

SECTION 1

**Thematic regional reviews**



# Regional review on mariculture: products demand and markets

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## INTRODUCTION

Over the past few years there have been tremendous developments in the seafood markets in this region. The most significant changes have taken place in the retail sector, where more varieties of fish are being sold that are locally produced or imported, more innovative presentations and product forms (whole, gutted, steak, fillet, breaded, frozen, dried, canned, ready-to-eat, preserved, etc.) are seen, more affordable and better quality products are offered (even imported products such as salmon and cod are getting cheaper); and more western-style seafood products are available (fish burger, fish sandwich, breaded products, white meat fish fillet, fish and chips, etc.).

Under this fast-changing scenario, particularly in Southeast and East Asian countries, aquaculture plays an increasingly important role in providing more supplies at affordable prices. Asia is the largest producer of cultured fish and also a large consumer of seafood; thus, the role of this sector in this part of the world is more important than in other regions. With this backdrop, this paper reviews the market trends for fishery products in the region with emphasis on marine aquaculture products.

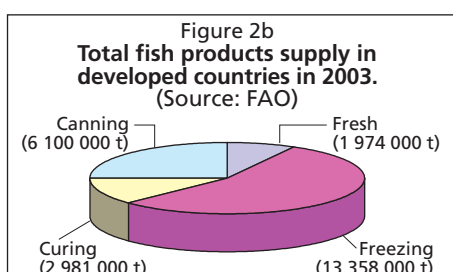
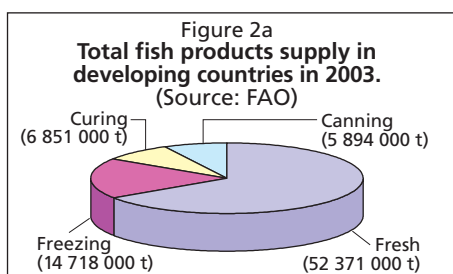
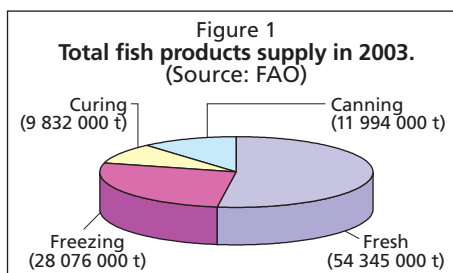
## GLOBAL DEMAND TRENDS

As a result of population growth and socio-economic development, global demand for fish and fishery products has continued to grow at the rate of 4.3 percent per year for the past two decades. Global foodfish supply (for human consumption) increased from around 53.4 million tonnes in 1981 to more than 104 million tonnes in 2003, resulting in an increase in the average per capita fish consumption (apparent consumption) from 11.8 kg to around 16.5 kg during that period. Demand for fishery products is expected to remain strong in the future, and the average apparent fish consumption is expected to reach around 18.4 kg/caput/year by 2010 and 19.1 kg/caput by 2015 (Table 1).

TABLE 1  
Past and projected fish consumption (kg/caput)

Group	1961/1965	1981/1985	1991/1995	2001	2010 <sup>1</sup>	2015 <sup>1</sup>
Finfish	8.2	9.9	10.6	12.1	13.7	14.3
Others	1.3	2.2	3.2	4.2	4.7	4.8
Total	9.5	12.1	13.8	16.3	18.4	19.1

<sup>1</sup> Projection.



From a total of more than 104 million tonnes of fish used for human consumption in 2003, fresh/chilled fish products were preferred by consumers. More than 52.1 percent of the total foodfish supply was sold in this form. Frozen fish products came second, accounting for around 26.9 percent, followed by canned (11.5 percent) and cured fish, including salted products (9.4 percent) (Figure 1).

There is, however, a big difference in fish consumption patterns between developed and developing countries. In developed countries, the large proportion (54.7 percent) of fish products was sold in frozen forms, followed by canned (25.7 percent) and cured (12.2 percent), and the rest was fresh fish (6.2 percent). In contrast, in developing countries, around 65.6 percent of fish for human consumption was sold in fresh form, followed by frozen products (18.4 percent), cured products (8.6 percent) and canned fish (7.4 percent) (Figures 2a and 2b).

By species groups, freshwater and diadromous fish were the main species group widely consumed, and their contribution to per caput apparent consumption increased from 1.6 kg in the early 1960s to 4.7 kg in 2001 (Table 2). This was mainly the result of an increase in supply from aquaculture. Similarly, the contribution of crustaceans and molluscs also increased because of the fast-growing production from the aquaculture sector.

However, the contribution of marine demersal and pelagic fishes has been dwindling as a result of declining fish stocks in many parts of the world.

TABLE 2

**Global apparent fish consumption (supply) by main species groups (kg/capita) (Source: FAO)**

Group	1961/1965	1981/1985	1991/1995	2001
Freshwater & diadromous	1.6	2.1	3.2	4.7
Demersal	2.9	3.3	2.9	2.9
Pelagic	2.6	3.1	2.9	3.0
Other marine (unspecified)	1.1	1.4	1.6	1.5
Crustaceans	0.5	0.8	1.1	1.5
Molluscs	0.6	1.1	1.6	2.1
Cephalopods	0.2	0.3	0.4	0.5
Other aquatic animals	0	0	0.1	0.1
Total	9.5	12.1	13.8	16.3

## DEMAND TRENDS IN MAJOR MARKETS

Demand for fishery products has been growing steadily in major markets, namely in the United States of America and European Union (EU), but is somewhat stagnant in Japan. Demand for cultured species like shrimp, tilapia and catfish is growing faster, particularly in the United States of America market.

Per capita fish consumption in the United States of America grew consistently over the past four years from 14.8 lb in 2001 to 16.6 lb (7.55 kg) in 2004, representing an increase of 12.2 percent during the period (Table 3). Fresh and frozen fish products were the main driving force, contributing 71 percent of the total consumption, while the consumption of canned and cured products is on the decline.

Fresh and frozen fishery products, dominated by shrimp and tilapia, contributed significantly to this growth. In contrast, consumption of canned fishery products declined, including canned tuna, which is the second most favourite seafood in the USA.

The demand for farmed fish has been on the rise, especially for shrimp, salmon, catfish and tilapia. Shrimp remained the favourite species (4.20 lb/caput) (Table 4) in the list of “Top Ten” fishery products, followed by canned tuna (3.30 lb), salmon, pollack, catfish, tilapia, crab, cod, clams and flatfish. Per capita consumption of tilapia doubled in three years, from 0.317 lb in 2002 to 0.696 lb in 2004.

The demand, in edible weight, of fishery products in the United States of America totalled 2.18 million tonnes in 2004.

TABLE 3  
United States of America per capita consumption of fishery products (lbs of edible meat)  
(Source: NMFS, 2005)

Year	Fresh & frozen	Canned	Cured	Total
2000	10.2	4.7	0.3	15.2
2001	10.3	4.2	0.3	14.8
2002	11.0	4.3	0.3	15.6
2003	11.4	4.6	0.3	16.3
2004	11.8	4.5	0.3	16.6

TABLE 4  
United States of America per capita consumption of selected fishery products (lbs)  
(Source: NMFS, 2005)

Year	Fillets & steaks	Sticks & portions	Shrimp
2000	3.6	0.9	3.2
2001	3.7	0.8	3.4
2002	4.1	0.8	3.7
2003	4.3	0.7	4.0
2004	4.6	0.7	4.2

As demand for fishery products increases, United States of America imports of edible fish in 2004 increased marginally to US\$11.3 billion compared to US\$11.1 billion the year before. Last year, the total imports into the United States of America set a new record at 2 393 673 tonnes valued at US\$12.2 billion.

Meanwhile in Japan, demand for fishery products is stagnant or even tends to decline, mainly because of the country’s long economic recession during the 1990s, changing lifestyle of the younger generation and declining domestic fish supply. Per capita fish food supply (apparent consumption) declined from the record high at 72.5 kg in 1994 to 68.6 kg in 2002. While per capita consumption of seaweed has remained stable at around 1.4–1.5 kg over the past few years, the consumption of fish and shellfish declined from 71 kg in 1994 to 67.1 kg in 2002 (Table 5).

TABLE 5  
Japan: per capita fish food supply (apparent consumption) (kg) (Source: MAFF, 2004)

	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Fish & shellfish	67.8	71.0	71.0	69.7	66.4	64.3	65.6	67.2	69.2	67.1
Seaweed	1.3	1.5	1.4	1.4	1.4	1.4	1.5	1.4	1.4	1.5
Total	69.1	72.5	72.4	71.1	67.8	65.7	67.1	68.6	70.6	68.6

Household surveys also suggest the same trend. Average consumption of fishery products at the household level declined over the years from 66.5 kg per year in 1993 to 56.3 kg in 2002. Household consumption of all types of fishery products also declined (Table 6).

TABLE 6

Japan: average consumption of fishery products at household level (kg) (Source: MAFF, 2004)

	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Fresh/frozen	49.9	47.5	47.8	45.6	45.6	45.1	44.1	43.6	42.5	43.9
Salted/dried	13.7	13.0	12.8	12.6	12.3	12.0	11.5	11.1	10.9	10.7
Seaweed (dried/prepared)	2.9	2.7	2.7	2.7	2.7	1.9	1.8	1.70	1.7	1.7
Total	66.5	63.2	63.3	60.9	60.6	59.0	57.4	56.4	55.1	56.3

Around 47 percent of fish supply into the Japanese market came from imports, while the rest was from domestic production, which has been declining over the years. Imports of fishery products, in the meantime, have been more or less stagnant for the past three years after reaching the highest record at 3.82 million tonnes in 2001. There were some signs of recovery during 2004 when total imports reached almost 3.5 million tonnes worth US\$15.1 billion. In 2005 the overall imports were slightly down in terms of quantity to 3.34 million tonnes but increased in value to ¥ 1 669 billion.

The positive trend comes from the growing imports of more value-added products, especially for farmed shrimp. In 2004, Japan imported 412 447 tonnes of high-value prepared products (excluding raw material) at a value of US\$2.85 billion compared to 355 271 tonnes and US\$2.35 billion in 2003. A large quantity of these is comprised of shrimp, fish and cephalopod-based products. During 2001–2004, imports of prepared (value-added) fishery products into Japan increased by 20.5 percent or 70 230 tonnes in quantity and 26 percent in value.

The demand for seafood in Europe is also growing, and per capita consumption within the 25 EU member countries is expected to increase by 1–12 percent from 2005–2006 (FAO). The general seafood consumption trend up to 2004 showed positive growth with significant increase in the consumption of convenience products. Economic growth, health consciousness, changing life styles and better distribution through modern retail outlets are the main forces behind the growth.

Demand for tropical farmed products such as shrimp is growing rapidly in the EU markets as reflected by increasing imports. The import of fresh and frozen shrimp reached a record level at 558 200 tonnes in 2003, then slightly declined to 554 000 tonnes in 2004, partly due to the antibiotic issue affecting supplies from some countries in Asia. In 2005, after the antibiotic issues disappeared and the EU had lifted the ban on Chinese shrimp in July 2004, the importation of shrimp increased in the main market (i.e. Spain, Italy, France, Germany and the United Kingdom). For example, as of October 2005, imports of frozen warmwater shrimp into the United Kingdom totalled 32 055 tonnes, or an increase of 6.8 percent from the same period of 2004. Similarly, imports of frozen warmwater shrimp into Spain increased by 8.2 percent last year, reaching 104 119 tonnes by October. The People's Republic of China is now the largest supplier of shrimp to Spain, overtaking Brazil. In Italy, for the period January–September 2005, imports of warmwater frozen shrimp increased by 9.9 percent compared to 2004, amounting to 34 148 tonnes.

Based on a study sponsored by the Food and Agriculture Organization of the United Nations (FAO), the future fish consumption in the EU will show three different trends: (i) consumption of cured fish and fresh/chilled fish will be more or less stable; (ii) consumption of crustaceans, molluscs, fish fillet and prepared/preserved products will increase; and (iii) consumption of frozen produce will decrease.

The highest consumption growth is predicted to be for crustaceans, especially shrimp, and fish fillets.

### DEMAND TRENDS IN SOUTHEAST AND EAST ASIA

Asia, particularly Southeast and East Asia, is a unique region, being the largest producer, exporter and importer of fishery products, especially aquaculture products. The following facts speak for themselves: The ten Association of Southeast Asian Nations (ASEAN) member countries plus East Asia (the People's Republic of China, Japan, China, Hong Kong SAR, Taiwan PC and the Democratic People's Republic of Korea), altogether in 2003:

Produced	:	79.2 million tonnes fish (60% of world total)
Cultured	:	46.1 million tonnes (84% of world total)
Exported	:	6.95 million tonnes of fishery products (24.8%) US\$7.7 billion (27.9% of world total)
Imported	:	9.62 million tonnes (33.3% of world total) US\$21.7 billion (31.8% of world total)
Per capita fish supply	:	39.6 kg (world 16.3 kg)

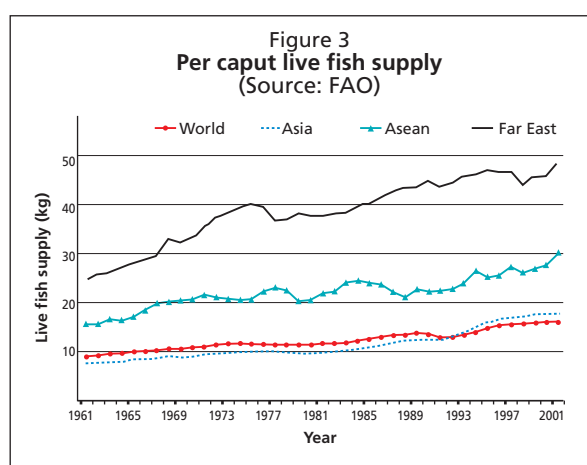
The demand for fishery products is high and growing in this region (except in Japan, as discussed earlier), as the consumers generally have a strong preference for fish, and there are abundant supplies both from wild and cultured fish; strong purchasing power (except in some countries in ASEAN); high consumption both at the household level and catering sectors; broad preferences for different species and forms (marine, freshwater, live, fresh, cured, dried/salted and also canned and frozen products); a booming tourism industry that stimulates demand for high-value species; and growing modern retail outlets and rapid economic growth (China, Viet Nam, Singapore, etc.).

In this region, people eat fish and fishery products almost on a daily basis, and thus the average fish consumption is far above the world level. In ASEAN countries, apparent fish consumption was around 30.5 kg/caput in 2001, while at the same time the world's average was only 16.3 kg/caput (Figure 3).

In Far East Asian countries, the average apparent fish consumption was 48.7 kg/caput, with China as the main force behind the growth. According to the Chinese Ministry of Agriculture, average per capita fish consumption increased from 16.4 kg in 2001 to 18.1 kg in 2003, with consumption in coastal areas reaching more than 40 kg/caput (USDA-FAS, 2005).

The demand growth in this region is driven by an increasing demand for almost all types of product form. In addition to the high consumption of live and fresh fish products, the demand for frozen and chilled convenience products, canned (especially tuna) and dried products is also growing rapidly. Frozen breaded fillet and steak products are a common sight in supermarkets throughout the region. There is also a growing demand for canned products (especially canned tuna), which are sold in various tastes and recipes. Various dried and "tit-bit" fish products are also popular in Southeast Asia.

The aquaculture sector plays a major role in fish food supply in this region, and in China the contribution of farmed fishery products is higher than wild fish. Reportedly, 67 percent of fish food supply in China currently comes from aquaculture, and this is expected to increase as much as 70 percent within the next five years. In other countries in this region, the contribution of aquaculture is generally lower than in China.



The Southeast and Far East Asian countries produced more than 46.1 million tonnes of cultured aquatic products in 2003 (including seaweed), contributing more than 84 percent to the global production. With the inclusion of China, aquaculture contributed around 58 percent of the total fish production in the region, indicating the importance of the sector in fish supply. Marine aquaculture (including brackishwater) contributed 57 percent to the total aquaculture production in 2003. The bulk of the marine aquaculture production is seaweed; however, shrimp, bivalves and finfish are also considered important cultured species in the region.

With the exception of shrimp and seaweed, a large proportion of marine cultured species in this region is consumed locally or traded among countries in the region. Well-known cultured marine finfish such as grouper, snapper, Asian seabass and milkfish are mainly consumed within the country or exported to neighbouring markets such as China, Hong Kong SAR (grouper), Malaysia and Singapore. Regional trade of farmed bivalves such as the exportation of blood cockle from Malaysia to Singapore and Thailand, and of clams from China to Japan and the Democratic People's Republic of Korea, is also significant.

While farmed shrimp (*Penaeus monodon* and *Litopenaeus vannamei*) are mainly exported to developed markets (e.g. United States of America, Japan and Europe), local consumption and regional trade are also increasing.

Nowadays, live, fresh, frozen and value-added shrimp products are widely sold in supermarkets in this region and often used as promotional items. Increasing supply (mainly of *L. vannamei*), better distribution, increasing consumer income, wider use in the catering sector and increasing trade barriers (e.g. anti-dumping duty, safety and antibiotic issues) in developed markets are the main factors behind the growing domestic market for farmed shrimp. The region is also becoming an important market for shrimp raw material used for reprocessing.

Consumption of seaweed products is also high, particularly in Japan, the Democratic People's Republic of Korea and China. The food industry is expanding rapidly; hence there is also a growing market for agar and carrageenan in the region. Japan, for example, consumed more than 200 000 tonnes of edible seaweed (dried *nori*, *kombu*, etc.), with more than 52 000 tonnes being imported. While China is the largest producer of seaweed and seaweed products, the country is also becoming an important market for carrageen-seaweed for reprocessing. The Democratic People's Republic of Korea, meanwhile, exports a large amount of dried *nori* and *hijiki* (fusiforme), mainly to Japan. The Philippines, Indonesia and Malaysia are the main producers of dried seaweed and semi-carrageenan products exported mainly to Europe and the USA.

## REGIONAL SEAFOOD TRADE AND MARKETS

Global trade of fish and fishery products reached US\$68.3 billion (import value) in 2003, with an average increase of approximately 5.1 percent per year for the past decade. At the same time, the global export value also increased by 5.4 percent annually, totalling US\$63.5 billion in 2003 (FOB price). Despite stagnant demand in some markets, especially in Japan, the overall global market shows a positive trend for fishery products (Table 7).

TABLE 7

Global trade of fish and fishery products, 1997–2003 (Source: FAO, 2005a)

Exports	1997	1998	1999	2000	2001	2002	2003
Quantity (tonnes)	24 525 564	22 599 429	24 230 015	26 434 946	27 550 549	27 410 474	28 008 554
Value (US\$1 000)	53 633 402	51 392 023	53 114 282	55 579 042	56 459 664	58 494 481	63 508 377
Imports	1997	1998	1999	2000	2001	2002	2003
Quantity (tonnes)	23 594 120	22 557 088	24 226 213	26 549 699	27 886 775	28 053 542	28 563 300
Value (US\$1 000)	57 573 408	56 108 158	58 574 571	60 995 816	60 558 951	62 500 451	68 261 513



Southeast and Far East Asia is still one of the growing markets, despite the fact that fish consumption is already high. It is estimated that total imports of fishery products into this region could have reached as much as US\$25 billion in 2004, representing an average growth of 2.6 percent since 1993, with Japan, China, Thailand and the Democratic People's Republic of Korea being the main importing countries. Excluding Japan, the import of fishery products into the region was estimated at approximately US\$7 billion in 2004, indicating a tremendous annual growth of about 9 percent since 1993, with China and Thailand as the main forces.

Meanwhile, as the main producers of fishery products, exports from Southeast and Far East Asian countries/territories also increased consistently over the years from US\$12.7 billion in 1993 to US\$17.7 billion in 2003 (Table 8). This represents an average annual growth of 4 percent in value terms. It is estimated that the total export value from the region reached US\$20 billion in 2004.

In ASEAN countries, trade of fishery products has been consistently growing since the economic crisis began and in 1998 when exports and imports hit their low levels. Export of fishery products from ASEAN countries increased from US\$7.75 billion in 1998 to US\$8.94 billion in 2003, i.e. up by 15.4 percent during the period.

TABLE 8

**Exports of fishery products from Southeast and Far East Asia by country/territory, 2000–2004 (Q=tonnes; V=US\$1 000) (Source: FAO, 2005a)**

Country		2000	2001	2002	2003	2004 <sup>1</sup>
Brunei Darussalam	Q	285	149	92	144	NA
	V	296	334	459	706	NA
Cambodia	Q	43 636	38 454	52 752	56 957	NA
	V	37 691	31 308	32 071	34 744	NA
China	Q	1 516 404	1 928 966	2 057 424	2 082 080	2 420 565
	V	3 706 339	4 106 214	4 600 704	5 362 366	6 966 483
China, Hong Kong SAR	Q	55 733	49 402	48 446	46 229	NA
	V	76 089	52 859	50 313	47 365	NA
Indonesia	Q	490 416	457 913	539 302	830 383	902 358
	V	1 610 291	1 560 078	1 516 537	1 579 783	1 780 833
Japan	Q	221 868	312 769	306 353	364 655	321 983
	V	832 088	794 897	817 593	952 419	1 369 425
Laos	Q	4	30	74	24	NA
	V	29	78	256	26	NA
Malaysia	Q	95 435	126 229	203 327	160 262	238 229
	V	200 469	220 126	381 983	256 197	545 526
Myanmar	Q	111 843	159 705	158 904	72 850	NA
	V	185 030	198 011	248 343	142 566	NA
Philippines	Q	213 839	170 091	171 279	201 630	NA
	V	449 376	414 430	453 030	465 734	NA
Republic of Korea	Q	530 870	431 319	424 905	418 799	406 435
	V	1 489 803	1 253 300	1 138 346	1 102 081	1 278 638
Singapore	Q	112 144	102 133	88 516	86 898	90 344
	V	457 274	388 205	325 179	329 952	340 627
Taiwan PC	Q	697 851	692 264	733 616	715 705	577 375
	V	1 762 576	1 815 892	1 617 687	1 305 633	1 578 800
Thailand	Q	1 162 099	1 217 310	1 247 270	1 401 915	1 685 177
	V	4 384 437	4 054 130	3 692 158	3 919 824	4 413 750
Viet Nam	Q	302 943	392 796	493 637	508 766	531 323
	V	1 484 413	1 783 913	2 035 515	2 211 050	2 400 781
TOTAL	Q	5 555 370	6 079 530	6 525 897	6 947 297	7 500 000 <sup>2</sup>
	V	16 676 201	16 673 775	16 910 174	17 710 446	20 000 000 <sup>2</sup>

<sup>1</sup> National statistics.

