

Ecological limits of high-density milkfish farming

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In the Philippines at present, milkfish farming in ponds includes a wide range of intensities, systems, and practices (Table 1). Many commercial farms now stock at rates of 10,000-30,000 fingerlings per hectare, encouraged by the improved market price of milkfish, the availability of good-quality feeds, and the need to recover from losses in shrimp farming. However, there is no information on how many farmers are engaged in which farming system, and in particular, the proportion now operating at semi-intensive to intensive levels. A new industry profile must be obtained to guide possible interventions. Economic analyses must be made of commercial farms at various farming intensities. It is well to remember that high-intensity farming involves not only higher stocking and feeding rates, but also higher levels of other farm inputs. Higher intensity milkfish farming may result in higher yields but not necessarily in higher profits.

At the low-intensity levels commonly practised in the Philippines and Indonesia, milkfish farming has been 'sustainable' for 400-500 years. But the effects of the milkfish industry on mangroves and larval fishery resources are clear and the social repercussions have begun to show. The future sustainability of the milkfish industry depends on a conscious and concerted effort to protect the coastal habitats required by milkfish during the life cycle: coral reefs

for milkfish spawning, shore waters for the transit of postlarvae into backwaters, mangrove swamps and estuaries for shelter and growth of juveniles, and rivers and lakes for migration and growth of sub-adults.

Aquaculture can be intensified only up to a limit and adverse ecological and socioeconomic impacts have been documented for uncontrolled aquaculture development. Given the environmental and economic conditions in the Philippines, intensive milkfish farming is not likely to be profitable nor sustainable if adopted by the majority of farmers. Demand will increase for imported fish meal, fuel oil, machinery, and other inputs for intensive farming, but the resulting glut in production will bring down milkfish prices and farmer incomes. Export-oriented feedlot-type intensive systems may be profitable at the farm level, but the benefits may be more dubious at the national level and the ecosystem level when the costs of resource use and the social costs of displacing traditional users are also considered.

Farmers and researchers must always consider aquaculture in the context of the environment. To make aquaculture possible, ecosystems are used as sources of energy and resources and as sinks for wastes. The growth of aquaculture is limited by the life-support functions of the ecosystem, and sustainability depends on matching the farming techniques with the processes and functions of the ecosystems, for example, by recycling some degraded resources. Intensive farming uses dispersed resources (such as fish for fish meal) collected from non-local ecosystems and concentrates these in the fish farm; this usually overloads the local ecosystem and generates wastes instead of recycling resources.

The fish farm has many interactions with the external environment. Serious environmental problems could be avoided if high-intensity farms are properly planned in the first place, at the farm level (in terms of initial farm siting, design, operation, and management) and at the level of the coastal zone where it can be integrated with other uses by other sectors. Before a shift to high-intensity farming, there must be adequate environment and site surveys to

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determine the potential risks inherent at the site (e.g., soil and water quality), the effects on the external environment (e.g., effects of effluents), and the impacts therefrom (pollution from agricultural and industrial sources). Milkfish farmers must produce a map of their own farms and the surrounding watershed and ecosystems, human communities, as well as agriculture, industries, commerce, and other economic activities. Congregation of too many farms in the same watershed with the same water

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TABLE 1 Milkfish farming intensities in ponds in the Philippines, 1990s. Modified from Cruz (1996) and Baliao & de los Santos (1997).

