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IDRC CAGE CULTURE PROJECT IN SRI LANKA

by

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ACKNOWLEDGEMENT

I would like to record my thanks to the Ministry of Fisheries for all the help rendered during my visit in Sri Lanka.

IDRC CAGE CULTURE PROJECT IN SRI LANKA

1. INTRODUCTION

Fish is one of the main sources of animal protein in Sri Lanka. Annual production has been estimated to be in the region of 140 000 tonnes from which over 60% of the population obtain their protein supply. In recent years, the per capita consumption of fish has dropped from 14 kg to 11 kg due to decreased imports and increasing price. Hence, the government of Sri Lanka has placed high priority in increasing fish production to meet the growing need for fish protein.

Over 90% of the fish landings in Sri Lanka are caught from the sea. Although Sri Lanka has over 10 000 man-made reservoirs or 'tanks' with a total area of about 138 000 ha., the annual production from these inland freshwater bodies was estimated to be only 13 500 tonnes per year which is less than 10% of the total landings. Obviously, the great potential of the reservoirs for fish production has not been fully tapped. Current activities involved stocking of the reservoirs with carps and *Tilapia*, however, due to the immense body of water and presence of tree stumps, harvesting has been difficult.

Cage culture has been proposed as one of the alternatives to utilise the vast area of water mass in addition to the stocking programme currently underway. The

International Development Research Centre (IDRC) has initiated a preliminary project to study the technical feasibility of cage culture system in these reservoirs. Raising fish in cages is new to this country and technical know how on cage culture has been lacking. Despite these, the Inland Fisheries Division had constructed some cages for experimental trials in 1979. With the financial assistance from IDRC, the project is aimed at:

i) *determining the applicability of cage culture system in reservoirs and lakes;*

ii) *selecting suitable species for culture;*

iii) *assessing its economic viability and superiority over other traditional pond culture or natural stocking;*

iv) *defining the technological applicability and constraints to development and*

v) *training Sri Lanka research and extention workers in research techniques and demonstration and implementation of the adopted technologies.*

In order to avoid unnecessary waste of time and monies through trial and error, it is essential to begin the project by adopting existing technology already available in other countries. Appropriate modifications of adopted technologies will depend on the local environmental conditions and availability of local materials. The role of the cage culture consultant in this programme is to assist in the transfer of such technology to Sri Lanka and to assist the researchers of the Inland Fisheries to plan a research programme aimed at achieving the above objectives.

2. TERMS OF REFERENCE

The terms of reference for the consultant are:

a) *to visit the Department of Fisheries in Colombo, Sri Lanka and the sites of the cage projects;*

b) *to advise on the specific details of floatation system, frames, netting, anchoring, siting and protecting these net-cages;*

c) *to advise on the practical operation of these cages including fish species, stocking density, size, feeding, disease and harvesting and*

d) *to make recommendations to IDRC for restructuring the project to achieve its objectives.*

3. ITINERARY

The programme prepared by the Department of

Fisheries after some modifications was as followed

Saturday	26th April	-	arrival in Sri Lanka
Sunday	27th April	-	review of literature
Monday	28th April	-	discussion at Inland Fisheries Division with: Miss Y.I. Raphael (Deputy Director of Research) Mr. S.M. De Silva (Research Officer) Mr. Don E.S. Jayamaha (Project Coordinator) Mr. Elmo Weerakoon (Aquaculturist)
		-	visit Dandugama Oya project
		-	inspection of Negombo Lagoon
Tuesday	29th April	-	leave for Polonnarawa
		-	visit cage culture project at Parakrana Samudra Reservoir
		-	discussion with Mr. A. Hettiaratchi (Fishery Officer-in-Charge)
Wednesday	30th April	-	leave for Nuwara Eliya
		-	visit Freshwater Research Stations at Nuwara Eliya
Thursday	1st May	-	visit trout stream in Hortan Plains
		-	visit cage culture project in Gerory Lake
		-	visit trout hatchery, discussion with Mr. Francis Anthony Craze

		- visit Sport Club's trout farm - discussion with Mr. A.D.S. Jayawardana (Fishery Officer-in-Charge)
Friday	2nd May	- leave for Uda Walawe - visit Freshwater Fish Breeding Station - Visit cage culture project in Uda Walawe Reservoir - discussion with Mr. K.S.B. Tennekoon and Mr. N.K.G. Chandrasekera (Fishery Officers of the Station)
Saturday	3rd May	- return to Colombo - review of literature - design of cages
Sunday	4th May	- discussion with Mr. Jayamaha and Mr. S.M. De Silva on model cage construction
Monday	5th May	- discussion with Mr. Thayaparan (Director of Inland Fisheries) - visit proposed cage culture site at Kalutara Lagoon
Tuesday	6th May	- visit proposed site for carps at Muruthawala Reservoirs

Wednesday 7th May	- visit Colombo Lake - advise on construction of model
Thursday 8th May	- inspection of cage model - discussion with Director of Inland Fisheries and Economist of IDRC Project
Friday 9th May	- return to Penang

4. REVIEW OF CAGE CULTURE PROJECT

4.1 PARAKRAMA SAMUDRA CAGE CULTURE PROJECT

4.1.1 Characteristics of the lake

Parakrama Samudra is an ancient man-made lake located in the dry zone in the district of Polonnaruwa. The lake is 7.9 km long and 4.3 km in width with a total area of 6 300 acres at full supply level. The depth of the lake varies at different localities. The depth was 30 - 40 ft where the present fish cages were located.

The hydrobiology of the lake had recently been investigated by an Austrian scientific team. Much information on the physical, chemical and biological characteristics are contained in the Interim Report of the team.

Characteristics which are of direct relevance to the selection of cage culture sites are summarised below:

Temperature	: 24.5 - 34.5°C (Euphotic Zone)
Wind Speed	: ≈7.5 m/sec (maximum in July)
pH	: 8.7 - 9.7
Dissolved Oxygen	: 7.6 mg/l
Conductivity	: 130 - 210 ohms/cm
Alkalinity	: 1.22 - 1.58 megu
Total Phosphorus	: 35.0 - 167.0 μg/l
Sediments	: organic rich fine, silty clay
Annual rainfall	: 19 - 555 mm, annual 1974 mm
Primary Productivity	: 4 gC/m/day
Zooplankton	: mainly rotifers, 1 500/l (zooplankton biomass low)
Main fish species	: *Tilapia mossambica, Etropus suranensis, Lates dussumeria*

4.1.2 Cage culture in the lake

A series of 10 cages had been installed in the lake closed to the shore. The locality at which the cages were sited measured 30 - 40 ft. deep.

The rectangular cage made up of bamboo frames, 8 ft x 4 ft and 5 ft high. The vertical wall of the cage was lined with closely arranged bamboo strips. Inside the bamboo cage was hung a net-cage. The edges of the net were attached firmly to the corners of the bamboo frame. The net was fully covered and only one corner of the net was opened to facilitate feeding.

The nylon nets inside the bamboo cages were then floated with one layer bamboo floats along the side. The top of the cage was also covered with a fairly heavy bamboo cover. Five of these cages were then joined together forming a battery of bamboo cages.

These cages were extremely clumsy and had the following defects:

1) *The bamboo cages were too heavy and difficult to operate.*

2) *The net inside the bamboo cage was permanently fixed and cannot be lifted up without raising the bamboo cage. Sampling of fish for measurement purposes was extremely difficult and time consuming.*

3) *The bamboo floats were too few in number and the cages were too heavy resulting in poor floatation and hence gradual sinking of the cages.*

4) *The design of the cage made it difficult to feed the fish and hence, feeding is extremely inefficient, resulting in a lot of wastage of feeds.*

5) *The nylon netting was too thin. The net*

was of 5 - 6 ply in thickness and was not sufficiently strong to resist abrasion.

