Coastal Management. Volume 17, pp. 119-127
Printed in the U.K. All rights reserved.

0892-0753/89 $3.00 + .00
Copyright 0 1989 Taylor & Francis

Aquaculture and Coastal Zone Management in Bangladesh

A.K.M. BASHIRULLAH

Institute Oceanografico, Universidad de Oriente, Cumand 6101, Venezuela

N. MAHMOOD A.
K.M.A MATIN

Institute of Marine Sciences, University of Chittagong,
Chittagong, Bangladesh

Abstract *This article gives a brief survey of the present status of brackish water shrimp culture and its increased importance in the economy of Bangladesh. The high and increasing population density is forcing people to engage in agriculture and aquaculture in low lying coastal areas where they are exposed to cyclones and tidal floods. Colonization of these areas has, however, led to deforestation and other adverse effects on the ecosystem. A policy of intensive farming using the most modern methods is necessary to reduce these effects caused largely by extensive low yield practices in a country where available land is extremely limited. It is proposed that the government augment its present policy of reforestation and take other steps to conserve the environment and to reduce siltation and erosion. Whereas the construction of coastal embankments to protect human life and property is necessary, much greater efforts should be taken to realize these engineering projects with minimum damage to the environment. A proper coastal zone management policy requires increased coordination among the numerous governmental agencies and the collection of sufficient reliable data on the ecosystem.*

Keywords aquaculture, Bangladesh, coastal zone management

Introduction

In recent years much attention has been given to aquaculture in many parts of the world and especially in the developing tropical countries. There are at least three very good reasons for this increased interest: aquaculture can help: (1) to meet the alimentary needs of the rapidly growing population, (2) to provide employment, and (3) to earn foreign exchange. Bangladesh, a densely populated riverine country, provides a typical example of the recent emphasis in aquaculture. Fishery is second to agriculture in the agro-based economy, contributes 2.9 percent to the nation's foreign exchange earnings, and provides 80 percent of the per capita animal protein consumption. Approximately 8 million people derive their livelihood from fishing and related activities.

Aquaculture in Bangladesh can be divided into (1) freshwater pond culture and (2) brackish water shrimp culture. Freshwater pond culture has been practiced in the nation for centuries. More recently, the culture of fish and shrimp in brackish water ponds has emerged as a highly lucrative business. The rapid expansion of shrimp culture in the past

few years has been remarkable. From less than 20,000 ha. of brackish water fish ponds in 1980, the area has expanded to 70,000 in 1985 and is expected to exceed 90,000 in 1990 and 130,000 ha. by the year 2005 (Man, 1984). The production of cultured shrimp has grown from less than 1,000 mt (metric tons) in 1980 to over 7,000 mt in 1986. The third five-year-plan (TFYP, 1985-90) attaches high priority to brackish water farming. The existence of large high potential coastal areas with favorable ecological conditions justifies the priority given to brackish water farming. By the end of the plan, shrimp production for export is expected to reach 34,000 mt, of which about 60 percent should be from aquaculture.

Shrimp exports increased from near zero in the late 1960s to Tk. 22.2 million in 1972-73 and exceeded Tk. 2,730 million in 1985-86. (In 1987, $1 U.S. was worth 33 Bangladesh takas, a rate that has remained relatively steady for the last few years.) In terms of export earnings, shrimp culture is third in importance, exceeded only by textiles and jute. It has been claimed that, with increased area and improved management, shrimp culture would be able to rival the two traditional Bangladesh export lines. Such optimism appears to be reasonable when we remember that Bangladesh has approximately 2.5 million ha. of coastal tidal lands, and that according to the Asian Development Bank, the present yield of 250 kg. per ha. could be increased to 2,000 kg. per ha. with the adoption of modern methods of aquaculture (ADB, 1985).

However, the need to protect the country from periodic cyclones and tidal flooding has caused the government to embark on an extensive construction program of coastal embankments and river dams, which, besides reducing the loss in life and property, has brought other socioeconomic benefits to the millions living in the rural coastal areas. Unfortunately, this program has resulted in ecological degradation, reduced the coastal tidal plains, and damaged the habitual nursery grounds of fish and shrimp.

