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Cage culture

FLOATING FISHPENS FOR REARING FISHES IN COASTAL WATERS, RESERVOIRS AND MINING POOLS IN MALAYSIA

by

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(Universiti Sains Malaysia)

MINISTRY OF AGRICULTURE MALAYSIA

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sea bass

1977
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CONTENTS

		Page
1.	Introduction	vii
2.	Merits of the Rearing System	1
3.	The Floating Cages	1
4.	Choice of Culture Site	5
5.	Suitable Fish for Culture	6
6.	Source of Fish Fry and Method of Collection	14
7.	Handling and Transportation of Fry	17
8.	Feeds	17
9.	Fish Diseases	20
10.	Other Problems	22
11.	Production and Yield	23
12.	Economic Aspects of the Culture System	23
13.	Family Unit Floating Fishpens	25
14.	The Problem of Seed Supply	27
15.	Acknowledgements	27
16.	References	27

LIST OF FIGURES

		Page
Figure 1	Floating net-cages suspended from a common platform	2
Figure 2	Wooden peg used to drive into sea bottom for anchoring floating fishpens	3
Figure 3	Fishpens arranged in row	4
Figure 4	Fishpens arranged in zig-zag manner	5
Figure 5	Fishes cultured in floating fishpens:	
	(*a*) *Lates calcarifer*	7
	(*b*) *Aristichthys nobilis*	8
	(*c*) *Siganus canaliculatus*	9
	(*d*) *Siganus javus*	9
Figure 6	Fishes cultured in floating fishpens:	
	(*a*) *Eleutheronema tetradactylum*	10
	(*b*) *Aristichthys nobilis*	11
	(*c*) *Oxyeleotrix marmorata*	11
	(*d*) *Hypophthalmichthys molitrix*	12
Figure 7	Growth curve of the estuary grouper, *Epinephelus tauvina* ...	13
Figure 8	Seasonal distribution of rainfall and water temperature in Penang and seasonal abundance of grouper fry in the Straits of Penang	14
Figure 9	Collection of grouper fry using a beach seine	15
Figure 10	A modified seine net used to collect rabbitfishes and threadfins ...	16
Figure 11	Transportation of fry or adult using polythene bag	17
Figure 12	Common parasites of estuary grouper: (A) gill fluke; (B) isopod	19
Figure 13	Grouper suffered from red boil disease	20
Figure 14	A floating house cum family unit cages in Gertak Sanggul Bay, Penang	25

FLOATING FISHPENS FOR REARING FISHES IN COASTAL WATERS, RESERVOIRS AND MINING POOLS IN MALAYSIA

INTRODUCTION

The use of floating fishpens for rearing fishes was first started in Japan in 1954 for yellowtail culture (Harada, 1970) and was later found to be successful. To-day it has become one of the most popular methods for marine fish culture in Japan. Similar method was later used in Europe and America for the culture of trout and salmon and until very recently floating fishpens were used for rearing bighead carps, *Aristichthys nobilis* and silver carps, *Hypophthalmichthys molitrix,* in reservoir in Singapore as well as marine fishes such as groupers, snappers, threadfins and rabbitfishes in coastal waters in Malaysia, Singapore and Hong Kong.

Floating fishpens were first introduced to Malaysia in 1973 (Chua, 1973) for rearing groupers, *Epinephelus tauvina,* in the Straits of Penang and over three years, this method of fish culture has proved to be technically feasible and commercially viable. The total production of groupers from floating fishpens in Penang is in the region of 10 tons a year, using a coastal area of about half an acre.

MERITS OF THE REARING SYSTEM

The floating fishpen system for rearing fishes has the following merits:

1. The system takes advantage of the good water quality of the open sea with adequate circulation of water by tidal flushing hence ensuring adequate oxygen supply and eliminating the accumulation of excretory waste from fishes.
2. In deep reservoir or mining pool where anaerobic condition prevails at the bottom, floating fishpens could take advantage of the upper layer of the water which is rich in plankton and high in oxygen content.
3. This system allows easy management at which the floating cages could be periodically checked, repaired, cleaned or even renewed. The condition of the nets which are used for containing the fish could be easily maintained.
4. The condition of the cultured fishes in floating fishpens could be checked periodically. The fishes could be easily hauled out for examination, weighing or treatment if suffered from diseases.
5. As the floating fishpens are not permanently installed to fixed locality the cages could be easily moved from one locality to another if threatened by water pollution.
6. By using off-bottom methods, the predator can be controlled with less loss of stock.
7. They can be used in areas where the bottom is not suitable for traditional shellfish farming or even where the bottom is rocky or uneven.

THE FLOATING CAGES

Both the fingerlings and adults can be reared in floating cages. The size and shape of the rearing cage depends on the types of fish cultured and the physical condition of the culture site.

The floating fishpen consists of a floating platform and net-cages suspended from the platform. For rearing marine fishes in open coast, construction of the fishpens should take into consideration factors such as the strength of the water current, winds and waves as well as the marine organisms fouling the nets. Hence when designing a floating fishpen, it is important to ensure that the cage and the platform is sufficiently strong to resist strong currents and winds or waves during a heavy storm. The size of the net-cages used ranges from 1 m^2 to 100 m^2. The cage should not exceed 100 m^2 as periodic change of the nets and maintenance is difficult. For fishes which are rather inactive and less mobile such as the groupers, smaller size cage is sufficient. For grouper culture, the ideal cage size should be about 12 m^2 for fingerlings of about 3-6 cm in total length and 35 m^2-100 m^2 for fish above 10 cm for growing to market size, which is about $\frac{1}{2}$-1 kilogram. The depth of the cage is about 2 meters.

Rectangular cages are usually made as it is easy to construct and is most suitable for mining pools and reservoirs. However, in open coast where sometimes the current is strong, the cage should be of considerable weight and properly anchored to avoid being carried away by strong tidal current. Hexagonal cages may be used as it reduces resistance to the tidal currents and stabilises the fishpens, however, it is rather difficult to construct.

Each net-cage is suspended from a floating platform or a number of smaller net-cages suspended from a larger and common platform (Fig. 1). The platform is anchored at four corners to the seabed by either using heavy anchor or wooden peg driven into the seabed (Fig. 2).

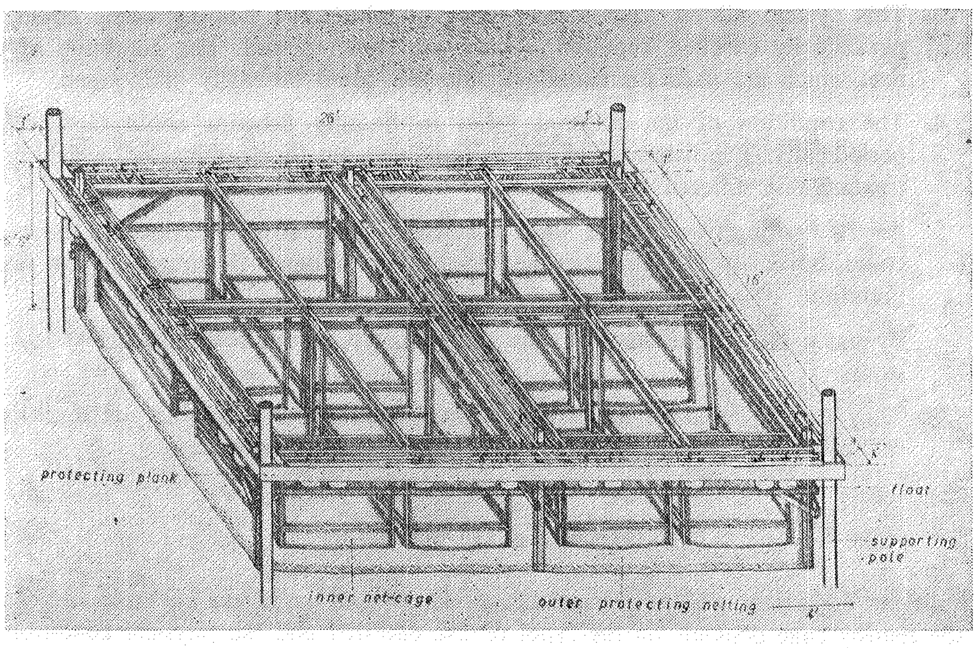

FIG. 1. Floating net-cages suspended from a common platform.

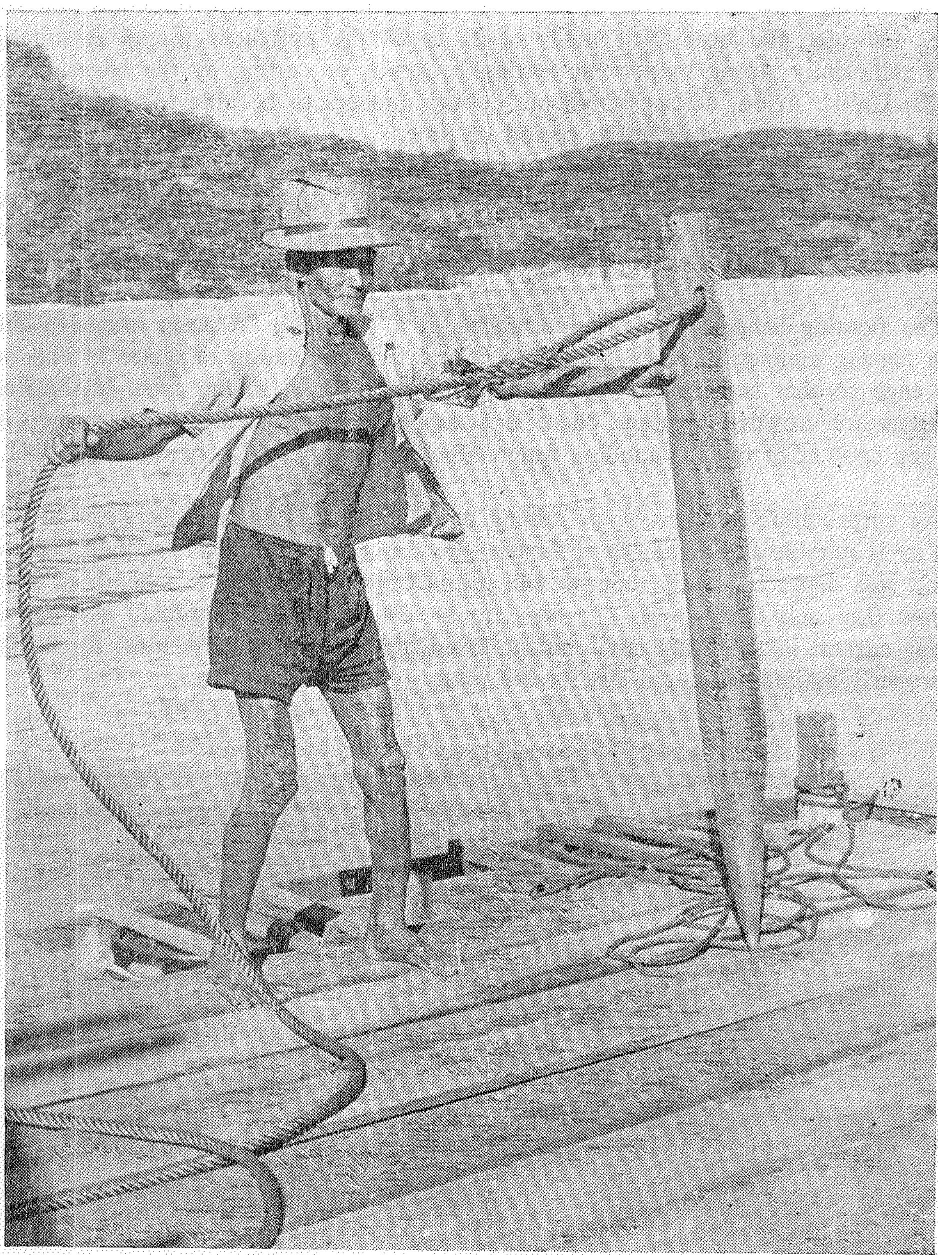

FIG. 2. Wooden peg used to drive into sea bottom for anchoring floating fishpens.