<sup>2</sup> Estimated.

Similarly, imports to ASEAN countries have recovered tremendously since 1998, with an annual growth of around 9.6 percent in quantity and 8.4 percent in value, reaching over 2 million tonnes worth a total of US\$2.4 billion in 2003 (Table 9).

TABLE 9  
Imports of fishery products into ASEAN and Far Eastern countries/territories, 2000–2004 (Q=tonnes;  
V=US\$1 000) (Source: FAO, 2005a)

Country		2000	2001	2002	2003	2004 <sup>1</sup>
Brunei Darussalam	Q	6 624	8 335	6 573	7 201	NA
	V	15 239	13 379	13 136	11 847	NA
Cambodia	Q	2 100	852	2 217	3 122	NA
	V	4 130	1 663	4 033	5 514	NA
China	Q	2 514 321	2 280 412	2 483 798	2 324 492	2 985 642
	V	1 820 699	1 816 022	2 226 628	2 426 254	3 239 443
China, Hong Kong SAR	Q	329 442	349 416	360 564	356 960	NA
	V	1 970 395	1 785 380	1 786 968	1 773 781	NA
Indonesia	Q	171 349	151 957	110 035	91 707	136 040
	V	101 644	93 730	79 095	76 088	154 032
Japan	Q	3 540 479	3 726 738	3 816 227	3 210 472	3 484 982
	V	15 742 561	13 649 228	13 862 980	12 623 644	15 128 617
Laos	Q	2 510	3 142	2 725	3 164	NA
	V	2 069	2 170	1 727	2 333	NA
Malaysia	Q	322 923	353 400	464 172	386 586	406 190
	V	307 340	336 705	400 345	377 504	509 211
Myanmar	Q	1 536	806	723	1 393	NA
	V	2 153	932	1 354	2 037	NA
Philippines	Q	248 407	180 992	217 069	168 846	NA
	V	111 596	71 362	92 524	86 445	NA
Republic of Korea	Q	755 301	1 068 715	1 191 622	1 240 217	1 280 915
	V	1 398 606	1 648 642	1 882 849	1 958 477	2 261 356
Singapore	Q	182 349	172 994	173 797	185 637	230 446
	V	566 286	489 009	512 404	542 383	744 842
Taiwan PC	Q	454 496	423 693	388 207	377 958	387 378
	V	578 932	565 893	496 541	494 222	531 699
Thailand	Q	813 789	977 350	1 006 011	1 078 620	1 255 223
	V	826 699	1 072 467	1 079 379	1 133 815	1 283 025
Viet Nam	Q	19 547	19 189	39 084	86 311	NA
	V	24 272	32 508	99 656	164 216	NA
TOTAL	Q	9 365 173	9 717 991	10 262 824	9 522 686	10 500 000 <sup>2</sup>
	V	23 472 621	21 579 090	22 539 619	21 678 560	22 000 000 <sup>2</sup>

<sup>1</sup> National statistics.

<sup>2</sup> Estimated.

Regional trade within ASEAN, between China – ASEAN and between South Asia–ASEAN/China is also growing, even though the value is relatively small compared with trade with the developed markets (Table 10). In 2003, regional trade (exports) within Far East and Southeast Asian countries (excluding China and developed markets like Japan) was less than US\$1 billion or only 9.2 percent of the total region's export value. China's export to Southeast and Far East Asian countries accounted for more than US\$1 billion or 15.4 percent of the country's total exports in the same year.

Meanwhile, only around 7.5 percent of the total exports value of fishery products from South Asia was destined to Southeast and Far East Asia, while to China it was 6.1 percent.

TABLE 10  
Regional trade flows (export values in US\$1 000) (Source: FAO, 2005a)

Destination by region	From					
	China		East and SE Asia		South Asia	
	Value	%	Value	%	Value	%
North America	1 234 460	(19)	3 261 577	(31.8)	540 239	(26.7)
European Union (25)	573 935	(8.9)	1 130 667	(11.0)	595 390	(29.5)
Other Western Europe	5 893	(0.1)	69 799	(0.7)	10 375	(0.5)
Other developed countries	3 129 819	(48.3)	3 672 899	(35.8)	463 224	(22.9)
South Asia	2 487	(0.04)	26 666	(0.3)	37 329	(1.8)
East and Southeast Asia	1 000 499	(15.4)	948 940	(9.2)	152 378	(7.5)
China	377 342	(5.8)	655 354	(6.4)	122 405	(6.1)
Others	151 454	(2.3)	497 525	(4.8)	99 852	(4.9)
Total	6 475 882	(100)	10 263 427	(100)	2 021 192	(100)

In the future, regional trade of fishery products is expected to grow faster as a result of growing demand in the region, the on-going trade liberalization process (ASEAN–China, Free Trade Areas, etc.), increased production (particularly from aquaculture), and external factors such as increasing trade and non-trade barriers from developed markets.

The following sections present brief reviews on trade and market trends for selected marine aquaculture products in the region.

## SHRIMP

*Litopenaeus vannamei* (white leg shrimp) and *Penaeus monodon* (black tiger shrimp) have been two main forces behind the growth of the global shrimp industry and market for the past decade. Together, both species contributed around 77 percent of the total cultured shrimp production in 2003. In the global shrimp trade, even though there is no official figure, together *L. vannamei* and *P. monodon* are estimated to contribute around 50–60 percent of the shrimp quantity traded internationally.

Farmed *L. vannamei* production has increased considerably over the past ten years, from only 109 397 tonnes in 1993 to 723 858 tonnes in 2003. Asia is mostly responsible for the growth, its share growing from almost nothing before 2000 to approximately 64 percent in 2003.

Farmed *P. monodon* production, on the other hand, has been fluctuating for the past ten years due to disease-related problems, and the annual production growth was only around 3.4 percent during the period 1993 to 2003. Thus in Asia, over the past two years, the growth of the shrimp-farming industry has mainly been accelerated by the growth of *L. vannamei* farming, which has become an important alternative to *P. monodon*.

As aquaculture has made more shrimp available at affordable prices to end users, demand for shrimp in general has increased in the global market, especially in the main traditional shrimp markets in the United States of America and Western Europe, but has leveled off in Japan, the former leading market. As of 1997, the USA replaced Japan as the leading market for shrimp, and Japanese imports, especially of frozen shrimp, declined over the years due to the country's lengthy economic recession. Nevertheless, in 2004, the overall shrimp imports into Japan increased by 6.5 percent compared with 2003, mainly due to the appreciation of the Yen and the anti-dumping case in the United States of America against six shrimp-producing nations. Imports of fresh and frozen shrimp also slightly increased by 3.5 percent in 2004, amounting to 242 037 tonnes, but then decreased slightly to 233 376 tonnes last year (Table 11).

Traditionally, Japanese consumers have a strong preference for *P. monodon* and the market is still dominated by this species, in both the shell-on and value-added products such as *nobashi* and other peeled products. In the shell-on market alone, around 63.5 percent of the market share is taken by *P. monodon*, followed by white

shell-on products (16 percent), consisting mainly of banana and white Indian shrimp. Farmed *L. vannamei* is mainly imported from China (particularly as peeled shrimp) and from Brazil and Ecuador. The exportation of *L. vannamei* from Ecuador, in fact, has gradually declined from more than 5 500 tonnes in 1999 to 852 tonnes last year. Brazil managed to increase its exports to 1 452 tonnes in 2002 then dropped to 1 068 tonnes in 2005. Thus, the impact of *L. vannamei* in the Japanese market, especially with regard to the *P. monodon* market, is very minimal.

TABLE 11  
Japan: imports of shrimp (all types), 1998 and 2001–2005 (tonnes) (Source: Japanese Customs)

Product Type	1998	2001	2002	2003	2004	2005
Live	364	577	406	293	383	271
Fresh/chilled	85	99	36	19	33	19
Frozen, raw	238 906	245 048	248 868	233 195	241 445	232 443
Dried/salted/in brine	2 349	1 704	1 875	1 977	2 351	2 008
Cooked, frozen	10 338	14 045	13 936	13 927	16 745	17 051
Cooked & smoked	376	515	468	453	618	422
Prepared/preserved <sup>1</sup>	13 984	23 980	27 678	33 361	39 692	42 181
Sushi (with rice)	50	160	194	92	341	263
Total	266 038	286 128	293 461	283 318	301 608	294 658

<sup>1</sup> Including tempura & canned shrimp.

However, there have been changes in the consumers' preference for shrimp in the Japanese market. As the market becomes more price sensitive, demand has moved from large to medium-size shrimp, as the latter is perceived to be cheaper. This trend is more visible in the retail market. In the food service sector, sushi bars have started to respond to this trend and serve required sizes of sushi shrimp that are smaller than before. Re-processors of sushi and tempura shrimp have also started to use relatively smaller sizes of shrimp in order to accommodate the final consumer's demand pattern and affordability. This strategy works out in favour of farmed white shrimp, where the predominant counts are 51/60 and above.

In the small-size peeled shrimp market segment, especially in the catering sector, white peeled shrimp is also preferred, as it gives room for *L. vannamei* to penetrate the segment. It is also worth noting that supermarkets in Japan have started promotional sales for farmed white shrimp from China (mostly *L. vannamei*); thus we can expect the increasing popularity of *L. vannamei* in the near future. It has been reported, however, that sushi bars still prefer *P. monodon* and they are reluctant to use *L. vannamei*.

Imports of shrimp into the USA continue to set new records at 518 379 tonnes in 2004, representing an average increase of 11.2 percent per year over the past five years. Even though supplies from six countries affected by the anti-dumping duties were lower in 2004, other major suppliers such as Indonesia, Bangladesh, Mexico and Malaysia managed to fill the gap and tremendously increase their exports to the market. Imports from the six anti-dumping-affected countries dropped by 13.4 percent from 372 890 tonnes in 2003 to 322 957 tonnes in 2004, while imports from non-affected countries went up from 131 605 tonnes to 194 660 tonnes, representing an increase of almost 50 percent. Last year, shrimp imports into the USA increased by 2.7 percent over 2004, reaching 532 160 tonnes worth US\$3.7 billion (for all product forms).

Imports of shrimp into the EU have also increased significantly recently, with imports into the United Kingdom, Spain, Italy, France and Germany increasing by almost 10 percent over the past five years. The popularity of warmwater shrimp (*Penaeus/Litopenaeus* spp.) has been growing rapidly in these five countries.

Generally, competition between *P. monodon* and *L. vannamei* is still limited in certain areas, especially in the small sizes and peeled market segments. Competition

is more obvious between producing countries exporting *P. monodon* or *L. vannamei* to different markets.

As the main producers of cultured shrimp, both *P. monodon* and *L. vannamei*, Southeast and Far East Asian countries are also becoming increasingly important markets for shrimp. The demand for shrimp in Malaysia, Singapore, China, Hong Kong SAR, China, Thailand, the Democratic People's Republic of Korea, Indonesia and Viet Nam has increased tremendously over the years due to the following factors:

- increase in supply of farmed shrimp at lower price, especially for *P. monodon* and *L. vannamei*;
- increase in consumer income;
- changing consumer lifestyle and preferences toward healthy food;
- improved distribution channels, especially the fast growing number of modern retail outlets/supermarkets;
- increase in popularity of Japanese-style seafood restaurants;
- trade barriers enforced by importing countries (such as the anti-dumping case in the United States of America and antibiotic case in the EU) that force producers to sell their product in the domestic and regional markets; and
- wider usage of shrimp in the catering sector.

In addition to *P. monodon*, *L. vannamei* is also widely sold and consumed in China, Thailand, China, Hong Kong SAR, Singapore and Malaysia. In Malaysia, where the farming of *L. vannamei* was previously banned, *L. vannamei* is sold in supermarkets and wet markets at around RM 15–19/kg (US\$4–5/kg). The ban of farming of *L. vannamei* in Malaysia was lifted in 2005. As the production has increased tremendously in China, *L. vannamei* has become abundant in local markets and its popularity is also growing.

Regional trade of *L. vannamei* is also growing as production increases; and at the same time producing countries such as China, Thailand and Viet Nam are facing anti-dumping duties in the United States of America market. Imports of shrimp into certain countries in Asia that are not affected by the anti-dumping duties increased tremendously in 2004 (Table 12). In 2004, China exported 12 069 tonnes to Indonesia, 6 540 tonnes to Malaysia and 3 976 tonnes to Singapore, representing an increase of 245.3 percent, 36.4 percent and 168.6 percent, respectively, compared to the previous year. Exports of fresh and frozen shrimp from Thailand to other countries in Asia also increased significantly by 6.9 percent in 2004 with exports to Malaysia, China, Hong Kong SAR and the Democratic People's Republic of Korea increasing by 2 500 percent, 20 percent and 29.4 percent, respectively, compared to the previous year.

TABLE 12  
Asia: fresh and frozen shrimp imports (excluding dried and processed products), 1997–2004 (tonnes)  
(Source: National statistics)

Countries	1997	1998	1999	2000	2001	2002	2003	2004
Taiwan PC	23 239	20 337	22 977	22 561	13 568	11 978	7 281	5 110
Singapore	16 716	15 119	14 319	14 091	12 148	12 812	12 000	12 695
China, Hong Kong SAR	23 019	22 044	19 609	29 335	25 104	25 373	20 348	18 571
Malaysia	23 773	23 110	19 892	16 469	23 971	22 814	32 080	21 017 <sup>1</sup>
Republic of Korea	9 407	2 740	4 654	6 666	12 965	22 200	21 883	25 000 <sup>2</sup>
China	14 160	15 142	1 677	57 358	63 114	67 691	68 315	57 878
Thailand	12 199	14 492	15 247	17 808	24 124	29 448	26 524	23 745
Total Asia (excluding Japan)	120 722	108 710	103 514	164 288	174 994	192 316	188 431	164 016

<sup>1</sup> Frozen only.

<sup>2</sup> Estimate.

From the above, it can be concluded that developing the shrimp farming industry to culture both *P. monodon* and *L. vannamei* seems to be the better option at present, rather than choosing only one of them. Among the reasons are:

- both species complement each other and can reduce business risk within the industry;
- shrimp farmers would have an alternative to switch to one of them should there be any technical or marketing problems;
- in the global market, both species generally serve different market segments, and the competition is still limited in small-size segments, especially in the retail sector;
- increasing availability of cheaper shrimp (from *L. vannamei*) will create more demand on domestic markets; and
- with technology development and improvement in the production efficiency, the industry is expected to be able to cope with the declining prices and offer cheaper products in the global market.

The strong competition in the near future seems to be among *L. vannamei* producers from Latin America and Asia. Among Asian producers, China should be reviewed closely, as the country is currently the leading *L. vannamei* producer and there are indications that the country will increase its production and its presence in the global market. Even though the bulk of *L. vannamei* production is currently smaller-size shrimp (60/70 and 70/80 pc/kg), many farmers are trying to produce larger shrimp, as this is said to be economically more viable, as larger shrimp fetch higher prices and are thus more cost effective to produce. Once this effort succeeds, there will be more competition with *P. monodon* in larger market segments.

It is interesting to note that the Thai government is reportedly trying hard to increase farmed *P. monodon* production's share from currently less than 10 percent to 35 percent within the next five years.

## BIVALVE MOLLUSCS

Bivalves contributed approximately 9.5 percent of the total fisheries production in 2003 (excluding aquatic plants), higher than the contribution of crustaceans (6.6 percent) and cephalopods (2.4 percent). Although the bivalve industry is important for many coastal nations, production and trade are mainly concentrated in a few countries or regions, such as the Far East (China, Japan and the Democratic People's Republic of Korea); Europe (France, Spain, Italy and Denmark); North America (the United States of America and Canada) and South America (Chile, Peru and Argentina).

The international trade in bivalves is very much regionalized, and not many countries are able to penetrate distant markets outside their regions, owing to technical barriers such as strict regulations on imports of bivalve products in major markets. As a result, bivalves' contribution to the total global trade in fish and fishery products was only around 2.5 percent in value in 2003, less than shrimp (17 percent), tuna (9 percent), salmon (6 percent) and cephalopods (4 percent).

Global bivalve production from aquaculture has consistently increased over the years, from 5.3 million tonnes in 1993 to 11.2 million tonnes in 2003, an average annual increase of 10.9 percent. As a result, aquaculture's contribution to overall bivalve production increased from 72.8 percent in 1993 to 84.0 percent in 2003. Meanwhile, the production from wild harvest has been more or less stagnant at around 1.9–2.0 million tonnes, its contribution in fact declining from 27.2 percent to 16.2 percent during the same period.

China became the single largest producer of bivalves with a production of 8.8 million tonnes in 2003, contributing 66.7 percent of the global harvest (both wild and cultured) in that year. Japan was the second largest producer, far behind China with a production of around 951 400 tonnes (7.2 percent), followed by the United States of



America (6.3 percent), the Democratic People's Republic of Korea (2.9 percent) and Spain (1.7 percent). Other main bivalve-producing countries are France, Thailand, Italy, Canada and Denmark.

In the aquaculture sector, the top five leading producers of bivalves are China, Japan and the Democratic People's Republic of Korea in Asia, and Spain and France in Europe. China contributed more than 79 percent of the global aquaculture production of bivalves in 2003.

World exports of fresh and frozen bivalves increased from 500 000 tonnes valued at US\$1.30 billion in 2001 to 553 600 tonnes worth US\$1.46 billion in 2003. On the global market, more than 90 percent of bivalves are traded in live, fresh, frozen and dried forms, and less than 10 percent as canned products.

In terms of quantity, clams (including cockles and ark shells) and mussels dominate the global fresh and frozen bivalve trade, accounting for around 32 percent and 44 percent, respectively. In terms of value, however, scallops contributed more than 38.4 percent to total bivalves export in 2003, followed by mussels (26 percent), clams (25 percent) and oysters (10 percent).

There is also an active trade in clams and cockles among ASEAN countries, particularly between Malaysia, Thailand and Singapore. Large quantities of cockles and clams from Malaysia are sold to Thailand for reprocessing and re-export and to Singapore for local consumption. Thailand imported 24 867 tonnes of blood cockle worth B 211 million (US\$5.3 million) in 2005, almost all from Malaysia. At the same time, Thailand also exported 4 239 tonnes of blood cockle, with the main markets being China, Hong Kong SAR, Japan and China. Meanwhile, Thailand is also the largest supplier of bivalves from the Southeast Asian region, especially canned clams. In 2005, Thailand exported 2 437 tonnes of canned clams worth Baht 267.4 million (US\$6.7 million) (Table 13).

TABLE 13  
Thailand: exports of canned clams, 2005 (Source: Thai Customs)

Main destinations	Quantity (tonnes)	Volume (Baht million)
Australia	22	2.4
Canada	47	38.3
China	26	2.1
Germany	22	2.0
United Kingdom	49	5.0
Italy	101	8.9
Japan	91	9.1
USA	1 535	142.4
Total (including others)	2 437	267.4

Japan is the largest market for bivalves in Asia, and in fact the country is the largest importer of clams, mainly from neighbouring countries such as China and the Korean Peninsula (Tables 14 and 15). Its imports of clams in 2004 totalled 90 236 tonnes valued at US\$147.4 million, and China accounted for 47.2 percent of the supply. Overall, bivalve imports into Japan in 2004 reached 99 087 tonnes worth US\$192.3 million, with China taking 44 percent market share followed by the Republic of Korea (35.3 percent) and the Democratic People's Republic of Korea (19.5 percent).

TABLE 14

Japan: imports of live, fresh and frozen bivalves, by main suppliers, 2004 (quantity (Q)=tonnes; volume (V)=US\$1 000) (Source: Japan Fish Traders Association, 2004)

Origins	Clam		Oyster		Scallop		Mussel		Total	
	Q	V	Q	V	Q	V	Q	V	Q	V
China	42 608	64 308	133	449	817	3 773	1	3	43 559	68 533
Korea Rep.	11 857	37 691	7 457	38 985	-	-	-	-	19 314	76 676
Korea DPR	321 938	42 992	-	1 731	-	-	-	427	34 938	42 992
New Zealand	3	12	191	-	2	14	115	-	311	2 184
Russia	1 182	1 908	-	-	-	-	-	-	1 182	1 908
Total (including others)	90 236	147 413	7 903	42 178	824	3 856	124	475	99 087	192 293

China, the largest market for bivalves, is mainly supplied locally. The country also imports high-value bivalves from other countries to serve the growing demand from the catering sector. The major bivalve suppliers to China are the Democratic People's Republic of Korea, New Zealand, United States of America and Canada (mussels, clams and oysters).

TABLE 15

China: exports of bivalves in 2004 (Source: Chinese Society of Fisheries, 2004)

	Quantity (tonnes)	Value (US\$1 000)
Oyster	17 404	23 868
Mussel	17 230	21 241
Scallops	12 681	39 942
Clam	89 628	149 043
Total	136 943	234 094

Other important markets for bivalves in Asia are China, Hong Kong SAR, Taiwan PC and Singapore. In 2004, China, Hong Kong SAR imported almost 19 000 tonnes of bivalves, mainly from mainland China, Japan, the United States of America and Canada, while Taiwan PC, an important market for oysters and scallops, imports mainly from the United States of America, Canada and Japan. In 2004, Singapore imported 8 597 tonnes of bivalves (molluscs) in live, fresh and frozen forms, mainly from Malaysia.

Bivalve trade between developing countries and major markets has not developed well like other seafood products. This is mainly because of food safety issues. Importing countries enforce strict import regulations on bivalves as compared to other seafood that many developing countries are unable to meet.

From Asia, only Japan, the Democratic People's Republic of Korea, Thailand and Viet Nam are currently qualified to export their bivalves to the EU markets. Bivalve-producing countries in Asia such as Indonesia have been attempting to get approval to export their products to the EU but without success.

Singapore, one of the main bivalve markets in the Southeast Asian region, also applied stringent import inspection procedures on bivalve products that are considered to be of high health risk. Imports of bivalve must be accompanied by a health certificate from the competent authority in the country of origin, and samples are collected from every consignment for laboratory tests.