The purpose of this article is, first, to review the present state and potentialities of aquaculture, and especially of shrimp farming, in the coastal areas of Bangladesh. We then consider the interaction and rivalry between flood control ("engineering of the landscape"), agriculture, aquaculture, and demographic pressures. Finally, we briefly study some of the proposals to find and implement an optimized compromise between competing factors.

Methodology

In the 10-month period from October 1986 to July 1987, we traveled extensively along the coastal areas of Bangladesh, interviewed farmers and laborers, and made on-site inspections of shrimp culture ponds and of collecting areas of shrimp postlarvae. We also questioned private owners and long-term leaseholders of government land about the different technical and economical problems that they confronted. During field research, we measured the pH of the soil and water and observed the systems of harvesting, stocking, and transport as well as the methods of construction of dykes and sluice doors.

Valuable information was provided by officials responsible for the different fishery projects of the Directorate of Fisheries (DOF), the Bangladesh Agriculture Research Council (BARC), and the Bay of Bengal Program (BOBP) of the Food and Agriculture Organization (FAO). These agencies provided us with valuable documents from the Asian Development Bank (ADB), the Swedish International Development Agency (SIDA), and the Master Plan Organization (MPO) of the Ministry of the Irrigation, Water

Development, and Flood Control. Statistical data were obtained from the DOF Statistical Bureau and the Export Promotion Bureau of the government.

Shrimp Biology

Of all the penaeids shrimp present in the Bay of Bengal, *Penaeus monodon* (the so-called tiger shrimp) is economically the most important. The biology of *P. monodon* resembles that of all the other penaeids. The *P. monodon* matures in about 10 months; the adult dwells on the bottom and spawns in the offshore, with the female releasing some 500,000 eggs, which hatch in about 12 hours. The hatched larva metamorphoses into a postlarva in 10 to 12 days after passing through 11 successive stages accompanied by molting. There are five nauplius, three protozoea, and three mysis stages. The molt following the last mysis stage completes the metamorphis into a postlarva.

The postlarva, although very tiny, has the general appearance of an adult. After about 2 weeks, the young postlarva starts migrating toward brackish water areas in search of mangrove or other suitable habitats, which can serve as its nursery or feeding grounds. The postlarva passes through several stages, each characterized by a particular rostral formula. The shrimp is considered a juvenile when it has achieved its complete rostral formula. It becomes a subadult on the completion of the differentiation of the external sexual organs (petasma in the male and thelycum in the female). The subadult feeds mainly on microscopic organisms, small crabs, molluscs, etc., and occasionally indulges in cannibalism. The shrimp is classified as an adult when it is able to reproduce. The adult mates in the estuary with the female becoming fully ripe after migrating to the offshore where it first spawns at about 10 months (Yap, 1980; Garcia and Reste, 1981; Motoh, 1981).

Coastal Shrimp Culture

There are, at present, four main types of shrimp culture in Bangladesh: (1) salt production cum shrimp-finfish culture, (2) shrimp-finfish culture, (3) "bheri" culture, and (4) shrimp monoculture.

Salt cum shrimp-finfish culture

During the 1960s, coastal aquaculture in the Chittagong region was normally a function of salt production. During the monsoon season, some salt producers would utilize their salt pans mainly for subsistence fishing but also occasionally to supplement their income through the sale of the shrimp and finfish surplus. With the increase of demand and price, this practice gained increased acceptance in the region.

Shrimp-finfish culture

This type of shrimp culture in which the harvest of finfish is secondary is mainly found in the low lying areas within and outside the coastal embankment and in the mangrove areas of the Cox's Bazar district. Excepting the ponds located outside the barrier, these farms operate almost the whole year round.

Bheri culture

Almost 50 percent of the shrimp farms in the Khulna region are of the so-called bheri type. Schuster (1952) has given a detailed description of the bheri system (also called gher in some parts of Bangladesh): An area is impounded by earthen dykes with facilities for tidal waters, and is exploited for fish and shrimp culture from January to July and for rice cultivation from August to December.

Shrimp monoculture

As a result of the large export market for tiger shrimp, monoculture of this species started in 1985 in the coastal regions both on private and on leased public lands. The size of the ponds vary from 8 to 200 ha., with an average of 28 ha. (MPO, 1986). Typically, each farm consists of one large pond equipped with wooden or concrete sluice gates. In order to exclude large predators, the gates are normally fitted with split-bamboo screens, which, however, are too coarse to be effective against the larval form of predators. The main predator is a carniverous fish, *Lates calcarifer,* whose larvae enter the pond with the tidal water, and outgrow and voraciously devour the shrimps. Recently, some farmers have started passing the tidal water through fine-meshed screens to exclude totally the entrance of predator larvae. In this case, the ponds are stocked with postlarvae or juveniles of *P. monodon* either collected from the nearby estuaries or purchased from seed suppliers.

