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Grow-out mariculture techniques in tropical waters : a case study of problems and solutions in Hong Kong

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Abstract — *Raft culture is practised and trash fish is being used as feed in Hong Kong. Culture space is limited and most of the culture sites are over-crowded. Food conversion ratio is poor (about 10-15), grow-out mortality is high (30-50 %) and fish kills caused by oxygen depletions, algal blooms and red tides occur frequently. Disease and water pollution are also problems. To solve some of these problems, a computer simulation model has been developed to : (a) determine the optimal stocking density, and (b) to forecast the likelihood of oxygen depletion at culture sites. The use of biological indicators for oxygen depletions and fish kills has also been proven successful. An efficient aeration system has been designed for use in periods of low oxygen values. The possibility of replacing trash fish with artificial feeds is also being studied.*

MARICULTURE PROFILE AND GROW-OUT TECHNIQUES

Marine fish culture has developed in Hong Kong over the past twenty years, and production has increased drastically from 565 tonnes in 1978 to 3000 tonnes in 1988 (valued at US$ 4 & 25 millions respectively) (Fig. 1). The high price of live fish offers great incentive for the development and proliferation of the industry. In 1988, the total mariculture area is 180 ha., and almost all of the 1800 farmers are owner operators dependent upon family workers.

Raft culture is practised in Hong Kong. The raft is built of timber (average size about 180 m2) and is supported by a number of floating units made of empty plastic drums or polystyrofoam floats. Net cages (3 × 3 × 3 m) are hung from the raft and the structure anchored to the