Developing countries need a lot of assistance with the pre- and post-harvest practices for bivalves in order to enable them to meet the requirements of importing countries and to improve product quality and safety. The prospects for developing the bivalve industry in developing countries will depend on their ability to build reliable monitoring and inspection programmes and develop sustainable farming practices.



## SEAWEEDS

The seaweed industry is diverse, covering hundreds of species that are found in the northern and southern hemispheres, ranging from coldwater to warmwater species. Seaweeds are classified into three main groups: green, red and brown seaweeds, based on their pigment. Commercially important seaweeds fall under the red and brown groups and account for almost 99 percent of the total harvest, which is derived from 42 countries.

The diversity of the industry is exemplified by the usage of seaweed products in our daily lives. Seaweeds are consumed as food (directly) and extracted into hydrocolloids for various uses in the food, medical, bacteriological, cosmetic, textile, toiletry and chemical industries. From a global seaweed (red, brown and green) production of about 8.65 million tonnes (wet basis) in 2003, about 5.5–6.0 million tonnes was consumed as food and about 1.2–1.5 million tonnes was extracted for hydrocolloids (agar, carrageenan and alginate), while the rest was used for other purposes such as fertilizer and feed.

The edible seaweed industry is concentrated primarily in three countries, namely China, Japan and the Democratic People's Republic of Korea, while the hydrocolloids industry is dominated by a few large companies in Europe and the USA, such as CP Kelco, Danisco, Degussa, FMC Biopolymer and ISP. These companies have a strong foothold in the industry, making it difficult for any newcomer to enter the hydrocolloids market. Meanwhile, seaweed farming is dominated by small-scale farmers who are mostly located in the Asia-Pacific region. Around 88 percent of the total seaweed harvest originates from culture that is almost exclusively carried out in Asia-Pacific countries. Thus more than 60 percent of the global dried seaweed (raw material) exports come from Asia, mainly destined for Europe, the USA and Japan.

In the global market, seaweed products are traded mainly in three different groups: dried raw-material seaweeds; hydrocolloids (agar, alginate and carrageenan) and edible seaweed products (*nori*, *hijiki*, *wakame* and *kombu*). The first two groups are widely traded in the international market, while the edible seaweeds are mainly traded regionally in Far Eastern countries (Japan, the Democratic People's Republic of Korea and China). The overall value of the global seaweed trade is estimated to be around US\$5 billion, with most value contributed by edible seaweed products.

Exports of dried seaweed have been hovering in the region of 250 000 tonnes per year, with the Philippines, Indonesia and Chile as the main suppliers taking approximately 45 percent of the total export quantity. In 2003, the global dried seaweed exports totalled around 255 000 tonnes valued at US\$340 million. The Philippines is the largest supplier of carrageenophyte seaweeds, while Indonesia exports both carrageenophyte and agarophyte (dried *Gracilaria*) seaweeds. Imports of dried seaweed into traditional markets in Europe and the USA have been declining as seaweed producers like Indonesia, the Philippines and Chile have also started developing their own agar and carrageenan processing industries. The market prospects for dried seaweed are good for carrageenophyte, as demand for carrageenan is growing, but the demand for agarophyte and alginophyte seaweeds is facing buyer markets.

## Agar

The global trade in agar is active and slowly growing. World exports reached almost 15 000 tonnes valued at US\$114.2 million in 2002. Germany, the Democratic People's Republic of Korea, Taiwan PC, Thailand and France were the main agar exporters, while Japan and the USA were the main importers. The imports of agar (*kanten*) into Japan reached more than 1 633 tonnes valued at US\$27.8 million in 2004, deriving mainly from Chile, the Democratic People's Republic of Korea, Morocco and China. The USA market consumes about 2 000 tonnes/year of agar, of which around 64 percent comes from imports. Its imports reached a peak of 1 286 tonnes valued at

about US\$19 million in 2003, with Chile, Morocco and Spain being the main suppliers. In 2005, the USA imported 1 222 tonnes of agar worth US\$19.4 million.

About 90 percent of agar is used in the food industry, while the rest is for bacteriological purposes (Table 16). The market for food-grade agar is predicted to remain stable, while the market for agarose will expand as its biotechnology uses increase.

TABLE 16  
Agar markets by product categories in 2001 (Source: FAO, 2003)<sup>1</sup>

Application	Markets by application (tonnes)	Percentage
Food	6 930	91
Bacteriological	700	9
Total	7 630	100

Grade/seaweed	Markets by grade and source (tonnes)	Percentage
Powder/ <i>Gracilaria</i>	4 100	54
Powder/ <i>Gelidium</i>	2 305	30
Square/ <i>Gracilaria</i>	250	3
Strips/ <i>Gracilaria</i>	275	4
Bacto/ <i>Gelidium</i>	700	9
Total	7 630	100

<sup>1</sup> The total market has a value of about US\$137 million.

### Carrageenan

Global carrageenan sales in the food industry are estimated to be around US\$320–340 million annually, and the market in Europe is about 15 000 tonnes/year, in the United States of America around 9 000 tonnes/year and in the rest of the world about 25 000 tonnes/year (Table 17). The global market growth for carrageenan is about 4–6 percent annually and is driven by modest growth in food applications, which take about 90 percent of the total carrageenan market.

Imports of carrageenan into the USA increased significantly over the past five years from 5 918 tonnes valued at US\$41.6 million in 1999 to 9 658 tonnes valued at US\$62 million in 2005. The Philippines is the largest supplier of carrageenan into the United States of America, followed by Denmark, Canada, France and Chile. The use of semi-refined carrageenan (SRC) in the food industry in the United States of America has been increasing since the 1990s, slowly replacing the more costly refined carrageenan.

In 2003, the Philippines exported 42 594 tonnes of seaweeds and seaweed products worth US\$80.8 million, free on board (FOB) value, consisting of:

Dried seaweeds	:	31 324 tonnes (US\$33.2 million)
Carrageenan	:	10 108 tonnes (US\$47.2 million)
Edible seaweeds	:	1 162 tonnes (US\$506 000)

Other than the USA and Europe, China, the Democratic People's Republic of Korea and Japan were also the main markets for seaweed products from the Philippines.

In Southeast Asia, the demand for carrageenan is also growing, and the current market size is estimated at around 1 800–2 000 tonnes. Indonesia, Malaysia and Thailand are the main markets, with the consumption of carrageenan estimated to be in the region of 280–300, 200 and 780 tonnes, respectively.

The prospects of the market for carrageenan are positive, driven by good demand from the dairy and meat industries and new methods in the health industry.

TABLE 17  
Market size of carrageenan in the food industry (from various sources)

Country	Quantity (tonnes)	Percentage
Europe	15 000	30.3
USA	9 500	19.2
Other markets	25 000	50.5
Total	49 500	100

### Alginate

Around 32 000–39 000 tonnes of alginate are produced annually in the world, mainly in the United States of America (10 000–12 000 tonnes), China (8 000–10 000 tonnes), the United Kingdom (6 000–8 000 tonnes), Norway (5 000 tonnes), France (2 000 tonnes) and Japan (1 500–2 000 tonnes). Approximately 67 percent of alginate is of technical grade for industrial purposes (such as textiles), while around 33 percent is used in the food and pharmaceutical industries (Table 18).

Around 12 000 tonnes of alginate was consumed in the United States of America in 2000. The United States of America is also the biggest importer of alginate, its imports totalling 4 179 tonnes worth US\$25 million in 2003. Japan also imports a significant amount of alginates, reaching its highest level in 2002 at 1 619 tonnes but dropping to 1 474 tonnes worth ¥ 717 million in 2003.

TABLE 18  
Alginate markets by sector, 2001 (Source: H. Porse, CP Kelco ApS, 2002, personal communication; FAO, 2002)

Application	Quantity (tonnes)	Percentage
Food and pharmaceutical	10 000	33
All technical grades	20 000	67
Total	30 000	100

Increasing at around 2–3 percent annually, the growth in the alginate market is predicted to be lower compared to carrageenan. The industry is facing strong competition from Chinese producers who sell cheaper alginate made from *Laminaria*.

### Edible seaweeds

The international market for edible seaweeds usually refers to four main product forms, namely *nori* (*Porphyra*), *kombu* (*Laminaria*), *hijikii* (*Hizikia*) and *wakame* (*Undaria*), even though there are other products or species that are also eaten in certain countries. These four edible seaweed products are mostly traded in China, Japan and the Democratic People's Republic of Korea. Japan consumes more than 200 000 tonnes of edible seaweeds (dried forms) annually, with almost 39 percent coming from imports (Table 19). Edible seaweeds enjoy strong demand as a health food product in Japan, its import mainly coming from China (*wakame*) and the Republic of Korea (*hijiki*). Japanese imports of edible seaweed reached their highest point at 76 414 tonnes in 2004. The export of dried *nori* (laver) from the Democratic People's Republic of Korea increased tremendously in 2004, reaching 5 079 tonnes worth US\$24 million, mainly to Japan and China. Meanwhile, Chinese exports of dried *Laminaria* totaled 36 906 tonnes valued at US\$63 million in 2004, mainly supplying the Japanese market (Table 20).

TABLE 19  
Japan: imports of edible seaweeds 1999–2004 (Quantity (Q)=tonnes; Value (V)=¥ million)  
(Source: Japanese Customs)

	1999		2000		2001	
	Q	V	Q	V	Q	V
Dried <i>nori</i>	114	301	196	552	234	835
<i>Hijiki</i>	7 460	5 253	6 088	3 557	6 838	4 243
<i>Wakame</i>	50 096	9 269	40 035	7 173	40 831	7 305
Other seaweed	3 590	1 635	4 221	1 832	4 281	1 921
Total	61 260	16 458	50 541	13 114	52 184	14 303

	2002		2003		2004	
	Q	V	Q	V	Q	V
Dried <i>nori</i>	239	802	343	852	365	695
<i>Hijiki</i>	6 088	4 671	6 603	5 220	6 880	4 751
<i>Wakame</i>	42 834	8 348	40 302	7 823	69 757	12 026
Other seaweed	4 434	2 033	4 938	2 276	4 785	2 874
Total	53 594	15 854	52 186	16 171	81 787	20 346

TABLE 20  
China: exports/imports of seaweeds and seaweed products in 2004 (Source: Ministry of Agriculture, China, 2005)

	Exports		Imports	
	Quantity (tonnes)	Value (US\$ million)	Quantity (tonnes)	Value (US\$1 000)
<i>Laminaria</i>	36 906	63 026	1 189	229
Other seaweeds	4 286	19 110	48 540	23 951
Agar	2 704	16 430	125	873
Alginate	12 882	36 561	314	1 889
Total	56 778	135 127	50 168	26 942

Generally, the prospects of edible seaweed in these three countries are not very encouraging, as the markets are fully supplied or even over-supplied for certain products. An aggressive marketing campaign is being launched by edible seaweed producers to introduce these products in other markets such as the United States of America, Europe and Asia.

## FINFISH

Grouper, Asian seabass, milkfish, snapper and bastard halibut are among the marine finfish popularly cultured in the region. The industry is diverse in terms of species being cultured with generally low production and/or productivity. Except for milkfish, the large proportion of farmed marine finfish in the region is sold in live form, as it is the only viable way to offset the high production cost. As the supply of marine finfish into the market comes mainly from wild catch that is generally much cheaper, farmed marine finfish like grouper, snapper and to some extent, Asian seabass, cannot compete in wider and processed products markets.

### Grouper

In the global market, grouper is usually traded in three different forms: live, fresh/chilled and frozen forms of whole fish; fillets and steak products. Southeast and Far East Asian countries are both the main suppliers and markets for groupers, which are mainly traded in live and whole fresh/chilled forms. Farmed grouper almost exclusively cater to the live fish-trade market in the region. The following are market segments for grouper:

- live grouper: mainly traded in Southeast and Far East Asia, with China, Hong Kong SAR as the largest market and distribution center. Supplies come from both wild and cultured grouper;
- fresh/chilled grouper: Asia is the largest supplier and market, while there is a significant amount of fresh/chilled grouper fillet imported into the United States of America from Mexico and other Latin American countries (wild grouper); and
- frozen grouper: a small amount of frozen grouper is widely traded in the international market with the United States of America, European and Middle Eastern (the Gulf) countries as the main markets (wild grouper).

China, Hong Kong SAR is the main market for live grouper, importing almost 6 000 tonnes of high-value live grouper annually worth more than HK\$ 550 million (US\$70 million). The exact import figure is believed to be much higher (estimated at 10 000–15 000 tonnes/year), as there is also a large amount of live grouper brought into Hong Kong SAR by registered live fish transport vessels that is mostly not recorded. The main species imported into Hong Kong SAR are coraltrout grouper, green grouper, flowery grouper and other grouper species coming mainly from the Philippines, Indonesia, Thailand, Malaysia and Australia.

Live grouper imported into China, Hong Kong SAR arrive mainly by air or sea, using live fish transport vessels that are usually owned by China, Hong Kong SAR traders. More and more live grouper nowadays are imported by air. After arrival in China, Hong Kong SAR, live grouper is sent to live wholesale markets around the territory and then distributed mainly to restaurants. Kwun Tong wholesale market is the main wholesale market in China, Hong Kong SAR for live grouper.

Other important live grouper markets are China, Thailand, Malaysia, Taiwan PC and Singapore. Except for Singapore, the other markets are largely supplied by local production, with Thailand, Malaysia and Taiwan PC being also the main exporters of live grouper. China is increasingly becoming an important market for live grouper and imports a significant amount from China, Hong Kong SAR. There is however, no official figure as to how much live grouper is imported into the mainland. Singapore also imports live grouper to satisfy local demand, mainly from Malaysia and Indonesia. INFOFISH estimates that around 400–500 tonnes of live grouper are imported annually into Singapore by boat from nearby Sumatra Islands (Batam or Riau), by air from other parts of Indonesia and Sabah and by truck from West Malaysia.

As indicated above, the international market for processed grouper is relatively small compared with that for other marine finfish, mainly because of limited production. FAO recorded that frozen grouper production reached its highest level at 16 144 tonnes in 2002 then declined to 13 504 tonnes in 2003, with Mexico and the Philippines being the two main producers. As many countries do not have separate trade statistics for grouper products, global trade (imports) recorded by FAO are also very small, being less than 4 000 tonnes worth over US\$18 million in 2003.

India, Pakistan and Indonesia are the main exporters of frozen grouper, while Mexico is the largest fresh/chilled grouper supplier, sending fish mainly to the USA market. India exported more than 5 000 tonnes of frozen grouper, known as reef cod, to mainly Middle Eastern and European countries, as well as the USA.

In supermarkets in Malaysia, whole chilled grouper is sold in tray packs or in bulk. Flowery grouper is sold at around RM 15.00/kg (US\$4/kg) while leopard coral trout is sold at around RM 18–22/kg (US\$4.8–5.9/kg) at the retail market. In live seafood restaurants, grouper can fetch a price as high as RM 120/kg (US\$32/kg). Demand for grouper is expected to increase in the domestic market as a result of increasing supply from aquaculture and increasing consumers' income.

### Asian seabass

International trade in Asian seabass is very limited, the bulk of production being consumed locally or traded among neighbouring countries in Southeast Asia. Thus, the main producers such as Thailand, Indonesia, Malaysia, Singapore and Taiwan PC are also the main markets for this species. The fish is mainly sold in live and whole fresh/chilled forms, while only a small amount is frozen. Unfortunately, there are no separate trade statistics for Asian seabass, as it falls under the general category “seabass”, which refers to various species such as European seabass, Japanese seabass, giant seabass, Chilean seabass and also Asian seabass.

Under this category, the global trade of “seabass” is on the rise, the total world exports increasing from 3 601 tonnes in 1994 to 26 058 tonnes in 2003, while the imports reached their highest level at 41 057 tonnes in 2002 before dropping to 38 624 tonnes in 2003. This statistic however, particularly refers to European seabass trade and only a small percentage involves Asian seabass.

The main Asian seabass exporting countries are Australia, Thailand, Malaysia, Taiwan PC and Indonesia. Australia is aggressively promoting its barramundi and targeting the USA and Europe as the main markets. It exports live fingerlings to the USA and the United Kingdom for grow-out and selling the harvest in those markets.

Thailand exports live and fresh/chilled Asian seabass to China, Hong Kong SAR, Malaysia and Singapore. Exports of live marine foodfish from Thailand are recorded at 3 225 tonnes valued at B 367 million (US\$9.2 million) in 2004, consisting mainly of grouper, snapper and also Asian seabass. The country also exports a small amount of frozen seabass, around 38 tonnes worth B 3.4 million in 2004, mainly to the United States of America, Japan and Saudi Arabia.

Meanwhile, Taiwan PC exported almost 200 tonnes of frozen seabass in 2003, with the main markets being the United States of America, Canada and Europe. Other supplying countries are Indonesia and Malaysia, which export mainly live seabass to the neighbouring Singapore market.

Singapore imports around 1 000 tonnes of live marine foodfish annually, and it is estimated that around 50 percent is live Asian seabass originating mainly from Malaysia and Indonesia. While the country also imports a large amount of frozen seabass (more than 2 700 tonnes in 2004), it is believed that this is mainly Chilean seabass. Even though the fish is relatively unknown in Japan, China and the Democratic People’s Republic of Korea, small amounts of Asian seabass are also imported into these countries mainly from Thailand and Taiwan PC.

There is a small but growing market for Asian seabass in the United States of America and the United Kingdom. In 2004, the United States of America imported 16 090 tonnes of various “seabass” products worth US\$132 million. The imports mainly consisted of Chilean seabass (9 580 tonnes) followed by perch (530 tonnes), bass (838 tonnes) and frozen seabass (302 tonnes). To target the growing United States of America market, Australis Aquaculture of Australia has set up Asian seabass growing facilities in Massachusetts whereby the company exports live fingerlings from Australia and grows the fish up to a market size of 600 g over a period of eight months. A similar arrangement has also been established by another Australian company, Aquabella Group Plc, in England. Even though European markets are still dominated by European seabass (*Dicentrarchus labrax*), there is high possibility that Asian seabass can compete in those markets, particularly in northern European countries.

The average value of farmed seabass declined over the years from the highest at US\$5.6/kg in 1995 to the lowest at US\$3.4/kg in 2002, before moving up again to US\$4.2/kg in 2003. Among the main producing countries, Australia and Singapore pay a higher price for Asian seabass, while Taiwan PC produces low-value fish cultured in earthen ponds. In Australia, the massive rise in volume of farmed seabass has driven down the average wholesale price from around \$A 10/kg for fresh/chilled gutted fish



in 2000 to around \$A 7.50–8.50/kg in 2005. Following the trend, fish fillet of Asian seabass (skin-on) also dropped from \$A 22/kg in 2000 to around \$A 17–18/kg in the Sydney wholesale fish market.

In Asia the price of Asian seabass dropped during the economic crisis in 1998/1999, then recovered in 2000/2001 before dropping again in the last few years. In Hong Kong SAR the live Asian seabass price reached its highest level at around HK\$ 50/kg (US\$6.5) in 2000/2001, then declined to HK\$ 33.3/kg (US\$4.3) in 2004. Ex-farm price of Asian seabass in Thailand, however, has been stable since 2001 at around B 90/kg (US\$2.3).

The domestic market in Malaysia for Asian seabass is mostly satisfied from local production; only when there is a short supply is the fish also imported from southern Thailand and Indonesia. About 90 percent of the local Asian seabass production is consumed in the local market, mostly in live form through the catering sector. Selling of fresh/chilled Asian seabass is also slowly growing, mainly through supermarkets where sales promotion is regularly conducted.

In the catering sector, Asian seabass is prepared in various styles such as steamed, deep fried, Thai-style, grilled, etc. Consumption is usually high during the festive seasons, such as the Chinese New Year.

The price of Asian seabass in the Malaysian retail market has tended to decline over the years from an average of RM 15.00/kg (US\$4/kg) in 1998 to RM 13/kg (US\$3.5/kg) in 2005, while in seafood restaurants, Asian seabass is priced (live) at around RM 40.00/kg.

### Milkfish

Milkfish is mainly cultured in Indonesia, the Philippines and Taiwan PC and raised largely for local consumption with only a small amount being exported to ethnic markets in the Middle East and North America. In Indonesia and the Philippines, milkfish (called *bandeng* in Indonesia and *bangus* in the Philippines) is a very domestic product. The Philippines produced 246 505 tonnes of farmed milkfish in 2003, mainly for local markets with a small amount exported to North America and the Middle East.

In 2004 Taiwan PC exported 8 166 tonnes of milkfish worth NT\$ 455 million, the bulk in frozen form, mainly to Saudi Arabia, the United States of America, Canada, Australia and Southeast Asian countries.

Indonesia produced around 226 000 tonnes of milkfish, largely for local consumption in Java and the South Sulawesi Islands where it is a popular foodfish. Milkfish is also used as bait in tuna long lining, which is widely practiced in Indonesia.

### THE CHALLENGES AND TRADE ISSUES

In recent years, trade of seafood products in the international market has been very challenging, with a lot of controversies and issues affecting the trade flows. Among the challenges and issues related to marketing of marine aquaculture products are:

- (a) Declining prices: Prices of selected farmed products such as shrimp (*Penaeus monodon* and *Litopenaeus vannamei*) have tended to decline over the years, especially for traditional products such as block frozen headless shrimp. For example, the price of *P. monodon* headless from Indonesia to Japan (C&F price) for size 16/20 has declined from the higher level at around US\$15.00–17.00/kg during the period of 1995–2000 to around US\$10.00–12.00 for the past few years. Similarly, there are signs of softening in the price of *L. vannamei* shrimp in Europe as a result of cheaper supply from China. In the local market, such as in Malaysia, shrimp is also becoming cheaper as a result of the abundant supply from aquaculture. Due to strong competition from other species, seabass price has also been declining. The declining prices of farmed products are not exclusively suffered by tropical species but also

hit coldwater species such as salmon, and European seabass and seabream. Reportedly the price of high-grade bluefin tuna in Japan declined sharply from around ¥ 5 000/kg ten years ago to currently around ¥ 2 000/kg because of the sharp increase in farmed bluefin tuna supplies.