The wooden platform is either made of meranti wood or "changai batu" which are able to last for at least 2-3 years against boring and fouling organisms. Periodic painting with anti-fouling paint would prolong the durability of the frame. Nibong is ideal for making the framework of the platform as it can stand seawater and boring organisms.

The netting used for making the net-cage should be of sufficient thickness and able to resist seawater and heat. Nets made of 21 to 24 ply polythene thread is suitable as it is sufficiently strong to prevent tearing by crabs or cutting by the edges of oyster shells. Unlike nylon, netting polythene netting appears to be able to stand the strong heat of the sun for considerable period of time.

The sides of each net-cage is further reinforced by polythene rope. Bricks or specially made cement weights are additional weight at each corner of the net-cage. In locality where strong current prevails, heavier weight should be used.

The floating fishpens are either arranged in a row (Fig. 3) or in intensive culture, in a zig-zag manner (Fig. 4). This is to ensure free circulation of water in and out of the cage so that sufficient oxygen is supplied to the fish in the cage. If the floating fishpens are crowded together, there is a danger of rapid depletion of oxygen if the oxygen content of the surrounding water is below saturation, i.e. between 3-4 cc/1.

For carp culture in reservoir or mining pool, net-cage of the size between 24 m^2 and 100 m^2 is suitable and the depth of the net should not exceed 2 meters as light penetration below this depth is greatly reduced and primary production below a depth of 3 metres is low (Lai and Chua, MS). The cage design could also be simplified as there is no strong current in the lentic environment. Used metal tar drums are ideal for floats and if properly maintained could last for 2-3 years.

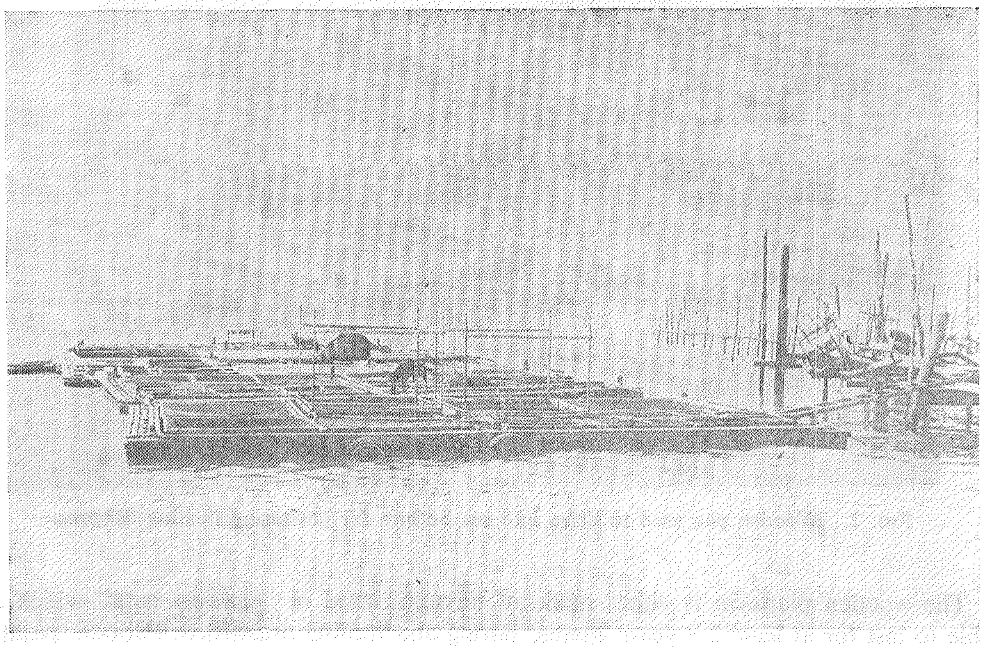

FIG. 3. Fishpens arranged in row.

CHOICE OF CULTURE SITE

In choosing a site for cages, the following factors must be taken into consideration:

1. The location should be calm and protected from strong wind or current. Bays and lagoons are usually suitable site for fishpens. Water current should not exceed 0.5 m/sec. as strong current would result in the waste of energy as the fish has to swim against the current to maintain its position. It has been noted that in strong current, the fish seldom feeds and this may affect their normal growth. In reservoir, mining pool and lake, the water is relatively calm, the problem of water current does not arise, however, like any coastal water, they are subject to the influence of heavy storm and hurricane.

2. Tidal range should not be too large, best range should be around 1-2 meters allowing sufficient exchange of water through the cages to wash away the faeces and uneatened food and to ensure adequate supply of oxygen in the cages. In reservoir and mining pool, water exchange in the cage is made possible by surface movement of the water generated by wind force.

3. The dissolved oxygen content of the water of any chosen location for cages should not be less than 3 cc/l. The dissolved oxygen content of the water around Penang coastal water ranges from 2 cc/1 to 6 cc/1 throughout the year (Chua, Ong and Teng, MS). In disused mining pools and reservoirs in Malaysia, the dissolved oxygen content of the surface water is usually between 3-7 cc/l (Jothy, 1968; Ho, MS; Lai and Chua, MS).

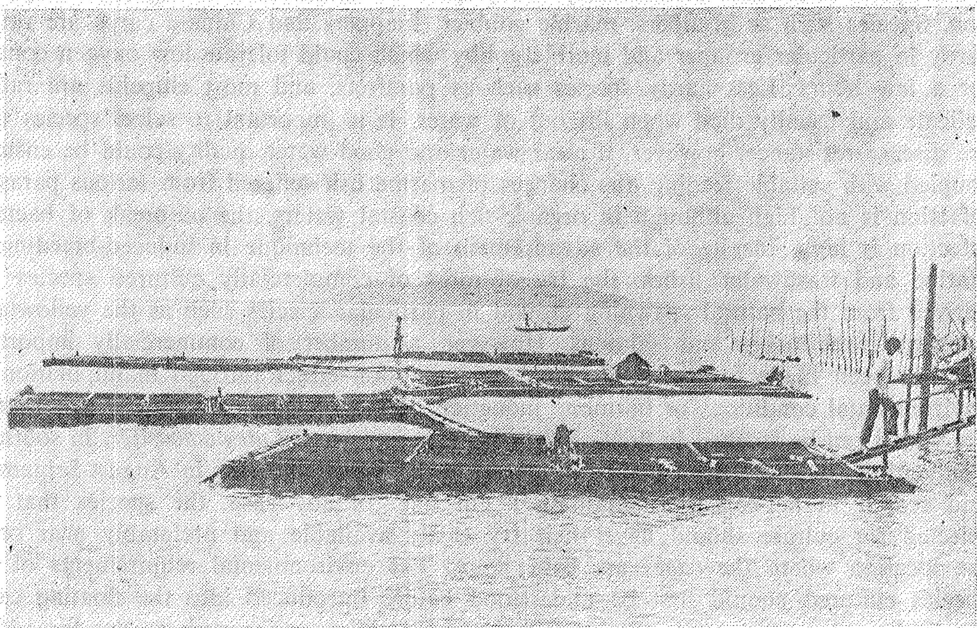

FIG. 4. Fishpens arranged in zig-zag manner.

4. Clear water is an advantage for cages as the nets will not be clogged by fouling organisms and silt particles. Turbid water should be discouraged as the silting particles not only affect sighting of food particles during feeding but also clog gills hampering respiration.
5. For coastal aquaculture, the salinity of the water should not be less than 15 $^{o}/oo$ for rearing groupers, 25 $^{o}/oo$ for rearing rabbitfishes, snappers and threadfins but a wider fluctuation of the salinity from 10 $^{o}/oo$ to 30 $^{o}/oo$ is suitable for the rearing of the sea bass, *Lates calcarifer*.
6. The site chosen should be easily accessible for the transportation of feeds for the fish as well as transporting the fish out for marketing.
7. The site chosen should as far as possible free from otters which are rather common around mining pools, rivers or coastal waters. Otters are known to tear the nets with their strong teeth. It has been reported that within a night, a culturist could loose all his fishes in the fishpens. Otters are usually seen in a group and when they attacked fishes in the cages, they could wipe out all of them just over a night.

SUITABLE FISH FOR CULTURE

When considering the types of fish for culture in the floating fishpens one should take into consideration factors such as hardiness of the fish, availability of fry in sufficient quantity, disease resistance, larval history, the environmental requirements as well as other factors such as the acceptability of the cultured fish to the consumers and the market price of the fish. Undoubtedly, hardy species is easier for handling and transportation. Species such as groupers, marble gobbies, snappers and Chinese carps are rather hardy in particular grouper and marble gobby which could tolerate low oxygen content for a few hours. Less hardy species such as pomfrets, and most clupeids are rather delicate and usually died when lift out of water. It is important to select species that are disease resistance, however, if clear water and good water quality could be ensured coupled with suitable feeding, the chances of marine fish suffered from serious parasitic infection is not high although in organic-rich coastal waters, the outbreak of bacteria infection is high. Inspite of the advancement of the technique in induced-breeding of marine and freshwater fishes, the fry of most of commercially cultured species are derived from the natural spawning ground in particular species such as the yellowtails, groupers, rabbitfishes and salmons. However, a number of commercially important fish has been made to spawn in laboratory condition either through manupulation of environmental conditions or hormone induction. If the fry could be successfully reared, the young can be stocked in floating fishpens. The sea bass, *Lates calcarifer*, in southern Thailand are cultured from the fry produced in the spawning tanks in August-September and reared in net-cages on attaining 5 cm size. In any case, the species that are selected for culture should have their fry easily available and preferably near or in the location where the cages are being kept. The environmental requirements of the species cultured should first be understood before introduced into the floating cages for large scale commercial culture. Pelagic and mobile species such as the threadfins, rabbitfishes, bighead carps and silver carps need more oxygen and therefore they should be cultured in location where the dissolved oxygen content is high and where there is sufficient circulation of water through the cages to maintain the high oxygen demanded by the fish. The species cultured should be easily acceptable by the consumers as in certain countries, the cultural background of the people limits the types of species to be cultured (Bardach 1976). The slightly high running cost incurred with floating fishpens leads to the need of culturing fish of higher market value. However, when the method of floating fishpens have been fully studied and improvement made, it is possible to reduce the cost and making possible the culture of fishes of lower market value but of popular demand by the lower income group. Having considering all the factors mentioned above, the following fishes are found to be suitable for rearing in floating fishpens in Malaysia and other parts of Southeast Asia.

