Fish farming techniques pdf

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Closed Systems: Closed systems, or closed containment farming methods, use a barrier to control the exchange between farms and the natural environment. This significantly reduces pollution, fish escapes, negative wildlife interactions, and parasite and disease transfer from farms to marine and freshwater ecosystems. The most common types of closed systems are raceways and recirculating systems. Raceways: Flowing water is diverted from natural streams or a well. Raceways are typically used for raising rainbow trout. To be considered and re-circulated, with minimal wastewater discharge. Almost any type of finfish can be raised in recirculating systems. Common species farmed this way include Arctic char, striped bass, barramundi, sturgeon, and increasingly, salmon. These systems are designed to treat effluent before it is discharged to natural water bodies, which reduces pollution, disease and parasite transfer. Fish escapes are virtually impossible, with appropriate barriers designed into the facilities. Suspended-aquaculture: Farmers grow shellfish farmed using these methods are filter feeders and require only clean water to thrive. Oysters, scallops, mussels and clams are cultured using suspension systems. Shellfish farming in suspended-aquaculture is often low risk, if the farmed species is native to the area, and if the farmed species is native to the area, and if the farmed species is native to the area. Farming 4.5 Pen and Cage Culture 4.6 Open Water Culture 4.1 Historical Perspective Aquaculture has a tradition of about 4 000 years. It began in China, possibly due to the desires of an emperor to have a constant supply of fish. It is speculated that the techniques for keeping fish in ponds originated in China, possibly due to the desires of an emperor to have a constant supply of fish. It is speculated that the techniques for keeping fish in ponds originated in China, possibly due to the desires of an emperor to have a constant supply of fish. It is speculated that the techniques for keeping fish in ponds originated in China, possibly due to the desires of an emperor to have a constant supply of fish. catch alive temporarily in baskets submerged in rivers or small bodies of water created by damming one side of a river bed. Another possibility is that aquaculture developed from ancient practices for trapping fish, with the operations steadily improving from trapping-holding-growing, and finally into complete husbandry practices (Ling, 1977). Table 5. Possible environmental Impacts of aquaculture Culture System Environmental Impact EXTENSIVE 1. Seaweed culture May occupy formerly pristine reefs; rough weather losses; market competition; conflicts/failures, social disruption. 2. Coastal bivalve culture (mussels, oysters, clams, cockles) Public health risks and consumer resistance (microbial diseases, red tides, industrial pollution; rough weather losses; seed shortages; market competition especially for export produce; failures, social disruption. 3. Coastal fishponds (mullets, milkfish, shrimps, tilapias) Destruction of ecosystems; especially mangroves; increasingly non-competitive with more intensive systems; nonsustainable with high population growth; conflicts/failures, social disruption. 4. Pen and cage culture in eutrophic waters and/or rich benthos (carps, catfish, milkfish tilapias) Exclusion of traditional fishermen; navigational hazards; conflicts, social disruption; management difficulties; wood consumption. SEMI-INTENSIVE 1. Fresh- and brackishwater pond (shrimps and prawns, carps, catfish, milkfish, mullets, tilapias) Freshwater: health risks to farm workers from waterborne diseases. Brackishwater: salinization/acidification of soils/aquifers. Both: market competition, especially for export produce; feed and fertilizer availability/prices; conflicts/failures, social disruption. 2. Integrated agriculture-aquaculture (rice-fish; live stock/poultry-fish; vegetables - fish and all combinations of these) As freshwater above, plus possible consumer resistance to excreta-fed produce; competition from other users of inputs such as livestock feeds (e.g., heavy metals) may accumulate in pond sediments and fish; pesticides may accumulate in fish. 3. Sewage-fish culture (waste treatment ponds; latrine wastes and septage used as pond inputs; fish cages in wastewater channels) Possible health risks to farm workers, fish processors and consumers; consumer resistance to produce. 4. Cage and pen culture, especially in eutrophic waters or on rich benthos (carps, catfish, milkfish, tilapias) As extensive cage and pen Systems above. INTENSIVE 1. Freshwater, brackishwater and marine ponds (shrimps; fish, especially carnivores - catfish, snakeheads, groupers, sea bass, etc.) Effluents/drainage high in BOD and suspended solids; market competition, especially for export product; conflicts/failures, social disruption. 2. Freshwater, brackishwater and marine cage and pen culture (finfish, especially carnivores -groupers, sea bass, etc. - but also some omnivores such as common carp) Accumulation of anoxic sediments below cages due to fecal and waste feed build-up; market competition, especially for export produce; conflicts/failures, social disruption; consumption of wood and other materials. 3. Other - raceways, silos, tanks, etc. Effluents/drainage high in BOD and suspended solids; many location-specific problems. Source: Modified from Pullin, 1989 Chinese who emigrated to other Southeast Asian countries probably carried the knowledge with them and inspired the local people to take up fish farming. Brackishwater aquaculture is thought to have originated in Indonesia with the culture of milkfish and grey mullet (Ling, 1977) and must have spread to neighbouring countries like the Philippines which has been practising it for about 300 to 400 years (Baluyut, 1989). The husbandry of fish is therefore not a new phenomenon. Ancient practices based on the modifications of natural bodies of water or wetlands to entrap young fish in enclosures until harvest, have just evolved into more systematic and scientific methods and techniques. Other regions of the world have shorter traditions of aquaculture. In North America, it is about a century old; in Africa, aquaculture production consists almost exclusively of tilapia culture in freshwater ponds and dates back to the 1940s (UNDP/NORAD/FAO, 1987). Aquaculture development has been very recent and is just gaining momentum in Australia, New Zealand, and the Pacific Island countries (Rabanal, 1988b).4.2 Overview of Aquaculture Methods and Practices A number of aquaculture practices are used world-wide in three types of environment (freshwater, brackishwater, brackishwater, and marine) for a great variety of culture is done mainly in fish ponds, fish pens, fish cages or, on a limited scale, in rice paddies. Brackishwater, brackish located in coastal areas. Marine culture employs either fish cages or substrates for molluscs and seaweeds such as stakes, ropes, and rafts. (Summarized information on major culture systems range from extensive to intensive depending on the stocking density of the culture organisms, the level of inputs, and the degree of management. In countries where government priority is directed toward increased fish production from aquaculture to help meet domestic demand, either as a result of the lack of access to large waterbodies (e.g., Nepal, Central African Republic) or the overexploitation of marine or inland fisheries (e.g., Thailand, Zambia), aquaculture practices are almost exclusively oriented toward production for domestic consumption (UNDP/NORAD/FAO, 1987). These practices include: (i) freshwater pond culture; (ii) brackishwater finfish culture; (iv) mariculture involving extensive culture and producing fish/shellfish (e.g., oysters, mussels, cockles) which are sold in rural and urban markets at relatively low prices. Table 6. Aquaculture production systems and practices, by region Region Major Culture Systems and practices for Further Expansion ASIA At least 75 species; diverse freshwater and marine species, including high-value shrimps, molluscs, seaweeds, with carps and seaweeds, with carps and fish cages - Floating rafts, lines, and stakes for molluscs and seaweeds Development of culture-based fisheries in inland lakes, rivers, floodplains, and permanent and temporary reservoirs and barrages Resource enhancement programmes integrated with environmental management PACIFIC Mussels and oysters, red seaweeds Intensive/semi-intensive to extensive - Hanging lines for select markets; Offshore cages for salmon Small-scale aquaculture for local markets; - Pond culture for shrimps, tilapia, catfish, milkfish Improved management of fishery resources, particularly reef fisheries - Freshwater pens for crayfish LATIN AMERICA 50 species of fish, crustaceans, and molluscs, including freshwater fish and marine shrimps in South America and molluscs in Central America Extensive to semi-intensive - Offshore cage farming of marine shrimp in coastal ponds and extensive farming of freshwater fish in ponds Production of species for export and marine shrimp and salmon AFRICA >26 freshwater fish; the most important being tilapia and common carp, molluscs and oysters also Mainly extensive, rural-based, integrated with poultry and animal husbandry, rice-fish farming; some intensive in raceways and floating cages for marine species Increased emphasised emphasised. on higher value catfishes for urban markets, on marine species of fish and crustaceans for select national market and export Culture-based fisheries in lakes and reservoirs Development of coastal lagoons which are almost totally unexploited MEDITERRANEAN >50 individual species, mostly freshwater and brackishwater fishes - most important being salmonids and carps; oysters and mussels Well-diversified modern practices, with highly technical and intensive systems in developing countries and semi-intensive elsewhere - Fish pond - Fish cages - Ocean ranching Production of high-value species of tourism and export Integrated coastal zone management CARIBBEAN About 16 species of tilapias, carps, marine shrimp and, freshwater prawns, oysters and seaweeds - Floating cages in reservoirs - Rope production for local markets - Fish pond farming in freshwater - Culture-based fisheries in reservoirs - Rope production for local markets - Fish pond farming in freshwater - Culture-based fisheries in reservoirs - Rope production for local markets - Fish pond farming in freshwater - Culture-based fisheries in reservoirs - Rope production for local markets - Fish pond farming in freshwater - Culture-based fisheries in reservoirs - Rope production for local markets - Fish pond farming in freshwater - Culture-based fisheries in reservoirs - Rope production for local markets - Fish pond farming in freshwater - Culture-based fisheries in reservoirs - Rope production for local markets - Fish pond farming in freshwater - Culture-based fisheries in reservoirs - Rope production for local markets - Fish pond farming in freshwater - Culture-based fisheries in reservoirs - Rope production for local markets - Fish pond farming in freshwater - Culture-based fisheries in reservoirs - Rope production for local markets - Fish pond farming in freshwater - Culture-based fisheries in reservoirs - Rope production for local markets - Fish pond farming in freshwater - Culture-based fisheries in reservoirs - Rope production for local