Aquaculture in Asia-Pacific and the Outlook for mariculture in Southeast Asia

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The principal sources for this overview are (i) the regional synthesis of aquaculture in Asia-Pacific developed for a regional workshop on the status and prospects of aquaculture development in Asia-Pacific by FAO and NACA in September 2005, (ii) a review of marine fish hatchery development in Asia in 2003, (iii) a survey of cage fish culture in China, Indonesia, Malaysia, Thailand and Vietnam in 2004, (iv) a status report on the research and development of grouper in Asia-Pacific under the Asia-Pacific Marine Finfish Aquaculture Network (or AP-MFAN), (v) a 2004 Regional review of the Status and Potential of Fisheries and aquaculture in the Asia Pacific Region by the Asia-Pacific Fishery Commission (APFIC) and (vi) a discussion paper on grouper aquaculture prepared for a meeting in the South Pacific.

The broad information on production trends by species from the regional synthesis provides a backdrop to the more focused review of mariculture in Southeast Asia in Section 5.

1. Trends in fish consumption

Asia and the Pacific represent the most important region for fisheries and aquaculture production. It has a number of States with the highest per capita consumption. Importantly, the source of fish in the diet of rural people in this region is gradually changing. Rural populations that were once almost entirely dependent upon inland or coastal-nearshore capture fisheries for their food have seen the decline of fisheries resources through environmental changes and changing water management regimes. Aquaculture fish has become an increasingly viable alternative to inland capture fish as cheap wild fish become less available. This trend is also accompanied by rising prices for fish.

2. Aquaculture production in the Asia-Pacific region

> Top 10 aquaculture producer States by quantity (excluding aquatic plants) in 2002 were China PR, India, Indonesia, Japan, Bangladesh, Thailand, Norway, Chile, Viet Nam, and USA. Seven of these are Asian States, dominating the top 6 ranks. By value, China PR, Japan, India, Chile, Thailand, Indonesia, Norway, Viet Nam and Bangladesh are amongst the top 10 producer States.

The Asia-Pacific region is the world's largest contributor to world aquaculture, producing 46.9 million tonnes [5] or 91 percent of global aquaculture production. In terms of production by value, the region's share is slightly less, at 82 percent of total value of global aquaculture

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[5] Regionally aggregated figures are based on national data, the quality of which is known to be very uneven among States.

production. Even when aquatic plant production is excluded (the vast majority of which originates in the Asia-Pacific area), the region still remains the dominant aquaculture production area, representing 89 percent of global aquaculture production by quantity and 80 percent by value.

The growth of aquaculture production in the region has been very strong for the last ten years, resulting mainly from increased production from China (annual growth rate of 13.8 percent[6]). Both inland culture and mariculture showed steady growth but the growth rate of the inland culture sector was more rapid.

China PR alone reported to have produced 36.6 million tonnes or 79 percent of the world's aquaculture production in 2002 (including aquatic plants). To understand the enormous scale of aquaculture production in China, it can be compared with the total fisheries production of Peru, the world's second largest fisheries producer after China PR, which was 8.8 million tonnes in 2002 (including both capture and aquaculture).

Even excluding China[7], the Asia-Pacific region still remains an important production area for aquaculture, exhibiting steady growth regardless of the culture environment. In particular, inland culture doubled its production from 1 854 000 tonnes in 1990 to 4 478 000 tonnes in 2002. Such advances far exceed the growth of aquaculture in the rest of the world.

Table 1. Aquaculture production by weight for countries in the Asia-Pacific Region

Country	Production Quantity (Metric Tons)
1. China [(a)]	39 004 750
2. India	2 215 590
3. Philippines	1 448 504
4. Japan	1 327 361
5. Indonesia	1 228 559
6. Viet Nam	967 502
7. Bangladesh	856 956
8. Korea, RO	839 845
9. Thailand	772 970
10. Korea, DPR	507 995
11. Myanmar	257 083
12. Malaysia	186 031
13. Iran	91 714
14. New Zealand	84 642
15. Lao PDR	64 900
16. Australia	38 559
17. Cambodia	26 300
18. Nepal	17 680
19. Pakistan	12 061
20. Sri Lanka	10 156
21. Singapore	5 024
22. China, Hong Kong SAR	4 857
23. Kiribati (mostly live rock, export of which has stopped)	3 913
24. New Caledonia (all is shrimp)	1 800

[a)] Inclusive of Taiwan, POC and Hong Kong, SAR

2.1. Southeast Asia

Aquaculture production in Southeast Asia is very diversified, comprising 39 percent of freshwater fish, 29 percent of aquatic plants, 13 percent of crustaceans, 13 percent of marine/diadromous fishes and 7 percent of molluscs (by quantity). In terms value, highly priced crustaceans constituted an increased share of 49 percent of the total production, followed by freshwater fish at 35 percent.

The growth trend is particularly strong for freshwater finfish culture, which has increased from 564 000 tonnes in 1990 to 1 556 000 tonnes in 2002 with an average annual increment of 83 000 tonnes. In the mariculture sub-sector, aquatic plants

[6] For the period of 1991-2001 without aquatic plants production
[7] Throughout this document – 'China' refers to the aggregated figures for PR China, Taiwan Province of China, Hong Kong SAR and Macao SAR.

showed surprising production growth. Crustaceans have been a major cultured species throughout the sub-region, although this has declined since 2000, but appears to have picked up again beginning 2005.

Zanzibar weed (*Eucheuma cottonii*) is the most widely cultured aquatic plant in the region with a production of 778 000 tonnes in 2002. Apart from aquatic plants, Giant tiger shrimp (*Penaeus monodon*) maintained the position of top produced species until 2001, although very recently the massive increase in production of *P. vannamei* is challenging this position. *P. monodon* production decreased sharply in 2002, back to the production level of 1992.

Table 2. Value of aquaculture production by country in South Asia, East Asia Southeast Asia, Iran and Oceania , 2003. (FAO FishStat)

Country	Production Value (USD1,000)
1. China [(a)]	37 124 252
2. Japan	4 428 962
3. India	2 515 592
4. Viet Nam	1 983 331
5. Thailand	1 910 050
6. Indonesia	1 715 901
7. Bangladesh	1 243 120
8. Korea, RO	1 058 475
9. Myanmar	790 550
10. Philippines	668 514
11. Korea, DPR	302 612
12. Malaysia	302 007
13. Iran (Islamic Rep. of)	273 855
14. Australia	251 327 (Pearl ca. 200 000)
15. New Zealand	246 836
16. Lao PDR.	129 800
17. French Polynesia	98 111
18. Sri Lanka	65 575
19. Cambodia	35 726
20. Nepal	21 661
21. New Caledonia	13 937
22. Singapore	9 480
23. Pakistan	7 848

[a)] Inclusive of Taiwan, POC and Hong Kong SAR

2.2. China

China has continued to show strong growth in all culture environments. Growth in production from marine waters has been driven by two major groups, namely molluscs and aquatic plants. The production of most cultured species showed an increasing trend. However, there are a number of species worth highlighting, as follows:

Japanese kelp (Laminaria japonica): this species has been the top cultured species in China and its production growth is remarkable; increasing from 1 222 000 tonnes in 1990 to 4 208 000 tonnes in 2002.

Miscellaneous aquatic plants: this massive volume of aquatic plants is not reported at the species level. However, production jumped from 196 000 tonnes in 1990 to 3 931 000 tonnes in 2002. The highest annual increment was 1 485 000 tonnes between 1997 and 1998. As this group and Japanese kelp are not particularly easy to culture intensively, these increases suggest the expansion of additional areas of seaboard for their culture. A description of the areas under seaweed culture and production intensity in China would be very useful.

