6 AQUACULTURE

SCOPE AND PRODUCTION

Aquaculture, aquatic farming, can be defined broadly as an intervention in the rearing process that enhances production, such as feeding and protection from predators. With regard to the LRFF trade, this definition covers a range of activities from full-cycle aquaculture to short-term holding and feeding of wild-caught fish to "fatten" them or to take advantage of market price fluctuations. Although there is a range of species supplied to the trade,[176] this chapter focuses on groupers, because groupers are among the highest-value fish in the trade and consequently are the fish favored by farmers. Snappers are also in demand in live fish markets, but because they generally bring lower prices than groupers, there has been less emphasis on snappers. Many snappers are produced for local markets, rather than the "high-end" export markets in Hong Kong, China and southern mainland PRC.

Most aquaculture production of groupers in the Indo-Pacific, as reported to FAO, is from Taipei,China and Indonesia (Table 6.1). However, mainland PRC produced an estimated 8,256 t of groupers in 1997 according to unofficial reports[177] and production there is likely to have increased substantially since then. Viet Nam produced an estimated 2,600 t of marine fish in 2001, of which a high proportion was cultured groupers.[178] Thus, the regional total production of groupers through aquaculture in 2001 may have been around 25,000 t.[179] The value of production of the fish reported to FAO in 2001 was $89 million. On this basis, the total value of grouper aquaculture production in the region in 2001, including mainland PRC and Viet Nam, was about $173 million.

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[176] Lau and Li 2000.
[177] NACA/TNC 1998.
[178] Le 2002.
[179] Based on a conservative 10,000 t for PRC, and 2,000 t for Viet Nam.

Table 6.1: Indo-Pacific Aquaculture Production (t) of Groupers Reported to FAO by Country, 1992–2001

Country	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Hong Kong, China	55	632	627	620	1,110	1,036	312	280	523	910
Indonesia[a]	–	–	–	–	–	–	–	1,759	1,159	3,818
Korea, Republic of	–	–	–	–	9	–	–	–	–	–
Kuwait	–	–	–	–	–	–	–	5	6	20
Malaysia	288	1,006	931	834	857	799	465	948	1,217	1,101
Philippines[b]	<0.5	63	18	10	36	158	115	145	151	97
Singapore	233	147	133	101	93	82	97	94	111	185
Taipei,China	1,125	3,845	1,749	1,899	1,789	2,525	3,471	4,112	4,992	5,285
Thailand	965	755	1,078	674	774	795	1,390	1,143	1,332	1,442
Total Volume (t)	2,666	6,454	4,536	4,138	4,668	5,395	5,850	8,486	9,491	12,858

[a] A recent estimate of grouper production in Indonesia for 2001 was 7,670 t (Asian Aquaculture magazine, September – October 2003 issue).

[b] The FAO data for the Philippines previously showed significantly higher production up to 2000, most of which was from brackishwater grouper culture. However in 2001, the year discussed in this text, the additional amount from brackishwater was only 39 t (making the total 136 t).

Source: FAO Fishery Information Data and Statistics Unit 2003.

Although there is increasing hatchery production of several species, much of the aquaculture production of groupers still comes from fish that are captured from the wild as juveniles and grown out in cages or in ponds in coastal areas.[180] The trade in newly hatched fish (fry) and fingerling-sized fish is complex and widespread in Asia. The annual grouper fry/fingerling catch is estimated to be in the hundreds of millions of fish.[181]

Hatchery Production

The major proportion of hatchery-produced grouper fingerlings originates in Taipei,China. Marine finfish production there is highly specialized into sectors; for example, one farm may produce grouper eggs from captive broodstock, a second rears the eggs, a third rears the juveniles through a nursery phase, and a fourth grows the fish to market size.[182]

The main species cultured in Taipei,China is the orange-spotted grouper. Recently, there has been some production of giant grouper, which is popular among farmers for its hardiness and its rapid growth—it is reported to grow to around 3 kg in its first year. Despite the high level of fingerling production, farms in Taipei,China also rely on wild-caught fry and fingerlings, which are generally imported.[183]

As production technology for groupers and other marine finfish species has improved, there has been increasing development of hatcheries and hatchery production of several species in Southeast Asia. In Indonesia, there is continuing expansion of hatchery production from “backyard” hatcheries. There are an estimated 2,000 units (1 unit = 4 larval rearing tanks) of backyard hatcheries in northern Bali, clustered around the Gondol Research Institute for Mariculture that introduced this technology in the 1990s.[184] The backyard hatcheries are significant sources of employment and economic benefit to the local community.[185] Formerly used mainly for rearing fry of