markets - Fish pond farming in freshwater - Culture-based fisheries in reservoirs - Rope production for local markets - Fish pond farming in freshwater - Culture-based fisheries in reservoirs - Rope production for local markets - Fish pond farming in freshwater - Culture-based fisheries in reservoirs - Rope production for local markets - Fish pond farming in freshwater - Culture-based fisheries in reservoirs - Rope production for local markets - Fish low stocking densities (e.g., 5 000-10 000 shrimp post larvae (PL)/ha/crop) and no supplemental feeding, although fertilization may be done to stimulate the growth and production of natural food in the water. Water change is effected through tidal means, i.e., new water is let in only during high tide and the pond can be drained only at low tide. ponds used for extensive culture are usually large (more than two ha) and may be shallow and not fully cleared of tree stumps. Production is generally low at less than 1 t/ha/y. Semi-intensive culture uses very high densities of culture organism (e.g., 200 000-300 000 shrimp PL/ha/crop) and is totally dependent on artificial, formulated feeds. Both systems use small pond compartments of up to one ha in size for ease of management. Semi-intensive and intensive culture systems are managed by the application of inputs (mainly feeds, fertilizers, lime, and pesticides) and the manipulation of the environment primarily by way of water management through the use of pumps and aerators. Feeding of the stock is done at regular intervals during the day. In intensive shrimp culture, the computed daily feed ration is given in equal doses from as low as three to as high as six times a day. Water change is also effected on a daily basis, with approximately 10-15% of the water in the pond replenished by the entry of new water in semi-intensive systems are therefore more labour-intensive systems which need little attention, and are costlier to set up and operate, not to mention the fact that they also carry higher risks of mortalities resulting from disease, poor management, and/or force majeure (e.g., from anoxia due to non-functioning aerators during times of power failure). Production is of course much higher (for example, ranging from a minimum of 1.5 t/ha/crop from semi-intensive shrimp culture to a high of 10 t/ha/crop from intensive shrimp culture). Financial returns are therefore much more attractive than those from extensive culture is better than from intensive culture due to the high cost of inputs (largely fry and feeds) used in intensive culture. A summary of the comparative features among these three main types of culture systems is shown in Table 7. 4.3 Fish Pond Culture 4.3.1 Culture 9.3.2 Site Selection 4.3.3 Pond Layout 4.3.4 Design of Pond Facilities 4.3.5 Pond Management Pond culture, or the breeding and rearing of fish in natural or artificial basins, is the earliest form of aquaculture with its origins dating back to the era of the Yin Dynasty (1400-1137 B.C.). Over the years, the practice has spread to almost all parts of the world and is used for a wide variety of culture organisms in freshwater, brackishwater, and marine environments. It is carried out mostly using stagnant waters but can also be used in running waters especially in highland sites with flowing water. Table 7. Summary of comparative features among the three main culture systems Parameter Extensive Semi-Intensive Intensive Semi-Intensive Intensive Semi-Intensive Intensive Semi-Intensive Semi-Int well laid-out With provisions for effective water management Very well engineered system with pumps and aerators to control water quality and quantity Very big ponds Manageable-sized units (up to 2 ha each) Small ponds, usually 0.5-1 ha each Ponds may or may not be fully cleaned ponds Fully cleaned ponds Fertilizer Used to enhance natural productivity Used regularly with lime Not used Pesticides Not used Used regularly for prohylaxis Used regularly for prohylaxis Used regularly for prohylaxis Food and Feeding of high quality feeds Full feeding of high-quality feeds Depending on stocking density used, formulated feeds may be used partially or totally Cropping Frequency (crops/y) 2 2.5 2.5 Quality of Product Good quality Good quality Good quality Good quality Culture species and occur Confined to culture water from rivers, irrigation canals, or plain rain water. The system approximates intensive culture in that it involves the application of rapid water is advantageous for fish culture as it supplies abundant dissolved oxygen and flushes away waste products and unconsumed feeds.4.3.1 Culture Species Commonly raised species in freshwater ponds are the carps, tilapia, catfish, snakehead, eel, trout, goldfish, gouramy, trout, pike, tench, salmonids, and the giant freshwater prawn Macrobrachium. In brackishwater ponds, common species include milkfish (Chanos chanos), mullet (Mugil sp.) and the different penaeid shrimps (Penaeus monodon, P. orientalis, P. merguiensis, P. penicillatus, P. japonicus, and M. ensis). The more popular species for culture in marine ponds are the sea bass, grouper, red sea bream, yellowtail, rabbitfish, and marine shrimps. In Asia, where the bulk of world production from aquaculture emanates, fish ponds are mostly freshwater or brackishwater, and rarely marine. In China and most of the Indian sub-continent, pond culture is traditionally dominated by freshwater species, mainly the carps, usually in polyculture and/or integrated with animal husbandry. In Southeast Asia, fish ponds are predominantly brackishwater, with milkfish and penaeid shrimps grown either in polyculture or in monoculture. Recently in Latin America and the Caribbean, brackishwater pond culture of penaeid shrimps has expanded rapidly, as it has in some parts of Asia. In Africa, the tilapias and carps dominate aquaculture or in monoculture. Recently in Latin America and the Caribbean, brackishwater pond culture of penaeid shrimps has expanded rapidly, as it has in some parts of Asia. Bagrus and, to a lesser extent, Lates niloticus, Heterotis niloticus, and Clarias lazera. Ten species of molluscs belonging to four genera (Crassostrea, Mytilus, Venerupis and Pinctada) are cultured. Crustacean culture has yet to be developed on a significant scale (Satia, 1989).4.3.2 Site Selection Proper site selection is recognized as the first step guaranteeing the eventual success of any aquaculture project and forms the basis for the design, layout, and management of the project (SCSP, 1982a). For fish ponds, especially those to be used for coastal/brackishwater aquaculture of high-value species like shrimps, site selection is critical and should be given utmost attention. Adisukresno (1982), Hechanova (1982), and Jamandre and Rabanal (1975) listed the following guidelines for the selection of a suitable site for coastal fish ponds: (i) Soil Quality: preferably, clay-loam, or sandy-clay for water retention and suitability for diking; alkaline pH (7 and above) to prevent problems that result from acid-sulphate soils (e.g., poor fertilizer response; low natural food production and slow growth of culture species; probable fish kills). (ii) Land elevation and tidal characteristics; preferably moderate at 2-3 m. (Sites where tidal fluctuation is large, say 4 m, are not suitable because they would require very large, expensive dikes to prevent flooding during high tide. On the other hand, areas with slight tidal fluctuation; say 1 m or less, could not be drained or filled properly.) (iii) Vegetation; preferably without big tree stumps and thick vegetation which entail large expense for clearing; areas near river banks and those at coastal shores exposed to wave action require a buffer zone with substantial growths of mangrove. (The presence of Avicennia indicates productive soil; nipa and trees with high tannin content indicate low pH.) (iv) Water supply and quality: with steady supply of both fresh and brackish water in adequate quantities throughout the year; water supply should be pollution-free and with a pH of 7.8-8.5. (v) Accessibility: preferably readily accessible by land/water transport; close to sources of inputs, and ice plants; and linked by communication facilities to major centres. (vi) Availability of manpower for construction and operation.4.3.3 Pond Layout The layout of the pond system depends on the species for culture and on the size and shape of the area, which in turn determines the number and sizes of ponds and the position of the water canals and gates. A fish farm is considered properly planned if all the water control structures, canals, and the different pond compartments mutually complement each other (SCSP, 1982a). A complete fish farm has nursery and grow-out ponds and, in some instances, transition ponds for intermediate-sized fish/shrimp, all of which are properly proportioned and positioned within (Fig. 1). Milkfish culture in brackishwater ponds in the Philippines follows the traditional practice of providing for nursery, transition, and rearing operations. In some cases, formation ponds are used for additional growth or stunting of fingerlings prior to stocking in rearing ponds (Fig. 2). The nursery ponds comprise about 1-4% of the total production area while the transition and formation ponds constitute about 6-9% of total area (Camacho and Lagua, 1988). It has been suggested that a similar progressive culture scheme be adopted for shrimp pond culture when no supplementary feeding is practised. For growing to larger sizes, a three-stage progression composed of nursery, transition, and rearing ponds is recommended (Fig. 4) (ASEAN/SCSP, 1978). Fig. 1. Layout of conventional pond system for milkfish culture (from Camacho and Lagua, 1988). Fig. 2. Modular pond system for milkfish culture (from Camacho and Lagua, 1988). Fig. 3. Pond layout with one nursery pond and three rearing ponds (from Camacho and Lagua, 1988). Fig. 2. Modular pond system for milkfish culture (from Camacho and Lagua, 1988). Fig. 3. Pond layout with one nursery pond and three rearing ponds (from Camacho and Lagua, 1988). ASEAN/SCSP, 1978). Fig. 4. Pond layout with one nursery pond, one transition pond, and one rearing pond (ASEAN/SCSP, 1978). In general, however, shrimp monoculture uses direct stocking of post larvae in rearing ponds and therefore requires only one type of pond with separate inlets and outlets for better circulation and aeration.4.3.4 Design of Pond Facilities A fish pond system consists of the following basic components (Fig. 5): (i) pond compartments: and (iii) gates or water control structures to regulate entry and exit of water into and from the pond compartments. Pond compartments are usually rectangular in shape although in Indonesia, running water ponds are generally triangular, raceway-shaped, or oval. They vary in size from less than a hectare to several hectares each, sometimes up to 20-50 ha in size. However, with the new intensive methods, the trend is to use smaller units for flexibility and ease of management. The separated from each other by partition dikes. The outer perimeter dike is usually wider and higher than the inner partition dikes are narrower and shorter. The design of the dikes depends primarily on soil characteristics. Dikes are usually earthen although intensive shrimp ponds are concrete-lined or brick-lined as in Taiwan (PC). The side slopes are designed for structural stability, the ratio of horizontal length to height ranging from 1:1 to 1:3 (Fig. 6). The height and width of dikes depend on