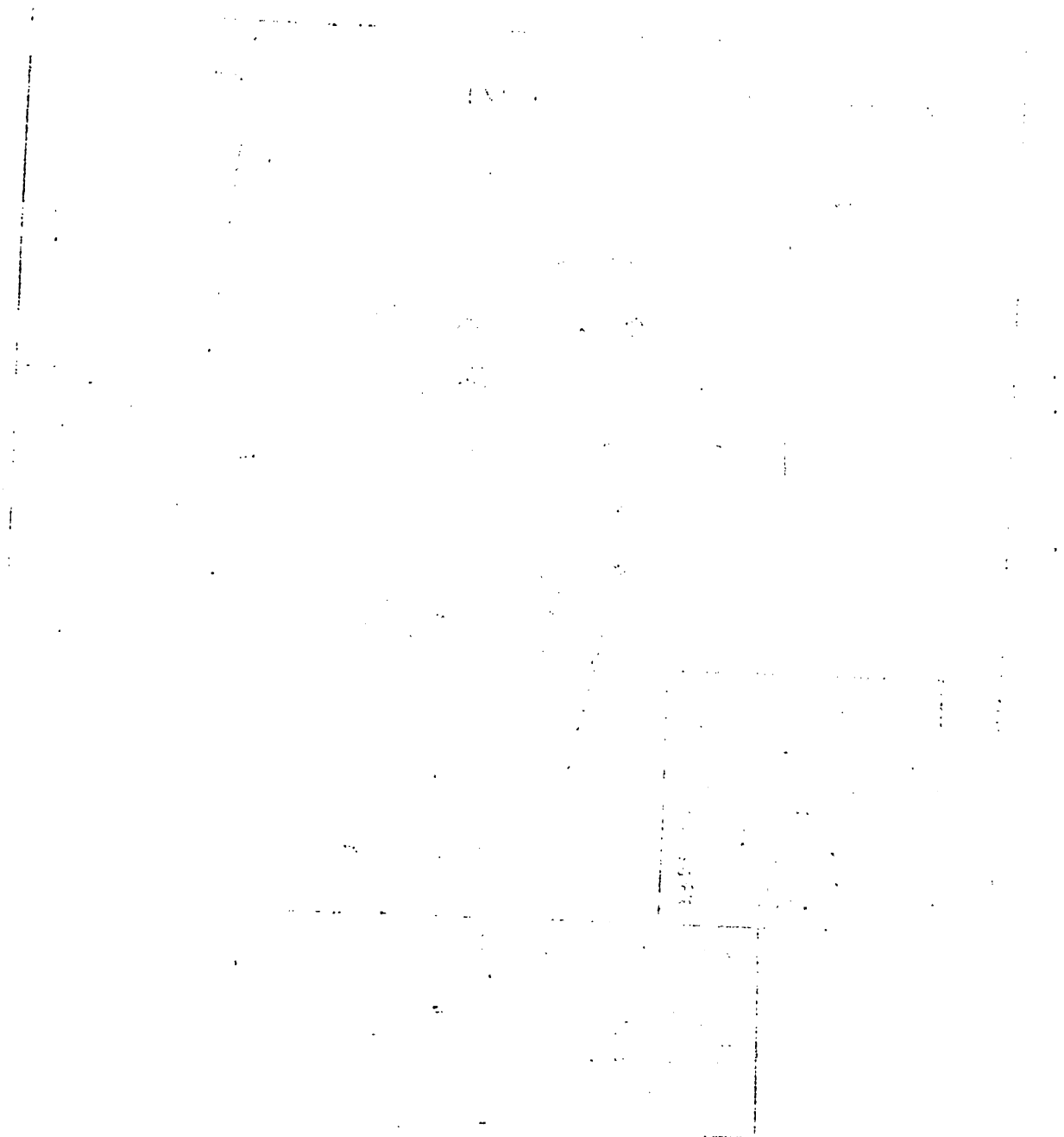


SECTION B-B"



PEAR TREE RIVER
PART OF
BELLE AIR ST. ANN
PREPARED FOR
I. I. C. A.
"CRAY FISH FARM PROJECT"

SHEET 2
SHEET R 3 OF 3
SECTIONAL VIEWS
SCALE 1" = 4'-0
DATE: 13th APRIL 1982
RUDOLPH F. BROWN
DRAUGHTSMAN



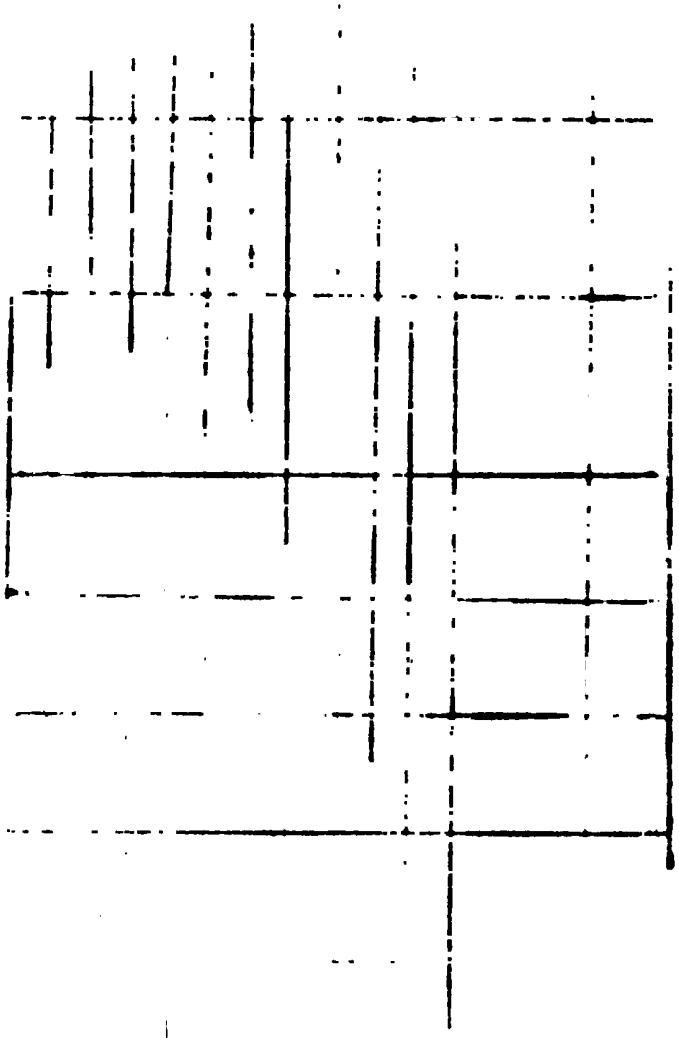
APPENDIX B.