(*a*) **Seabass** (*Lates calcarifer*) (Fig. 5a)

The seabass is a brackish water fish which could tolerate salinity from totally freshwater to 32 $^{o}/oo$. They are commonly found in river mouths, bays and lagoons where the water is brackish. The adult fish tend to be confined to salinity between 15 $^{o}/oo$ and 32 $^{o}/oo$. The fry or young are more abundantly found in upstream or river mouth where the salinity fluctuates between 5-10 $^{o}/oo$. During rainy seasons the young used to enter flood-plains and are stranded there during the dry season when the connection of the rivers or coastal channels dry up. It is during this period where the fry are caught in large abundance by simple collecting gears such as scoop nets and cast nets. Seabass is a carnivorous fish feeding voraciously on smaller fish and prawns. The fish is rather resistant to diseases and has been found to be an ideal fish to grow in floating fishpens. A survival rate of 94% and feed conversion ratio 1:7.22 have been reported by experiments conducted in southern Thailand (Swasdi, Sujin, Prachit, 1974a, b). The fish attains 1.3 kg in about one year, feeding on trash fish yielding between 225-361 kg per 100 m^2 cage. This species of seabass has been found to breed naturally in spawning tank by lowering the water level and increase the salinity to about 30 $^{o}/oo$. Hence the supply of seeds could be ensured (Swasdi and Sujin, 1975).

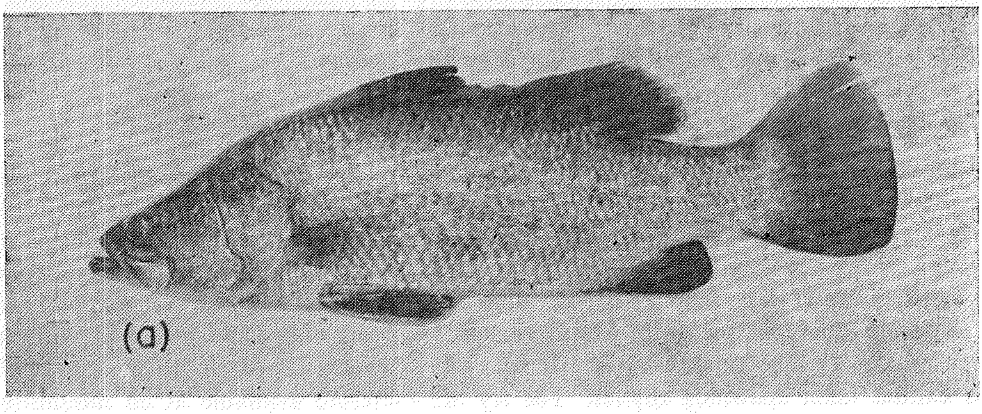

FIG. 5. Fishes cultured in floating fishpens:
(*a*) *Lates calcarifer*

(*b*) **Grouper** (*Epinephelus tauvina*) (Fig. 5b)

The estuary grouper, *Epinephelus tauvina,* has been found to be another suitable fish for culture in floating fishpens. Being carnivorous, it takes in trash fish very readily. Like the seabass, estuary groupers are rather immobile and usually stay quiet at the side or bottom of the cage. The fish could tolerate rather rapid change of salinity from 30 $^{o}/oo$ to 5 $^{o}/oo$ without suffering from any mortality. However, in totally freshwater, the fish can tolerate for not more than 3½ hours. In nature, the estuary grouper are usually found in coastal waters, river mouths, deep channels and amongst rocks and underwater structures such as sunken ships, etc. The young are abundant during the wet seasons between September and January in north-west part of Peninsular Malaysia. In Penang, the young are collected from the MIDDLE BANK in the Straits of Penang. The estuary grouper is a rather hardy fish and can be transported in little quantity of seawater. However, the fish is rather prone to bacteria infection and easily contacted red disease when exposed to organic-rich water, or when the fish is mechanically injured. The fish grows to marketable size (about 0.6 kg) in about 10-12 months from a size of about 5 gm (Fig. 7). Like the seabass, estuary grouper is considered to be one of the first grade fish in Malaysia and Singapore and hence there are of great demand from the market.

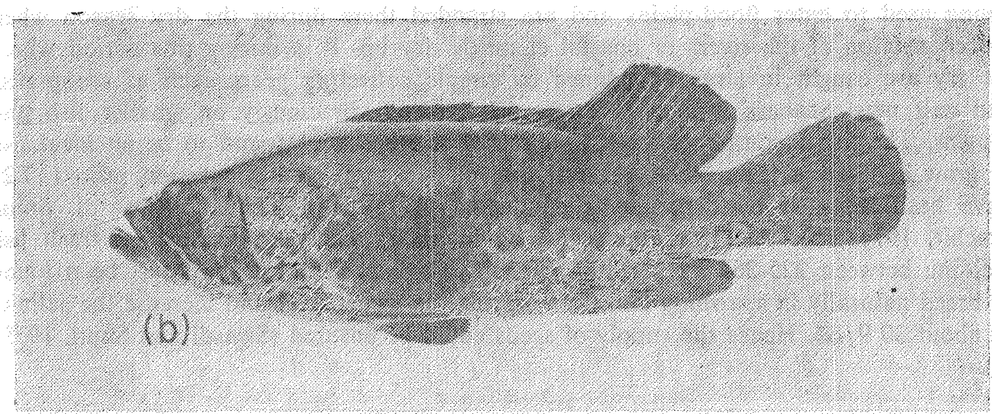

FIG. 5. (*b*) *Epinephelus tauvina*

(*c*) **Rabbitfishes** (*Siganus canaliculatus, S. javus*) (Fig. 5c and d)

Rabbitfishes belonging to the family Siganidae are herbivorous and ecological ideal fishes for cage culture. This fish occurs in large numbers along the coast of Peninsular Malaysia. The fry are easily available amongst seaweeds in coastal waters, bays and lagoons. However, they are less tolerant to wider change of salinity and are not found in brackish water less than 25 $^{o}/oo$. Both the young of *Siganus canaliculatus* and *S. javus* are found in plenty in Malaysia coastal waters and could easily be collected using seine nets. The rabbitfishes are lunar cycle spawners (Bardach, 1976; Lam, 1974) and exhibit lunar spawning rhythm. The fry are therefore available at an intermittent period of one lunar cycle. This fish has been extensively cultured in Palau and experimentally cultured in Penang. Although the fish grow very well in floating cage condition, they are rather delicate and easily die when the oxygen content of the environment falls below 2.2 cc/l. Transportation of the fry usually face serious mortality. The fish can grow fairly fast and reach marketable size in less than 9 months. During Chinese New Year, the market price of this fish increases by at least twenty-thirty folds. This is because of the Chinese superstitious belief that the rabbitfish is a symbol of luck and good fortune. During this period, most of rabbitfishes caught contain running roe and the fish taste sweeter and the meat are more tender. The rabbitfishes can be forced to spawn in laboratory conditions through hormone induction (Lam 1974). The young had been successfully reared in Palau (May *et al.*, 1974), and cultured in cages.

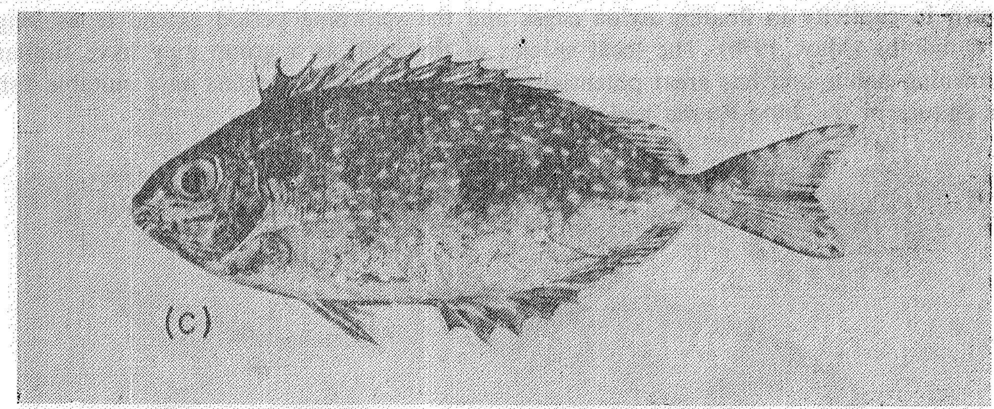

FIG. 5. (*c*) *Siganus canaliculatus*

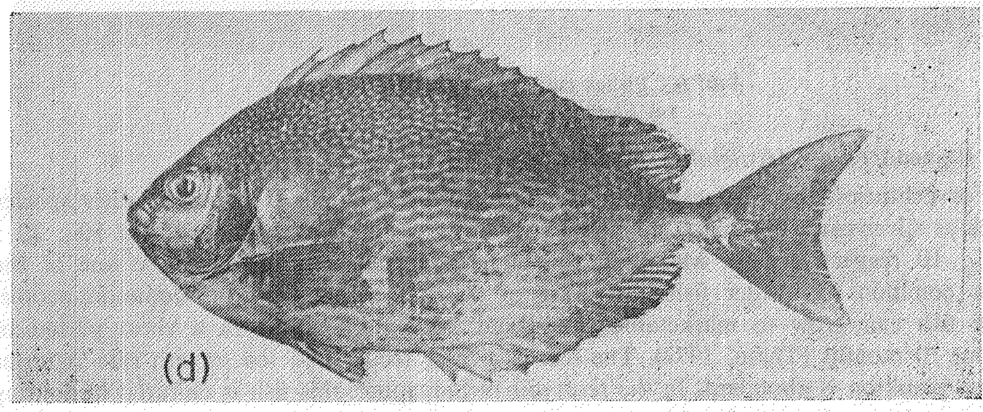

FIG. 5. (*d*) *Siganus javus*

(*d*) **Threadfin** (*Eleutheronema tetradactylum*) (Fig. 6a)

The threadfin is a highly priced fish in Malaysia and Singapore and are usually supplied by the gill-netters. It is a pelagic fish and is rather active and mobile. In cage condition, the fish tend to swim round and round the net incessantly similar to the behaviour of yellowtail *Seriola quinqueradiata,* which is popularly cultured in Japan. The threadfin takes both trash and pellet food readily and therefore is an easily cultured fish. The fry is available in muddy sand bottom where macrocrustaceans such as *Acetes* and mysids are abundant. In Penang, fry of threadfin are collected from mudflats at Tanjong Tokong and the Kra mudflats. The fish grows very rapidly in cage condition if they are fully fed. They grow to a size of 0.5 kilogram from 50 grams-fry in about 8-10 months.