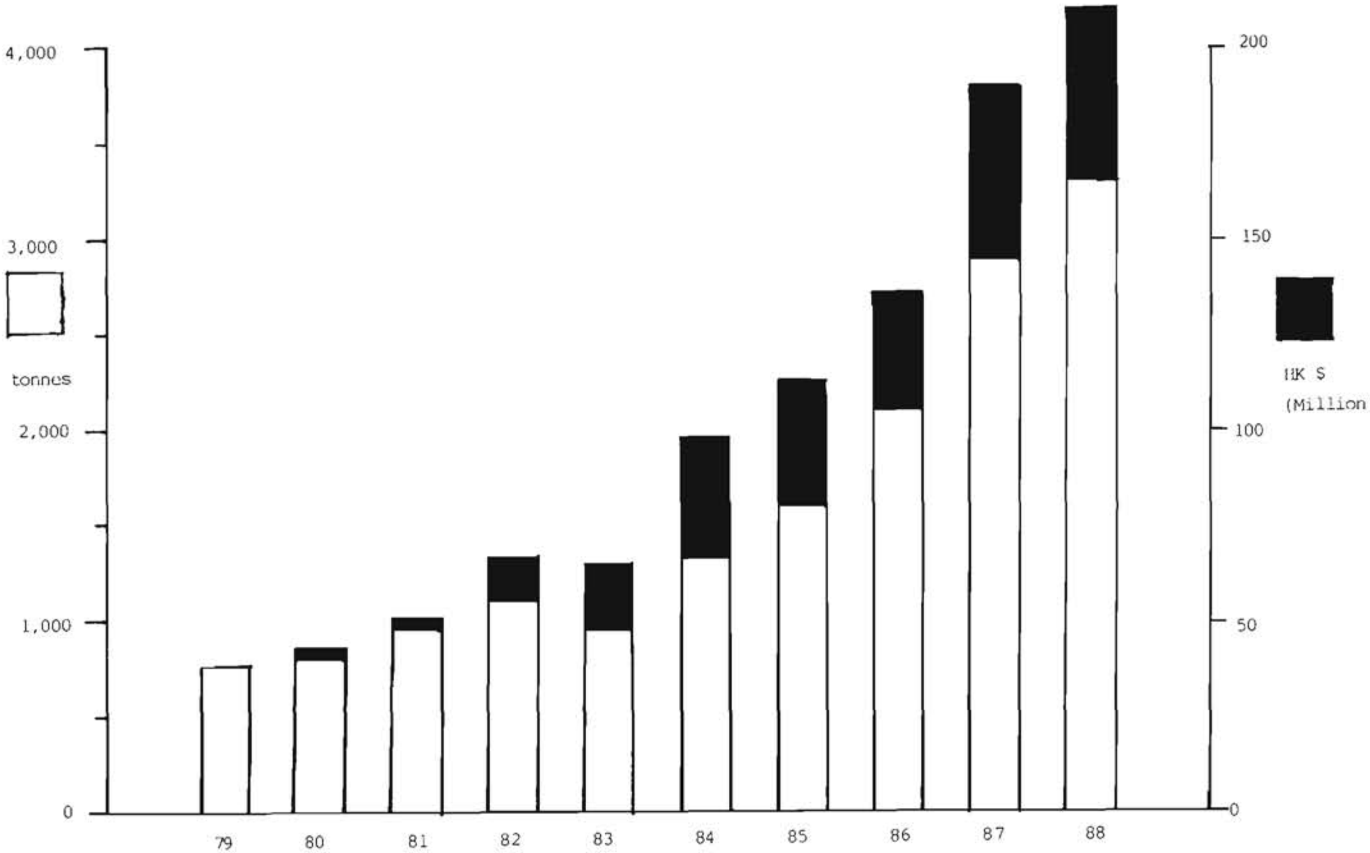

Fig. 1. — Mariculture production in Hong Kong (1979-1988).

sea bed. About 25 % of the raft area is normally set aside for transferring or holding fish during the clean up of fouling organisms from the cages.

Ten to fifteen species of marine fish are commonly cultured in Hong Kong (Table 1). A mixture of sea bream, grouper, snapper and giant perch is normally cultured in a single farm or cage and the average stocking density is 21 kg/m^2 cage. Sea bream fry are normally collected from local waters while over 80 % of grouper fry and all giant perch fry are imported from Thailand, Taiwan, China and the Philippines. Grow-out mortality is high (from 30-50 %) and fish diseases are common. These can be attributed to overcrowding, poor husbandry practises and the lack of imported fry quarantine facilities.

Tab. 1. — Major mariculture species in Hong Kong.

Serranidae	
	Epinephelus akaara
	E. tauvina
	E. awoara
Sparidae	
	Chrysophrys major
	Rhabdosarga sarba
	Mylio macrocephalus
	M. berda
	M. latus
Others	
	Lates calcarifer
	Lutjanus ruselli
	Letherinus nebulosus
	Pomadasya hasta

The cultured fish are fed daily with chopped or minced trash fish, although feeding frequency may be higher in the summer and lower in the winter. The overall food conversion ratio is poor (from 10-15). Malnutri-

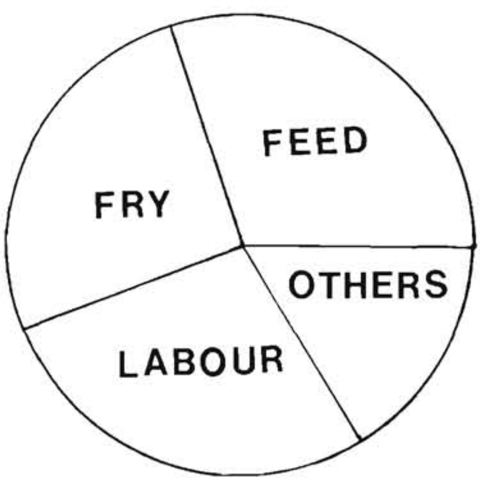

Fig. 2. — Breakdown of mariculture grow-out costs in Hong Kong.

tional syndromes are common and attributable to an unbalanced trash fish diet. Grow-out period varies from 12 to 30 months, depending on location and species cultured.

Despite the high grow-out mortality and incidence of disease, the capital return is fast (about 3 years). A breakdown of grow-out cost is shown in Figure 2. Labour, feed and fry constitute over 80 % of the fish price in roughly equal proportions.

PROBLEMS

The mariculture industry inevitably faces, and at the same time causes, considerable problems. For example, the development of fish farming is in direct conflict with other uses of the same coastal resources, e.g. reclamation, amenity, recreation and navigation. Conversely, pollution and squatter problems have developed in many culture zones. The Marine Fish Culture Ordinance was introduced in 1980 to regulate as well as to protect the mariculture industry. Under the Ordinance, 28 fish culture zones with a total area of 180 ha. have been designated. Farmers have to apply for a licence to culture fish in designated sites within these fish culture zones.

The results of a survey indicate that the major problems of the industry are, in order of priority : limitations of space, high mortality, poor growth and disease. Obviously, many of these problems are inter-related. Results of a one year water monitoring programme showed that ammonia, inorganic phosphate, nitrate and nitrite as well as phytoplankton numbers are generally higher, while dissolved oxygen levels are lower in fish culture zones (Table 2).

Tab. 2. — A general comparison of various water quality parameters at a fish culture zone (sha Tau Kok) and a control station (Kat O). Mean and range of each parameter are based on data collected over a one year study period (After Wu, 1988)

	FISH CULTURE ZONE		**CONTROL**	
PARAMETERS	Mean	Range	Mean	Range
Dissolved oxygen ($mg\ O_2\ l^{-1}$)	5.99	4.18-7.48	6.70	5.23-8.09
Phytoplankton (cells ml^{-1})	1,829	162-6,070	203	103-389
Inorganic phosphate ($\mu g\ l^{-1}$)	16.7	8.0-23.1	13.7	3.7-23.8
Nitrate ($\mu g\ l^{-1}$)	20.0	5.3-60.1	5.9	3.1-10.4
Nitrite ($\mu g\ l^{-1}$)	4.3	1.9-9.2	2.4	1.6-3.5

The bottom sediment in many of the fish culture zones is clearly enriched, as indicated by elevated percentages of organic matter (range : 6.2 - 13.3 %) compared with background levels (ranges : 1.2 - 2.7 %).

