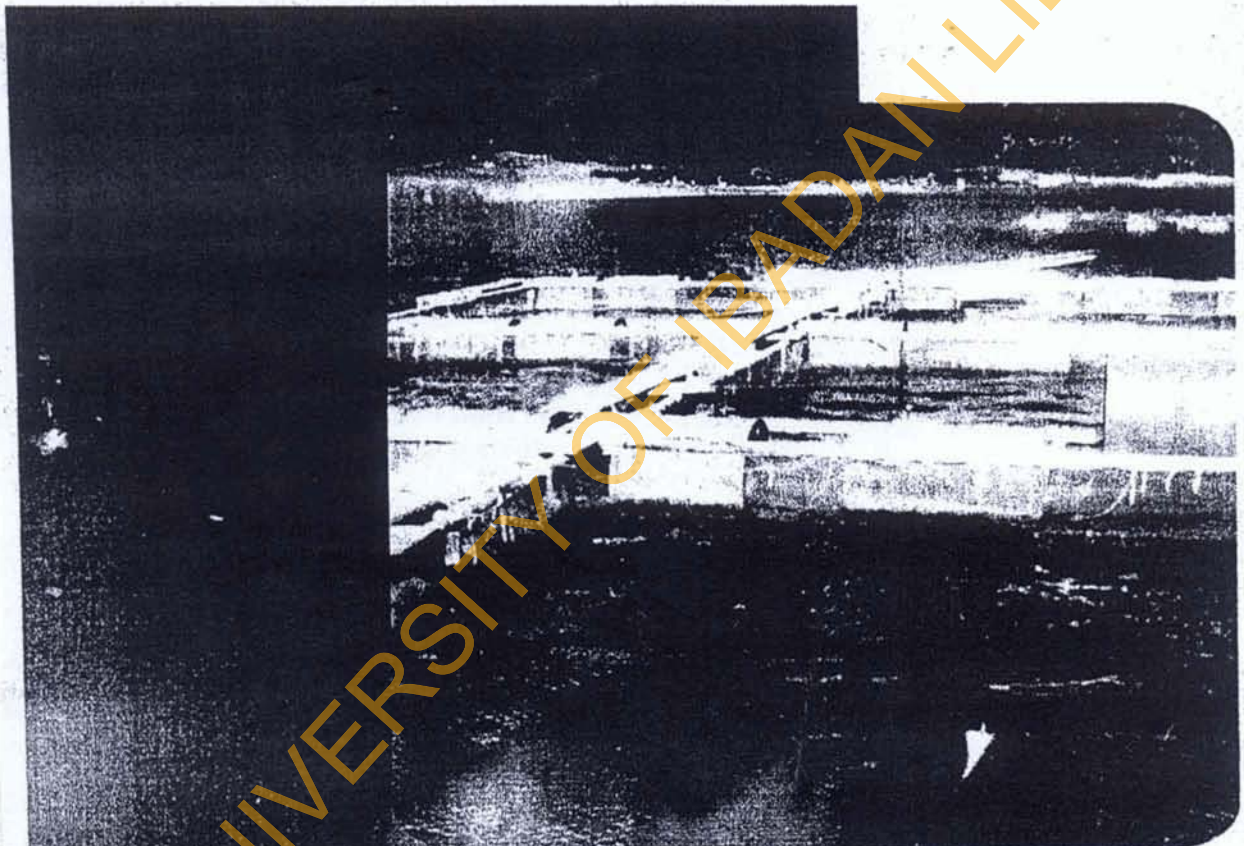
FEDERAL DEPARTMENT OF FISHERIES,
IN CONJUNCTION WITH
UNIVERSITY OF IBADAN VENTURES LIMITED

28

CAPACITY BUILDING WORKSHOP ON FISH CAGE AND PEN CULTURE IN INLAND WATERS OF NIGERIA



TRAINING RESOURCE MATERIALS

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ENVIRONMENTAL CONSIDERATIONS, LEGAL ISSUES AND OTHER PROBLEMS OF CAGE CULTURE

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Introduction

More than fifty percent of the world's fisheries are fully or over exploited (NEPAD, 2005). Analysis of trends show that many marine fish stocks are in decline , inland fish stocks are under threat from environmental changes and impacts , while aquaculture is on the increase (FAO ,2002). Aquaculture has been described as the only way to fill the coming "fish gap". Not only does aquaculture help reduce hunger and malnutrition by producing foods rich in protein, fatty acids, vitamins and minerals, it also improves food security by creating jobs and raising incomes .In Asia about 12 million people are employed in aquaculture .However in Africa, the per capita consumption of fish dropped and its share of global fish production is less than 1 % (FAO 2007).

