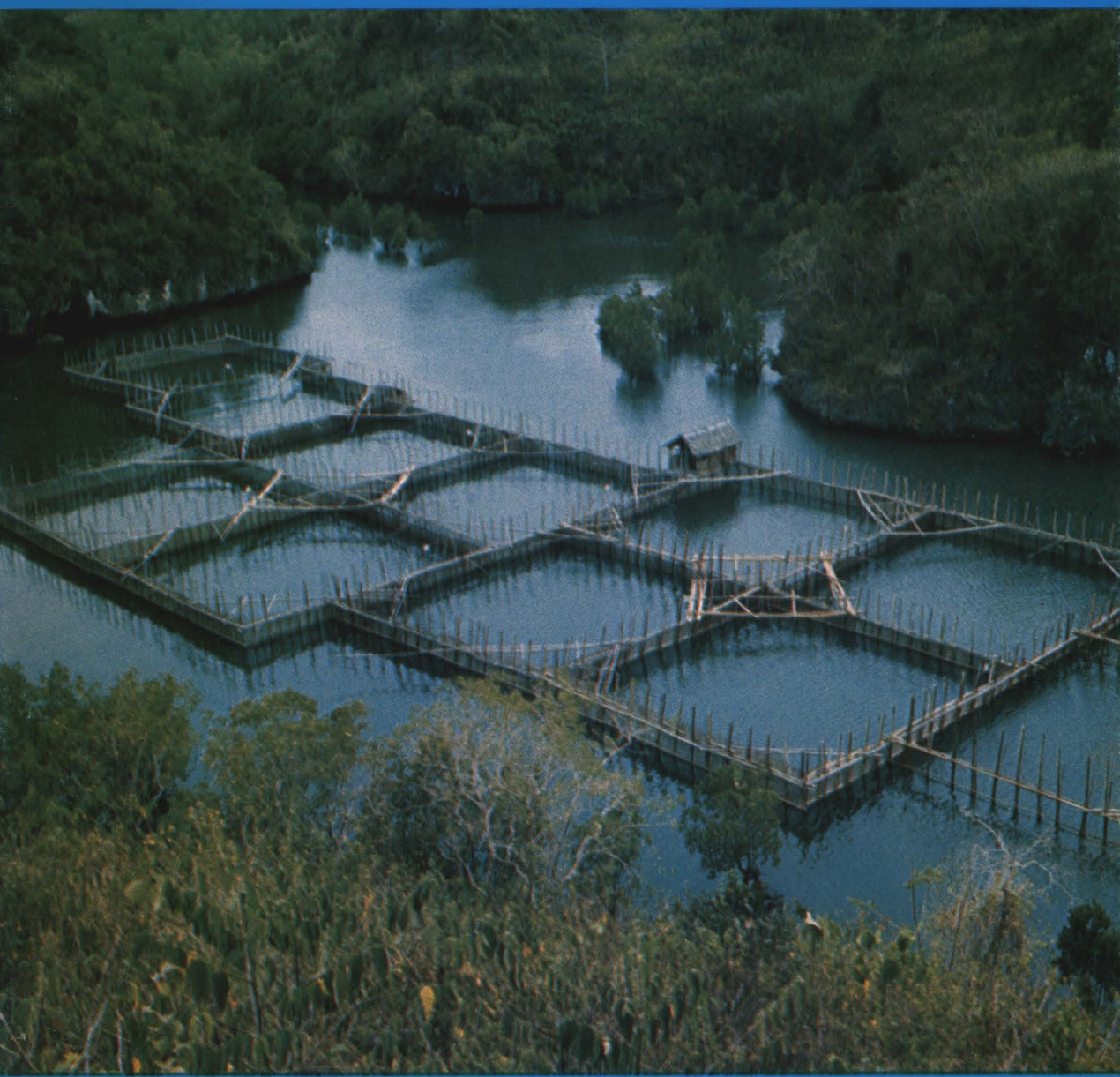
FISH FARMING

an account of the aquaculture research program
supported by the
International Development Research Centre



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Fish Farming

an account of the aquaculture research program supported by the International Development Research Centre

Bob Stanley

with the collaboration of

W. H. Allsopp and F. Brian Davy

Contents

Foreword

This is the second in a series of nontechnical booklets intended to give an in-depth account of the research supported by the Agriculture, Food and Nutrition Sciences (AFNS) division of the International Development Research Centre. The first, "Trees for People," described the forestry component of AFNS research. This one is concerned with aquaculture.

The IDRC fisheries program was structured to concentrate in areas where applied research could increase food fish production in a relatively short time. Aquaculture has been the major emphasis to date. With proper management aquaculture has great potential for increased production — sufficient to meet the demand for fish protein in many developing countries. Overcoming the major constraints to increased production has therefore been the primary aim of the aquaculture research program since it began operating in 1972.

Asia is the area of greatest aquaculture production, yielding more than 4 million tonnes annually — some 70 percent of the global total of cultured fish. The region has a tradition in aquaculture dating back 3000 years or more, making it the obvious place to begin a research program aimed at increasing food fish production for rural peoples.

Subsequently a worldwide network of projects has been developed. It has expanded rapidly from South and Southeast Asia to encompass the Middle East, Africa, the Caribbean, and Latin America. This networking approach, common to many of IDRC's programs, has enabled scientists in different parts of the world to share their experience as they work on projects of similar principle but involving different species. The network has also been supported by specialized research services carried out for the IDRC at laboratories in Canada.

This booklet describes the various aspects of the aquaculture program, and includes summaries of all the research projects supported under the program up to September 1978. These are not exhaustive accounts, however, and are written deliberately in a nontechnical manner for the general reader. The addresses of individual project leaders are included for those who require more exhaustive detail.

A description of the complete AFNS program is available in another booklet, "AFNS: the First Five Years."

Joseph H. Hulse
Director
Agriculture, Food and Nutrition Sciences Division, IDRC

Introduction

The word "aquaculture" is still relatively new to the English language. It has not yet found its way into all dictionaries, but one that does include it defines aquaculture as "the art of cultivating the natural produce of water." That definition could include plants and other aquatic organisms, but for the purposes of this booklet it can be taken to mean the culture and husbandry of fish — in short, fish farming.

If the word is new, the practice of aquaculture is not. The explorer Magellan on a visit to the Philippines in the 16th century described in his journal the coastal seawater ponds used for the production of fish and salt. Pliny's records of Republican Rome inform us that at least one enterprising citizen built very large oyster beds at the mouth of the Tiber. And it is known that the Chinese were culturing carp more than 2000 years ago.

In the centuries since then the practice of aquaculture in natural and man-made ponds has become widespread throughout much of Asia, where fish forms an important part of the average family's diet, but the techniques have remained virtually unchanged. For despite its relatively ancient origins, it is only comparatively recently that any systematic research has been devoted to aquaculture. What little research has been undertaken has usually been capital intensive, aimed at the lucrative markets of the industrialized nations — the mass production of trout or shrimp, for example. Little, if any, research was devoted to the needs of the protein-poor Third World countries.

In 1972, the IDRC's Agriculture, Food and Nutrition Sciences Division assigned high priority to aquaculture research. In the next six years the Centre's Board of Governors approved 22 projects for this program, with grants totaling some $4 million — about 7.5 percent of the Division's total project expenditure for that period.

Potential of Aquaculture

There are numerous reasons for this continuing emphasis on aquaculture research. First and foremost there is the need to increase food production in the Third World — and fish is high protein food. The world's oceans are no longer the inexhaustable source of fish they were once thought to be. Some experts believe that the maximum sustained yield of the oceans — the point beyond which total fish stocks actually start declining — is now being approached. Most agree that many important species will be "fished out" by the end of this century. In addition, the technology for marine capture fisheries is becoming increasingly

sophisticated and energy-consuming, and the capital cost of establishing and maintaining a deep-water fishing fleet, with all its attendant infrastructure, is simply overwhelming.

By contrast, the potential for increasing fish production through aquaculture is considerable, and much of the technology is relatively simple, inexpensive, and consumes a minimal amount of energy. There are vast underdeveloped, underutilized areas of water throughout the world — natural and man-made lakes and ponds, rivers, irrigation canals, estuaries, and coastal waters — that are suitable for aquaculture in one form or another. In India alone, for example, there are an estimated 4 million hectares of village ponds, but less than half a million hectares of these are used for aquaculture.

