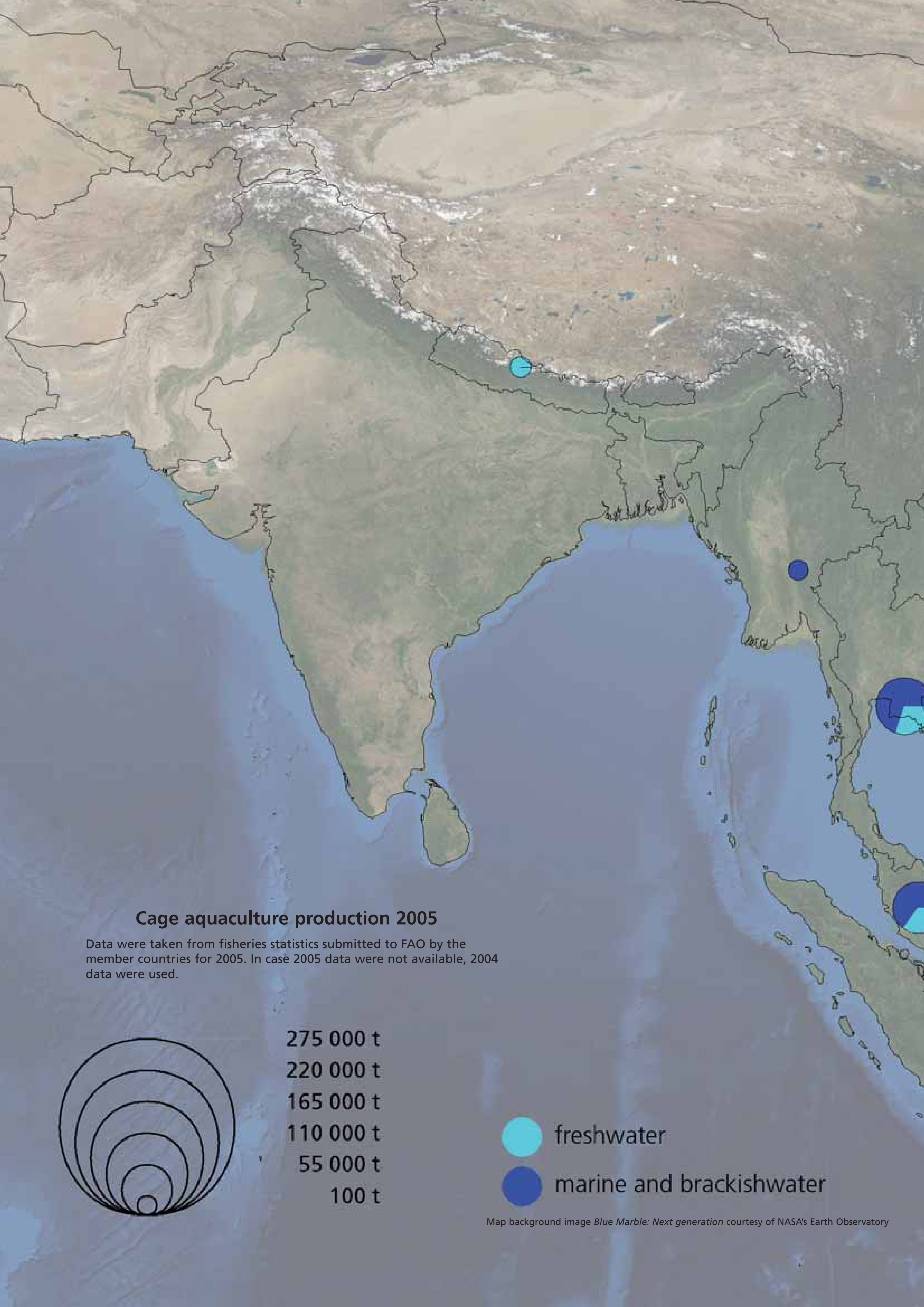
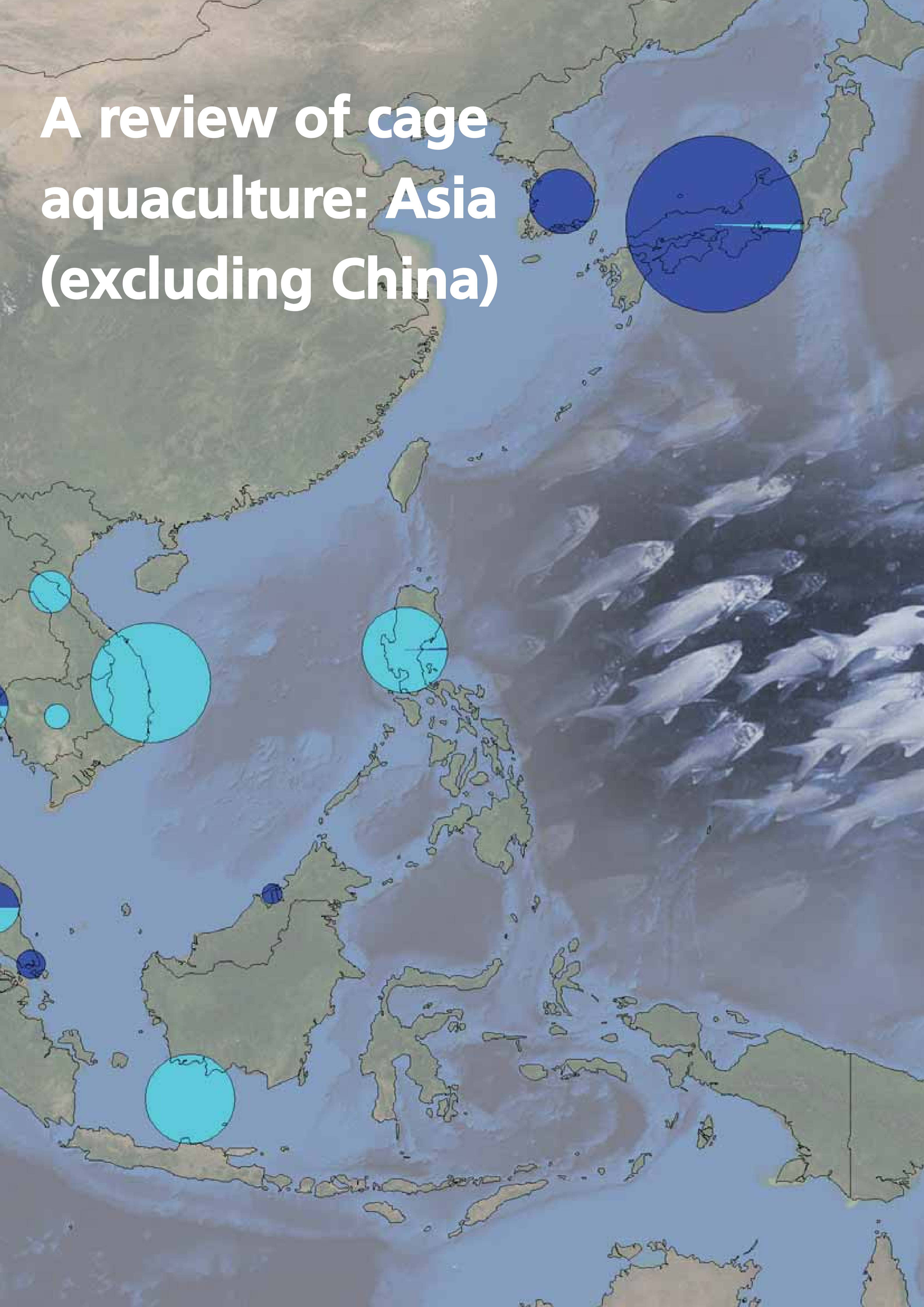


Cage aquaculture production 2005

Data were taken from fisheries statistics submitted to FAO by the member countries for 2005. In case 2005 data were not available, 2004 data were used.

A review of cage aquaculture: Asia (excluding China)



A review of cage aquaculture: Asia (excluding China)

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A review of cage aquaculture: Asia (excluding China). In M. Halwart, D. Soto and J.R. Arthur (eds). *Cage aquaculture – Regional reviews and global overview*, pp. 18–48. FAO Fisheries Technical Paper. No. 498. Rome, FAO. 2007. 241 pp.

ABSTRACT

Cage farming in Asia is practiced in fresh, brackish and inshore coastal waters. Freshwater cage farming is a very old tradition that is thought to have originated in some of the Mekong Basin countries. It currently occurs in all freshwater habitats and is extremely diverse in nature, varying in cage design, intensity of practice, husbandry methods and the species farmed. In general, freshwater cage farming is practiced on a small scale, but in some instances clustering of cage operations can contribute a significant level of production, as in the case of pangasiid catfish culture in the Mekong Delta and the combination of common carp (*Cyprinus carpio carpio*) and tilapia (*Oreochromis* spp.) farming in some Indonesian reservoirs. Overall, although clear-cut statistics are not available, cage farming is thought to be the most predominant form of freshwater aquaculture in Asia. In this paper, freshwater cage farming is only briefly considered; it has recently been reviewed by the authors (see Phillips and De Silva, 2006).

Cage farming in brackish and inshore waters in Asia is relatively recent, being started in Japan. It is estimated that over 95 percent of marine finfish aquaculture is in cages. Open sea-cage farming in Asia is not common. Marine and brackishwater cage farming in Asia is also diverse, with a variety of species being cultured at varying intensities. In most nations the individual operations are not large, and often a clustering of farming activities is seen. This clustering is primarily a result of the limited site availability in coastal waters. Cage farming is most dominant in East and Southeast Asia, but not in South Asian nations. The main species farmed in brackishwaters are the barramundi or Asian seabass (*Lates calcarifer*) and the milkfish (*Chanos chanos*). Almost all cage farming of these species is based on hatchery-produced fry and the use of pelleted feed.

In inshore marine cage farming, apart from traditionally farmed species such as amberjacks (*Seriola* spp.) and snappers (*Lutjanus* spp.), in Southeast Asia the cage farming of groupers (*Epinephalus* spp.) and cobia (*Rachycentron canadum*) is gaining ground, the former particularly to cater to the live-fish restaurant trade. Some cage farming in Asia is still dependent on wild-caught seed stock, particularly for grouper species. One of the main constraints to further expansion of marine-cage farming in inshore areas is the extensive dependence on trash fish, directly or indirectly, as a main feed ingredient.

In the synthesis, a number of factors that would impact on the"way foreward" in cage aquaculture in Asia is dealt with. Overall, the future prospects for all forms of cage farming look relatively bright for Asia. However, it is suggested that the large-scale, capital-intensive, vertically integrated marine cage-farming practices seen in northern Europe (e.g. Norway) and South America (e.g. Chile) are unlikely to occur in Asia. Instead of large-scale farms, clusters of small farms generating synergies, acting in unison and thereby attaining a high level of efficacy are likely to be the norm, well into the foreseeable future. Off-shore cage farming is unlikely to become widespread in Asia, as its development is likely to be hampered by availability of capital and the hydrography of the surrounding seas, which does not allow the technology available elsewhere to be easily transferred. Despite these limitations and constraints, cage farming in Asia will continue to contribute significantly to global aquaculture production and Asia will also continue to lead the world in total production.

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INTRODUCTION

As with most forms of aquaculture, cage culture probably originated in Asia and perhaps was associated with the "boat people" of the Mekong Basin who kept wild-caught fish in cages in their boats for fattening. Currently cage farming in Asia is conducted in fresh and brackishwaters, as well as in marine inshore areas. Apart from small quantities of crabs, lobsters and crocodiles, it is predominantly restricted to the farming of finfish.

Total aquaculture production of aquatic animals for 2004 was reported to be 45.5 million tonnes with a farm-gate value of US$63.4 billion. With the inclusion of aquatic plants, the production increases to 59.4 million tonnes with a value of US$70.3 billion. The reported growth in global aquaculture remains strong, as these figures represent an increase in production of 7.7 percent from the total aquaculture production reported for 2003, and a 6.6 percent increase when only aquatic animals are considered. Considering the ten-year period from 1994 to 2004, total aquaculture production shows an average annual increase of 7.9 percent (FAO, 2006). Of this production volume, around 90 percent comes from Asia.

It is not possible to determine the contribution of cage farming to the total volume and value of aquaculture production in Asia, particularly in respect to that in inland waters, which is the mainstay of cage aquaculture in Asia. On the other hand, 80–90 percent of the estimated one million tonnes of marine fish cultured in Asia probably comes from cage farming. In some countries and locations, cage farming provides an important source of fish production and income for farmers, other industry stakeholders and investors. In modern times, cage culture is also seen as an alternative livelihood, for example, for persons displaced by the construction of reservoirs.