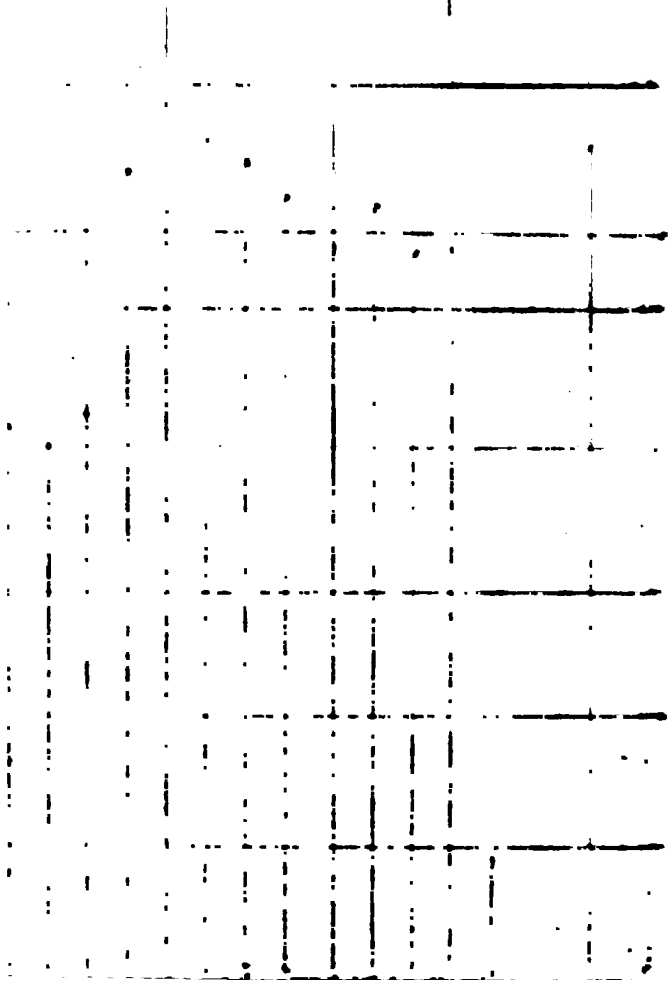
Hydrological and geological data on Pear Tree River Bottom System, St. Ann Parish, Jamaica, West Indies[1]

1. Hydrological (water chemistry and water quality) data

[illegible]	ALKALINITY (mg/l)	CALCIUM (mg/l)	CHLORIDE (mg/l)	CARBONATE (mg/l)	COLOUR (S.I.U.)[2]	HARDNESS (mg/l)	BICARBONATE (mg/l)	MAGNESIUM (mg/l)	NITRATE (mg/l)	pH	SULFATE (mg/l)	SPECIFIC CONDUCTIVITY (µmhos/cm)[6]	TOTAL DISSOLVED SOLIDS (mg/l)	TURBIDITY (S.T.U.)
[illegible] N5246 [illegible] N5642 [illegible] N5645 [illegible] N5630	A. SPRINGS AND RIVERS COMBINED													
[illegible]	150-240	58.4-108.0[7]	14.0-1,2500[7]	5.0-52.0[7]	15-135	190-550[7]	116-240	11.3-68.6[7]	2.7-39.9[7]	7.0-7.6[7]	0.6-100.0[7]	360-3,844[7]	186-2,321[7]	0.7-31.0
[illegible] [illegible]5.0.[7]	188.75±26.36	73.90±15.68	58.3±106.70	23.25±20.19	-	292.00±120.06	177.13±37.59	27.44±22.17	9.45±12.46	-	26.88±42.71	986.25±1,250.29	566.75±719.09	11.19±12
[illegible][3]	9.96	5.93	43.56	11.66	-	45.38	14.21	8.38	4.71	-	21.35	405.01	271.79	
[illegible] OF [illegible] (n)	3	8	7[8]	4	8	8	8	8	8	8	0.6-2.0	8	8	
[illegible]	B. SPRINGS ONLY 176-240	58.4-82.4	14.0-28.0	16.0-20.0	15-125	190-270	160-240	11.3-17.6	3.1-7.9	7.30-7.35	1.47±0.76	360-502	186-260	0.7-31.0
[illegible] [illegible]S.D.	201.20±23.90	70.72±8.81	18.40±5.86	18.00±2.83	-	229.20±34.83	194.00±30.73	14.82±2.87	5.46±2.28	-	0.44	402.80±50.83	238.00±26.19	10.38±17
[illegible].E.	10.69	3.94	2.62	2.00	-	15.58	13.74	1.28	1.02	-	5	26.76	11.85	
[illegible] [illegible] (n)	5	5	5	5	5	5	5	5	5	5	5	5	5	
[illegible]	B. SPRINGS ONLY 176-184	68.8-108.0	16.0-1250.0	5.0-52.0	15-135	256-550	116-184	20.0-68.6	2.7-39.9	7.00-7.60	30.0-100.0	420-3844	150-2321	1.9-[illegible]
[illegible] [illegible]S.D.	109.60±16.00	79.2±25.26	552.00±646.26	28.50±33.23	-	396.67±147.41	149.00±34.04	48.47±25.35	16.10±20.67	-	46.00±49.50	1958.67±1738.13	1172.00±1,035.87	11.82±[illegible]
[illegible].E.	9.24	14.58	573.12	23.50	-	85.11	19.66	14.64	11.93	-	35.00	1003.51	892.29	
[illegible] OF [illegible] (n)	3	3	3	3	3	3	3	3	3	3	2	3	3	

Footnote follows on page 76





NOTES:

1. These data are taken from an internal draft report drawn up jointly by several people and using various sources (e.g. FAO/UNDP/survey of Jamaica (1974), Barker (1968), Donaldson (1970) (Compiler), Investigations Bulletin (1978/1979), a copy of this draft report (Anon. 1973) is in IICA files.
2. S.D., Standard deviation, $= \pm \sqrt{\frac{X^2 - (2\ X)^2/n}{n-1}}$
3. S.E., Standard Error $= \frac{S.D.}{\sqrt{n}}$
4. N = sample size
5. S.I.U., Standard International Unit
6. μmhos/cm, resistance in micro-ohms per centimeter of water.
7. The upper part of these ranges is the effect of tidal sea-water mixing with river water.
8. The largest reading (1,250.0 mg/l) was not included in the analysis as it is incompatible with the rest of the data.
9. Means, standard deviations and standard errors were not computed for colour and pH for these qualities are based on arbitary and on logarithmic scales, respectively; the variables in both instances, therefore, are not normally distributed so that parametric statistics are inapplicable to them.