Cage culture of fish is an intensive method of fish production which permits the use of existing ponds , burrow pits and pits normally unsuitable for open culture by enclosing fish in open cages or pens .It is useful where open pond culture is not possible .Cage culture is an inexpensive method of fish husbandry and it is easier to monitor fish health and growth .Other advantages of cage culture are simpler harvesting and elimination of pond construction costs when existing pond s are used . However, the disadvantages of cage culture include high densities of fish confined to small cages which may lead to water quality problems and aid the spread of diseases. Also fish may escape from damaged cages and the production rate is lower than in open ponds .There are many types of cages such as bamboo frame cages ,wooden frame cages and nylon net cages

The objective of this work is:

- to cosider the problems emanating from cage culture of fish and suggest ways of mitgating them

Water quality considerations for cage culture of fish:

High water quality makes or mars the efforts of the farmer .Changes in water quality affects fish and the best way to prevent disease outbreaks is to practice good feed and water management.

Temperature:

Fish are poikilothermic and have approximately the same temperature as their surroundings. Environmental temperature affects the growth of fish and different species of fish have different optimal growth temperatures as well as upper and lower lethal temperatures. Below the optimum temperature, feed consumption and conversion decline leading to slow growth and feed is used only for body maintenance. Above the optimum temperature, feed consumption increases while feed conversion decreases. Warm water fish like Clarias and tilapia grow best within a temperature range of 29-32 °C

Dissolved Oxygen:

The concentration of dissolved oxygen is important to caged fish. The critical D.O. will depend on other water quality parameters like carbon dioxide, ammonia and nitrite. Warm water species like catfish and tilapia need a D.O. of 4 mg/l (ppm) or greater to maintain good health and feed conversion. Any prolonged exposure to lower D.O .levels will reduce growth and predispose the fish to diseases. In cage culture, it is very important to have adequate D.O. concentrations because large numbers of fish are crowded into small enclosures. D.O. management is important and can be done through removal of excess weeds, manure and aeration.

pH:

This is a measure of the alkalinity or acidity of water. It may fluctuate daily due to uptake and release of carbon dioxide during photosynthesis and respiration. The pH is lowest near dawn and highest at mid afternoon .The desirable range of pH for fish culture is 6.5-9 while the acid and alkali death points are pH 4 and 11 respectively .Outside this range, growth is slow, reproduction reduced, and susceptibility to disease increased. Liming is carried out to reduce acidity and 20 mg/l is the minimum lime concentration for fish ponds.

Ammonia and Nitrite:

Ammonia is the primary waste of fish from protein digestion. Nitrogenous waste s from feed, fertilization and plant decomposition is changed into ammonia by bacteria while *Nitrosomonas sp* converts ammonia into nitrite.Both ammonia and nitrite are toxic to fish. Ammonia toxicity is dependent on fish species, water temperature and pH while nitrite toxicity also depends on fish species and chloride ion concentration in the water .Sublethal levels of ammonia cause gill and tissue damage, poor growth and increased susceptibility to diseases while sublethal concentrations of nitrite lead to reduced oxygen transport in fish leading to poor feed conversion and high susceptibility to diseases. There are two forms of ammonia in water, the ionized and the un ionized forms. The ionized form (NH_4^+) referred to as ammonium ion is not toxic but the unionized form (NH_3) is .The two forms can be inter converted depending on the pH of the water with higher pH resulting in the higher concentration of the unionized form . Proper spacing and cleaning of the cage netting will reduce ammonia build up in the water

Turbidity:

This is the degree of light penetration in water. Soil, organic materials and plankton block light passage in ponds. High turbidity may reduce photosynthesis and oxygen production in ponds but ponds with a moderate amount of suspended clay may not show large D.O. variations .Large amounts of suspended particles may cause clogging of gills, irritation and secondary infections. A healthy plankton bloom has about 38.1-60.96 cm secchi disc visibility (Masser,2007)

Alkalinity and Hardness:

Alkalinity is a system which prevents wide fluctuations in pH and a measure of the carbonates (CO_3^{2-}) and bicarbonates (HCO_3^-)as expressed in terms of Calcium carbonate($CaCO_3$).Fish grow over a wide range of alkalinities but 120- 400 ppm is considered optimum .Alkalinities in water vary depending on the soils around the watershed . Mining pits usually have very low alkalinities and need to be increased before use for fish production by the addition of some buffers such as ground agricultural limestone.

Environmental implications of cage culture of fish:

There is a growing concern about the environmental implications of aquaculture on the environment. The intensity of the production system determines its effects. Environmental concerns from cage culture include eutrophication due to increased nutrient loadings arising from uneaten feed and faeces which dissolve or settle beneath the cage reducing water quality and kill stock the cage may impact negatively on wild populations of fish by producing genetic or competitive effects on wild populations and disease transmission. Under the cages oxygen depletion tends to occur due to decomposition of uneaten feed and accumulated wastes .Eutrophication can lead to phytoplankon blooms causing fish kills and economic losses. Nutrient wastes produce urea and ammonia as dissolved wastes and both uneaten feeds and faeces as particulates .In cage culture there is a higher incidence of diseases which require the use os antibiotics and drugs. Wastes can also lead to direct toxicities of fish.

Aquaculture is the fastest growing sector of the world food economy but has been undertaken far in advance of adequate environmental and public health safeguards. It accounted for 8% of fisheries production in 1984 and increased to 30% in 2002. The increase in production methods has been followed by an increase in the potential threat to the ecological equilibrium in streams, reservoirs and oceans. This intensification of aquaculture production has led to its being regarded as a leading polluter of the aquatic environment" (MacAllister and partners, 1999).

Such is sea cage fish farming's global reach that its demands on fish meal and fish oil is placing pressure on capture fisheries in the South Pacific, Africa, Asia and the Arctic.The environmental impacts of mariculture have received increasing international scrutiny (ICES: 1996, 1999a). Sea cage finfish farming poses problems in terms of mass escapes, GM fish, the spread of infectious diseases, parasite infestation, the reliance upon toxic chemicals, contamination of the seabed and the bioaccumulation of organochlorine pesticides like dioxins and PCBs (Milewski, 2001, Staniford,2002).

The need for the incorporation of high quality animal protein/fish meal / oils , farming of carnivorous species means that more protein is fed to fish than later harvested and complete replacement of fish meal of fish meals /oils may be difficult as they help prevent diseases and increase disease resistance Harvesting small fish for production of fish meal leaves less in the food web for other commercially valuable predatory marine fish, birds and mammals .Bivalve culture takes nutrient s away from the food web and may take out excessive amounts of carbon leaving little for phytoplankton and other herbivores .

Bivalves change particulates to heavier particles that fall back to the bottom so permanent extensive bivalve culture could change coastal food web and eutrophication structure. Seed collection from the wild using destructive techniques destroy or alter habitats. Varied and significant genetic changes occur through escapes of cultured fish or deliberate introductions leading to reduction in genetic variability which can have long term effect on the species . Even sterile fish which cannot affect the gene pool still compete with wild fish for food and disturb nesting sites .Transgenic fish can out compete wild fish for food and nesting sites

All forms of mariculture affect biodiversity at the genetic , species and ecosystems but under certain conditions , mariculture could also enhance biodiversity locally .Other major effects of mariculture are habitat destruction , trophic system degradation , depletion of natural seed stocks , transmission of diseases and reduction of genetic variabilty . Particulate matter including organic forms of nitrogen, phosphorus and sulphates enter the benthos while CO_2 dissolved organic carbon and various nutrients usually move into the water column. The commonly used chemicals in aquaculture are antibiotics, pesticides, disinfectants, antifoulants like tributyl tin.