- (b) Strong competition from other products: The fast growing regional market has attracted seafood products from all over the world. Coldwater species such as salmon, cod, pollack, etc. can now be found in almost every supermarket in the region. Nile perch fillet from Lake Victoria and tra and basa fillet from Viet Nam are flooding the regional markets, giving strong competition to locally produced marine finfish such as Asian seabass, snapper and grouper.
- (c) Limited marketing options for farmed marine finfish: Due to high production costs, farmed grouper, snapper and to some extent Asian seabass are only viable to be marketed in live form. At the moment selling them as processed products is not economically viable.
- (d) Trade issues: The anti-dumping duty enforced by the United States of America on shrimp from six countries has had significant effect on the shrimp industry and the market in the region. In addition to the economic and financial losses suffered by the industry in the affected countries (India, Thailand, China and Viet Nam), many shrimp processors and producers are now giving more attention to the local and regional markets. As a result, competition in the local and regional markets is increasing, resulting in decreasing prices.

This trend has also been exploited by a highly competitive retail sector that often uses shrimp as a promotional item. While this is a good thing for consumers, who can now buy shrimp at cheaper prices, producers and farmers are being squeezed out of their profit margin.

The reported imports of shrimp from the affected countries to non-affected countries such as Indonesia and Malaysia has also raised concern among the industry, resulting in the Indonesian authorities banning the importation of shrimp.
- (e) Environmental issues: The environmental issues affecting the marine aquaculture sector are well known, but recently these issues have increasingly been linked to trade and many feel they are also being used as trade barriers. “Green” groups are now targeting multinational chain retailers and the catering sector to influence them to buy and sell seafood from eco-friendly sources.
- (f) Safety issues: The uncontrolled use of certain antibiotics has also affected the trade of marine farmed products, especially shrimp. While the issue of residues of chloramphenicol and nitrofurans in shrimp is more or less resolved, malachite green found in fish products has become a new issue.
- (g) Traceability and country of origin labelling: While the industry players in this region, especially the big seafood processors and exporters, are fully aware and possibly capable of fulfilling traceability and country of origin labelling requirements, the implementation by small players, especially at the farmer’s level, would be somewhat difficult and possibly complicated. Due to the small and scattered nature of the aquaculture industry in the region, implementing traceability requirements will require extra work and expenditure.



- (h) Rules of origin: Rules of origin enforced by importing countries such as the EU's generalized scheme of tariff preferences (GSP) scheme can also have an effect on regional trade. For example, seafood products from ASEAN countries (except those from Myanmar, for political reasons) enjoy preference tariff under the EU-GSP scheme. As a result, some packers in other ASEAN countries are having problems with the importation of raw materials from Myanmar if the final product is to be exported to the EU.

### FUTURE PROSPECTS

The regional seafood market and trade in the region is expected to expand further, largely due to economic development, increase in supply from the aquaculture sector, growing retail and catering sectors and changing lifestyles that favour health foods. Demand for shrimp is predicted to grow faster than that for other farmed marine products. The growth will be driven by an increasing supply and by sales in the retail and catering sectors.

For marine finfish aquaculture, the market expansion will depend on the development of production technology and reduction in production cost. Otherwise, the market for certain farmed finfish species such as grouper and snapper will be limited to the live market segment.

In this region, the high level of bivalve consumption is achieved through the catering sector, such as hotels and restaurants, especially for high-value species such as mussel, oyster and scallop. With the catering sector growing as a result of increasing consumer income, changing lifestyles and a booming tourism industry, the demand for bivalves in this region is expected to grow. Aquaculture will play a major role in meeting the growing demand. Competition is also expected to come from imported products such as green mussels from New Zealand.

The prospects for seaweed products are generally good for hydrocolloid seaweeds, especially carrageenan. The international market for carrageenan is expected to grow by 4–6 percent per year as a result of the growing food industry. The demand for SRC, which is produced in a huge volume in the region, is also growing faster and replacing refined carrageenan.

For edible seaweed, however, the market is stagnant, and the current production level can fulfil the demand. With the increasing popularity of Japanese and Korean seafood restaurants in the region, demand for certain edible seaweeds may grow gradually in Southeast Asian countries.

### REFERENCES

- Chinese Society of Fisheries.** 2004. *China seafood imports and exports in 2004*.
- FAO.** 2002. *Prospects for seaweed production in developing countries*. By D.J. McHugh. FAO Fisheries Circular No. 968, 28 pp. Rome, FAO.
- FAO.** 2003. *A guide to the seaweed industry*. FAO Fisheries Technical Paper No. 441, 118 pp. Rome, FAO.
- FAO.** 2005a. *FAO yearbook of fisheries statistics: commodities 2003*. Vol. 97, 235 pp. Rome, FAO.
- FAO.** 2005b. *FAO yearbook of fishery statistics: aquaculture production 2003*. Vol. 96/2, 207 pp., Rome, FAO.
- Japan Fish Traders Association.** 2004. *Statistics of Japanese fishery products imports*.
- MAFF.** 2004. *The statistical yearbook of MAFF: fisheries 2001–2003*. Ministry of Agriculture, Forestry and Fisheries, Japan.
- NMFS.** 2005. *Fisheries of the United States 2004*. National Oceanic and Atmospheric Administration, National Marine Fisheries Service.
- USDA-FAS.** 2005. *China, PR of. Fisheries products annual 2005*. GAIN Report, CH 5098, United States Department of Agriculture, Foreign Agricultural Services.



# Regional review on livelihood opportunities related to mariculture development

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## INTRODUCTION

The United Nations Millennium Development Goals call for a reduction in the proportion of people living on less than US\$1 per day (economic or income poverty) to half the 1990 levels by the year 2015. Global poverty is considered one of the major causes of food insecurity, and poverty eradication is seen as essential in improving access to food (Tacon, 2000). It is expected that global poverty rates will fall to 13 percent, meaning that the goals will be met and there will be 360 million less people living in abject poverty. However, progress in eradicating hunger has been slower, with the situation actually worsening in regions such as South Asia.

This paper draws on secondary literature, media reports and country reviews from NACA/STREAM Communications Hub Managers in India, Indonesia, Myanmar, Pakistan and the Philippines. It examines the role mariculture could play in reducing poverty and providing alternative livelihood opportunities for people living in coastal areas. This includes a review of the current status of coastal poverty, coastal livelihoods and vulnerabilities within the Asia-Pacific region and the experiences and examples of sustainable economic development through mariculture. This review then identifies key follow-up actions and recommends strategies for future pro-poor mariculture development.

### **FOOD SECURITY AND THE ROLE OF FISHERIES IN ASIA-PACIFIC**

Fish and aquatic products contribute massively towards food security and currently supply around 7 percent of the global food supply (Haylor *et al.*, 2003). As fish is generally more affordable to poorer members of society, a greater amount of this protein source is consumed on a per capita basis than any other type of animal protein (Tacon, 2000). As a result, fish and aquatic products are the primary source of animal protein for over one-sixth of the global population. In the Asia-Pacific region, fish makes up more than 50 percent of animal protein intake (Haylor 2004) with the People's Republic of China dominating consumption (36 percent); India and Southeast Asia account for another 17 percent (Delgado *et al.*, 2003).

The demand for fish is also increasing, not only because of an increasing population but also due to a greater awareness of the importance of fish in the diet (Delgado *et al.* 2003; IMM, CFDO and CBNRM LI, 2005). There is consensus that traditional sources of fish such as global capture fisheries have peaked (FAO, 2002), and the future of wild-caught fishery production appears to be uncertain. Currently 47 percent of fish stocks are described as being fully exploited or close to their maximum sustainable limits (Delgado *et al.*, 2003; FAO, 2002; IMM, CFDO and CBNRM LI, 2005). Others are in a state of decline or are completely exhausted. Recent studies based on trawl surveys in eight Asia-Pacific countries by the WorldFish Centre indicate that the situation may be far more serious than these figures suggest, and that substantial degradation and over-fishing have occurred. According to the surveys, coastal stocks have declined by as much as 40 percent in five years (Silvestre *et al.*, 2003). Consequently, it is believed that the amount of fish available for the region's fishers is now only a fraction of what was available before the industrialization of fishing (Sugiyama, Staples and Funge-Smith, 2004).

Coastal populations that once almost entirely depended on inland or coastal capture sources of fish have seen their resources decline, and once cheap and plentiful wild fish have become less available and less affordable (Yap *et al.*, 2006). In some locations around coral reefs, fishers are turning to lucrative yet destructive practices such as the use of explosives (blast fishing) and cyanide to stun and capture fish (Burke, Selig and Spalding, 2002). There are also numerous reports of conflicts over diminished fishery resources and increased illegal fishing activities as fishers from one community, region or country encroach into the territories of their neighbours (Bulcock and Savage, 2005).

### **THE INTERNATIONAL FISHERIES TRADE**

Despite the apparent crisis in global fisheries, the international trade in aquatic products has grown significantly over the last few decades, supported by improvements in technology, transport, communications and increased demand (FAO, 2003a). Consequently, fisheries export values have increased from US\$15 billion in 1980 to US\$56 billion in 2001 (Macfadyen *et al.*, 2003), and a large percentage of fisheries and aquaculture production now enters international marketing channels and chains, with more than 37 percent exported in 2000 in

various forms. Once again, developing countries, predominately in Asia, play a major role in this trade (Macfadyen, Phillips and Haylor, 2005), and fisheries and aquaculture are therefore significant contributors towards national economies across the region, particularly Small Island Developing States (SIDS) (Table 1) (Sugiyama, Staples and Funge-Smith, 2004).

TABLE 1  
**Contribution of capture fisheries and aquaculture to gross domestic product (GDP). (Source: Sugiyama, Staples and Funge-Smith, 2004)**

Production value as % of GDP			
Capture fisheries		Aquaculture	
Kiribati	33.549	Lao PDR	5.775
Marshall Islands	28.378	Viet Nam	3.497
Maldives	17.294	Bangladesh	2.688
Cambodia	10.030	Philippines	2.633
Solomon Islands	7.787	China	2.618
Federated States of Micronesia	6.603	Thailand	2.071
Samoa	4.239	Indonesia	1.662
Viet Nam	3.702	Cambodia	0.893
Papua New Guinea	3.306	Kiribati	0.752
Vanuatu	3.294	India	0.540
Tonga	2.865	Sri Lanka	0.468
Indonesia	2.350	Malaysia	0.366
Philippines	2.184	Nepal	0.345
Fiji Islands	2.046	Taiwan PC	0.324
Thailand	2.044	New Zealand	0.189

## COASTAL COMMUNITIES

### Poverty status

It is estimated that about 1.9 percent of the world's population derive their livelihoods from fishing and fishing-related activities, in both inland and marine environments (FAO, 2004), with the vast majority found in Asia (Table 2) (FAO, 2002). The majority of these fishers are small-scale, artisanal, coastal operators and among the poorest in society, depending on open access to fisheries resources as a last resort (IFAD, 2002). Income generated by fisheries is generally lower than that from other sectors, and within the sector itself small-scale fishers earn the lowest incomes (Silvestre *et al.* 2003). Within Asia, poverty in coastal areas is a defining characteristic of countries such as Bangladesh, India, Indonesia, Myanmar, Pakistan, Philippines and Viet Nam (Table 3) (IFAD, 2002). The extent of poverty in coastal communities is difficult to measure (FAO, 2002), and while there have been many studies on poverty in farming and urban areas, there have been few that have concentrated on the fisheries sector. Most studies that have been conducted focused on an assessment of income rather than more broad-based approaches to the livelihoods of fishers themselves (FAO, 2002). Reviewing literature on the subject, Macfadyen and Corcoran (2002) found that there had been few studies and analyses on the extent, nature, causes and dynamics of poverty in fishing communities and limited study on the extent to which the fisheries sector and its various associated activities (e.g. fish processing, marketing and distribution) contribute to poverty alleviation and food security.

TABLE 2  
Poverty estimates in small-scale fisher communities in Asia (Source: FAO, 2002)

Category	Estimate for Asia
% of population on <US\$1 per day	25.6%
Inland fisheries	514 023
Marine coastal	95 837
Marine other	551 133
Unspecified	3 660 428
Total	4 821 421
Number of related income-poor jobs	14 464 262
Total number of income-poor	19 285 683

TABLE 3  
Poverty status in country reviews

Country	Poverty Status
India	The vast majority of India's poor people live in rural areas (Mohan, Sathiadhas and Gopakumar, 2006). Rural poverty is estimated at 42.7 percent, with 43.3 percent of India's rural poor people belonging to Scheduled Tribes and Castes (Mukherjee, 2006).
Indonesia	Over 70 percent of fishers are poor. In some areas it may be over 80 percent. Poverty levels in coastal communities are generally considered to be around 80 percent of the population (Suspita, 2006). In total, there are 36 million poor people in Indonesia (Jaya, 2006).
Myanmar	Of the population of 54 million, 22.9 percent are described as income-poor (Maung Soe, 2006).
Pakistan	No poverty profile dealing with the specific aspects of poverty in coastal communities of Pakistan has been developed (Wattoo, 2006).
Philippines	Of the Philippines' 88 million people, 22.78 percent are living below the annual poverty threshold of US\$220.64. The three regions with the highest percentage of income-poor families are found in Mindanao (Gonzales, 2006).
Viet Nam	Income poverty has been reduced by 50 percent between 1991 and 2000. However, the poorest communities are still those reliant on coastal fisheries (Nguyen, 2006).

### Livelihoods<sup>1</sup>

The fisheries sector provides employment to a large workforce, although they represent only a small proportion of the region's population. Asia has a total of some 25 million fishers and fish farmers, which is more than double the number in the 1970s, and 80 percent of the world's total (IFAD, 2002). In South and Southeast Asia, 10.4 million people work as full-time or part-time fishers, with about 8.6 million employed in marine fisheries and the remaining 1.7 million employed in inland fisheries (IFAD, 2002). Coastal fisheries provide employment to two million people in Indonesia, 1.55 million in Bangladesh and 1.4 million in Viet Nam (Silvestre *et al.*, 2003). The types of livelihoods are complex and vary tremendously (IMM, CFDO and CBNRM LI, 2005), from full-time small-scale operators to those involved in seasonal and migratory positions in the processing and marketing industries (Box 1).

<sup>1</sup> A livelihood is defined as comprising the capabilities, assets (including both material and social resources) and activities required for a means of living. A livelihood is sustainable when it can cope with and recover from stresses and shocks and maintain the natural resource base (DFID, 1999).

Where the diversity of systems and species remains high, such as in Cambodia, aquatic resources offer considerable opportunities (IMM, CFDO and CBNRM LI, 2005) to coastal people to “diversify their livelihoods” to suit changing needs. Aquatic resources provide an important social and economic safety net (IMM, CFDO and CBNRM LI, 2005), particularly for poorer members of society. Estimated incomes (Table 4) vary considerably with coastal communities.

**BOX 1**  
**Coastal livelihoods in Pakistan**

The dominant livelihoods in coastal areas of Pakistan can be categorized as follows: fishing and related activities that employ an estimated 90 percent of the population; agriculture and forestry, in which 8 percent of the population is involved; and the services sector, which employs 2 percent of the population. The fisheries sector employs the majority of the population of coastal villages (*talukas*) in a number of ways – as fishermen, boat owners, helpers (*khalasis*), boat captains (*nakho*), workers in ice factories, transporters and drivers of fish-carrier vehicles.

(Source: IUCN Pakistan, 2003; Wattoo, 2006)

**TABLE 4**  
**Estimated income levels in coastal communities of Olango and Batasan Islands, Philippines**  
**(Source: Gonzales and Savaris, 2005)**

Livelihood	Estimated income (US\$/month)
Ornamental fish collector	9–233
Odd job worker	18
Packers of ornamental fish	3.6–7.2
Fishers	36–144
Shell gleaners	2.7–4.5
Vendors of seafood products	43–50
Store owners	144
Carpentry work	54 (2.7 per day)

Country reviews collated in this study from India, Indonesia, Myanmar, Pakistan, the Philippines and Viet Nam are widely diverse but identify distinct characteristics of coastal livelihoods across the region, particularly of poorer members of society. These include (i) a tendency towards reliance on natural “key-stone resources” (Box 2), (ii) a diversified livelihoods approach and (iii) shifting, often seasonal, balances in resource use and the division of labour (Haylor *et al.*, 2003; Gonzales, 2006; IMM, CFDO and CBNRM LI, 2005; Mohan, Sathiadhas and Gopakumar, 2006; Nguyen, 2006; Suspita, 2006; Wattoo, 2006; Whittingham, Campbell and Townsley, 2003).



## BOX 2

**Role of coral reefs in the livelihoods of coastal communities in Asia-Pacific**

Around half a billion people live within 100 km of a coral reef, and many of these are dependent on fishery-based livelihoods that are in turn dependent on coral reefs. The diversity and productivity of coral reef resources in these areas also act as sinks for such people, providing a range of livelihoods strategies (Whittingham, Campbell and Townsley, 2003). Therefore coral reefs are vital to the livelihoods of millions worldwide and particularly within Southeast Asia. In some areas, for instance the coastal regions of major archipelagos including Indonesia and the Philippines, and small Pacific island states, this dependence is extremely high (Burke, Selig and Spalding, 2002; Whittingham, Campbell and Townsley, 2003). Reefs are known to act as a “key-stone resource” i.e. one ensuring that people just manage to escape poverty. They are described as “interstitial poor” in that they are often overlooked in coastal development projects, many groups do not have the resources to undertake alternative development options, and they are extremely vulnerable to any decline in reef condition.

(Source: Whittingham, Campbell and Townsley, 2003)

Associated post-fishery activities such as processing and the trading of aquatic products also generate employment and income to millions of people around the world (Macfadyen, Phillips and Haylor, 2005). At the local level, wealth generated through trade can make significant contributions to rural development through income and employment multiplier effects. At the household level, the catching or harvesting of fish and associated post-harvest activities such as processing and trading generate livelihoods, employment and income (Box 3) (Macfadyen *et al.*, 2003; Nguyen, 2006).

## BOX 3

**Fishery and aquaculture-based livelihoods in Viet Nam**

It is estimated that there are more than three million people in Viet Nam who depend either directly or indirectly on fisheries for their income. Ninety percent of all fishers are artisanal and small-scale and most of them are poor. The fisheries sector is a significant source of income, not only in the case of full-time fishers, but also for households that combine fishing as a component of their wider livelihood strategies. The biggest source of fishing and aquaculture income is generated from the Mekong Delta, where between 60 and 70 percent of households are involved in aquaculture. In this area, the average income from aquaculture ranges from US\$36–79 per month. Almost all aquaculture producers are small-scale in their activities and belong to private households, although some cooperatives have recently been established. The aquaculture sector provides employment for 668 000 workers and shrimp aquaculture accounts for more than half of this.

(Source: Nguyen, 2006; Macfadyen *et al.*, 2003; Tuan, 2003)

***Coastal livelihood trends***

Throughout Asia, coastal populations are increasing due to a combination of local population growth and migration (Haylor *et al.*, 2003). There has also been an increase



in overall fishery production and trade over the last few decades and a corresponding increase in employment in the fishery and aquaculture sector. In 2000 an estimated 38 million people were directly engaged in fishing and fish farming as a full-time, or more commonly part-time, occupation, compared with 28 million a decade earlier (Table 5) (FAO, 2002; IMM, CFDO and CBNRM LI, 2005). Despite the peaking of capture production, wild-caught fisheries are still considered a profitable livelihood, particularly for the owners of commercial fishing vessels (Silvestre *et al.*, 2003), and the number of fishers has been growing at an average rate of 2.2 percent per year since 1990 (FAO, 2002). The number of aquaculture workers has also increased by an average of 7 percent, with growth particularly marked in Asia (FAO, 2002). However, it is suspected that these positive figures disguise the plight of small-scale subsistence fishermen throughout the region. In general, it is thought that while owners of commercial vessels can and do earn large sums of money, small-scale fishers barely make a living (Silvestre *et al.*, 2003). Across the region, small-scale fishers are believed to be increasingly marginalized by a growing number of commercial fishing boats that often fish over quota and use illegal fishing practices; there is increasing disparity within the fisheries sector (Mohan, Sathiadhas and Gopakumar, 2006).

TABLE 5  
Number of fishers and farmers (x1 000) by region (Source: FAO, 2002)

Continent	1990	1995	2000	2001	2002
Africa	1 917	2 238	2 585	2 640	2 615
North and Central America	767	770	751	765	762
South America	769	814	784	760	770
Asia	23 654	28 552	30 770	31 493	32 821
Europe	654	864	821	796	746
Oceania	74	76	86	80	81
World	27 835	33 314	35 797	36 534	37 795
<b>Of which fish farmers</b>					
Africa	-	105	112	115	111
North and Central America	53	74	74	69	65
South America	16	88	92	92	93
Asia	3 698	6 003	8 503	8 720	9 502
Europe	11	36	37	39	39
Oceania	neg	1	5	5	5
World	3 778	6 307	8 823	9 040	9 815

### *Vulnerability*

Although communities are often relatively cash rich – in that they are able to sell their products more frequently and consistently than can land-based farmers (FAO, 2002) – they often remain vulnerable to sudden and seasonal variations in earnings (FAO, 2002), along with many other factors, the outcome of which may be income-poverty (FAO, 2002). These include climatic and severe weather events, storms, seasonally adverse weather conditions and natural disasters, e.g. exceptionally in 2004 there was a devastating tsunami in the Indian Ocean (Box 4) (CONSRN, 2005; Gonzales, 2006; Suspita, 2006). Because of its scale and severity, the tsunami focused the world's attention on the plight of poor coastal communities. They are vulnerable to economic factors such as debt, fluctuations in market price and access to markets, health issues such as ill health and accidents leading to a loss of income, and environmental factors such as pollution, over-exploitation of natural resources and destructive fishery practices (FAO, 2002; Gonzales, 2006; Maung Soe, 2006; Mohan, Sathiadhas and Gopakumar, 2006;

Silvestre *et al.*, 2003; Suspita, 2006; Wattoo, 2006; Nguyen, 2006). Poor coastal communities are also under the increasing threat of marginalization in the face of increasingly competitive commercial fishing enterprises (IFAD, 2002). Unfortunately, it appears that the vulnerability of coastal communities is increasing (FAO, 2002). This often forces poor individuals to develop short-term survival strategies such as destructive and over-fishing practices that further increase a community's vulnerability (IFAD, 2002; Wattoo, 2006).