The Indo-Pacific threadfin, *Polydactylus sexfilis,* is a lunar spawner and spawns punctually for 5-6 days around the last quarter of the moon from May to October in Hawaii (Bardach, 1976, May, Akiyama and Santerre, MS). The fish has been found to spawn in captivity in floating nylon cages and the spawning period extend to as long as 6 months (May, 1976). The local species of threadfin as a group may have similar sprawning habits and has great potential similar to that of *P. sexfilis* as a suitable fish for culture in the Indo-Pacific region.

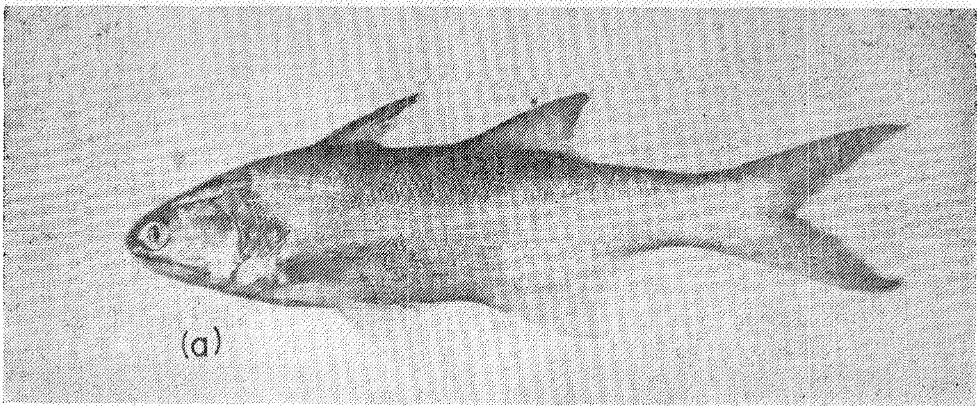

FIG. 6. Fishes cultured in floating fishpens:
(*a*) *Eleutheronema tefradactylum*

(*e*) **Bighead carp** (*Aristichthys nobilis*) (Fig. 6b)

For centuries, this Chinese carp has been cultured in ponds amongst other species such as silver carp, mud carp, common carp and grass carp in a proportion of 50 : 20 : 10 : 10 respectively. In Malaysia, the bighead carp is considered to be one of the best common freshwater fishes that are of popular demand by the common people. The fish can grow to marketable size about 2.5-3.0 kilograms in a short period of about 10 months (Tham, 1973). The fish is a filter feeder and the growth rate is faster when plankton is abundant. In the reservoir of Singapore, this fish is cultured in floating cages and reared to marketable size in about 10-12 months (Yang, personal communication). The fingerlings are readily available from local importers or can be obtained from the Government Fisheries Department. In Muda and Pedu reservoirs in northern part of Peninsular Malaysia, this fish is being cultured in floating fishpens supplemented with rice brans. In Seletar Reservoir, Singapore, bighead carps appear to do extremely well. The water there was found to be extremely rich in green algae and zooplankton. The pH of the water varies from 6-9. This species is considered to be a very suitable species for culture in shallow mining pools or lakes where the water is relatively rich; the fish may be able to grow well in floating cages. In areas where primary productivity is low, supplementary feeds is necessary.

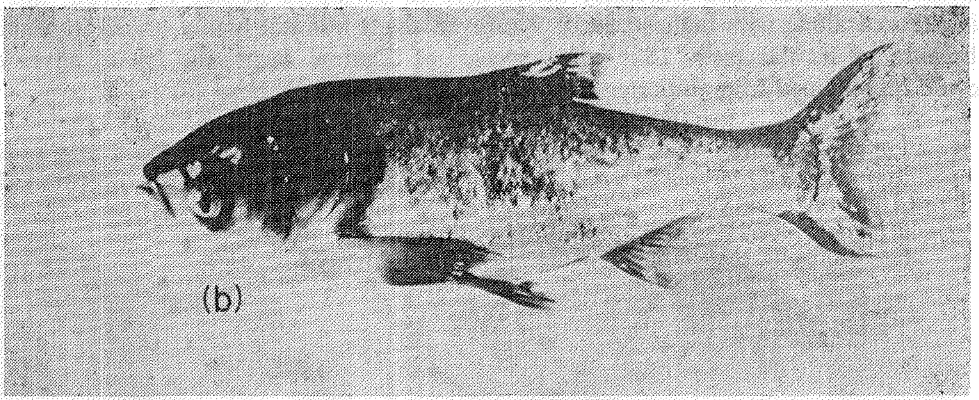

FIG. 6. (*b*) *Aristichthys nobilis*

(*f*) **Marble gobby** (*Oxyeleotrix marmorata*) (Fig. 6c)

The marble gobby has become one of the popular fishes in Malaysia in recent years. The market price for this species has gone up each year at an accelerated rate from a retail price of $1.60 a kati ($2.64 per kilogram) to about $8.00-$12.00 a kati ($13.2-$19.8 per kilogram). In restaurants in Kuala Lumpur, the fish is sold for $1.00 per tahil (37.8 gram) or $16.00 a kati ($26.4 per kilogram). The marble gobby occurs naturally in pools and rivers and the young are obtained in large numbers in mining pools and reservoirs. This species appears to live well in alkaline water of pH between 8-9. Induced spawning has become possible and the young could now be obtained from forced spawning by hormone induction (Tan and Lam, 1973). Unfortunately, this carnivorous fish is a slow grower. The fish require 16 months to grow from a 0.57 gm fingerling to a size of 176 gm (Tey and Siow, 1974). Food conversion rate was recorded as 1:15 (Tey, Siow and Tan, 1974). In Malaysia, the marble gobby has been reared in rectangular fish ponds and mining pools but on a smaller scale.

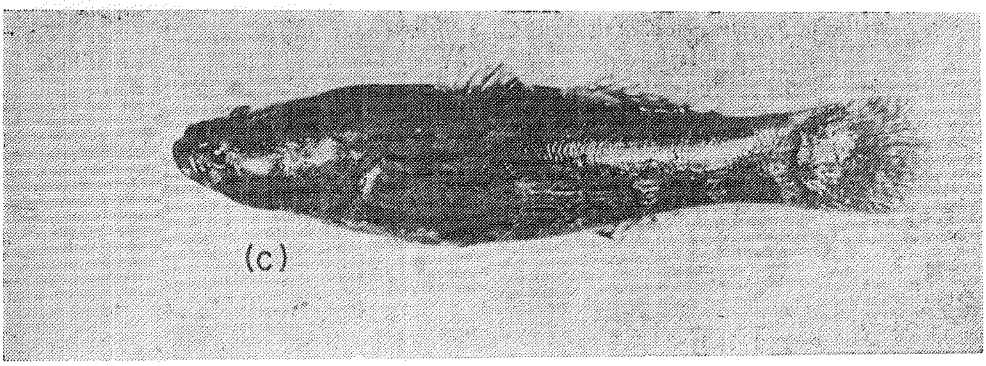

FIG. 6. (*c*) *Oxyeleotrix marmorata*

(*g*) **Silver carp** (*Hypophthalmichthys molitrix*) (Fig. 6d)

Like bighead carps, silver carp can be cultured either in ponds or in floating fishpens exploiting the plankton rich layer of the water column in reservoirs or mining pools. It is a filter feeder and extremely active fish. In Singapore Seletar Reservoir, this fish is cultured along with bighead carps. However, the fish is not highly priced in Malaysia because of its flat taste. Like other species of Chinese carps, the fry of silver carp could be obtained from importers or from Government hatcheries.

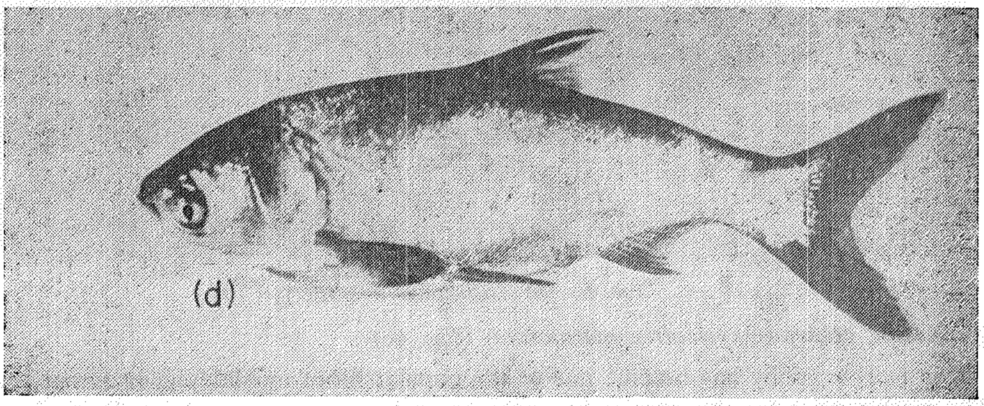

FIG. 6. (*d*) *Hypophthalmichthys molitrix*

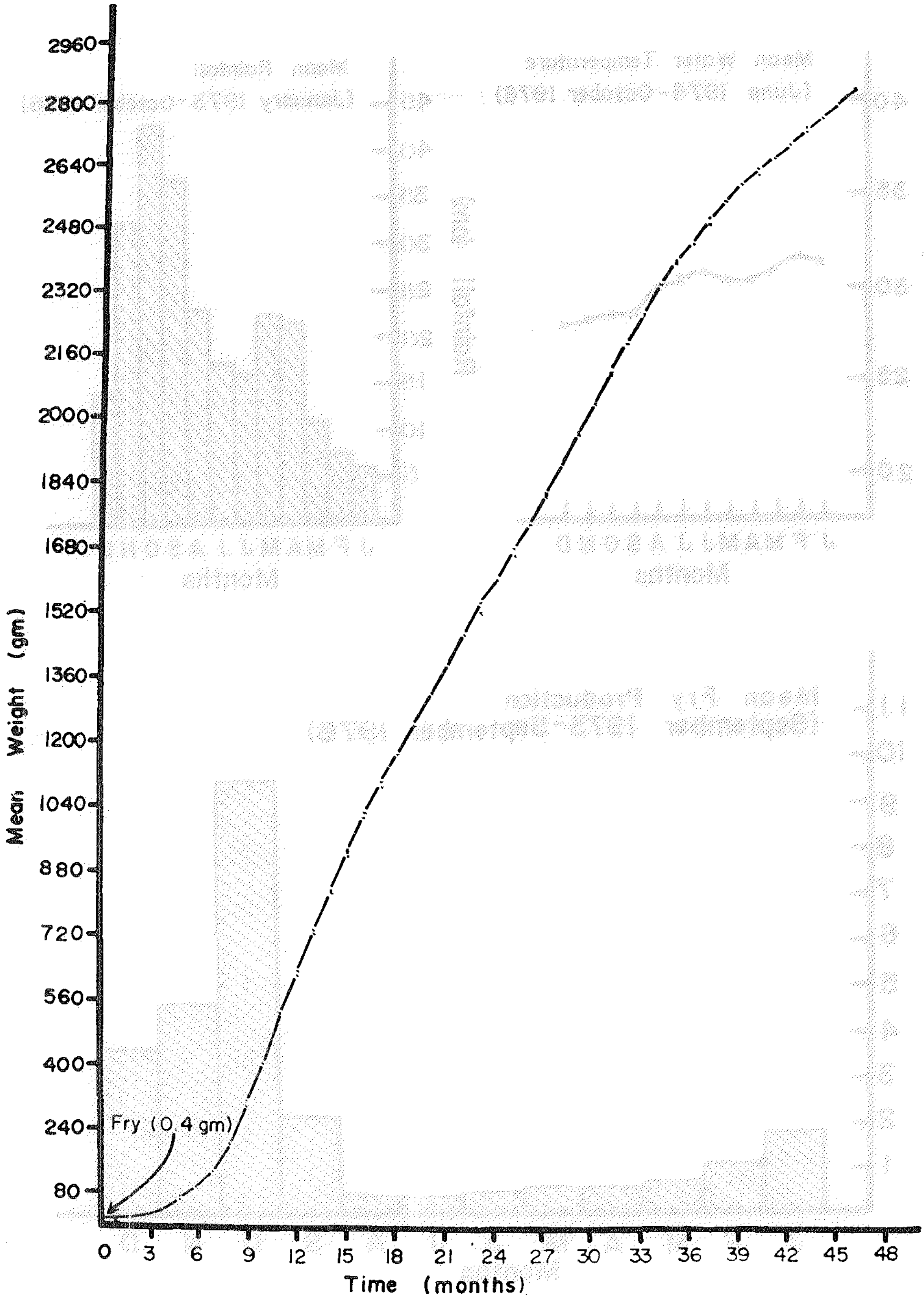

FIG. 7. Growth curve of the estuary grouper, *Epinephelus tauvina*.