The five main problems of cage farming are wastes, escapes, diseases /parasites, chemicals and feed/ foods.

1) Wastes:

In allowing sea cages to discharge contaminated wastes into the sea, however, countries are permitting farmers the free use of pristine coastal waters as an open sewer (Folke and Kautsky, 1994). Closed containment systems would not only stem the tide of pollution from sea cages but would also prevent escapes, stop the spread of diseases and parasites to wild fish and reduce the need for chemicals.

2) Escapes, Diseases and Parasites:

The results of a 10-year Irish investigation (funded by the EC) into the impact of escaped farmed salmon on wild fish (McDowell,2002) suggested that farmed fish escapes and hatchery-reared fish were having such an impact that wild salmon stocks were precipitating into an "extinction vortex". As well as spreading parasites and 'genetic pollution' by interbreeding and hybridisation, escapees can spread infectious diseases to wild fish populations. For example, in Scotland since May 2002 (when it became law to report escapes) 3 out of the 4 escapes (totalling 57,000 fish: equivalent to the entire wild salmon catch in Scotland) came from farms infected with Infectious Pancreatic Necrosis (Scottish Parliament, 2002b). Moving cages further offshore will only increase the risk of escapes. Closed containment systems are the only safe solution. The spread of diseases and parasites is a function of overstocking and intensive production (Paone, 2000b). It is therefore inevitable that new diseases on intensive fish farms will emerge

4) Chemicals:

Intensive finfish farmers, unlike shellfish farmers, rely on a lot of chemicals to control diseases and parasites (Costello, 2001). Reports by the World Health Organisation and GESAMP have shown the environmental and public health threats of chemical use on fish farms (GESAMP, 1997). Despite a reduction in the use of antibiotics and organophosphates in salmon farming (OSPAR, 1994) the use of synthetic pyrethroids, artificial colorants, antifoulants, antiparasitics and other 'marine pollutants' merit serious concern (Staniford, 2002a). The toxic chemicals used on salmon farms, in particular, jeopardise not only the environment but also the safety of workers. In Danish trout farms, for example, the abuse of antibiotics has raised consumer and environmental concerns. Chemicals used on salmon farms include carcinogens, mutagens and a myriad of marine pollutants (Staniford, 2002b). Since many chemical 'treatments' are designed to kill sea lice (which are crustacea) shellfish farmers have raised concerns in relation to the negative effects other shellfish such as lobsters, crabs, mussels, oysters and scallops

(Blythman, 2001). Cypermethrin, for example, has been linked to reproductive effects in wild salmon and significant impacts on shellfish over several hectares (Moore and Waring, 2001). The European Medicines Evaluation Agency openly concedes that "the proposed use of Azamethiphos in fish farming means that deliberate contamination of the environment will occur" (European Medicines Evaluation Agency, 1999). Such was the historical use of chemicals like dichlorvos (Ross, 1990) - banned by the UK in April 2002 as it was deemed carcinogenic (Department of the Environment, Farming and Rural Affairs , 2002) - that legal action from fish farm workers with cancers and other health issues is pending in the Scottish and Irish courts (Staniford, 2002b).

Chemicals like DDT, dieldrin, chlordane, hexachloro-benzene, PCBs, toxaphene and dioxins all bioaccumulate through the fish feed, have been found both under salmon cages and in the flesh of farmed salmon (Pesticides Residues Committee, 2002). Anti-fouling paints containing TBT, copper and zinc have also been found under salmon cages (SEPA, 1998b). The World Health Organisation concedes that "veterinary drug residues or heavy metals may accumulate in aquaculture products at levels of concern for public health. There is a wide information gap on the transfer of feed contaminants to edible fish tissues and any implications of this for human health. Studies should be conducted to determine whether the use of pesticides can result in residue levels in fish tissue that are potentially harmful to human health

5) Feed/Food:

Aquaculture's dependence on fish meal and fish oil is rapidly impacting on the capture fisheries sector. Over 3 tonnes of wild fish are required to produce one tonne of farmed salmon for example leading to a net loss on marine resources and a drain on the capture sector .Moreover,"It would be a mistake to abandon the significance of fish oils as subservient to that of fish meal. There is a risk that quality fish oils could prove to be the more finite commodity in the next decade as aquaculture is projected to use 87% of world supply in 2010. This has obvious implications for the salmon sector and others where much of the dietary energy is provided as oil at present" (MacAllister and Partners, 1999) Replacing fish oil in salmon diets with vegetable lipids has already caused problems with the Japanese sending back consignments of farmed salmon as it tastes too 'earthy'. The problem of consumer acceptability of salmon fed on vegetables is something that the EC are now investigating.