Pacific cupped oyster: this is another cultured species that has made outstanding growth; increasing from 532 000 tonnes in 1990 up to 3 646 000 tonnes in 2002. Mollusc production is difficult to intensify and increased production suggests developments of new production areas as in the case of aquatic plants.

Carnivorous species: Production of high value carnivorous species such as mandarin fish, Chinese river crab and marine finfish had been relatively low up to the early 1990s. However, rapid growth has started to occur since 1995. It produced 26 000 tonnes of the grouper species in 2003 (Rimmer 2005). China's total cage production of all species was more than half a million tons (Chawalit 2005)

2.3. Other East Asian states

In other East Asian States, aquatic plants continue to be predominant, accounting for 54 percent of total production. This is followed by molluscs (28 percent) and marine finfish (11 percent). However, the high economic value of marine finfish makes this species group the largest contributor in terms of value, constituting 42 percent of total production value.

Production trends by major species groups show that aquaculture production in this region has been very stable; most of the major species groups have been maintained at the current level of production for the last ten years. The only exception to this is aquatic plant production, which peaked in 1993 then decreased by almost half in 2000.

The percentage of carnivorous fish in the total for fish production is very high in East Asia (other than China), which was 82 percent in 2002. This is much higher than in South Asia, Southeast Asia and China, which all have levels below 10 percent.

2.4. Oceania

Aquaculture in the Oceania sub-region occurs in two different environs; larger developed States in temperate waters and small developing island States in tropical waters. Aggregate production from the small island States is relatively limited: 29 462 tonnes in 2002 (or less than one percent of aquaculture production in the Asia-Pacific region).

The major cultured species in terms of quantity are seaweed, clams, penaeid shrimp, tilapia and milkfish. Two commodities and three States dominate the value of commercial aquaculture production in region. They are cultured black pearl from French Polynesia and the Cook Islands and shrimp from New Caledonia. In 2002 the total export value was US$153 million.

Live reef fish, aquarium fish and pearls, which are relatively low in quantity but high in value commodities, bring significant income to some Pacific Islands. The Pacific is an important source of trade in the marine aquarium industry. Although the target species are mostly caught from the wild, there is an increasing desire for culture-based sources. Giant clam culture for the ornamental trade is widespread throughout the region and the total export is probably in the range of 30 000 – 50 000 pieces/annum. The Pacific is also a major supplier of 'live rock' (rock encrusted with coralline algae) with approximately 50 000 pieces of live rock currently being cultured in the Fiji Islands.

The larger States in the region (New Zealand and Australia) have shown a steady growth in aquaculture production, which is largely attributable to increased production of finfish species. Major cultured species of these States were marine molluscs, salmonids and tuna.

3. Aquaculture production trends by species group

The production trends of the major groups of species cultured in the Asia-Pacific region are described in this section. The grouping of species is according to their trophic needs and their degree of reliance on external inputs (such as feeds and infrastructure).

3.1. Carnivorous species or species requiring higher production inputs

Seabream. In Asia production of seabream (*Labrus* sp) is confined largely to East Asia: China, Japan, Taiwan POC, Korea, Rep. of and Hong Kong SAR with some production in West Asia particularly in the Mid-East probably using fingerlings coming from hatcheries in Spain. At the turn of the century but before 2003 when total world production was about 160 000 tonnes or less, Asian seabream production made up two-thirds of world production mostly coming from Japan. With the entry of some 65,000 tonnes from China in 2003 which boosted world production to 230,660 tonnes, Asian production came closer to three-fourths of all production even as European production also continued to grow. Japan remained as the world's top producer in 2003

Carangids. After salmon and seabream, the carangids, which consist of jacks, caravelles and pompanos is the third largest group of fish cultured in marine waters. Unlike seabream where European production is significant, very little of the 176 189 tonnes world production of carangid is produced outside Asia. Some 96.7 percent of farmed carangid consists of one species, the amberjack, *Seriola quinqueradiata* of which 89.4 percent comes from Japan. The yellowtail, as it is also called, is the most important farmed species in Japan. Japanese production has stabilized at the 140 000 to 160 000 tonnes level since the late 1990s. China PR started reporting production of the species in 2003 with 11 572 tonnes. It is also produced in RO Korea and Taiwan POC. As Chinese production of the species increases it is inevitable that it will become a source lower-priced yellow-tail for both Japan and RO Korea.

One carangid gaining popularity is the snub-nosed pompano, *Trachinotus blochii*, also known as yellow pomfret. Fingerlings of this species first came out from hatcheries in Taiwan POC although surprisingly there is no report of production from Taiwan POC. Its culture is gaining in Brunei Darussalam, Hong Kong SAR and the Philippines where fingerlings and locally made pellets are already available commercially. Although a carnivore it grows very well in cages with an FCR lower than 1.5. When sold live to restaurants it commands as good a price as live groupers in the Manila market.

Salmonids. The culture of salmonids in Asia and Oceania has quadrupled from 26 005 tonnes in 20 years from 26 005 in 1983 to 112 861 in 2003 with 86 percent grown in freshwater. In southeast Asia, Vietnam has recently started growing rainbow trout in the northern mountain areas of the country.

Eels. Some 96 percent of world production of eel comes from Asia. Europe produces 3.8 percent. Topping the list of Asian producers is China with 161 299 tonnes followed by Taiwan, Province of China (35 116 tonnes), Japan (21 742 tonnes), and RO Korea (4 312 tonnes). Indonesia, Australia and Malaysia together produced less than 600 tonnes. The main market for all these eels is Japan. China's production appears to have levelled off. In all eel producing countries, except Korea RO, production has declined considerably. It appears that eel production in Asia has already stabilized at the 220 000 tonne level and may decline in the near future. The main constraint is the supply of seedstock.

Asian Sea bass (*Lates calcarifer*) and Japanese Seabass. Barramundi (*Lates calcifer*) has not really taken off like it should with total production in the region fluctuating between 20 000 to 26 000 tonnes from 1995 to 2003. In all the Southeast Asian countries where it is farmed production has either stabilized or has even declined during the last five years. Thailand's production has increased but now appears relatively stable at the 7 800 tonne level, probably due to limited site availability and market saturation. Taiwan production hit the 10 000 tonne level in 1993 to 1995 but has been down to less than 5 000 tonnes since 1999. This may be due to a shift towards other high value species and limited site availability.

That said, a new farm in the UK is growing seabass in an indoor aquaculture facility with seed imported from Australia, and is starting to promote Asian seabass in the market.

Groupers. The biggest market for live grouper is in Asia, traditionally Hong Kong but now China is the major market. It is not surprising therefore that the amount of grouper cultured outside Southeast Asia and East Asia is negligible. Grouper production has never been large. Until 2002 reported production was only 22,814 tonnes. This more than doubled to 51,915 tonnes in 2003 due to the entry of China with 26,790 tonnes. Indonesia is also growing fast. Very few countries report up to the species level so that only five species are found in FAO's Fishstat : *Epinephelus coiodes* (orange-spotted grouper), *E. tauvina* (greasy grouper), *E, areolatus* (Areolate grouper), *E. akaara* (Hong Kong grouper) and the *Plectropomus maculatus* (spotted coral trout) but many countries lump together their grouper production at the genus level.