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[180] Johannes and Ogburn 1999; Sadovy 2000; Estudillo and Duray 2003.
[181] Sadovy 2000.
[182] Liao et al. 1994.
[183] Liao et al. 1994; Sadovy 2000.
[184] Siar et al. 2002.
[185] Siar et al. 2002.

milkfish (*Chanos chanos*) for grow-out in other parts of Indonesia and the Philippines for the food and baitfish markets, many of them now also produce grouper fingerlings including humpback grouper and brown-marbled grouper. Larger hatcheries maintain their own broodstock, and sell fertilized eggs to the smaller hatcheries. The hatcheries rear grouper larvae to the juvenile stage, 3–10 cm in length. These are sold to grow-out farms in other parts of Indonesia or overseas.

Indonesian farmers have shown a marked lack of interest in culturing camouflage grouper despite the availability of fingerlings from Balinese hatcheries and the importance of this fish in the Hong Kong, China market.[186] The farmers' main complaint is its slow growth rate in comparison with other groupers, such as the orange-spotted and brown-marbled groupers.[187] Similarly, demand for humpback grouper fingerlings in Indonesia is low because this fish has a reputation for slow growth and susceptibility to disease.[188] Consequently, there is now an oversupply of humpback grouper fingerlings in Indonesia and a large proportion are sold to the aquarium fish market.[189]

There is increasing development of hatcheries in other Southeast Asian countries including PRC, Philippines, Thailand, and Viet Nam. However, grouper culture in these countries (with the possible exception of the PRC) is still largely based on collection of wild-caught fry and fingerlings or importation of fingerlings from Taipei,China.

Production Economics

An economic assessment of the marine finfish hatcheries in Bali, Indonesia, showed that these hatcheries are extremely profitable, with annual returns (profit) of $4,100–65,000; internal rates of return (IRRs) from 12% to 356%; benefit-cost ratios of 1.27:1 to 3.09:1; and capital payback periods for the majority of farms of less than one year.[190]

[186] K. Sugama, personal communication.
[187] James et al. 1998.
[188] K. Sugama, personal communication.
[189] Siar et al. 2002.
[190] Siar et al. 2002.

Evaluations of the profitability of grouper farming in the Philippines by the Aquaculture Department of the Southeast Asian Fisheries Development Center have shown that grouper culture in both ponds and in coastal cages is highly profitable (Table 6.2) with high return on investment and short payback periods.[191]

Table 6.2: Economics of Pond and Cage Grouper Farming in the Philippines

	Ponds (0.9 ha)	Cages (6 x 75 m3)
Annual income[a] ($)	7,920	5,660
Net profit ($)	2,970	2,080
Break-even volume (kg)	–	684
Break-even selling price ($)	–	3.31
Return on investment (%)	82	59
Payback period (year)	1.22	1.68

[a] Exchange rate used was as of June 2003: $1 = P53.45.

Cage aquaculture of high-value species such as groupers is particularly attractive to poor farmers in the Philippines[192]: "This is because grouper can yield a profit margin of as much as $2.50 per kg as against only $0.15 to $0.20 /kg for milkfish. To earn $1,000 one only has to raise 400 kg of grouper as against at least 5,000 kg of milkfish. With an operating capital requirement of $3.00 per kg for grouper and $0.80 for milkfish it would take $1,200 to raise the 400 kg of grouper as against $4,000 for the 5,000 kg of milkfish."[193]

Economic sensitivity analyses have shown how the profitability of grouper grow-out in the Philippines can be increased by improvement in such factors as price of grouper juveniles, feeds, yield, survival and food conversion ratio. In one study, 88–89% of production costs were found to be attributable to fry and feeds.[194]

In Viet Nam, net income from grouper culture ranges from $21 to $89 per month. These incomes range from the lower end of

[191] Baliao et al. 1998; Baliao et al. 2000.
[192] Yap 2002.
[193] Ibid.
[194] Bombeo-Tuburan et al. 2001.