The farming of fish such as salmon so high up the food chain is an extremely efficient way of concentrating contaminants. Some fish feed is so contaminated it should be disposed of as hazardous goods rather than fed to farmed fish destined for human consumption. Baltic seafood is so contaminated there have been concerns over PCB contamination of fishery products (Kiviranta *et al*, 2002). Consequently, Finland and Sweden negotiated derogation out of the EC dioxin regulations (ENDS, 2001b). The EC estimate that approximately 20% of all industrial fish (mainly sprat and herring) is by definition 'contaminated' and above the new limits set for dioxins and PCBs (European Parliament, 2001) but for some countries such as Italy, Greece and Denmark over 50% of their industrial fish catches have "high conflict potential" with the new dioxin regulations (i.e. more than half of their industrial fish is contaminated). "PCB accumulates in fish, so there is more PCB higher in the food chain. That means that there is less PCB in krill, which is lower in the food chain" (Hjellestad, 2002). Consumers are increasingly concerned over higher levels of contaminants in farmed fish (Edwards: 2002b). As well as containing more PCBs, dioxins and DDT, farmed fish contain more fat and less of the healthy Omega 3 fish oils. According to the Food and Drug Administration in the US, farmed salmon, for example, are four times fatter than wild salmon (Paone: 2000a). And farmed sea bass and sea bream have been found to contain 17 and 7 times more fat than their wild relatives (Richardson: 2001b). "The study group concluded that there were considerable needs for information associated with the aquaculture sector of food production. The gaps in knowledge hinder the process of risk assessment and the application of appropriate risk management strategies with respect to food safety strategy for products from aquaculture"

Signs of Fish Stress:

It is important to observe very closely and note the behaviour of fish during feeding to recognize changes in behaviour .Signs of stress include reduction in feed consumed , feeding stops , fish swim to the surface gulping for air ,discolourations on skin of fish , dead or dying fish and erratic swimming .A reduction in feeding could be due to disease, parasitic load ,low oxygen and other water quality problems such as ammonia . The presence of scum on the surface may be due to low oxygen and sudden stoppage of feeding may also be due to low oxygen rather than disease .A few dead fish could be an indication of a slowly spreading health problem and skin disclourations due to parasites or diseases. This suggests a proper diagnosis before treatment.

Signs of pond Stress:

The accumulation of nutrients, overstocking or over feeding would lead to pond stress and water quality problems like excessive plankton bloom, surface scum, strong odours , excessive macrophyte growth , and rapid changes in the colour of the water . All these problems if left unchecked would lead to eutrophication. Excessive plankton blooms and weed growth lead to oxygen depletion at night and on cloudy days .Strong odurs occur due to decaying plant materials while quick changes in water colour could be caused by death of plankton .The water can be aerated to inrease oxygen supply and fish released temporarily from the cage to move freely in the pond or changed to another pond.

Problems caused by farmers:

Poor cage construction ,stocking of undersized or poor quality fish ,overstocking /understocking of fish, using ponds with problems , use of poor quality feed, overfeeding ,inadequate disturbance of fish 'disturbance and poor handling of fish . All these can make cage culture an unprofitable venture.

Other problems of cage culture include biofouling or growth of algae on the sides of the cage.These organims restrict water flow through the cage causing water quality problems.Biofouling agents can be removed by using a brush or broom to clean the sides.