Since 1986 a few farmers have begun liming and fertilizing the ponds with cow dung and chicken droppings in order to increase the primary productivity of the water. Inorganic fertilizers have also been used with positive results. Supplementary feed such as rice and wheat brans, mustard oil cake, fish meal, trash fish, etc., have been used but on a limited scale due to the high cost of the ingredients.

In all the above types of farming, the sources of the shrimp seed is the wild postlarvae and juveniles collected from the estuaries or shallow coastal region of the Bay of Bengal. The price and supply of the seeds vary with the seasonal abundance of the wild fry.

Constraints of Aquaculture

As with any other industry, the rapid development of aquaculture has been accompanied by a variety of problems and constraints. Ideally, these problems should be fully analyzed from the outset so that appropriate countermeasures can be applied, but this seldom occurs even in the most advanced countries and much less in the developing countries due to bureaucratic bottlenecks. The most important problems that we have observed are the following: (1) land use rights and policy, (2) technical assistance, (3) credit facilities, (4) availability of shrimp seed, (5) law and order, and (6) rivalry with agriculture and adverse ecological effects.

Land use rights and policy

Shrimp farmers usually exploit leased private land available only on a short-term basis of from 1 to 3 years. Public land is leased for 5 years, renewable for an equal period. In 1985, the government confiscated large estates and split them into smaller plots of 4 and 12 ha., which were later distributed to the public. The farmers are hesitant to invest heavily in permanent structures and land improvement due to the uncertainty of their land

rights. As well, a clear-cut land-use policy based on land topography, soil quality, hydrobiology, and environmental factors is lacking.

Technical assistance

Shrimp farming in Bangladesh is still mainly traditional. However, with the help of an FAO/SIDA supported demonstration farm at Satkhira (FAO, 1985) and through a series of short training courses, the government has introduced a number of improved culture techniques such as selective stocking, pest control screening, nursery ponds, pond preparation, and supplementary feeding.

Nevertheless, the application of improved techniques in most private farms is still haphazard and seldom adapted to the specific farm conditions. The government and FAO shrimp experts seldom visit individual farms to offer on-the-spot advice, and most farmers continue to lack sufficient knowledge of basic techniques of aquaculture. In our opinion, the most important problem in the field is the lack of knowledge of pest control. It should be pointed out, however, that a few affluent farmers are hiring university graduates with experience in aquaculture to help solve some of the technical field problems and to apply more modern methods.

Credit facilities

The smaller farmer does not have the ready capital to invest in the construction of dykes, sluice gates, etc.; at times, he is even unable to cover operating expenses. He is thus forced to turn to the money lenders and pay exorbitantly high interest rates. To alleviate the problem, the Asia Development Bank is financing a large Aquaculture Development Project (ADP) in Bangladesh, which has among its principal functions the granting of credit at reasonable terms (ADB, 1985). Nevertheless, the rural people have received little benefit from this project since they are usually unable to fulfill the credit conditions. In addition, the ADP appears to lack a coherent lending policy and often delays credit approval due to bureaucratic inertia.

The problem of credit may well become more acute in the coming years since until now most of the development has taken place in areas already cleared for paddy cultivation within polders or for salt pans. The conversion of these plots to shrimp culture has required relatively low capital investment and the returns have been high. Such favorable conditions have by now more or less come to an end.

Availability of shrimp seeds

The rapid expansion of the farming areas coupled with the recent trend toward selective shrimp monoculture has resulted in a tremendous demand for tiger shrimp postlarvae. Rough estimates suggest that in 1986 over 3 billion postlarvae of *P. monodon* were collected from the wild population, of which about 40 percent died because of improper handling and inadequate transport. It is expected that the demand for seed will increase each year while supplies will decrease due to the uncontrolled collecting of the postlarvae in the estuaries and heavy trawler fishing of the adults. At the moment, only one private farmer is planning to establish the first hatchery for *P. monodon* in the country.