the type (primary, secondary, or tertiary), tide conditions , pond water depth, soil shrinkage, and freeboard (SCSP, 1982a). The following slopes are recommended for dikes built with good clay soil: - 2:1 when dike height is less than 4.26 m and tidal range is greater than 1 m; and - 1:2 when tidal range is 1 m or less, and dike height is less than 1m. The dike crown should not be less than 0.5 m and the main dike surrounding the farm should be 0.5 m above the highest dike or flood level recorded in the locality (ASEAN/SCSP, 1978). Fig. 5. Pond layout showing shrimp pond compartments, canals, and gates. Fig. 6. Typical cross sections of dikes. (A) Fig. 6. Typical cross sections of dikes. (B) Water conveyance structures (canals/channels) supply new water into the pond and drain out old water. They also provide the facility for holding and harvesting of fish and of serving as waterways for transporting farm supplies. have separate supply and drainage canals. Canals which are to be used for harvesting should be 30 cm below the level of the pond bottom to allow draining of pond water. Having separate water intake and discharge canals in a pond complex brings about the following advantages (ASEAN/SCSP, 1978): (i) Better filling and non-contamination of pond by discharge from other ponds. (ii) Greatly reduced possibility of spread of disease. (iii) Maintenance of constant head in intake canal thus reducing leaching of acids into the ponds from dikes with acid-sulphate soils. (iv) Absence of conflict of usage between farmers. (v) Better water exchange for individual ponds, and (vi) Possibility of effecting flow-through systems. The width of the canals depends on the amount of water to be held in the ponds. (ii) Time requirement for filling or draining the pond. (iii) Amount of rainfall which must be carried off in a given period of time. (iv) Elevation of canal bottom in relation to tide. (v) Other uses like transportation, harvesting of milkfish, and holding of broodstock (ASEAN/SCSP, 1978). Diversion canals are constructed where there is much runoff from adjoining areas, to prevent sudden salinity changes and the possible entry of polluted, pesticide-loaded water and/or of silted water into the pond complex (Jamandre and Rabanal, 1975). The entry and exit of water into ponds through the canals is regulated or constructed of reinforced concrete (Fig. 7) or wood (Fig. 8). Reinforced concrete is more expensive but lasts longer. Such a gate has one or multiple (2, 3, 4, etc.) openings depending on the relative size of the pond unit to be served. A recent innovation for a smaller and less expensive main gate is the monk-type gate which uses culverts usually made of concrete hollow blocks (Fig. 9). The SEAFDEC Aquaculture Department has also introduced the open sluice gate made of ferro-cement (Fig. 10) (Corre, 1988). Fig. 7. Main water control gate of reinforced concrete (from Jamandre and Rabanal, 1975). (A) Fig. 7. Main water control gate of reinforced concrete (from Jamandre and Rabanal, 1975). (B) Fig. 7. Main water control gate of reinforced concrete (from Jamandre and Rabanal, 1975). (B) Fig. 7. Main water control gate of reinforced concrete (from Jamandre and Rabanal, 1975). (B) Fig. 7. Main water control gate of reinforced concrete (from Jamandre and Rabanal, 1975). (B) Fig. 7. Main water control gate of reinforced concrete (from Jamandre and Rabanal, 1975). (B) Fig. 7. Main water control gate of reinforced concrete (from Jamandre and Rabanal, 1975). (B) Fig. 7. Main water control gate of reinforced concrete (from Jamandre and Rabanal, 1975). (B) Fig. 7. Main water control gate of reinforced concrete (from Jamandre and Rabanal, 1975). (B) Fig. 7. Main water control gate of reinforced concrete (from Jamandre and Rabanal, 1975). (B) Fig. 7. Main water control gate of reinforced concrete (from Jamandre and Rabanal, 1975). (B) Fig. 7. Main water control gate of reinforced concrete (from Jamandre and Rabanal, 1975). (B) Fig. 7. Main water control gate of reinforced concrete (from Jamandre and Rabanal, 1975). (B) Fig. 7. Main water control gate of reinforced concrete (from Jamandre and Rabanal, 1975). (Concrete (from J gate of reinforced concrete (from Jamandre and Rabanal, 1975). (C) Fig. 8. Diagram of wooden gate (from Jamandre and Rabanal, 1975). (FRONT END VIEW) Fig. 9. Use of culvert pipes as secondary gates (from Jamandre and Rabanal, 1975). (A) Fig. 9. Use of culvert pipes as secondary gates (from Jamandre and Rabanal, 1975). (B) Fig. 9. Use of culvert pipes as secondary gates (from Jamandre and Rabanal, 1975). (C) Fig. 10. Ferrocement culvert developed at the SEAFDEC Aquaculture Department (from Corre. 1988). Secondary gates, which regulate water exchange between the ponds and the canals, are usually made of wood. Pipes or culverts can also be used for smaller ponds such as nursery or fry ponds and transition ponds for milkfish culture. Secondary gates are now usually located toward one end of the partories of the pond compartment to give good turbulence and circulation during the filling and draining. Shrimp ponds are provided with separate supply and drainage gates to effect flow-through water management and facilitate water exchange through supply and drainage canals (NACA, 1986). Inlet and outlet gates are best located at opposite corners of the same pond (ASEAN/SCSP, 1978), across which a diagonal trench, about 5-10 m wide and 0.3-0.5 m deep, extending from inlet to outlet gates is recommended for convenient draining of water (Fig. 11) (Kungvankij et al, 1986). Gates should be located where they are not exposed to strong weather forces and where water of good quality can be allowed to enter the fish pond system. circulation (SCSP, 1982a). During the construction of gates for shrimp ponds a number of requirements should be kept in mind (ASEAN/SCSP, 1978), and the gates should: (i) be durable, water-tight, and made of locally available materials; (ii) have adequate capacity for the amount of water to be taken in or drained; (iii) allow water to be taken in or discharged at the bottom; (iv) have provisions for draining pond surface water; (v) have gate bottom elevation that permits complete draining of pond water; (vi) have place for net installation for harvesting; and (viii) be easy to operate. 4.3.5 Pond Management 4.3.5.1 Pond Preparation 4.3.5.2 Stocking 4.3.5.4 Water Management techniques for finfish and shrimp culture, while varying slightly depending on the specific biological requirements of the culture organism, the type of culture system, and the culture environment (freshwater, brackishwater, and marine), are similar in that they involve the following basic activities: (i) Pond preparation/conditioning. (ii) Stocking. (iii) Feeding and/or fertilization (depending on the culture system used). (iv) Water management. (v) Pond maintenance and (vi) Harvesting. Fig. 11. Layout of improved shrimp pond showing diagonal trench extending from inlet to outlet (from Kungvankij et al., 1986). Variations would consist mainly of differences in application rates of fertilizers, lime, pesticides, and feeds; stocking rates and sizes of stocking material; rate of water change; and harvesting techniques (Table 8). As discussed earlier in Section 4.2, extensively managed systems generally require the least management, with no supplemental feeding and minimal water exchange on account of the low stocking density used. On the other hand, intensively managed ponds require full artificial feeding and substantial water management to ensure optimum culture conditions for the species being reared.4.3.5.1 Pond Preparation Ponds are totally drained and the pond bottoms dried prior to the application of pesticides. Tobacco dust, derris root/rotenone powder, teaseed cake/powder, or Gusathion-A are used to eliminate predators and/or wild species that may eventually compete with the cultured organisms for food and space. Teaseed cake is perhaps the best fish poison to use in brackishwater ponds to selectively kill unwanted fish without damaging the shrimps. On the other hand, rotenone is most effective in fresh water and works better in low-salinity water (ASEAN/SCSP, 1978). Ponds with acid-sulphate soils are repeatedly dried and flushed, i.e., filled and drained to remove the acids formed by pyrite oxidation. Agricultural lime is then applied to correct soil pH and bring it up to at least 6.5. Brackishwater ponds are usually treated by spreading 1.5 t of agricultural lime per ha, followed by another 1.5 worked into the soil. To stimulate and maintain the growth of natural plankton, organic (e.g., chicken manure) or inorganic fertilizer application. Intensively managed ponds or ponds where artificial feeding shall be given, do not need to be fertilized. Extensive ponds may use a mix of fertilization and supplementary feeding. Table 8. Variations in pond management techniques commonly used for differen species Species Stocking Rate Fertilization Feed Type Rate of Water Change Pesticides/Predator Control Reference Type Application Rate MILKFISH (Chanos chanos) 2 000- 5 000/ha 16-20-0 at 15 kg/ha; 45-0-0 at ammonium sulfate 1 t/ha 10 g/m2 Bombeo-Tuburan & Gerochi, 1988 TILAPIA (O. niloticus; O. mossambicus) 5 000- 20 000/ha Chicken manure at 500 kg/ha; Inorganic fertilizers at 50 kg/ha Rice bran, fish meal, ipil-ipil leaf meal Camacho & Lagua, 1988 CATFISH (Clarias botrachus and monocephalus) 60- 300/m2 9 parts trash fish and 1 part rice byproducts When necessary Sirikul et al., 1988 PENAEIDS From as low as 15 000 to as high as 300 000/ha Chicken manure at 1-2 t/ha followed by inorganic fertilizer at 75-150 kg/ha mono-ammonium phosphate (16-20-0) and 25-50 kg/ha of urea (46-0-0) Supplemental feed of rice bran with trash fish, mussels, and clam meat; artificial/formulated diets with 40% CP. 20-30% once every week or every two weeks for low density ponds; 5-20% daily for semi-intensive to intensive ponds Corre, 1988 4.3.5.2 Stocking After the pond is prepared, fish fingerlings, among others. The fingerlings are properly acclimated and conditioned prior to stocking and weak or diseased fish eliminated. Stocking is usually done in the early morning or late afternoon.4.3.5.3 Feeding Fish/shrimp grown in semi-intensive culture ponds are given supplementary and full artificial feeds, respectively, the former to augment the natural food in the pond, the latter to totally replace the natural organisms in the water as a source of nutrition. A wide variety of feed ingredients is used to prepare at the pond site using locally available raw materials like rice or corn bran, copra meal, and rice mill sweepings as a source of nutrition. sources of carbohydrates. These are usually mixed with animal protein like trash fish/fish meal, shrimp heads, and snail meat. Supplemental feeds for tilapia are prepared using 80% rice bran and 20% fish meal, shrimp heads, and snail meat. usually include fresh raw materials like snail/mussel/clam meat or carabao hide and other slaughterhouse leftovers. Commercial feed preparations are also available now in a wide range of brandnames, mostly for semi-intensive and intensive shrimp feeds.) These commercial diets consist of a number of ingredients like fish meal, blood meal, bone meat, and shrimp head meal (to serve as attractant for the shrimp), together with vitamin and mineral premix and carbohydrate sources like rice/corn bran or wheat. The crude protein (CP) content of these shrimp feeds is generally not lower than 30% to satisfy the high animal protein