II. Geological (water flow rates) data[1]

BROWNS TOWN AND VICINITY (7km inland, (approx.)					VICINITY OF FRESHWATER SPRINGS (2.0-2.5 km inland, approx.)			VICINITY OF COASTLINE, UP TO ELEVATION OF 15 m approx. (up to 1 km inland, (approx.)							
INFLOW FROM CRETACEOUS LIMESTONE ($mx10^6$/month) ($mx10^6$/year)			RAIN RECHANGE ON KARST LIMESTONE[3] ($mx10^6$/month)		DISCHARGE OF SPRING NO.1 (MAP 1) (ft/day)	DISCHARGE OF SIX OTHER SPRINGS (ft/day)	DISCHARGE OF ALL SPRINGS (ft/day)	OUTFLOW FROM RAIN ($mx10^6$/month)[2]		RECHARGE FROM RAIN ($mx10^6$/month		RIVER SYSTEM OVERFLOW[4] ($mx10^6$/month);		ESTIMATED SUBSURFACE FLOW TO SEA (REMAINDER ($mx10^6$/month)	
YEAR	Average per month	Annual total	Average per month	Annual total	Daily average	Daily average	Daily average	Average per month	Annual total	Average per month	Annual total	Average per month	Annual total	Average per month	Annual total
1970	No data	No data	78.5±85.5 (S.E.±24.7)	942	No data	No data	No data	No data	No data	10.08±9.31 (S.E.±2.69)	121	7.00±0.00 (S.E.±0.00)	84 (est)[3]	No data	No data
1971	3.67±1.87 (S.E.±0.54)	44	49.92±41.32 (S.E.±11.93)	599	No data	No data	No data	53.58±42.77 (S.E.±12.35)	643	7.16±6.59 (S.E.±1.90)	86	7.00±0.00 (S.E.±0.00)	84	11.50±50.65 (S.E.±11.73)	+138
1972	4.17±2.52 (S.E.±0.73)	50	59.42±46.46 (S.E.±13.41)	713	50.30±3.86 (S.E.±1.93)	22.58±2.00 (S.E.±1.00)	72.88±2.52 (S.E.±1.26)	63.58±47.75 (S.E.±13.79)	763	9.42±8.91 (S.E.±2.57)	113	7.00±0.00 (S.E.±0.00)	84	31.25±45.90 (S.E.±13.25	+375

NOTE: 1. These data based on the same internal draft/report from which the data in Part 1 of Appendix B were taken.

2. Meteorological records indicate that this area receives 850-1,000 mm of rain per annum but that it is variable from year to year. For example an average value of 1966-1978 is 1,445.33±51 mm with a S.E.±298.82. Note the large S.D. and S.E. values. Annual total river system outflow in 1970 is estimated from data or only three months in that year (Oct, Nov, and Dec.).

3. A surface run-off of 65,160 acre-ft/annum has been recorded for this system but this is the sole datum available.

4. A few measured flow rates are as follows: 78, 95, and 101/ft sec, in March, June and October respectively.

APPENDIX C

Project profile submitted to IDRC

PROJECT: EXPLORATORY WORK ON CRAYFISH PRODUCTION POTENTIAL AT BELLE AIR (PEAR TREE BOTTOM), ST. ANN JAMAICA

1. The Belle Air Estate, St. Ann, Jamaica which is a government-owned property, includes the Pear Tree Bottom River, in which there are known to exist species of shrimp which have a potential for commercial exploitation.

2. Jamaica imports shrimp and the above exploitation of the potential at Pear Tree Bottom, if found to be successful, could serve the two-fold purpose of providing import substitution (replacement) and export earnings. The Prime Minister of Jamaica has expressed a keen interest in this study and eagerly awaits the results of an evaluation.

3. The IICA/Jamaica Office has obtained the services of Dr. Michael Wiles, Professor of Biology and Chairman of the Biology Department of St. Mary's University, Halifax, Nova Scotia, Canada, presently on Sabbatical leave, to identify the project and undertake preliminary work necessary to provide some of the parameters required for undertaking a pre-feasibility study.

4. In this context, discussions have been held with the Ministry of Agriculture (MINAG), Jamaica and also with Professor Goodbody, Head of the Zoology Department of the Mona Campus of the University of the West Indies, with whom it has been possible to obtain involvement and collaboration.

   Preliminary investigations indicate:

   - excellent freshwater supply, quantitatively and qualitatively,
   - proximity to sea facilities and cheap seawater system for adjustment of salinity and for biological development;
   - the existence of three (3) spp. of Macrobrachium viz M. acanthurus, M. carcinus and M. faustinum all of which can be grown to cocktail size in relatively short periods under local conditions.

5. Recommendations

   (i) A research programme to investigate the conditions required for rapid and efficient courtship, mating, incubation, hatching, larval development, metamorphosis, development, sexual maturity and adult growth of the Jamaican freshwater shrimp species

M. acanthurus, M. carcinus and M. faustinum and the exotic M. rosenbergii under prevailing Jamaica conditions.

(ii) Special studies on the cannibalistic nature of these species, predation by other species, and on other factors likely to affect development of the proposed project.

(iii) Comparison of mortality rates, mating successes and growth rates up to commercial marketing sizes.

(iv) Profitability of each of the (4) species under projected commercial farming conditions.

(v) Determination of cost benefit for each of the four (4) species.

6. The Belle Air property has an area of approximately 400 acres. It has access roads, housing, buildings, etc. suitable for modification for project use, including the siting of research facilities. Support facilities such as electricity, water, drainage and sewage outlet facilities are available.

7. The project is estimated to last a period of 3 years. Selected University Graduate students will be engaged to work under the supervision of the Resident Research Director. It is desirable that an appropriate local counterpart (professional) be assigned to the project and that provision be made for training both at that level and at that for technicians.

8. IICA sees the advantages of the proposal and of the site of operation to be:

(1) The land is available and is owned by the Government

(2) Adequate security at reasonable cost can be established

(3) The quantity and quality of freshwater are satisfactory

(4) Seawater supply for early life development of shrimps is close by

(5) Buildings and basic services are already available

(6) Conditions in the Pear Tree Bottom River for the reproduction and growth of shrimps are favourable

(7) Existing demand for freshwater shrimps is high

(8) Brood stock for the 3 indigenous freshwater Macrobrachium spp. appears to be adequate, but can readily be complemented.