Law and order

The farms are located in distant low lying coastal areas without proper communication facilities and totally lacking in electricity. Such conditions are ideal for the bandits who rob either the harvest or else the cash the farmer receives for his produce.

Rivalry with agriculture and adverse ecological effects

The rapid expansion of low yield extensive shrimp aquaculture has made inroads on the extremely limited amount of available land and in some cases has resulted in conversion of agriculture areas, especially of grazing fields, to ponds for shrimp culture causing, for example, a sharp decrease in livestock in the Khulna region. Shrimp aquaculture has also been accompanied by destruction of the coastal marshes and mangrove forests. In our opinion, it is necessary to promote intensive shrimp aquaculture based on modem technology in order to limit as much as possible the incursions on agriculture areas and damage to the ecology.

Aquaculture, Agriculture, and Coastal Zone Management

The coast of Bangladesh stretches 710 km. from Teknaf in the southeast to Khulna in the southwest. The coast is crisscrossed by a network of complex estuarine systems created by the Ganges, Bramaputra, Karna-phuli, Megna, Mathamuhuri, and other rivers, which open into the Bay of Bengal (Figure 1). Detailed geomorphological features have been published by Coleman (1969), Curray and Moore (1971), Rashid (1977), Pramanik (1984), and others.

The region bordering the Bay of Bengal supports more than 600,000 ha. of salt-tolerant mangrove forests, which form a transition zone or swamp between the terestial and marine environment and serve as a supportative environment for a portion of the life cycle of many migratory birds and fishes. The destruction of these swamps has had adverse effects on both artisanal and commercial fishing and undoubtedly has had other unfavorable ecological effects that have not yet been sufficiently studied. The interested reader can consult the studies of these forests by Rashid (1977), Mahmood and Khan (1980), Karim and Khan (1980), Ahmed (1981, 1984), Rabanal (1984), and Chaffey *et al.*, (1985).

The entire coastal zone is subject to violent storms and tropical cyclones during the premonsoon (March—April) and postmonsoon (October—November) seasons. The cyclones are often associated with huge tidal waves causing enormous loss of human life and extensive damage to property and agriculture crops over and above the havoc caused by the monsoon floods, which regularly inundate large portions of the country. In fact, the low lying coastal region of the Bay of Bengal should be considered uninhabitable, and, indeed, there is hardly any industrial or urban development. Nevertheless the high population density (more than 100 million people squeezed into 144,000 km^2, about the area of Iowa) is gradually forcing the "excess" population into the low lying coastal areas where they engage in agriculture, aquaculture, and salt production.

To understand the significance of the population density of Bangladesh, it should be noted that it is almost twice that of New Jersey, three times that of Massachusetts, and five times that of New York State. Turning to Europe, the population density in Bangla-