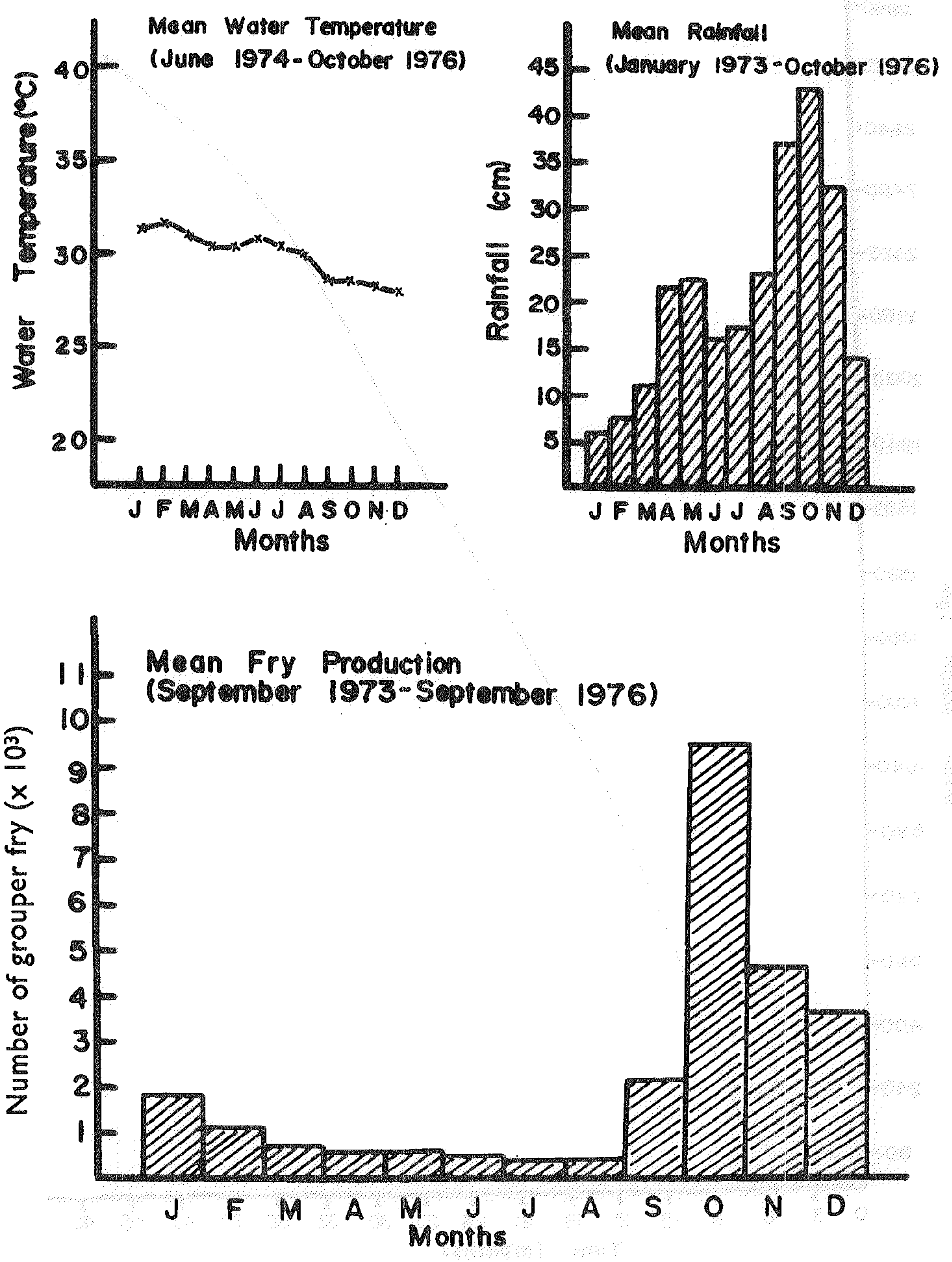

FIG. 8. Seasonal distribution of rainfall and water temperature in Penang and seasonal abundance of grouper fry in the Straits of Penang.

For any fish culture to be sucessful it is important to ensure there is a continuous supply of fish fry either from natural sources or from hatcheries. If fry can be obtained from forced breeding through hormone induction or by environmental manipulation, then there would not be much problem in the source of supply. However, in most fish culture today, the main source of seeds still come from the natural spawning and nursery grounds. The culture of milkfish in Southeast Asia depends exclusively on nature for seeds supply, so were eel culture in Japan. Although yellowtail could be induced to breed in laboratory condition, the amount of fry produced is unable to meet the demand of culturists; the main source of seed supply still remains from the wild.

In the case of groupers, threadfins and snappers suitable for fish culture in floating cages, the seeds are obtained exclusively from the natural ground. In Penang, grouper fry are obtained from the Middle Bank of the Straits of Penang. The fry are seasonal, beginning from September and reaching its peak in November or December (Fig. 8). The seed season lasted for approximately four months. Similar period appears to be true for snappers (*Lutjanus johni*). There are more fry during the northeast monsoon than in southwest monsoon. However, for lunar spawners such as rabbitfishes and threadfin, the young are available at intermittent periods during the spawning seasons.

In collecting seeds from the nature, beach seine, drag-nets, fish traps and scoop-nets are used.

For collecting grouper fry, a beach seine with a short bag is usually used in water not more than 2 meters deep. The net consists of a headline with floats at an interval of 0.7 m and vertical nylon netting of mesh 6.5 mm. The net is weighed down to the

FIG. 9. Collection of grouper fry using a beach seine.

bottom by a row of lead chains. A short bag is located at the center. The seine is about 300 yards long and is operated by two fishermen. The methods of operating is shown in Figure 9. The grouper fry tend to aggregate near rocks or wooden structure. In rocky grounds, where seining is not possible, fish traps are being used instead.

Similar method is used for collection of snapper fry in Penang. The snappers also tend to aggregate near corals or rocky shores and the best way of collecting them is by means of portable fish traps.

Beach seine with a blind bag at the center tend to be not suitable for collecting the fry of threadfin and rabbitfishes. A slight modification of the seine net has been made to enable the collection of these two types of fishes. The end of the bag of a seine net is slightly enlarged and fastened to a circular float or an inflated inner tyre tube. The young of rabbitfishes and threadfin being pelagic fishes are hauled by the seine net along the beach and the young fishes are driven into the bag as the operator moved forward. A third operator will hold the float and start using a scoop-net to catch the young which are concentrated within the circular ring of the float (Fig. 10). In this way the fry will not suffer from serious mechanical damage which may cause high mortality.

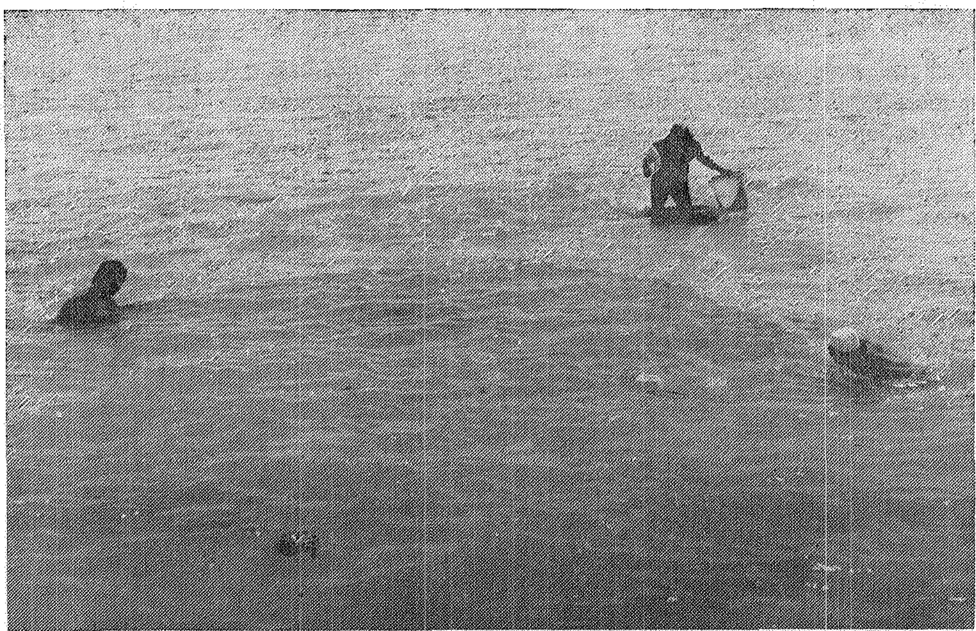

FIG. 10. A modified seine net used to collect rabbitfishes and threadfins.

For collecting the seabass fry either a small seine net or scoop net can be used. The fry usually enters rivers, irrigation canals or floodplains along the beach and could be easily spotted by naked eyes. During the dry spell the water level in the flood-plains dropped considerably and the fry could be scooped out by simple scoop-nets.

HANDLING AND TRANSPORTATION OF FRY

Fish caught from seine or drag nets are immediately sorted out into plastic containers and the water aerated with a battery operated air pump. Where air pumps are not available the fishermen has an indigenous way of keeping the fry alive and transport them to the farm site. They drill one or two holes on each side of the compartment of the boat which holds the fry. This will enable water from outside to enter the compartment from the hole on one side and leave through holes of the other. In this way, the water in the compartment of the boat is continuously exchanged. In transporting the fry from the collecting site to the farm nearby, the fish fry could be kept in a big polythene bag (Fig. 11) with each end tied firmly to a piece of bamboo. As the bag are drag along with the boat, water enters from the posterior end of the bamboo into the bag and leave through the anterior end.