(9) Collaboration with UWI is facilitated through the proximity of the site of the Discovery Bay Marine Laboratory of the U.W.I.

9. It is suggested that if accepted the pre-feasibility study should be conducted as a joint GOJ/IDRC/IICA exercise.

10. The estimated budget over a 3 year period will be US$651,100 (see details on the Annex to this note).

11. The Government of Jamaica's contribution will consist of land and in-kind provision of buildings and other relevant elements.

12. The detailed budget for this profile is an internal document of work of IICA/Jamaica.

APPENDIX D

Bibiography of scientific and technical literature on biology and culture of freshwater prawns (shrimps) and related organisms

1. ACKEFORS, H., and C.G. ROSEN, (1979). Farming aquatic animals. Ambio, 8(4): 132-143. (GA).

2. ANDERSON G., and J.A. FILLINGAME (1980). The occurrence of Macrobrachium olfersii (Wiegmann, 1936), and Macrobrachium carcinus (Linnaeus, 1758) in southern Mississippi, U.S.A. (Decapoda, Palaeomonidae). Crustaceana, 39(1): 90-94. (GB).

3. ANDREWS, J.A., L.V. SICK, and G.J. BAPTIST (1972). The influence of dietary protein and energy levels on growth and survival of penaeid shrimp. Aquaculture 1: 341-347 (ND).

4. ANON. (1979a) Macrobrachium rosenbergii culture in Polynesia, pH control in experimental pond waters by phytoplankton limitation with an algicide. Proc. 10th Ann. Meet. World Maricult. Soc.: 392-402 (GA; RCR).

5. ANON. (1979b) Intensive larval culture of Macrobrachium rosenbergii a cost study. Proc. 10th Ann. Meet. World Maricult. Soc.: 429-434 (E; LC).

6. ANON. (1980). Etude des possibilites d'elevaga de la crevette d'eau douce Macrobrachium rosenbergii en Nouvelle Caledonie (d'apres les essais d'elevage relises de mai 1977 a decembre 1979. (Feasibility of the culture of the freshwater prawn Macrobrachium rosenbergii in New Caledonia (after cultural testing from May 1977 to December 1979) Rapport Monographique de la Nouvelle Caledonie: 60 pp (RCR).

7. AQUACOP (Tahiti, Polynesie, Francaise) (1976) Incorporation de proteines vegetales dans un aliment compose pour crevettes Macrobrachium rosenbergii: (Incorporation of vegetable proteins into a diet for the freshwater prawn Macrobrachium rosenbergii). Aquaculture, 8(1): 71-80. (ND).

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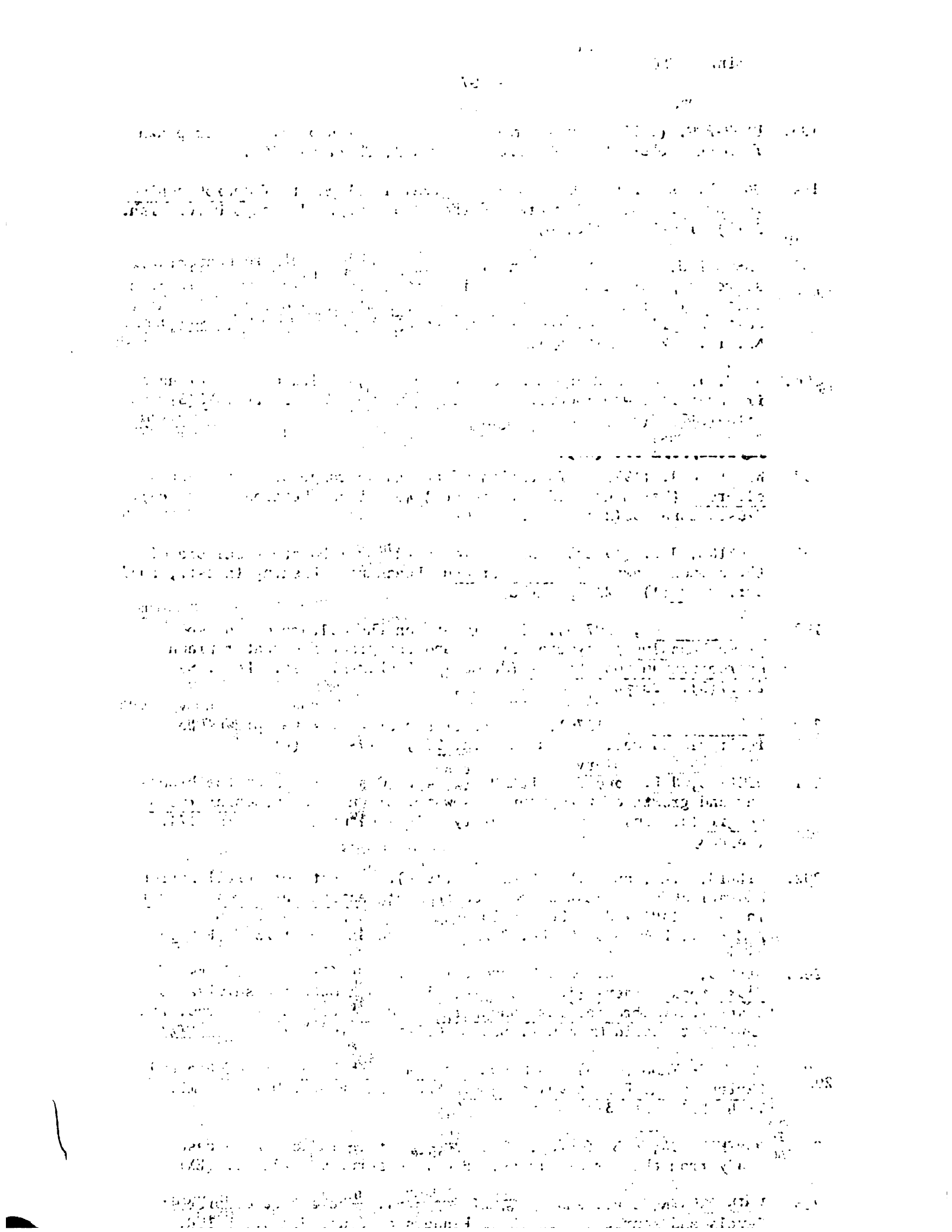