6) *The external bamboo frame serves no purpose to protect the fish inside the net-cages from predators such as monitor lizards, water snakes or otters as the space between the vertical bamboo strips was too wide to keep the predators away.*

Each cage was stocked with *Tilapia nilotica*, grass carps and common carps with stocking rate at about 75 per cage or 22 fish/m^3. As some of the cages were almost submerged, the fish inside the cage could not be sampled for measurement of growth rate. According to the Officer-in-Charge, the fishes were fed once a day with pellet feeds containing 25% of crude protein.

4.2 NUWARA ELIYA CAGE CULTURE PROJECT

4.2.1 Characteristics of site

Nuwara Eliya district has 20 000 acres of freshwater bodies, most of which are village 'tanks'. Big reservoirs such as Mousekella (1 950 acres) and Castle Reign (955 acres) are used for irrigation purposes.

The cage culture project is sited in Lake Gerory (about 300 acres), located in a valley surrounded by tea plantations.

Nuwara Eliya has a cooler climate with temperature usually below 20°C. The water temperature is usually around 16°C but there are reports that water temperature can drop to 2°C during extreme cold weather.

Lake Gerory is relatively calm with no records of strong wind nor severe wave action. The lake has a depth between 10 - 40 ft except close to the shore where the edge is relatively shallow.

The water appeared to be rich in plankton, though no measurement of the primary productivity had been made. Preliminary measurements of the water quality indicated that the lake was slightly acidic with pH ranging between 5.6 - 6.0. Alkalinity was low (0.45 megu) and dissolved oxygen at approximately 7 mg/l. The lake appeared to be enriched by organically rich drainage from the tea plantation where inorganic fertilizers were applied as well as from the waste derived from the dairy farms. The bottom of the lake was muddy clay.

The main species of fish found in the lake consisted of common carp, mirror carp and grass carp. No predatory fish had been reported. The lake was also commercially fished and daily production was estimated to be 50 pounds.

4.2.2 Cage culture in Gerory Lake

Similar types of bamboo frame enclosing a nylon net-cage as used in Polonnaruwa Reservoir were used for culturing of rainbow trout (*Salmo gairdneri*), common carp, mirror carp and grass carp in the Gerory Lake. The cages were in good shape although two of them appeared to sink at one end. Each cage was widely spaced.

Each net-cage was stocked with 75 fish. For each species, two net-cages with the same stocking density were used to determine the growth rate under different feeding conditions, that is, one without feeding and the other fed 10% body weight twice a day. One cage consisted of mixed species of grass carp, common carp and mirror carp and fed with pellet feeds prepared by the Institute of Fish Technology at Colombo.

Initial mortality was observed but of negligible significance. Measurements of the growth rate could not be determined because of the difficulty in sampling the fish. The net-cages were firmly fixed to the bottom of the bamboo frames, the fish inside could not be sampled without lifting the whole cage which are prohibitively heavy to be managed by two or three workers. The floating unit was too weak and floatation was insufficient to allow proper maintenance of the cages.

4.3 UDA WALAWE CAGE CULTURE PROJECT

4.3.1 Characteristics of Uda Walawe Reservoir

Uda Walawe Reservoir (8 430 acres) is the largest freshwater body in the district which has 12 000 acres of inland waters. It is located in the dry zone same as Polonnaruwa. Raining seasons are April to May and December to January.

The water source is mainly from Uda Walawe River as well as from rainwater from the catchment area. The water is being used for irrigation purposes and for running a 3 megawatt hydroelectric plant.

The reservoir is subjected to strong wind pressure and wave height of up to 2 feet had been reported.

Water quality was good with pH ranging from 6 - 8, dissolved oxygen between 7.5 - 8 mg/l, alkalinity 1.5 and conductivity 150 ohms/cm; water temperature fluctuated from $24^{\circ}C$ to $31^{\circ}C$.

There has been no detail limnological survey conducted for this lake.

Fish species found in the reservoir were *Tilapia mossambica*, *Etropus suranensis* and Chinese carps. Total fish production was estimated to be 250 - 300 tons/ year or 75 lb/acre/year. Main fishing activities were gill-netting, hook and line fishing. Approximately 80 fishermen were operating in the reservoir.

4.3.2 Cage culture project

The project began in March, 1980 with 10 cages similar in design and structure as that of the other areas described earlier.

The first batch of stocking experiments with 75 fish per cage were abandoned due to death of fishes during transportation and handling during sampling.

The second stocking was conducted in late March with 6 cages used for grass carp experiment, stocking at a rate of 150, 200, 250, 300, 350 and 400 fish per cage. One cage each for *Tilapia mossambica* (250/cage) and red common carp (150/cage) and two cages for polyculture of red common carp and grass carp.

Size of fish stocked ranged from 5 - 7 cm and the fish were fed with a specially prepared pellet containing 30% fish meals, 65% poultry feeds and 5% rice bran. No grass was given to the grass carp because of difficulty in feeding due to the poor design of the cage. The fishery officer then devised a feeding tube attached to a conical bag for his daily feeding operation. The growth rate measured so far was not satisfactory as the increase in growth was found to be 0.6 - 0.8 cm per month.

Major problems include poor floatation, difficulty in sampling inefficiency in feeding and slow growth. Other problems faced were mainly administrative in nature in that the officer involved in the project could not attach more time to the cage culture project because of other administrative duties.

4.4 CAGE CULTURE PROJECT AT DANDUGAMA OYA

4.4.1 Characteristics of Dandugama Oya River

The Dandugama Oya River is one of the inlet channels to the Negombo Lagoon which is a brackish lagoon located 14 miles from Colombo. The Dandugama River is brackish most months of the year except during April to May and November to December when the river water turns almost fresh with salinity ranges from 0 - 5‰.

The river is 8 - 10 miles in length and approximately 100 yards in width with depth ranging from 10 - 15 feet. The bottom of the river is mud up to 1 foot deep.

The river is affected by tidal current which brings saline water into the river at high tide. However, during the wet season, when land discharge is high, large volume of freshwater flows into the lagoon through this river.

The water quality therefore reflects that of the lagoon during the dry months. The pH value ranged from 7.5 during wet months to above 8 during the dry period. Salinity ranged from 15 - 21 ppt at dry period and dropped to between 0 and 5 ppt during the raining season. Dissolved oxygen is above 6 mg/l and water temperature fluctuated between 24 - 34^{o}C. Tidal fluctuation about 1.5 feet. The river is calm and no wave had been recorded.

4.4.2 *Cage culture project in Dandugama Oya*

Cage culture was initiated in mid 1979 with wooden frame cage for the rearing of *Tilapia nilotica* by Mr. S.M. De Silva. First harvest was taken during January 1980. Subsequently, the cage design had been improved and the project which was originally initiated by Mr. De Silva through the advice of Professor Arudpragasam, was converted into the Ministry project.

Existing cage culture programme consisted of 8 cages of size 6 x 6 x 5 ft and were stocked with the following:

T. nilotica	:	300/cage (with pellet feeds)
		300/cage (feeding with rice bran)
		400/cage (pellet feeds)
		150/cage (parent stock)
T. mossambica	:	400/cage (pellet feeds)
Etropus suranensis	:	350/cage (pellet feeds)
Cyprinus carpio	:	150/cage (pellet feeds)
Chanos chanos	:	5 000/cage (rice bran)

The pellet feeds given were made up of:

26% rice bran
19% coconut residue cake
5% ox blood

The pellet was estimated to contain 18% of crude protein. The fish was fed 5% body weight and supplemented with 2 lbs of mixture of duckweeds every day. Feeding was done twice a day.

The first harvest in January, 1980 netted 230 lbs of *Tilapia* weighing approximately ½ lb (250 g) each. The growth period was 6 months.