This paper reviews cage culture in Asia, but only briefly that in China, which is covered elsewhere in this volume by Chen *et al*.. Its focus is on brackishwater and marine environments, since the inland sector has been dealt with by the same authors in a review of inland cage farming in Asia (excluding China) that was commissioned by FAO in 2004 (Phillips and De Silva, 2006) and has been recently published as a background paper for cage-culture development in Africa (Halwart and Moehl, 2006).

INLAND CAGE FARMING

It is difficult, if not impossible to estimate the production from inland cage culture. What is important to note is that such practices contribute to rural livelihoods, are generally small scale, and are also relatively less perturbing environmentally, as in most cases finfish feeding lower in the food chain are farmed. However, where clustered, small-scale inland cage farming operations in Asia may have impacts whose sum total is almost equivalent to those of industrial fish farming operations. Some examples are seen in reservoirs in Indonesia and in the Mekong Delta. Collectively, such activities can be environmentally perturbing.

As stated earlier, inland cage farming is the dominant form of cage farming in Asia. It can still be very traditional in some regions, and these small-scale practices tend to support a significant number of livelihoods, particularly along rivers and reservoirs (Plate 1). Such traditional systems have been used in several parts of Asia and elsewhere for many generations (Beveridge, 2004). In general and traditionally, most cage farming in rivers occurs in nursery areas where an abundance of post-fry and early fingerlings associated with suitable food sources, such as macrophytes, are found. These traditional practices continue, with cage farming of Chinese major carps and in some instances, pangasiid catfishes and snakeheads (*Channa* spp.), the latter two species-groups being farmed predominantly in Cambodia and Viet Nam. However, in some countries, primarily those that have not had a tradition of cage farming in rivers (e.g. Lao People's Democratic Republic), species such as tilapias are grown, primarily for the restaurant trade.

In the past few decades such traditional systems have evolved into more "modern" cage farming, involving specially constructed cages having better designs and using synthetic net materials, and the use of hatchery-reared fry and fingerlings, a variety of commercial feeds and better organized management practices. Although such modern systems are increasingly common, there is a diversity of cage-farming systems in Asia, covering a spectrum of traditional to modern practices and involving a wide variety of species, environments, investments and inputs.

PLATE 1

Selected traditional, small scale, rural cage farming practices in Asia

Grass carp farming in Vietcuomg Reservoirs, northern Viet Nam.

Catfish farming in Nam Ngum Reservoir, Lao PDR.

Snakehead farming in the Tonle Sap, Cambodia (I).

Snakehead farming in the Tonle Sap, Cambodia (II).

Chinese carp farming in Kui Yang River, northern Viet Nam.

Chinese carp farming in Cai River, northern Viet Nam.

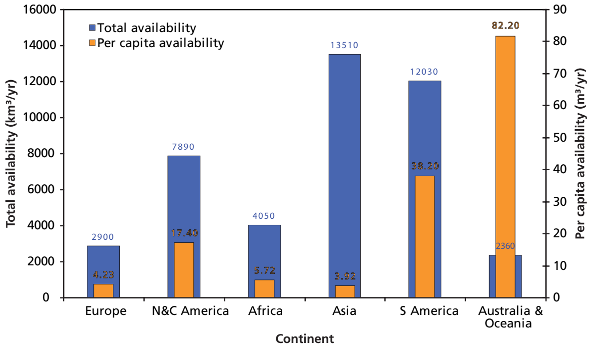
The importance of inland cage farming to Asia

Asia, excluding the Middle East, harbors 56.2 percent of the world's current population and is expected to reach 4.44 billion people, by year 2030 (http://earthtrends.wri.org/pdf_library/data_tables/pop1_2005.pdf). There is less land per person in the Asia-Pacific Region than in any other part of the world; at least ten major countries in the region have less than 0.10 ha compared to the world average of 0.24 ha (UNEP, 2000). Inland water resources in Asia are also rather limited. Although Asia is blessed with the highest quantity of usable freshwater, the per capita availability is the lowest of all continents (Figure 1). The limitations on these primary resources, i.e. land and water, have curtailed and/or discouraged significant increases in conventional pond culture in most countries in the region. Of course there are exceptions, the best example being in catfish culture in the Mekong Delta, where in spite of land limitations pond culture is expanding.

As such there is a need to use available waters effectively for foodfish production, without further demands on land use for such purposes. Reservoir impoundment in Asia, primarily for irrigation and hydroelectricity generation but never for foodfish production, is common although often politically and environmentally controversial. Asia has the largest number of reservoirs in the world, resulting from the impoundment of rivers and streams (Nguyen and De Silva, 2006). In recent times planners and developers have been driven to consider reservoir cage culture as an alternative livelihood for displaced persons and an effective non-water-consumptive secondary use of the reservoir resources in many countries. For example this practice has been successfully implemented in reservoirs (Jatilhur, Saguling and Cirata) of the Ciratum watershed in Java, Indonesia (Abery *et al*., 2005), in certain newly impounded reservoirs in Malaysia (e.g. Batang Ai in Sarawak, East Malaysia) and in China. In these instances, in each waterbody the cage farming collectively tends to become a relatively large operation, the produce is often not marketed locally and a certain proportion may even be exported. In most of these instances the commonly cultured species tend to be common carp (*Cyprinus carpio carpio*) and/or tilapia, the hybrid red tilapia (*Oreochromis niloticus* x *O. mossambicus*) often being preferred.

In addition in some countries cage farming is also seen as a useful means of rearing fry to fingerlings for other aquaculture grow-out systems, particularly where there is limited pond capacity (Ariyaratne, 2006). Further more, even in some developed countries such as Australia, cage farming of high-valued species such as the Murray cod (*Maccullochella peelii peelii*) in irrigation tanks is seen as a means of increasing farm income and an effective secondary use of water for food production (G. Gooley, personal communication).

FIGURE 1
Total and per capita water availability in each continent



Source: Nguyen and De Silva, 2006

Examples of recent noteworthy developments

The two case studies on catfish, and common carp and tilapia in the Mekong Delta region in Viet Nam and in the reservoirs of the Ciratum watershed in West Java, Indonesia, respectively were presented in detail by Phillips and De Silva (2006) and can be considered as two of the noteworthy developments of relatively large-scale inland cage farming in the region. In the case of the catfish farming in Viet Nam, which commenced primarily as the cage-farming of the pangasiid catfishes *Pangasius hypophthalmus* (sutchi or tra catfish) and *P. bocourti* (basa catfish), production reached 450 000 tonnes in 2005 and is projected to peak at 800 000 tonnes by 2010 (Le Tahnh Hung, personal communication). However, with the increasing cost of cage catfish farming in the delta there has been a gradual shift towards pond culture, and it is estimated that cage farming currently accounts for only about 30 percent of the production. Importantly most catfish farming activities are small scale, even though nearly 80 percent of the production is exported to the United States and the European Union. The industry directly and indirectly employs about 17 000 persons (Hung *et al.,* 2006; Nguyen, Lin and Yang, 2006). The catfish farming industry in Viet Nam has had its marketing problems, especially due to the introduction of a 37 percent tax by the United States of America on imports, based on a claim of "dumping". Although there were some severe short-term effects on prices and livelihoods of catfish farmers and other people (e.g. women in processing factories) caused by the antidumping measure, intervention of the Government of Viet Nam in assisting producers and processors to diversify markets and improve production practices and quality, combined with the entrepreneurial characteristics of the Vietnamese farmers, ensured that these effects were short lived. Since the case, the catfish industry in Viet Nam has continued to grow with expanded markets and competitiveness, exporting to many countries, including the United States of America and the European Union.

The dual cage-culture system locally referred to as the "lapis dua" in which common carp is cultured in the inner cage and tilapia in the outer cage (7 x 7x 3/5 m) in reservoirs in the Ciratum watershed, West Java, Indonesia, was initially mooted and encouraged as an alternative livelihood for persons displaced by the impounding of the reservoirs. However cage farming was seen as a lucrative endeavor resulting in high returns relatively quickly compared to most other investments, and the practices were thus bought up by entrepreneurs from outside. These entrepreneurs often had sufficient financial assets and consequently expanded their individual cage farms, often not heeding the regulations in operation. Thus the numbers of cages far exceeded the numbers that were legally permitted based on initial surveys of the carrying capacity of the individual waterbodies. For example in Cirata Reservoir there are nearly 30 000 cages in operation. Initially the total production from each waterbody increased significantly. However, within a five-year period the unit cage production in two reservoirs that had experienced a tripling of cage numbers began to decline, and regular fish kills began to occur, particularly in the drier months (Abery *et al.*, 2005). These changes have also brought about social conflicts and major environmental problems relating to water quality. These problems are currently being addressed, and a cage-culture management plan is being developed (Koeshendrajana, Priyatna and De Silva, 2006). A comparable situation has been reported in Lake Bato, the Philippines, where tilapia cage farming expanded unabated (Nieves, 2006).

In general, the environmental problems arising from unplanned cage farming have exacerbated because the operations tend to be localized in sheltered bays, with relatively easy access to supporting land facilities. In such areas the water circulation is rather limited and sedimentation rates are higher, leading to increased organic loads in the cage-farming areas.

Asian cage farmers are beginning to integrate cage farming with other forms of husbandry as a means of increasing income. Such practices, however, are not yet widespread. The integration could be with poultry and/or pigs on platforms over the cages, and in most ways conforms to the traditional land-based integrated aquaculture (Little and Muir, 1987). In the extreme case, as found in the Tri An Reservoir, southern Viet Nam, crocodile cages are annexed to fish cages, an interesting and novel diversification of cage farming.

Problems and constraints in inland cage farming

Although individual cage-farming holdings tend to be relatively small, in certain inland waterbodies large numbers of such units co-exist, as in the examples cited in the previous section (Plate 2). These collective, intensive cage-farming practices generate synergies that enable them to be relatively more profitable, and even allow a relatively high proportion of the produce to be exported. However, such positives can at times also be counter-productive and negatively affect the sustainability of the systems. This is evident in the case of Cirata and Saguling reservoirs, where the number of cages has far exceeded the estimated carrying capacities of the two reservoirs (Abery *et al.*, 2005). This has resulted in fish kills, social conflicts and increased susceptibility to disease, the most recent being the mass mortality of common carp brought about by koi herpes virus (KHV) (Bondad-Reantaso, 2004).

The great bulk of inland cage-farmed fish, with the exception of snakeheads in Tonle Sap, Cambodia and the Chinese perch (*Siniperca chuatsi*), are relatively low-valued food fish. Almost all the herbivores and omnivores farmed are destined for local markets, where farm-gate prices are often determined by wholesalers/middlepersons. On the other hand, most cage-farmed tilapia and catfish are marketed extensively, this being made possible because of the large quantities produced in specific areas and proper marketing strategies being developed over the years.

The availability of reliable supplies of good quality seed stocks is a major problem in most inland cage farming, particularly the vast majority that still depend on natural supplies. Apart from tilapia, adequate selective breeding plans have not been established for species that are farmed on a large scale, such as the catfishes and snakeheads. This lapse could possibly result in reduced production and most importantly, will not enable the full genetic potential of the species to be realized for farming purposes.

There is also considerable dependence on trash fish by some of the major inland cage farming activities in Asia, most notably catfish cage farming in the Mekong Delta in southern Viet Nam. Indeed, the relatively lower efficacy of using trash fish as a major feed resource, among other factors, principally the cost of wood used for cages and poor water flow during the dry season, has resulted in a decrease in cage catfish farming in the region, most farmers turning to pond culture. Cage-fish farmers often see trash fish as a relatively cheap feed resource. Trash fish is also used in catfish farming as the main ingredient in "farm-made" feeds where it is mixed with other ingredients such as rice bran, fortified with commercially available vitamin pre-mixes, subjected to some form of cooking (see Plate 2), and used as semi-dried "feed balls" and the like (Hung *et al.*, 2006; Nguyen, Lin and Yang, 2006). Studies on improving the preparation of such farm-made feeds will not only increase the efficacy of feed utilization, and thereby bring about higher returns, but also may be used in the long term to reduce the reliance on trash fish.

Catfish processors and farmers in the Mekong Delta tend to recycle almost all the processing waste, a practice that needs to be encouraged. However as substantial quantities of waste are being used in feeds, further studies are needed to ensure that potential disease transmission is averted.