EXPLANATION OF ABBREVIATIONS REFERING TO TOPICS IN BIBLIOGRAPHIC REFERENCES GIVEN AFTER EACH ENTRY

(BE) Bioenergetics

(BF) Biological filters

(CP) Commensal and/or parasites

(CT) Chemotherapy

(D) Disease

(E) Economics of production

(ENG) Agricultural engineering

(EX) Exotic species

(FH) Fertilization and Harvesting

(G) Growth

(GA) General aquaculture

(GB) General Biology

(GM) The genus Macrobrachium

(GN) Genetics and/or breeding

(IC) Instraspecific competition

(JN) Juvenile nursery production

(LC) Larval culturing

(LD) Larval development

(MC) Mass Culturing

(MM) Moulting and mortality

(ND) Nutrition and diet

(P) Physiology

(PC) Polyculture

(PLR) Post-larval rearing

(PM) Biological population models

(Pr) Predation

(RB) Reproductive behaviour

(RCR) Rearing and culturing of Macrobrachium rosenbergii

(RD) Research and development

(Ref) A reference work

(S) Spawning

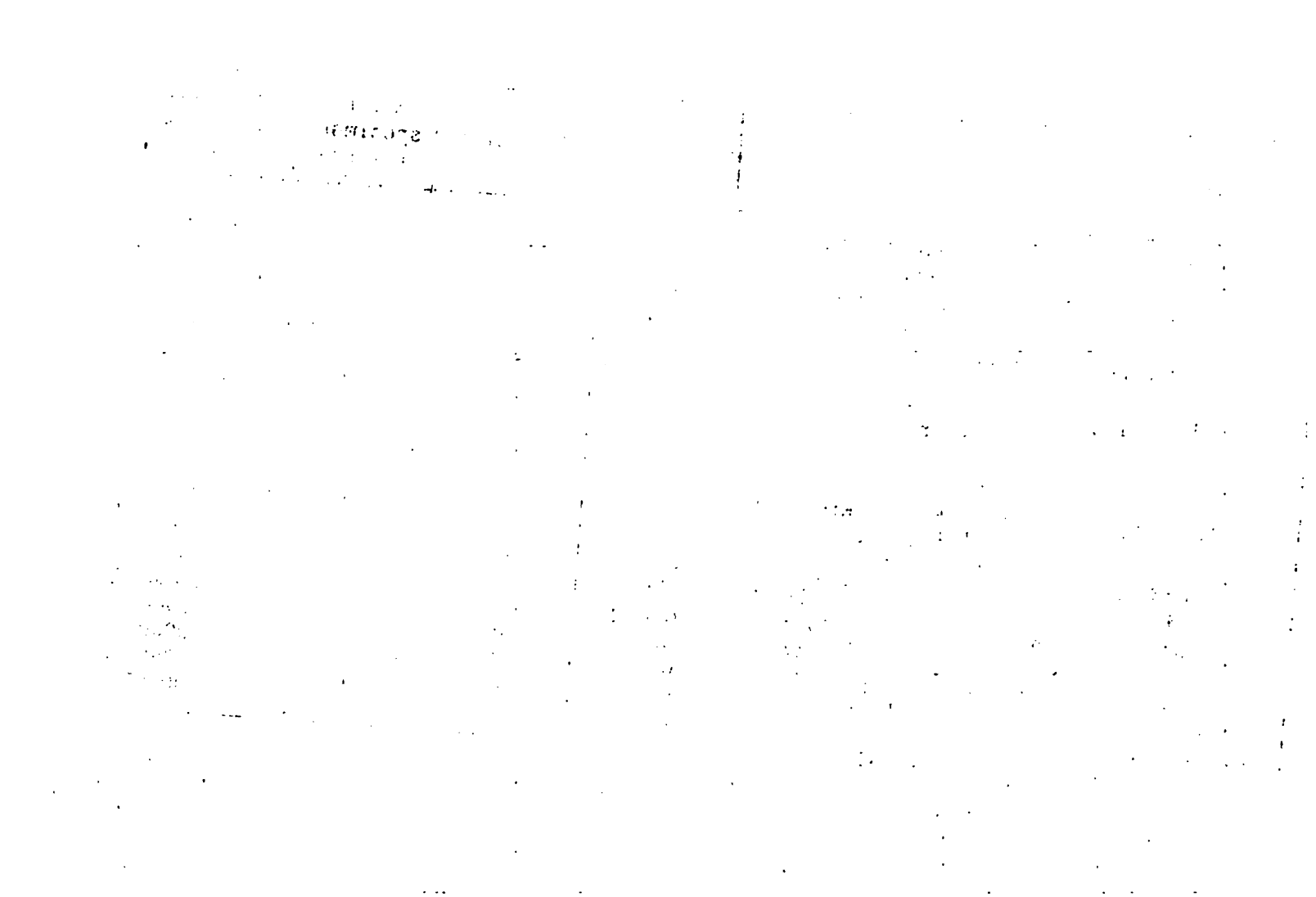
APPENDIX E

Pear Tree Bottom River System, totals and proportions of crustaceans collected by species