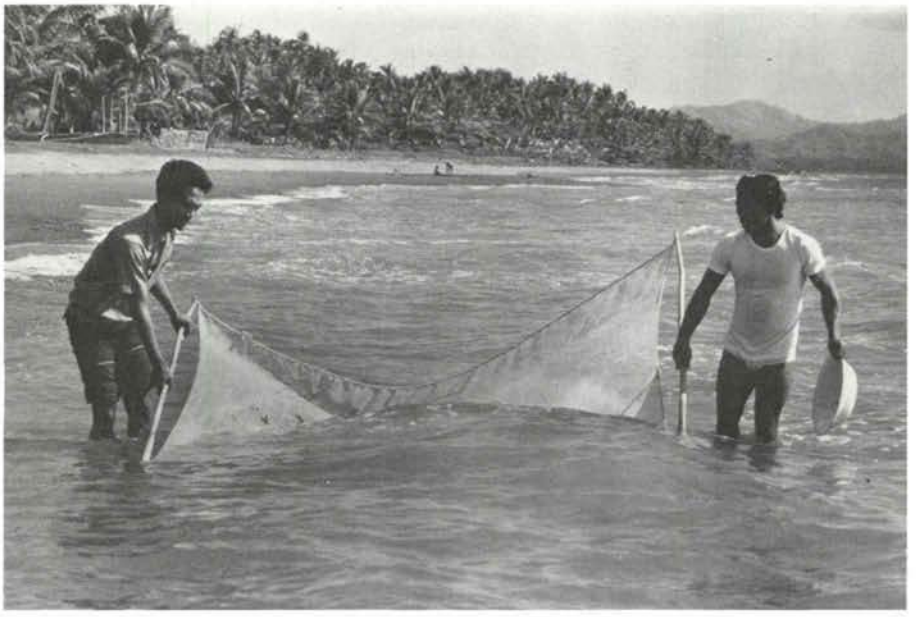
Then there is the nature of the product itself. Fish are cold-blooded animals, they adapt to the temperature of the water that surrounds them rather than wasting energy keeping warm. Consequently they are much more efficient feed converters than are most land animals: fish are about 50 percent more efficient than hogs, and perhaps three times more efficient than cattle.

Equally important, particularly from the point of view of the developing countries, is the fact that fish grow faster in warmer waters. There is a biochemical rule of thumb that for every 10-degree rise in water temperature the reaction rate doubles. This has been demonstrated with halibut and plaice off the coast of Scotland — the implied potential for fish production in warm tropical waters is obvious.

Fish production offers another advantage over both animals and plants: the fish occupy a three-dimensional space. In a polyculture system, for example, different species of fish that habitually feed at different water levels are raised together in one pond. Thus a pond with a surface area of 1 hectare, when stocked with three such compatible species of fish, becomes in effect a much larger pond.

Fish also require little space. Experiments using advanced technology to recycle the water around the fish have shown that trout can grow to their maximum size in a body of water no greater than their own volume. In coastal waters off Singapore, mussel culture experiments have produced yields as high as 250 kilograms per square metre. Such yields *theoretically* could produce as much as 100 tonnes of protein from a 1-hectare sea surface area of mussels. One hectare of land planted with protein-rich soybean will produce perhaps 1 tonne of protein.

Finally there is the fact that aquaculture is much closer to husbandry than it is to hunting, and it is therefore more compatible with farming than it is with conventional fishing. The problems to be overcome to improve aquaculture production are problems that the farmer can relate to. Even the terminology — stocking and breeding, feed and fertilizer — is familiar. A project to utilize more fully village ponds in several states of India has shown that farmers are both able and willing to adapt to new systems, and increase yields by as much as 20 times.



Catching milkfish the traditional way is no longer adequate to meet the demand. It is also destructive, as the survival rate of the tiny fish is low. (Photo: Neill McKee)

Research Priorities

The starting point for the IDRC's aquaculture research program was a review of all known aquaculture research sources and facilities. This inventory completed, aquaculture researchers from all over Asia were invited to attend a workshop in Malacca, Malaysia, in 1973. They collectively determined the priorities for a coordinated program of research.

Top of the list that emerged from that workshop was the need to improve the supply of breeding stock — the fingerlings or fry that are needed to stock the ponds and lakes and start growing the fish. At that time for instance Malaysia was importing some 40 million carp fingerlings annually, and the Philippines had a shortfall of about 800 million milkfish fingerlings each year. The critical problem was that certain fish do not normally breed well in captivity. The traditional method, still widely practiced, of capturing wild juvenile fish with nets in shallow waters after the spawning season simply could not meet the demand, and was damaging the spawning grounds and harmful to the juvenile fish.

As long ago as 1937, experiments in Brazil showed that sexually mature fish could be artificially bred with the injection of pituitary material; but despite the fact that the technique was developed over 40 years ago there remains more than 70 cultivated food-fish species that do not breed voluntarily in captivity. This situation, which the IDRC's program is seeking to remedy, is typical of the problems that exist with many other

areas in fish culture: initial progress has not been applied on a wide scale, resulting in husbandry practices that remain very much an art rather than a science.

The second major priority established by the workshop was the need to improve yields. Traditional yields in the region as a whole were about 200 kilograms per hectare per year, yet experiments in India showed that yields 20 times greater than this were quite possible. The problem is to close the gap between the results obtained under controlled conditions at research institutes and the meagre yields produced by village ponds.

The Asian scientists also identified a number of other areas closely related to these two important priorities. There was the question of feeding and nutrition of the fish — how to obtain the most from the least. This is especially important during the sensitive early larval stage. The transmission of diseases and parasites, though rarely a problem of catastrophic proportions in most of the current aquaculture practices, will inevitably increase with the stocking density as fish farming becomes more intensive. This leads naturally to the need for closer examination of the fishes' environment, which is also linked to the need for improved aquaculture management, a factor that is equally important whether you are farming oysters in a coastal estuary or carp in an inland freshwater pond. They also indicated the need to identify new indigenous species for fish culture purposes, and to demonstrate clearly the profitability of fish culture practices in order to attract more investment.

General Principles

Given these priorities and a limited amount of funds, it was necessary that the program be guided by some general operating principles. It was decided that research into species that feed low on the food chain should receive priority — species like carp, for example, that eat plant material, rather than carnivorous species that consume animal protein that might otherwise be used directly for human consumption. An added factor here was that many of the carnivorous species have high market prices, making them inaccessible to the majority of the population, and more attractive to commercially oriented private sector research. The IDRC program could have greater impact by supporting research into the less-studied species.

The efficiency of protein production in a fish polyculture system is known to be generally much higher than that obtained from a monoculture operation. So priority was also given to research proposals emphasizing polyculture systems.

The aquaculture potential of many species of fish has never been studied in detail, and there are many areas of the world — major river basins like the Mekong, the Amazon, the Nile, the Congo, and the Niger, for example — with vast undeveloped potential for fish farming. Research projects into these "growth areas" has also been given priority.

Wherever possible the projects have directly involved research institutions and universities as well as the fishery department in the

country concerned to ensure that the research results would have the greatest opportunity for direct application leading to practical increases in fish production. Other general approaches, common to all IDRC-supported projects, have included emphasis on projects with a regional application, training and utilization of research workers in the countries concerned, and attempting to increase regional cooperation. With this last point in mind, the Centre supports a regional coordinator for aquaculture research, based in Southeast Asia. His role is to provide a technical supporting link between related projects and to ensure communication among the researchers.

The IDRC is not alone in its support for the development of aquaculture. A number of other international agencies and various bilateral aid programs are also actively working in the field, and from the beginning the IDRC program has sought to be complementary to these activities, and where possible to link with them. It is likely, for instance, that IDRC-supported research in India, which to date has been very successful, may be followed up with development-scale funding by the World Bank and the Canadian International Development Agency.

Canadian Support

Although the bulk of IDRC's research support goes to institutions in the developing countries, it is sometimes necessary that some part of the research be carried out elsewhere, perhaps because the sophisticated technology required is simply not available in the field. A number of projects under the aquaculture program have been supported in this way by research carried out with IDRC grants at universities or research organizations in Canada.

To give just one example, the University of British Columbia, B.C. Research Council, and a commercial fish packer, collected 250 000 pituitary glands from Pacific salmon, extracted the crude gonadotropic hormone from them, stabilized it, and shipped it to various IDRC-supported projects around the world. This project bore spectacular fruit in 1977, when female milkfish at a Philippines aquaculture research station, after being injected with gonadotropin from Pacific salmon, spawned and bore live progeny in captivity for the first time in history.

The Canadian universities and the Fisheries and Marine Service of the Canadian Federal Government have cooperated with IDRC in making available short-term consultants to assist in various projects, and in providing training facilities for young researchers working on Centre-supported projects in the Third World.

Within the Centre itself the aquaculture program receives valuable support from other divisions. The Information Sciences Division, for example, provides a literature support service, which has led to the provision to all projects of selected bibliographies of aquaculture information on a quarterly basis. And the program is able to provide an input into other projects that may have an aquaculture component, such as a multicountry project currently being undertaken by the Health Sciences Division that is concerned with the treatment of wastewater effluent

Rearing tanks for milkfish at SEAFDEC's Pandan research station in the Philippines. It was here that the first milkfish were bred in captivity in 1977. (Photo: Neill McKee)

through a series of filtration ponds that in the latter stages may provide a suitable environment for fish culture.

The following sections of this booklet will examine in more detail the IDRC's support for aquaculture research. The projects are grouped under five headings: breeding and nutrition, polyculture production systems, diseases and parasites, mollusc culture, and inland fisheries.