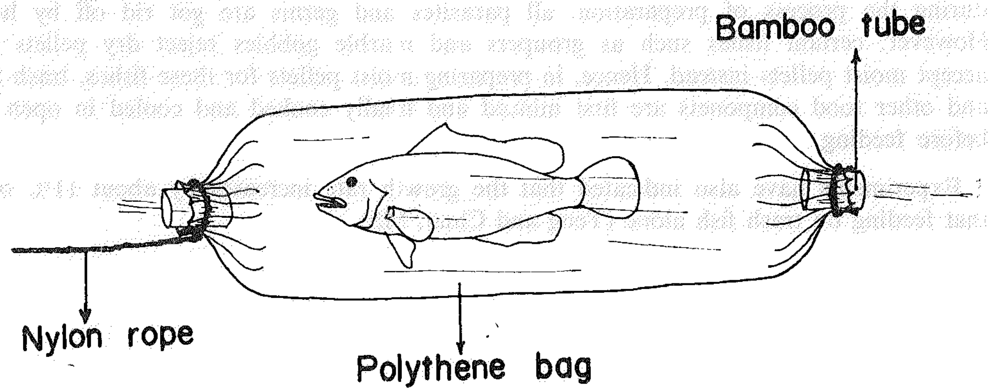

FIG. 11. Transportation of fry or adult using polythene bag.

In handling the fry, care should be taken not to cause any mechanical injury to the fish as a larger percentage of fish mortality during culture is due to mechanical injury during handling. For every active fish such as the threadfin bream or rabbitfishes, the fish could be kept in a weak solution of MS-222 and reactivated when arrived at the farm.

FEEDS

Carnivorous fishes such as groupers, sea basses, snappers and marble gobbies take sliced trash fish readily when they are more than 10 cm in length. Smaller fishes or fry about 2-8 cm in length should be fed with small shrimps such as *Acetes* or mysids. Minced trash fish mixed with wheat flour is also acceptable. For threadfin which has an inferior mouth, either small pieces of sliced trash fish (about 1 cm in length) or pellet food is desirable. In the case of rabbitfishes, green algae such as *Ulva recticulata* and *Enteromorpha* are used as supplementary to moist pellets which are made from trash fish, fish meal, wheat flour or rice brans, vitamins and minerals.

For freshwater fishes such as the bighead and silver carp, no feeding is needed if the reservoir is rich in planktonic organisms. However, for intensive stocking, supplementary feed such as rice brans should be given.

Experiments conducted so far have revealed better conversion and growth rate when the estuary groupers are fed once in two days with sliced trash fish rather than intensive feedings. Results also indicated that good conversion rate, less mortality rate and even growth are ensured (Teng and Chuah, MS).

Wherever possible, feeds given to the fish should be free from parasites to avoid introducing infectious diseases to the reared fish. Trash fish usually harbour certain amount of external or internal parasites such as gill flukes (Fig. 12A), isopods (Fig. 12B) etc., which may transmit to the reared fishes when the trash fish are given. Hence when trash fish is used as the main feed, it is pertinent to ensure that they are fresh and properly cleaned before given to the fish. Pellet feed is considered to be the best as during the process of preparation, all parasites and germs are got rid off by heat. However, certain fishes such as groupers and marble gobbies reject dry pellets but accept moist pellets instead. Hence, in preparing moist pellets for these fishes, trash fish and other food componets are first minced and finally cooked and cooled in open air before feeding.

Experiments have also indicated that the growth rate increases by about 11% over that feeding on trash fish alone (Teng and Chua, MS).

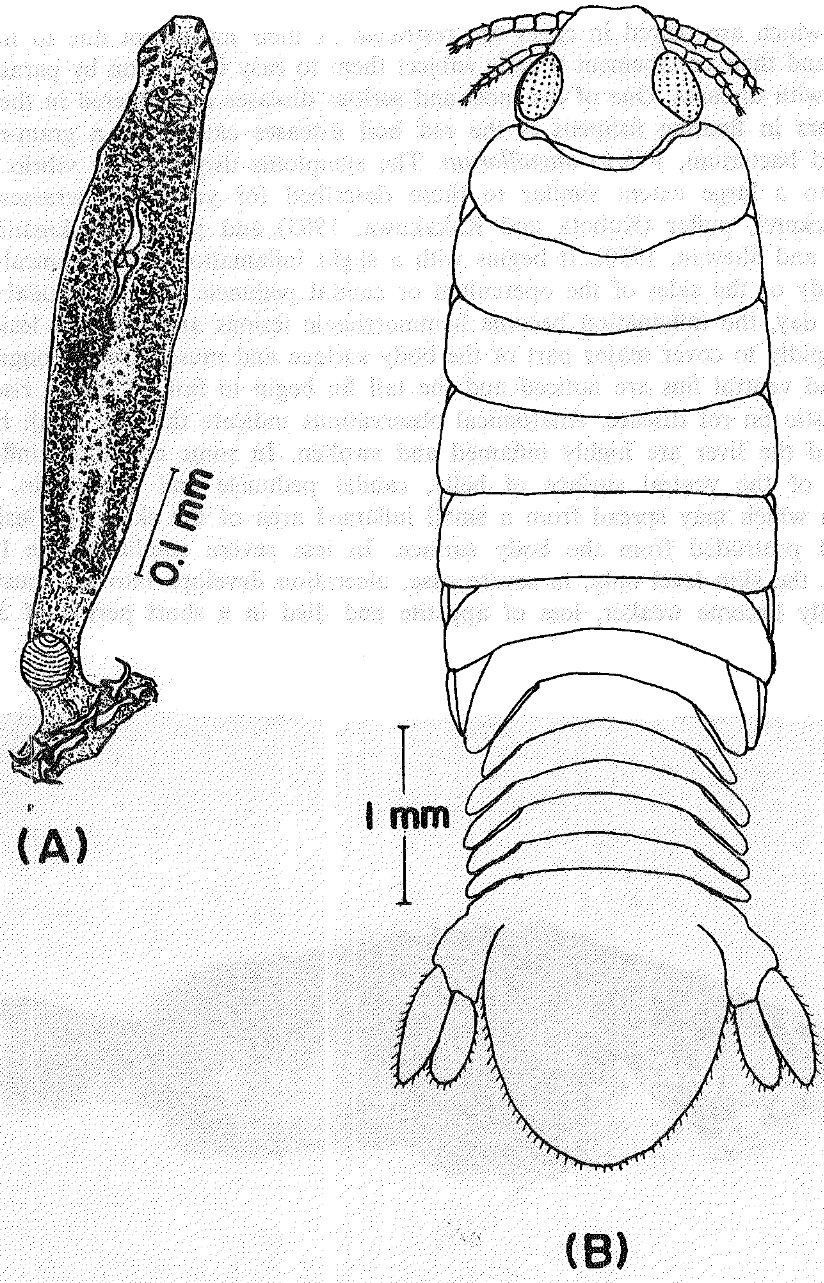

FIG. 12. Common parasites of astuary groupers:
(A) Gill fluke; (B) Isopod

FISH DISEASES

Fishes which are reared in cages are restricted in their movement due to limitation of space and their confinement usually subject them to easy infestation by parasites and infection with diseases. One of the most and serious diseases encountered in the rearing of groupers in floating fishpens is the red boil diseases caused by a gram-negative, curved-rod bacterium, *Vibrio anguillarum*. The symptoms displayed by vibrio infected fish are to a large extent similar to those described for yellowtail, wrasses, smelt, horse mackerel, puffer (Kubota and Kakakuwa, 1963) and plaice (Buckmann, 1952; Hodgkiss and Shewan, 1950). It begins with a slight inflamation at the ventral portion of the body or the sides of the operculum or caudal peduncle and the caudal fin ray. Within a day, the inflamation become hemmorrhagic lesions and boil-like lesions and spread rapidly to cover major part of the body surface and musculature. Congestion of caudal and ventral fins are noticed and the tail fin begin to fall off giving rise to the characteristic fin rot disease. Anatomical observations indicate that the small intestine, spleen and the liver are highly inflamed and swollen. In some condition, inflamatory abscesses of the ventral surface of belly, caudal peduncle and caudal fin, lead to ulceration which may spread from a small inflamed area of the skin. The lesion may swell and protruded from the body surface. In less severe condition, the lesion is limited at the skin level only, in severe case, ulceration develops into the muscle. The fish usually become weaker, loss of appetite and died in a short period of 3-5 days (Fig. 13).

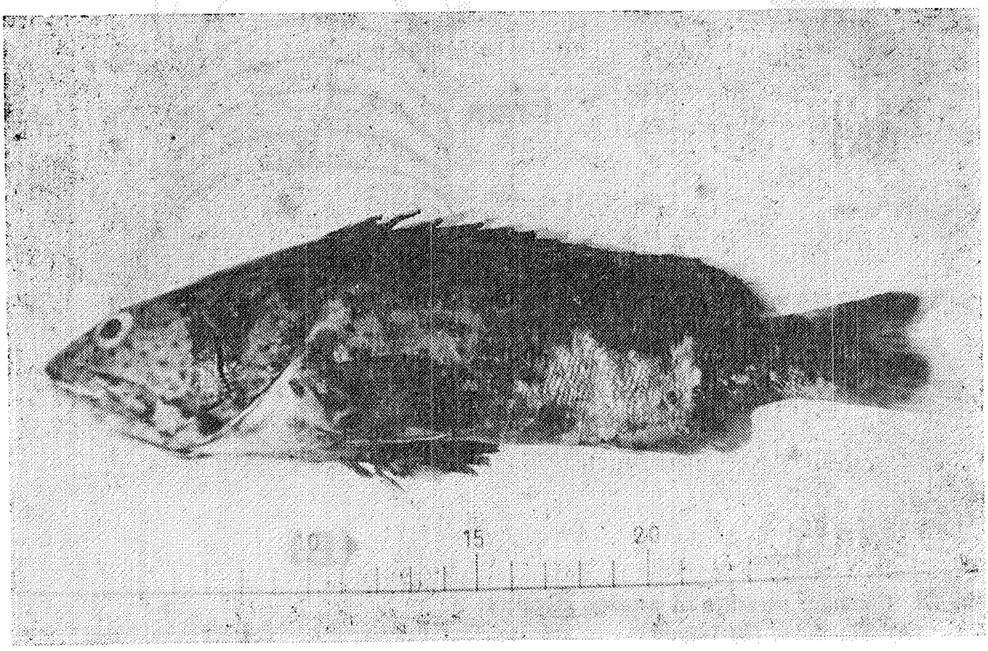

FIG. 13. Grouper suffered from red boil disease.

Because of the rapid spreading of the diseases, severe loss of fish has been encountered. In 1974 over 90% of the fishes reared in the grouper farm in Penang was infected and a loss of 70-80% had been reported. In 1975 of the 20,000 fishes reared, 50% of which died of red boil diseases.