Species	Site Name	Site Code	Site Number	Number of Specimens in sample	Proportion of sample by species
M. acanthurus	Parsons Creek	PRBS	1	0	0.0000
M. carcinus	Parsons Creek	PRBS	1	0	0.0000
M. faustinum	Parsons Creek	PRBS	1	19	0.8261
J. serrei	Parsons Creek	PRBS	1	0	0.0000
P. mexicana	Parsons Creek	PRBS	1	0	0.0000
X. elongata	Parsons Creek	PRBS	1	4	0.1739
M. acanthurus	Grassy Creek	GCSW	2	2	0.0870
M. carcinus	Grassy Creek	GCSW	2	0	0.0000
M. faustinum	Grassy Creek	GCSW	2	18	0.7826
J. serrei	Grassy Creek	GCSW	2	0	0.7826
P. mexicana	Grassy Creek	GCSW	2	0	0.0000
X. elongata	Grassy Creek	GCSW	2	3	0.1304
M. acanthurus	Pool Swamp A	PSA	3	0	0.0000
M. carcinus	Pool Swamp A	PSA	3	0	0.0000
M. faustinum	Pool Swamp A	PSA	3	0	0.0000
J. serrei	Pool Swamp A	PSA	3	0	0.0000
P. mexicana	Pool Swamp A	PSA	3	0	0.0000
X. elongata	Pool Swamp A	PSA	3	0	0.000
M. acanthurus	Lock Spillway	LS	4	2	0.0690
M. carcinus	Lock Spillway	LS	4	23	0.7931
M. faustinum	Lock Spillway	LS	4	0	0.0000
J. serrei	Lock Spillway	LS	4	0	0.0000
P. mexicana	Lock Spillway	LS	4	0	0.0000
X. elongata	Lock Spillway	LS	4	4	0.1379
M. acanthurus	Rowe's Canal Coconut Grove	RCCG	5	0	0.0000
M. carcinus	Rowe's Canal Coconut Grove	RCCG	5	7	0.5000
M. faustinum	Rowe's Canal Coconut Grove	RCCG	5	0	0.0000
J. serrei	Rowe's Canal Coconut Grove	RCCG	5	0	0.0000
P. mexicana	Rowe's Canal Coconut Grove	RCCG	5	0	0.0000
X. elongata	Rowe's Canal Coconut Grove	RCGG	5	7	0.5000
M. acanthurus	Pear Tree River Main Outlet	PTRMO	6	1	0.0039
M. carcinus	Pear Tree River Main Outlet	PTRMO	6	10	0.0394
M. faustinum	Pear Tree River Main Outlet	PTRMO	6	0	0.0000
J. serrei	Pear Tree River Main Outlet	PTRMO	6	20	0.0787
P. mexicana	Pear Tree River Main Outlet	PTRMO	6	0	0.0000
X. elongata	Pear Tree River Main Outlet	PTRMO	6m	222	0.8740
Unidentified	Pear Tree River Main Outlet	PTRMO	6	1	0.0039
M. acanthurus	Roger Clarke's Ditch	RCD	7	0	0.0000
M. carcinus	Roger Clarke's Ditch	RCD	7	0	0.0000
M. faustinum	Roger Clarke's Ditch	RCD	7	0	0.0000
J. serrei	Roger Clarke's Ditch	RCD	7	0	0.0000
P. mexicana	Roger Clarke's Ditch	RCD	7	0	0.0000
X. elongata	Roger Clarke's Ditch	RCD	7	11	1.0000

APPENDIX E (cont'd)

Species	Site Name	Site Code	Site Number	Number of specimens in sample	Proportion of samples by species
M. acanthurus	Pear Tree Bottom River Proper, Lower Reaches	PTBRPLR	8	0	0.0000
M carcinus	Pear Tree Bottom River Proper, Lower Reaches	PTBRPLR	8	34	0.2.36
M. faustinum	Pear Tree Bottom River Proper, Lower Reaches	PTRBRPLR	8	0	0.0000
J. serrei	Pear Tree Bottom River Proper, Lower Reaches	PTBRPLR	8	102	0.6108
P. mexicana	Pear Tree Bottom River Proper, Lower Reaches	PTBRPLR	8	0	0.0000
X. elongata	Pear Tree Bottom River Proper, Lower Reaches	PTBRPLR	8	31	0.1856
M. acanthurus	Rowe's Canal Upper Site	RCUS	9	2	0.0625
M. carcinus	Rowe's Canal Upper Site	RCUS	9	2	0.0625
M. faustinum	Rowe's Canal Upper Site	RCUS	9	0	0.0000
J. serrei	Rowe's Canal Upper Site	RCUS	9	0	0.0000
P. mexicana	Rowe's Canal Upper Site	RCUS	9	0	0.0000
X. elongata	Rowe's Canal Upper Site	RCUS	9	28	0.8750
Unidentified	Rowe's Canal Upper Site	RCUS	9	0	0.0000



APPENDIX F

ANNEX TO NOTE

SUGGESTED BUDGET OVER THREE YEARS

FIGURES IN 1982 U.S. DOLLARS

FIRST YEAR

		$
1.	PERSONNEL	
(i)	International	
	Resident Research Director, Ph.D in aquaculture or biology; senior scientist with proven record of administration and research.	
	Salary and fringe benefits	50,000
	Technical supervisor; MSc or professional technical qualifications and experience in aquaculture	
	Salary and fringe benefits	35,000
(ii)	Local	
	Professional Counterpart	15,000
	Two clerical assistants (Senior & Junior) with skills and experience in typing, shorthand, speedwriting, filing and reception; full time employees	18,000
	Field trainee; with capacity for outdoor work, including manual labour, inspection and security; full time employee	5,000
	SUBTOTAL	123,000

2. COST OF OPERATIONS

Equipment and Supplies	$ $
Pumping System renovation	25,000
Pond construction and drainage installation	24,000
Experimental facilities	15,000
Generator	12,000
Office Equipment	10,000
Compound microscope	8,000
Stereoscopic Microscope	6,000
Compressor	6,000
Water Quality testing apparatus	5,000
Salinity, Conductivity, Temperature Meter	3,000
Suspended solids recorder	2,000
Sampling equipment	2,000
Office supplies	2,000
SUBTOTAL	120,000

3. GENERAL SERVICES

Automobile; Jeep or 4-wheel drive half ton truck	12,000
Light, power, fuels etc.	10,000
Gasoline and truck maintenance	6,000
Travelling and subsistence	1,000
Rent	5,000
Maintenance	5,000
Insurance	5,000
SUBTOTAL	44,000
FIRST YEAR SUBTOTAL	297,000
Administration and Technical Supervision (15%)	43,050
TOTAL FOR FIRST YEAR $	330,050

SECOND YEAR

1.	PERSONNEL		
	(i) International Professional (Director)		50,000
	International Professional Supervisor		35,000
	(ii) Local		
	Professional Counterpart		15,000
	Farm Manager		8,000
	Technical Assistant		6,000
	2 Clerical Assistants		18,000
	Field Trainee		5,500
	Field Hands		4,500
		SUBTOTAL	142,000
2.	COST OF OPERATIONS		
	Equipment and Supplies		
	Fiberglass Tanks		10,000
	Experimental facilities extension		10,000
	Office equipment		6,000
	Water quality testing supplies		2,000
	Sampling equipments additions		2,000
	Office Supplies		2,000
	Harvesting seine nets		2,000
	Fiberglass tanks ancillaries		1,000
	Scholarships		10,000
	Training	SUBTOTAL	45,000

3. GENERAL SERVICES

Light, power, fuels, etc.	10,000
Gasoline and truck maintenance	6,000
Equipment depreciation	5,000
Pond maintenance	3,000
General repairs	3,000
Rent	5,000
Maintenance	5,000
Travelling and Subsistence	1,200
Insurance	5,000
SUBTOTAL	43,200
SECOND YEAR SUBTOTAL	230,200
Administration and Technical Supervision (15%)	34,530
TOTAL FOR SECOND YEAR	264,730