Hydrogen sulphide is present in the bottom waters and sediments of some zones. The poor water quality is mainly result from pollution with domestic sewage by the farmers, surplus fish feed, fish wastes resulting from over-stocking and by regular cleaning of fouling organisms attaching to the cages.

Pollution has also directly or indirectly caused a substantial loss to the mariculture industry. From 1976 to 1986, it was estimated that some 532 tonnes (valued at US$ 4.6 million) were lost to the industry in 106 fish kills. Of these, 36 incidents were attributed to oxygen depletions, algal boom and red tidal and another 16 incidents to direct pollution effects (Table 3). Fish kills caused by oxygen depletion is thus the most important problem facing the industry and hence forms the major target for research. Pathological infections have not been studied although they are apparently important.

Tab. 3. — Loss to the Hong Kong Mariculture industry due to various causes from 1976-1986

Cause :	No. of incidents
Pollution	
Oxygen depletions, algal blooms and red tide	38
Oil spills, toxic discharges and development	16
Pathological infections	30
Mis-management	9
Hot/cold spells	6
Unknown	7
Total	106

SOLUTION

Oxygen budget model to determine optimal stocking density

The limitations on space in Hong Kong makes it necessary to maximise the use of available fish culture zones. Conversely, over-crowding and over-stocking inevitably lead to enhanced disease transmission, a deterioration in water quality and hence fish kills. It is therefore important to determine the carrying capacity of the water body in relation to total organic loading and stock capacity, in order to optimize the culture activities in each zone. Where oxygen depletions are likely to occur, it would be of value to forecast the occurrence of oxygen depletions so that precautions may be taken to prevent fish kills. A computer simulation model has therefore been developed for the above purposes (Lee and Wu, in prep.). The model aims at predicting the depth-averaged dissolved oxygen level in a fish culture zone, by quantifying oxygen production and consumption resulting from CBOD, NBOD, sediment oxygen demand, fish respiration, photosynthetic production, algal respiration, and surface re-aeration in the system under varying environmental conditions. Light intensity, water temperature and salinity were identified to be the major environmental forcing factors. Extensive field and laboratory work have been carried out to collect the necessary data for the development of the model, and its predictability has been tested under varying environmental conditions. In all situations tested, predicted dissolved oxygen values agreed closely with actual field measurements. The maximum stock that the water body can sustain was also calculated. The model has proven to be a useful tool for mariculture management in Hong Kong.

A biological indicator for the onset of oxygen depletion

It would be highly desirable for fish farmers to anticipate the occurrence of oxygen depletions at their farm, so that the water could be aerated to prevent fish kills. Studies on the behaviourial responses of nine species of fish to hypoxic conditions revealed that *Chrysophrys major* is far more sensitive to hypoxia than with other species, and shows abnormal behavioural responses, e.g. jumping out of water and abnormal swimming, within 20 min. when dissolved oxygen values dropped to $< 1\ mg\ O_2\ l^{-1}$. Fish farmers are advised to keep a small number of *C. major* in their culture cages so that the quick behaviourial hypoxic response of the species may serve as a useful and effective biological indicator for the onset of oxygen depletions at their farms (Wu, 1988).

Design of an efficient aeration system

An efficient aeration system has been designed for use by fish farmers to increase dissolved oxygen levels within a relatively short time during oxygen depletions. The system includes an oil free blower operated on gasoline (since power supply is not available on most culture rafts), and is capable of producing $0.35\ m^{-3}$ air min^{-1} at 3 m depth. Air produced from the blower is supplied to the air diffuser through PVC tubing. The air diffuser is made of porous tube, and the aeration efficiency is greatly increased because of its large surface area and the small air bubbles produced (Fig. 3). The system has been tested *in situ*, and is able to bring dissolved oxygen levels in a volume of 9 m3 from 0.5 mg/l to 2.0 mg/l, the « safe » limit for the great majority of species, within 15 minutes. This means that as soon as the onset of oxygen depletion is discerned (as reflected by the abnormal behaviourial responses exhibited by *C. major)* the farmer would be able to bring the dissolved oxygen above the safe level within a short time.

