AQUACULTURE INDUSTRY

LEE SEONG WEI
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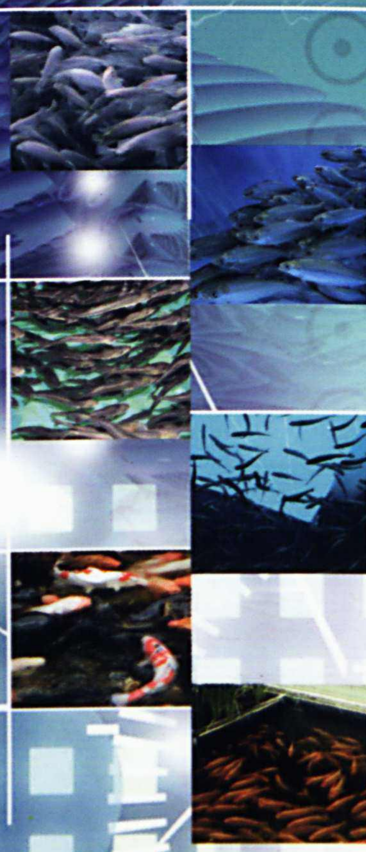

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PREFACE

As the Chinese proverb said, "Give fish to a man and he will have food for that day, but teach him how to fish then he will have fish for his whole life". This is practically true for aquaculture or aquatic farming, which has been deemed as one of the rapidly growing industry to supply food source besides capture fisheries. Demand for aquaculture products continue to increase as the world's population continues to grow. Major aquaculture products include finfish, shrimps, bivalves, gastropod, and seaweeds.

After decades of development since 1900s, aquaculture has emerged from subsistence level and hobbies into large scale production for local and export markets. There are vast aspects in aquaculture industry that one may get involved in, from farming to marketing, health management, food processing, system designing, water management, genetics improvement research and lots more.

Bear in mind that aquaculture business, like other investments, is challenging and comes with risks. This book presents fundamental principles of aquaculture practice from a practical how-to perspective for those who seek to understand aquaculture industry and might be in the industry someday. Laws and regulations practiced in the context of Malaysia and current issues are also highlighted in this text to provide readers with better understanding on aquaculture industry.

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CHAPTER 1
INTRODUCTION

By definition, aquaculture involved the rearing of aquatic organisms including fish, molluscs, crustaceans and aquatic plants under controlled or semi-controlled conditions. Aquaculture begun as early as 2000 B.C. and China is believed to have started this activity 4000 years ago. Common carp, given feed of nymph and by-product of silkworm industry, was the first species cultured in rivers and ponds to supply the need of emperor of China and the people. However, details on the fish farming was not well documented.

1.1 AQUACULTURE PRODUCTION

According to ISSCAAP (International Standard Statistical Classification of Aquatic Animals and Plants), top ten species groups for aquaculture production of aquatic animals in 2004 are carps and other cyprinids; oysters; clams, cockles and arkshells; miscellaneous freshwater fishes; shrimps and prawns; salmons, trouts and smelts; mussels; tilapias and other cichlids; scallops and pectens; and miscellaneous marine molluscs. All these give a total production of 45.4 million ton that equivalent to USD 63.4 billion.

Meanwhile, top ten countries in aquaculture production of aquatic animals in 2004 are China, India, Vietnam, Thailand, Indonesia, Bangladesh, Japan, Chile, Norway and USA, which accounted for 40.1 ton total production of fish, crustaceans, molluscs and amphibians. China alone accounted for 67.3% of world total production whereas the rest of the world excluding the top ten countries accounted for 11.8% of the world total production, or equivalent to 5.35 million ton.

In many poor and developing countries, aquaculture is indeed an important activity to obtain cheap animal protein source and .to generate income for the family. Per capita supply from aquaculture showed an increment from 0.7 kg in 1970 to 7.8 kg in 2006, an average annual growth rate of 6.9%. Aquaculture is not limited to self-subsistant scale, but intensively carried out in many countries that contributes substantially to the nation economics. According to FAO (Food and Agriculture Organization of the United Nation), aquaculture production specifically refers to output from aquaculture activities, which are designated for final harvest for consumption. In 2006, aquaculture contributed almost 50% of the world fisheries production of 110 million ton of food fish. On the other hand, world aquatic plant production by aquaculture was 15.1 million ton, worth of USD 7.2 billion. Asia countries (China, Philippines, Indonesia, the Republic of Korea and Japan) are known to be the main producers for world's total supply of aquatic plants. China by far dominated the world aquaculture production of aquatic animals and plants.