Indonesia's production actually consists mainly of two species, the tiger grouper, *E. fuscoguttatus*, and the mouse or humpback grouper, *Cromileptis altivelis*. These are the species in which Indonesia has had remarkable success in seed production; technology has been scaled down to and adopted at the backyard level. Other species are expected to follow with intensive R&D on marine fish ongoing in the country.

Elsewhere, the species of choice for grow-out has been either the orange spotted grouper or the greasy grouper although there is an increasing interest on tiger grouper. Although the humpback grouper commands a very high price in Hong Kong it takes 18 months to grow to the 0.5 kg size preferred by the market. The other species can be harvested in eight months. Outside Indonesia hatchery production of grouper fingerlings is still largely confined to institutional or large commercial facilities and use of wild-caught fingerlings is still widespread. The coral trout, *Plectropomus leopardus* and the Napoleon wrasse *Chelinus undulatus* are raised or fattened in cages using various sizes of wild-caught juveniles. The culture of Napolean wrasse in this way will be restricted by its recent CITES listing, providing fresh impetus to hatchery rearing.

3.2. Other carnivorous fish.

Over 20 species of other carnivorous finfish are reported and are principally cultured in marine or brackish waters, usually in cages.

Cobia or sergeant fish (Rachycentron spp) has increased rapidly in Taiwan Province of China to over 3,300 metric tonnes in 2001 from almost nil six years before. Culture of this species has also started in other countries such as China, as well as the Philippines, Thailand and Vietnam, possibly as a result of availability of fingerlings initially from Taiwan POC but increasingly from local hatcheries. Formulated commercial diets are available. The high growth rate of this species and relative hardiness in tanks and cages make it an attractive species for aquaculture. Due to its size and white meat it was thought that it can be developed into an alternative sashimi species particularly for the Japanese market. However it appears that market acceptance has to increase before the species can take off. As this species is relatively recent, it is not yet reflected in statistics and there is currently limited available production information.

Southern Bluefin tuna in Australia has emerged as a significant industry for the country over the past 10 years reaching 9,051 metric tonnes in 2001. Although the volume is relatively low compared with the Japanese Amberjack production, the very high value of this product makes it a significant economic activity where it is practised. The industry is based on collection of wild fish, then fattening for the market.

Other species cultured in brackish water requiring low input level

Milkfish. Milkfish culture is a strong tradition in the Philippines and Indonesia which reflects the country's preference for the species. There are also traditions of milkfish culture in some of the Pacific Islands (Kiribati, Nauru, Cook Islands and Palau). Milkfish have typically been produced in brackishwater ponds, and most production still comes from ponds but there is an increasing trend in the Philippines in mariculture (cage) production, indicating the use of more intensive cage systems where fish are fed with pellets or trash fish. This new development has inevitably led to environmental problems and mass fish kills in cages, previously unheard of for the traditional brackishwater pond farming.

Indonesia and the Philippines are traditionally the largest producers. Taiwan POC is reducing its production, possibly because of increasing attention to higher value species. Singapore has steadily developed its mariculture of milkfish.

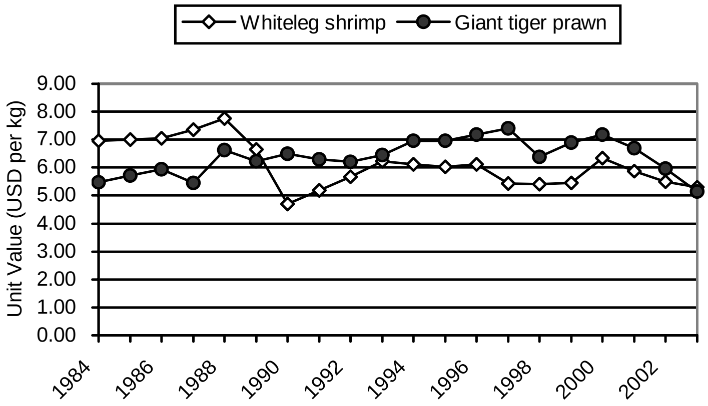
3.3. Crustaceans

Shrimp production levels in Asia reached 1.511 million tonnes by 2003 (accounting for more than 83 percent of total farmed shrimp and 47 percent of total landings). The production trends in the region have been increasing over the past 10 years for the major producers even as individual countries suffered major setbacks in the mid-1990 with the impact of viral diseases on shrimp culture. Since that time, production has slowly recovered. Generally the high international market demand has maintained interest in the culture of shrimp for export.

More recently, the growth has been led by *P. vannamei* (Briggs *et al.,* 2004). Chinese production of the species is 300 000 tonnes in 2003 based on officially reported figures but can be as high as 605 256 tonnes if production from freshwater farms is included (Miao, 2005). Other Asian countries with developing industries for this species include Thailand with 70 000 tonnes, Indonesia (49 413 tonnes) Viet Nam (30 000 tonnes), Taiwan POC, the Philippines and Malaysia (thousands of tonnes each) [8].

[8] The reported production of *P. vannamei* to FAO in 2001 was 5,809 mt; only Taiwan POC officially reported the production.

Comparison between the unit value of Penaeus monodon and P. vannamei, World 1984 to 2003 (FAO Fishtat)



There are problems associated with this dramatic increase in the production of *P. vannamei* in terms of the marketing of the product. With so many countries now producing essentially the same product (a relatively small white shrimp), global prices dropped dramatically during 2002 - 2003.

Shrimp prices appear to be on a steady decline with the value of *P. monodon* eroding at a faster rate than that of *P. vannamei*.

In 2000 *P. monodon* in Asia was 62.8 percent of total production in the region and 70.1 percent by value, in 2003 it was 43.5 percent by volume, 42.8 percent by value. *P. vannamei* was 30.7 percent by volume, 32.9 percent by value.

Freshwater prawns

Almost all of the cultured freshwater prawns, primarily *Macrobrachium rosenbergii*, are in Asia -- 99.7 percent of the world 2003 production of 280 416 tonnes. Although it is grown in freshwater, the larval phase requires brackishwater.

There is renewed interest for the species as production picked up in Thailand by 2000 so that by 2003 it reached 35 870 tonnes. China and India also entered the scene and became major players. In Thailand and India, the renewed interest was partly prompted by the increasing disease problem of *P. monodon*. India produced 35 870 tonnes in 2003. But Chinese production growth has been nothing short of spectacular with the volume starting at 37 363 tonnes in 1996 to reach 187,252 tonnes by 2003. Bangladesh is another significant player with production steadily increasing to top 10 000 tonnes by 2003. Other producers have had relatively small productions of up to a few hundred tonnes. .

Other niche crustacean species

Of all the other crustacean species for aquaculture, none probably receives as much attention in terms of research and market interest as the mangrove crab, of which there are four species: *Scylla serrata, S. tranquebarica, S. olivacea and S. paramomosain*. Of these, *S. serrata* has the highest market price due to its fast growth and large size. This species commands the highest price for export.

Mangrove crabs are attractive for export because they can be packed and shipped without water for a considerable length of time although the quality may suffer if not returned to water after more than a day.

Fattening of mangrove crabs in earthen ponds or in cages has a long history, almost as long as shrimp farming, in Southeast Asia and South Asia. There had also been sporadic work on its propagation, again almost as long as that of marine shrimps. But these early attempts were not sustained and the technology never attained commercial stage probably because the natural supply was still able to fill the existing market. Lately however with increased regional trade and local demand it is getting more difficult to catch the crab juveniles for on-growing. This spurred the development of hatchery technology. However, commercial venture has been slow and hesitant so that the research institutions (SEAFDEC Aquaculture Department in the Philippines and RIA-3 in Vietnam) are still the main source of hatchery-produced seed.