requirement of shrimps, actually estimated to be about 40% during the earlier stages of growth. Commercial feeds usually come in various formulations to match the protein requirement of the culture organism, which as a rule, decreases with age. with starter feeds having the highest CP content of about 40% and finisher feeds on the last month, and grower feeds in between. Some shrimp culturists prefer not to give artificial feeds during the first two weeks of culture when the newly stocked post larvae can subsist on the plankton available in the water. The feeding rate is computed as a percentage of the estimated animal biomass in the pond, with higher rations given when the animals are small and gradually decreasing as they become bigger. The daily feeding rate usually starts at 5% and 10-15% of estimated biomass of fish and shrimps, respectively, and decreases to a low of 2% and 5%, for fish and shrimps, respectively, toward harvest. The daily feed rations are given in equal portions during the course of a day. Freshwater fish like tilapia are usually fed twice a day - early morning and late afternoon. Penaeid shrimps, respectively, from three to four to as often as six to seven times a day. Feeds are broadcast into the water and/or supplied on feeding trays. In semi-intensive and intensive and in submerged into the water after known quantities of feed are put on the surface, to supply feed to the shrimps in the pond as well as to monitor feed consumption and shrimp growth. The feeding tray is lifted two to three hours after the feed was supplied to check how much of it has been consumed and to see if the shrimps are healthy and feeding. Empty feeding trays may indicate that the quantity given is inadequate and may have to be increased. Conversely, full or slightly touched trays indicate excessive feed quantities and/or sluggish shrimps. The feeding ration is subsequently adjusted accordingly to optimize feed utilization. By monitoring the feeding tray, one can get a good indication of the sizes and quantity of shrimps present in the pond without a need for cast-netting or actual sampling, since shrimps are invariably found on the tray when it is lifted out of the water.4.3.5.4 Water Management Water in the pond is kept at certain levels for culture of tilapia, carps, and shrimps; traditional milkfish ponds can do with just 40-60 cm of water. Pond water is not just maintained at a certain depth; its quality must also be kept high to ensure optimal growth of the culture organism. This is particularly important in semi-intensive and intensive culture systems where large amounts of metabolites are continuously excreted into the pond and where excess, unconsumed feeds add to the bottom load and serve to pollute the water is continuously freshened by the entry of new water from the river or water source (through the supply canal) while old water is drained through the outlet/drainage gate and through the drainage canal into the sea or river. A flow-through system of water management that allows the simultaneous entry and exit of water into and out lets for all the ponds, each inlet regulating the flow of water from the supply canal to the pond and each outlet controlling the discharge of water out of the pond into the drainage canal. Both the supply and drain water out of the pond, where water quality tends to get poorer faster as a result of the accumulation of wastes and their subsequent decomposition. Fig. 12. Feeding tray. The regular replenishment of pond water, independent of natural tidal fluctuations, is made possible by the use of pumps which draw water from the source even at low tide. Although there is no hard-and-fast rule as to the rate of water change necessary for medium- to high density aquaculture, semi-intensive culture systems usually change water at the rate of 10% daily for an equivalent total replacement of the culture cycle and bottom, especially toward the latter part of the culture cycle and bottom. when the animals excrete more wastes. Intensive ponds/tanks usually need to provide for aeration facilities/equipment to prevent anoxia that may lead to mass mortalities. Oxygen depletion in high-density ponds results not only from the faster rate of utilization of dissolved oxygen for respiratory activities; it is also caused by the fast rate of decomposition at the pond bottom by aerobic or oxygen-consuming micro-organisms. Paddlewheels or other types of aerators are thus provided in the ponds to effect the infusion/introduction of greater quantities of oxygen into the water and prevent fish/shrimp mortalities. The aerators are usually operated at regular/periodic intervals for certain fixed durations during the day but especially in the early morning hours when the concentration of dissolved oxygen is known to be lowest (as a result of the absence of photosynthetic, oxygen-producing activity in the pond). Toward the end of the culture period when oxygen demand is highest, aeration may have to be provided continuously and not just sporadically as could be done during the initial stages of rearing. At that time too, water pumps usually need to be run for longer periods to effect greater water exchange. Pond water is also regularly sampled and measurements taken of basic/essential parameters, particularly dissolved oxygen, pH, and salinity. This is important for the purpose taken of basic/essential parameters and measurements taken of basic/essential parameters. of determining the need for corrective/remedial action to bring water quality to optimum levels and obtain good yields. Dissolved oxygen levels are kept, as much as possible, above 5 ppm by pumping and aeration. Problems of acidity are corrected by liming. Salinity is an important parameter for penaeid culture and has to be maintained within a range of 15-25 ppt for best results. During summer months, high-salinity water can be diluted by mixing with fresh water from springs or deep wells.4.3.5.5 Pond Maintenance (i) Fertilizers, lime, and pesticides, lime, and pesticides are carried out: regular application of fertilizers, lime, and pesticides are carried out: regular application of fertilizers, lime, and pesticides are carried out: regular application of fertilizers, lime, and pesticides are carried out: regular application of fertilizers, lime, and pesticides are carried out: regular application of fertilizers, lime, and pesticides are carried out: regular application of fertilizers, lime, and pesticides are carried out: regular application of fertilizers, lime, and pesticides are carried out: regular application of fertilizers, lime, and pesticides are carried out: regular application of fertilizers, lime, and pesticides are carried out: regular application of fertilizers, lime, and pesticides are carried out: regular application of fertilizers, lime, and pesticides are carried out: regular application of fertilizers, lime, and pesticides are carried out: regular application of fertilizers, lime, and pesticides are carried out: regular application of fertilizers, lime, and pesticides are carried out: regular application of fertilizers, lime, and pesticides are carried out: regular application of fertilizers, lime, and pesticides are carried out: regular application of fertilizers, lime, and pesticides are carried out: regular application of fertilizers, lime, and pesticides are carried out: regular application of fertilizers, lime, and pesticides are carried out: regular application of fertilizers, lime, and pesticides are carried out: regular application of fertilizers, lime, and pesticides are carried out: regular application of fertilizers, lime, and pesticides are carried out: regular application of fertilizers, lime, and pesticides are carried out: regular application of fertilizers, lime, and pesticides are carried out: regular application prevention of entry of predators; monitoring of the stock for growth rate determination as a basis of feeds and water management; and regularly using either organic fertilizers like chicken, cow, or pig manure, or inorganic fertilizers like urea, ammonium phosphate, or both, to maintain the plankton population in the pond. The fertilizers are either broadcast over the pond water surface or kept in sacks suspended from poles staked at certain portions along the pond periphery. Semi-intensive culture systems do not require fertilization since they are not natural food-based, except for those which grow plankton feeders like milkfish whose diet is largely algae dependent. (ii) Liming In addition to fertilization, ponds also need to be given regular doses of lime to maintain water pH at alkaline or near-alkaline levels (preferably not lower than six). Agricultural lime is broadcast over the pond and applied on the sides of the dikes to correct soil and water acidity not lower than six). (iii) Elimination of Pests and Predators Unwanted and predatory species which may have survived the application of pesticides, preferably organic, into the pond. Crabs, which are a serious problem in shrimp ponds because they are carnivorous and cause damage to the pond dikes, are not usually affected by known pesticides and are therefore best eliminated by the use of crab traps situated in the pond. It is also important that the gates are properly screened and the screens kept whole, to prevent the entry of small unwanted fish into the pond. Double screens are usually installed at the main intake to ensure that pests and predators are prevented from entering the pond system. (iv) Stock Monitoring The culture organisms are monitored closely and regularly to determine their rate of growth and the general condition of the stock. They are regularly sampled for lengthweight measurements as a basis for determining/estimating their biomass in the pond and therefore their daily feed rations, as well as for making projections on harvest schedules and procurement of pond inputs. In the first few months of culture, the feeding tray is a good tool for stock monitoring, as explained in Section 4.3.5.3. As the organisms grow in size, cast-netting is used as a sampling tool, with those caught in the throw of the cast net providing an indication as to sizes and weights of stock. Based on the sampled weights and the daily feed consumption, it is possible to predict the available biomass (i.e., stock surviving after initial mortalities) and make projections on volume of harvest For this purpose, it is essential that accurate records are kept for analysis at a later time. Data on initial size/weight and number of fry/post larvae stocked, average body weight at each sampling, and feed consumption on a daily basis, are important to have on file. (v) Regular Upkeep and Maintenance of Facilities The pond dike and gates are checked regularly for cracks that could lead to seepages and losses of stock. The dikes are best planted with grass or vegetative cover to prevent erosion. The gates and other support infrastructure are properly maintained for efficient operation. 