Culture techniques of aquatic animals and plants are still developing and more varieties are being cultured than before. Though over 240 different cultured aquatic animals and plant species were reported in 2004, many more are unspecified for record. Fish, shrimp and molluscs are the most commonly cultured animal whereas seaweed is the most commonly cultured plant (Table 1.1). Expansion and intensification of aquaculture activities are particularly driven by the following factors:

- overexploitation of capture fisheries
- declining fish stock from the wild
- increasing demand from continuous growth of human population

Table 1.1: Common aquaculture species (Stickney, 2005).

Species	Group	Examples
Fish	Freshwater	Tilapia, catfish, carp, eel, snakehead, salmon, trout, sturgeon
	Marine/ Brackish	Seabass, grouper, sea perch, cod, cobia, ayu, scad, scat, flounder, halibut, milkfish, mullet, pompano, sole, sea bream, snapper, yellowtail
Crustacean	Shrimp/ prawn	Giant tiger shrimp, Pacific white shrimp, Indian white shrimp, blue shrimp, banana shrimp, kuruma shrimp, giant freshwater prawn
	Lobster/ crayfish	Spiny lobster, American lobster, European lobster, red claw crayfish, red swamp crayfish
	Crab	Mud crab, blue swimming crab
Molluscs	Gastropod	Abalone
	Bivalves	Oyster, mussel, clam, cockle, scallop
Plant	Seaweed	*Porphyra, Laminaria, Undaria, Eucheuma, Gracilaria, Caulerpa*

1.2 OVERVIEW OF AQUACULTURE OPERATION

Seed production is very important and key to the success of an aquaculture practice. Fully dependence on wild seed often limit the production of cultured species as quality varies and quantity uncertain. Moreover, pathogens from the wild may be introduced into the culture system. Therefore, broodstocks obtained from the wild or farm-raised have to be carefully screened before introduced into the hatchery. Broodstocks are being conditioned to ensure the production of good quality offsprings.

Fish spawning can be carried out in natural or artificial manner. Natural spawning involves putting the mature males and females together at a proper ratio to induce spawning and fertilisation. Meanwhile, artificial spawning for fish is performed with the aid of hormone injection to stimulate spawning. Other methods to induce spawning include eye ablation for crustacean and temperature manipulation for molluscs. Fertilised eggs then hatch into larvae and transferred into larval rearing tanks. Post larvae and juveniles are usually kept in the nursery tanks before stocking into the grow-out system for further development into marketable size (Figure 1.1). When the cultured species is ready to harvest and market, activities such as off-flavour removal, molluscs depuration, sorting and grading, storage of live aquaculture species, and transportation of live and fresh aquaculture species are carried out.

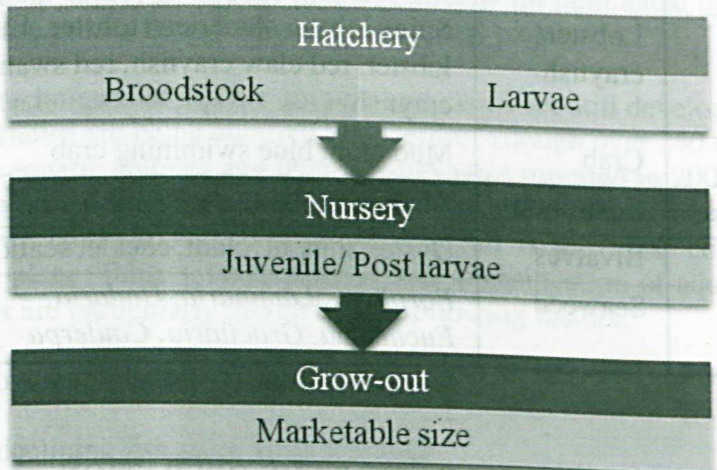

Figure 1.1: Overview of aquaculture production cycle.

In most cases, decision on culture site and target species is made after evaluating factors such as geographical location, environmental condition, socio economic importance, and governmental policy. Because aquaculture is an activity that requires good quality and large volume of water resource, strategic geographical location to carried out aquaculture activity is likely to near natural water sources like rivers, estuarines, bays, lagoons, mangrove swamps, lakes and reservoirs. Environmental condition as well as the climate must be taken into consideration in species selection. For example, species selected for culture in the temperate countries must be able to tolerate to the temperate climate and vice versa for tropical countries. Socio economic importance and governmental policy have significant roles in shaping the aquaculture activities in a nation. For instance, the availability of man power, infrastructures, consumer preference, financial support, land use, and etc. Furthermore, target species should possess favarouble traits including fast-growing, low in food conversion ratio (FCR), easy to handle, good quality of meat, resistant to disease, plenty of seed supply and etc.