Water Quality monitoring in cage fish culture

Monitoring is the regular collection of biological, chemical or physical data from predetermined locations such that ecological changes due to aquacultlure can be quantified and assessed (GESAMP, 1996).Monitoring is an important part of fisheries

management. Good water quality is essential for maintaining the health of cultured organisms which can be for reasons of optimal fish growth or legal liability in case of litigation arising from unacceptable environmental change affecting other users .Also, the consumer needs to know about the safety of the cultured fish. Monitoring shows the changing state of the environment and allows data collection to control fish diseases.
Monitoring also provides research data for many processes such as identification of impacts , developments of methods for future monitoring and the validation of the decision making tool s .In monitoring , determinants of inputs from fish farming include direct measures of ionized and unionsed ammonia , nitrate, nitrite, and dissolved reactive phosphorus , and indirect measures of productivity such as dissolved oxygen , chlorophyll 'a' content , turbitdity ,biological oxygen demand , temperature and pH.Particulates settle to sediments and can be estimated using determinants such as changes in sediment composition (Edwards and Griffiths, 1996), decrease in D.O. or sulphur reduction due to increase in microbial production (Davies *et al* ,1996),and changes in benthic biota(Karakassis *et al* , 1998). Physical and chemical changes in sediments can be investigated using particle size analysis, determination of concentration of organic carbon and nitrogen, redox potential and measurement of sulphide content. Biological changes may be indicated by the presence of sulphur reducing bacteria, abundance of species which are indicative of nutient enrichment.

Available methods and techniques for avoiding adverse effects of cage culture on biological diversity:

All environmental effects are stongly dependent on the sensitivity of a particular ecosystem or its type Some wetlands and ecosystems are particularly vulnerable such as mangroves , estuaries sea grass beds , coral reefs and benthic communities .Wastes can be reduced by better management ,and formulation of feeds to use less animal protein .In enclosed systems , effluents can be treated to avoid outflow of chemicals , antibiotics , diseases and excess nutrients ,better site selection and reduction of nutrient inputs . There is a need to reduce nutreint loss for example by polyculture. The application of integrated marine and coastal area management can optimize spatial distribution and reduce cultural effects. Wastes contain high concentrations of organic and inorgainc nutrients leading to eutrophication and increased organic matter into the ecosystem .Reduction of inputs can be through improvements of feed conversion efficiency which can be through improvement of feed formulations to give better palatability and use of improved strains of fish and shellfish .The use of automated feeders may also reduce feed losses Farm worker can be taught to waste less feed during feeding to avoid economic and environmental losses Removal of sluge from the pond bottom after every harvest would avoid eutrophication and all pond effuents should be treated in a reservoir containing macroalgae , bivales and fish to decrease turbidity and reduce nitrogen and phosphorus release by recycling or reuse .
Fears of disease resistance in human populations are fuelled by overuse of antibiotics in foods including fish .To reduce antibiotic use , there is a need to train workers on proper ways to use them ,Also proactive monitoring and proper diagnosis needs to be done before treatment with antibiotics . The use of antibiotics can also be reduced through proper legislation .Pesticides are highly toxic , persitent and kill non target organisms .Their uses can be reduced by lowering stocking densities ,keeping large distances among

farms ,training on proper use , better hygiene and use of self contained systems where possible.

An alternative to the use of hormones is proper genetic selection. The use of photoperid management has been practiced in salmon farming and studies could be carried out to find suitable methods for other fish species .Cryo preservation could also be considered to optimize broodstock management and seed supply.

Diseases can be be prevented through improved monitoring programmes for known and emerging illnesses. All sick animals should be quarantined and treated.Effluents from such farms should be properly disinfected with ultra violet or ozone .Protocols must be put in place for quarantine and movement of animals. The use of international code of practices , agreements and technical guidelines to minimize risk of diseases associated with the movement of animals .Also regionalally-oriented guidelines need to be operational and there should be close collaboration on issues of trans boundary movement of aquatic animals . Indigenous species should be used for aquaculture. Aquatic health capacity should be strengthened by training personnel, improving laboratories, control protocols and therapeutic strategies Tthere should be establishment of harmonized regional reference laboratories for standardization and validation of diagnoses. There should also be regional training programmes on aquatic animal health which should include transboundary movement, risk assessment and contingency plans.