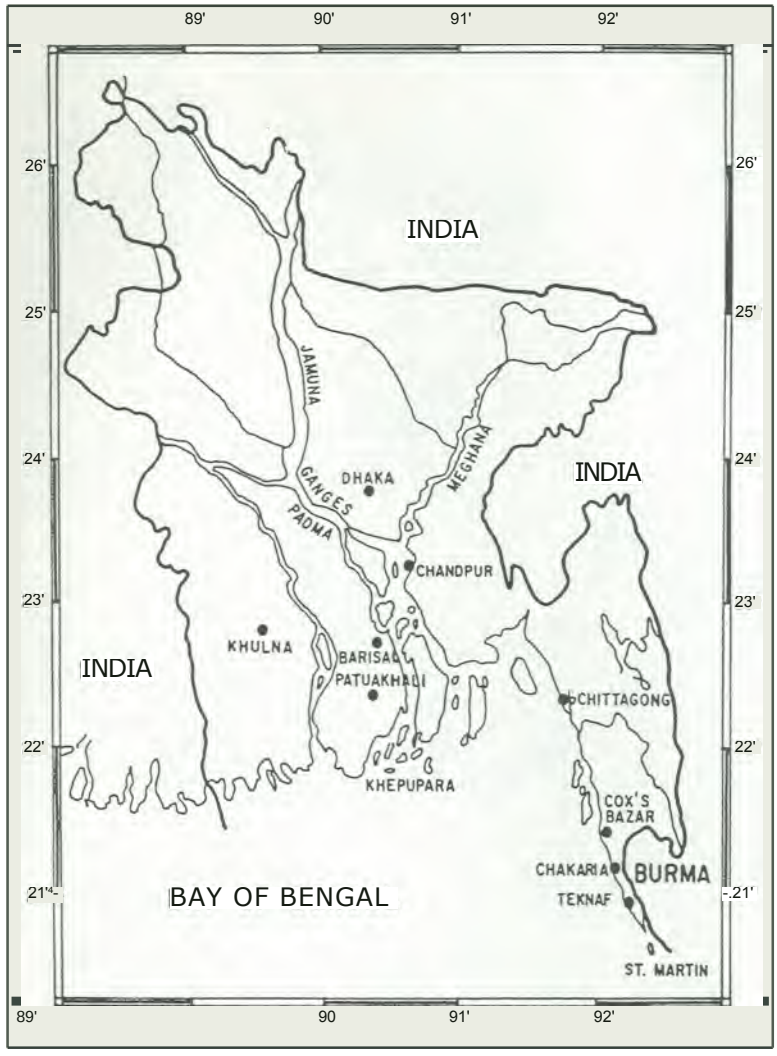

Figure 1. Map of Bangladesh, showing main coastal cities and rivers.

desh is 1.5 times that of The Netherlands and three times that of Great Britain. Worse still, despite the government's success in reducing the birth rate, the population of Bangladesh is still growing at about 2 percent per annum, whereas the growth rate is less than 1 percent in the United States and about zero in Great Britain and The Netherlands. Of far greater significance is the fact that Bangladesh does not have the industry that could provide gainful employment in large cities nor does it have the advanced technology needed to provide decent living conditions in high-density urban centers. As a result, economic necessity is forcing millions to work and live on a "temporary" seasonal basis in the low lying coastal areas despite the risks of natural calamities and the lack of minimum living conditions.

Responsibility for trying to solve the numerous complex problems of the coastal regions is divided among six governmental ministries: The Ministry of Land and Revenue

is in charge of leasing the land to the public. The Directorate of Forestry of the Ministry of Agriculture and Forestry is responsible for the management, exploitation, and reforestation of the mangrove forests. Coastal aquaculture and marine fishery come under the jurisdiction of the Ministry of Fisheries. All marine affairs, including management of the coastal zones, is the responsibility of the Department of Science and Technology of the Ministry of Education, whereas Marine Science Education belongs to the Department of Education of the same ministry. The Ministry of Irrigation, Water Development, and Flood Control oversees the construction of embankments and cross-dams. Finally, the powerful Ministry of Planning has the final say on any project that the other five ministries might suggest.

Normally, the senior officers in the different ministries have had little technical or scientific training and have little understanding of ecological problems. As well, there is often a lack of sufficient reliable data necessary for decision making. These factors, combined with a complicated ministerial structure, results in numerous bureaucratic bottlenecks seriously delaying the approval of many urgent projects. Final approval, when it does come, is almost always based on economic and political benefits with little attention paid to ecological factors. For example, the construction of cross-dams and embankments, although necessary for reducing the devastation of flooding, has been carried out with little or no consideration to the ecological damage resulting from the reduction and elimination of water fluctuation necessary for the preservation of valuable marsh grasses and of migratory species such as the prawn, *Machrobrachium*, and the fish, *Hilsa.* Solutions to such complex problems, involving the rival claims for the protection of life and property, for the promotion of agriculture and aquaculture, and for the preservation of the ecological balance, are extremely difficult and never completely carried out: nevertheless, the government should make more serious efforts in considering the countries urgent problems in their entire complexity.

One of the main and most urgent problems is deforestation caused by collection of wood for fuel and by clearing in order to extend agriculture lands, salt pans, and, more recently, ponds for shrimp culture. The multiple pernicious effects of deforestation are, in general, sufficiently well known that there is no real need to list them in any detail here. Nevertheless, we should mention the increase in the sediment load and discharge in the Mathamuhuri basin where the mean annual rainfall is 3,500 mm. Siltation has increased to such an extent that the ferry service between Chittagong and Cox's Bazar has been suspended since 1980 due to the shallowness of the Moheskhali-Kutubdia channel.