5. RECOMMENDATIONS

5.1 IMPROVEMENTS OF EXISTING CAGE STRUCTURE

There are 30 cages being constructed and used in Polonnaruwa, Uda Walawe and Nuwara Eliya. All these cages are not suitable for experiments nor for commercial culture purposes. The reasons for rejecting these cages are:

1) *The cages are too heavy and floatation too weak to maintain the cage in a floating position for the whole culture period. The cages may be sinking further.*

2) *It is not possible to conduct any meaningful scientific experiments with the present cage design as sampling and feeding of the culture fish are extremely difficult and inefficient.*

In order to attain the objectives as contained in the IDRC Project Proposal, a new set of net-cages have to be reconstructed to provide a working platform on the cages to enable scientist to sample or measure the fish as well as to allow easy maintenance of the cages. It is therefore suggested that existing cages be dismantled and the material used for construction of new cages or the cages further improved and used for stocking purposes (not for experiments). Improvement should be directed towards:

a) *increasing floatation of the bamboo cage by adding two layers of bamboo floats to each side of the cage. Each layer of bamboo floats should consist of at least 4 bamboo poles of 3" diameter;*

b) *reducing the bamboo strips on the vertical, oblique and bottom frames, leaving only the rectangular framework as shown in Figure 1a;*

c) *the bamboo cover should be removed completely;*

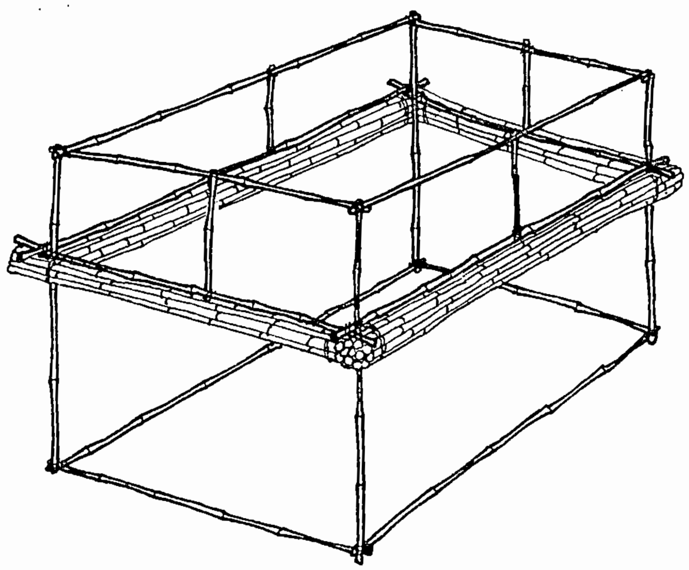


Fig. 1a

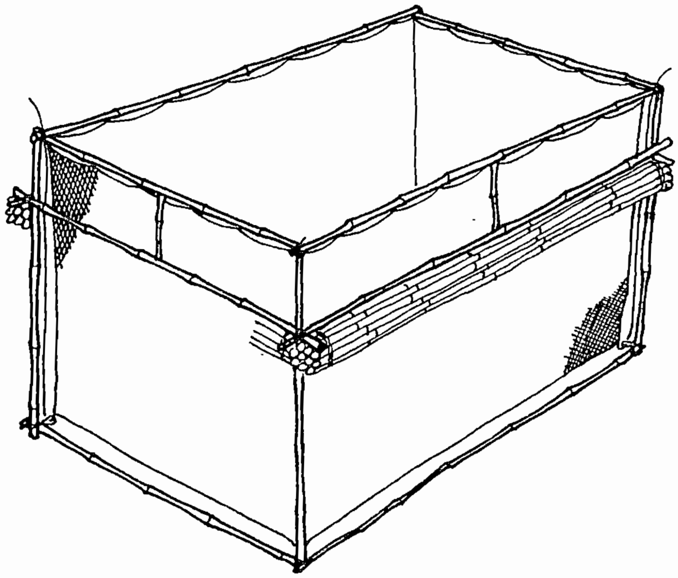


Fig. 1b

d) *the net-cage should be tied to the rim of the top bamboo frame so that at least 1½ - 2 ft above the water level;*

e) *the mouth of the net should be covered with 1½" netting (not fine mesh nets) to prevent bird predation and to facilitate easy feeding and*

f) *the rope connecting the edges of the net-cage at the bottom should pass through a rattan ring and tie to the bamboo poles at the surface (Fig. 1b). The rope should be strong and have a length of at least 2 times the height of the cage. This will enable the net to be lifted up for harvesting or examination.*

As the netting material is made up of 3 ply threads, it is necessary to have another outer protective layer of netting to prevent fish from escaping.

(Copy was given to Mr. Oudara – 14/5/81) Pgs. 18 - 33

5.2 NEW CAGE DESIGN AND STRUCTURAL DETAILS

5.2.1 *Principles*

The designing for new cages is based on the following assumptions that:

a) *the cages are to be used for experimental purposes and that scientists* *and workers need to operate the cage regularly for samplings and cage maintenance;*

b) the nets need to be lifted up periodically for sampling of fish and for maintenance and repair;

c) the cages are to be used in inland freshwater and to withstand wave height up to 2 feet and

d) it is necessary to minimise cost to its basic necessity.

In view of the fact that it is desirable to build cheaper cages using local available materials, such considerations have been given to the present cage designing.

5.2.2 Cage design for experimental work

In view of the high wave in certain reservoirs such as that of Uda Walawe and Parakrama Samudra in Polonnaruwa, the cage structure must be strong and rigid so as to withstand against wave action.

The proposed floating cages will be suspended from a floating platform measuring 20 x 20 ft with catwalk of approximately 2 ft all round (Fig. 2). Each

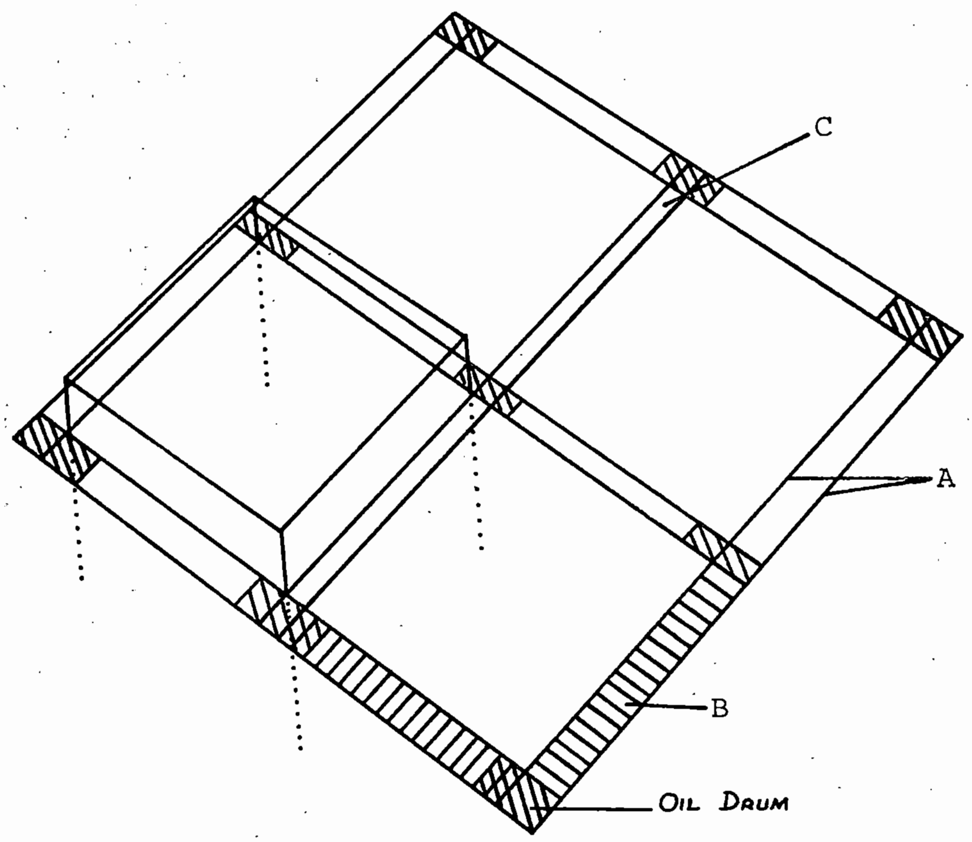


Fig. 2

platform has a floating unit consisting of oil drums. There are four compartments in each platform to enable suspension of unit cage.

