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1.1

DIFFERENT KINDS OF AQUACULTURE

As habitats of aquaculture, there are three categories of waters, viz. fresh, salt and brackish. Fresh waters, generally abounding in the inland areas of a country, and the salt water of the seas and oceans, are characterized by a wide difference in their salinities ranging from nil in the former to nearly 35 ppt in the latter. The difference in salinity within each category of water, fresh and sea, is restricted to rather narrow limits. The salt content of fresh and sea water exercises a very selective influence on the fauna and flora that live in each type of water.

In as far as finfish and shellfish are concerned, the normal residents of each type of water are said to be stenohaline, i.e. they can withstand only a narrow variation in the salinities of their surrounding medium. A carp is an example of stenohaline freshwater fish and a sardine or a mackerel may be cited as examples of stenohaline saltwater fish. Brackish water normally naturally occurs in estuaries, deltas of rivers, lagoons and backwaters, which everywhere in the world are under tidal regime. In such habitats the salinity of the water fluctuates widely between negligible to 35 ppt, depending on the phase of the tide and volume of fresh water discharged through the river into the sea. The finfish and shellfish that inhabit brackish waters are invariably euryhaline i.e. they form a group of organisms which physiologically withstands wide changes in salinity of the surrounding medium. Stenohaline organisms are devoid of physiological mechanisms to tolerate wide changes of salinity. So, a special type of fauna inhabits the estuarine habitat beyond the sea-end of which live the stenohaline and saltwater forms. Examples of euryhaline fish are a mullet (*Mugil cephalus*) and mud-skipper, Periophthalmus and those of crustaceans are several species of penaeids (e.g. *Penaeus monodon*) and crab (e.g. *Scylla serrata*). The capacity of the residents of an estuary to tolerate a wide range of salinity that prevails there is by virtue of a dynamic physiological process of osmoregulation in which the gills, the kidneys, the skin and the buccal cavity lining play significant roles. *Periophthalmus koelereuteri, Penaeus notialis* and the crab, Callinectes are corresponding species which we encounter in ARAC fish farm at Buguma.

There are finfish and shellfish which spend different phases of their lives in sea, estuaries and freshwater streams. These forms transcend the salinity barrier by their osmoregulation. Such animals are either anadromous or katadromous. Anadromous fish, as exemplified by salmon or Acipencer or shad, are those that bread naturally in freshwater streams but spend the middle years of their lives in the sea. Katadromous forms, as exemplified by the eel, display the opposite kind of life cycle. These animals breed in the sea and spend the middle years of their lives in fresh water streams.

There are forms which restrict their migration between fresh water sections of the river and the estuary. Several species of palaeomonid prawns (*Macrobrachium ros*enbergi; *M. vollenhovenii*) are examples of shellfish which undergo such a life cycle. These forms breed in estuaries but spend the mid-years of their live in fresh waters. Then, there are forms which migrate back and forth between the estuary or a lagoon and the sea in different phases of their lives. A mullet (e.g. *Mugil cephalus*) or a shrimp (e.g. *Penaeus mododon, P. notialis*) are examples of finfish and shellfish which show such a pattern of migration. These forms breed in the sea but spend part of their juvenile and adult lives in the estuary where they form a sizeable fishery.

Apart from salinity of the water, its temperature exercises a selective influence on fish that thrive there e.g. warmwater fish as contrasted with temperate or coldwater fish. Even in tropical countries, a river may have and usually does have a coldwater section in its upper reaches and a warmwater section in its middle and lower reaches. In temperate countries and in the upper reaches of tropical countries (e.g. at high altitudes), coldwater fish (e.g. trout, loach etc.) live. Then warm waters have their distinctive fish fauna (e.g. scores of species of carps and catfishes and several species of murrels etc.).

Notwithstanding the fact that the capacity of water to dissolve oxygen (DO) is negatively correlated with temperature, the oxygen content of water at a given temperature can vary a great deal depending on turbulance, photosynthesis and BOD. Do of water exercises a selective influence on quality of fish life. In water of low oxygen content, air-breathing fish thrive best e.g. Clarias*, snakeheads** etc. Fish that are used to living in well-oxygenated water e.g. trout, do not thrive in waters of low oxygen content.