THIRD YEAR

		$
1.	PERSONNEL	
(i)	International Professional (Director)	50,000
	International Professional Supervisor	38,000
(ii)	Local	
	Professional Counterpart	15,000
	Farm Manager	8,000
	Technical Assistant	6,000
	2 Clerical Assistants	18,000
	Field trainee	5,500
	Field Hands	4,500
	SUBTOTAL	145,000
2.	COST OF OPERATIONS	
	Equipment and Supplies	
	Demonstration facilities for farmers	25,000
	Operating experimental supplies	5,000
	Office equipment	3,000
	Water quality testing supplies	2,000
	Sampling equipment	2,000
	Office supplies	2,000
	Seine nets	1,000
	Tank ancillaries	1,000
	Scholarships	3,000
	Training	5,000
	SUBTOTAL	49,000

3. GENERAL SERVICES

Light, power, fuels etc.		10,000
Gasoline and truck maintenance		6,000
Equipment depreciation		5,000
Pond maintenance		4,000
General repairs		5,000
Rent		5,000
Maintenance		5,000
Travelling and Subsistence		1,400
Insurance		5,000
	SUBTOTAL	46,400
	THIRD YEAR SUBTOTAL	240,400
Administration and Technical Supervision (15%)		36,060
	TOTAL FOR THE THIRD YEAR	276,460

PROPOSED PROJECT BUDGET

	EXPENSES	YEAR 1	YEAR 2	YEAR 3	TOTAL
1.	Personnel	123,000	142,000	145,000	408,000
2.	Equipment & Supplies	120,000	45,000	49,000	214,000
3.	General Services	44,000	43,200	46,400	133,600
4.	Administration & Technical Supervision	43,050	34,530	36,060	113,330
		330,050	264,730	276,460	868,930

TOTAL COST FOR THREE (3) YEARS US$868,930

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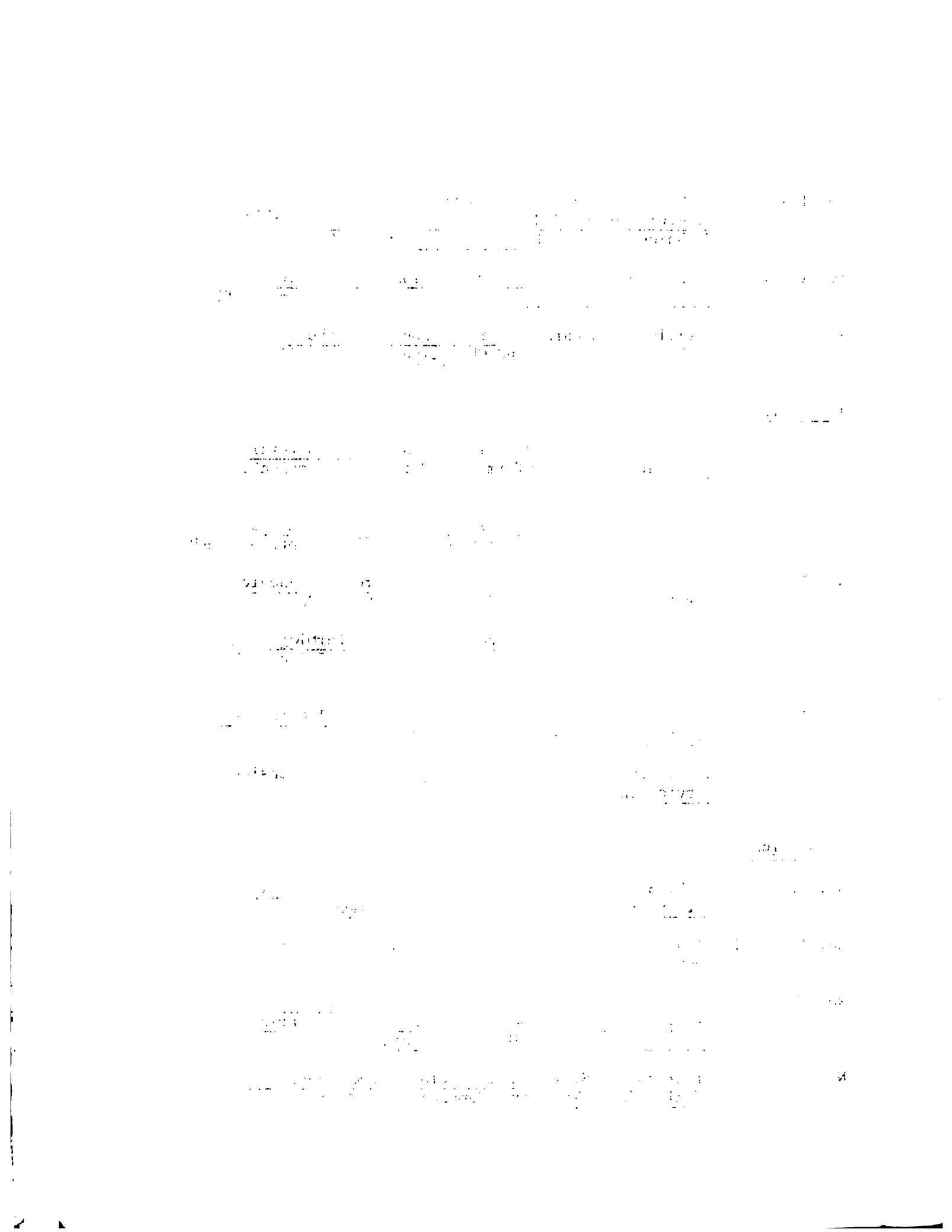