a) The floating unit

The floating unit consists of:

i) 9, 45-gallon oil drums which have been painted with 3 layers of tar and

ii) a wooden platform floated by the 9 oil drums located at the corner of the platform (Fig. 2). The outer frame (A) of the platform is made up of 2 pieces of 2" x 3" timber of length 20 ft at each side. The catwalk (B) is lined with 1" x ½" timber placed at 4 inches apart. The 20 x 20 ft cage is divided into 4 compartments by 4, 2" x 2" timber of length 20 ft (C). The distance between two parallel dividers (C) is 2 feet. The top surface of the framework should be flushed. Nuts and bolts are used to fasten the timber together.

b) The cage frame (Fig. 3)

From each compartment, a cage frame is constructed which consists of:

i) a square frame (E) of size 7.0 x 7.0 ft made up of 2" x 1" timber;

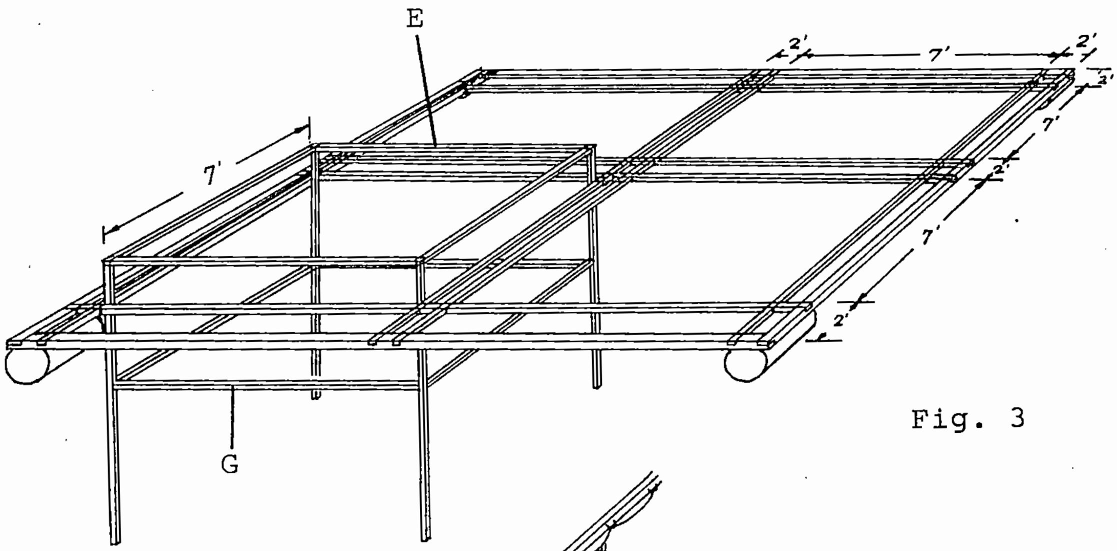


Fig. 3

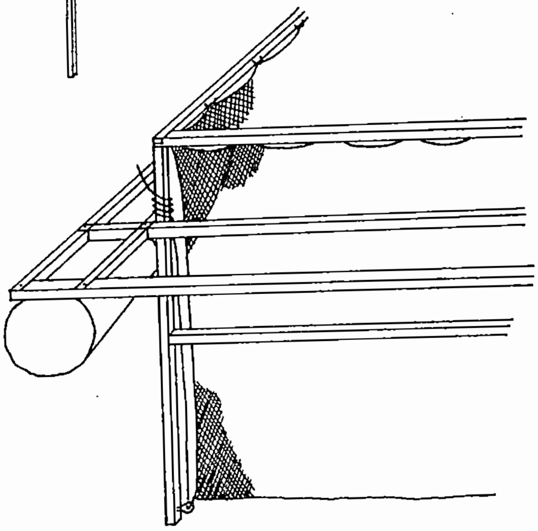
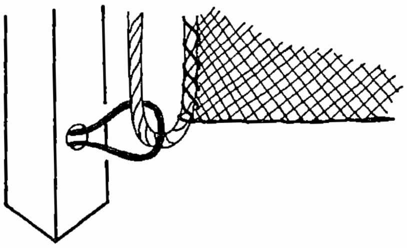


Fig. 4



H

ii) the four corners of the frame are supported by 4, 2" x 2" timber of length 8 ft permanently fixed to the floating unit. Each side of the cage frame is reinforce by a 1" x 2" horizontal timber (G);

iii) the side of the square frame are fixed with hooks sleeved with plastic tubing to prevent rusting and to facilitate hanging of the net-cage. The hooks are spaced at 1 foot interval and

iv) 6" above the tip of the suspended poles from the frame is a hole at which a rattan ring passes through (H).

c) The net-cage

The size of each net-cage is 7.0' x 7.0' and 7 feet high. When hung to the wooden frame only 5 feet of the vertical net is below the water level. The top portion of the net above the water level prevent fish from jumping out.

Each net-cage must be properly fixed with a headline (nylon rope) around the mouth and the side of each cage to be strengthened by vertical rope of diameter 6 millimetres. The rope extending from the vertical edge of the net-cage at the bottom should be at least twice the height of the height of the cage.

When fixing the net, the headline is first fastened on the hooks and the extended rope at the corner of the net is allowed to pass through the metal or rattan ring (H) and then securely fastened to the frame at the floating platform as shown in Figure 4.

d) Anchoring of platform

The floating platform should be anchored properly. In area where the water is deep near shore, such as at Polonnaruwa, one side of the platform can be fastened by synthetic rope to the rocks on the shore front which serve as excellent anchoring facilities for the cages. The other ends of the floating platform should be anchored to the bottom using a 10 kg rocks. The length of the anchor line depends on depth and expected maximum stress. In view of the strong wind in Polonnaruwa and Uda Walawe, cages are expected to rock vigorously with strong wind, the anchor-line should be at least 3 times the depth (Figs. 5, 6 & 7).

e) Construction of net-cages

Nylon or polyethelene netting material is recommended for construction of net-cages. Polyethelene netting material is strongly recommended as it is rather resistence to the immense heat of the tropical sun. Both knobless or knob netting material can be used, however, knobless netting is difficult to mend.

Fouling of net-cages in freshwater is less severe than that of sea cages and in view of the relatively calmness of the water bodies in the inland region,