4.3.5.6 Harvesting Marketable-size fish/shrimps are harvested at the end of the culture period by draining the pond and using harvesting nets to catch the fish or shrimps. The latter are harvested with a bag-net attached to the sluice gate as water is drained to half-level the night before. Harvest of milkfish takes advantage of their behaviour of swimming against the current. The method, known in the Philippines as "pasulang" or "pasubang" involves draining 85-90% of the pond water during low tide and allowing in the water at the incoming high tide so that the fish swim against the current through the tertiary gate and into the catching pond, whose gate is closed once a large number of fish is impounded. The fish in the catching pond are then harvested by seining and the rest hand-picked.4.4 Integrated Fish Farming In a number of countries in Asia (e.g., China, Nepal, Thailand, Malaysia, Indonesia) and in some parts of Africa, freshwater fish culture is integrated with the farming of crops, mainly rice, vegetables and animals (usually pigs, ducks, and chickens). This leads to greater overall efficiency of the farming system as wastes/by-products or one component are used as inputs in another. For example, poultry or pig manure can be the fish and the vegetables can be fed to the fish and the vegetables can be fed to the fish and the vegetables can be fed to the fish and the vegetable garden and the vegetables can be fed to the fish and the pigs (Fig. 13). In Africa, fish culture in rice fields and in combination with pig and duck rearing, is not too widely practised but has significant potential. Reported fish yields ranged from 2 000-4 900 kg/ha/y with poultry in Gabon. It has also been proven economically viable since it involves minimal investment. Its spread has, however been constrained by the widespread use of pesticides in many countries (Satia, 1989). 4.5 Pen and Cage Culture 4.5.1 Culture Species 4.5.2 Site Selection 4.5.3 Design and Construction 4.5.4 Pen and Cage Culture 4.5.1 Culture Species 4.5.2 Site Selection 4.5.4 Pen and Cage Culture 4.5.1 Culture Species 4.5.2 Site Selection 4.5.3 Design and Construction 4.5.4 Pen and Cage Culture 4.5.1 Culture Species 4.5.2 Site Selection 4.5.3 Design and Construction 4.5.4 Pen and Cage Culture 4.5.1 Culture Species 4.5.2 Site Selection 4.5.3 Design and Construction 4.5.4 Pen and Cage Culture 4.5.1 Culture Species 4.5.2 Site Selection 4.5.3 Design and Construction 4.5.4 Pen and Cage Culture 4.5.1 Culture Species 4.5.2 Site Selection 4.5.3 Design and Construction 4.5.4 Pen and Cage Culture 4.5.1 Culture Species 4.5.2 Site Selection 4.5.3 Design and Construction 4.5.4 Pen and Cage Culture 4.5.1 Culture Species 4.5.2 Site Selection 4.5.3 Design and Construction 4.5.4 Pen and Cage Culture 4.5.4 Pen and Cage Culture 4.5.1 Culture Species 4.5.2 Site Selection 4.5.4 Pen and Cage Culture 4.5.4 Pen and Cage Cult wood, or metal, and set in sheltered, shallow portions of lakes, bays, rivers, and estuaries. Compared to fish pond culture with its 4 000-year tradition, fish pen/cage culture is of more recent origin. Cage culture seems to have developed independently in at least two countries - in Kampuchea where fishermen in and around the Great Lake region would keep Clarias spp. and other commercial fishes in bamboo or rattan cages and baskets; and in Indonesia where bamboo cages have been used to grow Leptobarbus hoeveni fry as early as 1922. Since then, cage culture has spread throughout the world to more than 35 countries in Europe, Asia, Africa, and the Americas (Beveridge, 1984). Fig. 13 Diagram showing interrelationships among the various components of an integrated fishfarming system. Pen culture is said to have originated in the 1950s for rearing carps in freshwater lakes (Beveridge, 1984), and introduced to culture milkfish in the shallow, freshwater, eutrophic Laguna de Bay in the Philippines in the 1970s (Baguilat, 1979). From there it has been successfully extended for the culture of tilapia and carps (Rabanal, 1988b). Its development and adoption as a popular technology has not been widespread, though, perhaps because of its site-specific requirements like its suitability mainly in shallow lentic environments. At present, it is commercially practised only in the Philippines, Indonesia, and China (Beveridge, 1984). The wider popularity of cage culture as compared to pen culture may be due to its greater flexibility in terms of siting the structures. For example, cages may be installed in bays, lagoons, straits and open coasts as long as they are protected from strong monsoonal winds and rough seas. Floating cages can also be set up in deep mining pools which could not be used otherwise for culture due to harvesting difficulties (Chua, 1979 and Gargantiel, 1982). In general, however, both pen and cage culture have expanded rapidly, especially over the past two decades vis-a-vis the decreasing availability of land-based resources for fish culture, such as: (i) their applicability in different types of open water bodies like coastal waters, protected coves and bays, lakes, rivers, and reservoirs; (ii) their high productivity (of as much as 10-20 times that of ponds Of comparative sizes) with minimal inputs and at lower costs to develop and operate; and (iii) the greater socio-economic opportunities they provide to low-income families in the rural areas, particularly those displaced by the reduction of fish catches in over-exploited coastal, municipal waters, because they require comparatively low capital outlay and use simple technology. Yields from fish productivity of the water body. In the Philippines, for example, the yields of milkfish from fish productives in over-exploited coastal, municipal waters because they require comparatively low capital outlay and use simple technology. in Laguna de Bay were as high as 4 t/ha/crop (compared to a national milkfish fish pond average of 1 t/ha/y in 1980 when the productivity of the lake was very high at 1 700 mg C/m3/hr (Baluyut, 1983). In Indonesia, the cage culture of common carp in the Lido Reservoir in Cigombong gave a total production of 28 kg/m2 at a stocking density of 6 kg/m2 (Baluyut, 1983). The cage culture of marine finfishes has likewise been shown to give high yields (Table 9).4.5.1 Culture Species The choice of species for stocking and rearing in pens and cages is governed by much the same criteria as in species for stocking and rearing in pens and cages is governed by much the same criteria as in species selection for pond culture, including (Guerrero, 1982): (i) fast growth in confinement; (ii) good consumer acceptance; (iii) high tolerance to a wide range of environmental conditions; (iv) resistance to disease; (v) ready supply of fish seed for stocking; and (vi) ease of culture and management. Table 9. Comparison of production of cage-cultured marine fish Species Seriola T: quinqueradiata Trachinotus carolinus Polydactylus sexfilis Epinephelus salmoides* Country of culture Japan Florida, USA Hawaii, USA Penang, Malaysia Initial stocking density fish/m3 10 250 50 60 kg/m3 0.15-0.55 1.75 0.4 3.4 Rearing period (days) 225 273 300 240 Production (kg/m3) 0.85-14.45 44.7 - 41.4 Average production rate (kg/m3/day) 0.004-0.06 0.16 - 0.17 Mean size of fish Initial (g) 10-50 7 9 55.7 At harvest (g) 1 000-2 000 213.6 300 795.9 Average growth rate (g/fish/day) 4.40-8.67 0.76 0.97 3.08 *Based on existing commercial culture. Source: SEAFDEC/IDRC, 1979 There are approximately ten species of fish which are commercial culture. Source: SEAFDEC/IDRC, 1979 There are approximately ten species of fish which are commercial culture. carps (Chinese, Indian, and common varieties); milkfish; snakeheads and catfishes; marble goby; and salmonids (rainbow trout, salmon). Marine species include mainly grouper, sea bass, mullet, snapper, and milkfish (Chanos chanos); tilapia; and the Chinese carps: bighead (Aristichthys nobilis), silver carp (Hypophthalmichthys molitrix), grass carp (Ctenophanyngodon idella); and common carp (Cyprinus carpio). Other species have been suggested as possible candidates for utilization in pen/cage culture in the following three different environments (SEAFDEC/IDRC, 1979): (i) Freshwater Habitats with high natural productivity (e.g., lakes, oxbow lakes, swamps, mining pools, rivers, and reservoirs): mullets, eels, catfish, Puntius gonionotus. Habitats with low natural productivity: Leptobarbus, Clarias batrachus, Oxyeleotris, and Macrobrachium. (ii) Brackishwater Sea bass, mullet, siganids, sea bream, grouper, snapper, threadfin, carangids. Hilsa spp., Sparus spp., and eels. (iii) Marine Siganids, pampano, yellowtail, tuna, grouper, sea bass, sea bream, carangids, pomfret.4.5.2 Site Selection The selection of sites for fish pen/cage culture should be guided by the following basic criteria (Felix, 1982; Mane, 1982; and Chua, 1979): Table 10. Commercially important species in inland water cage and pen farming Species Countries Climate Type of feeding Lotic/Lentic Cage/Pen Salmonids Rainbow trout Europe, North America, Japan, high altitude tropics (eg Colombia, Bolivia, Papua New Guinea) Temperate Intensive. High protein (40%) Lentic Floating cage Salmon (various species) smolts Europe, North America, South America, Japan Temperate Intensive, High protein (452) Lentic Floating cage Carps (Silver carp, grass carp, bighead carp) Asia, Europe, North America Temperate -tropical Mainly semi-intensive, although also extensive (Asia) and intensive (Europe North America) Lotic and lentic Cages and pens Indian major carps (Labeo rohita) Asia Sub-tropical -tropical Semi-intensive Mainly lentic Mainly cages Common carp Asia, Europe, North America, South A semi-intensive, although also intensive Mainly lentic Mainly cages Catfishes Channel catfish North America Temperature -sub-tropical Intensive Lotic and lentic Floating cages Snakeheads Channa spp. Southeast Asia, Africa Tropical Semi-intensive/intensive/intensive Lotic and lentic Floating cages Pangasius spp. Southeast Asia Tropical Semi-intensive Lentic Floating cages Milkfish Southeast Asia Tropical Semi-intensive Lentic Floating cages (ii) Good water quality (high or adequate dissolved oxygen, stable pH, and low turbidity, and absence of pollution). (iv) Firm bottom mud to allow pen framework to be driven deep into substrate for better support. (v) Freedom from predators and natural hazards. (vi) Accessibility to sources of inputs, including labour and markets, and (vii) Good peace and order condition. The factors to be considered in selecting sites for pens and cages in freshwater, brackishwater, and marine environments are shown in Table 11. It is important to note that the selection of a suitable site is vital to the success of the culture system; a good site selected solves much of the management problems of pen/cage culture (Chua, 1979).4.5.3 Design and Construction Both fish pens and fish cages are built around the same basic design concept: a net enclosure supported by a rigid framework. They differ, however, in a number of respects. Firstly, a pen does not have a net bottom; the edges of its net wallings/fencings are built around the same basic design concept: a net enclosure supported by means of bamboo pegs and the lake bottom is the pen bottom (Fig. 14). In comparison, a cage is like an inverted mosquito net with the cage bottom made of the same netting material used for its four sides (Fig. 15). Secondly, fish pens theoretically have no limit to their size/area while cages cannot exceed 1 000 m2 in area for reasons of the quantity of material required for cage construction (due to the need for a flooring) and manageability of operation (cages have to be lifted and the fish scooped out and not harvested using nets as in pens). Thirdly, design of the structures and methods of construction are different. Fish pens are fixed structures; fish cages may either be fixed or floating. Fish pens for milkfish culture in Laguna de Bay, Philippines consist of a nursery pen within the grow-out; they are, however, usually