Notwithstanding differences in the physioco-chemical characteristics of its habitats (viz. fresh water, brackish water and sea water) aquaculture systems are of several kinds. Most of the systems are highly variable in mannitude and intensity ranging to serve as one-family units or large scale commercial enterprises. The different kinds of aquaculture are:

i. Static water ponds.
ii. Running water culture.
iii. Culture in recirculating systems: in reconditioned water and in closed systems.
iv. Culture in rice fields.
v. Aquaculture in raceways, cages pens and enclosures
vi. Finfish-culture cum livestock rearing.
vii. Hanging, ‘on-bottom’ and stick methods of oyster culture.

Based on the number of species that are cultured in a system aquaculture may be classified into: (a) monoculture and (b) polyculture.

Pond Culture

Static freshwater ponds

Ordinary fresh water fish culture ponds are still-water ponds. They vary a great deal in waterspread area and depth. Some are seasonal and some perennial. The ponds may be rainfed (also called sky ponds) and/or may have inlet and outlet systems. The water supply may be from a stream or a canal or from an underground source such as wells, tubewells etc. The water retentivity of the ponds depends on soil composition of the pond bottom and subsoil water level. The natural biological productivity of such ponds depends on soil and water qualities. Homestead ponds are usually small and shallow. Commercial freshwater ponds have to have an assured water supply and inlet and drainage systems.

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In organised aquaculture, the carrying capacity of still-water ponds is enhanced by manuring and/or fertilizing and exercising water quality control. Fish are also fed from an extraneous source for obtaining fast growth.

Science of freshwater pond fish-culture has made great strides in recent years and there is a fast advancing frontier of knowledge on every aspect of pond culture starting from farm designing and construction upto production of marketable fish of a wide variety of cultured fresh water species of finfish and shellfish. Examples are: carp culture systems in India, China, Israel, Germany, etc; catfish culture in U.S.A.

There is considerable competition with agriculture and other land-use agencies in this system of aquaculture and its success would, by and large, depend on comparative economics of land use. But much also depends on national policies on land use and the encouragement government gives to aquaculture as a means of producing fish protein.

Brackishwater ponds

Not only are the species different from those cultured in freshwater ponds but the principle of operation of brackishwater ponds is different from those of freshwater ponds. Here the pond or the farm is essentially located on a tidal creek or stream and there is a system of sluices to control the ingress and egress of water into and from the ponds. Examples are: Milkfish farms in Philippines, Taiwan, Indonesia etc. Brackish water fish farming is a fast growing science. Here also there is competition with other land use agencies, especially forestry, but the extent of competition with agriculture is relatively less because coastal land is generally not suitable for agriculture. The ARAC farm at Buguma is tidally fed and the salinity range is 5 – 21 ppt.

Mariculture:

Mariculture is aquaculture in the saltwater of the sea. It may be in seas, bays, bayes, sounds etc. e.g. traditional mariculture in inshore and offshore waters by a large number of countries notably, U.S.A., France, Spain, Japan etc. Mariculture of finfish in cages is relatively recent. Though a new development, it has assumed considerable importance and has great potential e.g. mariculture of several species of <u>salmonids; Salmo salar, Oncorhynchus</u> spp; of yellow tail, <u>Seriola quinaueradiata</u>; of red seabream (<u>Pagrus major</u>) etc.

<u>Running water culture</u>

In Japan, at places where there is abundant supply of water, common carp is cultured in running water ponds. The most intensive common carp is cultured in running water ponds. A very high common carp production rate of 980 t/ha has been achieved at the Tanka Running water fish farm in Japan where there is plentiful supply of running water of high dissolved oxygen content and optimum range of temperature for feeding. Running water culture of common carp is done in a small way in Europe, Indonesia and Thailand.

<u>Culture in recirculatory systems</u>

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This system is comparable to running water culture system except that in the latter, water goes waste whereas here the same water is reused. In this system, water is filtered continuously and recirculated, often after aeration, to the fish pond. The filtering element is a biological filter comprising 3 – 4 cm diameter pebbles, or honey-comb synthetic strips, designed to arrest faecal matter and to denitrify catabolic wastes through bacterial action. The Motokawa Fish farm in Japan is well known for carp production in recirculatory filtering ponds. This system has been tried experimentally for carp fry rearing at the Central Inland Fisheries Research Institute, Barrackpore (W.B) India, with commendable results. There are several new developments in reusing water for fish culture, given in two volumes, by Tiews (1981). See also EIFAC (1986).