Farming intensity, methods	Grow-out stocking density (*fingerlings per ha)	Food supply	Water depth (cm)	Pond size (ha)	Water management	Crops a year	Expected yields (tons per ha-yr)
Extensive (shallow-water straight-run)		natural food grown with or without organic fertilizers					
(1) traditional, lumut	1,000-2,000	lumut (needs freshwater)	40-60	2-50	tidal exchange	1-2	0.5-0.6
(2) 'improved,' lablab	2,000-3,000	lablab (needs lots of sun)	40-50	2-50	tidal exchange	1-2	0.7-1
Modified extensive		natural food grown with organic & inorganic fertilizers, plus supplemental energy-rich feed					
(1) deep-water, plankton	3,000-5,000	plankton (unpredictable growth)	60-100	1-10	tidal exchange	1-2	0.5-1.7
(2) multi-size stocking**	3,000	lablab + plankton or lumut	80-100	1-10	tidal exchange	2-3	1.5-2
(3) modular or progression	3,000	lablab + plankton	40-50	1-10	tidal exchange	6-8	2-3
Semi-intensive	7,000-12,000	lablab for 30-45 days, then protein-rich feed	40-50, then 75-120	1-5	tidal, supplemental pumping	2-3	2-4
Intensive	20,000-30,000	complete feed only	100-150	0.1-1	mainly pumping, with aeration	2-3	4-12

Lumut is filamentous green algae, lablab is cyanobacterial mat with diatoms, small invertebrates
 *Fingerlings usually 2-5 g. **Sizes: 2-5 g, 10-25 g, 30-60 g, 80-120 g each group at 1,000 per ha

sources must be avoided — even in areas not used for other economic activities — because ecosystems have limited carrying capacities.

Various factors and processes inside and outside the farm may limit the extent, scale, profitability, and sustainability of the farming system and the growth and production of milkfish in the farm. For one, unpolluted waters are now very difficult to find in many coastal areas. Total water demand increases with intensification as more water is required to flush away metabolites, feces, and other wastes. The acquisition and maintenance of good soil and good water quality are costly, but the environmental services of the water and soil in the farm and the ecosystem around the farm are not accounted for in the cost of milkfish production.

Hatchery-reared fry will have to fill the requirement of high-intensity farms but

hatcheries also require land, water, feed, and energy. The import of milkfish fry from Taiwan could move potential pathogens to the Philippines where they did not occur previously. Diseases have not been much of a problem in milkfish farming in the Philippines, but they have been quite common and have been treated with various chemicals and antibiotics in the more intensive systems in Taiwan. Chemotherapeutics often become necessary in intensive farming and lead to the development of resistant strains of pathogens and greater frequency of diseases.

Inadequate supply and high costs of feeds and fertilizers are no longer serious constraints to the intensification of milkfish farming. Many feed companies now make milkfish feeds, and farmers will buy these feeds when they can make a profit. The problems with feeds and feeding of milkfish are real but not all obvious. Feed

mills and the making of fish feeds constitute still another drain on limited land, water, energy, feedstuffs, and other resources. Formulated feeds compete with human requirements for fish (that goes into fish meal), flour, vitamins, and other ingredients. Use of fish meal in the making of feeds for omnivorous fish like milkfish is ecologically inefficient — an extra trophic level is inserted in the food chain leading to the consumers. Increasing the stocking and feeding rates increases the waste loads and affects the water quality within and outside the ponds. A high proportion of the nitrogen and phosphorus added to a shrimp pond as feed is wasted, more in intensive than in semi-intensive ponds.

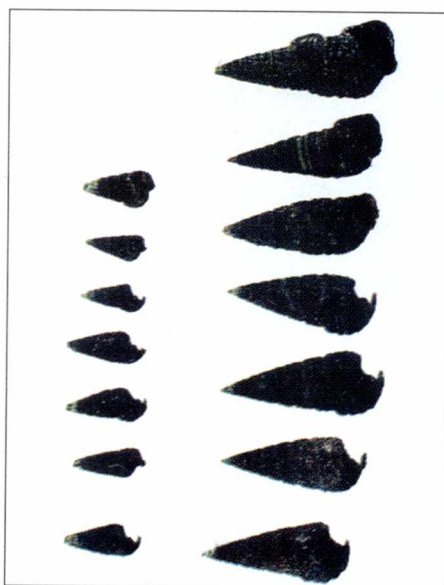
Free solar energy runs the algal pantry and oxygen-producing machinery in extensive farms, but more imported oil will be needed to run the paddlewheels, pumps,