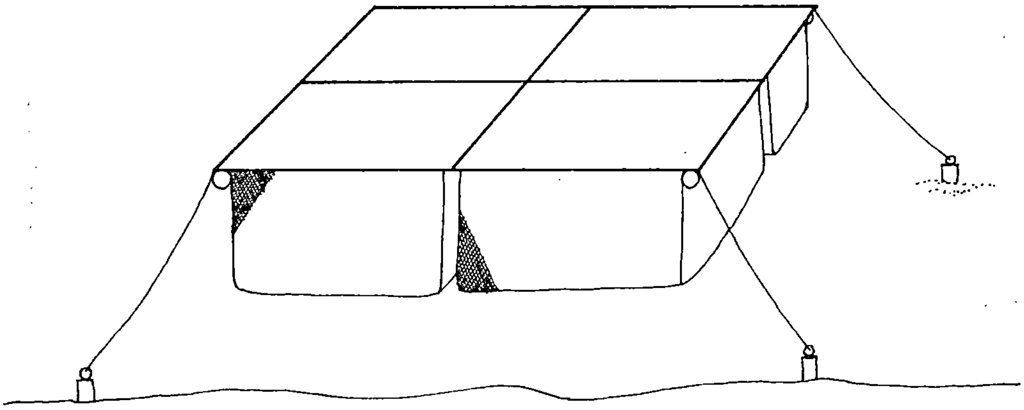


Fig. 5

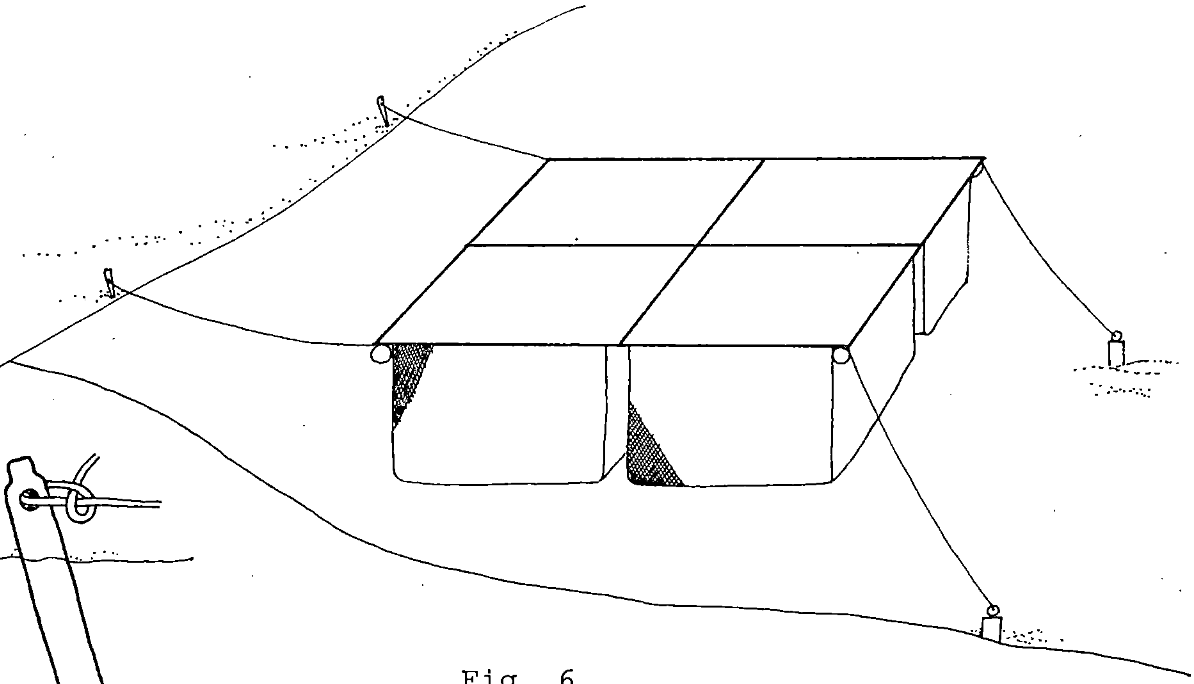


Fig. 6

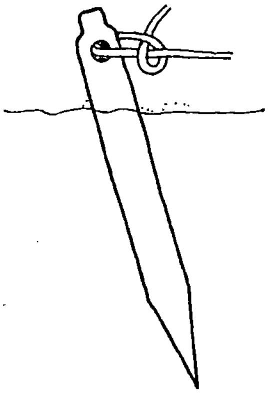


Fig. 7

the netting material used should not be less than 9 ply. In areas such as Uda Walawe and Polonnaruwa where strong waves prevail, stronger netting material of 15 - 20 ply is recommended.

Mesh size used must be small enough to retain the fish, but, as the fish grow, net cages of larger mesh size should be used so that the cage will take longer time to be fouled and also it will reduce the cost. It will also provide better water circulation.

The mesh size recommended are as follow:

Length	Thickness	Mesh size
1½" - 3"	6 ply	½"
4" - 6"	9 - 12 ply	¾"
8" - 12"	18 - 24 ply	1"
> 14"	18 - 24 ply	1½"

The number of pieces of net-cages for each depends on the species cultured. For *Tilapia* culture, the fish is usually harvested at a size of ½ - 1 lb and as such, ½", ¾" and 1" mesh net are required. For big-head and grass carps, 1½" mesh net-cages may be required to contain larger fish. In usual practice, two net-cages of each mesh size should be kept, one for replacement during repairs or cleaning and maintenance of nets.

The net should be cut and then sewn to the required size. The edges of each must be reinforced by synthetic rope.

5.2.3 Cage design for commercial practices

Cages used for commercial fish production should be cheap but also strong enough to stand wear and tear in the aquatic environment. Apart from regular maintenance of cages, the fish in the net-cages are usually not temper with until they are harvested.

Since bamboo is relatively cheap and abundant in Sri Lanka, it is an excellent material for the construction of the floating cages. Bamboo pole of 25 feet long is available in the market. The size of the cage can be large as long as it is easily managed. The larger the cage size, the lower will be the cost of construction. However, too large a cage will render maintenance and management difficult. Commercial cages up to 50m x 50 m had been used in Philippines and Indonesia. For the present cage culture project, it is suggested that the cage should not be bigger than 10 x 10 ft and 7 ft high. The design of the cage follows the same principles outline earlier:

a) Floating unit - Instead of using oil drums to float the working platform, it is suggested that at least three layers of bamboo poles be used as floats and at the same time serve as the catwalk (Fig. 8). The bamboo poles must be of the same diameter (3" diameter) and securely fastened with synthetic rope.