A recirculatory system is sometimes classified as a system of waste-water aquaculture and reducing biological oxygen demand (BOD) of the waste water. Several mechanisms of handling waste-water exist viz.

1. pretreatment of waste water e.g. cascading through a series of ponds: air system etc;
2. dilution of waste water;
3. pretreatment and dilution;
4. no treatment of waste water.

Benefits lie in:

a. increase in fish yields through increase in natural fish food, 5000 kg/ha at Aquaculture Research Station, Dor Israel from fluid cowshed manure; sewage fed system in Bengal and Tamil Nadu, India - 15,000 kg/ha/year.
b. direct use of solid organic matter in natural waters by phytoplankton and zooplankton.

Restraints in wastewater fish culture systems lie in:

1. Do level in ponds;
2. toxic material in wastewater;
3. tastes and odour in fish;
4. parasites and diseases;
5. public health problems (Salmonella, Shigella) of other Enterbacteriacae;
6. pond effluent standards; and
7. (7) public acceptance.

These lead to problems of fish pond management i.e. acquiring understanding of physioco-chemical dynamics of pond in relation to physiological requirements of cultured species. Polyculture system need to be encouraged where productivity is based on natural foods. e.g. ecological niche approach in the polyculture of Chinese and Indian carps in India.

In reconditioned water:

Water reconditioning in aquaculture is necessary where there is inadequate water supply for the fish culture programme or where water quality requirements are such that reconditioning is indicated.

The different fish rearing systems using reconditioned water are:

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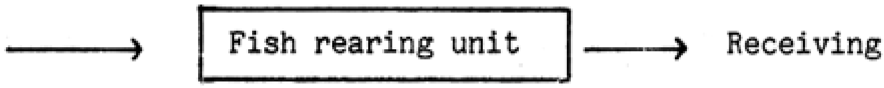
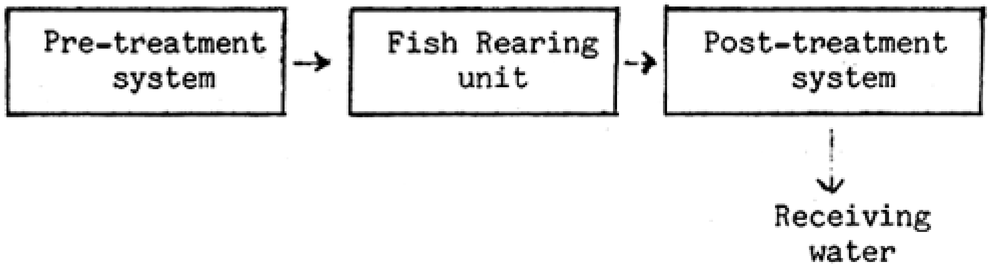
i. simple flow-through (single pass) system i.e. ample water-supply of appropriate quality

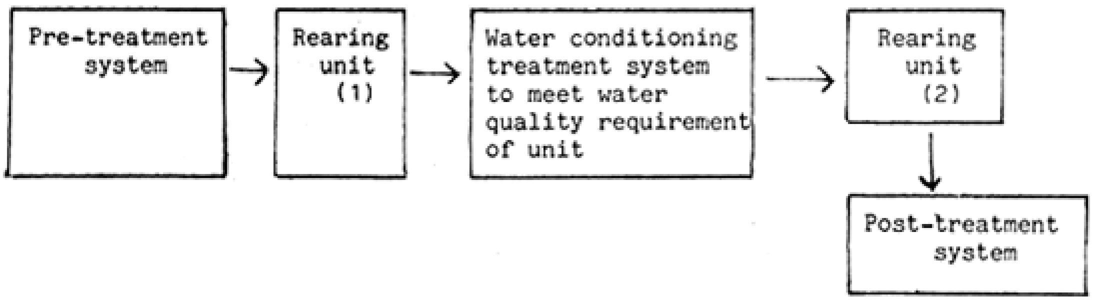


ii. single pass system with pre and post-treatment:

i.e. Water supply



iii. a system re-using water in fish rearing unit:



The pre-treatment processes used are:

(1) sedimentation; (2) screening; (3) shocking to kill aquatic life; (4) filtration; (5) sterilization; (6) aeration; (7) degassing (nitrogen, CO_2 removal) (8) heating or cooling if necessary (9) pH control.