In fact, most of the projects deal in one form or another with all phases of aquaculture. These groupings are adopted merely for convenience and refer to the major areas of emphasis for each project. Completing each section are summaries of all the projects, current and completed, supported by the IDRC in that field.

Breeding and Nutrition

The saltwater fishponds that Magellan reported in the Philippines 500 years ago probably were originally stocked by accident centuries earlier as young fish became trapped in bays, grew larger in these naturally fertile areas, and were then captured by the local villagers, thus introducing the idea of aquaculture.

The attractions of fish farming, as opposed to ocean fishing, were obvious: it was easier, the catch was predictable, and it was a good deal less hazardous than ocean fishing, a fact that will readily be appreciated by anyone who has seen the little boats that fish Asia's oceans in all weathers. But the transition from hunting to husbandry was not quite complete. Because the fish did not breed well in captivity, it has been necessary to catch the fry to restock the ponds from shallow waters and spawning grounds. In an age of intensive aquaculture, this age-old method of netting fish "seed" is simply inadequate, apart from being chancy, wasteful, and destructive. So it was to this problem of breeding the main species used in Asia that the IDRC aquaculture research program first applied its resources.

The reluctance of certain species of fish to spawn in captivity is clearly hormonally controlled. In fact it has been demonstrated in the Philippines that an inhibitory factor exists in the eye of the prawn, and that if the eyestalks are removed the female will mate and reproduce in captivity. It was also known that sexually mature fish could be artificially bred by injecting them with pituitary material. It was this method that led to success in two IDRC-supported projects.

In Malaysia, where the Centre is cooperating with the Malaysian Agricultural Research and Development Institute (MARDI), the Chinese carps, which had rarely been bred in captivity, can now be spawned every month of the year — a significant step. And in the Philippines the recalcitrant milkfish was also bred at the Aquaculture Department stations of the Southeast Asian Fisheries Development Centre (SEAFDEC) — an accomplishment that made front-page news in the Philippines and earned the researchers involved a special citation from President Marcos.

In both cases the pituitary material used was purified gonadotropin from Pacific salmon, extracted and processed using techniques refined in two IDRC-supported projects in Canada. Researchers in Asia are now looking to the possibility of producing gonadotropin closer to home as the demand continues to increase. Local tuna seemed an obvious choice, but to date there have been problems in obtaining an adequate supply. Several other local species are being studied as possible donors, among them the

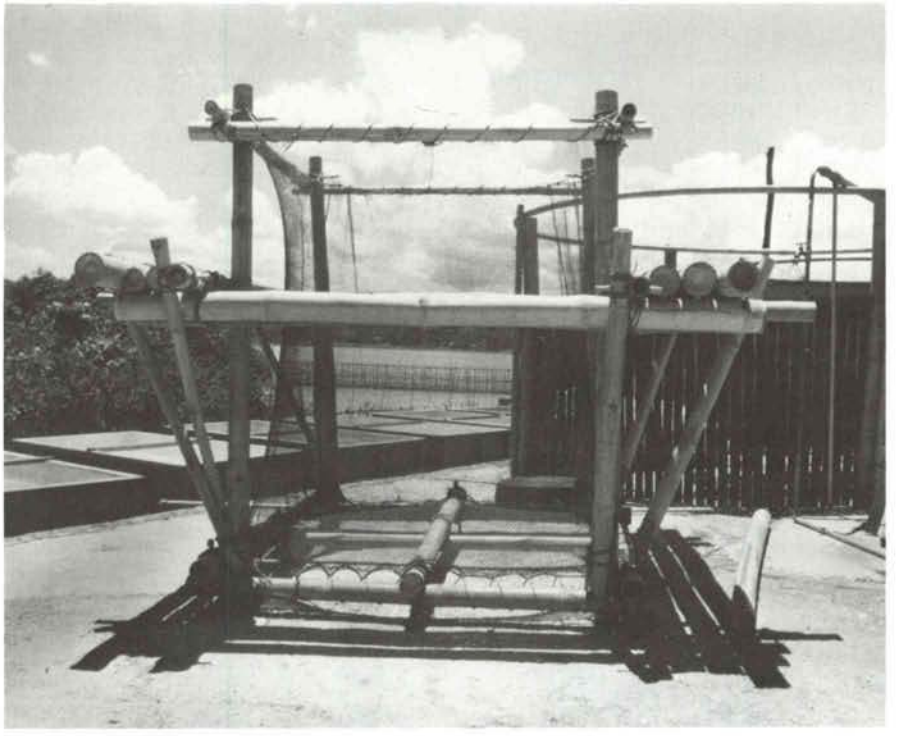
Hormone extract from the pituitaries of Pacific salmon in Canada is injected into Chinese carps during breeding experiments at MARDI in Malaysia. (Photo: W.H. Allsopp)

common carp. This has led to the important, although perhaps not surprising, discovery that the carp pituitary appears to be many times more potent with carp than is that of the salmon. If extraction techniques can be perfected, the whole process may be made more economical.

In Singapore the successful breeding of the grouper and their use in culture associated with *kelongs* or fish traps is another outstanding development. The use of recirculation systems and the development of an enlarged hatchery and egg incubation-breeding centre will provide a much better opportunity for mass production of fry and fingerlings of cultivated species.

While much of the research in Asia is concerned with induced breeding, in Africa the Centre recently approved support for a project that deals with the reverse problem — fish that breed so prolifically that they overcrowd their environment and rarely grow to a good marketable size. The fish are tilapia, one of the most widely cultured species in the world, and the object of the project, to be carried out in Kenya, is to develop a fast-growing nonreproducing hybrid to meet the East African demand for a larger fish.

As aquaculture becomes more intensive, and even as artificial breeding techniques are perfected, the other critical factor becomes apparent: fish nutrition. Nutrition is particularly crucial during the fishes' early stages of development when they have absorbed their yolk sacs and must depend on the foodstuff available in the water, and is made more complex by the fact



Small experimental fish cage at SEAFDEC in the Philippines illustrates one type of construction. Its size is limited by the depth of water it requires. (Photo: Chua Thia Eng)

that the fishes' nutritional requirements change at various stages in their lives.

Because of this interrelationship between breeding and feeding, research into fish nutrition is an important part of both the MARDI and the SEAFDEC projects, and is being built into new projects to develop an integrated approach to aquaculture production. As with the breeding program, this research is also backed up by specialized research in Canada. In fact one of the significant developments in fish nutrition research to date resulted from a small project at the University of Victoria, where scientific studies of the microbiology and biochemistry of the carp, supported by an IDRC grant, revealed that grass carp have digestive systems rather like ruminants, and are able to cope in an as yet undetermined way with cellulose and inorganic nitrogen. Further research in this area could have a significant impact on diet formulation and feeding programs in future.

If Asia, because of its long history of aquaculture, seemed the obvious place to begin a program of aquaculture research, other areas of the world have not been neglected. The research findings and techniques emerging from the early projects are now being applied to a number of projects in Africa, Latin America, and the Middle East, areas where such applied research could show rapid and extremely beneficial results.

Carps (Malaysia)

IDRC grant:
Phase I $280 000,
3 years from 1974;
Phase II $152 500,
3 years from 1977

recipient contribution: Phase I $142 800;
Phase II $316 322

file: Phase I 73-0058
Phase II 77-0051

contact: Assistant Director, Animal Production
MARDI, Bag Berkunci 202
Pejabat Pos Universiti Pertanian
Serdang, Selangor, WEST MALAYSIA

Objectives

To develop standard procedures for bulk production of fish seed at all times of the year by induced breeding of carp using salmon gonadotropin; to develop a pilot hatchery for the production of seed fry, and train personnel for its practical operation; to investigate local sources of gonadotropin; to determine the nutritional requirements of the various stages of the fish being studied; and to develop suitable feeds from inexpensive local materials.

Background and Progress

The major emphasis in the initial years of this project was on spawning procedures for the three Chinese carps. The percentage of spawning success has increased to its present level of 80% to 90% for bighead and silver carp, but the grass carp still requires further work, as its success rate is still only about 30%. It has also been possible to spawn bighead and silver carp every month of the year — through hormone manipulation the fish have now become adapted to the constant temperature and day length.

Some progress has been made in Malaysia to find a local gonadotropin source. Although tuna proved not to be a practical source, other species are now being examined, including the local common carp, since evidence from field tests suggests that carp donor gonadotropin is more potent on carp broodstock than that of the salmon. Success in improved hatching using tannin treatment of the eggs has also been achieved, and methods for controlling predatory insects and noxious weeds are being worked out. Improved hatchling survival rates have been achieved. The nutrition laboratory for use in long-term research was established, and to date approximations of dietary protein requirements and protein-to-energy ratios for grass carp fingerlings have been carried out. Despite this and other progress, considerable research on the standardization of breeding procedures remains to be done, and the transfer of these techniques to the Department of Fisheries carried out. With this in mind MARDI and IDRC initiated a second phase of the project, which began in 1978 with special emphasis on these two aspects of the program, as well as experimentation with indigenous species.