Another crustacean receiving considerable interest is the freshwater crayfish or "yabbies" in Australia. Total production reported in Asia and Oceania as of 2003 was only 255 tonnes from Australia and Samoa. Indonesia is working on its own species endemic to Papua province. China exported 24 523 tonnes worth USD 99.6 million in 2003 and is known to be the largest supplier of crayfish to the United States. Crayfish production figures in China does not appear in the FAO Fishstat database but according to the China Fisheries Yearbook China produced 51 593 tonnes of the red crayfish (*Procambarus clarkii*) in 2003.

Pet shops in Asia also import crayfish. In the Philippines they are marketed as "fortune lobster. A limited introduction for trial rearing has been made of the Australian *Cherax* sp. to the Philippines where they were subjected to an Import Risk Analysis. There are some concerns on the possibility of the crayfish becoming a pest in the same manner as the golden apple snail (*Pomacea*).

Other crustaceans being grown from wild-caught juveniles or fattened in captivity are the lobsters. In the Philippines, fishers have ventured into the growing of the spiny lobster *Panulirus* sp. and the slipper lobster in bamboo pens set in sub tidal areas. Their market value (ca. USD25 per kg) live has made their venture profitable. Farmers in Phang Nga Bay have been raising *Panulirus*, fed on horse mussel meat and trash fish, in floating cages. They report a very attractive price for live product. There is also a major industry for fattening of lobsters in cages in central Vietnam.

3.4. Molluscs

Mollusc culture is split into low value species produced in extensive cultured systems (*e.g.* seeded blood cockle mudflats, mussel and oyster stake culture) and high value species in intensive systems (fed and possibly in recirculation). Many States report mollusc production in a large grouping - marine molluscs nei.

The IFPRI/WFC[9] had projected an increase in mollusc production, but this may have been based on production trends rather than the resource potential.

Table 3: Mollusc species

Country	Higher value species	Tonnes
China PR	Pacific cupped oyster	3 625 548
China PR	Yesso scallop	935 585
Japan	Yesso scallop	271 996
Japan	Pacific cupped oyster	221 376
Korea, RO	Pacific cupped oyster	170 286
Taiwan POC	Pacific cupped oyster	19 800
Thailand	Cupped oyster nei	16 110
Philippines	Slipper cupped oyster	12 569
Australia	Pacific cupped oyster	4 924
Australia	Sydney cupped oyster	4 605

[9] Delgado, C.D, Wada, N., Rosegrant, M.W., Meijer, S. And Ahmed, M (2003).Fish to 2020. Supply and demand in changing global markets. WorldFish Centre Technical report 62. 226pp

Site availability is likely to constrain future development of mollusc culture in several States as can be seen for the examples of Japan and Korea. In these countries, the production of molluscs and seaweeds has been stable for many years. This indicates they may have run out of suitable sites. Unlike fish culture, the intensification of mollusc culture is quite difficult and probably not economically viable. The trend in mollusc culture is more likely to be a shift from lower value species to higher value species in those areas where sites are suitable. A further prospect is the development of intensive on-shore culture operations such as those for abalone and a number of gastropod species like the spotted Babylon snail (*Babylonia areolata*).

3.5. Aquatic plants

Aquatic plants consist of species grown in temperate waters solely and traditionally used for food purposes and of tropical species mainly as a source of commercially valuable biopolymers (carrageenan, agar), which are used for various food and non-food purposes.

Major cultured aquatic plants in East Asia are Laver (Nori), Japanese kelp and Wakame. They are all sea weeds for food purposes in contrast to those produced in Southeast Asia, which are mainly used as a source of commercially valuable biopolymers

Seaweeds for food

This group includes Japanese kelp, laver (Nori), green laver and Wakame. The production of these species is confined to East Asian States and has a relatively stable production. The only exception to this is Japanese kelp culture, which has the largest share of production (41 percent in 2002). Its production was doubled from two million tonnes in three years to 1993 and another one million tonnes was added in the next six years. This rapid increase was probably due to continued expansion of cultured areas in China. Production of Japanese kelp peaked in 1999 and since then has stabilised, which might indicate that the rapid expansion of production area reached a limit and further sites are not available.

Table 4. Seaweed species

	Tonnes
Japanese kelp	4 726 400
Laver (Nori)	1 330 325
Zanzibar weed	790 563
Wakame	287 563
Red seaweeds	223 080
Spiny Eucheuma	83 051
Elkhorn sea moss	21 409
Gracilaria seaweeds	17 643
Warty gracilaria	16 775
Eucheuma seaweeds	12 920

Seaweeds for biopolymers

This group consists of *Eucheuma*, *Gracilaria*, red sea weeds and others. The Philippines has the highest production of these aquatic plants and *Eucheuma cottonii* (Zanzibar weed) production in the Philippine far exceeds the production of other seaweeds (778 000 tonnes in 2002).

New areas are being investigated for the expansion of seaweed production since global demand for carrageenan and other alginates is expected to continue to rise.

3.6. Niche aquaculture species

There are a number of niche aquaculture species either cultured at the pilot/experimental level or simply not reported by many States. Some of the species are not food type commodities (*e.g.* sponge and pearls, ornamental shells, ornamental fish) and are therefore not routinely monitored by the authority reporting fisheries information. But these are a significant source of revenue, and in the case of breeding of (mostly freshwater species) ornamental fish (and plants), can be a good source of family income as in Indonesia, Malaysia, Sri Lanka and Thailand.

4. Outlook for aquaculture

Since the yield from capture fisheries is not expected to increase greatly, there is an emphasis being placed on the aquaculture sector's ability to provide increasing quantities of fish to satisfy increasing demand in all regions. Several conditions must be satisfied in order that aquaculture is able to achieve this expectation:

- The massive expansion of aquaculture required will need increased production area, as well as higher intensity of production. Obtaining the land and water space may be possible if the value of fishery products increases so that aquaculture can challenge other production systems for the use of the feeds, land and water required to effect this production.
- Alternatively, increased efficiency in the use of water and intensified production will reduce land requirements. The current intensity of production in many Asian countries is such that there is considerable scope for increased production per unit area. However, the increased feed usage and probable increased (fresh) water requirement need to be technologically addressed.
- The reliance on fish meal as a protein source for aquaculture feeds is a growing constraint. Of the some 100 million tonnes of catch a year, 30 million t is reduced to fish meal and oil. Aquaculture consumes 70 percent of fish oil and 30 percent of fish meal (IFFO 2002, in Chawalit 2005). If fish value increases, the "purchasing power" of aquaculture may draw away more of this feed resource from the livestock sector. There are calls and indeed efforts to increase the efficiency of feed use as well as develop plant based substitutes for aquaculture to reduce its reliance on fish meals. More efficient use of fish meal is possible but reduced reliance may be more difficult to achieve.
- One scenario considered in the IFPRI/WFC report is that a rapid expansion of both the scale and efficiency of aquaculture could lead to decreasing fish prices (this was the only scenario where fish price decreased). The efficient culture of herbivorous/omnivorous fish is already a reality; however, current trends indicate that aquaculture is drifting towards higher value species that present greater profit margins per unit production.
- The production of higher value aquaculture species allows investment in more intensive production systems and their associated effluent treatments. The higher value products may also be easier to market and often have greater export potential.

5. Outlook for mariculture in Southeast Asia

5.1 Prospects - overall

Demand. Southeast Asia's average per capita supply is now 24.7 kg a year. Maintaining this level for a projected population of 655 million by 2020, will require 16.2 million mt of foodfish. Assuming 30 percent continues to be contributed by aquaculture, almost 5 M mt of food fish will have to be supplied by culture, or imported, by the region.