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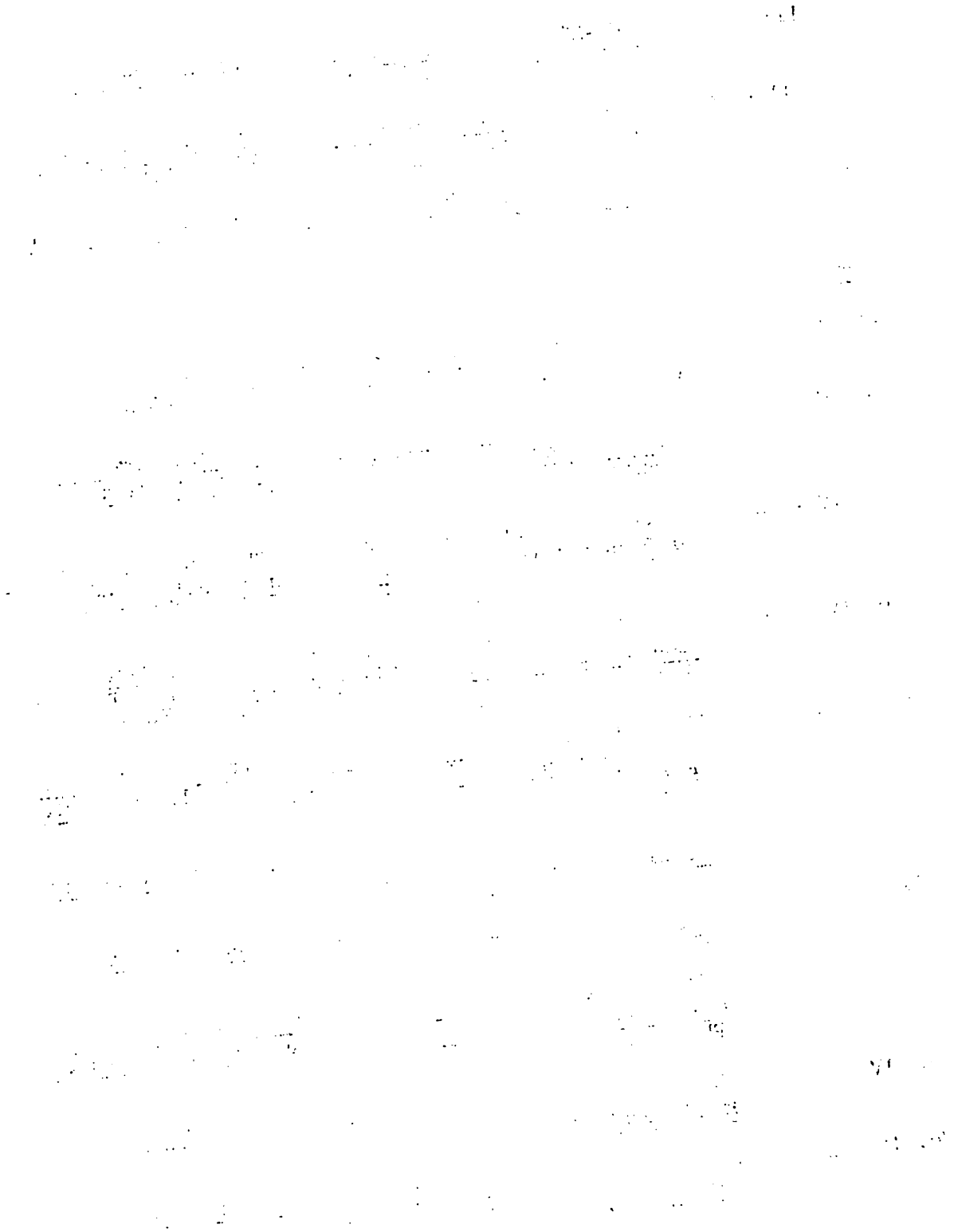

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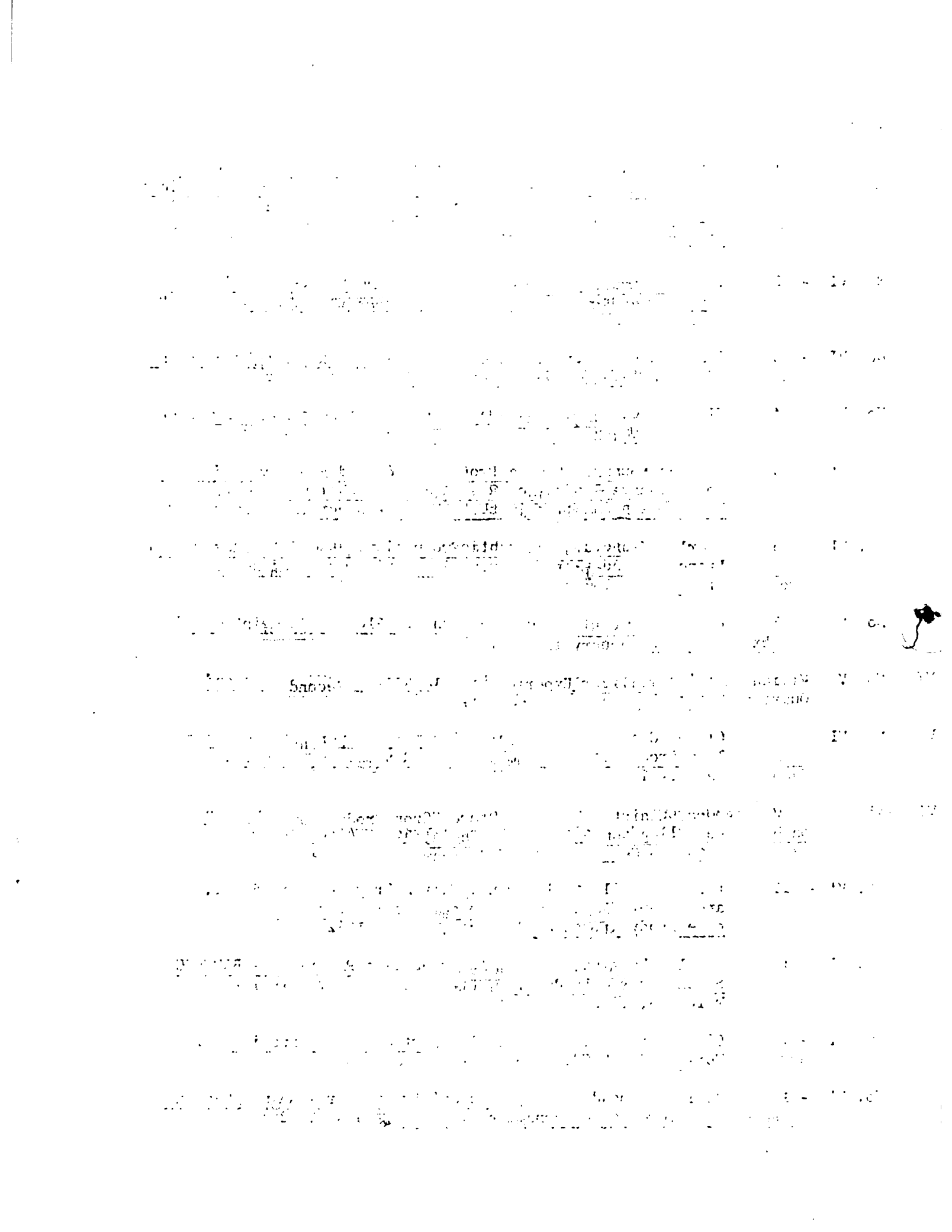

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