Milkfish (SEAFDEC)

IDRC grant: $826 000 recipient contribution: $2 180 000
3 years from 1975 file: 74-0146

contact: Chief, Aquaculture Dept.
Southeast Asia Fisheries Development Centre
Ilo Ilo, PHILIPPINES

Objectives

Generally to concentrate on all factors directly concerned with improved cultivation of milkfish. Specifically to ensure an adequate and reliable supply of milkfish fry and to extend and stabilize the period of fry availability throughout the year; to develop economically and nutritionally effective feeds from local sources for juvenile stages of fish and improve methods of pond culture and management; to provide means for overseas training of researchers as well as short-term local training for milkfish pond operators, technicians, and extension workers; and to undertake economic studies of existing aquaculture practices in the Philippines in order to assess the effects of innovations arising out of milkfish research at SEAFDEC.

Background and Progress

The milkfish, *Chanos chanos* (Forskal), is a very important food source in Southeast Asia, particularly in the Philippines, Indonesia, and Taiwan, which produce annually about 250 000 tonnes of milkfish. In the Philippines alone, some 170 000 families earn their livelihood from milkfish farming. The fish is adaptable to both fresh and brackish waters as well as the sea, feeds on plant material, and grows fast. But it will not breed in captivity, and this results in a major constraint on the industry. Thus when the artificial breeding of milkfish in the SEAFDEC project was announced in April 1977 it was a matter of both national and regional significance. The breakthrough was made by using injections of gonadotropin from Pacific salmon, and has since been successfully repeated in the 1978 season.

The results of these experiments are conclusive and encouraging, but the techniques will have to be refined and standardized for the development of a technology that will ensure a year-round supply of milkfish fry.

Meanwhile, numerous other activities are on-going. Broodstock ponds have been developed and are monitored regularly; studies of the milkfish larvae and fry are being conducted; experiments are determining the minimum dietary level of protein required by fingerlings for growth and survival; environmental studies have been carried out, and the possibilities of polyculture systems using milkfish with other species are being tested.

Fish Nutrition (University of Victoria)

IDRC grant: $94 000
2 years from 1976 file: 76-0061

contact: Chairman
Dept. of Bacteriology & Biochemistry
University of Victoria
P.O. Box 1700
Victoria, B.C., CANADA

Objectives

To determine some of the basic nutritional requirements of grass carp, and to develop a test diet to provide best growth for the least cost. Specifically to formulate test diets and determine the digestibility of the major nutrients; to examine the microflora of the alimentary tract and determine the nutritional contribution of the intestinal microflora and whether this might be enhanced to improve food conversion or diet formulation; to determine the principal enzymes in digestion related to the most suitable foodstuffs; and to make a preliminary characterization of the changes in dietary biochemical changes at different steps of maturity.

Background and Progress

The carps project currently underway with IDRC support at MARDI in Malaysia seeks in part to determine the nutritional requirements and develop suitable feeds for the various developmental stages of the local carps. This project is designed to support that work. The University of Victoria has a unique combination of researchers in the areas of the nutrition, biochemistry, and bacteriology of fish, and their collaborative efforts could resolve some of the specific nutrition problems associated with carp culture. The Department has earlier developed salmon diets using this same integrated approach.

The understanding of the microbiology and biochemistry of the grass carp was significantly improved during the project's first year. Diets were formulated and preliminary growth trials begun, and numerous detailed experiments carried out. Early indications suggest that the grass carp is not a herbivore as commonly believed, but rather is omnivorous, with distinct preferences in both feed composition and texture. Substantiation of these conclusions can have a significant impact on grass carp aquaculture in the developing world.

Gonadotropin (University of British Columbia)

IDRC grant: $15 375
4 months in 1973/74 file: 73-0069

contact: Dean, Faculty of Science
University of British Columbia
Vancouver, B.C., CANADA

Objectives

To conduct research on the induced spawning of Indian and Chinese carps, and specifically to develop and standardize a system for the selection of salmon pituitaries at the cannery from which sufficient quantities of the hormone gonadotropin of sufficient potency can be extracted and purified; to determine the potency of the gonadotropin to induce spawning in Indian and Chinese carps; and to prepare sufficient quantities of gonadotropin for subsequent experimentation in India, Malaysia, and Canada.

Background and Results

The importance of this project, and the Fish Pituitary Extracts project that follows, are outlined in the summaries of the projects dealing with research on the breeding of milkfish and carp elsewhere in this booklet. The research team at the University of British Columbia succeeded in producing a semi purified hormone extract from Pacific salmon that subsequently proved vital in the development of induced breeding techniques in several aquaculture projects supported by IDRC in Asia.

Fish Pituitary Extracts (B.C. Research Council)

IDRC grant: $128 200
1 year 1975/76 file: 75-0103

contact: Associate Head
Applied Biology Division
B.C. Research Council
3500 Wesbrook Crescent
Vancouver, B.C., CANADA

Objectives

To establish a system for the bulk collection and preparation of salmon pituitary glands that can be accommodated within the normal commercial fish plant operations for Pacific salmon. Specifically to collect mature salmon pituitary glands during the salmon season; to produce hormonal extracts of pituitary; to standardize the dosages by field tests in IDRC-supported projects in Asia and Africa; and to determine the feasible commercial procedure for the bulk collection, processing, packaging, and application of fish pituitary extracts for tropical fish breeding.

Background and Results

This project followed up on the preliminary work in this field carried out at the University of British Columbia in 1973/74 with IDRC support. Working in close collaboration with commercial packers in Vancouver, B.C. Research Council collected pituitaries from 250 000 salmon of different species and runs, and was able to develop a processing technique to make available a constant and relatively inexpensive supply of the hormonal extract for the induced breeding projects in Asia and Africa.

Fish Culture (Singapore)

IDRC grant: $230 000 recipient contribution: $1 262 800
3 years from 1977 file: 76-0045

contact: Director, Primary Production Dept.
Ministry of National Development
7th floor, National Development Building
Maxwell Road, SINGAPORE 2

Objectives

This project aims to establish an economically viable intensive fish farming system, specifically through the development of: intensive culture techniques in cages and raceways, including engineering, management, and disease control; repeatable techniques for induced breeding of selected species of marine and freshwater food fishes; mass culture techniques for production of various micro- and macroorganisms as live food for fish larvae and fry; and fish food technology using inexpensive raw materials available in the region.

Background and Progress

Singapore, with an area of just 584 square kilometres and a population of 2.2 million, imports more than 75% of its annual fresh fish requirements, about 65 000 tonnes, and concerted efforts to develop capture fisheries have not been able to improve the situation. Under its Aquaculture Development Plan, the government therefore proposes to establish an intensive tank/raceway culture system that can be adopted by traditional fish farmers and coastal fishermen to establish an effective industry. This transfer of the evolving technology would be effected through the existing extension and training system presently used to support pig and poultry farming. The results will also be made available to other Southeast Asian countries.

The project began in 1977, and much of the first year was taken up in the design and establishment of the necessary research facilities, and in providing additional training for project staff. There have been some early successes in the artificial breeding of several fish species, however, and work has begun on the investigation of potential live food organisms. Other research activities include the development and maintenance of broodstocks, identification of suitable fish species for cage and tank culture, and the formulation of artificial feeds, all with encouraging preliminary results.

Tilapia (Kenya)

IDRC grant: $197 100 recipient contribution: $195 400
3 years from 1978 file: 74-0144

contact: Director
Gecaga Institute of Tropical Comparative Endocrinology
University of Nairobi, Zoology Department
P.O. Box 30197
Nairobi, KENYA

Objectives

To produce a hybrid tilapia with optimum growth characteristics under Kenyan pond conditions. Specifically to produce hybrid crosses utilizing selected parents of *Tilapia nilotica, T. zilli, T. nigra,* and *T. leucosticta;* to develop and(or) apply techniques of sperm preservation and artificial fertilization in *Tilapia* sp.; to examine the relative growth rates and monitor comparative gonad development and reproductive conditions of the F_1 hybrids in comparison with the parents; and to initiate field trials at the Sagana Fisheries Station and at selected neighbouring farms using the most promising crosses.

Background

The *Tilapia* species have often been proposed as the solution to the problem of the shortage of fish protein in tropical rural areas. Some 14 species of tilapia are presently cultured as far afield as Asia, Africa, the Near East, and North and South America. They possess such desirable characteristics as adaptability, hardiness, disease resistance, and rapid growth; they are mostly herbivores, produce high quality meat, and they breed prolifically in captivity from the age of 4-6 months. It is this last quality that has proven a major drawback in tilapia culture: the fishes' fecundity results in large numbers of small fish of low market value.

The future of tilapia culture throughout the world is limited by this stunting problem, and it is especially serious in East Africa, where consumers prefer larger fish. The Kenyan researchers have selected four of the most likely species and will attempt to produce a viable hybrid that will grow to marketable size without reproducing. Fish hybridization is a relatively new area of research, and little of this work has been done in Africa to date. This project will also allow for the training of a number of researchers, and three of the project staff will work on their M.Sc while participating in the project.