Local markets. Domestic changes will have a significant influence on species promoted for aquaculture. China for instance is increasingly going for so-called fine (or high value) species geared towards the rising demand of a more affluent population. More fundamentally, increasing populations are prompting more intensive culture systems. A major impact is from China's becoming a major importer of fishmeal, as well as most other countries' relying more and more on artificial feed formulation.

Economic growth and a higher purchasing power of the local population have spurred greater demand for quality and better-packaged food. As consumers demand higher quality products, the "cost of compliance" with the demands will rise. For the exported items, this would favour countries with an already well-developed infrastructure for the handling and processing of export-quality seafood. It will also impose additional costs on countries wishing to increase exports to quality conscious consumers. On the other hand, rising costs in importing countries is already leading to an increase in the production of value-added products in the producing countries.

Intra-regional trade. As the Asian economies develop and become more affluent, there will be increased opportunities for intra-regional trade. In fact before the economic downturn in the region in late 1997, seafood trade between Asian countries was increasing steadily. Some countries such as China and Singapore (other than Japan) continue to be significant importers of seafood within the region. Demand for seafood in China will undoubtedly have a significant effect of seafood trade flows in the region. AFTA measures are meant to encourage and facilitate trade in ASEAN and stimulate further competitiveness of the members' agriculture industries. FTAs have been initiated as well between ASEAN and India, ASEAN and China, as well as bilaterally between some countries in ASEAN and those in other regions.

Competition. As more countries within the region develop and input costs rise, there are likely to be changes in the production cost of aquaculture products destined for export as well as changes in the trade privileges accorded to different countries. This has led to increasing competition between countries within the region for key markets. Countries with lower costs of production will obviously take a larger share of exports either directly or through third countries. In some cases, however, it is not cost alone but quality and the ability to deliver on demand gives some countries like Thailand a competitive advantage. Nonetheless, most countries in the Asian region produce aquaculture products for export to the same markets and price competition for some commodities can be strong.

Marketing of Asian seafood internationally has largely been generic, without any attempt to build specific brands or a specific image. Without branding fish or shrimp are bought largely on the basis of price as the average consumer is not aware of the difference between species, much less the origin. The structure of the seafood exporting industry in Asia, particularly that which depends on small scale aquaculture, means that there is not the same level of awareness of the importance of such mechanisms in the international seafood market.

Quality and safety. Hazard management is increasingly given attention to shrimp production and processing, largely because of the quality standards of importing countries and the higher profile recently given to environmentally friendly practices in production and processing. With more international trade, requirements for food safety have been drawing more and more attention from the international community. Some 200 different types of illness have been identified as being transmitted by food (Yang 2003). For shrimp, food safety was driven home to exporters by the burning of shipments that were detected to have nitrofurans or chloramphenicols. For live reef fish (at least the wild caught fish), it was the ciguatera poisoning cases in Hong Kong.

5.2 Prospects - mariculture species

The prospects for mariculture (coastal, nearshore and offshore) continue to be good, considering a potentially huge market in Asia, particularly for live fish in Southern China, and declining wild catch. The growing shortage of land will hasten the shift towards seafarming.

Marine fish farming has become a promising area of aquaculture. The problem, among others, is that seed from wild fishery sources is dwindling or getting more expensive to obtain. There is also a growing concern over damage to the environment and resources from over-fishing or destructive collection of seed or adults from the wild, feeding them with by-catch, and the deterioration of the waters from feeding. Phillips, et.al. (2003) characterized SEAsian mariculture as follows:

a. **General picture.** There is wide range of marine fish farming practices in Asia, and there is a close relationship between aquaculture and wild fisheries harvest/collection. Commonly, and particularly in tropical and sub-tropical SEAsia, marine fish aquaculture relies on collection of fish seed, juveniles, or feed, from the wild fishery. Within SEAsia, most marine fish aquaculture can be defined as a long-term "holding", and not true aquaculture. However, there is an accelerating transition to "true farming" based on hatchery reared stock. Brackishwater fish farming in SEAsia, principally of seabass (*Lates calcarifer*) and milkfish, is more established with hatchery fry and fingerlings available. There is a gradual transition of marine fish farming to hatchery based aquaculture throughout the whole region, as wild stocks diminish, production expands and environmental restrictions are imposed on collection of wild fish for stocking of cages[10] (Marine Aquarium Council/The Nature Conservancy, 2004).

[10] APEC economies in Asia have developed set of "standards" for the live reef fish trade that will emphasize use of hatchery-reared stocks in aquaculture.

b. **Major cultured species groups**. Marine fish culture in Asia is characterized by an extreme diversity of species farmed, and in SEAsia, a heavy reliance on capture of wild fry/fingerlings/sub-adults for stocking. It is expected that as hatchery techniques develop, marine fish demand increases, and various constraints appear with wild stock collection, the industry will increasingly focus on a narrower range of key species based on hatchery production.

c. **Production trends**. FAO aquaculture statistics include both marine and brackishwater fish, and in reality it is difficult to separate the two. These statistics for the past 10 years show continued growth in Asian marine and brackishwater fish production and a regional production total of 1.4 million tons. Based on these statistics, in order of production, China leads, followed by Indonesia, Japan and the Philippines. RO Korea, and Taiwan POC are some way behind, but are the only two countries reporting more than 10,000 tons in 2001.

The production statistics for major species are shown in the table below based on the species group classification of FAOSTAT and culture environments (marine and brackishwater). These statistics a few main species that are being cultured and classified as brackishwater or freshwater species such as milkfish, tilapia, seabass and salmonids.

Table 5. Farmed production of major species groups from 1992 to 2001, based on FAO statistics (FAO FishStat) (www.fao.org).

	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Marine Fish Nei	64 809	79 243	109 221	157 271	190 884	266 663	318 821	351 142	441 820	509 088
Grouper	3 015	7 254	6 739	5 048	5 321	5 891	5 870	8 502	9 568	12 970
Snapper	384	1 724	2 368	2 696	3 199	2 126	2 034	1 965	3 635	2 827
Seabream	68 555	76 023	82 317	81 014	83 036	87 726	88 417	92 693	87 285	77 755
Mullet	9 301	9 113	10 952	11 518	11 936	14 206	9 698	14 235	12 694	12 864
Amberjack	148 988	141 850	148 451	169 929	146 057	139 253	148 510	141 703	137 974	153 722
Mackerel	9 014	8 637	8 525	7 652	6 231	5 743	5 980	5 987	6 110	6 707
Halibut	10 327	10 804	12 562	13 578	16 553	34 857	29 882	28 583	21 202	23 064
Seabass	9 287	10 740	11 222	10 032	13 533	12 502	16 053	18 568	17 301	23 018
Milkfish	308 166	305 802	314 963	317 110	329 305	321 589	335 849	397 312	429 622	453 937
Tilapia	36 359	32 866	42 187	40 901	39 317	33 912	33 250	36 090	38 912	59 565
Salmonids	25 519	21 148	22 824	13 524	8 401	9 927	8 721	11 148	13 107	11 616
Other species	4 517	5 317	4 896	4 629	8 611	18 783	20 145	16 282	14 261	16 262
Cobia	0	0	0	3	13	9	961	820	2 626	3 224
Total	**698 241**	**710 521**	**777 227**	**834 905**	**862 397**	**953 187**	**1 024 191**	**1 125 030**	**1 236 117**	**1 366 619**

The "Marine fish nei" category consists of marine fish that are not identified in the statistics. This figure is heavily influenced by China, which reports all its marine fish farming in this category. In reality, China has a large diversity of species and a fairly well developed hatchery industry that supports it. A survey in 2004 of cage culture in China, Indonesia, Malaysia, Thailand and Vietnam (C. Oranchuwong et. al. 2005) came up with an estimated 542,000 mt total production from these countries. Around 85 percent of China's total production of 520,000 mt is from marine cages,of which there were more than 1 million units in 2004. Of this, seabass made up 17.2 percent, yellow croaker 12.9 percent, red drum 10 percent, sea bream and snapper 9.3 percent, grouper 5.9 percent, cobia 3.6 percent, and amberjack 2.5 percent.