installed in clusters or modules with a common framework (Fig. 17). Pens and cages come in various shapes and are made of different types of materials. Most pens and cages are rectangular or square although some may be circular, as in some milkfish pens in Laguna de Bay and the milkfish pens ind Rectangular cages are preferred for easy operation and management. Circular cages are more suitable for some species like milkfish and yellowtail but are more expensive to build (SEAFDEC/IDRC, 1979). Table 11. Factors to be considered in the selection of cage/pen sites Marine Brackishwater Protection from Elements Natural Wind direction Water current Wind direction Lagoons, bays and coves offer Erosion and Water currents Currents Currents Currents Currents Tidal levels Stratification and up-welling Net pen spacing Well-spaced Well-spaced Well-spaced Water Quality and Soil Type of bottom PH, NH3, BOD, hardness Pesticides and fertilizer run-off Saltwater intrusion Tidal fluctuation Tidal fluctuation Depth fluctuation Topography Topography Topography Topography Topography Topography Topography Floating objects and competitors Plankton bloom Vegetation Diseases and parasites Diseases and parasites Diseases and parasites Natural productivity Pollutants Industrial pollutants Industrial pollutants Industrial pollutants Agricultural pollutants Agricultural pollutants Agricultural pollutants Agricultural pollutants Industrial pollutants Agricultural pollutants Agricultural pollutants Industrial pollutants Industrial pollutants Agricultural pollutants Agricultural pollutants Agricultural pollutants Fingerlings Fingerlings Fingerlings Markets (live and fresh sales) Close to market Close to market Close to market Labor Availability Availability Availability Availability Find interference of all sorts. Others Frequency of navigation Frequency of navigation Frequency of navigation Property rights, policies and laws Pro fishpen wall showing how it is anchored on the lake bottom. (B) Fig. 15. Perspective view and parts of a floating cage. (A) Fig. 15. Perspective view and parts of a floating cage. (B) Fig. 16. Perspective view and parts of a floating cage. (C) Fig. 17. Cluster/module of fish cages. Fig. 18. Circular milkfish broodstock cage used at the SEAFDEC Aquaculture Department (from Yu et al, 1979). Fig. 19. Cylindrical fish cage made of bamboo and rattan (from Watson and Tingang Raja, 1979). For your of the several countries. The framework structure is generally made out of bamboo and other locally available wood. Cage floatation materials include bamboo, PVC pipes/containers, steel or plastic drums, styrofoam, and aluminum floats. The type of anchor for floating cages varies depending on the depth of water, nature of bottom, tides, and currents. Concrete slabs of different sizes and shapes, sand bags, and iron anchors are widely used in different countries (Fig. 20).4.5.4 Pen and Cage Operation Basic procedures involved in the management of pen and cage culture are very much like those in pond culture, starting with completion of construction and preparation of the culture facilities for stocking, rearing, and harvesting. Slight variations in specific activities exist, however, as the result of the very nature of the system. For example, it is obviously not possible to apply fertilizers, lime, and pesticides since the system has open water exchange between the inner compartment and the outside environment. fry/fingerlings for stocking. Milkfish pens have a nursery compartment into which milkfish fry are grown for 3-4 weeks to 12 cm long fingerlings which can be released into the grow-out compartment. The nursery pen and the grow-out compartment are prepared for stocking by clearing the bottom of predatory fish like Megalops cyprinoides and Elops hawaiiensis. The milkfish fry/fingerlings from the nursery pen are stocked in the rearing pen at 20 000-50 000 per ha where they are cultured to marketable size. In the Philippines, the milkfish stock in the pen is not generally given supplemental feeding except for occasional rations of bread crumbs, rice bran, broken ice cream cones, fish meal, and ipil-ipil leaf mill. On the other hand, cage-reared fish may or may not be fed supplemental or artificial diets depending on the stocking density used and the level of technology in the country. Cage feeding trials in the Philippines showed the adequacy of a ration composed of 77% rice bran and 23% fish meal with feed conversion ratios of 2.2-2.8. Current feed practices in freshwater cage culture involve the provision of supplemental feeds using readily available ingredients like rice bran and poultry feeds. Other countries use artificial feeds based on simple diets (Table 12) preferably prepared in pelleted form for best results. At the end of the culture period, the fish are harvested from penset from penset in pelleted form for best results. using harvesting nets (e.g., gill nets, cast nets, seines) or from cages by lifting the cage and causing the fish to collect in one corner for scooping out using a pail. Fig. 20. Types of anchor used for floating cages (from SEAFDEC/IDRC, 1979). (A) Fig. 20. Types of anchor used for floating cages (from SEAFDEC/IDRC, 1979). (B) Fig. 20. Types of anchor used for floating cages (from SEAFDEC/IDRC, 1979). (C) Fig. 20. Types of anchor used for floating cages (from SEAFDEC/IDRC, 1979). (C) Fig. 20. Types of anchor used for floating cages (from SEAFDEC/IDRC, 1979). (C) Fig. 20. Types of anchor used for floating cages (from SEAFDEC/IDRC, 1979). (C) Fig. 20. Types of anchor used for floating cages (from SEAFDEC/IDRC, 1979). (C) Fig. 20. Types of anchor used for floating cages (from SEAFDEC/IDRC, 1979). (C) Fig. 20. Types of anchor used for floating cages (from SEAFDEC/IDRC, 1979). (C) Fig. 20. Types of anchor used for floating cages (from SEAFDEC/IDRC, 1979). (C) Fig. 20. Types of anchor used for floating cages (from SEAFDEC/IDRC, 1979). (C) Fig. 20. Types of anchor used for floating cages (from SEAFDEC/IDRC, 1979). (C) Fig. 20. Types of anchor used for floating cages (from SEAFDEC/IDRC, 1979). (C) Fig. 20. Types of anchor used for floating cages (from SEAFDEC/IDRC, 1979). (C) Fig. 20. Types of anchor used for floating cages (from SEAFDEC/IDRC, 1979). (C) Fig. 20. Types of anchor used for floating cages (from SEAFDEC/IDRC, 1979). (C) Fig. 20. Types of anchor used for floating cages (from SEAFDEC/IDRC, 1979). (C) Fig. 20. Types of anchor used for floating cages (from SEAFDEC/IDRC, 1979). (C) Fig. 20. Types of anchor used for floating cages (from SEAFDEC/IDRC, 1979). (C) Fig. 20. Types of anchor used for floating cages (from SEAFDEC/IDRC, 1979). (C) Fig. 20. Types of anchor used for floating cages (from SEAFDEC/IDRC, 1979). (C) Fig. 20. Types of anchor used for floating cages (from SEAFDEC/IDRC, 1979). (C) Fig. 20. Types of anchor used for floating cages (from SEAFDEC/IDRC, 1979). (C) Fig. 20. Types (from SEAFDEC/IDRC, 1 used for floating cages (from SEAFDEC/IDRC, 1979). (C) Fig. 20. Types of anchor used for floating cages (from SEAFDEC/IDRC, 1979). (E) Table 12. Feed types given to cage-reared fish Country Culture Species Feed Type Reference GDR Common carp Formulated feed/pellets, 33.7% CP Muller, 1979 USSR Common carp Mixture of minced trash fish, molluscs, crayfish, and grown cereals - do - Hungary Wels (Silurens glanis) Trash fish, slaughterhouse wastes, cereal grain meals - do - do- Carp polyculture (common, silver, bighead) Pelleted common carp feed India Indian carp polyculture Soya bean powder, ground nut, oil cake, rice polish (1:1.1) Natarajan et al., 1979 Indonesia Leptobarbus hoeveni and Thynnichthys thynoides Coconut water, cassava, rubber leaves Reksalegora, 1979 Indonesia S. niloticus Aquatic plants (Lemna, Hydrila, Chara) Rifai, 1979 Nepal Common carp Wheat flour, rice bran, mustard oil cake Sharma, 1979 Thailand Catfish, sand goby, common carp, local carp, tilapia, snakehead Pellets consisting of ground fish meal, soy bean, peanut, and rice bran Tangtrongpiros, 1979 4.6 Open Water Culture 4.6.1 Mollusc Culture 4.6.2 Seaweed Farming The farming of molluscs and seaweeds in open marine waters has become increasingly popular in a number of countries, especially in the Third World where it is seen as a viable alternative to municipal or artisanal fisheries or as a means of supplementary income for small-scale fishermen. Because seafarming is generally low-cost and labour-intensive and could thus involve entire coastal communities, it is particularly appropriate in areas where production from municipal fisheries has substantially declined and where, as a result, subsistence fishermen have little or no means of livelihood. 4.6.1 Mollusc Culture Bivalves are widely cultured in a number of countries world-wide. In Asia and the Pacific, they represent a high quality food resource with annual production higher than from crustacean culture on a per hectare basis (Sitov, 1988). In 1984, molluscs accounted for approximately 35% of the total production of coastal aguaculture in terms of gross weight in the region (Shang, 1986). The most important species for culture in Southeast Asia are the ovsters (mainly Crassostrea spp.), mussels (mainly Perna spp.), clams, cockles, and scallops (Pagcatipunan, 1987; Sitoy, 1988; Cheong, 1988; Liong et al., 1988). In Japan, the most commonly cultured species include Crassostrea gigas, C. rivularis, C. nippona, C. echinata, and Ostrea denseramellosa, with C. gigas as the predominant species (Honma, 1980). In Africa, the culture of Venerupis is reported in Tunisia and Pinctada spp. in Sudan (Shehedah, 1975). In Mexico, the culture of the large oyster Crassostrea spp. is carried out by cooperative societies and of the mussel Mytilus edulis on floating rafts by private investors. Oysters are widely distributed in estuaries and bays which receive some run-off from land and have somewhat lower salinity than the open sea. As they filter their food from the water, they grow best in areas with moderate to high concentrations of phytoplankton (SCSP, 1982c). Oysters grow best in intertidal areas where they are exposed for some minutes or a few hours during low tide (Pagcatipunan, 1987). Mussels, on the other hand, cannot tolerate tidal exposure even during low tide. The best sites for culturing molluscs are therefore those that meet their biological requirements, including the following: (i) Water depth of 1-10 m, and (iii) Muddy bottom for mussels and hard rocky or coralline substrates for oysters. In addition, the area for mollusc culture depth of 1-10 m, and (iii) Muddy bottom for mussels and hard rocky or coralline substrates for oysters. should be protected from strong water currents reaching three knots and should be accessible to source of seed, transport, and markets. Furthermore, the presence of local available stock in an area is a good indicator of its suitability for mollusc culture. Countries which have successfully cultured bivalve molluscs have developed their own systems of culture which depend entirely on natural seed stock, which are either gathered from natural seed beds or collected using suitable materials for collection. However, since natural ropes, which have been found to attract more