Polyculture Production Systems

There are several ways to increase fish production from any particular body of water, but perhaps none is so essentially logical, practical, and economical as the practice of polyculture.

The basic principle behind polyculture is that when a pond is stocked with several compatible fish species of different feeding habits, the yield will be far greater than if the pond was stocked with an equal number of fish of a single species.

There are several reasons for this phenomenon. In general, the different species are chosen so as not to compete among themselves either for food or for living space, because they have different feeding habits and prefer different environments. Some fish, for example, feed on the bottom of the pond, others near the surface, and still others prefer to feed on aquatic organisms in the middle depths.

Some fish also have beneficial or complementary effects on the growth of others: the grass carp efficiently converts plant material into fish flesh and at the same time fertilizes the pond with its excrement, producing plankton that serves as food for some of the other species. In short, the polyculture system is designed to create a balanced community within the pond that is beneficial to both the fish and the fish farmer.

Polyculture has been a standard practice in China for centuries. Its adaptation to Indian conditions in combination with indigenous Indian carps has been developed in a most successful manner. Since 1964 scientists at India's Central Inland Fisheries Research Institute (CIFRI), which is responsible for all federal research on inland fisheries, worked to perfect a polyculture system that could help to overcome the country's dire shortage of fish for human consumption.

Using a combination of three local Indian carps (catla, rohu, and mrigal) and three exotic species (Chinese silver carp, grass carp, and the common carp), they were eventually able to produce yields 10 or more times greater than those obtained from monoculture systems — with the use of fertilizers and supplementary feeds, as much as 9000 kg could be produced per hectare of pond surface in a year. At about the same time, Indian scientists perfected techniques of induced breeding of these six species and simplified egg incubators, permitting greatly increased production of fish seed. They were now ready to leave the research station and test their techniques in the countryside. It was at this point that IDRC became involved in the project.

From the beginning the project went well. The farmers and villagers quickly showed that they could learn the new techniques. Some increased

their yields by as much as 20 times in a single year, enabling them to pay for the essential inputs of fish seed, supplementary feed, and mohua oilseed cake (a degradable poison-fertilizer developed by the researchers to clear and prepare the pond for the new system), and still have profits left over to invest, perhaps in their own breeding pond.

Farmers were also encouraged to test the new system, to try their own experiments and to suggest alterations wherever they felt it appropriate. This has led to some considerable experimentation with the system — such as combining fish culture with raising ducks by way of a variation.

The remarkable increase in output resulting from the adoption of polyculture systems could do much to meet the 8.5-million tonne demand (a fivefold increase over current fish production levels) predicted in India's 5-year plan. In addition, the large profit potential could provide a powerful incentive to rural people to cooperate with their community councils to utilize village ponds, with the proceeds being used to upgrade community facilities, as has already happened in some areas. It is thus not surprising that fish culture is now part of the Government's official strategy for rural development.

In a proposed second phase the system will be further developed and extended, but the government of India has already recognized the success of the project by singling out two of the senior CIFRI scientists to receive India's most prestigious scientific awards for their work in polyculture research. Films on the breeding work and the polyculture systems have won two international awards.

The significance of this applied research could also have great potential outside India, since few other countries have developed similar intensive polyculture systems. The Indian carps occur naturally in Pakistan, Bangladesh, and Burma, and have been introduced into many other Southeast Asian countries as well as parts of Africa and some of the Pacific Islands. Increased emphasis on the polyculture approach using local species makes good ecological sense, and should be highly productive.

A healthy catch of carp from a village pond demonstrates the efficiency of the polyculture system developed by the Indian researchers. (Photo: J.H. Hulse)

Aquaculture (India)

IDRC grant: $324 000
3 years from 1974
Supplement of $49 100
to 31 December 1978

recipient contribution: salaries, operational costs, facilities

file: 73-0065

contact: Director
Central Inland Fisheries Research Institute
Barrackpore, West Bengal, PIN 743101
INDIA

Objectives

To develop highly productive systems of composite culture; to establish and evaluate the most productive experimental systems in village pond conditions at various locations in Orissa and West Bengal; and to identify and investigate the principal constraints to the wider application of the improved composite culture system.

Background and Progress

The Central Inland Fisheries Research Institute developed polyculture systems using local Indian and exotic carps that could yield up to 10 times more fish than a pond stocked with a single species. This work, combined with the timely development of artificial breeding techniques that made possible abundant supplies of carp fry, set the stage for a wide-scale expansion of aquaculture at a time when it was estimated that a fivefold increase in fish production was required to meet the country's food needs. CIFRI then approached the IDRC for assistance in field testing CIFRI techniques at 40 village sites.

From the beginning, the results of this project were extremely encouraging. Farmers quickly showed that, given the appropriate inputs and technical advice, they could increase fish production from 6 to 10 times within the first year of using the new techniques.

In addition, training programs have been run in each area where the project teams have been active, to provide practical training in induced breeding, fry and fingerling rearing, and polyculture technique. One such course was attended by 77 persons, including farmers, school teachers, pond owners, and unemployed village youths. In a proposed second phase this emphasis on training will continue, together with further demonstration trials and greater support for seed production by the farmers themselves.

Diseases and Parasites

Fish diseases are a major hazard to intensive aquaculture in many temperate climates of the world. Although the problem is not particularly widespread in Southeast Asia, because the science of aquaculture is most highly developed in that region, when disease outbreaks do occur they can become epidemic or even endemic.

The importance of research into parasitic diseases of fish was underlined by a recent outbreak in Indonesia of a leechlike parasite called *Lernea*. Believed to have been accidentally introduced into the country by way of some imported exotic species, *Lernea* has since spread throughout the islands of Java, Sumatra, Sulawesi, and elsewhere, with catastrophic results to the survival of fish fry in nursery ponds.

The parasite attaches itself to the fish and drains it of its body substance, its energy, and its nutrients. Infestations of the order of 50 percent, with a mortality rate of 25 percent, have been reported from several Indonesian locations. The production of fry and yields of cultured food fish have remained almost static in Indonesia over the past 6 years.

In addition to external parasites there are bacterial or other microbial diseases as well as internal parasites. The latter include worms that are transmissable to humans, and therefore must be effectively controlled in aquaculture.

Fortunately Indonesia has a well-equipped laboratory to carry out research into the identification, life cycle, distribution, and control of parasitic diseases. Scientists at the Inland Fisheries Research Laboratory (LPPB), supported by an IDRC grant, have already encountered some success in the battle against *Lernea*. Specially formulated chemical dips to eradicate the parasites in adult fish as well as the treatment of water for the hatcheries through coarse sand filters to prevent further infestation are the techniques being used.

Much research remains to be done to obtain a clearer understanding of the nature and life cycle of *Lernea* and other important parasites that prey on cultured fish species, so as to refine the new techniques for simplified but effective application. But a promising start has been made. Some good may yet come from Indonesia's misfortune: there is a strong possibility that the experience gained by the scientists at LPPB could lay the foundation for Southeast Asia's first fish disease diagnostic centre.

Fish Parasites (Indonesia)

IDRC grant: $181 500 recipient contribution: $164 654
2 years from 1976 file: 73-0147

contact: Director
Conservation Services
Directorate General of Fisheries
Djalan Salemba Raya No.16
Jakarta, INDONESIA

Objectives

To conduct research on the most effective measures for the eradication and control of *Lernea* and other parasitic infestations and diseases of important food fish through studies of the detailed biology of the parasites. Specifically, the project will conduct detailed studies on the epidemiology, life cycle, and ecological factors favouring *Lernea* and similar ectoparasites; identify their life-cycle patterns under different water, climatic, and fish cultivation conditions in Indonesia; determine the susceptible and resistant hosts for such parasites; and investigate the most suitable fry sizes for safe distribution to farmers.

Background and Progress

Since 1970 efforts have been made in Indonesia to control fish diseases, but despite these attempts infestation by *Lernea* and other fish parasites and diseases continues to grow. Until effective measures of control are devised, a serious decline in fish production in the affected areas must be anticipated. The project is therefore of great significance both to the 10 000 inhabited islands of Indonesia, and to the rest of Southeast Asia.

The project has made progress in the development and application of two major parasite control measures, filter installation and chemical control. A full-time advisor was provided by the IDRC to provide on-site training, while other staff have received training overseas. Much remains to be done to consolidate the advances made in the project, and it is hoped that the additional trained staff will form the nucleus of a fish disease diagnostic centre to serve the increasing needs of the widespread aquaculture activities of the inland fisheries of Indonesia.

Mollusc Culture

Molluscs — and in particular bivalves — are in many ways ideal animals for aquaculture. They require no cages or enclosures, since they are sedentary, and filter their food from the waters around them. Their nutritional requirements are simple, they can be stocked at remarkably high densities with no apparent ill effects, and they are comparatively easy to harvest. Their meat is high in protein and even the shells can be put to good use. There is also considerable potential for greatly increased production right across the tropical world.