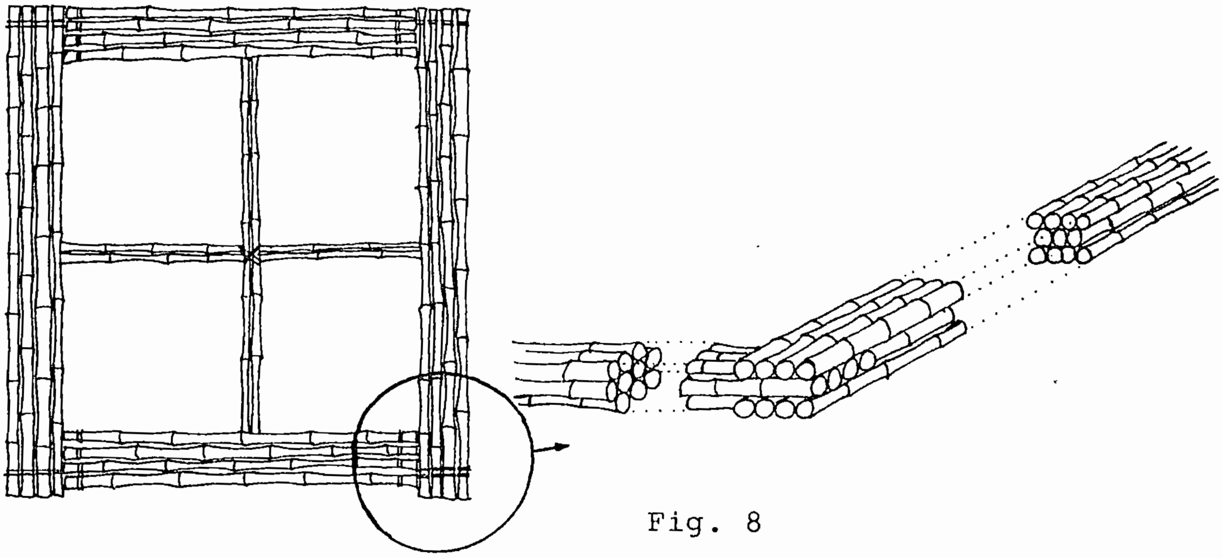


Fig. 8

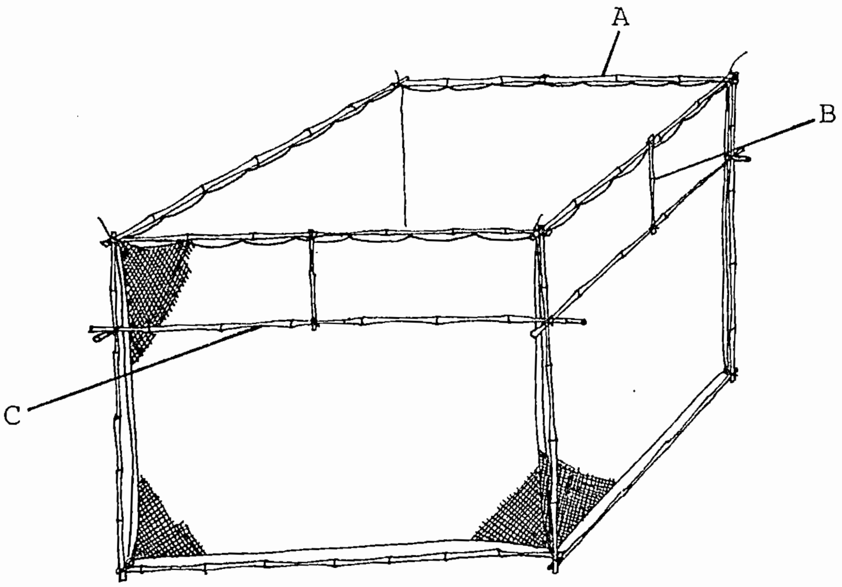


Fig. 9

b) Cage frame - The cage frame (Fig. 9) is also made up of bamboo poles. The surface frame (A) should be constructed with bamboo pole 1" diameter. The vertical poles (B) should be 2" diameter and the horizontal supporting bamboo pole (C) is 1" diameter. In order to ensure the cage is securely fastened and rigid, a central vertical bamboo pole is inserted to reinforce the structure.

c) Net-cage - The net-cage is suspended inside the frame with the headline hung around the surface frame work (Fig. 9). The edges of the net-cage at the bottom are securely fastened with synthetic rope to a rattan ring at each corner of the frame (Fig. 9) and the net can be raised at will without having to lift the framework.

5.2.4 Operational procedure

a) <u>Stocking</u>

Once the cage construction is over and the floating unit securely fastened to the platform, the net cage is now ready to be stocked with fish fingerlings. Stocking density depends on the environmental conditions prevailing in each locality and varies greatly with different habitats and species. The optimum stocking should be determined through a series of experiments in the local habitat concerned. Stocking density is closely related with the environmental parameters such as dissolved oxygen content, primary and secondary prodcutivity, types of feeds, feeding rations, feeding frequency, current velocity, etc.

The following stocking rates were practised in other countries for the following species:

Species	Stocking density	Stocking size
Common carp	6 kg/m^2	120 g
Milkfish (in pen)	30 000/ha	2 - 5 g
Tilapia mossambica	16 $fingerlings/m^3$	5 - 10 g
T. nilotica	250 - 1 000 fingerlings/m^3	5 - 20 g
Rainbow trout	20 - 22 kg/m^3	50 - 120 g
Grass carp	6 kg/m^3	50 - 120 g
Bighead carp	6 kg/m^3	50 - 120 g

b) Feeds

Cage culture is an intensive culture system and the fish confined in the cages are usually heavily fed.

Most of the above species under cultivation are herbivorous and plankton feeders except rainbow trout, which are carnivorous. However, all the species take pellet feeds very well.

The feeds for the rainbow trout has been well studied and commercial trout chow are available in the market. If trouts are to be commercially farmed at Nuwara Eliya which is climatically feasible and may be commercially viable, it is necessary to use local material to prepare local feed pellets. Ox blood and feather meals should be favourably considered as protein sources as trash fish in this country are rather rare. It is suggested that the pellet feeds for trout should consist of at least 30 - 40% crude protein.

In the Philippines, *Tilapia nilotica* has been fed with 23% fish meal and 77% rice bran which give a conversion rate of 2.5:1. If there are 40% of crude protein in the fish meal, the amount of animal protein in the pellet is only 9.1%. However, in view of the availability of ox blood, it may be advisable to increase protein content of *Tilapia* feed to 20 - 25% so that a faster growth can be expected.

Milkfish can be fed with rice bran, or bread crumbs. However, the area selected must be rich in plankton and of muddy-clay-loam bottom.

The Chinese carps accept pellet feeds readily and supplementary feeds consist of rice bran or high protein feeds will enhance growth rate. For grass carp, appropriate grass should be given regularly to supplement the pellets.

Bighead carp had been found to grow to marketable size in 10 - 12 months without feeding in plankton-rich reservoirs in Singapore and Malaysia. Similar experiments could be conducted in Sri Lanka as there are some reservoirs or village 'tanks' which are reported to be rich in both phyto and zooplankton.

c) Feeding

i) Feeding frequency and ration

The optimum feeding frequency for each species also varies and highly dependent on the environmental conditions. It is necessary to conduct experiments to find out the optimum feeding frequency in order to attain maximum production.

In most species such as *Tilapia*, common carps or milkfish, the fish are usually fed 5% of body weight but spread over two or three feedings. In some other practices, common carps are fed 4 or 5 times a day.

For rainbow trout, feeding should be given 3 times a day at fingerling stage and twice daily at 5 - 10% body weight.

ii) Feeding time

It has been found that fish fed well before sunrise and sunset. Hence feeding should be regulated between 6 - 8 a.m. and 4 - 6 p.m. everyday. If feeding is to be given 3 times a day, the second ration should be around noon.

d) Disease and prevention

If the water quality is good and the cages well managed, the rate of infestation by parasites is usually low. In most cases where the water is rich in organic content and often enriched by sewage discharge, the fish in cages can be attacked by *Vibrio* bacteria giving rise to red-boil disease. If this happens, antibiotic treatment (terramycin, streptomycin and vibramycin) or sulfa drug will be necessary. Treatment of 1% sulfamonomethaxine for 3 minutes will be effective.

Fungus disease due to *Saprolegnia* has also been reported to infest *Tilapia*. White spots are usually common in pond fish but rarely reported in cages. However, one should look out for parasitic copepods, such as the anchor worm, *Lernea* sp. which could be extremely damaging when the caged fish are infested.

Culture site with good water circulation usually reduces the rate of disease break-out. Every effort should be made in choosing good site before cages are introduced.

In addition, fingerlings should be handled with extra care when introduced unto the cages. Fingerlings suffering from mechanical injury during transportation should be kept separate from other healthy fishes. It is worthwhile remembering that fish under stress during handling and transportation are more susceptible to bacteria and virus infection.

e) Harvesting

Since the net can be easily hauled up, fish can be harvested at will. However, if the fish were to be transported alive, they should be harvested in the morning or evening when the weather is cooler.

5.3 MANAGEMENT

Management of cages play a vital role in the success of cage culture practices. On the technical aspects, it is necessary to:

i) ensure that the cage is clean; there is ample circulation of water through the cages and fouling has to be removed periodically. The fouling substances on wall can be brushed off. In brackishwater, fouling organisms may also attach onto the net which has to be changed periodically. Old net should be replaced periodically for cleaning and if torn, should be mended before use;

ii) prevent predators from getting into the cage. In both freshwater and brackish sites, the following predators often harm the fish in cages:

1) Otters

2) Cormoront or other predatory birds, such as kingfisher

3) Monitor lizards

4) Water snakes

The main predators are otters, monitor lizards and predatory birds. An outer preventive net is useful to keep out most predators, however, it is expensive to build. The best way is to look out for otters if they were found to prevail in the neighbourhood. As they usually come in a group of 4 or 5, by shooting one of them will scare the rest from coming to the cage for at least a few months. Watch dogs are extremely useful as they would chase the otters away when sighted.

According to the fishery officers, there is no damaging effect of the nets by otters or monitor lizards as yet. Therefore, sufficient surveillance by the watchman or watch dogs will be sufficient for the time being.