BOX 4

**The Indian Ocean tsunami**

The Indian Ocean tsunami event of 26 December 2004 demonstrated vividly the vulnerability of coastal communities throughout Asia-Pacific and eastern Africa. Estimates put the human cost of the tsunami at just under 300 000 people killed and a negative impact on the livelihoods of around five million people, particularly in Indonesia and its region of Aceh, and in Sri Lanka. The majority of those affected followed agricultural or fisheries-based livelihoods or were employed in associated enterprises. The degree of damage to lives and property varied within and between countries and communities, with some suffering a complete loss of villages, homes, fishing and aquaculture infrastructure (including port and post-harvest facilities), fishing vessels and gear, aquaculture facilities (including ponds, cages, hatcheries and broodstock), markets and other livelihoods assets (CONSRN, 2005).

In Sri Lanka at least one million people were directly affected, with the worst affected areas being the underdeveloped coastal regions in northeast, east, south and southwest coastal areas of the country. The majority of job losses were in the service sector, followed by fishing, agriculture and industry. Up to 100 000 fishermen are now unemployed and 18 500 fishing vessels have been lost or badly damaged (<http://www.ilo.org>).

In Aceh Province, Indonesia, aquaculture is a significant livelihood for many coastal dwellers. The tsunami destroyed or severely damaged more than 50 percent of all brackishwater aquaculture ponds (*tambaks*), the main farming systems for milkfish (*Chanos chanos*) and shrimp (*Penaeus monodon* and other species). Aquaculture production has effectively stopped in the major farming areas of the east coast. As the economy in these areas is heavily dependent on aquaculture and fisheries, farmers and labourers are also faced with few opportunities for alternative employment.

(Source: Suspita, 2006)

The extent to which international trade can benefit poor rural and coastal communities is also vulnerable to key factors and trends. These include changing demand for different types of fish products, increasing moves towards Corporate Social Responsibility (CSR) certification and traceability, increasingly strict health and hygiene regulations, and requirements of the regulatory framework for international trade, including trade barriers and subsidies. All these factors, while offering opportunities for poor people, also present certain risks in terms of their exclusion from the market chain and the benefits of increased trade (Macfadyen, Phillips and Haylor, 2005).

## THE CURRENT STATUS OF AQUACULTURE AND MARICULTURE IN ASIA-PACIFIC

Since yields from capture fisheries are not expected to increase, an emphasis is being placed on the aquaculture sector's ability to provide increasing quantities of aquatic products. Production from inland aquaculture and marine and brackishwater-based aquaculture (mariculture) are both increasing (FAO, 2002, 2003a, 2004; Sugiyama and Funge-Smith, 2003; Sugiyama, Staples and Funge-Smith, 2004) and now account for 30 percent of total aquatic production (Delgado *et al.*, 2003). Low-income food deficit countries (LIFDCs) lead the way in this growth, dominated by China PC and other Asian countries (FAO 2003a). As a result, the Asia-Pacific region (including China PC) is the largest contributor to world aquaculture, producing 46.9 million tonnes or 91 percent of total global aquaculture by volume and 82 percent by value (Yap *et al.*, 2006). Aquaculture production within the region is diverse, but in terms of volume it is still dominated by freshwater fish production (39 percent), followed by aquatic plants (29 percent), crustaceans (13 percent), marine and diadromous fish (13 percent) and molluscs (7 percent). In terms of value, crustaceans such as the tiger prawn (*Penaeus monodon*) dominate, accounting for 49 percent of production, followed by freshwater fish (35 percent) (Yap *et al.*, 2006).

### The potential role of mariculture in poverty reduction and food security

The shifting emphasis in production from fishing to aquaculture and mariculture, and the growth in the international trade in aquatic products are often believed to offer the potential to contribute towards poverty reduction and food security through the creation of jobs and alternative sources of food. They may also provide a way to encourage those involved in destructive fishing practices to adopt a more sustainable form of livelihood (Gonzales, 2006; Haylor *et al.*, 2003; Mukherjee, 2006; Nguyen, 2006; Suspita, 2006). From the country reviews undertaken for this study, mariculture practices considered potentially "pro-poor" were identified in every country except Pakistan, which currently has an extremely limited and mostly experimental mariculture industry focusing on shrimp (Wattoo, 2006) (Table 6).

TABLE 6

**Mariculture practices identified in country reviews (Source: Gonzales, 2006; Maung Soe, 2006; Mukherjee, 2006; Nguyen, 2006; Suspita, 2006)**

Country	Mariculture activity
India	Mud crab fattening Shellfish culture Shrimp processing
Indonesia	Traditional milkfish production in <i>tambaks</i> (ponds) Traditional prawn culture Mud crab fattening Shellfish culture Sea cucumber Seaweed culture Shrimp and finfish hatcheries
Myanmar	Traditional shrimp farming Mud crab fattening Marine finfish seed supply
Philippines	Shellfish farming Milkfish production in cages and pens Backyard grouper production in cages Seaweed culture
Viet Nam	Integrated shrimp-mangrove farms Marine finfish culture and fattening in cages Lobster culture and fattening in cages Shrimp processing Shrimp and finfish hatcheries

Livelihoods from mariculture include:

- fry collection and supply for milkfish, grouper and shrimp; small-scale trading and middlemen for mariculture products and inputs;
- production of milkfish, groupers, mud crabs, and lobsters in cages and pens, seaweed production (including family-owned and operated seaweed farms), mussel and oyster production;
- waged labour for hatcheries such as feeders and tank cleaners;
- waged labour in production, caretaking of fish cages and pens, and shrimp ponds; seasonally hired pond and cage work and hired labour for cage construction and fish harvesting; and
- waged labour (cleaning and labouring) in processing facilities such as shrimp and other seafood product packing and processing facilities (Gonzales, 2006; Mukherjee, 2006; Nguyen, 2006; Suspita, 2006; Wattoo, 2006) (Appendix I).

### Examples of pro-poor mariculture in Asia-Pacific

#### *Finfish farming*

Throughout the region, groupers (*Epinephelus* sp.) and other marine finfish such as milkfish (*Chanos chanos*) are typically farmed in ponds or cages (which can sometimes offer the opportunity for landless individuals and fishers to become involved in mariculture activities). Marine finfish culture comprises an increasingly well-known set of technologies. However, the fattening of wild-caught fish and juveniles needs to be conducted within the context of sustainable management of the capture fishery. Nursing fish seed, production and processing may provide employment or small-scale business opportunities for poor people in coastal areas. Table 7 illustrates the opportunities that small-scale grouper culture is thought to possess, as perceived by poor coastal villagers in Khanh Hoa Province, Viet Nam.

Successful examples of where small-scale finfish culture has benefited poor coastal communities exist in Tubigon, Bohol, Philippines, where the small-scale cage culture of grouper was introduced by local government as an alternative to destructive fishing practices. There are now 141 grouper farmers organized into nine groups throughout several villages (Gonzales, 2006). Another Philippine example is the so-called “backyard type of grouper culture” such as in Day-asan, Surigao City. Here each farmer owns between two and four 3x3 m cages, each stocked with around 100 fish. Where these are fed wild-caught fish as feed and cultured for a period of five to six months, there are question marks over sustainability. Production costs are estimated at P 200 (US\$3.88) per kg, with farmers claiming it is more profitable than more familiar livelihoods such as backyard pig production. The average selling price ranges from P 400–1 000 per kg (US\$7.77–19.42), depending on the type of grouper and season (Gonzales, 2006).

However, there are also many potential constraints to finfish culture and its suitability as an alternative livelihood for poor fishers. These include the high-technology, capital-intensive and long-term payback characteristics of finfish farming, and the difficulty of uptake of mariculture, including breaking the cycle of debt among poor fishers and persuading people to change vocations (Haylor *et al.*, 2003). In the Ilocos region of the Philippines, where the milkfish industry is concentrated, the production costs per cage are reported as US\$23 504, although a profit of just over US\$3 000 is expected (Gonzales, 2006). Such high costs have deterred small-scale fishers from investing in these technologies and the cages are owned by wealthier individuals (Gonzales, 2006). There are also environmental considerations, for example, the proliferation of fishpens and fishcages in shallow and narrow waterbodies has resulted in occasional but severe fish kills (Gonzales, 2006; Rosario, 2006). In Indonesia, the *tambak* culture of finfish is also thought to have led to environmental degradation in some instances (Suspita, 2006).

TABLE 7

The potential of small-scale cage aquaculture to improve livelihoods (Source: Hambrey, Tuan and Thoung, 2001)

Problem and constraint as identified by villagers	Rating	Comment
Low income	high	Cage aquaculture generates high returns compared with alternative activities.
Dense population and lack of land	high	There are many available sites for cage aquaculture in Khan Hoa.
Poor and/or impoverished soils	high	-
Shortage of freshwater	neutral	This is an infrastructure issue.
Forest fires and mangrove destruction	medium	Cage aquaculture development could take the pressure off mangrove systems.
Shrimp disease	medium	Cage culture offers an alternative.
Flooding	high	Cage aquaculture is not vulnerable to flooding.
Erosion	neutral	-
Overexploitation of fisheries	low-medium	Development of cage aquaculture could take the pressure off inshore fisheries – although feed and seed supply are a problem in this regard.
Use of destructive fishing gear (e.g. cyanide, electric fishing push-nets)	low-medium	Unsustainable with efforts impacted by punitive measures as well as alternative livelihoods, which could include cage culture (see Philippines example below).
Degradation of coral reef	medium	Fishing for seed does not involve habitat destruction.
Pollution from shrimp farming, shrimp hatcheries and animal husbandry	neutral	Cage aquaculture may cause similar pollution problems, although far less concentrated.
Poor roads	neutral	This is an infrastructure issue.
Access to markets	high	Cage aquaculture generates high-value products and marketing channels are well developed.

### Crab and lobster fattening

Mangrove crab production or the fattening of mangrove crabs (*Scylla* spp.) in earthen ponds and simple cages has a long history in the region. The crabs are attractive for the growing export market as they can be easily packed and shipped live (Yap *et al.*, 2006). Small but successful mangrove crab industries exist throughout Asia-Pacific, for instance in Indonesia where hatchery technology is now available (Suspita, 2006) and Myanmar where fattening is common along the coasts of Rakhine, Ayeyarwady and Tanintharyi and is being extended by research institutes (Maung Soe, 2006). Mangrove crab culture also has the advantage of being able to integrate within mangrove systems and therefore is often seen as a way to promote sustainable forms of aquaculture to benefit income-poor groups.

Other crustacean species under culture include lobsters, which are fattened and again rely on wild-caught seed. Species such as the spiny lobster (*Panulirus* sp.) can fetch US\$25 per kg (Yap *et al.*, 2006) and are cultured throughout the region. Viet Nam in particular is a major producer, with 17 000 lobster cages recorded along the south central coast alone (Nguyen, 2006). However, operating costs are high, for example lobster farming in Nha Trang Bay, Viet Nam has operating costs of almost US\$1 750 for seed and feed (IUCN, 2003), which is a deterrent to uptake by poorer members of communities who often have extremely limited access to credit. However, within Viet Nam, the pro-poor culture of lobster, finfish and a range of aquatic species is being investigated under the SUMA (Support to Marine and Brackishwater Aquaculture) component of the Danish International Development Agency (DANIDA)-funded FSPS (Fisheries Sector Programme Support) project. SUMA has already introduced sustainable breeding and culture technologies adapted to Vietnamese conditions for a range of species including top shell (*Trochus niloticus*), abalone (*Haliotis asinina*), mud crab (*Scylla serrata*), swimming crab (*Portunus pelagicus*), hard clam (*Meretrix meretrix*), sea cucumber (*Holothuria scabra*) and oyster clam (*Lutraria philippinarum*). Demonstrations have also been carried out in Quang Ninh, Nam Dinh, Nghe An

and Ha Tinh provinces for species such as shrimp, seabass, rabbitfish, abalone, sea cucumber, green mussels and grouper in ponds and cages.

#### *Extensive seaweed and shellfish production*

In contrast to these semi-intensive systems is the extensive or traditional culture of seaweed and shellfish. Due mainly to their low input requirement and extensive nature, these are regarded as environmentally sustainable (Suspita, 2006) and another potential “entry point” for the inclusion of poor coastal communities in mariculture activities. Seaweed is thought to be a particularly promising culture method and is the focus of government promotional campaigns in Indonesia and the Philippines (Suspita, 2006; Gonzales, 2006). It is of interest to other governments in the region, including Cambodia. Indonesia has a rapidly growing seaweed industry and the Directorate General of Aquaculture (DGA) views seaweed production as an opportunity to reduce poverty in areas such as West Nusa Tenggara, Bali and Lampung. Seaweed technology is considered as relatively easy to implement, with a short lifecycle and an existing market, and the DGA is currently promoting seaweed culture through collaboration with local banks that provide the capital needed for start-up operations (Box 5). It also has the potential to involve various household members including women, which makes seaweed culture particularly attractive as a poverty reduction strategy (Suspita, 2006). Such approaches have resulted in farmers reporting incomes of around US\$300–500 per month. Although culture itself may be less capital intensive, depending on the seaweed type and the production objective, processing may be a particular issue, especially facilities or processes for drying prior to transport and particularly in remote areas.

#### BOX 5

##### **Seaweed culture in Sembilangan Village, Java, Indonesia**

Sembilangan Village is situated in the northern part of Bekasi District, Java, Indonesia, where villagers earn a living from the sea and through brackishwater pond culture of milkfish and shrimp. Environmental degradation has led to the collapse of shrimp farming, while the culture of milkfish was erratic and unpredictable. Any income from harvests often went towards paying back loans and many would lose ownership of their ponds. Polyculture in the form of integrated seaweed and milkfish or shrimp culture has recently been introduced. Through improved organization and planning within the village, producers began to receive a regular income (every two months) from the production of dried seaweed. Seaweed production has also improved the quality of the water and once again shrimp is being produced. In 2004 a group from the village known as KBTT won first prize in the seaweed category of a national aquaculture competition held by the Marine and Fisheries Department.

*(Source: Mauksit, Maala and Suspita, 2005)*

In the Philippines, where seaweed contributes the majority of the total mariculture production (Gonzales, 2006; Rosario, 2006), it is viewed by the government as one of the main species, along with milkfish and tilapia, that has the potential to generate both food and income for poorer groups (Box 6) (Gonzales, 2006).

The traditional or extensive culture of shrimp is also considered to hold potential in countries such as Myanmar (Maung Soe, 2006). However, these so-called “low-input extensive” and “extensive plus” systems rely on the stocking of shrimp from natural sources, with associated sustainability issues (Maung Soe, 2006). In India shrimp are



often cultured on a rotational basis in rice fields known as *kbazans* in Karnataka and *bheri* in West Bengal (Mohan, Sathiadhas and Gopakumar, 2006; Mukherjee, 2006) and result in production volumes of up to 0.5 tonnes per ha. Upon the establishment of these farms, employment is reported to have increased by between 2 and 15 percent, with the average income rising by between 6 and 22 percent and were reported as particularly important employment opportunities for women (Mohan, Sathiadhas and Gopakumar, 2006).

## BOX 6

**Seaweed (*Eucheuma*) culture in Guimaras Island, Western Visayas, Philippines**

In 2001, the local government unit of San Lorenzo requested the Bureau of Fisheries and Aquatic Resources (BFAR) Region VI to introduce seaweed farming in Nadulao Island as a potential alternative to blast fishing. A fishers' organization with 17 members was formed to be responsible for four seaweed farms. Under the GMA, or *Ginintuang Masaganang Ani*, programme, the Seaweed Culture Project was created in collaboration with the Office of the Provincial Agriculturist and the Office of the Municipal Agriculturist. The site was expanded to include three other villages in San Lorenzo and 19 additional villages in the municipalities of Buena Vista, Nueva Valencia and Sibunag.

In April 2004, a Provincial Seaweed Development Council (PSDC) Technical Working Group (TWG) was formed, composed of representatives from government and commercial institutions. The PSDC-TWG then created the Seaweed Growers and Traders Association (SGTA), which now sells their products directly to Cebu exporters. There are now 16.65 ha under cultivation and benefiting 162 farmers. In 2005 the beneficiaries sold over 6 tonnes of fresh seaweed and 22 tonnes of dry seaweed valued at US\$14 977. Farmers who were interviewed reported that the supplementary income from seaweed culture kept them away from illegal fishing activities and enabled them to send their children to school.

(Source: Gonzales, 2006)

However, extensive systems are subject to particular constraints, in particular the access to and availability of sites. Due to their extensive nature, such practices require access to relatively large areas of near-shore and coastal land and therefore exclude landless individuals and can also lead to resource use conflicts.

**Mariculture market chains and coastal communities**

Mariculture is constrained as a livelihood option for resource-poor people by their lack of access to capital, capacity-building and other resources; high capital investment costs; limited access to sites, markets and processing infrastructure; and the potential for resource use conflicts. However, the increasing international trade and exports from LIFDCs offer other opportunities. The market chains for the supply, production and export of aquatic products such as live reef fish, ornamental reef fish, shrimp and seaweed are typically defined by their complexity, which facilitates the inclusion of a wide range of stakeholders involved in the supply of inputs, production, harvesting, product marketing and consumption. Many of these stakeholders are classified as income-poor, and many are women who are heavily involved in the processing of aquatic products throughout Asia (for example in Viet Nam where women account for 90 percent of the labour force) (Macfadyen *et al.*, 2003; Nguyen, 2006). Appendices II and III demonstrate this complexity and describe a typical market chain for shrimp

production in Viet Nam and, although not strictly a mariculture activity, a market chain for the collection and export of ornamental fish from Mindanao, Philippines to the United Kingdom.

### Risks to mariculture development

Pollution and environmental degradation have the potential to impact heavily on mariculture and poorer stakeholders who are often less well equipped to deal with risk and livelihood shocks. Other risks, such as mariculture's reliance on wild seed collection and the use of fish in feed sources, demand solutions, some of which may provide opportunities for the inclusion of poorer groups.

#### *Ecosystem degradation*

One of the main risks to mariculture development is the degradation of the ecosystems that provide key environmental goods and services. Prime among these are the services that coral reefs and mangroves provide (UNEP-WCMC, 2006). These are a valuable resource for coastal communities and often act as a nursery for many fish species (Haylor *et al.*, 2003; FAO/NACA, 2003; UNEP-WCMC, 2006), including mariculture species such as grouper. In purely monetary terms, recent estimates have placed the value of coral reefs at between US\$ 100 000 to 600 000 per hectare per year and the value of mangroves at between US\$200 000 to 900 000 per hectare per year (UNEP-WCMC, 2006). Increasingly these systems are under the threat of degradation from a range of anthropogenic factors (Burke, Selig and Spalding, 2002; Chou, 2000; FAO, 2003a; Haylor *et al.*, 2003; NACA and FAO, 2003; Silvestre *et al.*, 2003; UNEP-MCMC, 2006). This is particularly severe in Southeast Asia, which accounts for 27 percent and around 43 percent of the world's reefs and mangroves, respectively (Burke, Selig and Spalding, 2002; UNEP-WCMC, 2006). Ecosystems that can no longer provide their full ecological services have an economic and social cost that often can be felt both locally and many miles away (UNEP-WCMC, 2006). The degradation of corals and mangroves may cause:

- reduced fish catches and tourism revenues in coastal communities and potentially a loss of food security;
- loss of export earnings; and
- increased coastal erosion and destruction.

#### *Coral reefs*

The main threats to coral reefs are coral bleaching and death due to climate change and increased El Niño events, over-fishing, and unsustainable and destructive fisheries practices such as dynamite and cyanide fishing. Other factors include habitat destruction and sedimentation through coastal development (Table 8).

TABLE 8  
Anthropogenic threats to coral reef biodiversity in selected Southeast Asian countries (Source: Chou, 2000)

Country	Over-exploitation	Destructive fishing	Sedimentation	Pollution
Cambodia	X	X		
Indonesia	X	X	X	
Malaysia	X	X	X	X
Philippines	X	X	X	X
Thailand	X		X	X
Singapore	X		X	
Viet Nam	X	X	X	X



There is regional diversity in the state of reef decline but the situation in Southeast Asia is described as serious and probably under the greatest threat from human activities (Burke, Selig and Spalding, 2002). Some 88 percent of Southeast Asia's reefs are severely threatened. The situation is especially severe in Cambodia, Singapore and Taiwan Province of China where 100 percent of reefs are at a medium or higher level of threat<sup>2</sup>, followed by the Philippines (98 percent), Viet Nam (96 percent), China (92 percent), Indonesia (88 percent) and Malaysia (88 percent).

### *Mangroves*

Global trends in mangrove systems indicate a similar pattern of decline (Silvestre *et al.*, 2003; UNEP-WCMC, 2006), and the total area covered by mangroves worldwide has now fallen from 19.8 million ha in 1980 to below 15 million ha (FAO, 2003b), or 25 percent of the extent found in 1980. Mangrove deforestation continues, although at a lesser rate than in the 1980s (1.1 percent per year compared to 1.9 percent per year) (FAO, 2003b). Many fish species use mangroves as nurseries or make use of these systems in some part of their life cycle; mangroves also provide sources of feed and act as a buffer to the impacts of severe weather events (FAO/NACA, 2003; UNEP-WCMC, 2006). The disturbance and alteration of mangrove habitats therefore lead to a departure of fish populations and other nekton that will not easily return to the impacted zone (FAO, 2003b; FAO/NACA, 2003) and ultimately to impoverished livelihoods for those who depend upon the fishery sector.

The main threats to mangroves include clearance for industrial and coastal development, salt production and shrimp pond construction. However, due to an increased awareness of the important roles mangroves play in the marine food web and in providing wood and non-wood forest products and coastal protection, most countries in the region have long since restricted or banned the conversion of intertidal mangrove into shrimp pond culture. Where the demand for land for agriculture or aquaculture (e.g. to increase production of rice and fish for local consumption) or for infrastructure development necessitates the conversion of mangrove areas, the decision should be based on the results of a thorough Environmental Impact Assessment (EIA), including a valuation of all the direct and indirect benefits mangroves provide to livelihoods and the environment. Therefore, the use of these systems must seriously consider the value of the services they already provide to ensure the regional sustainability of fisheries production and the ecosystem services on which they rely. At the minimum, decisions on the use of reefs and mangroves must be based on ecological and livelihoods-based research to ensure that returns from an activity introduced into mangroves (such as aquaculture) are far greater than the opportunity costs of the services that the targeted mangroves provide (FAO/NACA, 2003).