larvae than synthetic polyethylene or polypropylene ropes, do not last long, natural fibrous materials like coconut coir are sometimes interwoven with synthetic nylon ropes to make them more attractive to the larvae (Yap et al., 1979; Sitoy et al., 1983). The string seed collectors are submerged in the sea water for seed collection at the right time They are hung on a collector rack, normally 12 strings along a distance of 1.8 m to hold about 1 000 shells. Sometimes, strings are put together for hanging to prevent branches from attaching to strings when they occur in large quantities (Fig. 21) (Honma, 1980) Three principal methods of oyster culture are used in the Philippines and Japan: (i) hanging method (SCSP, 1982c; Honma, 1980). In Japan, the earliest method used at the Hiroshima Prefecture, where oyster culture began in the 17th century, was the stick culture method. In 1927, the simple hanging method, raft method, and longline method, to suit different variations, viz., the simple hanging method, raft method, and longline method, to suit different variations, viz., the simple hanging method of culture was introduced which later developed into different variations, viz., the simple hanging method, raft m broadcast system is actually used throughout the world in places where the bottom of shallow bays is firm enough to support the materials used as collectors and for growing oysters. Oyster shells, stones, or other hard objects are scattered on the bottom in areas where setting or the attachment of oyster larvae is known to occur. The young oysters or spat are left in places attached to the collectors until they are large enough for harvest (SCSP, 1982c). The stake method is usually applied in shallow areas with soft or muddy bottom, usually not more than 1 m deep during low tide. The stakes, usually applied in shallow areas with soft or muddy bottom, usually applied in shallow areas with soft or muddy bottom. similar materials are staked on the sea bottom in rows spaced about 0.5 m apart, to serve as attachment for oyster shells or other material such as coconut shells as collectors. The collectors are strung on synthetic twine or heavy monofilament nylon, and placed about 10 cm apart by using bamboo tubes as spacers or by tying knots in the twine. The strings are hung from a platform or rack/tray made of bamboo or wooden splits or welded wire with wooden frame, and placed on the trays until they are big enough for the market (SCSP, 1982c; Pagcatipunan, 1987). Fig. 21. String seed collectors for mollusc spat (from Honma, 1980). Harvesting procedures vary with the culture method. Oysters grown on stakes or by hanging are removed from the stakes or by hanging are removed grown by broadcasting are usually collected at low tide (SCSP, 1982c). Mussel farming makes extensive use of bamboos either as stakes or as floating rafts. The mussels are harvested by divers after 6-10 months when they reach a length of 5-8 cm. Alternatively, mussels are harvested by divers after 6-10 months when they reach a length of 5-8 cm. Alternatively, mussels are harvested by divers after 6-10 months when they reach a length of 5-8 cm. Alternatively, mussels are harvested by divers after 6-10 months when they reach a length of 5-8 cm. Alternatively, mussels are harvested by divers after 6-10 months when they reach a length of 5-8 cm. Alternatively, mussels are harvested by divers after 6-10 months when they reach a length of 5-8 cm. Alternatively, mussels are harvested by divers after 6-10 months when they reach a length of 5-8 cm. Alternatively, mussels are harvested by divers after 6-10 months when they reach a length of 5-8 cm. Alternatively, mussels are harvested by divers after 6-10 months when they reach a length of 5-8 cm. Alternatively, mussels are harvested by divers after 6-10 months when they reach a length of 5-8 cm. Alternatively, mussels are harvested by divers after 6-10 months when they reach a length of 5-8 cm. Alternatively, mussels are harvested by divers after 6-10 months when they reach a length of 5-8 cm. Alternatively, mussels are harvested by divers after 6-10 months when they reach a length of 5-8 cm. Alternatively, mussels are harvested by divers after 6-10 months when they reach a length of 5-8 cm. Alternatively, mussels are harvested by divers after 6-10 months when they reach a length of 5-8 cm. Alternatively, mussels are harvested by divers after 6-10 months when they reach a length of 5-8 cm. Alternatively, mussels are harvested by divers after 6-10 months when they reach a length of 5-8 cm. Alternatively, mussels are harvested by divers after 6-10 months when they reach a length of 5-8 cm. Alternatively, mussels are harvested by divers after 6-10 months when they reach a are grown on floating rafts (Fig. 22) which have the following advantages: (i) faster growth; (ii) possibility of regular thinning and therefore higher production using more durable materials (Sitoy, 1988). Mussels and oysters grown in waters contaminated by domestic and industrial wastes need to undergo depuration or cleansing, using artificially cleaned water or clean seawater from saltwater wells, to ensure satisfactory microbiological and chemical quality of the product. The depuration process flow and schematic diagram of a shellfish purification plant are shown in Figure 23.4.6.2 Seaweed Farming Seaweeds, aside from being used as food, are important sources of colloids or gels, such as agar, as well as minerals of medicinal important industrial compound used in stabilizing and improving the quality of a great number of products. Caulerpa lentillifera, a green algae, is economically important because it is a favourite and nutritious salad dish containing essential trace minerals such as calcium, potassium, magnesium, sodium, copper, iron and zinc. It is also known for its medicinal properties, being used as an anti-fungal agent and as a natural means for lowering blood pressure Gracilaria, another red alga, is economically important in Taiwan (PC) for its agar extracts. The culture of the seaweed Porphyra is believed to have started as early as between 1596 and 1614 in Hiroshima Bay utilizing pole and net devices originally installed to catch fish. At present, commercial seaweed culture is limited to five countries in East Asia, viz., Japan and Korea (which both grow mainly Porphyra, Undaria and Laminaria), China (Porphyra and Laminaria), Taiwan (PC) (Gracilaria and Porphyra), and the Philippines (Eucheuma spinosium, E. cottonii and Caulerpa lentillifera). which only three out of the 31 species are green algae (Table 13) (Trono, 1986). In 1988, the estimated world seaweeds, of which nearly 66% was supplied by the Philippines and the rest by Indonesia, Chile and Canada. The bulk of the Philippine seaweed production consists of Eucheuma produced mainly in the southern part of the country in reef-protected coastal areas. Caulerpa is also successfully farmed in seawater ponds in Mactan, Cebu (Trono, 1986). Fig. 22. Diagram of a mussel raft unit (from SCSP, 1982c). Table 13. Species under cultivation in the Asia-Pacific region Seaweed Groups/Species Country Where Cultivated A. Green Seaweeds (Chlorophyta) Caulerpa lentillifera J. Agardh Philippines Japan Enteromorpha sp. Japan Eisenia sp. Japan Heterochoradaria sp. Japan Hizikia sp. Japan Korea, Republic of Laminaria japonica Areschoug Japan L. japonica China Korea, Republic of Macrocystis sp. Japan Nemacystus sp. Japa (Yendo) Okamura Japan C. Bed Seaweeds (Rhodophyta) Eucheuma alvarezii Doty Philippines E. denticulatum (Burman) Collins et Harvey Taiwan, Pr. of China Japan Gloiopeltis sp. Jap China G. lichenoides (L.) Harvey Taiwan, Pr. of China P. haitanensis Chang et Zhang Baofu China P. tenera Kjellman Taiwan, Pr. of China P. haitanensis Chang et Zhang Baofu China P. tenera Kjellman Taiwan, Pr. of China P. tenera Kjellman Taiwan, Pr. of China P. tenera Kjellman Korea, Republic of P. tenera Kjellman Taiwan, Pr. of China P. tenera Kjellman Taiwan, Pr. of China P. tenera Kjellman Korea, Republic of P. tenera Kjellman Taiwan, Pr. of China P. tenera Kjellman Korea, Republic of P. tenera Kjellman Taiwan, Pr. of China P. tenera Kjellman Korea, Republic of P. tenera Kjellman Taiwan, Pr. of China P. tenera Kjellman Taiwan, Pr. of Ch Ueda Japan P. quangdongensis Tseng et T.J. Chang Korea, Republic of China Source: Trono, 1986 In Taiwan (PC), Gracilaria is cultured in ponds for milkfish, with Pingtung County alone accounting for 110 ha of the total 400 ha of Gracilaria ponds in Taiwan (PC) in 1974 and producing 1 000 t of dried Gracilaria seaweed. In Japan, indoor facilities are used to obtain buds/seedlings for on-growing at sea. The facilities consist of 70-80 cm deep square or rectangular concrete tanks provided with illumination, a temperature control system, and ventilation (Mito and Fukuhara, 1988). The successful cultivation of seaweeds depends on four important factors (Velasco, 1988): (i) Type of Seaweeds Used The seaweeds cultured must be healthy and resistant to disease and breakage. They must be able to grow fast and give high amounts of dry matter from which will be extracted high concentrations of carrageenan of high gel strength and viscosity. (ii) Ecological Conditions of the Farm The farm must be well-sited and fulfill the bio-ecological requirements of the culture species in an area is a good indicator of the suitability of that site for culture of the species under consideration. (iii) Access to Sunlight Seaweeds being cultivated need abundant sunlight for photosynthesis. Shading by other seaweeds and plants must be prevented by regular inspection and removal of the unwanted plants. (iv) The Seaweed Farmer is an important factor since the farmer is an important factor since the farmer since the farmer is an important factor since the farmer since the farmer since the farmer is an important factor since the farmer must visit the farm regularly and carry out routine inspections. Some of the farmer is an important factor since the farmer must visit the farmer must visit the farmer must be prevented by regular inspections. chores include shaking off silt and other foreign materials from the seaweeds, repairing broken lines, restoring uprooted stakes, and picking up drifting branches of seaweeds. Trono and Ganzon-Fortes (1988) listed the following criteria for selecting good sites for Eucheuma in open waters and Caulerpa and Gracilaria in seawater ponds: (i) Unpolluted seawater supply. (ii) Salinity of 30-35 ppt Eucheuma and Caulerpa and 8-25 ppt for Gracilaria. (iii) Water temperature of 27-30* C. (iv) Moderate water movement of 20-50 m/min. (v) Water temperature of 27-30* C. (iv) Moderate water movement of 20-50 m/min. (v) Water temperature of 27-30* C. (iv) Moderate water movement of 20-50 m/min. (v) Water temperature of 27-30* C. (iv) Moderate water movement of 20-50 m/min. (v) Water temperature of 27-30* C. (iv) Moderate water movement of 20-50 m/min. (v) Water temperature of 27-30* C. (iv) Moderate water movement of 20-50 m/min. (v) Water temperature of 27-30* C. (iv) Moderate water movement of 20-50 m/min. (v) Water temperature of 27-30* C. (iv) Moderate water movement of 20-50 m/min. (v) Water temperature of 27-30* C. (iv) Moderate water movement of 20-50 m/min. (v) Water temperature of 27-30* C. (iv) Moderate water movement of 20-50 m/min. (v) Water temperature of 27-30* C. (iv) Moderate water movement of 20-50 m/min. (v) Water temperature of 27-30* C. (iv) Moderate water movement of 20-50 m/min. (v) Water temperature of 27-30* C. (iv) Moderate water movement of 20-50 m/min. (v) Water temperature of 27-30* C. (iv) Moderate water movement of 20-50 m/min. (v) Water temperature of 27-30* C. (iv) Moderate water movement of 20-50 m/min. (v) Water temperature of 27-30* C. (iv) Moderate water movement of 20-50 m/min. (v) Water temperature of 