Predatory birds, such as cormoronts and kingfishers can be kept out by means of a 1" - 1½" netting covering the surface of the cages.

iii) regularly inspect the nets for wear and tear through thorough checking of the nets under water or during sampling of fishes.

iv) record the feeding behaviour at each feeding. One important criteria to ensure that the fish is in a healthy condition is their reaction to feedings. If the fish do not actively response to feeding, this may be an indication of disease. The fish should be hauled and sample taken for examination. Corrective measures will have to be taken immediately. In this respect, the fishery officer-in-charge of the project should be given full authority to manage the cage he thinks fit. He should be permitted to make decisions on treatment of diseases or purchase of medicines if disease outbreak is suspected without going through the normal procedure to obtain clearance.

v) periodically change the nets for cleaning and repairs. At least two sets of nets for each mesh size should be available for each cage. It is suggested that the net should be changed when fouling became too heavy that affects circulation of water. In freshwater body, the cage should be changed at least once every three/four months. In brackish or marine water, the net-cages should be changed more often depending on the degree of encrustation.

5.4 DAILY ROUTINE FOR CAGE FARMING

A cage culture farmer would carry out the following routine every day:

6 - 9 a.m. :
- i) preparation of feeds
- ii) feeding
- iii) general inspection of cage-nets and floating units for wear and tear
- iv) look out for diseased fish
- v) general inspection of water condition
- vi) checking of water quality if necessary

12 - 1 a.m.:
- i) feeding if necessary

4 - 6 p.m. :
- i) feeding
- ii) cleaning or changing of nets if necessary
- iii) records of feeding conditions

5.5 PROPOSED SITES FOR CAGE CULTURE

The Ministry has proposed the following new sites for cage culture under IDRC projects. The sites are:

a) Kalutara Lagoon
b) Panadura-Bolgoda Estuary
c) Muruthawalla Reservoir
d) Udukiriwella Reservoir
e) Colombo Lake

The above water bodies were visited on the 5th, 6th and 7th May 1980.

5.5.1 Kalutara Lagoon

The lagoon has a small inlet where seawater enters through tidal current. Tidal range is reported to be about 0.5 meter and the lake is approximately 20 feet deep.

Initial examination indicates that distinct stratification exists in the lagoon where a layer of warmer seawater prevails underneath a layer of cooler freshwater continuously discharged from upland area and rivers. This means that there is drastic change in salinity and temperature over a relatively shallow body of water. Fish confined in cages suspended in such environment will have to be extremely hardy to withstand the great physiological stress imposing on them due to ionic differences in the external medium. *It is recommended that such water body be not considered for cage culture until a full investigation of the vertical and seasonal distribution of the lagoon is made.*

5.5.2 Panadura-Bolgoda Estuary

This estuarine system has been studied by Mr. Jayasinghe of the Colombo University and his data indicated that strong vertical stratification were observed in the relatively shallow water system. Although *Tilapia nilotica* may be able to survive and grow in such environment, it is not considered as the best water body for cage culture for the time being.

However, it is suggested that a detail investigation be conducted at each proposed points by the Ministry. Important parameters should include salinity, temperature and dissolved oxygen, gradients, pH and productivity.

5.5.3 Muruthawalla and Udukiriwella Reservoirs

Both reservoirs are located close by. Muruthawalla is relatively large and the water is used extensively for irrigation purposes. The water level in the reservoir fluctuated greatly in the region of 30 - 40 feet and there are plenty tree stumps in the reservoir.

Technically, cage culture can be operated, however, in view of its remoteness and lack of proper facilities at the Muruthawalla station, the site is not considered to be area of priority for cage culture experiments. If however, the choice of the above site is obligatory, then perhaps, a better site at Udukiriwella reservoir may be a better substitute in view of the fact that:

i) the reservoir is relatively rich and has an area of approximately 500 acres;

ii) the reservoir is relatively shallow and water level fluctuation is small and

iii) it is located close to the town and can be operated easily for demonstration purpose.

It is recommended that detail investigation of the limnological characteristics should be carried out before cages are introduced.

5.5.4 Colombo Lake

The Colombo Lake which is situated inside the city of Colombo has been investigated fairly thoroughly and the limnological characteristics are as follow:

Water temperature	: $30^{\circ}C$ - $33^{\circ}C$ (shallow area) $27^{\circ}C$ - $29^{\circ}C$ (deeper area)
Turbidity	: high due to heavy plankton blooms and floculent material
Dissolved Oxygen	: 0.6 - 13.4 ppm
pH	: 7.9 - 9.1
Salinity	: less than 0.5‰
Alkalinity	: high
Bacteria	: high coliform

Plankton	: rich, phytoplankton blooms; high plankton count; main species consists of diatoms, rotifera, copepods and cladocera
Fish	: about 17 055 kg/year has been caught

In view of the fact that the lake is highly eutrophic and has extremely high standing crops of plankton, the lake may be suitable for the production of bighead carps and silver carps without supplementary feeds. Preliminary trials should be made in cages located where water movement is greatest and stocking density should be regulated to prevent suffocation when the dissolved oxygen content drops severely at night. A stocking experiment should be conducted with the following stocking rate: 1 kg/m^3, 3 kg/m^3, 5 kg/m^3, 10 kg/m^3 and 15 kg/m^3. Size of fingerling for initial stocking is preferably 100 grams.

5.6 SPECIES SELECTION

Based on the environmental characteristics and the acceptability of the fish in Sri Lanka, the following species is suggested for experimental culture in cages. Other species should be tried out at a latter stage so that major manpower and attention can be focused on a selected potential species.

The species suggested are:

a)	*Tilapia nilotica*	- hardy, omnivorous, fast growth, reproduce easily, seeds available throughout the year and easily acceptable by local consumers
b)	*Aristichthys nobilis* (Bighead carp)	- plankton feeders, fast growth, fingerling available, though not familiar with local consumers have great potential as cheap protein source
c)	*Cyprinus carpio* (common carp, mirror carp)	- hardy, omnivorous, easily bred, acceptable in local market
d)	*Salmo gairdneri* (rainbow trout)	- carnivorous, high market value, can be spawned in N. Eliya, has potential for restaurant trade
e)	*Ctenopharyngodon idellus* (grass carp)	- herbivorous, accept pellet feeds, spawn locally and fast growth, accept locally
f)	*Labeo dussumieria*	- local carp of high market value, spawn in ponds and fast growth, accept pellet feeds

g) *Etropus suranensis* - good market value, brackish water but slow growth, omnivorous and browsers

h) *Chanos chanos* - omnivorous, locally acceptable, good market demand, fingerling available, suitable for pen culture

Although the above species have been cultured in cages or pens in other countries, optimum production varies with different environmental conditions. As such, adaptive research to optimize production in local waters is essential to warrant success and development of cage culture in Sri Lanka.

5.7 RESEARCH CONDUCTED BY EACH STATION SHOULD CONCENTRATE ON ONE OR TWO SPECIES

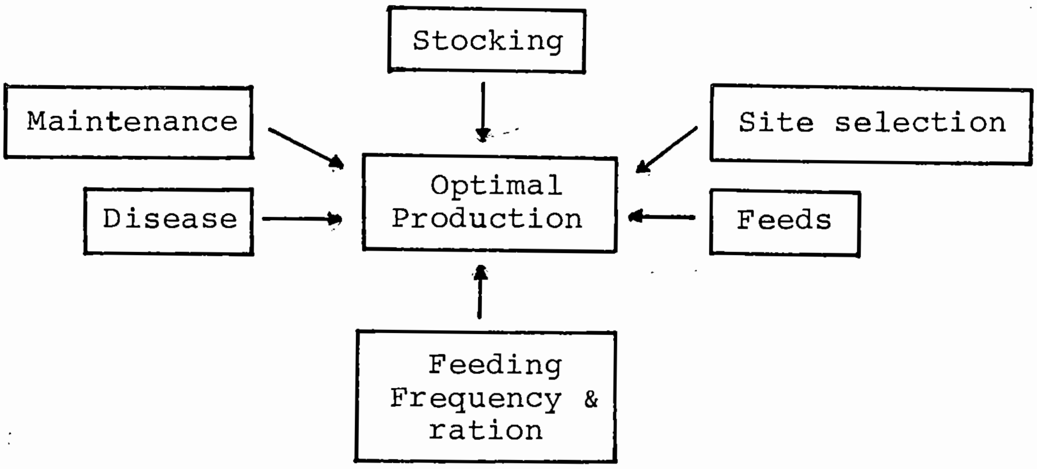
Each research station has two graduates and a number of assistants, however, the graduates are heavily involved in administration and other projects leaving them relatively little time to concentrate on cage culture. In view of this, it is recommended that each station conduct detail research leading toward optimising production for one or two species which are most suited in the particular area. The results obtained by each station for the particular species can then be utilised for other stations.