### *Wild seed collection vs small-scale hatcheries*

The reliance on wild-caught seed for mariculture purposes is another potential constraint, since not only do such activities have the potential to cause over-fishing and ecosystem degradation, but discarded by-catch from seed collectors also impacts upon future fisheries and fishers' livelihoods (Suspita, 2006). The development of small-scale or backyard hatcheries, however, can help alleviate this risk and still involve poor stakeholders in mariculture activities (Gonzales, 2006; Sim *et al.*, 2005a; Suspita, 2006). Small-scale hatcheries are those where the capital costs are relatively

<sup>2</sup> Based on the Reefs at Risk in Southeast Asia (RRSEA) model and the Reefs at Risk Threat Index. The index is designed to highlight areas where, in the absence of good management, coral reef degradation might be occurring or where it is likely to happen in the near future, given ongoing levels of human activity. The threat indicators therefore gauge current and potential risks associated with human activities, not actual reef condition (Burke, Selig and Spalding, 2002).

low, technologies are accessible, and that focus on the larval rearing and nursery aspects of fingerling production. They do not hold broodstock; instead they purchase fertilized eggs from larger hatcheries. They offer the advantages of low capital costs, simple construction, ease of operation and management, flexibility and use for a range of marine fish species, as well as the potential for quick economic returns (Sim *et al.*, 2005a).

### *Fish feed*

Mariculture, particularly the production of marine finfish and lobster, still relies heavily on the supply of “trash fish,” which can be considered inappropriately named, as this protein source would never be wasted but used for other purposes (Sim *et al.*, 2005b). The increased use of this resource in mariculture therefore has the potential to lead to resource use conflicts and impact on people’s food security and livelihoods (Suspita, 2006). An increased demand for trash fish could also encourage over-fishing, destructive fishing practices and environmental degradation. Other problems with its suitability for mariculture use include a short storage life, seasonal variation in supply, wastage due to disintegration and the pollution from these causes. It has the potential to act as a disease or parasite vector (Sim *et al.*, 2005b). Significant progress has been made in the development of partial or full feed alternatives (Sim *et al.*, 2005b; Suspita, 2006) and like small-scale hatchery production, small-scale feed production provides an opportunity for poorer stakeholders to become involved in mariculture activities (Sim *et al.*, 2005b; Suspita, 2006).

### *Intensification and consolidation*

New technologies are likely to accelerate the intensification of inland and coastal aquaculture that has already occurred. Environmental legislation is likely to contribute significantly towards this, as controlling pollution requires capital investment. In addition, if developing countries adopt aquaculture subsidies similar to those already present in China and industrialized countries (e.g. cheaper land, lower taxes and tariffs), then the large-scale, capital-intensive model of aquaculture is likely to emerge at the expense of small-scale systems (Delgado *et al.*, 2003). Weak legislative frameworks for the promotion or protection of access rights for rural and coastal communities and people will also aggravate this issue. In addition, growing international markets and the increasing power of export markets will likely cause market chain consolidation, which could force out smaller operators (Macfadyen, Phillips and Haylor, 2005).

### *Trade barriers*

The risks inherent with international trade are often passed on to the poorest stakeholders (Macfadyen, Phillips and Haylor, 2005), and aquaculture processing countries in Asia have to address a wide array of trade issues (Bueno, 2004), including tariff and non-tariff trade barriers.

The aquaculture industries of the Asia-Pacific region are susceptible to the imposition of tariffs by importing countries, and over the last few years the United States of America has successfully placed import tariffs on Vietnamese catfish (*tra* and *basa*) and on shrimp from a range of Latin American and Asian countries (Bulcock and Savage, 2003, 2004, 2005). Such measures can have a dramatic effect on national aquaculture industries and can often lead to poorer stakeholders becoming marginalized (Box 7).

## BOX 7

**The impact of shrimp trade tariffs in Viet Nam**

In 2004 under the direct impact from an anti-dumping case, Vietnamese shrimp export and processing activities declined, with some fish export-processing companies ceasing operations. The case has seriously affected the export turnover and trading activities of shrimp companies, especially those with established market ties to the United States of America. Prices of shrimp dropped quickly (by at least VND 10 000/kg (US\$0.67/kg) for every size of shrimp. Collectors of shrimp were most affected, as processing companies not only reduced the quantity they required but also stopped informing collectors of the purchase price. In addition, when prices fall, shrimp farmers' incomes are also reduced and as a consequence, farmers find it difficult to prepare their finances for the next culture cycle. The fall in prices also has also had knock-on effects for others involved in the market chain, such as those working in shrimp hatcheries, as the demand for seed is lower.

(Source: Macfadyen, Phillips and Haylor, 2005; Nguyen, 2006)

It is also becoming increasingly important for producers to assume responsibility for the quality of the product and the actions taken in producing it (Bueno, 2004). In a recent poll in the European Union (EU) by the Seafood Choices Alliance on consumer attitudes towards seafood and the state of the world's ocean, 79 percent said that the environmental impact of seafood is an important factor in their purchasing decisions (Bulcock and Savage, 2005). Environmental and social responsibility issues are therefore joining food safety and quality as requirements to market access and can sometimes be used as so-called non-tariff trade barriers by importers. As most farms in Asia are small and producers are sometimes not well organized, it is difficult for farmers to comply with international standards (Bueno 2004). There have been several recent and high-profile trade conflicts, including a zero tolerance policy by the EU, over the use of prohibited antibiotics (Bueno, 2004; Bulcock and Savage, 2003, 2004). However, this growing awareness and demand for environmentally sensitive aquaculture also presents opportunities (Bueno, 2004; Macfadyen, Phillips and Haylor, 2005). In the same Seafood Choices Alliance poll, 86 percent of consumers would prefer to buy seafood that is labelled as "environmentally responsible". Consumers added that reassurances that the product was environmentally sound were more important than price. In fact, 40 percent were willing to pay 5–10 percent extra for seafood identified as eco-friendly (Bulcock and Savage, 2005). Environmentally sensitive aquaculture makes good business sense and has helped push efforts to promote the adoption of environmentally and socially responsible farming practices through appropriate standards or codes of conduct and the discussion of suitable certification programmes (Bueno, 2004).

**THE WAY FORWARD****Actions needed***Livelihood diversification*

The diversification of economic activities is seen as an important part of the development of economies. With respect to poverty reduction, diversification is considered as:

- a coping strategy of poor people to deal with increasing competition, and therefore a familiar strategy within coastal communities; and

- a development strategy enabling poorer members of society to graduate out of poverty (IMM, CFDO and CBNRM LI, 2005).

Therefore, it is not surprising that the rural development strategies of governments sometimes focus on the role of livelihood diversification as a way of reducing poverty (IMM, CFDO and CBNRM LI, 2005). In addition, governmental agencies and nongovernmental organizations (NGOs) that are concerned with the sustainable use of natural resources are promoting livelihood diversification as a way to encourage people to move away from exploitative and destructive use of those resources (IMM, CFDO and CBNRM LI, 2005). Mariculture presents an opportunity to diversify coastal livelihoods and provide an alternative income-generating activity for coastal communities and those involved in destructive fishing practices (Haylor *et al.*, 2003). It also has the benefit of being an alternative source of fish protein. However, before promoting pro-poor mariculture activities, there are many specific issues that must be addressed. These vary according to the type of activity, and must be considered in a context-specific manner, but typically they include:

- the relatively high capital costs and skills required for mariculture;
- the right focus of mariculture activities with respect to gender and age and its ability to integrate with existing aspects of coastal management, livelihoods and resource uses;
- the willingness and ability of people to adopt alternative livelihoods (or to diversify their livelihoods);
- the ability of farmed products to replace wild-caught products in markets;
- the environmental footprint of the activities;
- seed, broodstock and feed supply; and
- unproven economic, technical and environmentally sustainability factors (Briggs 2003).

In some countries, there are also questions regarding access to technology, extension support, capital and security (FAO/NACA, 2003). Therefore, key factors to the development of pro-poor mariculture in the region include the introduction and extension of appropriate mariculture technologies and activities, the provision of support services, and the development and implementation of sustainable mariculture practices based on an analysis of the goods and services provided by ecosystems and their carrying capacity.

#### *Pro-poor international trade*

The opportunities presented by domestic and international trade and their market chains should also be recognized, and effective and equitable ways of linking coastal communities into regional, national and global markets found to achieve long-term livelihood improvements (Macfadyen, Phillips and Haylor, 2005). In some cases, the building of the capacity of fisheries administrations to deal with international trade issues is required. There is also the need to focus on issues regarding the reliability and quality of the product. However, once again there is limited access to credit, and therefore pro-poor trade initiatives could include support for micro-finance programmes (Macfadyen, Phillips and Haylor, 2005).

### **Strategies for development**

#### *Pro-poor mariculture policies*

The opportunities that the growth in aquaculture and mariculture production and the international trade in their products present for livelihoods diversification, and the actions needed to achieve this, have been recognized by regional governments, and this recognition is now being voiced through government policies and statements.

For instance, in Viet Nam in January 2006, Decision 10/2006/QD-TTg was issued by the Prime Minister, approving a Master Plan for the fisheries sector development until 2010 with perspectives for 2020 (Bulcock and Savage, 2005; Nguyen, 2006). In this legal document, the need to develop fisheries into a major commodity was detailed, along with a call for increased productivity, production and competitiveness, characterized by product diversity, to meet the increased demand from domestic consumption and foreign trade. The decision also outlined the importance of ensuring the sustainable development of the aquaculture and fisheries sector (Nguyen, 2006). In the Philippines in response to the president's recent "10-Point Agenda", which focuses on job generation, the Bureau of Fisheries and Aquatic Resources (BFAR) has begun to identify areas in which mariculture could contribute towards providing small-scale fishers and coastal communities with alternate types of employment (Gonzales, 2006). The Government of Pakistan is currently emphasizing the importance of the fisheries sector in creating food security and income-generating opportunities, and national fisheries policy is currently being formulated (Wattoo, 2006).

#### *Adopting a livelihoods-based approach*

Livelihoods in coastal areas and the factors that affect them are complex (IMM, CFDO and CBNRM LI, 2005). Therefore, interventions that intend to help reduce poverty in these areas need to understand this complexity and how it evolved (IMM, CFDO and CBNRM LI, 2005). However, the majority of efforts to support livelihoods diversification have tended to be supply-driven and focused on single-issue solutions. Services such as mariculture have been offered to communities to address perceived needs without any real understanding of the underlying causes of the lack of livelihood diversification (IMM, CFDO and CBNRM LI, 2005). As a result, rural development efforts tend to be well supplied with development initiatives but lack the corresponding level of livelihood improvement (IMM, CFDO and CBNRM LI, 2005).

Therefore, to implement effective pro-poor mariculture strategies, an acknowledgement and understanding of the complex nature of livelihoods in poor coastal communities is essential. The use of mariculture as a potential livelihood option for poor rural and coastal communities must be based on a careful and realistic assessment of communities' needs, priorities, access to resources and the vulnerabilities people and communities face (Gonzales, 2006; Suspita, 2006; NACA/FAO, 2000). Due to the complex and shifting nature of coastal communities and livelihoods, it is possible that mariculture may actually adversely affect the livelihoods of rural and coastal communities by diverting food resources, degrading the environment, disrupting access to common resources and therefore disrupting already vulnerable livelihood strategies. Therefore, for research and development in mariculture to support poor people's livelihoods, people and communities must be placed at the centre of development planning, where an understanding of their livelihoods will require a comprehensive and broad-based approach that goes beyond a focus on assessments of locally available resources and technologies.

The adoption of livelihoods-based approaches is one such method. These involve learning about the resources that people and communities command, the choices they make and the circumstances of their livelihoods. They are therefore better able to identify poor people and understand the contexts of poor rural and coastal communities' lives. Such approaches are increasingly becoming endorsed by international organizations (such as the Food and Agriculture Organization of the United Nations, FAO), development organizations, donors (including the United Kingdom's Department for International Development, DFID) and governments, notably in Asia-Pacific. The Network of Aquaculture Centres in Asia-Pacific (NACA) and its Governing Council of 17 Asia-Pacific governments recently



endorsed a regional consensus on the value of livelihoods approaches,<sup>3</sup> calling for:

- investment in livelihoods approaches that go beyond a focus on resources and technology alone;
- the participation and shared understandings of all stakeholder groups to build community capacity, trust and ownership; and
- livelihoods approaches and analysis to be a bridge between communities and policy-makers in the assessment of the impact of decision-making processes and policies on people.

#### *Identifying appropriate entry points*

Through a consideration of people's needs and priorities, livelihoods-based approaches can therefore help better identify:

- whether mariculture interventions are appropriate; and
- if so, whether they can help to identify appropriate low-risk entry-points where coastal communities (including women) can become involved in mariculture activities and where they can receive maximum benefits (Gonzales, 2006; Maung Soe, 2006; Mukherjee, 2006; Nguyen, 2006; Suspita, 2006).

They can also help identify the most suitable livelihoods along the mariculture market chain and can often recognize potential income-generating opportunities such as backyard hatcheries and feed production.

#### *Integrated coastal management approaches*

The increase in mariculture production and trade of marine products also presents a challenge to ensure sustainable development and that a balance between valuable ecosystems and reducing poverty is preserved (Macfadyen *et al.*, 2003). The Indian Ocean tsunami has brought issues such as coastal planning, resource use and potential resource use conflicts into the spotlight, and there is continued interest in the issues concerned with coastal management. As a result, it is widely accepted that the introduction of mariculture practices should be part of a coherent wider programme of intervention in coastal resources management, and that these programmes should involve the participation of resource users in the design of interventions along with partnerships with relevant institutions (Haylor *et al.*, 2003). Effective management is the key, although sometimes inadequate across the region. Improved community-based coastal resources co-management is encouraged in collaboration with government and private sector and aimed at addressing the lack of integration of mariculture in development plans. Such approaches can be consolidated under well-managed Marine Protected Areas (MPAs) (Box 8). MPAs are internationally recognized and in operation throughout the Asia-Pacific (Briggs, 2003; IUCN Pakistan, 2003; Gonzales, 2006; Santos, Pador and De La Torre, 2003; Suspita, 2006; Nguyen, 2006).

#### *Pro-poor trade approaches*

International trade in seafood products and the associated seafood market chains within each country offer many opportunities for the inclusion of poor people and the improvement of their livelihoods. However, there is a low level of awareness regarding this key finding. The importance of the seafood trade needs to be much more widely appreciated along with a greater awareness of the role it can play in poverty reduction (Macfadyen, Phillips and Haylor, 2005). Trade issues and market chain analyses need to be incorporated into poverty reduction strategies, including those focused on mariculture development. The capacity of development of country governments and fisheries administrations also needs to be supported for them to be more proactive in engaging with international trade issues to ensure that trade is beneficial to small-scale and poor producers,

<sup>3</sup> The FAO-NACA Regional Workshop on Aquatic Resources and Livelihoods: Connecting Policy and People, 17–19 March 2005 in Los Baños, Philippines.



rather than being reactive to problems once they have occurred. Such capacity-building could involve improvement in trade negotiation skills, product quality issues, developing and following through marketing strategies and promotional tools, analysis and understanding of people's livelihoods and how best to support them and improve policies, how to adapt to health and safety measures in export markets, and monitor and respond to on-going developments in trade, methods of dissemination of trade-related information and support to all links in the market chain. Other key recommendations for improved pro-poor trade in Asia-Pacific are given below (Box 9).

## BOX 8

**Mariculture parks**

Promotion of mariculture parks is one strategy through which BFAR intends to create livelihood opportunities for coastal communities and increase fish production. A mariculture park is described as “an industrial estate put in the sea for the fishing industry” where infrastructure (a pre-developed area complete with a road network, power, water and communication lines) and utilities (mooring system) are provided by the government and mooring space is leased to investors. The first mariculture park was formally opened in August 2001 in Samal Island in Davao Region.

*(Source: Gonzales, 2006)*

## BOX 9

**Key policy recommendations for improved pro-poor trade in Asia-Pacific**

- The importance of trade in aquatic products needs to be more widely appreciated.
- The capacity of fisheries departments should be developed on issues such as trade negotiations, promotion and extension.
- Capacity in local-level organizations should be developed.
- Traceability of products must be encouraged.
- Development of fishery policy and trade policy must be participatory and include poor stakeholders and their representatives.
- Support improved communications regarding international trade, including raising awareness on the impacts of trade barriers.
- Pro-poor trade policy implementation must be backed up by wider local management of resources and good governance initiatives.
- Greater support for pro-poor trade research.
- Establish preferential tariffs for socially certified products.
- Focus on quality and reliability of supply.
- Support detailed studies on the impacts of certification schemes; and the potential of poor stakeholders to be marginalized by these needs to be recognized.
- Governments and donors should work through NGOs and their associated networks to reach poor stakeholders.
- Governments in Asia should examine whether parts of the international market chain can be encouraged to relocate to Asia.
- Support the increased availability of micro-finance.
- Complementary activities of those engaged in trade who remain poor should be investigated.
- Occupational health and safety issues should be incorporated in any eventual certification schemes.

*(Source: Macfadyen, Phillips and Haylor, 2005)*

## CONCLUSIONS

Small-scale fishers and poor coastal communities in Asia-Pacific that had traditionally relied on coastal capture fisheries as a cheap source of animal protein are faced with an increasingly competitive and declining capture fisheries sector associated with increased food insecurity and unsustainable fishing practices. Therefore there is a need to support diversified coastal livelihoods and promote alternative and sustainable income-generating activities and sources of affordable fisheries products. Mariculture and the international trade in fishery products hold a great deal of potential towards achieving this. There is a wide range of small-scale mariculture-based technologies and practices available and in operation throughout the region. However, the livelihoods of poor coastal communities and people are complex and subject to particular vulnerabilities and risks that often lead to an increased level of marginalization as well as the failure of mariculture activities. For mariculture and the international trade in aquatic products to be truly pro-poor, a broad-based, people-centered approach is needed to understand coastal livelihoods more completely and identify context-specific and appropriate mariculture entry points that could be adopted as alternative income-generating activities. These livelihoods-based approaches could be incorporated into recognized and established integrated coastal management plans and policies such as MPAs to reduce resource use conflicts and encourage sustainability.

Finally, although the international seafood trade has been recognized as an important source of employment and income for poor coastal communities and in particular women, there needs to be more awareness of its pro-poor potential and more focus in this area in development strategies, government policy and institutions. This could include building the capacity of government and local-level institutions in understanding and dealing with issues specific to the trade in aquatic resources.

## REFERENCES

- Briggs, M.R.P.** 2003. Destructive fishing practices in South Sulawesi Island, east Indonesia and the role of aquaculture as a potential alternative livelihood. *In* NACA, eds. *Improving coastal livelihoods through sustainable aquaculture practices*. pp 37–122. Bangkok, NACA-STREAM.
- Bueno, P.** 2004. International trade and aquaculture in Asia *In* NACA, ed. *Emerging trends in aquaculture in Asia-Pacific aquaculture: 2003*. pp.40-48. Bangkok, NACA.
- Bulcock, P. & Savage, W.** 2003. *STREAM media monitoring reports (January to December 2006)*. Bangkok, NACA-STREAM.
- Bulcock, P. & Savage, W.** 2004. *STREAM media monitoring reports (January to December 2006)* Bangkok: NACA-STREAM.
- Bulcock, P. & Savage, W.** 2005. *STREAM media monitoring reports (January to December 2006)* Bangkok, NACA-STREAM.
- Burke, L., Selig, E. & Spalding, M.** 2002. *Reefs at risk in Southeast Asia*. Washington DC, World Resource Institute.
- Chou, L.M.** 2000. Southeast Asian reefs – status update: Cambodia, Indonesia, Malaysia, Philippines, Singapore, Thailand and Vietnam. *In* C. Wilkinson, ed. *Status of coral reefs of the world 2000*. pp.117–129. Townsville, Queensland, Australian Institute of Marine Science.
- CONSRN.** 2005. *Regional strategic framework for rehabilitation of fisheries and aquaculture in tsunami affected countries in Asia*. Bangkok, FAO Regional Office for Asia and the Pacific.
- Delgado, C.L., Wada, N., Rosegrant, M.S., Meijer, S. & Ahmed, M.** 2003. *Outlook for fish to 2020, meeting global demand. A 2020 vision for food*. Penang, Worldfish Center, and Washington DC, International Food Policy Research Institute.
- DFID.** 1999. *Sustainable livelihoods guidance sheets*. London, DFID.
- FAO.** 2002. *The state of world fisheries and aquaculture 2002*. Rome, FAO Fisheries Department.