Studies indicate that grouper contacted red boil diseases through mechanical injury sustained during handling, transportation, overcrowding, feeding or after parasitised by gill-flukes. Fishes which are collected by hook and line and trawling tend to be mechanically injured and are easily infected with red boil diseases when reared in cages in coastal water. Sometime mal-handling of fishes during transportation may cause injury. Overcrowding may also cause mechanical injury to the fishes during feeding because during feeding time, the rush for food tend to knock one against another and this gives rise to vibrio infection. Fishes could also sustained mechanical injury if they are kept in too small cages and in area where the current is too strong. Fouling organisms such as barnacles, oysters, mussels may cause injury to fishes when the fish brush their body against the sharp edges of these fouling organisms, either during the frantic dashing for food or when rushing for hide out when frightened.

Fishes which are infested with gill-flukes become weak when the population of gill-flukes per gill is large. The fish becomes thinner and less active. This gives rise to secondary infection by vibrio when the fish starts brushing its operculum against the side of the net to get rid of the gill-flukes, thereby causing mechanical injury to the operculum and sides of the body. Inflamation of the injured area develops rather rapidly within 2-3 days and if no treatment is given, the fish may die.

Other species of marine fishes such as snappers and thread-fin are occasionally infected with red boil disease, however, the grouper appears to be more prone to vibrio infection than other species such as rabbitfishes, snappers, breams, puffer fish, etc., which are reared together.

Various antibiotics and sulfur drugs have been recommended to cure red boil diseases, of which terramycin, streptomycin and vibramycin has been found to be effective and sulfamonomethoxine and sulfisoxazole are equally effective for a wide range of bacteria infection, whilst sulfamonomethoxine is found to be rather effective for vibro bacteria.

Gill-flukes can be got rid off by using freshwater treatment for about 45 minutes. The flukes which infested groupers usually die in freshwater in about 30-40 minutes but the fish can tolerate total freshwater for a length of more than 1½ hours.

Ectoparasite infestation has also been frequently observed. In coastal water where organic matter is prevalent, isopod infection is fairly common. Isopod infection has been reported to infest glassfish (Tham, 1972) and a number of other local species (Chua, 1971) in Singapore waters. In floating fishpens, rabbitfishes are always found to harbour a pair of parasitic isopods, *Nerocilia sundacia*, in the oral cavity. Fishes which are found to be infested by isopods are weak and thin because isopod feeds on blood of it's host (Tham, 1972). Sometimes the isopods are found on one side of the caudal peduncle or near the ventral side of the operculum. Occasionally, snappers and groupers have been found to harbour one or two isopods.

For freshwater fish culture such as bighead and silver carp, the incidence of parasitism and diseases are not that frequent if the fishes are cultured in floating cages in mining pools or reservoirs. If there is no introduction of parasites through feed or new stockings then the fishes could be maintained relatively free of parasites and diseases throughout the culture period.

Although nematods, cestodes, are expected to be present in some of the reared fish, there is no report of serious infestation. One other parasite that could infest carp in floating cages is the anchor worm, *Lernea* species, which when introduced into the fish population may multiply at such a rate that the whole fish population will be infested. When this happens, the fish has to be removed from the cages and treat in big tanks with Neguvon or potassium permanganate solution.

OTHER PROBLEMS

Apart from diseases, floating fishpen system also faces other problems such as fouling of net-cages, durability of platform, theft, pollution and other natural disasters such as red tides, storms, etc.

Fouling has been one of the most important and serious problems facing all marine activities and has caused millions of dollars each year to get rid of them. Floating fishpens in coastal waters usually collect plenty of fouling organisms on the net-cages and wooden framework, within a relatively short period of time. Cheah (1974) reported that net with 38 mm mesh will be fouled in two months, whilst nets with 25 mm mesh and 7 mm mesh will be fouled in a period 2 and 1 week respectively. Fouling of nets may limit circulation of water and thereby decreasing oxygen content in the cage. Turbidity of the water accelerate fouling as silt particles which are deposited on the nets tend to provide suitable base for the growth of many other marine invertebrates and seaweeds such as *Enteromorpha.*

Under tropical climate which accelerate faster rate of fouling, the wooden platform and the net-cage may soon deteriorate. Cotton netting is not suitable, nylon netting is not recommended as the exposed part of the cage might lost its tension under the direct heat of the tropical sun. It has been found that polythene netting is a better selection over nylon as it can resist solar energy and the durability of polythene net is much longer. The wooden material chosen for the construction of the platform should be able to stand the high salt content of the sea and be more resistent to fouling and boring organisms. For this purpose, Changai Batu is recommended as it is rather resistent to boring organisms. Meranti wood could also be used but the quality is inferior to the former. Nibong palm has been found to be a suitable material for the construction of the platform as it can resist salt water and are less susceptable to boring organisms. Nibong poles used for fishing stakes have been reported to last for more than 10 years.

Theft of fish by nearby fishermen is a social problem. In Singapore and Penang, dogs are usually kept on the floating raft and they serve as excellent "watchman" at night.

With the increased contamination of the coastal water due to industralization, more and more of coastal water will eventually be polluted and this will pose serious problem to the survival of fishes. Organic pollution increases the rate of bacterial infection in fishes and may reduce the oxygen level in the water to a level where stocking density has to be reduced. Metalic contamination will undoubtedly rendered cultured fish unfit for consumption. Natural disasters such as the occurence of red tides, sudden storms and typhoons may bring unexpected disaster to the fish farm.

PRODUCTION AND YIELD

The floating fishpen system of rearing fishes is among the most productive means of fish production through aquaculture. The present grouper farm produced 8 tons of fish in a total area of 619 m^2 (including the area between two cages) or approximately 12.2 kg/m^2. The yield per hectare, i.e. 122 tons, is many times higher than that of pond culture of Chinese carps (3-5 tons/hac), milkfish culture (450 kg-1 ton/hac) or mullet culture (150-300 kg/hac). The yield of bighead carps from productive reservoir is also extremely high. The production is estimated to be 296 tons per hactare if only the net area is considered under culture. This yield is rather comparable with that of the yellowtail production from the Japanese coastal water (280 tons per hectare). In the case of the seabass production, the Thai scientists have obtained a yield of 200-250 kg per 100 m^2 or between 22 and 25 tons per hectare. This production is rather low when compared with that of yellowtail and grouper in coastal water or bighead carps in reservoirs.

ECONOMIC ASPECTS OF THE CULTURE SYSTEM

The success of the floating fishpen system of fish farming, like many other aquatic farming ventures, depends largely on the marketability of the product and the wise and efficient use of the natural factors of the culture site. For the system to be profitable, it is important to produce fishes which fetch higher market value and have ready market. The question of whether one should produce "luxury good" for the rich or cheap fish protein for the poor is debatable and is not within the scope of this paper. In order for the project to be commercially viable, groupers, sea bass, marble gobbies, snappers and threadfin which have good market value are recommended for culture. The choice of a culture site is important because a wise selection and efficient utilization of the invironmental factors of the culture site such as temperature, salinity, dissolved oxygen content and plankton productivity, contribute to the success and profitability of the venture. For example, mullets will grow fast in places where the temperature is high, plenty of algae, muddy sand bottom and brackish water. Groupers grow well in conditions where there are abundant of water supply, high oxygen content, high temperature and clear water. Similarly, the bighead carp prefers sites which are organic-rich and have plenty of algae, high temperature and adequate supply of oxygen. A faster growth depending on the natural factor minimise operating costs if such factors have to be provided for.

The capital costs involved in floating fishpens include investment costs such as equipment for preparation of feeds, deep freezer, building for storage and disease treatment, boat and operating costs generally include items such as cost of seeds, feeds, disease treatment, electricity, fuel, labour and rental.

The economics of an on-going grouper project (pilot scale) has been worked out. Table 1 shows the total investment costs and Table 2 shows the cost-benefits analysis of a pilot project conducted at Penang Straits. The capital investment for the grouper farm to yield an annual production of 10,000 fishes or 7,562.5 kg has been estimated to be $59,620 of which the operating costs constitute 54.5% whilst the capital investment constitute only 45.5%. Of the operating costs, much of the expenses were on seeds (26.6%), labour (25.8%) and feeds (22.4%). The other items such as fuel, electricity, disease control, etc., are minor expenses which constitute collectively less than 15% of the total cost.

In computing the total production cost, it is necessary to take into consideration the depreciation of the capital equipment such as net-cages, boat, building and equipment. The computation is based on the following formula as suggested by Kloke and Potaros (1975):

$$\frac{\textit{Current new value or Cost—Salvage value}}{\textit{Economic Life}}$$

It should be noted that calculation for the depreciation of the building is based on 10 years as usually, the building is constructed on state land with a temporary permit of occupation. Under such situation, it is better to estimate complete loss of the building after 10 years. The total cost includes both operation and depreciation of the capital equipment.

With a 50% mortality due to diseases, the farm is able to yield 7,562.5 kg or 10,000 fish with an average weight of 0.756 kg (1.25 kati), in a total area of 619 m^2 (0.153 acre), the production is 12.2 kg/m^2. Based on the current wholesale price of $4.00 a kati, the farm managed to make a small profit (Table 1). Operating ratios are shown in Table 2. The net income to gross returns ration is calculated to be 24.9%, that of net income to operation cost 38.36% and net income to total capital cost is 19.28%. The profit margin for a single crop is much lower than that for catfish (*Clarias* species) culture in Thailand (Kloke and Potaros, 1975).

The above analysis of the economics of the pilot project in Penang excludes the research costs, a substantial amount of which was borne by the fish farm owner. The calculation is purely based on the expenses in the actual running of the farm. The poor profit margin is due to high mortality and large expenses incurred in combating the diseases as the farm is originally situated in an organic-rich, highly turbid, polluted area. This involved high labour costs in maintaining the nets and disease treatment. Mortality of fish could be greatly reduced to below 20% if the fish are cultured in clear water free from pollution. A similar experiment conducted at Pulau Langkawi yielded 80% survival rate. Labour costs could be reached whilst the number of cages could be expanded. The ratio of net income to total capital is 51.0%. If the fish are sold to restaurants in big towns and cities such as Penang, Kuala Lumpur and Singapore, the price of grouper could be double.

The profitability of the floating fishpen system depends largely on the market value of the fish. This is best illustrated by the cost-benefit analysis of the bighead carp cultured in floating fishpens in plankton-rich reserviors (Table 3). Although with a stocking of 10,000 fry and the culturist could produce 40 tons of fish in about 10 months, the net income over total capital investment is only 9.3% (Table 4) as against 21% in groupers and 108.1% in catfish. The low profit margin is partly due to the high capital cost of net-cages to contain bighead carps which when grown to marketable size weigh between 2-2.5 kilograms, as well as low market value of the cultured fish. The whole-sale price for bighead carp in Malaysia is about $0.70 a kati as against $4.00 for grouper. From investment point of view, although the growth of bighead carps is most ideal, the poor market value of the fish has made the venture less attractive in view of the risk an investor has to bear in case of natural disaster.