By and large most of the hardware used in cage farming, even in the case of large-scale developments, as for example, in the Mekong Delta and the Indonesian reservoirs, rely on bamboo and/or hard woods. Both these commodities are typically obtained from the wild, risking considerable environmental damage. Apart from the direct impacts on forest resources, this practice may also enhance soil erosion of the catchments and increase siltation in the waterbodies, with potential long-term negative effects on the farming activities per se.

One of the main constraints to developments is the relative lack of research on key issues pertaining to inland cage farming. Foremost among these are the carrying capacities of static waterbodies such as reservoirs and lakes, feed usage and related efficacies, species suitability, adoption of polyculture practices as in the case of the dual cage farming system ("lapis dua") in Indonesian reservoirs, economic evaluations (e.g. see Dey *et al.,* 2000) and marketing strategies.

BRACKISHWATER AND MARINE CAGE FARMING

Brackishwater and marine cage farming is relatively new in Asia, having first been developed in Japan for marine cage culture for species such as the Japanese amberjack or yellowtail (*Seriola quinqueradiata*) and red seabream (*Pagrus major*) (Watanabe, Davy and Nose, 1989). Over the last 20 years, marine finfish aquaculture, predominantly cage farming, has spread throughout Asia. The predominant countries engaged in this activity are China (see Chen *et al.*, this volume), Indonesia, Taiwan Province of China (Taiwan POC) and Viet Nam. Marine fish aquaculture, particularly in Southeast Asia, relies on the collection of fish seed, juveniles or feed from the wild. Within Southeast Asia, most marine fish aquaculture can be defined as a form of "holding" and not true aquaculture[2]. However, this scenario is changing. In Southeast Asia marine fish culture industries are increasingly reliant on hatchery stock, such as in grouper (*Epinephalus* spp.) farming in Indonesia (Plate 3), and therefore can be defined as "true" aquaculture. Brackishwater fish farming, principally of barramundi or Asian seabass (*Lates calcarifer*) and milkfish (*Chanos chanos*), is more established, being based on hatchery-produced fry and fingerlings.

Production trends

FAO aquaculture statistics include both marine and brackishwater fish, and it is difficult to separate the two. These statistics for the past 13 years show continued positive growth in Asian production (see Table 1) and a regional production of 1.7 million tonnes. The trends in overall production and value

[2] According to FAO (1997) "Aquaculture is the farming of aquatic organisms including fish, molluscs, crustaceans and aquatic plants. Farming implies some sort of intervention in the rearing process to enhance production, such as regular stocking, feeding, protection from predators, etc. Farming also implies individual or corporate ownership of the stock being cultivated. For statistical purposes, aquatic organisms which are harvested by an individual or corporate body which has owned them throughout their rearing period contribute to aquaculture while aquatic organisms which are exploitable by the public as a common property resource, with or without appropriate licences, are the harvest of fisheries."

PLATE 2

Clustered, relatively large-scale cage farming activites in Asia

Cage farms using the "lapis dua" – two cage systems in the Cirata Reservoir, West Java, Indonesia.

Cage farming in BatanAi Reservoir in Sarawak, East Malaysia.

Cage farming of red tilapia in the lower Mekong, South Viet Nam.

Preparation of trash fish for feeding catfish.

Preparation of "home made" feeds for catfish cage farming using trash fish and other ingredients (I).

Working with fishermen to identify the species used as trash fish for cage farming in Cambodia.

TABLE 1
Farmed marine and brackishwater fish production from 1992 to 2004, based on FAO statistics

Country	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
China	58 716	71 672	101 110	144 957	182 155	254 979	306 697	338 805	426 957	494 725	560 404	519 158	582 566
Indonesia	193 136	215 065	208 824	212 733	250 617	195 543	232 708	265 511	278 566	308 692	314 960	316 444	315 346
Japan	263 503	259 273	271 351	279 182	256 223	255 774	264 018	264 437	258 673	263 789	268 405	273 918	262 281
Philippines	153 714	133 580	147 914	144 039	144 868	150 965	154 771	172 574	203 832	231 419	229 708	235 075	256 176
Taiwan POC	22 687	29 915	44 049	51 869	46 047	51 834	50 899	44 157	40 100	55 235	70 326	76 653	64 671
Korea, Republic of	4 595	5 471	6 643	8 360	11 384	39 121	37 323	34 382	27 052	29 297	48 073	72 393	64 195
Viet Nam	-	-	-	-	-	-	-	-	-	-	-	51 893	57 739
Bangladesh	16 000	17 520	17 379	13 301	22 126	26 748	25 851	26 912	27 801	28 044	32 026	34 101	39 493
Australia	4 402	4 977	5 878	8 585	10 466	10 730	9 816	11 796	14 517	17 774	19 728	20 382	21 469
Thailand	3 832	3 794	5 293	5 131	6 235	5 616	8 761	7 359	9 300	9 497	12 238	14 598	16 978
Malaysia	3 561	6 508	5 999	5 767	5 943	6 215	7 548	8 302	9 267	9 508	10 110	11 802	11 969
New Zealand	2 800	3 300	3 800	4 800	6 200	4 200	5 500	5 400	5 685	7 887	6 989	4 800	5 196
India	-	-	-	-	-	1 429	1 740	-	-	-	-	2 644	2 778
Singapore	786	536	480	644	644	818	593	914	1 402	1 088	1 294	1 897	2 366
China, Hong Kong SAR	3 400	3 010	2 989	2 950	3 144	3 032	1 271	1 284	1 787	2 473	1 215	1 492	1 541
Brunei Darussalam	8	31	51	74	72	69	74	77	59	30	39	38	104
Kiribati	41	52	32	17	9	7	4	13	14	18	14	9	9
Tuvalu	-	-	-	-	-	-	-	-	-	-	-	5	1
Cook Islands	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Micronesia, Fed. States of	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Tonga	-	-	-	-	-	-	-	-	14	19	14	20	<0.5
Fiji Islands	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	1	1	393	133	-
French Polynesia	3	6	-	3	10	2	3	3	10	19	19	19	-
Guam	<0.5	<0.5	4	5	5	5	5	7	7	7	7	-	-
TOTAL	**731 184**	**754 710**	**821 796**	**882 417**	**946 148**	**1 007 087**	**1 107 582**	**1 181 933**	**1 305 044**	**1 459 522**	**1 575 962**	**1 637 474**	**1 704 878**

Source: FAO, 2006

of brackishwater and marine aquaculture in the Asian region are shown in Figure 2. Based on these statistics, China leads in production, followed by Indonesia, Japan and the Philippines. Taiwan Province of China, the Republic of Korea and Viet Nam are some way behind, but are among the countries reporting more than 50 000 tonnes in 2004. China in particular has shown spectacular growth in marine and brackishwater fish farming in the past decade (see Figures 3 and 4).

FIGURE 3
Trend of production in the leading five Asian countries in marine farmed species

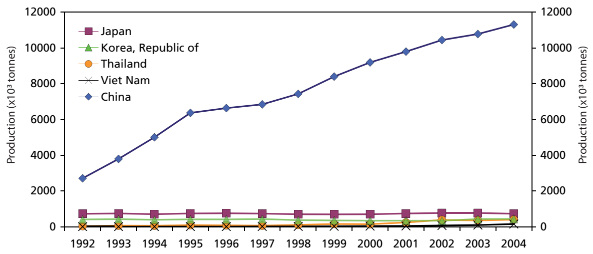


FIGURE 2
Production and value of marine and brackish aquaculture in Asia

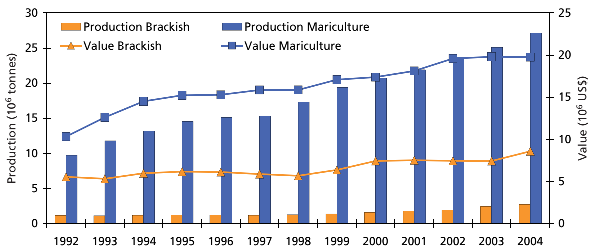


FIGURE 4
Trend of production in the leading five Asian countries in brackishwater farmed species

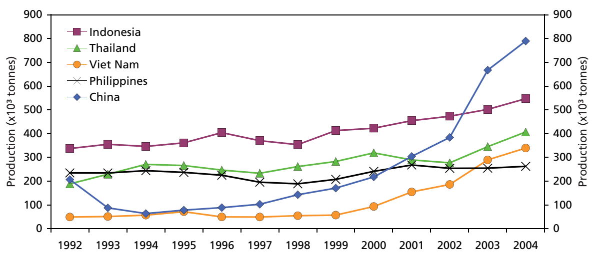


PLATE 3
Cage-farming activities

Grouper farming in Indonesia.

Grouper farming in Thailand.

Grouper farming in Viet Nam.

Cobia farming in Viet Nam.

Preparation of trash fish for feeding grouper in Thailand.

Trash fish for feeding cobia in Cat Ba Island, Viet Nam.

TABLE 2
Farmed brackishwater fish production from 1992 to 2004, based on FAO statistics

Country	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Indonesia	193 136	215 065	208 824	212 733	250 617	195 543	232 708	263 262	275 979	300 155	303 213	302 025	305 424
Philippines	153 714	133 182	147 628	143 818	144 747	150 528	147 103	163 669	194 708	221 145	211 965	212 927	218 390
Taiwan POC	22 395	29 480	43 590	51 159	45 006	50 062	47 891	42 057	35 934	50 046	64 078	69 056	58 743
Viet Nam	-	-	-	-	-	-	-	-	-	-	-	51 893	57 739
Bangladesh	16 000	17 520	17 379	13 301	22 126	26 748	25 851	26 912	27 801	28 044	32 026	34 101	39 493
Australia	4 067	4 341	4 603	6 658	8 453	8 546	8 117	10 194	11 786	13 699	15 716	16 882	17 439
Thailand	3 832	3 794	5 293	5 131	6 235	5 616	8 761	7 359	9 300	9 497	12 238	14 598	16 978
Malaysia	3 561	6 508	5 999	5 767	5 943	6 215	7 548	8 302	9 267	9 508	10 110	11 802	11 969
India	-	-	-	-	-	1 429	1 740	-	-	-	-	2 644	2 778
Brunei Darussalam	8	31	51	74	72	69	74	77	59	30	39	38	104
Singapore	-	-	-	-	-	-	-	1	3	3	4	3	58
Kiribati	41	52	32	17	9	7	4	13	14	18	14	9	9
Cook Islands	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Micronesia, Fed. States of	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Tonga	-	-	-	-	-	-	-	-	14	19	14	20	<0.5
China, Hong Kong SAR	187	211	210	207	144	72	71	34	18	5	4	6	-
Fiji Islands	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	1	1	393	133	-
French Polynesia	-	-	-	-	-	-	-	-	-	-	7	7	-
Guam	<0.5	<0.5	4	5	5	5	5	7	7	7	7	-	-
TOTAL	**396 941**	**410 184**	**433 613**	**438 870**	**483 357**	**444 840**	**479 873**	**521 887**	**564 891**	**632 177**	**649 828**	**716 144**	**729 124**

Source: FAO, 2006

TABLE 3
Farmed marine fish production from 1992 to 2004, based on FAO statistics but with brackishwater fish statistical categories removed

Country	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
China	58 716	71 672	101 110	144 957	182 155	254 979	306 697	338 805	426 957	494 725	560 404	519 158	582 566
Japan	263 503	259 273	271 351	279 182	256 223	255 774	264 018	264 437	258 673	263 789	268 405	273 918	262 281
Korea, Republic of	4 595	5 471	6 643	8 360	11 384	39 121	37 323	34 382	27 052	29 297	48 073	72 393	64 195
Philippines	-	398	286	221	121	437	7 668	8 905	9 124	10 274	17 743	22 148	37 786
Indonesia	-	-	-	-	-	-	-	2 249	2 587	8 537	11 747	14 419	9 922
Taiwan POC	292	435	459	710	1 041	1 772	3 008	2 100	4 166	5 189	6 248	7 597	5 928
New Zealand	2 800	3 300	3 800	4 800	6 200	4 200	5 500	5 400	5 685	7 887	6 989	4 800	5 196
Australia	335	636	1 275	1 927	2 013	2 184	1 699	1 602	2 731	4 075	4 012	3 500	4 030
Singapore	786	536	480	644	644	818	593	913	1 399	1 085	1 290	1 894	2 308
China, Hong Kong SAR	3 213	2 799	2 779	2 743	3 000	2 960	1 200	1 250	1 769	2 468	1 211	1 486	1 541
Tuvalu	-	-	-	-	-	-	-	-	-	-	-	5	1
French Polynesia	3	6	-	3	10	2	3	3	10	19	12	12	-
TOTAL	**334 243**	**344 526**	**388 183**	**443 547**	**462 791**	**562 247**	**627 709**	**660 046**	**740 153**	**827 345**	**926 134**	**921 330**	**975 754**

Source: FAO, 2006

Milkfish, a brackishwater species based on wild and hatchery collection, is the major contributor to these statistics for Indonesia and the Philippines. These two countries account for 70 percent of total brackishwater fish production in Asia (Table 2). The marine production statistics without brackishwater species show (Table 3) a total marine farmed-fish production in Asia of around 975 000 tonnes. China currently leads both brackishwater and marine aquaculture production in Asia and globally.