"medium" to the higher end of the "rich" wealth categories in that country.[195]

CONSTRAINTS

The major constraints in the development of sustainable grouper aquaculture are:

- *Availability of fingerlings*. Hatchery production of grouper fingerlings is still well below demand and is constrained by poor and unreliable survival of larvae in hatcheries; few species are available.[196] A regional survey concluded that there were indications that supplies of grouper fry and fingerlings taken from the wild had declined in many areas, and that these declines likely involved overfishing of grouper adults and seed, habitat destruction, destructive fishing practices, pollution, and high export demand.[197] There has also been high mortality of captured fry.[198]

- *Availability of feed supply*. Most marine finfish culture in Southeast Asia relies heavily on the use of small low-value or bycatch fish, commonly termed *trash fish*. The term is inaccurate because these fish would not necessarily otherwise be wasted; alternative uses include reduction to fish sauce for human consumption, protein sources for other agricultural commodities (such as pigs and poultry), and even direct human consumption.[199] The availability of trash fish is often seasonal; for example, fishers may not be able to fish for them during rough weather. The low value of trash fish often means that they are poorly handled, and rancidity and vitamin degradation may lead to nutritional deficiencies in the fish to which they are fed. Feeding losses from trash fish

[195] Haylor et al. 2003.
[196] Rimmer et al. 2000.
[197] Sadovy 2000.
[198] Estudillo and Duray 2003.
[199] New 1996; Tacon and Barg 1998.

are high and increase local pollution in the vicinity of the cages. The use of trash fish may also assist the spread of fish diseases.

- *Use of compounded diets.* There are several constraints to the widespread use of compounded diets for grouper aquaculture. First, farmer acceptance of pellet diets is often low because of the (usually incorrect, as discussed below) perception that these diets are much more expensive than trash fish. Other factors include wastage of pelleted feeds by inexperienced farmers; poor acceptance of pellets by fish fed on trash fish; lack of suitable feed storage facilities in rural areas, which can result in degradation of the pellets, particularly vitamin content, resulting in poor growth and disease in fed fish; and variable product quality, which may also affect farmer acceptance of pellet diets.

- *Health management.* The largely unregulated trade in aquatic organisms for aquaculture in the region is widely recognized as being responsible for the spread of aquatic animal pathogens. Aquaculture of LRFF contributes to this trade through the movement of juvenile fish (both wild-caught and hatchery-reared) throughout the region[200] and, to a lesser extent, the movement of grown-out fish to local or international markets. Of specific concern in relation to groupers are the diseases viral nervous necrosis (VNN – also known as viral encephalopathy and retinopathy, VER) and parasitic blood flukes.[201] Measures are required in order to minimize spread of these and other serious diseases.

- *Environmental impact.* Marine fish culture interacts with the coastal environment in several ways. Environmental changes occurring in some coastal areas caused by non-aquaculture uses have an influence on the success of marine cage culture. The discharge of nutrients in coastal

[200] Bondad-Reantaso et al. 2000.
[201] Bondad-Reantaso et al. 2000.

waters has been blamed for the increased incidence of red tides, which have caused heavy economic losses to fish cage farms in some countries, most recently during 1998 in Hong Kong, China. Environmental impact from culture operations derives mainly from nutrient inputs from uneaten fish feed and fish wastes.[202] These nutrient inputs, although small in comparison with other coastal discharges, may lead to localized water quality degradation and sediment accumulation. In severe cases, this "self pollution" can overload the capacity of the local environment to provide inputs (such as dissolved oxygen) and assimilate wastes, contributing to fish disease outbreaks and undermining sustainability.

PROSPECTS

Hatchery production of groupers is expanding rapidly in Asia. Recent improvements in hatchery production technology have resulted in an overall increase in the survival of grouper larvae in hatcheries, which has led to increased commercial hatchery production of several species, particularly orange-spotted grouper, brown-marbled grouper, and giant grouper. Consequently, availability of hatchery-reared fingerlings is expected to increase in the future, although the selection of species may remain limited. There is little prospect for large-scale hatchery production of the high-value LRFF species, such as the coralgroupers or the threatened humphead wrasse, in the short term.

The problems associated with the use of trash fish as feed are being overcome to a certain extent through the increasing use of pelleted compounded diets. Although pellet diets still utilize comparatively high proportions of aquatic resources (typically 2–3 kg of fisheries product inputs for each 1 kg of cultured product),[203] these are better than the typical input ratios for trash fish (usually 5–10:1). In addition, up to 80% of the fish protein sources can be replaced by terrestrial protein, such as meat and blood meals derived from abattoir byproducts.[204] Further, the food conversion

[202] Phillips 1998.
[203] Tacon and Barg 1998.
[204] Millamena and Golez 2001; Millamena 2002.

ratios of pellet diets (usually 1.2–1.8:1) are dramatically better than those of trash fish and so the relative cost of pellet diets is often comparable, or lower than, the cost of trash fish required to produce the same biomass of fish—a factor not yet appreciated by many farmers.

Commercial feed companies in Indonesia and the Philippines are now testing specialized grouper feeds. However, because of the farmer acceptance issues for compounded feeds listed above, trash fish will continue to be a major feed source for marine finfish aquaculture in the region for the immediate future.