The reconditioning processes are:

1. sedimentation;
2. mechanical filtration;
3. biological filtration;
4. extended aeration;
5. activated sludge;
6. pH control;
7. heating or cooling as the need be;
8. sterilization;
9. de-gassing and
10. ion exchange.

Post-treatment processes are:

(1) aeration; (2) sedimentation; (3) filtration; (4) disinfection; (5) activated sludge; (6) lagooning; (7) digestion or equivalent; (8) coagulation; (9) absorption taste or odour removal by activated carbon.

These systems are mostly applicable to sophisticated and intense aquaculture.

In Closed System:

Fresh water model developed at Ahrenbury in Germany is a 50 m^3 in_3 circuit for mirror carp, Cyprinus carpio, 6 m^3 in fish tanks and 44m^3 in purification unit. Temperature kept constant at 223°C and quantity of food (g of food/fish/day) has been kept equal. Rate of flow: 25 m^3/hour; maximum carrying capacity, determined experimentally being 1.5t of fish and ratio of water volume to fish weight 30:1. Closed circuits have limited carrying capacity and when the capacity is exceeded, the system may break down.

The highest production, an annual yield of 8.6t of carp is obtained using semi-monthly rather than monthly and 1.5 monthly stocking sequence, fish are harvested when 500 g in weight (rather than 1000, 1500, or 2000 g) and fed on fish having raw protein content of 36% (rather than 47%).

The cost of feeds are the main operating costs when using the system. The decrease in income is proportionately more rapid than decrease in production when the size of fish harvested increase and stocking sequence are prolonged. The most economical has been found to be when heat is derived from heat exchanges from industrial cooling water rather than when centrally heated or when diverting one circuit out of 12 to fingerlings production i.e. all circuits producing 500 g fish for the market. As indicated earlier many such trials have been done (see Tiews, 1981).

Culture in Rice Rields

Culturing fish and growing rice together in the same paddy fields is an old practice in Asia and the Far East. Interest in producing rice and fish together had declined in recent years because of use of fish-toxic pesticides required to protect high yielding varieties (HYV) of rice introduced as part of green revolution in Asia. Now, newer HYV of rice strains are being developed with inbred resistance to insects and insect-transmitted diseases which decrease the need for pesticide protection or growing rice. Four trials conducted in Philippines on Tilapia mosambica and Cyprinus carpio stocking have resulted in standing crops of fish in paddy fields averaging 69 – 288 kg/ha at harvest time. More developments in rizi-pisciculture are described in the ICLARM Conference Proceedings on "Integrated Aquaculture - Agriculture farming systems (Pullin & Shehadeh, 1980).

Aquaculture in Raceways: Cages, Pens and Enclosures

Marine aquaculture farms may be located at six possible sites viz. either on the shore with pumped sea-water supply; in the intertidal zone; in the sub-littoral zone, or offshore with surface floating, mid-water floating or seabed cages. The first three are enclosures and the last three cages. The enclosures in Europe have by and large stemmed from those set up for 'yellow tail' (Seriola quinqueradiata) farming in Japan. e.g. of inter-tidal enclosure:

1. Adoike near Takasu in Inland sea in Japan;
2. Ardtoe in Great Britain. Since concrete seawalls or stone-pitched anbankments are expensive, few intertidal enclosures are now built.

Rigid structures

A large number of rigid net enclosures have been built in Inland sea in Japan in recent years, but not all are successful: because of poor siting providing less circulation, others fouled by marine organisms which restrict circulation. More modern successful net enclosures have been positioned after hydrographic surveys to insure sufficient water exchange and research on building material. (Most suitable: galvanised "chain-link" and galvanised "weldmesh") e.g.

a. yellow tail 3.5 ha farm at Sakaide in Seto Inland Sea, Japan.
b. Faery Isles, Lake sween, Scotland.
c. Bamboo barricades for milkfish farming in Laguna de Bay, Philippines.
d. Sub-littoral enclosures for salmon farming in Norway e.g. Flogoykjolpo (1.2 ha) and Volokjolpo (3.5 ha) near Movik, west of Bergen (Farming potential os salmon 1000 t.)
e. Sub-littoral enclosure built in 1974 at Loch Moidart (40 m^3 capacity) (tidal range of 5m).