Effects of escaped fish can be reduced by carrying out risk analysis before the intrduction of any exotic fish to an area to assess any likely impacts .Management practices need to be improved to limit escapes and sterile invividuals can be used . Each farm must have a proper broodstock management plan to limit the spread of selected species by supporting the production of sterile offsprings(UNEP,2002) .

There is a growing concern about the environmental impact o.f cages and that the inevitable escapes of caged fish can have significant effects on existing fish communities (Phillips *et al*. 1985b). Knowledge of the environmental load from fish farrning and of the physical, chemical and biological characteristics of a body of water,is important for decisions on the number and size of fish farms that can be established there (Karlgren, 1981).

Conclusion:

Cage fish culture can provide a more assured source of income where water is unsuitable for fish culture or where fish catches from the wild have dwindled. Cage culture of fish is now receiving attention due to increasing demand for fish; declining wild stocks and poor farm economy have produced a lot of interest in cage fish culture. Cage culture offers the farmer an opportunity to use existing water resources which in most cases would have limited value for other purposes. Also cage culture has been successfully used for mariculture in China with high levels of profitability.

The future of fish farming lies in moving away from the intensive monoculture of finfish towards shellfish farming and integrated polyculture systems. There should be research in the field of sustainable aquaculture, including technical constraints to, and economic viability of onshore and offshore aquaculture, waste water treatment techniques, alternative protein sources to fish meal and oils, and development of polyculture option

.If cage fish farming is to have any long-term future it must treat its wastes and focus on non-carnivorous species that do not lead to a net deficit in fisheries resources

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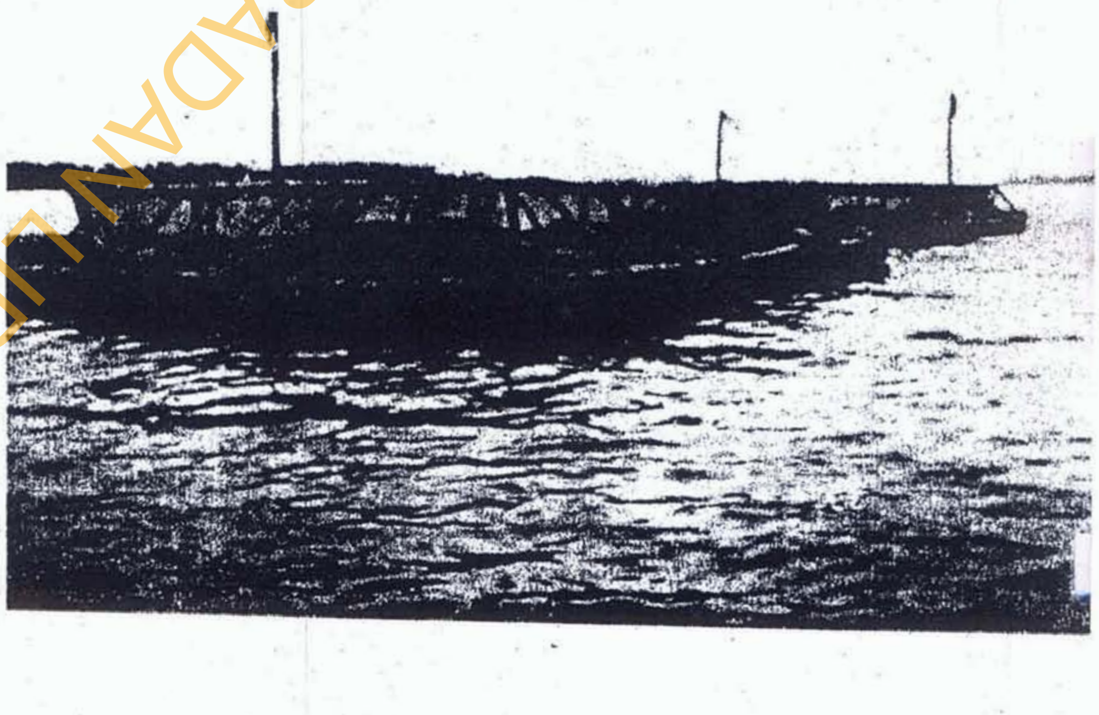

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