Some fish health concerns in the trade have been addressed through groups focusing on general issues. The (inter-governmental) Network of Aquaculture Centers in Asia-Pacific produced the "Asia Regional Technical Guidelines on Health Management for the Responsible Movement of Live Aquatic Animals," which provides guidelines for reducing risks associated with transboundary movements.[205] The Southeast Asian Fisheries Development Center's Aquaculture Department developed a practical grouper health manual[206] that provides guidance on hatchery and farm health management, and is available in English, Tagalog (Philippines), Indonesian, Thai, Mandarin, and Vietnamese.

There is increasing appreciation of the environmental impact of marine finfish culture in Southeast Asia, partly because of the worldwide focus on the environmental impact of Atlantic salmon farming and unregulated shrimp culture. In some countries, there is a lack of legislative frameworks and enforcement. Problems can be addressed by more emphasis on local planning and co-management (government-industry), and zoning of coastal areas for marine fish farming as has been done in Hong Kong, China—although critics argue that the present zoning there is inadequate.[207] Such zoning has to be accompanied by control measures that limit farm numbers (or fish output, or feed inputs) to ensure that effluent loads remain within the capacity of the environment to assimilate wastes.[208]

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[205] FAO/NACA 2000.
[206] APEC/SEAFDEC 2001.
[207] Lai 2002; Sadovy and Lau 2002.
[208] Phillips 1998.

Increasing market demand for groupers with assured quality (and food safety), produced using environmentally sound farming practices, will provide further incentives for LRFF farmers to adopt improved environmental management practices. A voluntary set of standards is being prepared for the region as part of the standardization project mentioned in Chapter 5.

A recent development in the Pacific and in the Caribbean is the use of light traps and special nets to harvest the larvae or fry of fish and invertebrates before they settle onto the reef, for subsequent grow-out.[209] At this stage these pre-settlement fish are subject to extremely high mortality, such that harvesting a proportion of them should have negligible impact on adult fish populations.[210] In contrast, the natural mortality of settled fingerlings may be relatively low and the fisheries for these larger fingerlings may be subject to the same harvesting constraints as fisheries for adult fish.[211] However, catches using the new techniques vary substantially seasonally and between sites. While some species of value to the LRFF trade are caught at some sites at various times, the techniques appear to show most promise for the capture of high-value aquarium fish and invertebrates.[212]

There has been significant interest in enhancement of grouper populations by seeding reefs with hatchery-reared fish. The studies that have been carried out range from short-term survival experiments[213] to long-term stocking of leopard coralgrouper in Japan. Although some releases of groupers have been monitored for their short-term survival[214] and ecological adaptation,[215] there has been little assessment done of the impact of stocking on wild populations or of the appropriate times and places for releases into the wild. Population enhancement of groupers, like that of other marine finfish, needs to be undertaken using a "responsible approach"[216] that provides a framework for assessing a range of potential impact, including ecological, genetic, and disease issues.

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209 Dufour 2002; Hair et al. 200; Watson et al. 2002.
210 Doherty 1991; Sadovy and Pet 1998.
211 Sadovy and Pet 1998.
212 Hair et al. 2002.
213 Roberts et al. 1995.
214 e.g., Roberts et al. 1995; Uwate and Shams 1997.
215 e.g., Kayano 2001.
216 Blankenship and Leber 1995.

Unfortunately, restocking has often been used as an alternative to fisheries management. Restocking should only be used to complement, not replace, management of fisheries resources.

The genetic consequences of restocking are important. Given that there is potential for some high-value grouper species to become rare in the wild, hatchery populations may become important sources of genetic material for these remnant populations. Were this to occur, it would be important to manage the captive stocks to ensure the retention of maximum genetic diversity. Maintenance of fish stocks in hatcheries can result in decreased genetic diversity due to small founder populations and inbreeding effects if hatchery-reared fish are retained for future use as broodstock.[217]

The challenge remains to undertake marine finfish farming within a sustainability framework that incorporates a range of measures to reduce environmental impact while simultaneously providing socioeconomic benefits. One proposed framework[218] comprises four core stages: analysis, knowledge, constituency-building, and action, drawing on case-study experiences with coastal communities, and attempts to discourage destructive fishing practices and to encourage sustainable livelihoods through aquaculture. Market incentives, perhaps associated with the adoption of live reef fish standards and possible eco-labeling schemes, will also have an influence on the future development of marine finfish farming that targets live fish markets.

[217] Allendorf and Ryman 1987.
[218] Haylor et al. 2003.