Artificial Feed to replace trash fish

Experimental results showed that both food wastage and leaching of organic matter and nutrients can be significantly reduced when artificial feed is used instead of trash fish, particularly for extruded feed which is relatively buoyant and provide a longer feeding time in the water column. Food wastges may be further reduced if extruded feed is used in

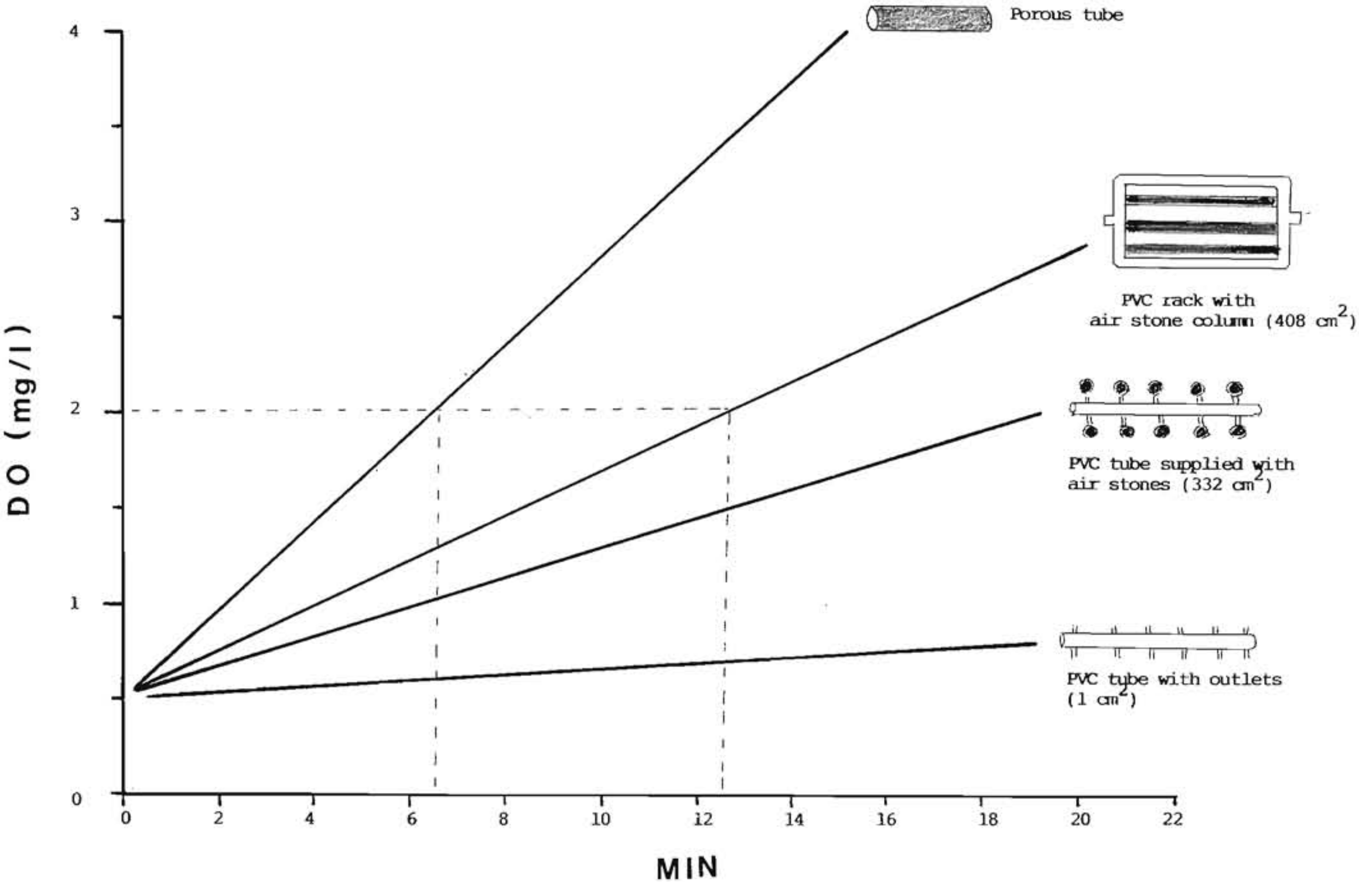

Fig. 3. — A comparison of aeration efficiencies by different types of diffusers *in situ*. Total aeration surface of the various types of diffusers is given in brachets. For detailed design of the system see text.

conjunction with auto-feeders/demand feeders. Research is now underway to study the nutritional requirements of local cultured species, with a view to replacing trash fish with suitable artificial feeds and to rectifying the malnutritional and pollution problems.

Wu R.S.S., 1988. Marine pollution in Hong Kong : a review. *Asian Marine Biology*, **5** : 1 - 23.