Species cultured

A large number of fin fish species are farmed in cages in Asia. As yet there is a significant reliance on wild-caught young for farming of some species, such as in grouper culture in Thailand.

Major species production profiles

The marine fish production statistics presented in Table 4 are obtained from FAO FISHSTAT Plus (FAO, 2006). The species-group classification is based on FAOSTAT species-group and culture environments (marine and brackishwater). These statistics have filtered out a few main species that are currently being cultured and/or classified as brackishwater or freshwater species. These include milkfish, tilapia, barramundi (Asian seabass) and

TABLE 4
Farmed production of major species groups from 1992 to 2004, based on FAO statistics but with brackishwater fish statistical categories removed

Species	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Marine fishes nei	64 469	77 144	106 713	152 158	188 625	262 279	314 369	348 557	439 217	505 501	573 542	200 843	212 359
Japanese amberjack	148 988	141 799	148 390	169 924	145 889	138 536	147 115	140 647	137 328	153 170	162 682	157 682	150 113
Silver seabream	66 067	72 896	77 066	72 347	77 319	81 272	83 166	87 641	82 811	72 910	73 199	88 082	85 297
Japanese seabass	-	-	-	-	266	-	-	797	605	873	2 006	81 124	82 475
Large yellow croaker	-	-	-	-	-	-	-	-	-	-	-	58 684	67 353
Lefteye flounders nei	-	-	-	-	-	-	-	-	-	-	-	36 227	57 270
Porgies, seabreams nei	156	253	278	296	357	320	372	385	636	728	1 637	45 610	49 514
Red drum	-	-	-	-	-	-	-	-	-	-	-	44 925	43 506
Groupers nei	369	271	255	320	407	379	415	2 271	1 573	4 341	7 845	36 159	40 000
Milkfish	-	-	-	166	78	1 197	7 693	9 070	9 548	10 597	18 437	23 314	39 211
Bastard halibut	10 327	10 804	12 562	13 578	16 553	34 857	29 882	28 583	21 202	23 064	29 569	40 473	37 382
Cobia	-	-	-	3	13	9	961	820	2 626	3 224	2 395	20 667	20 461
Scorpionfishes nei	-	-	-	-	2 036	12 430	14 634	10 180	8 698	9 330	16 636	23 938	19 708
Puffers nei	4 068	4 427	3 456	4 031	5 552	5 961	5 389	5 100	4 733	5 769	5 231	14 602	19 190
Amberjacks nei	-	-	-	2	20	69	406	154	97	119	292	11 847	12 751
Coho(Silver) salmon	25 519	21 148	22 824	13 524	8 401	9 927	8 721	11 148	13 107	11 616	8 023	9 208	9 607
Righteye flounders nei	-	-	-	-	-	-	-	-	-	-	-	5 356	8 048
Chinook(Spring, King) salmon	2 800	3 300	3 800	4 800	6 200	4 200	5 500	5 400	5 685	7 887	6 989	4 800	5 196
Southern bluefin tuna	335	636	1 275	1 927	2 013	2 089	1 652	1 373	2 649	3 889	4 011	3 500	4 030
Flathead grey mullet	<0.5	<0.5	<0.5	<0.5	27	-	-	-	968	1 415	3 938	4 151	3 663
Jack and horse mackerels nei	1 853	2 183	2 391	2 653	2 343	2 217	2 568	2 935	3 058	3 396	2 931	2 313	2 668
Japanese jack mackerel	7 161	6 454	6 134	4 999	3 869	3 526	3 412	3 052	3 052	3 308	3 462	3 377	2 458
Barramundi (Giant seaperch)	396	233	204	288	292	255	248	732	1 076	4 191	1 917	2 521	1 825
Greasy grouper	45	90	89	88	360	562	132	170	419	671	208	677	643
Groupers seabasses nei	-	63	18	10	36	149	115	145	151	97	88	120	171
Areolate grouper	-	512	508	502	750	474	180	110	104	239	117	155	155
Mangrove red snapper	-	572	568	560	690	266	144	321	73	116	24	122	149
Orange-spotted grouper	-	-	-	-	-	-	-	-	-	-	-	76	139
Spinefeet(=Rabbitfishes) nei	<0.5	8	4	<0.5	3	40	4	19	66	51	60	84	120
Snubnose pompano	-	331	329	325	-	30	12	7	32	49	19	26	76
Russell's snapper	-	-	-	-	300	296	192	83	263	392	231	115	72
Snappers nei	93	92	53	42	81	64	36	70	152	61	29	9	51
Jacks, crevalles nei	-	-	-	-	-	-	-	4	13	9	-	4	36
Threadsail filefish	-	-	-	-	7	-	-	35	9	3	-	3	19
Goldlined seabream	1 253	963	956	943	240	799	180	64	86	82	19	6	17
John's snapper	-	-	-	-	-	-	-	-	-	-	-	10	11
Spotted coralgrouper	-	-	-	-	-	-	-	-	-	-	-	16	7
Malabar grouper	-	-	-	-	-	-	-	-	-	-	-	-	3
Tilapias nei	-	-	-	-	-	-	2	33	4	9	12	17	<0 .5
Blackhead seabream	118	103	80	-	18	16	13	7	15	24	-	-	-
Croakers, drums nei	-	-	-	31	27	28	39	72	71	148	269	228	-
Daggertooth pike conger	-	-	-	-	-	-	-	-	3	-	-	-	-
Hong Kong grouper	10	30	30	30	-	-	-	-	-	-	-	-	-
Snappers, jobfishes nei	-	-	-	-	-	-	157	61	16	63	311	254	-
Yellowback seabream	-	-	-	-	-	-	-	-	7	-	-	-	-
Crimson seabream	117	122	52	-	-	-	-	-	-	-	-	-	-
Filefishes nei	99	92	148	-	-	-	-	-	-	-	-	-	-
Okhotsk atka mackerel	-	-	-	-	19	-	-	-	-	3	-	5	-
TOTAL	**334 243**	**344 526**	**388 183**	**443 547**	**462 791**	**562 247**	**627 709**	**660 046**	**740 153**	**827 345**	**926 134**	**921 330**	**975 754**

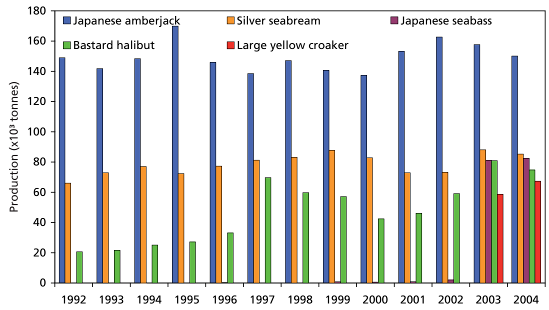
Source: FAO, 2006

salmonids. A brief description of the different groups is given below, together with some preliminary estimates of fingerling demand for grow-out.

The "Marine fish nei" category consists of marine fish that are not further identified in the statistics. This figure is heavily influenced by China, which until recently reported all its marine fish farming in this category. The reality is that China has a large diversity of species (see Chen *et al.*, this volume) and a fairly well developed hatchery industry that supports it.

Overall both brackishwater and marine farming is dominated by a few species. In the case of marine farming, which is almost entirely cage farming, the leading species are those that have been farmed for a long time, particularly in Japan, and the production of emerging marine species such as groupers and cobia is still in its infancy (Figure 5).

FIGURE 5
Top five cultured marine fin fish species in Asia



Groupers

Grouper production in Asia was estimated by FAO in 2004 at around 58 000 tonnes. Additional grouper production from Viet Nam (which is not reported separately from other marine finfish production) is likely around 2 000 tonnes per annum, bringing total global production to around 60 000 tonnes (Rimmer, Phillips and Yamamoto, 2006). Probably at least 70 percent of this grouper production relies on the collection of fry, fingerlings and juvenile fish from the wild. Grouper culture is expanding rapidly in Asia, driven by high prices in the live-fish markets of Hong Kong SAR and China, the decreasing availability of wild-caught product due to overfishing (Sadovy and Lau, 2002) and general consumer resistance to the wild-caught "live-fish" trade.

A diversity of grouper species are cultured, but only a few are produced in hatcheries to any significant extent. *Cromileptes altivelis*, *Epinephelus fuscoguttatus*, *E. coioides*, *E. malabaricus*, *E. akaara*, *E. lanceolatus*, *E. tukula*, *E. areolatus*, *E. tauvina* and *E. polyphekadion* are reported (Rimmer, Williams and Phillips, 2000; Rimmer, McBride and Williams, 2004) from hatcheries around the region and are expected to form the mainstay of grouper production in the future. Most grouper grow out is conducted in cages located in marine estuaries or sheltered coastal areas. Groupers are generally sold alive at a size range of 0.5–1.2 kg per fish, with the average weight for table-size fish being 850 g, requiring ready access to markets.

Snappers

There are several species of seabream cultured in Asia, mainly in more temperate parts of the region. These include squirefish (*Chrysophrys auratus*), goldlined seabream (*Rhabdosargus sarba*), black porgy (*Acanthopagrus schelgelii schlegelii*) and red seabream (*Pagrus major*). FAO statistics suggest around 135 000 tonnes were produced in Asia in 2004. Seabreams are a mainstay of Asian finfish mariculture. Most seabream fingerlings are hatchery produced, and there is a well developed hatchery system in East Asia. The market sizes for seabream range from 350 to 450 g. Marine cage culture is the predominant means of culture.

Amberjacks and other Carangids

The Japanese amberjack (*Seriola quinqueradiata*) is the main marine fish species cultured in Asia (Figure 5), comprising 17 percent of total marine finfish production, with just under 160 000 tonnes produced in 2003 (FAO, 2006). Nearly all of this production comes from Japan, where production has been relatively stable at 140 000–170 000 tonnes per annum since the 1980s. Most if not all these fish are cultured in cages. Other carangids that are becoming popular for culture are snubnose pompano (*Trachinotus blochii*) and silver pomfret (*Pampus argenteus*).

Mackerel

Japanese jack mackerel (*Trachurus japonicus*) is the main mackerel species cultured. Okhostk atka mackerel (*Pleurogrammus azonus*) is also farmed, but only contributes a small portion to mackerel production. Some Japanese jack mackerel are cultured in marine cages in East Asia.

Cobia

Cobia (*Rachycentron canadum*) is increasingly being cultured in more subtropical and tropical waters, including in Taiwan Province of China, China, Malaysia and Viet Nam. Production, while still small, has increased significantly over the past three years. Most production currently comes from China and Taiwan Province of China and totaled around 20 000 tonnes in 2003 (FAO, 2006). Production of this fast-growing (to 6 kg in the first year) species is set to expand rapidly, not only in Asia but also in the Americas.

Cobia fingerlings used for aquaculture are mainly hatchery produced, with Taiwan Province of China being one of the first to establish hatchery production. Seed production in 1999 was around three million fingerlings of about 10 cm with a market value of US$0.50 per fish. The average adult fish for market is quite large, 6–8 kg; however the market size varies from country to country. Cobia is becoming a popular fish because of its fast growth and its relatively easy culture. The survival rate in grow out is high, and it is not difficult to obtain 90 percent average survival. Most cobia is produced in marine fish cages.

Barramundi

Production of barramundi (also known as Asian seabass, *Lates calcarifer*) increased during the past ten years, and FAO statistics estimated that 26 000 tonnes were produced in 2004 (FAO, 2006). Barramundi farming in Asia is carried out in freshwater, brackishwater and marine environments, with most production based on hatchery-reared stock. Global production has been relatively constant over the past 10 years at around 20 000–26 000 tonnes per annum, although production has decreased in Asia and increased in Australia during this time. Most barramundi is cultured in ponds and cages located in brackishwater estuaries or coastal areas.