So it is not surprising that there have been considerable efforts recently to increase the yields of certain shellfish, among them tropical oysters. The oyster is not a luxury food in Third World countries as it is in the West, but it is rich in protein, and provides a valuable supplement to the diets of people living in coastal communities — when it is available.

The female oyster's eggs consist of a gelatinous substance known as "spat" that drifts in the water allowing eggs to attach themselves to fixed objects such as mangrove roots. There the young oyster grows a protective shell and remains for the rest of its life. Life on a mangrove root can be hard, however. The oysters are often overcrowded, and are exposed to the sun and to predators at low tide. As a result they grow slowly, and rarely attain a good size.

IDRC is supporting a network of projects in Africa, Asia, the Caribbean, and Latin America that are aimed at improving the oyster's environment — and growth rate. The "spat" is collected on artificial devices known as "cultch" suspended on strings from rafts or racks, strategically placed so that the growing oysters benefit from clean water, a good food supply, and are permanently immersed and thus protected. Experiments with different locally available materials for use as cultch range from coconut shells in Sabah to pieces of old car tires in Jamaica.

The results have been impressive: in Sierra Leone, the first of the Centre-supported oyster culture projects, raft oysters grow to be several times the size of their mangrove-dwelling cousins in 6-9 months. In cooler waters off the east coast of Canada or the USA they may take 3 or 4 years to reach the same size.

There are many advantages to oyster culture as a source of both food and extra income for coastal peoples. Once the researchers have determined what the optimum conditions for survival and growth are, the basic technology is simple and inexpensive. The rafts used in the Sierra Leone project are constructed from bamboo poles and old oil drums, and each raft

can produce hundreds of kilos of oysters in a year. Once the raft is in place it requires little attention, thus freeing the oyster farmer for other work. And at harvest time there is always a ready market for his product.

The processing, harvesting, and marketing of the oysters are other aspects of oyster culture to which researchers are now turning their attention. Hygiene is a particular concern, as is the preservation of the oysters, which do not normally keep well in the tropics.

Oysters are also appreciated in South America. A project has recently begun in Colombia to develop suitable culture techniques for cockles and oysters, and several others are under consideration for the culture of various bivalves along the Pacific coast of South America.

The most recent addition to the oyster culture project network, however, is not primarily concerned with oysters as food. On Sudan's Red Sea coast researchers are attempting to solve the mystery of the mass die-off of the black lip pearl oysters that occurred in 1969 and again in 1975. These oysters have long been prized for their mother-of-pearl shells, and their cultivation had developed into a considerable cottage industry where only nomadic settlements occur, but in a region that has now all but been wiped out. The researchers in Sudan will benefit from the combined experience of the other projects in the network as they attempt to solve the mystery and reestablish the mother-of-pearl oysters. The project could also provide a starting point for the development of other types of aquaculture along the Red Sea coast.

In Singapore, IDRC is supporting a project to improve the cultivation of another important shellfish, the mussel. One of the most widely distributed and hardiest of seafood organisms, mussels are very rich in protein, they have a higher percentage of meat than most other shellfish, and even their calcium-rich shells have potential for use in animal feeds.

At present, mussels are cultured mainly in France, Spain, the Netherlands, and Korea. In tropical regions with plentiful sources of plankton and warmer water temperatures, the potential for mussel culture should be even greater, a fact that was not missed by the aquaculture experts of the Association of Southeast Asian Nations (ASEAN) when they recommended setting up the Singapore project as a pilot for the entire region.

In the Sabah oyster culture project oysters are being grown in trays on the mud flats, and are easily harvested at low tide. (Photo: Frank Green)

Oyster Culture (Sierra Leone)

IDRC grant:
Phase I $164 500,
3½ years from 1974;
Phase II $157 300,
3 years from 1978

recipient contribution: Phase I $54 650;
Phase II $302 000

file: Phase I 73-008
Phase II 77-0146

contact: Chief Fisheries Officer
Freetown, SIERRA LEONE

Objectives

The objectives of Phase I were to determine which technique — stick culture, bottom culture, or raft culture — is most suited to local conditions; to provide basic information on mangrove oysters related to seasonal changes, acclimatization to salinity changes, meat volume and shell size relationships, fouling organisms, and predators; to evaluate current processing and marketing of oysters and suggest practical improved techniques; and to identify areas relatively safe for the culture and harvest of mangrove oysters and provide the basis for decisions on the level of biological inspection control necessary for developing an industry. The second phase aims to build on the work already completed through intensive small-scale production at six village sites; development of appropriate village-level technologies for processing and packaging oysters; extension and demonstration programs for the rural communities; and an assessment of the pilot-scale operations, with particular emphasis on their profitability.

Background and Progress

This project was the first of a network of five tropical oyster culture projects that have effectively grown edible-size oysters from the small indigenous mangrove species. When the project began, little was known in Sierra Leone about oyster culture. During Phase I, techniques of suspended oyster culture have been standardized using local materials and resources, and it is now possible in 9 months to produce oysters of an average meat weight of 9 grams, four times the size of wild mangrove oysters.

Biological studies have defined the period for breeding, indicated areas of best spat-fall, salinity conditions for maximum growth, periods of minimum and maximum fouling, optimum harvesting conditions, and have succeeded in identifying larvae in plankton samples. Of equal importance, the project has shown that, contrary to general belief, the culture and harvesting of oysters may continue throughout and beyond the rainy season.

In the second phase, which has just begun, the project will move into intensive small-scale production at six village sites. Processing and marketing studies together with a survey of sanitation and bacteriology will be completed. An advisory committee composed of researchers and representatives of the village communities will be established to provide guidance and to encourage community participation with a revolving fund set up to support the pilot activities in the early stages.

Finally, a regional seminar will be organized to discuss all aspects of the program, and this dissemination work will be supplemented with the publication of several technical papers and a simplified instructional manual.

Oyster Culture (Sabah)

IDRC grant: $105 600 recipient contribution: $190 000
3 years from 1975 file: 74-0113

contact: Director of Fisheries
Ministry of Agriculture and Fisheries
P.O. Box 1064
Kota Kinabalu, Sabah
EAST MALAYSIA

Objectives

To survey Sabah for potential areas for the development of oyster culture; to develop practical, economic methods of oyster production; to establish a seed supply station; to train local officers and fishermen in oyster culture; to improve techniques of processing and marketing oysters and related hygiene control; and to establish regulations for the oyster industry in Sabah.

Background and Progress

In its 10-year development plan, the Fisheries Department of Sabah included oyster farming as a coastal family industry that is labour-intensive, food-oriented, financially rewarding, requires little capital, and is applicable to poor, isolated communities. Experimental production of oysters began in 1974.

Sabah had obtained promising results in earlier experiments, and the IDRC-supported project continued to build on that base. Different materials for collecting seed were tested, ranging from strips of asbestos roofing material to coconut shells, with the aim of finding a cheap but practical spat collector. Comparisons between rack and raft culture have been carried out to see if the more expensive rafts can justify their cost through higher returns. Tests are underway to see if oysters can be cultured in brackish water ponds, and studies are being made to determine the ratios of different oyster species in various waters.

In addition, a pilot-scale production system consisting of 2 hectares of racks has been established, and a more detailed examination of much of the coastline is planned to determine the availability of sites and to choose locations for village demonstration units.

Staff training overseas has also strengthened the capability of the research team.

Oyster Culture (Jamaica)

IDRC grant: $198 100 recipient contribution: $202 000
3 years from 1977 file: 76-0057

contact: Dept. of Biological Sciences
University of the West Indies
Mona, JAMAICA

Objectives

The project has two principal objectives, to conduct research on the culture of the mangrove oyster to determine the optimum conditions for their effective cultivation; and to establish an economic and practical system of oyster culture to be adopted by rural fishing communities of Jamaica and other Caribbean countries.

Background and Progress

In the Caribbean and South America the important commercial oyster is *Crassostrea rhizophorae*. The natural population of this species is presently harvested by coastal fishermen in Jamaica, but no effective culture systems have yet been developed, although small-scale research since 1973 indicates that this species can be "farmed" satisfactorily.

The full-scale research program is helping to determine the most effective ways of cultivating the oysters. Once the principles are established, they will provide the basis for promoting practical oyster culture among coastal communities, thus helping to reduce Jamaica's present dependence on imported fish protein products. The project will also benefit from experience already gained in IDRC-supported projects in Southeast Asia and West Africa.

Although the project has only recently begun operations, some progress has already been made in studies of spat collection and fouling organisms, and the pace has accelerated with the acquisition of the project's equipment and facilities. The development of oyster culture is of considerable interest to a number of other Caribbean nations, and some preliminary contacts have already been established with other researchers in the region.