To operate an aquaculture business, the farm operator has to work hard all the time from farm setup to feed and health management of the cultured species, human resource management, farm maintenance, production, marketing, and financial control. For farm setup, things to do include site survey and clearance, system design and construction, and water supply, treatment and discharge. Supply of feed must be able to fullfill the nutrional requirement of the cultured species and cost effective as well. Quality food not only promote growth, but also help to improve the health of the cultured species. When health of the cultured species is well-managed, cost for disease treatment can be reduced. Besides, skillful workers are needed to carry out tasks such as pond preparation for stocking, tanks cleaning, stocks transfer, feeding and harvesting. A farm manager is responsible to organise workers and to schedule overall farm operation. Apart from that, the farm operator also has to set a profitable production target, plan for marketing and monitor the operational cost from time to time.

On the whole, operating an aquaculture business is challenging!

CHAPTER 2

WATER QUALITY REQUIREMENT AND ABIOTIC FACTORS

Minerals, suspended solids, settleable solids and gases components in water support life of aquatic organisms. Aquaculture product quality greatly relies on water quality. Fish nutrition and general fish health are closely related to the water condition in the culture system. Good water quality is the key of success to an aquaculture project. Before stocking cultured species into a pond, aquaculturist must make sure that the water supply is free from toxic algae, causative agents disease, and harmful chemical compounds. The following highlights water quality requirement and abiotic factors in aquaculture.

2.1 TEMPERATURE

Aquatic animal is poikilotherm or cold-blooded, where body temperature can be regulated according to temperature changes in the environment. For that reason, water temperature in the culture system should be monitored and remain constant at all times, except for system that has frequent water exchange rate. In tropical country like Malaysia, water temperature in an aquaculture system should be above 25 °C but below 30 °C. Temperature changes should not more than 5 °C within an hour, or else this sudden change of water temperature can cause stress and mortality to the cultured fish.

2.2 DISSOLVED OXYGEN (DO)

Dissolved oxygen is expressed in parts per million (ppm) or milligram per liter (mg/ L). In general, the concentration of dissolved oxygen (DO) in an aquaculture system should be maintained at 5 mg/L and above. Low concentration of DO may affect the growth rate of cultured fish whereas critical DO level at 3 mg/L or less can cause mortality of the cultured fish. Fluctuation of DO level during day time and night time are likely to happen, especially for outdoor system. Usually, DO level during day time is higher than night time owing to photosynthetic activity that produces oxygen. Concentration of DO tend to falls dramatically at night and most critically at dawn. Mass mortality of cultured fish can occur at dawn due to oxygen depletion in the aquaculture system when decomposition of organic matter and respiration of organisms take place actively. Therefore, farmers are advised to equip the culture system with aerators or paddlewheels and switch them on whenever needed to maintain the DO level. Oversaturation of DO should be avoided as this is going to cause gas bubble disease to the fish. The DO level can be easily measured using DO meter or manually determined by a calorimetric titration method, known as the Winkler method.

2.3 pH

pH is an expression of the acid-base relationship designated as the logarithm of the reciprocal of the hydrogen-ion activity. Water is neutral at pH 7. For most aquatic animals in the freshwater culture system, optimum pH level ranges from 6.5 to 8.5 whereas for marine species should above pH 7.0. However, optimum pH level is depending on physiological need of an aquatic animal. For instances, fighting fish (*Betta* sp.) prefers acidic environment to grow and breed; goldfish requires high calcium and high pH environment for the better scale formation.

2.4 SALINITY

Salinity refers to dissolved salt content of a body of water and is expressed in parts per thousand (ppt or $^{o}/_{oo}$). Freshwater is defined to have salinity less than 0.5 ppt while salinity of the brackish water ranges from 0.5 to 30 ppt. As for marine water, salinity used to range from 30 to 40 ppt. When salinity exceeds 40 ppt, the water is regarded as hypersaline or brine water. For fish farmers, hand-held refractometer provides a simple and quick way to obtain salinity measurement. It is important to know the salinity in culture system since salinity affects fish physiology and breeding, particularly for those anadromous and catadromous species. For example, adult Malaysian giant freshwater prawn (*Macrobrachium rosenbergii*) that lives in freshwater can only breed when salinity is around 3 to 5 ppt, while the larval stage grows up in brackish water.

2.5 TURBIDITY

Presence of suspended solids restricted light penetration and cause turbidity to the water. Suspended solids consist of tiny particles which are smaller than 0.45 μm such as silt, mud, sand, plant particles, animal detritus, algal mats, food particles, faecal pellets, planktonic organisms and etc. Despite that turbidity helps to cool down water tempertature and at the same time retain the water temperature, extreme turbidity has adverse effects on cultured species in which causing fish gill clogged, eggs being buried, and visual obstruction for fish larvae to sense for live feed. Secchi disk is a simple tool that used to measure water clarity. To obtain a measurement, the disk which is tied with a string is lowered into the water while observing the depth at which the black and white quadrants on the disk are no longer visible. Then, the disk is slowly raised again to record for the depth at which it reappears. The Secchi disk measurement is the average of the two observations, based on the Secchi depth that is related to water turbidity. Optimum reading is about 30 cm.