5.3 Prospects – market

Now and the foreseeable future, cage cultured finfish are generally high value product, targeted at wealthy urban markets or the tourist seafood markets. There are however high and low value species targeted at the domestic markets - sold live or chilled – such as sea bass, milkfish, cobia and grouper. These are sold mostly to urban restaurants or supermarket chains.

The rapid development of grouper aquaculture in the Asia-Pacific region is driven by market demand for high-value live reef food fish. A market analysis done in 1995 indicated the total seafood market in Southern China including Hong Kong SAR – the main markets at present – was over 220 000 mt a year and that the market for high quality live reef fish was 1 600 to 1 700 mt per year. Six years later, in 2001, Hong Kong SAR imported an estimated 15 000-19 000 tons of live reef fish (caught and farmed) valued at more than US$ 315 million. The trade in fry, fingerling and juveniles is also flourishing.

Consequently, information on market trends is vital to support the continuing development of this sector. The following table lists the constraints and issues, required responses and priorities for marketing of live reef food fish. These were identified at the 'Development of Sustainable Marine Finfish Aquaculture in the Asia-Pacific Region' workshop, Ha Long City, Vietnam, 30 September – 4 October 2002 (Rimmer et al. 2005).

Table 6. Constraints to marine fish marketing and measures to address them.

Constraint / issues	Activities required	Priority
• Certification, eco-labelling	• Voluntary codes of practice	Medium
• Better meeting market requirements.	• Market demand information. • Forecasting.	High
• Need to improve market chain.	• Increase communication, interaction between producers and market. • Develop farmer cooperatives to improve bargaining power. • Promote cultured fish as higher quality, ciguatera free product.	High
• Lack of understanding and uncertainly on long-term demand for marine fish	• Include market assessment for non-live fish markets.	
• Consumer perception regarding quality of aquaculture / wild product, esp. fat quality.	• Feeds development research to incorporate assessment of end-product quality.	
• Focus has been on high-value species.	• Need to focus on other species that are cultured. • Market study for full range of marine fish in A-P region.	

The need to differentiate cultured and wild-caught product, and to promote cultured product fish as sustainably sourced, of higher quality and ciguatera-free was emphasized. The issue of market intelligence (market demand and price responses for live and dead fish markets) was also regarded as one of vital importance for fish farmers to enable them to business decisions on the basis of sound market information. (*Groupers are **most** valuable only when marketed live. Price of dead* *grouper drops to less than 50 percent or even 30 percent of live price, no matter how fresh*).

The information below showing the potential production from Taiwan POC and Indonesia (from M. Rimmer 2005) raises the question of market capacity (what capacity can absorb the increase) and the impact of higher fingerling production and lower cost of seed on production.

Table 7. Potential grouper production and market impact

	Fingerlings 2004 (million pcs)	**Survival %**	**Harvest size (kg)**	**Production (mt)**
Taiwan POC				
E. coioides	8.7	35	0.7	2,100
E. lanceolatus	2.5	30	2.0	1,500
E. fuscoguttatus	9.1	30	0.7	1,900
P. leopardus	0.4	30	0.5	60
Indonesia				
E. fuscoguttatus	3.8	30	0.7	800
C. altivelis	1.1	35	0.7	180

Potential market impact

	Existing supply	**Potential culture production**
E. fuscoguttatus	<500 t/yr	2,700 mt
C. altivelis	14-20 t/yr	189 mt

As the table indicates, hatchery production of grouper fingerlings is increasing rapidly. The major producer countries are Taiwan and Indonesia with reported fingerling production of 21 and 5 million fingerlings respectively in 2004. Fingerling production in Taiwan is relatively stable at around 20–25 million grouper fingerlings per annum; fingerling production in Indonesia is increasing steadily and this trend is expected to continue in the immediate future. Development of hatcheries in other countries will further increase the availability of fingerlings throughout Asia. The diversity of species produced in hatcheries is also increasing.

As fingerling production increases, and there is more competition amongst hatcheries, price of seed will decrease. As seed cost can be a major component of the production, lower fingerling costs will reduce grow-out production costs. These factors: increased fingerling availability and lower fingerling costs, will drive increasing aquaculture production of groupers in Asia. This will lead to high volumes of some products. In the short term, there will be substantial quantities of *E. fuscoguttatus* produced. In the longer term, there will be increasing production of several other species, including *E. lanceolatus* and *Plectropomus* species.

In response to increased production and the expected decrease in price, grouper farmers will have to become more efficient by increasing the intensity of production and reducing input costs. Given that the major input cost for grouper aquaculture in Asia is feed, feeds and feeding strategies will need to become more cost effective. The impacts of increased production of marine finfish, including groupers, in Asia will lead to a range of follow-on effects, including:

- increased demand for fishery products ('trash fish') to feed marine finfish;
- increased disease prevalence and outbreaks of previously unrecognised or unreported diseases as culture intensity increases;

- environmental impacts of unregulated cage culture development (local pollution, fish health issues due to poor water quality, etc.).

In response, many countries in Asia are developing management techniques and processes to deal with the rapid expansion of marine finfish aquaculture. The major focus remains on feeds (particularly the heavy reliance on 'trash' fish) and disease control.

5.4 Issues on species

Growing the higher value species also costs relatively higher because of the feed and the seed cost. Initial capital cost is low however with the use of wood and bamboo structures.

The species being grown such as seabass, snapper, grouper and *panulirus* are used to slow moving water. There are almost no pelagic-type species, other than common sea bream and cobia, being farmed in the SE Asian region, unlike the yellowtail (seriola) in Japan and the southern Bluefin tuna in Australia.

The species grown in cages are not particularly suited to open water or exposed locations: grouper and sea bass prefer light water movement. Milkfish would be suited to more exposed conditions but its price is low and has little international market. Cobia shows some promise but its international market still remains to be developed.

5.5 Issues on feeds and practices

The lack of feeds for the cage culture fish is another major constraint - most of the fish grown in cages in Southeast Asia are fed on trash/low value fish. Around 85 percent, by tonnage, of feed used in China and Southeast Asia is trash fish, which gives an FCR of 8-15 depending on fish quality and the health of the animals (Chawalit Oranchuwong et. al. 2005).

Apart from its ecological and localized environmental impacts, use of trash fish requires more man-hours for feeding. Automated feeding with pellet feed would be an advantage to large cage systems but requires quality feed, which is still in its infancy in most countries although the technology exists and is in use in Australia, Japan, Taiwan POC and others.

Specifically, for Southeast Asia, the constraints to trash fish include the limited supply of good-quality seed, its potential to cause diseases such as ecto-parasites, bacteria and virus, its impact on water quality and the local environment, and the increasing cost and growing shortage of trash fish.