- FAO. 2003a. *World fisheries and aquaculture atlas*. 2<sup>nd</sup> edn. Rome, FAO Fisheries Department. [CD Rom].
- FAO. 2003b. *Status and trends in mangrove area extent worldwide*. Forest Resources Assessment Working Paper No. 63. Rome, FAO Forestry Department.
- FAO. 2004. *The state of world fisheries and aquaculture 2004*. Rome, FAO Fisheries Department.
- FAO/NACA. 2003. *Myanmar aquaculture and inland fisheries*. RAP Publication 2003/18. Bangkok, FAO Regional Office for Asia and the Pacific.
- Gonzales, E. 2006. The current status of mariculture in the Philippines and livelihood opportunities for coastal communities. *The future of mariculture: a regional approach for responsible development of marine farming in the Asia-Pacific region*. Bangkok, NACA-STREAM.
- Gonzales, E. & Savaris, J. 2005. *Output 2. Marine ornamentals trade in the Philippines and options for its poor stakeholders*. Prepared under the DFID-funded EC-PREP project (EP/R03/014) “International Seafood Trade: Supporting Sustainable Livelihoods among Poor Aquatic Resource Users in Asia” Bangkok, Poseidon Aquatic Resource Management Ltd. (United Kingdom), NACA-STREAM.
- Hambrey, J., Tuan, L.A. & Thuong, T.K. 2001. *Aquaculture and poverty alleviation 2: cage culture in coastal waters of Vietnam*. Stirling, DFID-AFGRP.
- Haylor, G. 2004. Poverty reduction and aquatic resources *In* NACA, ed. *Emerging trends in aquaculture in Asia-Pacific aquaculture: 2003*. pp.51–57. Bangkok, NACA.
- Haylor, G., Briggs, M.R.P., Pet-Soede, L., Tung, H., Yen, N.T.H., Adrien, B., O’Callaghan, B., Gow, C., De Vantier, L., Cheung, C., Santos, R., Pador, E., De La Torre, M., Bulcock, P. & Savage, W. 2003. Improving coastal livelihoods through sustainable aquaculture practices. *In* NACA, ed. *A report to the collaborative APEC grouper research and development network* (FWG/01/2001). pp.1–35. Bangkok, NACA.
- IFAD. 2002. *Assessment of rural poverty Asia and the Pacific*. Rome, International Fund for Agricultural Development.
- IMM, CFDO & CBNRM LI. 2005. *Understanding the factors that support or inhibit livelihood diversification in coastal Cambodia. An output from DFID-funded research in Cambodia*. Exeter, IMM Ltd.
- IUCN. 2003. Improving local livelihoods through sustainable aquaculture in Hon Mun marine protected area, Nha Trang Bay, Vietnam. *In* NACA, ed. *Improving coastal livelihoods through sustainable aquaculture practices*. pp.151–192. Bangkok, NACA.
- IUCN Pakistan. 2003. *Environmental degradation and impacts on livelihoods. Sea intrusion – a case study*. Sindh, IUCN.
- Jaya, I.B.M.S. 2006. *Development of mariculture in Indonesia. The future of mariculture: a regional approach for responsible development of marine farming in the Asia-Pacific region*. Bangkok, NACA.
- Macfadyen, G., Banks, R., Phillips, M., Haylor, G., Mazaudier, L. & Salz, P. 2003. *Output 1. Background paper on the international seafood trade and poverty*. Bangkok, Poseidon Aquatic Resource Management Ltd. (United Kingdom), NACA-STREAM.
- Macfadyen, G. & Corcoran, E. 2002. *Literature review of studies on poverty in fishing communities and of lessons learned in using the SLA in poverty alleviation strategies and projects*. FAO Fisheries Circular No, 979. Rome, FAO.
- Macfadyen, G., Phillips, M. & Haylor, G. 2005. *Output 3. Synthesis report with pro-poor trade research findings and policy recommendations*. Bangkok, Poseidon Aquatic Resource Management Ltd (United Kingdom), NACA-STREAM.
- Mauksit, A., Maala, L. & Suspita, A. 2005. Seaweed culture and farmer incomes in Bekasi, Indonesia. *STREAM J.* 4(4): 1–3.

- Maung Soe, K. 2006. The current status of mariculture in Myanmar and livelihood opportunities for coastal communities. *The future of mariculture: a regional approach for responsible development of marine farming in the Asia-Pacific region*. Bangkok, STREAM.
- Mohan, J.M., Sathiadhas, R. & Gopakumar, G. 2006. Marine farming: country analysis-India. *The future of mariculture: a regional approach for responsible development of marine farming in the Asia-Pacific region*. Bangkok, STREAM.
- Mukherjee, R. 2006. The current status of mariculture in India and livelihood opportunities for coastal communities. *The future of mariculture: a regional approach for responsible development of marine farming in the Asia-Pacific region*. Bangkok, STREAM.
- NACA/FAO. 2000. *Report of the Conference on Aquaculture in the Third Millennium*. Conference on Aquaculture in the Third Millennium, 20–25 February 2000. Bangkok, NACA and Rome, FAO.
- Nguyen, S.H. 2006. The current status of mariculture in Vietnam and livelihood opportunities for coastal communities. *The future of mariculture: a regional approach for responsible development of marine farming in the Asia-Pacific region*. Bangkok, STREAM.
- Rosario, W.R. 2006. Country report on marine farming in the Philippines. *The future of mariculture: a regional approach for responsible development of marine farming in the Asia-Pacific region*. Bangkok, STREAM.
- Santos, R., Pador, E. & De La Torre, M. 2003. Improving coastal livelihoods through sustainable aquaculture practices – the case of Tubigon, Bohol, Philippines. In NACA, ed. *Improving coastal livelihoods through sustainable aquaculture practices*. pp. 193–256.. Bangkok, NACA-STREAM.
- Silvestre, G., Garces, L., Stobutzki, I., Luna, C., Ahmed, M., Valmonte-Santos, R.A., Lachica-Ali, L., Munro, P., Christensen, V. & Pauly, D. 2003. *Assessment, management and future directions for coastal fisheries in Asian countries* WorldFish Center Conference Proceedings. Penang, WorldFish Center.
- Sim, S.Y., Rimmer, M.A., Toledo, J.D., Saguma, K., Remengan, I., Williams, K. & Phillips, M.J. 2005a. *A guide to small-scale marine finfish hatchery technology*. Bangkok, NACA.
- Sim, S.Y., Rimmer, M.A., Toledo, J.D., Saguma, K., Remengan, I., Williams, K. & Phillips, M.J. 2005b. *A practical guide to feeds and feed management for cultured groupers*. Bangkok, NACA.
- Sugiyama, S. & Funge-Smith, S. 2003. Asian regional trends in aquaculture and related fishery activities. In NACA, ed. *Emerging trends and experiences in Asia-Pacific aquaculture: 2003*. pp. 2–29. Bangkok, NACA.
- Sugiyama, S., Staples, D. & Funge-Smith, S.J. 2004. *Status and potential of fisheries and aquaculture in Asia and the Pacific* RAP Publication 2004/25. Bangkok, FAO Regional Office for Asia and the Pacific.
- Suspita, A. 2006. The current status of mariculture in Indonesia and livelihood opportunities for coastal communities. *The future of mariculture: a regional approach for responsible development of marine farming in the Asia-Pacific region*. Bangkok, STREAM.
- Tacon, A.G.J. 2000. Increasing the contribution of aquaculture for food security and poverty alleviation. In R.P. Subasinghe, P.B. Bueno, M.J. Phillips, C. Hough, S.E. McGladdery & J.R. Arthur, eds. *Aquaculture in the Third Millennium*. pp. 63–72. Bangkok, NACA.
- Tuan, L.Q. 2003. *Trade in fisheries and human development. Country case study: Vietnam*. UNDP, Asia-Pacific Initiative on Trade, Economic Governance and Human Development.
- UNEP-WCMC. 2006. *In the front line: shoreline protection and other ecosystem services from mangroves and coral reefs*. Cambridge, UNEP-WCMC.

- Wattoo, J.M.** 2006. The current status of mariculture in Pakistan and livelihood opportunities for coastal communities. *The future of mariculture: a regional approach for responsible development of marine farming in the Asia-Pacific region*. Bangkok, STREAM
- Whittingham, E., Campbell, J. & Townsley, P.** 2003. *Poverty and reefs: a global overview*. Exeter, IMM Ltd Innovation Centre.
- Yap, W.G., Funge-Smith, S., Rimmer, M., Phillips, M.J., Sim, S.Y., Kongkeo, H. & Bueno, P.B.** 2006. *An overview of aquaculture in Asia-Pacific and the outlook for mariculture in Southeast Asia*. Bangkok, NACA.

## APPENDIX I Target communities and stakeholders identified by the country reviews

Country/Commodity	Target communities
<b>India<sup>1</sup></b>	
Shrimp culture	Farmers and workers, feed and seed suppliers
Traditional rice-shrimp culture	Small-scale farmers and fishers and women
Green mussel farming	Small-scale farmers and fishers and women
Lobster fattening	Small-scale farmers and fishers and women, seed and feed suppliers
Crab farming	Small-scale farmers and fishers and women
Edible oyster culture	Small-scale farmers and fishers and women
Seaweed culture	Small-scale farmers and fishers and women
<b>Indonesia<sup>2</sup></b>	
<i>Tambak</i> mariculture	Ethnic groups
Intensive mariculture	Migrant workers
Seed collectors	Farmers, women
Seaweed culture	Low-paid cleaners
Pearl culture	Crafters of discarded shells
Mud crab culture	Farmers
Mussel culture ( <i>Perna</i> spp.)	Farmers
Fisheries extension	Women in extension, research and education
	West Bengal, Kerala, Andhra Pradesh, Tamil Nadu and Karnataka states
	Coastal lowlands (Pokkali fields in Kerala, Khar lands in Goa, Khazans in Karnataka State and Bheri in West Bengal)
	Beksi District, Bali (US\$0.30–0.60 month per household), Palu Bay, Central Sulawesi

<sup>1</sup> Coastal communities of Tamil Nadu, Chennai, Pondicherry, Andhra Pradesh, Orissa and West Bengal and scheduled castes and tribes.

<sup>2</sup> Many people not listed as fishers are at least part-time harvesters of marine organisms



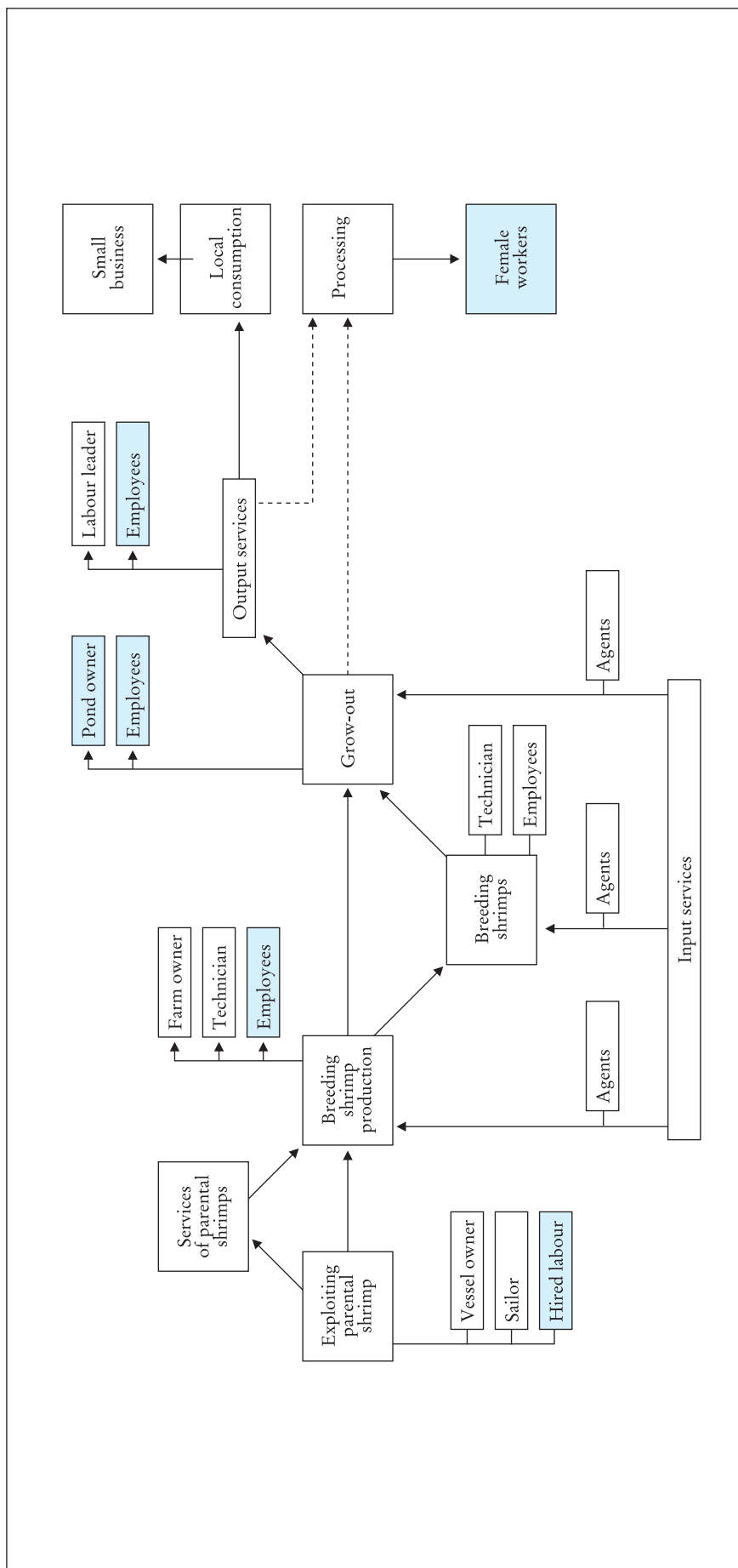
**APPENDIX I**  
Continued

Country/Commodity	Target communities
<b>Myanmar</b>	
Shrimp fry collection	Fry collectors, women and children
Mud crab and grouper cage farming	Cage farmers
Shrimp culture (extensive, extensive plus and semi-intensive)	Small-scale operators, caretakers, pond preparation labourers, harvest and post-harvest labourers, sorters, buyers, traders and exporters
Shrimp hatcheries	Operators, caretakers, tank cleaners
Grouper cage culture	Small-scale operators/farmers and grouper fry collectors (700 to 800 fishers)
Sea bass ( <i>Lates calcarifer</i> ) pond culture	
Mud crab fattening in ponds and cages and feed preparation	Farmers and women
Collection of live lobsters ( <i>Parulirus</i> ) and <i>Squilla</i> or mantis shrimp	Collectors and buyers
Mother of pearl culture	Hired labourers, divers and cleaners
Post-harvest activities	Women
	Rakhine State
	Rakhine State
	Rakhine State, Yangon, Tanintharyi Division
	27 shrimp hatcheries, 12 run by DoF and 15 private
	Southern, western parts of Myanmar: Myeik Archipelago and Gwa Township
	Ayeyarwady and Tanintharyi divisions
	Ayeyarwady and Rakhine states
	Myeik
	Myeik and Tanintharyi divisions

## APPENDIX I Continued

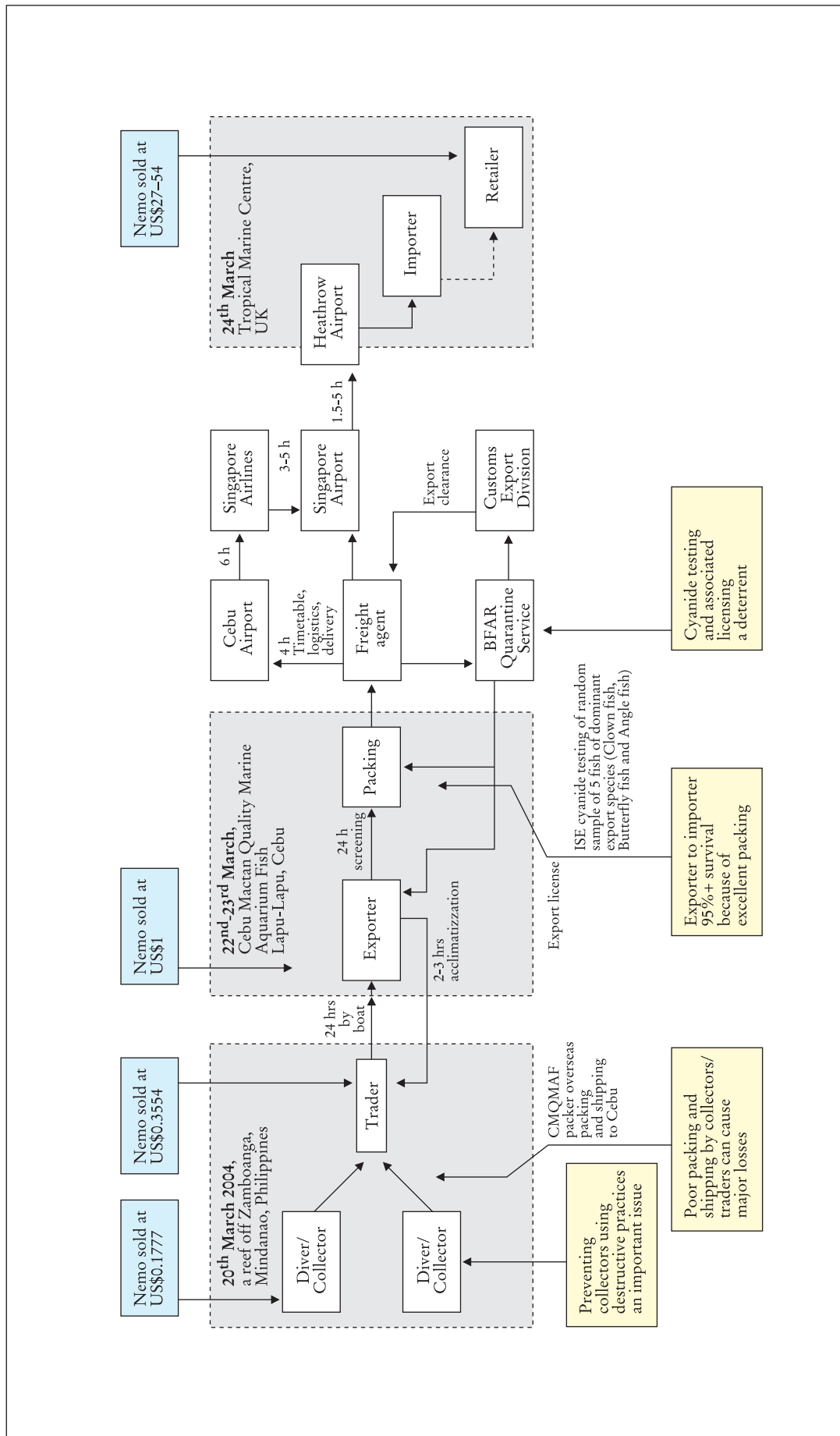
Country/Commodity	Target communities
<b>Philippines</b>	
Milkfish cage operation	Small-scale cage operators, caretakers, extra feeders, pre-operation workers/labourers, small-boat operators delivering farm inputs, fish vendors and viajeros
Seaweed farming in coastal waters	Small-scale farmers, women, farmers associations, producers and traders association, seed suppliers, buyers, processors and exporters
Oyster and mussel farming	Farmers and women
Fish and seafood trading	Fish vendors, peddlers and women peddlers
Grouper cage culture	Small-scale operators, small buyers and seed suppliers
Wild fry collection	Fry collectors, concessionaires and other middlemen
Shellfish gleaners and seafood vending	Women and children
Live fish, ornamental fish collection	Grouper collectors, ornamental fish collectors, abalone, sea horse, sea cucumber collectors (seasonal), seasonal octopus fishers, packers, women packers and children running errands in "financiers" facilities
Commercial fishing	Captain and crew
<b>Viet Nam</b>	
Agriculture and animal husbandry	Crop farmers, migrant workers, hired labourers, livestock and poultry raisers
Aquaculture products processing	Women
Commercial fishing	Hired workers
Hatcheries	Hired workers
Shrimp farming ( <i>Penaeus monodon</i> and <i>Litopenaeus vannamei</i> )	Small-scale operators, shrimp farm employees, feed suppliers, fry suppliers
Shrimp processing factory (seasonal; working 12–15 hours per day during peak season)	Hired factory workers and women workers
Fish and lobster sea-cage farming	Small-scale farmers, landless people
Shrimp-mangrove farms	Farmers
Cage culture	
Mollusc, crab, seaweed farming	
	Receiving US\$13.33 per trip Income = US\$33.33–40.00
	Income = US\$33.33–40.00 Income = US\$1.67 per day State-owned = US\$23.33–80.00
	Khanh Hoa benefited Mekong Delta Bai Tu Long and Ha Long bays Long An to Ca Mau

**APPENDIX II**  
 The market chain for shrimp in Thua Thien Hue, Viet Nam (From Macfadyen, Phillips and Haylor, 2005)<sup>1</sup>



<sup>1</sup> The blue-shaded areas indicate potential roles for income-poor stakeholders.

**APPENDIX III**  
**Trading Nemo – The market chain of marine ornamentals from Mindanao to Manchester (From Macfadyen, Phillips and Haylor, 2005)**



# Mechanisms for technology transfer

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## INTRODUCTION

Applied research activities on existing and potential mariculture species are being carried out throughout the region by specialized national research facilities. Many of the commercial marine species are farmed regionally and rarely confined to the industry of any given country. The transfer of farming technologies and better practices in the region through a strengthened collaborative mechanism could further support the development of the sector and ensure that lessons learnt are widely shared. The objectives of this review are to:

- review existing mechanisms for technology transfer and propose alternatives for effective dissemination of research and development (R&D) to farmers and other stakeholders;
- identify present training activities and future training requirements for the sustainable development of mariculture; and
- identify centers of excellence in various forms of mariculture.

The information summarized below on regional mariculture research, training activities and future needs has been compiled from a variety of sources including:

- country review papers for this workshop;
- the Report of the Expert Workshop and Regional Aquaculture Review for Asia (November 2005);
- the Report of the 8<sup>th</sup> Network of Aquaculture Centres in Asia-Pacific (NACA) Technical Advisory Committee (October 2005);
- the Report of the 17<sup>th</sup> NACA Governing Council, (23–28 February 2006);
- NACA publications (reviewed content from 2001–2006);
- Asia-Pacific Marine Finfish eNewsletter (reviewed content from 2001–2006)
- institutional websites (content reviewed as of February 2006); and
- profile of NACA Centres (December 2001).

## EXISTING AND ALTERNATIVE MECHANISMS FOR TECHNOLOGY TRANSFER

### Existing mechanisms

Most of the existing mechanisms used to transfer mariculture technology are largely standard practices in fisheries and aquaculture (or more broadly, in agriculture). They may be loosely categorized into the four following areas:

*Hands-on training-short courses, study tours, training schools and on-the-job experience*

Due to the highly technical nature of some aspects of mariculture, particularly

hatchery technology, hands-on training is often the most practical mechanism for technology transfer. Short, intensive courses on specific aspects of mariculture (such as the Regional Grouper Hatchery Production Training Course offered annually by Indonesian research centers in collaboration with NACA) are among the most common technology transfer mechanisms cited by countries. Hands-on mariculture training opportunities are also provided through vocational training schools (as those in Australia and Malaysia) and on-the-job in some research centers where farmers may work for a period in a government station to gain experience in the practical and technical aspects (as in Indonesia). Demonstration farms and exchange visits to exceptionally good private farms are used in some countries to raise awareness and encourage the private sector to enter into new industries or to adopt new practices (as in India, Indonesia and Thailand).

While hands-on training can provide practical and effective learning opportunities for transferring technology between all kinds of stakeholder groups, there is a shortage of specialized facilities where such training can take place and the number of opportunities/placements is generally not sufficient to meet demand. Participants often have to travel great distances at considerable expense, so that such training is accessible only to people who are relatively wealthy or have a sponsor (government, research and industrial-scale farmers).