On the above basis it is suggested that efforts on each species be concentrated as follow:

N. Eliya	- rainbow trout mirror carps
Uda Walawe	- grass carp common carp
Polonnaruwa	- *Labeo dussumieria* bighead carp
Dandujama Oya	- *Tilapia nilotica*
Colombo Lake	- bighead carp

5.8 EXPERIMENTAL DESIGN

Experiments at each station should be conducted with the objective to optimise production from cages. Factors that affect optimal production is shown in the following diagram.



Therefore, it is essential to conduct adaptive research to determine for each species the optimum stocking density, feeding time, ration size, feeding frequency and optimum feeds. The guidelines for conducting such research are given in the following subsections.

5.8.1 Optimum stocking rate

The optimum stocking rate is usually expressed in terms of weight or number per square or cubic metre.

Experiments should be conducted for each species to determine the optimum stocking rate. The following is a guide for the proposed stocking rate experiment.

Species	Initial Stocking size	Recommended stocking rate for experiment m^3			
Tilapia nilotica	10 g	100 (1kg)	300 (3kg)	500 (5kg)	700 (7kg)
Rainbow trout	100 g	50 (5kg)	100 (10kg)	150 (15kg)	200 (20kg)
Bighead, grass carp, common carp, *Labeo*	50 g	50 (2.5kg)	70 (3.5kg)	90 (4.5kg)	120 (6kg)

Note: Feeding at 10% BW divided into 3 portions; feeding at 6 - 8 a.m., 12 - 1 p.m. and 4 - 6 p.m.

5.8.2 *Optimum feeding frequency, optimum feeding rates*

It is also important to run experiments to determine the optimum feeding rate, that is, the quantity of feeds taken by the fish, so that efficiency of the feeds is maintained. The optimum frequency in feeding should also be determined in order to ensure efficient conversion of feeds.

Such experiments can be conducted once the optimum stocking rate has been determined. Experiments to determine optimum ration should spread between 3% and 10% body weight and feeding frequency experiments for each food ration should be in the following order. 1 - 6 feeding/day, once every two days and once every three days. The optimum feeding frequency will be one that gives the best yield. In both stocking and feeding experiments, it is important to record the mortality and count the total number of fish in the cage. Measurement should be made once a fortnight.

5.9 PROJECT STRUCTURE

The objective of the IDRC project consists of two parts. The immediate or short-term objective is to ascertain technical feasibility of cage system for rearing fishes in the inland waters. The long-term objective is to implement and develop such culture system in Sri Lanka. The immediate objective can be achieved within a period of 1 - 2 years in which time the technological details in optimising fish production in cages in local water will be established. The long-term objective depends very much on the success of technical and economic feasibility.

5.9.1 Administration

The Government has assigned this research project under the Department of Inland Fisheries. The administration of the project is as followed:

Director (Inland Fisheries)

↓

Research Coordinator (Research Division)

↓

Project Coordinator

↓

Aquaculturists

↓

Assistants   Technicians   Watchman

The administrative structure appeared to be satisfactory, however, the role of research coordinator and project coordinator should be clearly defined. I was given to understand that the research coordinator is to function as technical director to advise on experimental design and assessment of technical data. On the other hand, the project coordinator serves to coordinate all the field projects at different stations. His role appears just to liaise between the Director, Research Coordinator and the Aquaculturists. I am of the opinion that the administrative structure should be further simplified and reduced to:

Director
↓
Project Coordinator (Research & coordination)
↓
Aquaculturists
↓
Field Staffs

The project coordinator should serves as a research coordinator as he is the one who visits and discuss with the aquaculturists who are working in the field. Modification of experimental design and even cage design could be done after joint discussion between aquaculturist and project coordinator. It is no use to have a research coordinator unless he/she is fully involved in the field experiments and participated fully in the whole project.

5.9.2 Economist

The role of the economist is also questionable. I am not sure what his main roles are even after discussing with him. In the first place, it is meaningless and highly subjective if his main task is to cost the cage system at the experimental stage. Costing of the system to assess whether the system is economically viable could be conducted once the scientists have completed the experiments. During which time, the optimum production rate can be estimated. Like any aquaculture system, the cost of production is highly sensitive to net-production of fish raised. Time required to make such costing is also relatively short (about a month) and do not require 2 years.

I see the role of the economists only in obtaining the baseline information on the socio-economic status of the village communities that are likely to take up such new system in fish production. Information pertaining to the acceptability of such new system of fish culture by the local communities will be useful. Religious and cultural constraints if any, should be assessed before introducing such method of fish rearing to the rural communities. Information on the socio-economic structure of the rural communities concerned to determine the priority area for cage culture development is essential to ensure successful implementation of the proposed programme. In view of this, I wish to recommend that the functions of the economists be clearly defined before he undertakes the responsibility.

5.9.3 Aquaculturists

I was given the impression that the aquaculturists assigned to cage culture could not conduct their research on a full-time basis as they have many other functions besides cage culture. As such, the aquaculturists could not concentrate their efforts to run the experiments. It is obvious that the IDRC projects demand full-time aquaculturists to conduct the experiments in order to attain the objectives of the project proposal.

It is my personal opinion that the aquaculturists in each station need to be upgraded in research planning and experimental design in order that the project is carried out most efficiently. There is no doubt in my mind that there are many enthusiastic and hardworking aquaculturists in the stations to conduct the experiments.

5.9.4 Research areas

Under the research project proposal, the Department of Fisheries will conduct research on feeding rate, feeds, stocking density, polyculture, cage design and construction. These research are extremely useful but they also demand greater input of research staffs. As it is necessary to conduct research towards optimising production for each species, there is necessity to increase present research inputs, especially in terms of research officers.

5.9.5 References

References are extremely limited and it is suggested that IDRC make an attempt to send the main literature on culture to Sri Lanka.

5.9.6 *New cage culture sites*

The Ministry wishes to expand cage culture to other potential culture sites, such as Kalutara and Muruthawella. Although some of the sites shown to me are potentially good cage culture sites, it may not be advisable to spread research efforts and funds too thin so as to cover too many areas within a short period of time.

I incline to suggest that present cage culture experiments on optimising production for different species be concentrated only in the existing 3 or 4 sites as suggested earlier. Transferring of technology could be conducted after the first year. By which time, basic information on the experimental culture of the new system is available.

5.9.7 *Cost of cages*

The initial cost for experimental cages is expected to be high as the cages are constructed to enable scientists and workers to perform research work. Unlike commercial cages, fish in the experimental cages are regularly sampled for different experimental programme. Once the various factors that affect optimum production of each species are worked out, simpler and cheaper cage could be constructed to minimise the cost of production.

5. 9.8 Seed supply

One of the major constraints in rapid development of cultured fishery is the limitation of fish seed supply. It is recommended that the Ministry should place high priority in seed supply in order to provide the necessary fish fingerlings for stocking of cages or the reservoirs.