Most marine finfish culture in Southeast Asia relies heavily on the use of small low-value or bycatch fish species, commonly termed 'trash fish'. The term trash fish is inaccurate in that these fish species would have alternative uses including reduction to fish sauce, protein sources for livestock and poultry, or for direct human consumption. The availability of trash fish is often seasonal; fishers may not be able to fish for these low-value species 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 are much higher than those from pellet feeds, e.g. 20–38% for trash fish versus 10% for pellet feeds used in salmonid culture (Phillips 1998 in Rimmer et. al. 2005). Because of these losses, feeding trash fish increases local pollution in the vicinity of the cages. The use of trash fish may also help spread fish diseases.

There is an increasing trend towards the use of pelleted compounded diets for marine finfish culture. Although pellet diets still utilise comparatively high inputs of aquatic resources (typically 2–3 kg of fisheries product inputs for each 1 kg of cultured product) (Tacon and Barg 1998 in Rimmer, et. al. 2005) these are better than the typical input ratios for trash fish (usually 5:1–10:1; or 8-15 according to C. Oranchuwong). There are now several companies producing specialised grouper diets, although the cost of these diets may be high because of relatively low demand compared with high-volume commodities such as milkfish and shrimp. The increasing demand for cultured groupers, and the continuing demand for high quality product, as well as the problems of trash fish availability and quality, are driving the need to develop compounded diets for these species.

There are several constraints to the widespread use of compounded diets for grouper aquaculture:

- Farmer acceptance of pellet diets is often low because of the perception that these diets are much more expensive than trash fish. Farmers often do not appreciate that the food conversion ratios of pellet diets (usually 1.2–1.8:1) is dramatically better than that 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.
- Lack of farmer experience in feeding pellets may result in considerable wastage.
- Fish fed on trash fish may not readily convert to a dry pellet diet, resulting in poor acceptance and perceived lack of appetite.
- Many rural areas have no storage facilities, and this can result in degradation of the pellets, particularly vitamin content, resulting in poor growth and disease in fed fish.
- Variable product quality may also impact substantially on farmer acceptance of pellet diets.
- Small-scale fishers or farmers operating fish cages may not have access to the financial resources necessary to invest in purchase of pelleted diets or infrastructure such as refrigeration, finding it easier to collect trash fish themselves, or in small amounts as and when financial or trash fish resources are available.
- Distribution channels for pelleted feed are not widely available in rural areas. As well as limiting accessibility to the feed, this factor increases the cost of the feed.

The lack of adequate capital or financial support for the small-scale operations is offset by the presence of a well established patron-client relationship supply chain of trash fish. Other reasons for the continuing popularity of trash fish is the highly fluctuating prices of fish. Then there is also the prevailing belief among farmers that trash fish is good for marine fish and that marine fish do not adapt well to manufactured feed. (C. Oranchuwong, et al. 2005). Consequently, although many fish farmers are slowly changing to the use of compounded diets, trash fish will continue to be a major feed source for marine finfish aquaculture in the Asia-Pacific region for the foreseeable future.

5.6. Issues on health management and the environment

The largely unregulated trade in aquatic organisms for aquaculture in the Asia-Pacific is widely recognised as being responsible for the spread of aquatic animal pathogens within the region. Aquaculture of live reef food fish contributes to this trade through the movement of juvenile fish (both wild-caught and hatchery-reared) throughout the region (Bondad-Reantaso *et al.* 2000 in Rimmer et al. 2005), 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.

Environmental impacts associated with marine finfish cage aquaculture derive mainly from nutrient inputs from uneaten fish feed and fish wastes (Phillips 1998). For example, studies carried out in Hong Kong indicate that 85% of phosphorus, 80–88% of carbon and 52–95% of nitrogen inputs (from 'trash' fish) to marine finfish cages may be lost through uneaten food, faecal and urinary wastes (Wu 1995). These nutrient inputs, although small in comparison with other coastal discharges, may lead to localised water quality degradation and sediment accumulation. In severe cases, this 'self pollution' can lead to cage farms exceeding the capacity of the local environment to provide inputs (such as dissolved oxygen) and assimilate wastes, contributing to fish disease outbreaks and undermining sustainability.

As noted earlier, the adoption of dry pellets rather than wet feeds reduces nutrient inputs through better feed utilisation. Other solutions to self-pollution of sea cage sites are

- ensure adoption of 'best or better management practices', including efficient feed formulation and feeding practices,
- keep stocking densities and cage numbers within the carrying capacity of the local environment,
- minimal and responsible use of chemicals, and
- ensure adequate water depth below cages and sufficient water movement to disperse wastes (Phillips 1998).

There is increasing appreciation of the environmental impacts of marine finfish aquaculture in Southeast Asia, partly because of the worldwide focus on the environmental impacts of Atlantic salmon farming, and unregulated shrimp aquaculture. However, in most countries there is a lack of legislative frameworks and enforcement. Problems can be addressed by more emphasis on local planning initiatives and co-management frameworks, and zoning of coastal areas for marine fish farming. Hong Kong provides one example where the government has designated marine fish farming zones, however critics argue that zoning has allowed too much crowding and localised water pollution (Lai 2002b, Sadovy and Lau 2002 in Rimmer et al 2005). Therefore, zoning of marine fish farming areas has to be accompanied by control measures that limit farm numbers (or fish output, or feed inputs) to ensure effluent loads remain within the capacity of the environment to assimilate wastes (Phillips 1998 in Rimmer et al. 2005).

Increasing market demand for groupers with assured quality (and food safety), produced using environmentally sound farming practices, will provide further incentives for farmers to adopt improved environmental management practices for grouper aquaculture. A voluntary set of standards has being prepared for the Asia-Pacific region that, if adopted by aquaculture farmers and the live reef fish trade, would support wider adoption of better environmental management practices in grouper farming (Marine Aquarium Council/TNC, 2004).

5.7. Issue on the systems

The cages in SEast Asia are cheap structures and not built to withstand heavy seas. This limits their distribution to mangrove creeks, sheltered bays and shallow waters. But the lower start up capital and cost of operation compared to the more durable offshore cages makes the system affordable to small, family-run and medium scale enterprises. On the other hand, large-scale sea-cage farms need excellent sites (which still abound in SEAsia), are beginning to enjoy high level government support, but currently lack trained people and support infrastructure (M. Rimmer 2004).

At one end of the scale are the small family run cages or pens now found in rural communities in Southeast Asia, at the other is a model of an industrialized cage farming (medium and large operations) such as the ones established in Langkawi, Malaysia or the open-sea or semi-exposed facilities in Europe. The basic technical support to both scales of operations would not be different: reliable supply of quality seed, quality feed, and health management. But going farther ashore makes the security of the crop a major concern and this requires living facilities to be built into the cage system. The same problem constrains farmers from moving to open waters. If they do, a more complicated logistical arrangement than they are currently following would have to be devised.

5.8. Socio-economic benefits from mariculture

Marine finfish aquaculture provides important socio-economic benefits to coastal communities throughout the Asia-Pacific region. The examples below are cited in Rimmer et. al. (2005):

The development of 'backyard' hatcheries in northern Bali has contributed substantially to the economic development of this region. A socio-economic assessment of marine finfish hatcheries in Bali, (Siar *et al.* 2002) showed that these hatcheries are extremely profitable:

- Annual return (profit): AU$6,312 to AU$100,037.
- Internal Rate of Return (IRR): 12% to 356%.
- Benefit cost ratio: 1.27:1 to 3.09:1
- Payback period: 7 farms had a payback period of 1 year; only 1 farm had a payback period exceeding 10 years.