Milkfish

Milkfish (*Chanos chanos*) production in Asia is significant, with Indonesia and the Philippines contributing the bulk of the 515 000 tonnes as reported by FAO in 2004. Production, which has been increasing in the past 10 years, is based on wild fry and increasingly, on hatchery-produced fry. Milkfish culture takes place in coastal brackishwater ponds and to some extent in cages and pens. Milkfish aquaculture has a long tradition in the Philippines, where this fish is an important food item. Indonesia is a major producer of seed, much of which comes from "backyard" or small-scale hatcheries. Most of the milkfish produced in Indonesia is used for bait by the Japanese tuna fishery. There is also a tradition of milkfish culture in some Pacific Islands, including Kiribati, Nauru, Palau and the Cook Islands. Although most milkfish culture is undertaken in brackishwater ponds, there is increasing production from intensive marine cages where the fish are fed pellets or trash fish.

Other species

A wide range of other species are cultured, including pompanos, rabbitfish, threadfins, croakers, drums, gobies, puffers, scorpion fishes and others. Many of these species are grown at least on an occasional basis in marine cages.

COUNTRY PROFILES

South Asia

South Asia comprises India, Sri Lanka, Pakistan, the Maldives and Bangladesh. This subregion has very little marine fish culture (there is none reported in FAO statistics), although capture and holding of marine fish for the live reef fish trade is carried out in the Maldives and India.

In India, the live reef fish trade is mainly based on capture and holding in cages on the Andaman and Nicobar islands, which have some good coral reef fisheries. There are some new semi-government hatchery developments for barramundi (e.g. Rajiv Ghandi Centre for Aquaculture in Tamil Nadu and the Central Institute of Brackishwater Aquaculture in Chennai), and marine fish farming is expected to develop slowly in the future. A private hatchery near Mumbai reportedly produced around 10 million barramundi fry in 2003; however the present status is unknown. New investments are planned for 2006 for a marine fish hatchery and grow-out farm on the Andaman Islands, with support from the Marine Products Export Development Authority (MPEDA).

There is no marine fish farming in Pakistan or Bangladesh, except for the collection of by-catch of barramundi, mullet and other species in brackishwater shrimp ponds in the latter country. The Maldives has a grouper export industry to the live reef fish trade and is interested in grouper farming, but there have been no marine fish-farming developments to date. Feasibility studies for mariculture are being planned in the Maldives, which may lead to some investments in marine fish farming in the near future.

Southeast Asia

Southeast Asia comprises Brunei, Myanmar, Thailand, Malaysia, Singapore, the Philippines, Indonesia, Cambodia and Viet Nam. This subregion is an increasingly important producer of marine fish from aquaculture, as well as a supplier of marine fish for the live reef fish trade.

Myanmar

Groupers (*Epinephelus* spp.), known locally as "*kyauk nga*" or "*nga tauk tu*", are exported live and in chilled/frozen forms. Live groupers are exported primarily to Hong Kong Special Administrative Region (SAR) for the live reef fish trade, and a boat carrying live fish travels to Myanmar four or five times per year, reportedly carrying five to six tonnes each time. This suggests a production of 30 tonnes/yr, which is an underestimate, but total farmed production is probably less than 100 tonnes/yr. Marine fish farming occurs in the Ayeyarwady Delta area, in Rakhine and in southern Myanmar. There is some extensive pond culture of barramundi, which is also collected as a by-product of traditional "trap and hold" shrimp ponds. Some fry and fingerlings have been imported from Thailand.

Groupers are cultured using fry and juveniles caught from the wild. Floating net-cage culture is conducted in the coastal areas of southern and western Myanmar (Myeik Archipelago and Gwa Township). Approximately 20 species of groupers are found in Myanmar's waters, but so far only four have been cultured to any significant scale – orange-spotted grouper (*E. coioides*), greasy grouper (*E. tauvina*), Malabar grouper (*E. malabaricus*) and duskytail grouper (*E. bleekeri*).

No marine fish hatcheries currently exist in Myanmar. A private entrepreneur is planning to establish a grouper hatchery on the western side of the Ayeyarwady Delta, and the government is planning to build two or three marine fish hatcheries in the southern and western parts of the country. The government also plans to establish a marine aquaculture station at Kyun Su Township in Tanintharyi Division.

Thailand

Six groupers (*Epinephelus coioides*, *E. malabaricus*, *E. areolatus*, *E. lanceolatus*, *E. fuscoguttatus* and *Plectropomus maculatus*) and two snappers (*Lutjanus argentimaculatus* is the main species), as well as barramundi, squaretailed mullet (*Liza vaigensis*) and milkfish are cultured in Thailand. Barramundi and groupers (primarily *E. coioides*) contribute some 99 percent of the marine fish farmed in Thailand, barramundi comprising about 85 percent of the total (14 550 tonnes) in 2004, while groupers accounted for 14 percent (2 395 tonnes) (Table 5).

Marine fish culture in Thailand takes place on the East Coast and the West Coast of the Gulf of Thailand, and on the Andaman Sea Coast. The East and West coasts contribute 30 and 20 percent of the marine fish production in Thailand, respectively, while the Andaman Sea Coast contributes the remaining 50 percent. The Andaman Sea Coast probably has the greatest potential for future development. Eighty percent of Thailand's marine fish grow out takes place in cages, with the remainder occurring in ponds.

Some statistics on marine production and culture areas are provided in Tables 5 and 6. Barramundi is cultured in marine, brackish and freshwater, whereas groupers are cultured mainly in the sea. Farmers prefer cage culture to pond culture because partial harvesting of live fish for market is easier, cages are more conveniently managed and the costs of initial investment are also lower. For security, cages are always kept in front of farmers' houses or adjacent to floating guard houses. In the marine environment, farmers prefer to stock groupers due to their higher price. However, they may shift to stocking with barramundi seed if grouper seed is

TABLE 5
Production (tonnes) from brackishwater and marine fish farming in Thailand

Species	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Barramundi (*Lates calcarifer*)	3 884	4 087	4 090	6 812	6 056	7 752	8 004	11 032	12 230	14 550
Groupers nei	674	774	793	1 390	1 143	1 332	1 443	1 170	2 338	2 395
Mossambique tilapia (*Oreochromis mossambicus*)	327	602	283	267	128	190	30	27	19	23
Squaretail mullet (*Liza vaigensis*)	246	363	295	288	32	26	20	9	11	10
Fourfinger threadfin (*Eleutheronema tetradactylum*)		409	155	4	-	-	-	-	-	-
Total	**5 131**	**6 235**	**5 616**	**8 761**	**7 359**	**9 300**	**9 497**	**12 238**	**14 598**	**16 978**

Source: based on FAO (2006) statistics

TABLE 6
Production of barramundi and grouper in ponds and cages in Thailand in 2000

Culture system	No. farms	Area (m²)	Quantity (tonnes)	Value (million US$)
Barramundi				
Pond	378	4 516 464	1 414.10	2.89
Cage	2 805	265 517 800	6 256.51	14.47
Total	3 183	270 034 264	7 670.61	17.36
Groupers				
Pond	154	1 116 656	357.91	2.05
Cage	1 983	148 876	989.88	5.93
Total	2 137	1 265 532	1 347.79	7.98

Source: Department of Fisheries, Thailand

not available. In brackish and freshwater areas, barramundi is commonly cultured in cages along rivers and canals in close proximity to the live fish markets of main cities and tourist spots, in order to save transportation costs and achieve good survival. Barramundi is also becoming increasingly available in chilled forms through supermarket chains in Bangkok.

There are an estimated 5 000–6 000 farms producing brackishwater and marine fish in Thailand in cages and ponds. Further detailed information from the most recently available Department of Fisheries statistics (for 2000) are shown in Table 6.

Most marine fish farms in Thailand are small-scale, and farmers usually feed the stock with trash fish. Trash fish cost around US$0.15-0.2/kg, and the food conversion ratio (FCR) for trash fish is around five to six[3]. Farm-made moist diet is also being tried for grow out, although progress is limited. Commercial floating pellet is also used in hatcheries and for adult fish; however, farmers still believe that growth performance is not as good as with fresh feed.

Barramundi seabass is produced mainly for local markets and is also exported chilled and live to Singapore and Malaysia by land. Some grouper production is exported (live by air) to Hong Kong SAR and China, and some is sold live in local markets, particularly live seafood restaurants. In 2003 the price for table-size barramundi (500–600 g) was US$2.5-3/kg and for grouper around US$4-5/kg. Although there is good potential for expansion of barramundi culture, in terms of availability of land, good water sources, fry and fingerling production, know-how, skilled labour, feed and expanding domestic markets, the lack of export markets for frozen table-size fish is a major constraint. Farmers also consider it not economic to culture large barramundi (e.g. 1–3 kg) for export of fillets because of stunting problems after 600–800 g.

Major problems for the grouper grow-out industry in Thailand include market access and fluctuating prices (because Thai groupers do not have a good reputation among Hong Kong importers), lack of reliable seed supply, feed availability and disease. While there has been some interest in establishing large-scale "industrial" marine fish farms in Thailand, no projects have yet materialized. A new Norwegian public/private investment in southwest Thailand, however, may start in 2006.

Malaysia

In Malaysia, government agricultural policy is actively encouraging investment in aquaculture, and there has been increasing number of marine and brackishwater aquaculture operations. Cage culture has received special attention. Cage farming takes place in protected coastal waters, especially in the states of Perak (26 percent), Johor (21 percent), Penang (20 percent), Selangor (20 percent) and Sabah (9 percent) (year 2000 estimates).

The marine and brackishwater finfish species cultured in Malaysia include barramundi, snappers, groupers, travelly, pompano, threadfin, cobia and tilapia (Table 7).

TABLE 7
Species of interest in Malaysian mariculture

Common name	Scientific name
Barramundi	*Lates calcarifer*
Yellowstreaked snapper	*Lutjanus lemniscatus*
Mangrove red snapper	*L. argentimaculatus*
John's snapper	*L. johnii*
Crimson snapper	*L. erythropterus*
Orange-spotted grouper	*Epinephelus coioides*
Malabar grouper	*E. malabaricus*
Sixbar grouper	*E. sexfasciatus*
Brown-marbled grouper	*E. fuscoguttatus*
Leopard coraltrout	*Plectropomus leopardus*
Humpback grouper	*Cromileptes altivelis*
Fourfinger threadfin	*Eleutheronema tetradactylum*
Cobia	*Rachycentron canadum*
Red tilapia	*Oreochromis* sp.
Snubnose pompano	*Trachinotus blochii*

Source: Department of Fisheries, Malaysia

[3] US$1 = 40 THB

Farmers switch species depending on markets and disease problems. The number of species coming into play has increased drastically over the past five years, following hatchery breeding success.

Barramundi, a traditional species, still leads in culture practice. Snappers (Lutjanidae) are next in importance; these include the yellowstreaked snapper (*Lutjanus lemniscatus*), the mangrove red snapper (*L. argentimaculatus*), John's snapper (*L. johnii*) and the crimson snapper (*L. erythropterus*). Interest in grouper culture has led to at least six species being introduced. Commonly cultured species include brown-marbled grouper (*Epinephelus fuscoguttatus*), orange-spotted grouper (*E. coioides*) and Malabar grouper (*E. malabaricus*). Other minor species include fourfinger threadfin (*Eleutheronema tetradactylum*), cobia (*Rachycentron canadum*), snubnose pompano (*Trachinotus blochii*) and red tilapia (*Oreochromis* sp.).

In Malaysia the main production system for marine fish is still floating net-cages. Pond production may be suitable for high-value fish species that require water of higher salinity than that found in inland ponds. However, fish cultured in ponds are susceptible to an off flavor, and pond systems may not be convenient for producing fish for the live-fish market.

Seeing its potential, the Malaysian Department of Fisheries ventured into mass production using deep sea cages a decade ago. However, progress has been rather limited; as of end of 2005 there were 100 units of the square-type cages measuring 6 x 6 m each and a total of 21 units of round type-cages with a diameter of 15 m each. All of these cages were located at Langkawi Island, off peninsular Malaysia's northwestern coast. The main reason for slow growth of the deep-sea marine farming sector seems to be the seed supply.

TABLE 8
Facilities and operators involved in Malaysian marine fish culture from 2002 to 2004

Facilities	2002	2003	2004
Hatcheries (units)	12	59	56
Cages (m^2)	940 948	1 034 664	1 110 221
Cage operators (individuals)	1 374	1 651	1 623

Source: Department of Fisheries, Malaysia

Until a new system of fish production or cage culture technology is introduced, traditional floating cages will continue to be the main marine fish production system. As of 2003 and 2004 there were a total of 1.0 million square metres of cage area, an increase of about 14 percent from year 2002 (Table 8). These cages were run by about 1 400 and 1 600 operators during the production years 2002 and 2003/2004, respectively (Table 8). The majority are small-scale farmers who operate small (3 x 3 m) to medium-size (6 x 6 m) cages. Stocking varies from 300 to 1 000 fingerlings per cage, the culture period extending 6-12 months depending on the species. Because of its low price and ready availability, trash fish remains the major feed type, and commercial feed is only occasionally supplemented. Many farmers believe that trash fish produces fish of higher quality and better texture.