and other equipment in the intensive milkfish farm. Such farms can not operate at high stocking rates and feeding rates if aeration and water exchange can not be assured in the long term. Through algal photosynthesis and temperature regimes, solar energy also affects the supply of dissolved oxygen in milkfish farms. Oxygen saturation levels are a major factor in the carrying capacity of ecosystems for aquaculture. These saturation levels decrease at high temperatures and high salinities. The tropical temperatures of the Philippines limit the amount of dissolved oxygen in fresh, brackish, and sea water to about 5-8 mg/l. Examples of successful high-density fish culture, i.e., carps in China, carps and tilapias in Israel, and channel catfish in the southern USA, are temperate freshwater farming systems that have higher oxygen saturation levels and are able to accommodate higher stocking rates and feed loads for high yields.

Inside the farm, limits to production are ultimately set by water and soil quality, specifically the amounts of dissolved oxygen and toxic metabolic wastes. Oxygen demand increases with temperature, stocking rate, feeding rate, total feed input, and the density of algae, benthic animals, and sediment bacteria. Farm wastes (dissolved nutrients and organic solids) stimulate the rapid growth of bacteria, phytoplankton, zooplankton, and benthos. Excess nutrients and organic matter lead to eutrophication and oxygen depletion. Sediment accumulation leads to anoxic conditions and the release of sulfide and methane. Ammonia, sulfide, carbon dioxide, methane, and hydrogen ions reduce the dissolved oxygen levels (e.g., ammonia-oxidizing and sulfide-oxidizing bacteria need oxygen to do their work) and are themselves toxic to fish. Hydrogen sulfide from sediments is responsible for the deterioration in the health of farmed fish (increased stress, reduced growth, gill damage), mortality, and loss of production. Farmers must understand the interplay of the various factors and processes that affect milkfish production. They must invest in soil and

The mud snail *Cerithidea cingulata* has become a pest, establishing large populations inside and outside milkfish ponds.



water quality measuring devices as well as in new information sources, training, and good technicians.

Discharge of effluents from high-intensity farms reduces the dissolved oxygen in the receiving waters and results in siltation and changes in productivity and community structure of benthic organisms such that only the pollution-tolerant species thrive. The pest mud snail *Cerithidea cingulata* seems to be one such pollution-tolerant species that has established large populations outside as well as inside milkfish ponds, although they were not recorded in milkfish ponds in the 1920-30s. Where waste production exceeds the capacity of the receiving environment to dilute or assimilate the waste materials, major water pollution results. Self-pollution is more serious in enclosed coastal waters, irrigation canals, or rivers subjected to heavy farming and poor water exchange; farms located on open coastlines have better water exchange and suffer from fewer diseases.

There are methods to reduce the environmental impacts of high-intensity farms. For example, good-quality dry diets can be used instead of 'fresh' diets. Feeding rates

can be matched to fish requirements and the feed conversion ratios improved. Highly digestible 'low-pollution' diets have been developed for some high-value species. The development of such diets, plus effective management of the ponds, reduce the pollutant loads and have long-term benefits for the fish farmer and the coastal environment. Waste treatment and the application of market-based deterrents and incentives can also reduce effluents.

In conclusion, the key to immediate success in the mass production of milkfish for local consumption and for export of value-added forms may be in semi-intensive farming at target yields of 3 tons per ha per yr, double the current national average. Intensive milkfish farming will be limited by environmental, resource, and market constraints. Milkfish farming must be seen in its proper context, not only as a producer of food and revenue, but as a consumer competing for finite resources and which must live in harmony with other sectors. Aquaculture is essentially livestock rearing that uses common resources with agriculture and also draws inputs from, and impacts upon, capture fisheries, with which it shares processing and marketing. Integrated intensive farming systems are the appropriate long-term response to the triple needs of the next century: more food, more income, and more jobs for more people, all from less land, less resources, and less non-renewable energy. This integrated approach needs the mass participation of farmers and requires that engineers and scientists from various disciplines work together.

Literature citations are given in full in the paper *Historical and recent trends in milkfish farming in the Philippines* (in press). In: S. S. de Silva (ed) *Tropical Mariculture*. Academic Press, London.

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