One reason for the large-scale adoption of backyard hatcheries is the substantial increase in income that Indonesian farmers can obtain from fish culture compared with more traditional agricultural pursuits such as coconut plantations (Siar *et al.* 2002).

Pomeroy *et al*. (2004) estimated the production cost of *E. coioides* and *E. malabaricus* fingerlings in the Philippines at US$ 0.23 each. This is comparable to the 1994 fingerling production cost for Taiwan (Su 2005), and reflects the relatively undeveloped nature of the hatchery technology for these species in the Philippines, compared with current production in Taiwan. In comparison, wild-caught fry (6 cm TL) in the Philippines sell for US$ 0.36–0.50 (Pomeroy *et al.* 2004).

A major issue in regard to socio-economic benefits from aquaculture is the ability of the poor to access and benefit from this technology (Haylor *et al.* 2003). Hatcheries, in particular, require substantial capital investment and training and may be less accessible to poor people because of the limited availability, and high repayments costs, of capital (Haylor *et al.* 2003). Pomeroy *et al*. (2004) undertook economic analyses of grouper broodstock maintenance, hatchery, nursery, and grow-out operations, plus a combined broodstock / hatchery / nursery / grow-out system for the Philippines. They concluded that all four systems are financially feasible, but access to the high capital requirement for broodstock, hatchery and integrated systems would put these beyond the reach of many small producers. They estimated the costs for a broodstock and nursery / hatchery system at US$68,400 and for an integrated system at US$98,970 (Pomeroy *et al.* 2004). However, Siar *et al*. (2002) found that capital requirements for small-scale 'backyard' hatcheries in Indonesia could be as low as US$ 4,700 (1 unit, or 2 larval rearing tanks), making this technology relatively affordable to poor people in coastal areas.

In Bali, it is the larger hatcheries (often supported by Javanese or Chinese investment) that have the greater capacity to culture high value groupers, due to their ability to diversify their operations and absorb the higher risk that is inherent in culturing these species (Siar *et al.* 2002). The smaller hatcheries tend to concentrate on milkfish culture which, although less profitable, is also less risky (Siar *et al.* 2002).

In contrast to hatcheries, grow-out operations require considerably less capital: US$1,470 – excluding the cost of fish transport boxes – to produce 1.4 tonnes p.a. (Pomeroy *et al.* 2004). However, operating costs, particularly for feed, are much higher for grow-out farms.

Evaluations of the profitability of grouper culture in the Philippines by SEAFDEC AQD have shown that grouper culture in both ponds and in coastal cages is highly profitable (Table 8) with high return on investment and short payback periods (Baliao *et al.* 1998, Baliao *et al.* 2000).

Table 8. Estimated profitability of grouper (*E. coioides*) grow-out in ponds and in cages in the Philippines (Baliao *et al.* 1998, Baliao *et al.* 2000).

	Ponds (0.9 ha)	Cages (6 × 75m^3)
Annual income	$ 9,392	$11,631
Net profit	$ 6,105	$ 4,278
Break-even volume	–	684 kg
Break-even selling price	–	$ 6.80
Return on investment	82%	59%
Payback	1.22 years	1.68 years

Similarly, Pomeroy et al. (2004) found that economic analysis of grouper (*E. coioides*/ *E. malabaricus*) grow-out operations in the Philippines indicated that were profitable, generating a net income of US$ 9,600 p.a. for a 1.4 tonne p.a. farm.

Yap (2002) notes that cage aquaculture of high-value species such as groupers is particularly attractive to poor farmers in the Philippines. 'This is because grouper can yield a profit margin of as much as US$ 2.50 per kg as against only US$ 0.15 to $0.20 /kg for milkfish. To earn US$ 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

US$ 3.00 per kg for grouper and US$ 0.80 for milkfish it would take US$ 1,200 to raise the 400 kg of grouper as against US$ 4,000 for the 5,000 kg of milkfish'.

6. Where to go next?

The above review points to a number of practical concerns from the farmer's point of view: developing effective substitutes for trash fish in feed, more economical feed; better feeding systems, better culture systems and techniques for hatchery and grow-out, and good management practices. And the overriding concern is incorporating into research planning and technology development the priorities of farmers and translating the outcomes into socio-economic benefits for the industry, especially for the small farmers and their communities.

This leaves a few critical issues that relate to the envisioned expansion into nearshore and offshore areas. The first and foremost is developing the scale and arrangements that would enable the small farmers and communities to become the principal beneficiaries of mariculture. The second is to make these arrangements worth investing into without subsidies. Everything else follows, including which species to grow and what appropriate technological support to provide, and the incentives to devise. In this connection, a look at the requirements of live reef food fish culture would be a good guide (Marine Aquarium Council/The Nature Conservancy. 2004. "International Standards for the Trade in Live Reef Food Fish") the section on aquaculture, which was contributed by the Asia Pacific Marine Finfish Aquaculture Network, is reproduced below. The principles for better management included in these standards provide a comprehensive framework for future management of the sector. The challenge is their implementation.

3. Requirements for the Aquaculture of Live Reef Food Fish

3.1 Management Requirements

3.1.1 Use of hatchery reared fry and fingerlings

a) Preference shall be given to use of hatchery-reared fingerlings for LRFF aquaculture.

b) Hatchery and nursery producers should use and promote the use of appropriate procedures for the selection of broodstock and the production of eggs, larvae and fry that lead to healthy and good quality fry and fingerlings.

3.1.2 Limits to harvesting wild caught fry, fingerlings and juveniles

a) The harvesting of wild caught fry and fingerlings shall occur only when it can be demonstrated that it does not damage or negatively impact the sustainability of wild stocks.

b) Aquaculture farms that use wild caught fry, fingerlings and juvenile must have a program in place to eliminate their use for LRFF aquaculture.

3.1.3 Compliance with national and international laws

All participants engaged in LRFF aquaculture shall comply with the applicable laws of international, national, sub-national and local authorities.

3.2 Operational Requirements

3.2.1 Post-capture treatment of wild caught larvae and juveniles

Measures shall be taken to minimize post-capture mortality of wild caught larvae and juveniles.

3.2.2 Fish health management (including stock movements)

Aquaculture farms shall adopt effective farm and fish health management practices that minimize risk of spread of fish pathogens.

3.2.3 Aquaculture feed supply and management
The protein used for fish feed shall be derived from a sustainable resource.

3.2.4 Grow-out farms siting and habitat interactions
Aquaculture farms should be sited so as to:
a) Maintain fish in optimum health;
b) Minimize damage to habitats; and
c) Minimize interference with of other coastal resource users.

3.2.5 Harmful algal blooms
Aquaculture farms shall have an action plan to deal with a local occurrence of harmful algal blooms.

3.2.6 Chemical and drug use in aquaculture
a) Hazardous chemical inputs and drugs shall be used in a manner consistent with known best practices.

b) Therapeutants, hormones, drugs, antibiotics and other disease control chemicals shall be employed in a manner to ensure their safe, effective and minimal use.

3.2.7 Waste control and effluent management
Aquaculture farming shall be practiced in ways that minimize the environmental impacts of waste.

3.2.8 Food quality and safety
Aquaculture farms shall ensure the food safety and quality of aquaculture products by promoting efforts that maintain product quality at the appropriate national and international standards. The standards shall apply before and during harvesting, during on-site processing, in storage and during transport of the products.

3.2.9 Socio-economic, gender and poverty issues
Responsible aquaculture-practices shall be adopted that support rural communities, involve women and marginalized groups and contribute to poverty alleviation.

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