In recent years increased intensification in production and area of cage farming has led to many disease problems. Frequent reports of mass mortalities related to water quality and oxygen depletion have occurred. Die-hard farmers seem to

TABLE 9
Production statistics and wholesale value for marine and brackishwater fish farming in Malaysia, 2002–2004

Year	2002	2003	2004	2002	2003	2004
Fish species	**Production (tonnes)**			**Value (Malaysian Ringgit)**		
Barramundi (*Lates calcarifer*)	4 003.73	4 210.93	4 000.54	46 220.13	49 260.86	46 241.57
Mangrove red snapper (*Lutjanus argentimaculatus*)	591.44	706.56	572.97	6 157.05	8 415.69	7 742.36
Yellowstreaked snapper (*L. lemniscatus*)	1 556.15	2 351.55	2 263.33	20 188.00	32 491.55	32 771.81
Crimson snapper (*L. erythropterus*)	989.68	1 402.09	1 162.85	12 951.31	18 513.27	14687.02
Groupers	1 210.43	1 977.33	2 283.59	30 385.26	49 954.09	54 628.69
Tilapias	283.97	222.07	264.42	1 683.98	1 049.09	1 387.08
Total	**8 635.4**	**10 870.53**	**10 547.70**	**117 585.73**	**159 684.55**	**157 458.53**

Source: Department of Fisheries, Malaysia take this for granted and are willing to invest in new operations despite these losses.

In Langkawi, three large projects initiated for cobia using fry imported from Taiwan POC seem to be successful except that the farms have problems with marketing. Plans are on line to breed cobia and also work on giant grouper. Cage-fish production is also growing in eastern Malaysia (Malaysian Borneo), particularly in the Tuaran and Sandakan areas of Sabah, where there are plans to expand large-scale cage farming.

Production of the major species has fluctuated in recent years, and grouper is the only species-group that has shown continuous growth (Table 9).

Indonesia

Indonesia is the largest producer of marine finfish in Southeast Asia and has major development potential. According to government statistics, the potential marine aquaculture area is around 2 million ha and there are also 913 000 ha of land-based brackishwater areas. Present estimates suggest that 0.17 and 45.4 percent, respectively, are in use. Therefore, the potential for marine aquaculture is considered by both government and some industry sources to be particularly high.

The main species groups cultured are barramundi, milkfish, grouper and snapper (Table 10). Other species that are considered to have potential for future development include the bigeye trevally (*Caranx sexfasciatus*), golden trevally (*Gnathanodon speciosus*), humphead wrasse (*Cheilinus undulatus*) and tunas (*Thunnus* spp.). There is a recent Japanese investment in a tuna hatchery in Bali, which will be interesting to watch over the next few years.

According to FAO statistics, the total production of marine and brackishwater fish in Indonesia was estimated at 305 000 tonnes in 2004. The bulk of this production is milkfish (241 000 tonnes), with smaller quantities of grouper (6 552 tonnes), barramundi (2 900 tonnes), mullet and tilapia. However, these figures are almost certainly under estimated, but more up-to-date or accurate figures are not available.

TABLE 10

Aquaculture species and the status of their development in Indonesia

Species		Status of development[1]	
Common name	Scientific name	Grow out	Hatchery
Milkfish	*Chanos chanos*	D	D
Barramundi	*Lates calcarifer*	D	D
Mangrove red snapper	*Lutjanus argentimaculatus*	ED	R/D
Emperor red snapper	*L. sebae*	ED	R/D
Rabbitfish	*Siganus* spp.	D	R/D
Humpback grouper	*Cromileptes altivelis*	LD	D
Brown-marbled grouper	*Epinephelus fuscoguttatus*	LD	D
Malabar grouper	*E. malabaricus*	ED	R/D
Camoflage grouper	*E. polyphekadion*	ED	D
Giant grouper	*E. lanceolatus*	ED	R/D
Orange-spotted grouper	*E. coioides*	ED	D
Leopard coralgrouper	*Plectropomus leopardus*	ED	R/D
Humphead wrasse	*Cheilinus undulatus*	ED	R/D

D = developed, ED = early development, LD = limited development, R/D = under research and development
Source: Directorate of Aquaculture, Indonesia

TABLE 11

Estimated annual production of fry and fingerlings of marine finfish from hatcheries in Indonesia

Species	1999	2000	2001	2002
Milkfish (*Chanos chanos*)	227 989 617	NA	240 000 000	NA
Barramundi (*Lates calcarifer*)	15 000 000	NA	NA	NA
Groupers (*Cromileptes altivelis*, *Epinephelus* spp.)	186 100	287 000	2 742 900	3 356 200

NA = not available
2001 data on milkfish are unpublished data from private hatcheries.
Data for grouper seed production are from Kawahara and Ismi (2003).

Milkfish have been cultured in traditional coastal ponds (“tambaks”) for several hundred years in Indonesia. Grouper and barramundi culture is a more recent activity. Grouper farming relies on a mixture of wild-caught and hatchery-produced fingerlings, but is increasingly shifting to the latter. Barramundi production, although small by Indonesian standards, has increased significantly in the past 10 years. However, production peaked in 2001 at 9 300 tonnes and has been constant at around 4 000 to 5 000 tonnes since then.

Grow out is carried out in many areas of Indonesia, and grouper farming in particular is growing fast, especially in the Lampung area of southern Sumatra. Cage culture can be found throughout Indonesia, including the islands Sumatra, Bangka, Bengkulu, Lampung, Kepulauan Seribu, Banten, Java, Lombok, Kalimantan and Sulawesi. However, much of this culture is based on wild fish seed. Recent developments in Lampung have been largely driven by the availability of hatchery-reared grouper seed. The estimated annual hatchery production of marine finfish fry and fingerlings in Indonesia is presented in Table 11. Milkfish make up the bulk, with 240 million produced in 2001. Hatchery production of grouper is expanding, with 3.56 million produced in 2002. Of this total 2.7 million were brown-marbled grouper (*Epinephelus fuscoguttatus*), just less than 0.7 million were humpback grouper (*Cromileptes altivelis*) and the remainder were orange-spotted grouper (*E. coioides*) from the Lampung area.

The increase in grouper hatchery production in Gondol on the island of Bali has been very significant since 2002. Initially hatchery-produced fingerlings targeted export markets, but the demand was not consistent. This created a surplus of grouper fingerlings, particularly for brown-marbled and humpback groupers. To boost the domestic demand for grouper fingerlings, the government encouraged the development of marine fish culture. As a result, there has been a major development of grouper grow out in Indonesia over the last few years, particularly in the Province of Lampung where many large-scale grouper farms have been established. As a result, grouper fingerling production jumped from 2.7 million in 2001 to 3.3 million in 2002.

Constraints to marine fish farming in Indonesia include access to markets, fluctuating prices, insufficient hatchery supply, diseases (particularly viral nervous necrosis, VNN) and iridoviruses, which are both significant in hatcheries) and lack of suitable feeds for grow out.

The Philippines

In 2004 Philippine production of marine finfish reached 23 542.35 tonnes in marine cages and 14 294.42 tonnes in pens. Commodities produced include milkfish, grouper and other marine species (Table 12).

Milkfish is an important aquaculture commodity in the Philippines. For the past five years, production has steadily increased from 194 023 tonnes in 2000 to 269 930 tonnes in 2004, with an average annual growth rate of 8.7 percent (Table 13). Freshwater culture contributed 10 percent to the total milkfish production; brackishwater recorded the highest share (77.4 percent) due to improved practices, increased stocking density and expansion of operations, while marine cages and pens contributed 12.6 percent, an amount that has increased recently.

Major problems affecting marine fish farming in the Philippines include degradation of fingerling quality due to inbreeding, insufficient supply of quality fry in far flung areas, high cost of farm inputs, poor quality of feeds, lack of manpower to transfer technology effectively to the municipal level, marketing layers that stand between producers and consumers, and lost opportunities to participate in global markets for value-added products.

Viet Nam

Viet Nam has a growing marine fish-culture industry and with major government backing is embarking on a significant expansion programme. Government plans call for the production of

TABLE 12
Marine fish production (tonnes) from cages and pens in the Philippines in 2004

Culture system	Total	Milkfish	Groupers	Others
Fish cages	23 542.35	23 179.06	136.45	226.84
Fish pens	14 294.42	14 172.61	33.69	88.12
Total	37 836.77	37 351.67	170.14	312.96

Source: Philippine Fisheries Profile (2004)

TABLE 13
Philippine milkfish production (tonnes), 2000–2004

Year	Production
2000	194 023
2001	225 337
2002	231 968
2003	246 504
2004	269 930

Source: Philippine Fisheries Profile (2004)

200 000 tonnes of marine fish by 2010. Viet Nam therefore, has a potentially significant emerging marine fish-culture industry.

Marine finfish are cultured in three main areas of Viet Nam: the northern coastal areas, which produce around 600 tonnes; the south-central areas, which produce around 900 tonnes; and the east and southern parts, which produce 1 100 tonnes, giving a total production for the country of 2 600 tonnes in 2001. These Ministry of Fisheries figures are probably underestimates, the total farmed marine fish production in 2002 probably being at least 5 000 tonnes. There was considerable investment in hatcheries and cages ongoing during 2003, and the industry is expected to expand significantly in the next five years.

Eleven marine fish species are common in marine cages and ponds in Viet Nam's coastal waters (Table 14). These include cobia, which is increasingly popular in the north and also beginning to be cultured in the south-central provinces, barramundi, several grouper species and snappers. The main grouper species are orange-spotted grouper and Malabar grouper, with smaller amounts of brown-marbled grouper and duskytail grouper being produced.

Marine fish in Viet Nam are grown in cages and ponds. The farms tend to be small family-owned operations, although industrial-scale developments are also starting. According to the Department of Aquaculture (Ministry of Fisheries), the total number of cages in 2004 was 40 059 (not including cages for cultivated pearls). Production of fishes and lobsters for the year 2005 is estimated at 5 000 and 1 795 tonnes, respectively. Cage culture has developed mostly in Quang Ninh, Hai Phong, Thanh Hoa, Nghe An, Ha Tinh, Phu Yen and Ba Ria –Vung Tau provinces. There are two kinds of cages: wooden frame cages of 3 x 3 x 3 m or 5 x 5 x 5 m are the most popular cages in most provinces, while Norwegian-style cages with plastic frames that can withstand 9–10 level winds and waves are popular in Nghe An and Vung Tau These Norwegian style cages (Polar circle type) were introduced to Nghe An three or four years ago, and in 2003 a local company started to manufacture similar cages from local materials. A large-scale Norwegian investment is also in the early development stages for Nha Trang in central Viet Nam, and a local company is developing a large-scale operation in Nghe An (possibly 100 plus cages). There is cobia farming with Taiwanese management near Vung Tau in southern Viet Nam, but it is facing problems with low prices and limited markets. The fry are imported from Taiwan POC and are fed with trash fish and a mixture of mash and trash fish.

TABLE 14
Main finfish species used for mariculture in Viet Nam

Species	Sources of seed
Epinephelus coioides	Hatchery + Wild
E. tauvina	Wild + Hatchery
E. malabaricus	Wild
E. bleekeri	Wild
Rachycentron canadum	Hatchery
Lates calcarifer	Hatchery + Wild
Psammoperca waigensis	Hatchery
Lutjanus erythropterus	Wild
Rhabdosargus sarba	Wild
Sciaenops ocellatus	Hatchery
Siganus sp.	Wild

More than 90 percent of marine fish farms use trash fish, with some farms (perhaps 10 percent) using farm-made feeds with trash fish as the main ingredient, mainly for the first phase of grow out. The use of manufactured feed is not common. In 2004 Viet Nam had 30 feed mills producing 81 000 tonnes of feeds for aquaculture, contributing 55 percent of total consumption; however, as yet there is no domestic production of feeds for marine finfish. Nearly one million tonnes of trash fish is currently used as direct feed in aquaculture in Viet Nam, the bulk of it in mariculture (Edwards, Tuan and Allan, 2004).

Viet Nam is in the process of expanding marine fish farming, with a production of 200 000 tonnes predicted in government plans for the industry by 2010. Several trials and species look promising, however there are still several constraints. These include a need to develop markets, hatchery and nursing technologies, and feed alternatives to trash fish, and problems with disease control and health management. Feeds are likely to be a major constraint, and hatchery development will be essential to support future growth.