On the positive side, the government is promoting an extensive plan of reforestation that has included the planting of 24,000 ha. of mangrove forests, but much more remains to be done. Rabanal (1984) has suggested the creation of buffer strips 100 meters wide along the sea coast and along the banks of the principal waterways and 30-50 meters wide along the secondary tributaries. In our opinion, it would be beneficial if neighboring ponds were separated by lanes of mangroves and other suitable marsh grasses. The government could condition the granting of leases of public land on the creation and maintenance of such protective zones. We also suggest the creation of a pilot integrated mangrove-shrimp culture project, which could serve as a training farm to increase the awareness of the population to the necessity of the conservation of the coastal marshes and mangrove forests.

However, the successful implementation of the most advanced and effective policies will unfortunately result only in short-term benefits unless Bangladesh is able to reduce its birth rate drastically. If this is not achieved in the near future, nothing can prevent the country from becoming a Malthusian nightmare.

References

A.D.B. 1985. Bangladesh Second Aquaculture Project. Report prepared by Aquatic Farm Ltd. for the Asia Development Bank.

Ahmed, M.K. 1981. "Behundi Net Fisheries in the Brackish Water Areas of Satkhira with Emphasis on Bionomics and Mortality of Shrimps." *Freshw. Fish. Res. Stn.* Chandpur, Bangladesh, no. 3, 42 pp.

Ahmed, M.K. 1984. "Behundi Net Fisheries in the Brackish Water of Patuakhali with Emphasis on Bionomics and Mortality of Shrimps. *Freshw. Fish. Res. Stn.*, Chandpur, Bangladesh. no. 3, 26 pp.

Chaffey, D.R., F. Miller, and J.H. Sandon. 1985. A Forest Inventory of Sundarbans, Bangladesh. Main Report, ODA Land Resource Devt. Center, Surrey, England, 196 pp.

Coleman, J.M. 1969. "Bramaputra River: Channel Processes and Sedimentation." *Sediment. Geol.* 3:131-239.

Curray, J.R., and D.G. Moore. 1971. "Growth of Bengal Deepsea Fan and Denudation in the Himalayas." *Geol. Soc. Amer. Bull.* 82:563-572.

F.A.O. 1985. "Report on Tidal Area Study of Bangladesh." *Fish. Res. Survey Syst.* FAO/UNDP BGD/79/015.

Garcia, S., and L. Le Reste. 1981. "Life Cycles, Dynamics and Exploitation and Management of Coastal Penaeid Shrimp Stocks." *FAO* Tech. Pap. No. 203.

Karim, A., and M.A.A. Khan. 1980. "Phytosociological Studies of Mangrove Forest of Chakaria Sundarbans " *Bano Biggyan Patrika* 9(1 &2): 17 — 28.

Mahmood, N., and Y.S.A. Khan. 1980. On the Occurrence of Postlarvae and Juvenile Penaeid Prawns at Bakkhali Estuary and Adjacent Coastal Area of Cox's Bazar with Notes on their Utilization in Aquaculture. Final Report, University Grant Comm. Dhaka, 26 pp.

Marr, J.C. 1984. Twenty Year Fishery Development Plan For Bangladesh. FAO/UNDP.

Motoh, H. 1981. Studies on the Fisheries Biology of the Giant Tiger Prawn, *Penaeus monodon* in the Philippines. Tech. Rep. No. 7, SEAFDEC, Aquaculture Dept. Iloilo, Philippines, 128 pp. M.

P.O. 1986. Technical Report No. 18: Coastal Shrimp Aquaculture Resources. Ministry of Irrigation, Water Develop. and Flood Control, Dhaka.

Pramanik, M.A.H. 1984. Remote Sensing Application to Accretion and Erosion Studies and Affects on Mangroves. UNESCO/UNDP Training Seminar Geology, Sedimentol. Erosion & Accretion in Mangrove Areas, Jan—Mar, 1984, Dhaka.

Rabanal, H.R. 1984. Fisheries Integrated Development in the Sundarbans, Bangladesh. Report prepared for the Govt. of Bangladesh. FAO:TCP/BGD/2309, 75 pp.

Rashid, H. 1977. *The Geography of Bangladesh.* Dhaka: University Press, pp. 40-41.

Schuster, W.H. 1952. "Report on the Possibility of Fish Culture in East Pakistan." *FAO,* 52/7/4280, 9-17.

Yap, W.G. 1980. Overview of Prawn Culture Industry. Seminar Workshop on Aquabusiness in Project Development and Management. Tigbavan, Iloilo, March 3, 1980, 7 p.