Oyster Culture (Sudan)

IDRC grant: $231 500 recipient contribution: $1 167 410
3 years from 1977 file: 77-0021

contact: Head, Fisheries Research Centre
P.O. Box 1489
Khartoum, SUDAN

Objectives

The general objective is to revive the formerly successful mother-of-pearl culture industry along the Red Sea coast. Specifically the project will compare alternative culture techniques at three locations to determine which conditions appear most effective in eliminating or reducing mortality; determine the technical and economic viability of alternative technologies; train Sudanese scientists in research methods and production control; and demonstrate successful techniques to Sudanese oyster farmers.

Background

For as long as can be remembered, the black lip pearl oyster has been plentiful in the shallow waters of Dongonab Bay on Sudan's northern Red Sea coast. Highly prized for the mother-of-pearl coating of its inner shell, the oyster formed the basis of a substantial industry in the area until 1969, when the oysters suddenly and inexplicably began to die off, and the industry collapsed. The phenomenon occurred again in 1973, and in 1975. Efforts by the Sudanese Fisheries Department to solve the mystery have made little progress without trained personnel or proper laboratory facilities. The government, however, attaches high priority to the revival of the industry, and asked IDRC for technical assistance.

Dongonab Bay has the potential to produce 1000 tonnes of shell per year — 10 times the production rate in 1969. The income would be extremely beneficial in providing amenities for the area as the nomadic population gradually adjusts to a more settled existence. Once the mysterious mortality of the black lip pearl oysters is solved, the trained Sudanese scientists who have participated in the project could expand their research program to other forms of mariculture along the Red Sea coast, such as other shellfish, cage culture of milkfish, mullets, or shrimp, even seaweed culture, thus forming the basis of an aquaculture industry. This could be of particular importance in an area where attempts are being made to provide sedentary occupations to settle the nomadic people in small villages along the Red Sea coast.

Mussel Culture (Singapore)

IDRC grant: $100 800 recipient contribution: $1 400 000 approx.
3 years from 1978 file: 77-0121

contact: Director, Primary Production Dept.
Ministry of National Development
7th floor, National Development Bldg.
Maxwell Road, SINGAPORE 2

Objectives

To establish guidelines for the identification of areas suited to mussel culture; develop a culture system most suitable for Singapore and Southeast Asia in terms of production and cost; conduct research on various biological aspects of mussels; develop postharvest technology for mussels suitable for transfer to farmers, including sanitation, handling, storage, processing, and market development; and establish an effective system for the smooth transfer of this technology to other Southeast Asian countries through training, demonstrations, publications, and seminars.

Background

Mussels are one of the most widely distributed and hardiest of seafood organisms, and are highly suitable for extensive mass mariculture production. Rich in protein, they compare favourably with foods such as eggs, chicken, beef, mutton and pork. Even the shell, which contains about 90 percent calcium, could be used in crushed form in animal feed.

In recognizing the development potential of mussels for the production of cheap protein and the provision of alternative employment for small-scale fish farmers and coastal fishermen, the first ASEAN Meeting of Experts on Aquaculture in 1977 recommended the establishment of an ASEAN mussel culture project in Singapore, which has the highest per capita consumption of fish products in the region.

This is the first mussel culture project to be supported by the IDRC's aquaculture program. The main emphasis will be on refining the techniques already developed by Singapore scientists, perfecting postharvest aspects, and resolving questions about sanitation. It is also hoped that the project will develop into a site for regional training for mollusc culture in a tropical environment.

Mariculture (Colombia)

IDRC grant $236 800 recipient contribution: $182 000
3 years from 1978 file: 77-0110

contact: Professor of Biology
Universidad del Valle
Departmento de Biologia
Cali, COLOMBIA

Objectives

The project will concentrate on two areas on the Atlantic and Pacific coasts. On the Pacific coast it will develop an aquaculture system for the marine culture of the mangrove crab *Callinectes toxotes* and the mangrove cockle *Anadara tuberculosa* through detailed biological and environmental studies; and provide the mangrove fishermen with the necessary scientific assistance and leadership to farm these species. On the Atlantic coast the project will establish an experimental station with ponds and other facilities for the culture of the mangrove oyster *Crassostrea* spp.; involve the coastal fishermen and their families in the development and application of appropriate technologies; and assist in the creation of an oyster culture cooperative.

Background

Supported by COLCIENCIAS, the Colombian Fund for Scientific Research, this project brings together researchers from the Universidad del Vallee and the Instituto de Investigaciones Marinas (INVEMAR) in a project to improve the rational utilization of marine and inland waters for the benefit of low income populations, and for the country's economy as a whole.

Mangrove crabs and cockles form a natural stock in the mangrove tidal swamps of the Colombian Pacific coast. Both species are caught regularly by the local people for their own consumption, and a small but irregular supply finds its way to the local markets. The oysters are common on the Atlantic coast, and are harvested on the mangrove roots at low tide, usually by children, since the roots grow too close together to allow adults to pass. The oyster population is dwindling rapidly, however, due to overharvesting.

The development of suitable cultivation techniques for these three species should lead to rapid adoption by the communities involved, since they are already a small part of the people's livelihood, and in fact some families have already developed simple techniques for keeping harvested oysters alive. The ecological conditions are distinctly favourable for the intensive production of oysters, fish, and crustaceans, and offers great potential for much increased production and local employment.

Inland Fisheries

Man-made lakes of one kind or another cover hundreds of thousands of square kilometres of the earth's surface. Ranging in size from small farm ponds to the huge reservoirs of Africa, such as lakes Nasser and Volta, these bodies of water are increasing in number due to the need for irrigation, hydroelectric power, and domestic water supply to rural communities. For instance, Africa is estimated to have 40 percent of the world's potential water power, but to date only 5 percent has been developed. Asia and Latin America have large numbers of reservoirs already, and more can be expected. In short, this is a field in which many future developments are imminent.

Aerial view of fishponds in the Baram district of Sarawak. The people of this region depend on their fisheries for both food and income. (Photo: Neill McKee)

In almost any reservoir a fishery can be established to provide a significant fish protein production. Because the primary reasons for building reservoirs are usually either for irrigation or hydroelectric power, or both, the establishment of a fishery usually takes low priority. As a result comparatively little investment has been made in evaluating those factors that influence the establishment of a successful fisheries industry.

The need exists, therefore, for more research to determine the optimum conditions for the establishment and maintenance of an efficient fishery system in man-made reservoirs. Ideally a comprehensive fisheries study should be undertaken before the dam is built, since the results might well influence the pattern of construction. In any event, a research program is essential before any major stocking program takes place in order to determine the optimum conditions for each species. The same general principles also apply in the establishment of a successful fishery in a natural lake.

Though each location will possess its own characteristics and specific problems, a general pattern of methodology can be formulated for a study of those factors that are congenial to a fisheries program, and those that might conflict with it. These include the need to acquire basic environmental and biological data, study of the suitability of fish species to be introduced if any are required, the interrelation among species, with particular concern for pathological problems, and the techniques of conservation and overall management.

The Centre is supporting a number of very different projects in this field that, although not strictly aquaculture projects, both contain strong aquaculture components.

Aquaculture (Turkey)

IDRC grant: $212 500 recipient contribution: $873 454
3 years from 1977 file: 75-0034

contact: Head of the Fishery Dept.
DSI
Isletmeve Bakim Dairesi Baskanligi
Yucetepe, Ankara
TURKEY

Objectives

To develop methods for assessing the productivity of fish and fish food organisms using various limnological and fisheries biology techniques; to test selected methods of fish culture such as floating cages on various established species, including trout and carp; to identify and elaborate means of controlling major fish pathogens, and to establish a fish disease diagnostic service; to perfect methods of harvesting suitable for small fishing cooperatives; and to train local staff in the areas of limnology, fisheries management, fish diseases, and fish culture.

Background and Progress

The Keban reservoir in eastern-central Turkey is one of the largest of some 70 reservoirs controlled by the General Directorate of the State Hydraulic works (DSI). Some 125 km long, it is conservatively estimated to be capable of producing 4000-5000 tonnes of fish per year based on natural production alone. DSI sought IDRC assistance to maximize fish production at Keban, and to develop methods that could be applied to all the other reservoirs under its jurisdiction.

In the project's first year, a laboratory complex has been set up adjacent to the reservoir, various limnological studies have been carried out, and a fish survey of the Keban is underway to provide an understanding of the current fish population dynamics of the reservoir. Assistance is being provided to local fishermen, and studies have begun on the design and operation of fishing cooperatives that would provide more work for the local people.

Five cages have been installed for the cage culture experiments; some are in use for growth studies and others for breeding studies. A fish diseases program has also been initiated in conjunction with the Veterinary Virology Faculty of the University of Ankara. Several project staff are receiving training at research institutions in Canada and Europe to obtain further background on recent developments in inland fishery applicable to Turkish conditions.