Flexible Structures

Buoyed fish net enclosure but resting on bottom e.g. 10 ha trial enclosure in Laguna de Bay, Philippines.

Floating Fish Cages

Most important development of the decade is aquafarming. Its merits lie on:

a. can be used where seabed is unsuitable for shellfish.
b. being off bottom, predators can be controlled more easily.
c. can be towed out of danger if threatened by pollution.

Cages with Rigid Framework

e.g.

(a) 8m diameter 6m deep (b) 14m diameter 7m deep	having galvanised steel collar, galvanised chain link bag net for yellow-tail farming in Japan.
(c) cages at Loch Ailort (d) cages at Loch Moidart (6m × 4 × 3. 1m)	for Salmon farming in Scotland provided with rigid collars and cat-walks for inspection of fish.

(f) 50 × 12m Pacific Salmon cage at Reservation Bay near Anacortes, Washington U.S.A.

Cages with Flexible Framework

a. 55m diameter and 25m deep chum salmon (<u>Oncorynchus keta</u>) in Lake Saroma at Hokkaido, Japan. Here netting material can be changed even when fish are in stock.
b. Midwater fish cage of the Hiketa Fishermen's Cooperative Association of Japan in Inland sea: 9m sq. × 8.25m deep with a buoyed feeding neck. These are grouped in 10– 12 cages. They can be raised in calm sea and lowered in rough sea.

c. Domsea Farm cage of Puget Sound, Washington U.S.A. 15.2 × 15.2 × 7.6m cage.
d. Floating fish cage of Kampuchea and Southern Vietnam.

Several new developments in this area and allied aquaculture are described and reported in British monthly, "Fish farming International".

Merits of Cage Culture

Advanced type of aquaculture having scores of advantages over pond culture.

1. 10 – 12 times higher yields than pond culture for comparable inputs and area;
2. Prevents loss of stock due to flooding;
3. No question of seapage and evaporation losses;
4. No need for water replacement;
5. No problem of pond excavation and dependence on soil characterics;
6. Avoids proximity of agricultural areas hence reduces hazards of pesticide contamination;
7. Can be conveniently located near urban markets avoiding the need for fish preservation and transportation;
8. Eliminates competition with agriculture and other land uses;
9. Affords easy control of fish reproduction in Tilapia sp;
10. Complete harvest of fish is effected;
11. Optimum utilization of artificial food;
12. Reduced fish handling;
13. Initial investme nt relatively small.

Limitations of Cage Culture

They are relatively few. They are:

1. Difficult to apply when water is rough;
2. High dependence on artificial feeding. High quality feed fesirable especially in respect of protein, vitamins and minerals. Feed losses are possible through cage walls.
3. At times interferes with natural fish populations round cage.
4. Risk of theft is increased.

In view of these, it is reasonable to consider cage culture practice as one which will prevail in future years. Research on this system deserves to be encouraged.

Finfish Culture-cum-Livestock Rearing

Commercial scale fish-cum-duck culture is practiced in Central European countries such as Czeckslovakia, East Germany, Hungary and Poland, as well as in Taiwan Province of China. FAO has organised this system in C.A.R., Zambia and Ivory Coast and also in Nepal recently. In this system of culture, fish pond water surface maintains brood stock of ducks, rear one-day-old ducklings as well as 14–21 day-old advanced ducklings. This is a synergic system of mutual benefit to each organism cultured: duck droppings manuring the pond, duck foraging consuming a variety of unwanted biota for fishculture such as tadpoles, frogs, mosquito and dragonfly larvae, molluscs, aquatic weeds etc.

One duck produces about 6kg of droppings in 30 – 40 days in a pond and 100kg of duck manure may increase fish flesh to the extent of 4 –6kg. 300 ducks led to an increase by 100kg of carp in East Germany. In Taiwan fish-cum-duck-culture produces 3500kg/ha of fish.

Both poultry droppings and pig excreta are used to manure fish ponds. To save transport costs poultry pen and pig sties are advised to be located at or near fish pond site. A fat pig produces, on the average 1.6 – 1.8t of manure (including urine) per year and fresh manure of 15 – 25 pigs can be used in a one hectare pond. Hungary has developed carbon-manuring technique in early fifties with ducks acting as carbon-manuring machines. In Hungary 30 – 60/ha/100 days of manure is spread. Recently in India polyculture of Chinese and Indian carps in a pig manure fertilized pond led to nearly 7.5 tons/ha/yr production of fish. In C.A.R., production of 10 – 15 tons/ha/yr has been achieved. See Pullin and Shehadeh (1981) for several other experiments on integrated agriculture-aquaculture systems.