27-30* C. (iv) Moderate water movement of 20-50 m/min. (v) Water temperature of 27-30* C. (iv) Moderate water movement of 20-50 m/min. (v) Water temperature of 27-30* C. (iv) Moderate water movement of 20-50 m/min. (v) Water temperature of 27-30* C. (iv) Moderate water movement of 20-50 m/min. (v) Moderate water movement of bottom for Caulerpa ponds. Seaweeds are grown using different types of planting material (vegetative cuttings, natural seeds) and methods are described in detail by Trono (1986) and are summarized in Table 14. Types of planting material and methods of culture A. Green Seaweeds (Chlorophyta) Caulerpa lentillifera J. Agardh Philippines Vegetative propagation by cuttings; pond culture Enteromorpha sp. Japan Naturally produced "seeds" grown on hibi nets in open seas B. Brown Seaweeds (Phaeophyta) Ecklonia sp. Japan Natural seeding on improved substrates Eisenia sp. Japan Natural seeding on improved substrates or introduction of fertile plants on natural or artificial substrates; seeding of naturally produced spores or embryos on rocks Laminaria japonica Areschoug Japan Hatchery produced "seeds"; rope cultivation in open waters using artificial support system; natural recruitment on improved substrates; stone planting or bottom culture using artificial support system; natural recruitment on improved substrates; stone planting or bottom culture using artificial support system; natural recruitment on improved substrates; stone planting or bottom culture using artificial support system; natural recruitment on improved substrates; stone planting or bottom culture using artificial support system; natural recruitment on improved substrates; stone planting or bottom culture using artificial support system; natural recruitment on improved substrates; stone planting or bottom culture using artificial support system; natural recruitment on improved substrates; stone planting or bottom culture using artificial support system; natural recruitment on improved substrates; stone planting or bottom culture using artificial support system; natural recruitment on improved substrates; stone planting or bottom culture using artificial support system; natural recruitment on improved substrates; stone planting or bottom culture using artificial support system; natural recruitment on improved substrates; stone planting or bottom culture using artificial support system; natural recruitment on improved substrates; stone planting or bottom culture using artificial support system; natural recruitment on improved substrates; stone planting or bottom culture using artificial support system; natural recruitment on improved substrates; stone planting or bottom culture using artificial support system; natural recruitment on improved substrates; stone planting or bottom culture using artificial support system; natural recruitment on improved substrates; stone planting or bottom culture using artificial support system; natural recruitment on improved substrates; stone planting or bottom culture using artificial support system; natural recruitment on improved substrates; stone planting or bottom bottom culture using artificially seeded stones Korea, Rep. of No information (probably same used In Japan) Macrocystis sp. Japan No detailed information available Nereocystis sp. Japan No detailed information available Sargassum sp. Japan Introduction of mother plants or seedlings; artificial substrates in open seas; management of natural stocks by improvement of substrates for natural seeding U. peterseniana (Kjellman) Okamura Japan Same as used for U. pinnatifida U. undariodies (Yendo) Okamura Japan Same as used for U. pinnatifida C. Red Seaweeds (Rhodphyta) Eucheuma, alvarezii Doty Philippines Vegetative cuttings using artificial support system on open reefs E. denticulatum (Burman) Collins et Harvey Philippines Same as used for E. alvarezii E. gelatinae (Esper) J. Agardh China Vegetative cuttings tied to pieces of corals and planted on the bottom Gloiopeltis sp. Japan Artificial seeding of substrates using spore suspension or embryos Gracilaria verrucosa (Hudson) Papenfuss Taiwan, Pr. of China Vegetative cuttings inserted in bamboo splits; net method; scattering cuttings on the substrate G. gigas Harvey Taiwan, Pr. of China Same as used for G. verrucosa in Taiwan G. lichenoides (L.) Harvey Taiwan, Pr. of China Hatchery produced seeds; net-raft system in outgrowing areas P. dentata Kjellman Taiwan, Pr. of China Hatchery produced seeds; net-raft system in outgrowing areas P. haitanensis Chang et Zhang Baofu China Hatchery produced seeds; net-raft system in outgrowing areas P. haitanensis Chang et Zhang Baofu China Hatchery produced seeds; net-raft system in outgrowing areas P. haitanensis Chang et Zhang Baofu China Hatchery produced seeds; net-raft system in outgrowing areas P. haitanensis Chang et Zhang Baofu China Hatchery produced seeds; net-raft system in outgrowing areas P. haitanensis Chang et Zhang Baofu China Hatchery produced seeds; net-raft system in outgrowing areas P. haitanensis Chang et Zhang Baofu China Hatchery produced seeds; net-raft system in outgrowing areas P. haitanensis Chang et Zhang Baofu China Hatchery produced seeds; net-raft system in outgrowing areas P. haitanensis Chang et Zhang Baofu China Hatchery produced seeds; net-raft system in outgrowing areas P. haitanensis Chang et Zhang Baofu China Hatchery produced seeds; net-raft system in outgrowing areas P. haitanensis Chang et Zhang Baofu China Hatchery produced seeds; net-raft system in outgrowing areas P. haitanensis Chang et Zhang Baofu China Hatchery produced seeds; net-raft system in outgrowing areas P. haitanensis Chang et Zhang et Zh Korea, Rep. of Same as used for P. tenera in Japan P. tenera in Japan P. tenera in Japan Acrea, Rep. of Same as used for P. tenera in Japan Korea, Rep. of Same for P. tenera in Japan China Same as used for P. haitanensis Source: Trono, 1986 Fig. 24. Three methods of Eucheuma culture practised in the Philippines (from Alih, 1989). (MONOLINE METHOD) Fig. 24. Three methods of Eucheuma culture practised in the Philippines (from Alih, 1989). (NET METHOD) Fig. 24. Three methods of Eucheuma culture practised in the Philippines (from Alih, 1989). (FLOATING METHOD) In the Philippines, the monoline culture of Eucheuma species based on the Philippine experience are as follows (Trono and Ganzon-Fortes, 1988): (i) Securing a license from the Bureau of Fisheries and Aquatic Resources (BFAR) prior to farming the area. (ii) Preparing required materials needed for farm construction. materials, followed by measuring it according to the proposed dimensions of the farm. Wooden stakes are then driven into the bottom with the help of an iron bar and sledgehammer and arranged into 10 m rows at 1 m intervals. An 11 m nylon line is securely tied to one end of each stake about 0.5 m above the ground and then stretched to the corresponding opposite stake and tied securely. If the current is very strong, an additional row of stakes is placed in the middle to provide additional support. (iv) Obtaining seedlings from the nearest source and transporting them to the farm site within the shortest possible time. wind, heat or rain. If the transport of seaweeds will take several hours, the seaweeds are kept damp during the trip and upon arrival at the farm, are immediately submerged in water. (v) Preparing the seedlings by tying bunches weighing about 50-100 g with soft 25 cm long plastic straw, and then tying these to monolines in the water at 20-25 cm intervals. The plants are allowed to grow to about 1 kg or larger before harvesting. (vi) Building a farm house if drying of the harvested seaweeds is part of the operations. The farm house if drying and storage, will depend on the farmer's financial capacity and market commitments. (vii) Maintaining planted seaweeds by inspecting them regularly while they are growing. Unwanted seaweeds which will compete with the Eucheuma for nutrients and sunlight are removed along with dirt and other foreign materials clinging to the seaweeds. Lost or broken Eucheuma are replaced. (viii) Harvesting the whole plant and reserving select portions as seedlings for the next crop. (ix) Sun-drying of the rest of the harvest by spreading these on a drying platform of bamboo slots initially lined with coarse fine-mesh nylon net. The seaweeds are freed of all foreign matter clinging to them. During hot and sunny weather, it takes about 3-4 days to dry the seaweeds to a moisture content of about 30% or less. The dried materials are then packed in plastic sacks for storage in a dry place or for delivery to the buyer. The pond culture of Caulerpa involves the following major steps (Trono, 1988): (i) Pond Construction The pond is divided into manageable units measuring about 0.10-0.25 ha. The pond design allows for a flow-through system by providing each unit with its own supply and drainage gates. Water flows uniformly from the main gate to the secondary and exit gates during the drainage gates. divert run-off water from the ponds during the rainy season. (ii) Planting To facilitate planting activities, pond water is drained to a depth of about 0.3 m. Caulerpa seedlings are obtained from the nearest source available and transported to the farm site within the shortest possible time. The ponds are stocked at a rate of 1 000 kg seedlings/ha or 100 g/m2. A handful of seedlings is uniformly buried on one end at approximately 1 m intervals using a string as quide. After planting, the pond water is gradually raised to a depth of 0.5-0.8 m or just until the plants can be seen from the surface of the water. The newly planted seaweeds are inspected after a few days. Uprooted seaweeds are replaced and bare areas are replanted. (iii) Pond Management Water is changed daily or every other day to maintain adequate levels of nutrients. During the initial stages of growth, the seaweeds deplete the water of nutrients at a high rate and frequent water changes are needed to replanish lost nutrients. however, carefully maintained to prevent the collapse of the dikes. Unwanted seaweeds, sea grasses, and animals which will compete with the Caulerpa for nutrients are regularly to check for leakages, which are regularly to check for leakages, which are regularly to check for leakages. The application of fertilizer may not be necessary as long as frequent water change is maintained. However, fertilization is resorted to when the stocks appear unhealthy and pale in colour, i.e., from light green to yellowish. When this happens, pond water is changed and fertilizer with a high nitrogen content is applied at the rate of 16 kg/ha by broadcasting or by suspending the fertilizer contained in several layers of plastic sack in strategic areas in the pond. The pond water is not changed in the next two to three days. (iv) Harvesting Two months after planting, the Caulerpa forms a uniform carpet on the pond bottom, a good indicator for harvest time. About 75% of the crop is harvested by uprooting the Caulerpa from the mud and placing it on to a wooden raft. About 25% of the original crop is left behind, uniformly spaced on the pond bottom to serve as seedstock for the next crop. This may be harvested after two to three weeks. Harvested seaweeds are washed in clean sea water to remove mud and other dirt. The clean seaweeds are then placed in a basket or clean plastic sheets for further sorting and cleaning before packaging and immediate transport to the market.

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