Inland Fisheries (Sarawak)

IDRC grant: $145 000 — recipient contribution: $140 875
3 years from 1976 — file: 75-0035

contact: Senior Fisheries Officer
Department of Agriculture
Inland Fisheries Branch
Kuching, Sarawak
EAST MALAYSIA

Objectives

Generally to increase the availability of fish from the inland waters of the Baram district. Specifically to examine present fish stocks, the relevant ecology, and current fishing techniques; to investigate the biology of the commercially important species and its relation to fish stocks and techniques of capture; to assess the suitability of local species for fish capture; to determine suitable regulatory measures to maintain a sustained optimum yield in the future; to examine current processing and handling procedures, and test possible improvements; and to train local scientists in these techniques and procedures.

Background and Progress

The Baram people of Sarawak have traditionally depended on fish from the district's numerous lakes, rivers, and streams to provide them with both food and cash income. Now a combination of factors — including overfishing, land development, forest industries, and pollution — threatens both the fish and the livelihood of the people. The Government of Sarawak asked for IDRC's support in carrying out a research project that would examine the problems with the aim of reversing the trend, and possibly developing fish culture techniques suitable to the region.

In the early stages the project concentrated on staff development and improvement of existing facilities. With the support of two Canadian University Service Overseas (CUSO) volunteers and a full-time advisor, the research effort was divided into four interrelated programs: assessment of rivers and lakes, pond and cage culture; fish processing, and training. Considerable progress has been made in each of these areas: a survey of the longhouses (communal dwellings) when completed will result in a set of recommendations for the future of fisheries in the district; locally built floating cages are in use and being introduced to the local people by extension workers; a variety of smoked and salted fish preparations have been developed and are being tested for acceptance; and training programs have been devised for project staff, farmers, and school leavers, and even for the children attending the regional school.

Fish Culture (Rwanda)

IDRC grant: $276 100
3 years from 1978

recipient contribution:
facilities and service equivalent
to $442 430
file: 77-0042

contact: Le Chef
Division Pêches et Pisciculture
Ministère de l'Agriculture et de l'Élevage
Kigali, RWANDA

Objectives

The general objective is to increase current fish production through fish culture in rural communities. Specifically the project will examine local species in selected lakes and select those suitable for aquaculture; test these species at the Division of Fisheries and Fish Culture ponds; and train local staff at the applied research and extension levels to carry out further experimentation on fish culture techniques and their transmission to farmers.

Background

Landlocked Rwanda is listed as one of the 10 poorest countries in the world. Its rapidly growing population of 4 million depends largely on small-scale agriculture. Intensive aquaculture would do much to improve their diet, yet the total fish production from the country's lakes in 1975 was only 1500 tonnes, equivalent to the average annual catch of a single Canadian trawler. At present fish culture in ponds using several *Tilapia* species yields annually about 200 kilograms per hectare. With the application of existing technology production could be increased to as much as 2000 kg/ha, and the many rivers and streams in the valleys of Rwanda could be ideal locations for the construction of more fish culture ponds.

New emphasis on the importance of fish culture and the provision of more trained staff should do much to overcome the present limitations. The Division of Fisheries and Fish Culture in cooperation with the National University will carry out the research and extension studies, and the IDRC is providing an advisor for a 2-year period to give both on-site training and practical demonstrations of aquaculture techniques for project staff and local farmers.

Aquaculture (Sudan)

IDRC grant: $117 200 recipient contribution: $436 600
3 years from 1977 file: 76-0157

contact: Head, Fisheries Research Centre
P.O. Box 1489
Khartoum, SUDAN

Objectives

The general objective is to increase the production of fish through freshwater aquaculture in ponds. Specifically the project will adapt and develop improved systems of polyculture; develop suitable techniques for spawning selected Nile fishes that are locally well accepted; develop improved nursery rearing and management techniques; and test and apply these experimental techniques in the government fish culture station at Essilaat.

Background and Results

Sudan, one of the largest countries in Africa, has inland waters with an estimated surface area of 4 million hectares, a vast freshwater resource that is largely unexploited for fish production. Partly as a result of a chronic shortage of meat in tsetse-infested areas, however, the government is now placing great emphasis on fish production, and hopes to obtain fully one-third of the total — some 60 000 tonnes — from aquaculture by 1990.

There are approximately 200 species of fish in the Nile River system, of which the most important cultivable species is *Tilapia nilotica*, though several others show promise. Incorporation of a number of species into a polyculture pond system, which can in turn be integrated with poultry rearing, would serve both to increase the amount of edible fish available and to supplement rural incomes.

Most of the project's efforts to date have been spent in selecting equipment. Two Sudanese members of the Fisheries Research Centre are studying for MSc degrees in the USA, and will return to Sudan to carry out their course work as part of the project. Meanwhile other project staff have begun breeding and feeding trials with existing stocks at the El Shegara research station, and are collecting and rearing stocks of other species from local fishermen. With the importance now attached to aquaculture by the government, and the demand for fish in the market, the project looks promising.

Aquaculture (Egypt)

IDRC grant: $233 600 recipient contribution: $402 000
3 years from 1977 file: 77-0035

contact: Director
Academy of Science Research & Technology
Institute of Oceanography and Fisheries
101 Kasr El-Ainy Street
Cairo, EGYPT

Objectives

Generally to develop effective methods for increasing fish production and fish culture in selected inland waters. Specifically the project will develop experimental techniques for fish pen or enclosure culture in brackish water and for floating cage culture in freshwater irrigation and navigation canals; and carry out detailed comparisons of the relative technical and economic efficiencies of the two culture methods with the aim of developing a system suitable for use by local farmers and fishermen.

Background

In spite of its long coastline, wide delta lakes, and vast inland waters, Egypt's production of fish is relatively low, and aquaculture accounts for only 6 percent of the total fish production. The potential exists, however, and the need is made all the more urgent by the decreasing production of the Nile delta fisheries. In its latest 5-year plan, the Egyptian Government stresses the expansion of fish farming as a priority for both government and the private sector.

In this project the Institute of Oceanography and Fisheries will test two related types of aquaculture that have been shown to work well in the Philippines and Japan. In shallow bays or lakes, bamboo fish pens are staked to the bottom, whereas in rivers and canals floating cages are used. Both approaches would seem to be very suitable to Egypt's situation, and have the added advantage of making use of existing waterways, so that it is unnecessary to construct ponds. The successful development of these techniques could also help to stamp out some of the existing fishing practices that are extremely destructive of young fish, with resulting losses to future stocks, while providing employment and food production to an area of increasing population. Initial cage designs developed by the Institute's engineers have been constructed and are being tested at one project site.

The Future

Despite its relatively small scale, the results obtained through the IDRC's aquaculture research program in just 6 years are very encouraging. They clearly indicate that there is a remarkable potential benefit to be gained from the development of tropical aquaculture. Equally important, they also show vast gaps in our knowledge related to aquaculture in general, and emphasize just how great the extent is of the research that needs to be done in the future in order to bring economical aquaculture within reach of the rural poor.

To better understand the magnitude of the problem, consider that there are only about 10 farm animals of economic consequence. By comparison, there are literally thousands of different fish that could possibly be cultured, and about which we know very little. We need to know which of those thousands of species are the most suitable for aquaculture: more about their reproductive life cycles, their nutritional requirements, their relationship with the environment, and a score of other factors that are essential knowledge before any fish species can be effectively farmed.

There are other areas of equal importance. As some of the projects achieve useful results, it is vital to ensure that these results are applied in the most effective way. Greater attention will have to be paid in the future to the development of mechanisms for the transfer of results between research and development agencies and the appropriate national government bodies within the country.

Making the best use of ecological opportunities can also be expected to play a major role in the future expansion of aquaculture. These opportunities may occur in many ways — the use of domestic and municipal effluents, animal and agricultural wastes, and floating fish cages in multiple-use water bodies such as canals, to give just a few examples. Some research has already begun in these areas, but more work is needed, possibly in projects of a multidisciplinary nature, to further test out these ideas.

Finally, there is the need for more research on an international scale, as is done for the major food crops. The scope of the work is such that it is far beyond the resources of any single agency. Recognizing this fact, IDRC commissioned Sir Charles Pereira, former Chief Scientist, Ministry of Food and Agriculture of Britain, to head a special mission to make a comprehensive study of the aquaculture research activities of South and Southeast Asia. The other members of the mission came from Thailand, Japan, Canada, and the USA. Their report, completed in June 1978, strongly recommended the creation of an Asian organizational network for aquaculture research that would serve the needs of Asia in addition to

Sierra Leone: on the left, wild oysters; on the right, oysters grown by raft culture. The smile on the face of the researcher speaks for itself. (Photo: Neill McKee)

serving as an invaluable resource for aquaculture researchers in other regions of the world.

Such an institute would have to have a broad base of financial support, and the Pereira mission's report has been presented to the Technical Advisory Committee of the Consultative Group on International Agricultural Research for consideration. This group, a voluntary association of national governments, foundations, and agencies, of which IDRC is a member, already funds a worldwide network of specialized regional international agricultural research centres for the major food crops and livestock.

The creation of an aquaculture research institute in Asia, the "home" of aquaculture, would not only provide a natural focus for future research, it would also establish once and for all that aquaculture is no longer an art — it is now very definitely a science.

The Future

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