2.6 AMMONIA (NH_3)

Ammonia/ammonium (NH_3/NH_4^+) are nitrogenous wastes from the fish wastes and unfed fish feed. Detectable level of ammonia in an aquaculture system should less than 2.5 ppm for warmwater fish and less than 1.0 ppm for coldwater fish. To ensure low ammonia level in the culture system, water exchange and application of probiotics are essential. Probiotics play important role to convert NH_3 to NH_4^+, which is less harmful. High concentration of NH_3 in an aquaculture system is harmful to the cultured fish when combination of NH_3 in fish blood forms methaemoglobin that cannot carry oxygen. Fish mortality can occur due to the oxygen depletion.

2.7 LIGHT

Exposure to light for certain period benefits aquaculture species. Source of light can be obtained from direct sunlight or artificial lamp. Photoperiod can be regulated to boost phytoplankton bloom and also speed up biological process in the cultured species such as gonadal development in shrimp, egg hatching, metabolism, etc. For indoor system, photoperiod at light : dark (hour) ratio 12:12 and 14:10 are commonly practiced for live feed culture of microalgae, copepod and artemia. It is rather difficult to manipulate the photoperiod for outdoor system because the photoperiod is subjected to seasonal and climate changes. Besides the exposure period, light intensity of the light source also pose effect on the cultured species.

2.8 SUBSTRATE

Substrates are materials that placed on purpose in the culture system to serve as sites for hiding, breeding, attachment, or egg protection. Materials used as substrates included fibreglass, plastic, metal, concrete, PVC pipe, clay, sand and even aquatic plants. Netting also serves as useful material in the shrimp larval rearing tank to avoid cannibalism among the larvae.

2.9 STOCKING DENSITY

Stocking density is not a static parameter, where the biomass of fish stocked at an initial density increases as the fish grows. Optimum stocking density allowed cultured species to live in normal behaviour with minimal pain and stress, thus promote uniformity in size, better growth performance and survival. For the case in Malaysia, stocking density of fish in pond ranges from 10 to 25 per m^3 of water volume. Stocking density that overloads the carrying capacity of an aquaculture system often creates problems to management. Overcrowding deteriorates water quality more easily and cultured species becomes stressed and more vulnerable to diseases. In contrary, low stocking density is not practical and non-economical to farmers.

2.10 WATER SOURCE

Although more than 70% of the earth surface is covered with water, not all of the water is suitable for aquaculture activity. Water sources for aquaculture use can be obtained directly from municipal water or from natural resources such as surface water and groundwater.

Municipal water is abundant, clean and clear but costly for aquaculture which requires large volume of water. This water source is feasible for small scale aquaculture. Presence of chlorine or chloramines in the water source is toxic to the cultured fish. Dechlorination must be carried out prior to water usage by allowing the water to stand for 24 h or by aeration.

Surface water which includes of ocean, bay, river, lake and wetlands is recognized as the largest water source for aquaculture activities. This natural water resource is cheap and plentiful. However, aquaculturist must always monitor or check for the existence of contaminants such as heavy metals, herbicides and pesticides before supply to the farm.

Groundwater is the second option after surface water. Typically, groundwater (well water, spring water) offers better water quality for aquaculture activity. Nevertheless, groundwater which located nearby industrial area is potentially exposed to pollutants. For safety precaution, any water source that intended for aquaculture activity must be screened before entering the farm water system.

CHAPTER 3
CULTURE SYSTEM

In different regions of the world, culture system adopted for aquatic organisms are different. Aquaculture can be operated land-based or water-based. Most popular land-based systems are earthern ponds and raceways, whereas the water-based systems are cages and pens. Water-based system is also regarded as an open system, where fish culture unit interact directly with the immediate water bodies. On the basis of feeding, mode of operation for aquaculture are classified as extensive, semi-intensive and intensive (Table 3.1). Due to the fact that the intensive culture relies almost completely on external supply of feed and the feeding cost is much higher than extensive and semi-extensive cultures, use of intensive culture is only feasible if the fish being cultured is of high value and profitable when harvested.

Table 3.1: Classification of extensive, semi-intensive and intensive culture (Rahman et al., 1992).

Mode of operation	Feeding	Fish species	Site selection
Extensive	Solely depends on naturally available food source, e.g. plankton, detritus, benthos and drift.	Planktivorous and omnivorous fish species	Rivers rich in organic matters, detritus and insect life.
Semi-intensive	Depends on naturally available food source with the addition of low protein (<10%) feed from agricultural by-products.		Rivers and slow -flowing lowland or delta sites.