Singapore

Singapore has a small marine fish-farming industry, supplying mainly fresh and live fish to local markets. The total production of brackishwater and marine fish in 2004 as reported in FAO statistics was only 2 366 tonnes, the majority (2 308 tonnes) being marine fish. Most marine fish are produced in cages, and a smaller number are grown in brackishwater ponds. Fry for stocking of cages are mainly imported.

Although marine cage culture has been conducted in Singapore for several decades, the government is now promoting the development "industrial" aquaculture. A Marine Aquaculture Centre (MAC) has been opened at St John's Island for mariculture development activities. The centre was set up to develop and harness technology to facilitate the development and expansion of large-scale hatcheries and fish farming in Singapore and the region. The Centre aims to promote the reliable supply of a variety of tropical foodfish to local consumers as well as establish benchmarks on price and quality of fish in the market; help stabilize Singapore's fish supply and reduce dependence on foodfish caught from the seas, since this is not sustainable in the long term; and promote the culture of fish using good quality and healthy fry that can be grown to market size using good and safe farming practices (e.g. minimal use of antibiotics and other drugs).

East Asia

East Asia comprises China, the Republic of Korea, Hong Kong Special Administrative Region (Hong Kong SAR), Japan and Taiwan Province of China. This subregion is the region's largest producer of marine fish from aquaculture, as well as a major market for other parts of Asia. As far as the authors are aware there is no cage farming in the Democratic People's Republic of Korea and therefore it is not considered here.

Hong Kong Special Administrative Region

There are about 1 400 mariculture farms with an average size of 250 m^2 covering a total area of 335 500 m^2 of sea and one land-based private experimental farm using a water recirculating system. Cage culture is the only commercial marine aquaculture system being used in Hong Kong SAR, and there is no major expansion plan for mariculture. The industry has suffered various setbacks in recent years, including devastating red tides, and fish farmers have found it difficult to compete with the neighboring provinces of China. The total marine fish production in 2001 was 2 468 tonnes valued at HK$136 million[4].

The consumption of live marine fish, popularly referred to as the live fish restaurant trade, in Hong Kong SAR was about 19 200 tonnes in 2001. Aquaculture production contributed only 13 percent; capture fisheries accounted for 8.2 percent; and the remaining 74 percent was derived from importation, which was worth US$128 million.

There are about 14 marine fish species being cultured in Hong Kong SAR (Table 15). Grouper is the main species group, contributing 37 percent of the total marine fish production. The second main species group is snapper, which accounted for 29 percent of the total marine fish production in 2001.

Trash fish, moist diet and dry pellets are used for grow-out culture. There are no precise data on the volume of feed used. The price of trash fish is about HK$1/kg, while the price of dry pellets ranges from HK$5-10/kg, depending on the nutritional content.

There is no marine fish hatchery in Hong Kong SAR, but local fishfarmers have established a few hatcheries and nurseries in Guangdong, China. According to the fry/fingerling traders in Hong Kong SAR, many of the fish originate from such hatcheries, as well as from Taiwan Province of China, Thailand, the Philippines and other Southeast Asian countries. The normal price for green and brownspotted (*E. chlorostigma*) grouper fingerlings ranged from HK$8 to 12 (10–15 cm length), and for seabreams and snappers, from HK$1 to 2 (for fish of 2.5 cm length). The value of fingerlings imported to Hong Kong SAR in 2001 was US$7.8 million.

TABLE 15
Major marine fish species cultured in Hong Kong SAR in 2001

Species	Percentage of total
Greasy grouper (*Epinephelus tauvina*)	27
Cobia (*Rachycentron canadum*)	17
Russell's snapper (*Lutjanus russellii*)	16
Brownspotted grouper (*E. chlorostigma*)	10
Red mangrove snapper (*L. argentimaculatus*)	5
White blotched snapper	5
Head grunt	5
Crimson snapper (*L. erythropterus*)	3
Goldlined seabream (*Rhabdosargus sarba*)	3
Japanese meagre (*Argyrosomus japonicus*)	2
Pompano	2
Red drum (*Sciaenops ocellatus*)	2
Black porgy	1
Yellowfin seabream (*A. latus*)	1
Others	1

[4] HK$8=US$1.

China

The development and current status of cage and pen culture in China is described in detail elsewhere in this volume (see Chen *et al*., this volume), and thus will only be briefly mentioned. China has a coastline of 18 400 km with 1 million km^2 of area suitable for aquaculture, and 0.13 million km^2 of area suitable for marine finfish culture. The country has a large marine area covering both temperate and subtropical waters, so there are many finfish species found in Chinese aquaculture. At present, more than 50 species of marine finfish are being cultured. China is the region's largest producer of farmed marine fish, and its marine fish farming is certain to expand further. In line with the country's rapid economic development, the market demand for marine fish is very large, especially the demand for high-value species.

Japan

The importance of mariculture production to Japanese fisheries is growing, and it presently provides around 20 percent of products by quantity. The gross value of Japanese mariculture production is around US$3.8 billion. Major mariculture species include seaweeds, yellowtail, red seabream, Japanese oyster, amberjack and scallops. New target species for marine fish farming include northern bluefin tuna (*Thunnus thynnus*), barfin flounder (*Verasper moseri*) and groupers (*Epinephelus* spp.).

The most serious problem faced by mariculture in Japan is self-pollution from marine net cages. The level of pollution by Japanese mariculture is estimated to be equal to that produced by five to ten million people. These results clearly show the importance of environmental management of marine aquaculture.

Recently there has been considerable interest in bluefin tuna because of its high market value and demand in Japan, the decreased wild fish populations, and increased regulation of pelagic fisheries, the technical development of methods for the production of high-quality fish and the successes in production of artificial seed. The barfin flounder is an important species that can grow to a large size. Because of its high commercial value and rapid growth in the cold waters of northern Japan, the culture of this species has been expanding in Hokkaido and Iwate prefectures. Grouper culture has been practiced in the western part of Japan, but many aquaculture producers have hesitated with this species because of disease problems, particularly viral nervous necrosis (VNN).

Taiwan Province of China

Taiwan Province of China has a well-developed marine fish industry and is a major supplier of seed to other countries throughout the region. In 1998 over 64 species of marine fish were under culture, 90 percent of which were hatchery produced. The total production of marine and brackishwater fish in 2004 is estimated at around 58 000 tonnes. The cultured species include grouper, seabream, snapper, yellowtail, cobia, barramundi and pompano. Recent developments include expansion of cobia culture using large "offshore" cage technology, with cages that can be submerged during typhoons.

Some 2 000 freshwater and marine fish hatcheries are estimated to be operating in Taiwan Province of China, with a production worth over US$70 million. In recent years Taiwanese hatchery operators have increasingly been involved in the establishment and operation of hatcheries in China and in other countries. Connections with Fujian Province seem to be particularly strong.

Marine finfish production is typified by highly specialized production sectors, e.g. one farm may produce grouper eggs from captive broodstock, a second will rear the eggs, a third may rear the juveniles through a nursery phase (to 3–6 cm TL) and a fourth will grow the fish to market size.

Taiwanese hatcheries typically use either indoor (concrete tanks up to 100 m^3 with intensive greenwater-culture systems) or outdoor (extensive pond-culture systems) rearing systems for larviculture. Indoor rearing systems are used for high-value species such as groupers. Other species such as some snappers and cobia are only cultured in outdoor systems because of their specific early feed requirements. The orange-spotted grouper (*Epinephelus coioides*) is the main grouper species cultivated. More recently, there has been some production of giant grouper (*E. lanceolatus*), which is popular with farmers for its hardiness and rapid growth (reported to grow to around 3 kg in its first year). Despite the high level of fingerling production, Taiwanese farms also rely on wild-caught fry and fingerlings, which are generally imported. Information from Taiwanese hatcheries suggests that more than 40 species of marine fish can be raised in large numbers. Among these are *E. coioides*, *E. lanceolatus*, *Trachinotus blochii*, *Lutjanus argentimaculatus*, *L. stellatus* and *Acanthopagrus latus*. Cobia production in Taiwan Province of China is well advanced, and the technology is gradually expanding through the region.

Republic of Korea

Total marine and brackishwater fish production in the Republic of Korea was estimated as 64 000 tonnes in 2004. Lower production in 2000 and 2001 was considered to be due to increasing constraints on using coastal waters for mariculture and to environmental problems. The species cultured include Okhostk atka mackerel (*Pleurogrammus azonus*), bastard halibut (*Paralichthys olivaceus*), flathead mullet (*Mugil cephalus*), small numbers of groupers (*Epinephelus* spp.), Japanese amberjack (*Seriola quinqueradiata*), Japanese seaperch (*Lateolabrax japonicus*), squirefish (*Chrysophrys auratus*) and threadsail filefish (*Stephanolepis cirrhifer*). FAO statistics for 2004 show that the major cultured species are the bastard halibut (*Paralichthys olivaceus*) with 32 141 tonnes and the scorpion fishes (Scorpaenidae) with 19 708 tonnes.

Culture of marine fishes is mainly in cages, although some land-based farms have also been constructed in recent years. The marine subsector has experienced a sharp growth in recent years in terms of total quantity and value, with the production topped by two high-value species, bastard halibut (*Paralichthys olivaceus)* and Korean rockfish (*Sebastes schlegelii*) (Table 16). Bastard halibut is cultured in onshore tank farms while rockfish is farmed in offshore floating net-pens.

Currently, efforts are being made to further develop the offshore aquaculture technology in the Republic of Korea.

TABLE 16
Finfish mariculture production and species produced in the Republic of Korea in 2003

Species	Quantity (tonnes)
Bastard halibut (*Paralichthys olivaceus*)	34 533
Rockfish (*Sebastes schlegelii*)	23 771
Barramundi (*Lates calcarifer*)	2 778
Japanese amberjack (*Seriola quinqueradiata*)	114
Mullet (*Mugil cephalus*)	4 093
Red seabream (*Sciaenops ocellatus*)	4 417
Black porgy (*Acanthopagrus schlegelii schlegelii*)	1,084
Parrot fish (*Oplegnathus fasciatus*)	
Puffer (*Takifugu obscurus*)	14
Filefish (*Monacanthus* spp.)	
Convict grouper (*Epinephelus septemfasciatus*)	39
Okhostk atka fish (*Pleurogrammus azonus*)	
Total	72 393

Source: The Fisheries Association of Korea (2004)

CONSTRAINTS AND CHALLENGES TO BRACKISHWATER AND MARINE CAGE CULTURE DEVELOPMENT IN ASIA

The majority of constraints to development in brackishwater and marine cage culture in Asia are common to most nations. In considering the major constraints one has to bear in mind that, as yet, marine cage culture in Asia is still mainly restricted to the inshore areas, is often small scale, and apart from some practices in Japan, is of recent origin.

Availability of suitable sites

The rather simple cage designs utilized in the current practices, apart from a few exceptions, make it imperative that cages are sited in sheltered areas. This fact imposes a limitation on site availability for marine cage culture.

Experiences with larger, more robust cages such as those of Norwegian design have been less successful than expected, as exemplified by the case in Langkawi Island, Malaysia. This is primarily due to the fact that the supporting facilities to maintain such large cages have not been adequate, and consequently most cages have been not been used to their full capacity. Open-ocean cage farming in Asia, apart from in Japan and perhaps in the Republic of Korea and Taiwan Province of China, is believed to be a long way off. The South China Sea, which is shared by current and emerging aquaculture nations such as China, Viet Nam, Malaysia and others, is relatively shallow and has strong surface and bottom currents but less wave height, except during the seasonal severe typhoons. Accordingly, open-ocean cages for such areas need to be modified to reduce drag rather than to withstand wave height, as in the case of the Chilean and Norwegian operations.

Available sites for brackishwater cage farming in lagoons and estuaries in the main cage-farming countries are now almost fully utilized.

Fingerling supplies

The availability of hatchery-produced fry and fingerlings of truly tropical species such as groupers is rather limited. Unlike in Indonesia, grouper culture in countries such as Thailand and Viet Nam is almost entirely dependent on wild-caught juveniles, the availability of which is often unpredictable and of varied species composition. The cobia is the only emerging tropical mariculture species for which the life cycle has been fully closed and fingerling availability is not a limiting factor (Nhu, 2005).