FAMILY UNIT FLOATING FISHPENS

In view of the rapid decline of inshore catch which has seriously affected the income of most fishermen in both East and West Coast of the Peninsular Malaysia, the floating fishpens system of culturing fish may help to alleviate the situation by absorbing some of the fishermen into culture fishery. In this way, not only the unemployed fishermen could be diverted to a new and emerging industry but also increase production of

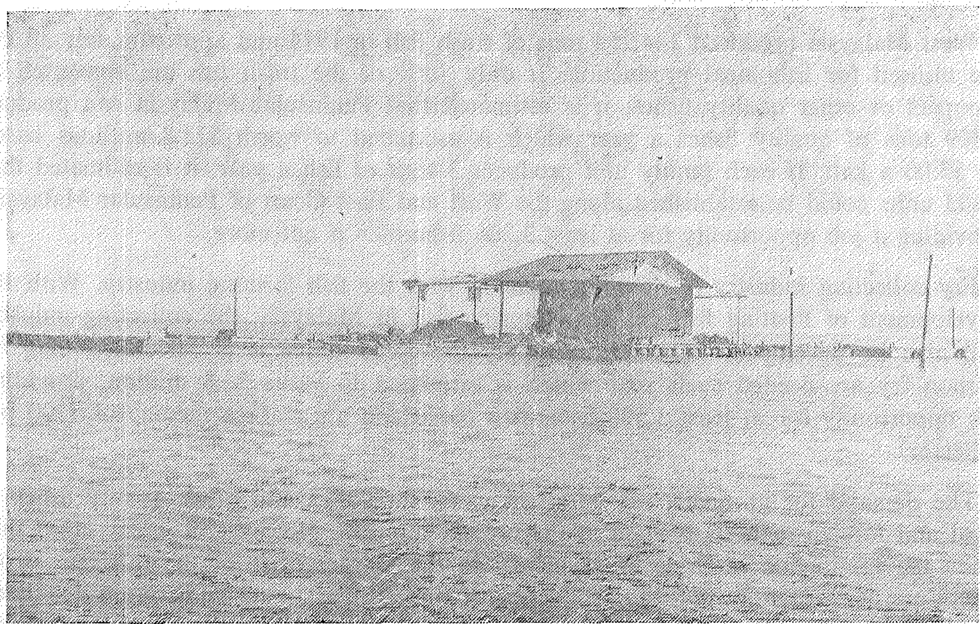

FIG. 14. A floating house cum family unit cages in Gertak Sanggul Bay, Penang.

quality fishes. An estimate of a family size floating cage system is shown in Table 5 based on the technical information obtained over the past three years. A family of 2 can easily handle and operate four floating net-cages of size 28′ × 18′ ×5′, which is estimated to contain 1,000 fishes each. If grouper has been chosen as the target species, a total investment of $13,810 would yield $15,000 worth of grouper (based on a wholesale price of $3.00 per kati) at the end of one year. The main expenditure is in feeds and seeds whilst the rest are spent on maintenance of the cages. The ratio of net income over total capital cost is calculated to be 51.2% (excluding labour cost). As illustrated in Table 5, the net income of each fisherman per month is $294.

There are also large areas of rich inland waters which are not fully utilised such as the reservoirs and disused mining pools in Malaysia which could be fully utilised for fish production. The cost-benefits for bighead carp culture in floating fishpens in plankton-rich reservoir is shown in Table 6. However due to the poor market value of the fish, the income that is derived is less than that obtained from grouper culture. A potential family unit of floating fishpens operated by two persons would give an income of $217 per person per month. Inspite of the slightly lower income and higer capital cost (Table 7), this method of fish farming will at least provide a much higher income than fishermen in capture fishery in the East and West Coast which is $58 and $115 respectively.

Other species of fish could be introduced depending on the availability of the fry as well as the market value of the fish. In the East Coast of Peninsular Malaysia, for example, there are large numbers of carangids such as *Carangoides chrysophrys, C. ferdau* and *C. malabaricus* which have been found to grow very fast in fishpens in Penang, can be cultured there.

West Malaysia produced 144,259 tons of trash fish in 1974 and approximately 38.5% are utilised for fish meal production. If only 10% of the trash fish are converted to groupers or other quality fishes, it is estimated that Peninsular Malaysia can produce 4,809 tons of quality fishes a year which is estimated to worth $23.8 millions based on $3.00 a kati. If each family unit produces 3 tons of fish a year, it is estimated that 1,603 units could be established along the West and East Coast of Peninsular Malaysia, providing a job opportunity for at least 3,206 fishermen if not more.

Fry collecting industry is closely associated with the fish farming industry. With the development of floating fishpens for culturing fish in Malaysia, the collecting industry will also be developed. In order to supply the 1,603 units, it is calculated that 7.6 million fry are needed each year which is estimated to value $3.8 million, providing job opportunity for at least 1,590 fishermen (based on an average income of $200 per collector).

The demand for groupers, sea bass, snappers, threadfins and other quality fishes in local and foreign markets is good at the present moment. However, it is envisaged that when the production of these fishes increased, the market price of the fish may drop. Therefore, it is essential that the production of these fishes should be carefully regulated to maintain the market price of the fish and to ensure a steady income of the floating fishpens operators.

THE PROBLEM OF SEED SUPPLY

The development of fish culture will depend very much on whether there will be a steady supply of seeds. At the present moment, information on the availability of seeds in Malaysian waters is rather scanty. Apart from some freshwater fishes such as the common and local carps (*Cyprinus carpio* and *Puntius gonionotus*), many species for cage culture don-ot spawn in captivity and the supply of seeds depend on wild collection. As such information on the distribution and abundance of seeds of the species for cage culture should be obtained. One way of providing seeds is to induce the fish to spawn in laboratories. Unfortunately, in view of the limited success in induced spawning and larval rearing, full dependence on laboratory supply of the fry will not be realised in the coming decade. However, research along this line should receive top priority.

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TABLE 1

ECONOMICS OF AN ON-GOING GROUPER PILOT PROJECT

I.	Gross return from sale of 10,000 fishes (12,500 katis or 7,562.5 kg) at current restaurant rate of $4.00 per kati ...	$50,000	%
II.	Seeds (20,000 at $0.50 each)* ...	10,000	26.6
III.	Feeds ...	8,400	22.4
IV.	Disease Control ...	1,000	2.6
V.	Labour (4 × $200 × 12) ...	9,600	25.8
VI.	Fuel and electricity ...	1,000	2.6
VII.	Licence Fee (TOL) ...	480	1.3
VIII.	Miscellaneous expenses ...	2,000	5.2
IX.	Total operating cost ...	$32,480	
X.	Depreciation (one year)		
	net-cage (25%) ...	$ 2,500	6.7
	equipment (20%) ...	358	1.0
	boat (25%) ...	1,000	2.6
	building (10%) ...	1,200	3.2
XI.	Total cost ...	$37,538	100.0
XII.	Net profit ...	$12,462	
XIII.	Cost of production ...	$2.90/kati or $4.80/kg	

* Calculated on 50% mortality.

TABLE 2

CAPITAL COSTS AND OPERATING RATIO OF GROUPER CULTURE IN FLOATING FISHPENS

CAPITAL COSTS

I.	Net cages (8) 28′ × 18′ × 5′ × 8	$ 10,000
II.	Boat	3,000
III.	Electric mincer	600
IV.	Tanks (5) $60 × 5	300
V.	Air pumps (20) $12 × 20	240
VI.	Building	12,000
VII.	Freezer	1,000
		$27,140

OPERATING RATIO

	Grouper	*Catfish*
Net income/Gross return	24.90%	37.7%
Net income/Operating cost	38.36%	71.4%
Net income/Total capital	20.90%	108.1%

TABLE 3

ESTIMATES ON COST-BENEFIT OF BIGHEAD CARP CULTURE IN RESERVOIR

I.	Gross return from sale of 10,000 fish (40,000 katis or 24,200 kg) at $0.70 per kati	$28,000
II.	Seeds (12,000 fry at $0.35 each)*	$ 4,200
III.	Feeds (natural food, no supplementary feeding)	—
IV.	Labour (5 × 200 × 12)	12,000
V.	Fuel	1,000
VI.	Licence (TOL) $50/acr. × 5	250
VII.	Miscellaneous expenses	1,000
VIII.	Total operating cost	$18,450
IX.	Depreciation (one year)	
	net-cage (25%)	$ 5,100
	equipment (25%)	375
	boat and engine (25%)	250
X.	Total cost	$24,175
XI.	Net profit	$ 3,825
XII.	Cost of production	$0.60/kati or $0.99/kg.

* Based on 20% mortality.

Table 4

CAPITAL COST AND OPERATING RATIO OF BIGHEAD CARP CULTURE IN FLOATING FISHPENS

Capital Cost

I.	Net-cage (34) 6 × 4 × 2 meters at $600	$20,400
II.	Boat + outboard engine	1,000
III.	Small equipment (plastic tanks, scoop nets, tools, etc.)	1,500
	Total ...	$22,900

Operating Ratio

Net income/Gross return	13.7%
Net income/Operating cost	20.7%
Net income/Total capital	9.3%

TABLE 5

ESTIMATES ON COST-BENEFIT OF A FAMILY UNIT FISHPENS FOR GROUPER CULTURE

I.	Gross return from sale of 4,000 fish (5,000 katis or 3,025 kg) at current wholesale rate of $3.00 per kati	$15,000
II.	Seeds * (4,800 at $0.50)	2,400
III.	Feeds	3,360
IV.	Labour (not included as farm be managed by 2 family members) ...	—
V.	Fuel	500
VI.	Licence fee (TOL)	50
VII.	Miscellaneous expenses	500
VIII.	Total operating cost	$ 6,810
IX.	Depreciation (one year)	
	net-cage (25%)	$ 625
	equipment (scoop nets, tools, basin, etc.)	250
	boat and engine (25%)	250
X.	Total cost	$ 7,935
XI.	Net profit	$ 7,065
XII.	Net income per person	$ 294 per month

* Based on 20% mortality.

TABLE 6

ESTIMATES ON COST-BENEFIT OF A FAMILY UNIT FISHPENS FOR CULTURING BIGHEAD CARPS IN RESERVOIR

I.	Gross return from sale of 3,600 fish (14,400 katis or 8,712 kg) at current wholesale rate of $0.70/kati	$10,080
II.	Seeds (4,320 × $0.35)	$ 1,512
III.	Fuel	500
IV.	Miscellaneous	500
V.	Labour (not included, to be managed by 2 family members) ...	—
VI.	Licence fee	50
VII.	Total operating cost	$ 2,562
VIII.	Depreciation (one year)	
	net-cage	$ 1,800
	equipment	250
	boat and engine	250
IX.	Total cost	$ 4,862
X.	Net profit (including labour)	$ 5,218
	Net income per person—$217 per month	

TABLE 7

CAPITAL COSTS INVOLVED IN GROUPER AND BIGHEAD CARP CULTURE IN A FAMILY UNIT FLOATING FISHPENS

	Item	*Grouper*	*Bighead Carp*
I.	Net-cage		
	(*a*) For grouper 28′ × 18′ × 5′ × 4	$5,000	—
	(*b*) For carp 4m × 6m × 2m × 12″	—	$7,200
II.	Outboard motor boat	1,000	1,000
III.	Small equipment (plastic tanks, scoop nets, tools, etc.)	1,000	1,000
	Total ...	$7,000	$9,200

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