Monoculture

Monoculture, as the name implies, in the culture of a single species of an organism in a culture system of any intensity, be it in any type of water, fresh, brackish or salt.

e.g. Fresh water

Common carp in East Germany

Common carp in Japan

Tilapia nilotica in several countries of Africa

Rainbow trout (*Salmon gairdneri*) culture in several countries.

Channel catfish (*Ictalurus punctatus*) in U.S.A.

Catfish, *Clarias gariepinus* in Africa.

Brackish water

Milkfish, *Chanos chanos* in the Philippines.

Mullet culture in several countries.

Seawater

Yellowtail, *Seriola quinquer*adiata in Japan.

Kuruma shrimp, *Peneaus jap*onicus

Nori: Porphyra sp. in Japan

Scallop (*Patinopecten yessoesin*) in Japan

Red seabream (*Pagrus major*) in Japan

Pacific salmon (*Oncorhynchus spp*) in Nort America

Eel (Anguilla spp) in Japan.

Feeding with species spefific feed is the main basis for monoculture in the case of finfish.

5.8 Polyculture

Polyculture, as the name implies, is the culture of several species in the same waterbody. The culture system generally depends on natural food of a waterbody sometime augmented artificially by fertilization and/or by supplementary feeding. If artificial food is given it is a common food acceptable to all or most species that are cultured.

e.g. Fresh water

1. Polyculture of *Clarias gariepinus* and tilapias in Africa.
2. Polyculture of several species of Chinese carps in China, Taiwan etc.
3. Polyculture of several Indian major carp species in India.
4. Polyculture in Indian major carps, Chinese carps and other fish in India (called composite fish culture in India).

Brackish water

1. Milkfish and shrimp culture in Philippines and Indonesia.
2. Mullet and shrimp culture in Israel. In systems where production depends on natural fish pond zonation i.e. ecological niches assume great importance.

Hanging, 'on bottom' and stick methods of oyster culture

In the hanging method, oysters as they grow, are suspended from rafts, long-lines or racks.

Raft method is used in protected areas as in the Seto Inland sea of Japan.

The long-line system has horizontal lines attached to wooden barrels or metal drums at or near the surface from which strings of seed oysters are suspended. The long-line system is used in offshore grounds. The system can withstand rough seas which might destroy rafts.

The structures in the rack method consists of vertical poles or posts driven into bottom which support horizontal poles. Strings of seed oyster are tied to horizontal poles such that they do not touch the bottom. The trend of rack method is downward because of coastal pollution.

In the sowing method, oysters are directly placed on the bottom.

In the stick method, seed oysters are attached to wooden sticks riven into bottom in the intertidal zone.

In both stick & "on bottom" method, crawling predators take a toll of oysters.

Raft and long line methods are most productive as they minimise losses by predation and maximise production. U.S.A., Japan, Republic of Korea, France and Mexico are some of the major oyster producing countries. U.S.A. and France largely use 'on bottom' method. The traditional species in France has been Ostrea edulis and Crassostrea angulata but in recent years, heavy mortalities have occurred and France imported Crassostrea gigas from Japan, Canada and U.S.A. to circumvent the problem. In West Africa, including Nigeria, C. gasar, is being tested for mass scale adoption of aquaculture.

Reference:

BASED ON LECTURES 'INTRODUCTION TO AQUACULTURE' PRESENTED BY V. G. JHINGRAN AT ARAC FOR THE SENIOR AQUACULTURISTS COURSE UNITED NATIONS DEVELOPMENT PROGRAMME FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS NIGERIAN INSTITUTE FOR OCEANOGRAPHY AND MARINE RESEARCH PROJECT RAF/82/009. AFRICAN REGIONAL AQUACULTURE CENTRE, PORT HARCOURT, NIGERIA CENTRE REGIONAL AFRICAIN D'AQUACULTURE, PORT HARCOURT, NIGERIA ARAC/REP/87/WP/11. APRIL, 1987.

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