TABLE 17
Average small-scale grouper hatchery operating costs (as % total) in Indonesia

Operating expenses	Gondol	Situbondo	Average
Brown-marbled grouper (*Epinephelus fuscoguttatus*)			
Fertilized eggs	7.4	8.7	8.0
Feeds	41.7	49.6	45.7
Chemicals and drugs	4.7	5.6	5.2
Electricity and fuel	4.1	4.9	4.5
Labour	36.3	24.2	30.2
Maintenance and miscellaneous	5.9	7.0	6.4
Humpback grouper (*Cromileptes altivelis*)			
Fertilized eggs	10.3	13.3	11.8
Feeds	31.5	40.6	36.0
Chemicals and drugs	3.3	4.2	3.8
Electricity and fuel	2.9	3.7	3.3
Labour	47.9	32.8	40.4
Maintenance and miscellaneous	4.1	5.3	4.7

Source: Sih, 2006

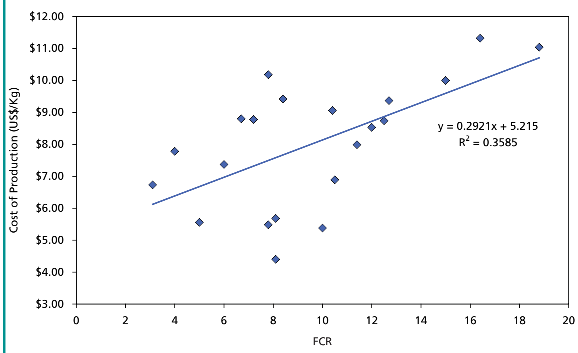
The above constraints are, however, being gradually overcome. For example, large quantities of grouper (*Epinephelus fuscoguttatus*, *E. coioides* and *Cromolepis altivelis*) are hatchery produced in Indonesia, *E. fuscoguttatus* and *C. altivelis* being commercially produced by the private sector. *Epinephelus coioides* and *E. fuscoguttatus* are two of the main species produced in Thailand, while the former is also produced in Viet Nam (Sih, 2006). According to Sih (2006) the grouper hatcheries in Indonesia are mostly small scale but profitable. Even though the survival rate to fingerling stage averages only 10–15 percent, it is often compensated by the high fecundity of groupers. Information on the cost of hatchery production of grouper fry in Indonesia is given in Table 17. Hatcheries are considered to be financially viable only if the price of grouper fingerlings is above 700 Indonesian rupiah (IDR)/fingerling[5]. Currently grouper cage culture in Indonesia is primarily sustained through fry and fingerlings supplied by government hatcheries.

Feeds

The total amount of trash fish used in Asian aquaculture is estimated to be about 4 million tonnes per year (Edwards, Tuan and Allen, 2004), the great bulk of which is used in marine cage farming in China, Hong Kong SAR, Indonesia, Thailand and Viet Nam. Trash fish in marine cage farming, particularly for grouper culture, is used directly (chopped into pieces whose size depends on the size of the stock), and the food conversion rates in Indonesian cage farms are reported to range from 6 to >17 (Sih, 2006). According to Sih (2006) the cost of producing a kilogram of grouper in cage-culture farms using trash fish in Indonesia, Thailand and Viet Nam, as expected with all types of feed, is directly correlated to the FCR (Figure 6). This relatively large range in FCR among grouper cage-farming practices indicates that there is significant scope for improving the efficacy of the use of trash fish, leading to greater cost effectiveness, less pollution and most importantly, a significant reduction in the quantity of trash fish used.

When marine cage culture initially started in Japan, it was almost entirely based on trash fish (Watanabe, Davy and Nose, 1989). It took a certain length of time to develop formulated feeds, and a major breakthrough in that era was the development of a soft-dry diet with high palatability for Japanese amberjack. This development continued to revolutionize feed development for marine cage farming and literally removed its dependence on trash fish (Watanabe, Davy and Nose, 1989). Of course, feed formulations and feed manufacturing technology for finfish have progressed much further now. Currently much research effort is being expended on feed formulation for emerging marine-cage-farming species in the Asian tropics such as grouper and cobia (Rimmer, McBride and Williams, 2004).

FIGURE 1
Relationship of cost of production to food conversion rate (FCR) in grouper cage farming in Indonesia, Thailand and Viet Nam using trash fish as the primary feed



Source: Sih, 2006

5 8 500 IDR = US$1.

The main reasons for the continued use of trash fish in grouper culture and in marine cage farming in general, are:

- farmer perceptions that stocks perform better on trash fish;
- the lower price of trash fish as compared to commercially available pelleted feed, and its continued ease of availability;
- the lack of availability of suitable commercial pelleted feed for all stages of the life cycle of cultured stocks; and
- social and economic constraints, including the availability of capital or credit to purchase commercial feed and the fact that collection and/or purchase of smaller quantities of trash fish on a regular basis is more compatible with the existing livelihood strategies of many coastal fish farmers as compared to more "organized" commercial feed lot farming.

Diseases

Increased intensification of culture practices has resulted in an increase of incidence of all forms of disease in marine finfish farming in Asia (Bondad-Reantaso, Kanchanakhan and Chinabut, 2002).

Arthur and Ogawa (1996) identified the principal diseases that are caused by environmental and management affects, nutritional causes, and viral, bacterial, parasitic and fungal pathogens in cultured marine finfish in Asia. Bondad-Reantoso, Kanchanakhan and Chinabut (2002) reported that several viruses affect cultured grouper species:

- nodavirus – viral nervous necrosis (VNN);
- iridoviruses – grouper iridovirus-1 (GIV-1), grouper iridovirus-2 (GIV-2), Singapore grouper iridovirus (SGIV) and Taiwan grouper iridovirus (TGIV);
- lymphocystis virus;
- herpes virus;
- astro-like virus (golden eye disease); and
- red grouper reovirus.

Although there have not been major disease outbreaks, except in isolated instances, there is much concern that further intensification and clustering of marine cage farming in restricted areas will lead to major epizootics.

It is also important to note that there is high degree of trans boundary movement of broodstock, fry and fingerlings across much of Asia. When such movements occur, little attention is often paid to their potential to spread serious exotic diseases, pests and invasive alien species, with related potential impacts on biodiversity and socio-economic well being.

Markets

One of the primary reasons for the recent increase in marine cage farming in the region, particularly of species such as grouper, is the increasing demand for live fish for the restaurant trade, particularly in China, Hong Kong SAR and Singapore, among others.

This increase in demand, hand in hand with consumer resistance to wild-caught "reef fish", particularly because of the destructive methods often used for catching (poisoning, dynamiting, etc.), has been responsible for the demand for farmed marine fish from this sector.

However, the live food-fish trade is a sensitive market, often being significantly affected by the economic conditions of importing countries and global catastrophic events such as the 9/11 terrorist attack, the occurrence of severe acute respiratory syndrome (SARS) and wars in general (Sih, 2005).

In such circumstances the demand is reduced significantly, and to obtain a fair price the farmers have added costs associated with holding their stock until conditions return to normality. Small-scale marine cage farmers often find it difficult to sustain themselves when such conditions prevail.

Technological challenges

Fry and fingerling survival rates of the major species raised in marine cage farming in Asia, groupers foremost among these, remain too low. For example, the current average rate of grouper survival is less than 15 percent. These low survival rates increase the current dependence on wild-caught seed stock.

Marine cage farmers do not yet accept the importance and cost effectiveness of using dry pelleted feeds for the long-term sustainability of the sector, and perhaps even for marketing purposes. In the future some importing nations may enact legislation to curtail the use of trash fish as a feed in marine fish farming and consequently place the farmers at a disadvantage.

Vaccines for preventing disease in such major species farmed as groupers and cobia are lacking.

Genetically improved strains of selected species that are pivotal to the development and sustenance of cage farming in Asia for faster growth and enhanced disease resistance have not yet been developed.

THE WAY FORWARD

This final section identifies some likely future trends in Asian cage culture and gives recommendations that will assist countries to meet the challenge of achieving continued growth of the sector while addressing the marketing, environmental and other challenges that have been mentioned in the preceding section:

- Most countries in the region have plans for the future expansion of marine fish farming, Viet Nam perhaps being the most ambitious. The next five years will see a transition of marine fish farming to hatchery-based aquaculture, as wild stocks diminish, production expands and restrictions are imposed on collection of wild fish for stocking of cages[6].
- The multiple use of coastal waters in countries such as the Republic of Korea will restrict further development of marine fish farming, and it is possible that local cage-culture industries will in some cases decline or at best remain static in the coming few years.
- Brackishwater cage farming in Asia uses relatively simple technology and occurs in clusters, a trend that is likely to continue in the foreseeable future.
- As hatchery techniques develop, marine fish demand increases and various constraints appear with wild stock collection, the industry is expected to focus increasingly on a few key species based on hatchery production.
- Cobia is set to become a global commodity, in the same manner that Atlantic salmon (*Salmo salar*) has become a global commodity in temperate aquaculture.
- As marine cage farming in Asia is based mainly on small-scale holdings, the management practices currently employed have considerable scope for improvement. The most potential for improvement lies in proper feed management, which is the single highest recurring cost in all practices. Other improvements to management practices that are required include reducing the use of chemicals and antibiotics, improving fry and fingerling transport and developing market chains and strategies.
- The optimum stocking densities for the species and systems currently in use in Asian marine cage culture should be established, and farmers should be encouraged to adopt polyculture where applicable.
- Farmers should be encouraged to use formulated feeds by stressing the negative impacts the use of raw fish may have on the environment. High-energy feeds with high digestibility should be formulated and used so as to reduce the nutrient load in effluents.
- The current dependence of the marine cage culture sector on trash fish should be reduced. This could be done in stages by:
    - initially demonstrating to the farmers ways and means of increasing the efficacy of using trash fish, such as through the adoption of better feeding management strategies;
    - using trash fish to prepare suitable "on-farm" moist feed using other additional agricultural products such as soybean meal, rice bran, etc.;
    - demonstrating the efficacy of dry-pelleted feeds over the former through demonstration farms; and
    - perhaps providing market incentives for farmers to adopt more environmentally sound feeding methods using formulated diets.
- Efforts are needed to transfer the findings of current research on feed formulation for species such as grouper and cobia into practical application by the commercial sector.
- In order to ensure an adequate supply of healthy fry and fingerlings of grouper so that the cage-culture sector can continue to expand and intensify, the private sector should be encouraged to develop sufficient viable grouper hatcheries.
- Important lessons in disease prevention and water usage can be learned from the shrimp-farming sector. Siting of marine cages should take into account the suitability of the environment for the species to be cultured and avoid problems caused by self-pollution.
- To address the increasingly stringent requirements imposed by importing nations such as the United States of America and the members of the European Union, Asian countries need to develop internationally accepted systems for ecolabeling of their aquatic produce.
- To ensure that their aquaculture products remain acceptable on international markets and fully conform to international standards, small-scale

[6] For example, Asia Pacific Economic Cooperation (APEC) economies in Asia have drafted a set of "standards" for the live reef-fish trade that emphasize the use of hatchery-reared stocks in aquaculture.

Asian cage farmers must further reduce their reliance on antibiotics and other therapeutants.

- Given the volatile nature of the live food-fish market for the restaurant trade, farmers should diversify the range of stock that they farm to include both exportable products and those that can be sold on domestic markets.
- There is an urgent need to develop better management measures in relation to disease prevention and to accelerate the development of vaccines for specific diseases of farmed marine finfish.
- Countries should take appropriate biosecurity and risk management measures to prevent the introduction of exotic diseases, pests and invasive aquatic species along with their international and domestic trade in live aquatic animals.
- Currently most Asian nations have inadequate regulatory measures in place for marine cage farming, a situation that could lead to the use of available inshore sites beyond their carrying capacities. More governmental intervention in stream lining cage-farming activities may be desirable and would also help to develop firmer market chains and vertically integrate the different sectors, bringing about more efficacy and cost effectiveness.
- The sustained development of finfish cage farming in Asia will only be ensured if proper regulatory measures are in place. Thus national governments have to be pro-active and work in cooperation with the farmers.

Overall the future prospects for all forms of cage farming look relatively bright for Asia. However the large-scale, capital-intensive, vertically integrated marine cage-farming practices seen in northern Europe (e.g. Norway) and South America (e.g. Chile) are unlikely to occur in Asia. Instead of large-scale farms, clusters of small farms generating synergies, acting in unison and thereby attaining a high level of efficacy are likely to be the norm. Off-shore cage farming is unlikely to become widespread in Asia, as its development is hampered by availability of capital and the hydrography of the surrounding seas, which does not allow the technology available elsewhere to be easily transferred. Despite these limitations and constraints, cage farming in Asia will continue to contribute significantly to global aquaculture production and Asia will also continue to lead the world in total production.

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