#### *Extension services, seminars and discussion groups*

The accessibility issues that small-scale producers and rural communities face in centralized training opportunities are widely recognized. Most governments therefore employ a range of “mobile” mechanisms to bridge the gap with rural communities and take training opportunities to the producer.

Extension officers are a traditional technology transfer mechanism providing technical support to producers through on-farm advice, local seminars, distribution of publications and other information, and even provision of mobile laboratory services on water quality or health (as in Thailand). Extension officers can also play an important role in the social cohesion of local producers. The scale on which extension officers are deployed varies widely between countries, with officers serving individual communities (People’s Republic of China) to entire states (Australia). While the provision of a decentralized extension network can improve accessibility to information for rural communities, it is expensive. In most countries it is generally accepted that extension services are in decline and do not have sufficient staff or resources to meet demand. They may function most effectively where there are organized groups of producers with which they can interface. The role of nongovernmental organizations (NGOs) involved in rural development as an alternative avenue for the delivery of extension service is well recognized by some governments. Such NGOs may provide training or work in partnership with appropriate groups (as in India and Thailand).

A common issue with regard to mariculture is that existing extension staff may not have sufficient technical training to adequately support farmers (as in Cambodia, China, India and Thailand), particularly with regards to emerging technologies.

While most extension services are funded by the public sector, farmer groups may employ their own extension staff to provide specialist services (notably in aquatic animal health), although this is seldom seen outside of industrial-scale producer groups (as in Australia, but being considered by the Marine Products Exports Development Authority [MPEDA] in India).

#### *Publications*

Printed publications are a mainstay of technology transfer employed by virtually all governments as a (relatively) cheap mechanism for reaching large numbers of producers, although where cost-recovery policies are pursued, cost is still often a



significant issue both for the publisher and for the end user. As stand-alone products, the usefulness of publications is constrained by many factors, including the literacy and technical ability of the target stakeholders, and so they need to be prepared with due consideration of the needs of the target group, for whom they often play a supporting role in training courses and other ways of learning. An issue that remains understated is that the accessibility of printed matter is often a significant issue for people in rural communities, just as distribution can be an issue for the publisher. Producing a publication is relatively simple, but ensuring that it is widely available, accessible and affordable to the people that actually need it is far more difficult. In many ways, the problems that rural communities face in accessing printed media are not dissimilar to those they face in accessing the web.

### *Mass media*

Regular television and radio programmes are utilized by both governmental authorities and the private sector as a mechanism to keep farmers informed of developments, emerging issues and improved practices. These range from current affairs segments in broader agricultural programmes (as in Australia) to dedicated documentary segments (as in Thailand) and talk-back programmes where farmers may “call in” (as in Cambodia). Clearly such devices have enormous potential, although agricultural programmes tend to be broadcast outside of peak hours.

### **Alternative mechanisms**

In a climate of increasing demand for knowledge and diminishing extension resources, the transfer of technology to a large decentralized stakeholder base will become increasingly difficult and require fresh approaches. Some promising alternative approaches to technology transfer are described below.

### *Information access surveys*

An Information Access Survey (IAS) is not a mechanism for technology transfer in itself, but rather a tool that can help make sensible decisions about the best ways to communicate with different groups of stakeholders. The purpose of an IAS is to conduct an objective assessment to:

- identify key issues about people and what information needs they have;
- identify what media sources are available, what strategies people use to get their information and how cost-effective these are; and
- suggest the most appropriate methods of communication that are useful for different groups of people.

An IAS should:

- take into consideration the needs of the target group;
- involve as many people as possible;
- be socially and culturally acceptable;
- be flexible, so that it can be modified to suit different circumstances; and
- provide recommendations that are easy to put into practice.

For each stakeholder group, issues to consider/include in preparation of an IAS include:

- the geographical area of the survey;
- the existing communications networks available to target stakeholders;
- the needs of the stakeholders;
- the kinds of information that would be useful to them;
- how this information would help them;
- how people prefer to get this kind of information;

- mitigating social, political or cultural factors; and
- what techniques work well, and why.

An IAS provides an indication of how effective different media are in reaching target stakeholders and forms the basis for developing an integrated communication strategy. Some approaches are likely to be more useful than others or may only be useful to part of the target group. It is quite likely that an IAS will reveal that an integrated or mixed approach using multiple strategies may be most effective. IAS's have been conducted by the NACA STREAM Initiative for Cambodia, Viet Nam and the Philippines.<sup>1</sup>

### *Farmer associations (aquaclubs)*

The formation of farmer associations is an approach that has demonstrated excellent potential as a mechanism to facilitate technology transfer, both between stakeholder groups and within farmer communities. In India, MPEDA in cooperation with NACA, the Indian Council of Agricultural Research (ICAR), the Australian Centre for International Agricultural Research (ACIAR) and the Food and Agriculture Organization of the United Nations (FAO) has provided support to bring clusters of shrimp farmers together into cooperative associations to implement Better Management Practices (BMPs) as part of projects on shrimp health and coastal zone management. The groups, locally known as “aquaclubs”, were initially established to engage farmers in the development of locally appropriate BMPs and to demonstrate and promote the advantages of working as a group to plan their crops. The group collectively manages common resources such as the water supply, thus reducing inter-farm interference, reducing the impact of disease and substantially increasing survival, size, yield and price received for the crop. Similar approaches have been applied in Viet Nam with equal success.

The benefits of aquaclubs are that they:

- serve as focal points for extension services, leveraging the accessibility and impact of better farmers and available extension staff among small-scale producers, as well as providing good opportunities for farmer-to-farmer learning;
- provide a mechanism for rapid implementation of new technologies or BMPs across the group, such as food safety directives from export markets or traceability systems;
- provide economies of scale in purchasing technical services, such as the testing of seed for health problems, which in turn facilitates the access of small-scale farmers to these services;
- provide a mechanism for self-regulation, as there is considerable economic incentive and peer pressure for farmers to participate and comply with the groups' management principles;
- provide increased market power in negotiating prices for inputs and for the sale of the harvest;
- are self-sustaining – as they are economically viable they may also be independent of government support and maintained by the farmers themselves.

Farmer associations have good potential in situations where farmers have a strong common interest and can benefit from working together, for example in the procurement of inputs or the management of shared natural resources.

### *One-stop aqua shops*

Farmer groups can also be linked to structures that facilitate sharing of experience or access to outside knowledge. Research reported in academic journals, often in English, is an

<sup>1</sup> These and guidelines on conducting IASs are available for download from the STREAM website at: <http://www.streaminitiative.org/Library/Communications/communications.html>.

important step to sharing new aquaculture knowledge and technology but has little development impact in itself. As a consequence there is increasing interest in “Research into Use” programmes. A particular communications and learning challenge is the exchange of learning with and among poor people who farm in rural areas.

The evolution of local-level institutions that facilitate learning and planning and the availability of accessible local language media are helping farmers to draw down the information and other support services they need and even beginning to provide a platform for policy debate and monitoring and evaluation from farmers’ perspectives.

NACA has established nine “One-Stop-Aqua-Shops” (OAS) in eastern India, one in Pakistan and one in Viet Nam to provide local-level support. The OAS function under the guiding principle of a single-point, under-one-roof provision of services, but are managed by different groups such as NGOs and federations of Self-Help Groups (SHGs), farmer groups and local community officials. The OAS provide a variety of services according to local demand including information, training, fish fingerlings, and access to sources of micro-credit and loans necessary to enter into farming. Previously farmers had struggled and engaged in considerable travel to gain access to resources such as quality fish seed and market information and had often been unaware of governmental, inter-governmental and NGO support, and rural banking services.

To support these facilities, in particular with the media required to fulfill their communications role, NACA/STREAM responded with the launch of OASIS (the “One-Stop Aqua Shop Information Service”). OASIS, like the OAS concept, intends to support changes to the way that information is made available to farmers and through the OAS network offer the following services to:

- offer farmers aquaculture and improved service delivery orientated Better-Practice Guidelines;
- enable farmers to learn from each other’s experiences and share these with other primary stakeholders throughout the Asia-Pacific through publications made available in local languages at OASs;
- find out who is who from a “contacts” database, including details of OASs, banks, departments of fisheries, NGOs, SHGs, insurance providers and input suppliers;
- enable farmers to gain access to information and facilitated access to web resources such as the STREAM and NACA Virtual Libraries;
- enable farmers to ask aquaculture-related questions and receive feedback via the NACA web-based “discussion forum”;
- offer awareness raising in aquaculture through documentaries, videos and drama; and
- offer exchange visits with successful aquaculture operations within the local area.

OASIS aims to make available information from farmers and fishers, service providers, news agencies, the Internet, academia (including databases of research and outputs from specific research programmes) and on-line communities of shared-interest groups, as well as learning from other countries.

The OAS has become a focus of improved service provision in an age where previously unprecedented levels of communication are possible and has changed the way that information is being made available. The OAS enables service providers to get “closer” to communities through the development of information and service focal points.

### *Cooperative research networks*

Cooperative research networks have gained favour over the last decade as an effective mechanism to leverage limited scientific resources against common problems, fast-tracking technological development while reducing duplication of effort. NACA coordinates one such network, the Asia-Pacific Marine Finfish Aquaculture Network (APMFAN).

APMFAN links researchers and institutions working on marine finfish aquaculture throughout the NACA network. The primary mechanism for information exchange is a regular email newsletter and digital magazine (PDF format) that carries a summary of the latest research findings contributed by participants or collated by the secretariat, links to relevant websites and downloadable publications and contact information. The network conducts periodic workshops and also serves as a vehicle for convening training courses such as the Regional Grouper Hatchery Production Training Course offered by Indonesian research centers and the development of proposals for regional research projects.

Factors contributing to the success of APMFAN have been its focus on a suite of technical problems common to the region (i.e. bottlenecks in reproduction, larviculture, nutrition and health management of marine fish), a regular and common means of communication and exchange, and the presence of a dedicated coordinator to drive network activities.

As many of the scientists and institutions participating in the Marine Finfish Aquaculture Network are also engaged in other forms of mariculture, there may be scope to expand the focus of the network to include other mariculture activities.

### *The internet*

The Internet is the most powerful network for exchanging information that has ever existed in human society. Its scope of coverage, accessibility and influence grow every day. With recent advances in personal web publishing technology and content management systems, it is now possible even for a small organization with a shoestring budget and limited information technology (IT) capabilities to establish an effective website with a global reach. With careful planning, web publishing offers:

- massively improved accessibility and circulation of information and publications (The sheer scale and worldwide nature of the Internet means that even the simplest of web pages can be a highly effective communication tool);
- low publishing costs (good web publishing tools are available for free and most of the costs are fixed; the web offers the opportunity to publish information that may not otherwise be able to be made available in any form);
- fast publishing (it is often possible to publish a new document and inform people of its availability in only a few minutes, making “real time” reporting possible, as well as the provision of time-sensitive services such as market information); and
- community participation (many web-based digital publishing tools are designed to be interactive, allowing groups of people to communicate and collaborate in the process of creating and publishing information via the Internet; this allows the publishing process to be decentralized, giving the creators of the content more ownership of the process).

There are, of course, limitations to using Internet as a mechanism for technology transfer:

- The Internet is not accessible to everyone (in most cases it is useful only to the subset of people that have access to the Internet and/or computers, which tends to be relatively low in rural areas and among farming communities, although in terms of absolute numbers this group can be very large; internet usage tends to be better in the public/research sectors); and
- Some degree of computer literacy is required to make effective use of a digital publishing system and deal with daily security issues such as viruses, and a somewhat higher level to plan, install and administer such a system (these skills are often limited or unavailable in public-sector organizations involved in aquaculture).

The value of digital publishing as a mechanism for technology transfer depends to a large extent on the nature of target stakeholder groups. In most situations it is best seen as a suite of additional tools for communicating with people that should be used in concert with other media, preferably through an integrated communications strategy tailored to meet their needs (for example, as determined through an information access survey).

#### *E-mail newsletters*

E-mail is probably the simplest, most ubiquitous and widely understood Internet technology, and email newsletters can provide a personal and highly effective way to link relevant stakeholder groups. The Asia-Pacific Marine Finfish Aquaculture Network has published a regular email newsletter since 1998, as a mechanism for researchers to publish their research findings and share experience. The newsletter contains hyperlinks to relevant web pages, publications and other information resources.

#### *Online communities*

Community websites take the web publishing concept one step further by allowing members of the public to participate as well. Instead of merely presenting information to people, community websites allow their members to communicate and exchange information among themselves. The most common form of community website is a “discussion forum”, but the community concept can be applied to nearly any form of Web site.

Online communities are a unique tool in that they allow an individual to access the collective knowledge of a large group of people that may be scattered all over the world. They provide a “venue” where people with similar interests can “meet” each other, share experiences and solve common problems. One of the most powerful applications of online communities is a “self-help” group. In a highly decentralized environment, empowering stakeholders to help each other through a community website may be more practical than trying to provide direct assistance to them on an individual basis.

As with other Internet technologies, online communities are only useful to a subset of most stakeholder groups. They must reach a critical mass of participants in order to become effective tools for technical exchange. Once activity reaches a certain level, the feedback and mutual interaction among members becomes largely self-sustaining. Achieving the critical mass of members needed to initiate an ongoing “conversation” can be difficult. The most important aspect is to identify an area of common interest to target stakeholders that will bind them together as a social group.

NACA is piloting the development of an online community on the NACA website, [www.enaca.org](http://www.enaca.org). The community is still in the early stages of formation, although it has attracted more than 2 000 members to date. The community is open to public participation, but there is considerable potential to make use of the facilities to support research networks (a dedicated marine finfish aquaculture forum is available). NACA is also engaged in training staff from network institutions in website administration and management, with a view to building the capacity of member countries to provide online services and to train their own staff.

## **PRESENT MARICULTURE TRAINING ACTIVITIES AND LIKELY FUTURE REQUIREMENTS**

### **Regular training activities**

There are currently few short-term mariculture training activities that are held on a regular basis, and most are aimed at the national or local level. The available courses



are summarized below (the country reports give more detail on national-level training activities):

- *Regional grouper hatchery production training course.* A three-week course organized annually since 2002 by Indonesia and NACA, it has been hosted at both the Gondol Research Institute for Mariculture and the Brackish Water Aquaculture Development Center at Situbondo. The course covers all aspects of broodstock management, captive reproduction, larviculture, nutrition, health management and grow-out. It is a paid course.
- *Principles of health management in aquaculture.* A 19-week online training course convened by the Southeast Asian Fisheries Development Center (SEAFDEC) Aquaculture Department in the Philippines. The course covers disease prevention, diagnosis and management for finfish and crustaceans. It is a paid course.
- The Malaysian Department of Fisheries offers six training courses relevant to mariculture through the Institute of Marine Aquaculture (Kedah) and the Marine Finfish Production and Research Centre (Trengganu). These are aimed at the national level, but may be open to international participation through the Malaysia Government Technical Cooperation Programme. The courses are:
  - *Fundamental aquaculture practice* (7 days).
  - *Seed production and management of marine finfish* (30 days).
  - *Cage culture of brackish water finfish* (5 days).
  - *Feed formulation and preparation at farm scale* (3 days).
  - *Seed production and culture of oysters* (30 days).
  - *Seed production and culture of mussel* (14 days).
- *Marine hatchery management.* A one-year vocational course offered by the Fremantle Maritime Centre (Australia). The course covers general management of recirculating hatchery systems, live food production and health management. It is a paid course.

Other ongoing training initiatives include:

- The Yellow Sea Fisheries Research Institute plans to conduct training courses on the introduction of Hazard Analysis and Critical Control Point (HACCP) management systems, European Union (EU) Food Safety and Sanitation Regulations and Directives on the mariculture of shellfish (particularly on assessing water quality and safety), the implementation of harvesting area classification systems and implementation of marine biotoxin/algae bloom monitoring systems and information on EU markets and entry requirements for Chinese products.
- Thailand has established a programme on food safety for fisheries production aimed at assisting producers to meet requirements for domestic and export markets. The programme targets farmers, government officers and other stakeholders.
- Thailand provides training to around 25 000 farmers and other interested people each year through short courses on aquaculture, breeding and nursing, home-made feeds, health management and value-adding of fisheries products. Demonstration sites are also established in selected fishing communities that provide technical assistance in water analysis and health management.
- The Marine Aquaculture Development Centre at Lombok, Indonesia is conducting training on abalone culture for vocational school teachers from seven provinces, to accelerate spat production and support industry development.
- The Republic of Korea has introduced programmes to assist people (in particular, youth) to study mariculture and to establish aquaculture businesses, to encourage new entrants into the industry.
- The Busan Fisheries Technology Institute, Republic of Korea, has established test farms for the clam *Meretrix lusoria* in four locations around Buan. This included resource management and development of value-added products.



- The Indian Central Marine Fisheries Research Institute has established open sea cage demonstration farms at four sites, two on the east coast and two on the west coast of India.

### **Potential training activities/training providers**

Some research centers in the region have indicated that they have either recently held or have the capability to provide ad-hoc training courses in particular aspects of mariculture in response to requests, as summarized below:

#### *Freemantle Maritime Centre (Australia)*

- culture of specific temperate species of marine finfish through short course training programmes;
- aquaculture mechanics;
- water quality analysis and environmental impact assessment of aquaculture.

#### *Central Marine Fisheries Research Institute (India)*

- pearl production;
- bivalve hatchery design and management;
- mussel culture;
- edible oyster culture;
- live feed and phytoplankton culture;
- seaweed culture.

#### *National Bureau of Fish Genetic Resources (India)*

- cryopreservation of fish milt;
- genetic characterization using isozyme and isoelectric focusing markers.

#### *Brackish Water Aquaculture Development Center (Jepara, Indonesia)*

- milkfish hatchery production;
- nutrition.

#### *Center for Marine Aquaculture Development (Lampung, Indonesia)*

- breeding and culture of marine finfish (Asian seabass, various groupers, seahorse);
- breeding and culture of sea cucumber;
- breeding and culture of pearl oyster;
- seaweed culture;
- fish health management;
- live food production.

#### *Wando Maritime and Fisheries Office (Democratic People's Republic of Korea)*

- laver reproduction.

#### *Pohang Regional Maritime Affairs and Fisheries Office (Democratic People's Republic of Korea)*

- polyculture of Japanese flounder and abalone in land-based tanks;
- production of the sea squirt (ascidian) *Halocynthia roretzi*.

#### *National Aquaculture Development Authority (Sri Lanka)*

- community-oriented shellfish farming.

#### *Thailand (institute not identified)*

- Babylon snail production;
- development of information technology for fisheries.

### **Future training needs**

Recent requests for training related to mariculture as identified in the country review papers, the eighth NACA Technical Advisory Committee Meeting in the Islamic Republic of Iran (November 2005) and the seventeenth NACA Governing Council (February 2006) and by a range of other stakeholders were:

- training opportunities for extension officers in mariculture technology (Cambodia, China, India, Thailand) including livelihoods approaches and communications skills (Cambodia) so as to more effectively support the industry;
- training of extension officers in BMPs in various fields of mariculture;
- extension of broodstock management programmes and improved nursery techniques to prevent genetic deterioration of broodstock, to lay the foundation for future genetic improvement programmes and to assist in providing high-quality seed to farmers (China, Malaysia);
- good handling and storage of fisheries products (China);
- depuration and traceability of shellfish products and enforcement of EU hygiene regulations (China);
- fish health management (Islamic Republic of Iran), disease surveillance and reporting (India);
- marine ornamental fish culture (Sri Lanka);
- seaweed culture (Cambodia, Indonesia, Islamic Republic of Iran);
- aquaculture project development and management; and
- economic and financial planning of aquaculture (Secretariat of the Pacific Community, SPC) (future efforts by SPC will provide tools and training, such as software tools to assist businesses in addressing these areas).

Although some of these issues may be addressed by existing training programmes, further emphasis may be warranted in these areas. Other common issues were:

- poor linkage between research institutes, extension stations and farmers (it is often the interface between different classes of stakeholders that is the most serious problem, for example, between farmers and researchers); and
- a shortage of training opportunities/facilities for youth (new entrants to the industry), farmers and entrepreneurs (India, Islamic Republic of Iran, the Democratic People's Republic of Korea).

### **CONCLUSIONS**

Mariculture is, in general, at an earlier stage of development and technically more complex than freshwater aquaculture. The weakest links in the transfer of technology are often the interface between different stakeholders, for example between researchers and farmers, leading to a considerable delay in the implementation of technological advances by producers and a shortage of skilled labour at the farm level, particularly among small-scale farmers. Development of a whole-of-chain approach to technology transfer will require a hybrid approach that takes into account the needs and behaviour of different stakeholder groups and mechanisms to facilitate interaction between them.

Given the ongoing decline of traditional extension services, there is a need to investigate alternative approaches to technology transfer, including the role of the private sector. Approaches that encourage networking between and within stakeholder groups may offer effective solutions. Collaborative research networks communicating via email and the Internet are an effective mechanism for accessing research resources and exchanging experience in the international context. Farmer associations and locally owned/maintained information centers can offer an excellent and sustainable mechanism for facilitating rapid technology transfer at the local level.

# Regional review on existing major mariculture species and farming technologies

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## INTRODUCTION

For the purposes of this review, “mariculture” is regarded as aquaculture of aquatic plants and animals that is undertaken in the sea. It thus excludes land-based aquaculture, particularly pond culture. However, because much pond production is classified as “mariculture” in the Food and Agriculture Organization of the United Nations (FAO) statistics, it is difficult to get an accurate estimate of mariculture production in the Asia-Pacific region.

Taking the FAO data at face value, mariculture production in the Asia-Pacific region has grown from around 14.6 million tonnes in 1995 to around 26 million tonnes in 2003 (Table 1). Total value was in excess of US\$21 billion in 2003.

## STATUS OF FARMING OF SELECTED SPECIES

This paper provides an overview of mariculture in the Asia-Pacific region. A feature of mariculture in the region is that it is exceptionally biodiverse, particularly in comparison with European mariculture, which relies on large-scale production of relatively few species. Because of this and the rapidly changing nature of mariculture development in the region, it is difficult to undertake a detailed review of mariculture production at the specific level. Numerous species and commodity-group reviews have been undertaken in the past few years, and others are in preparation or nearing completion. In particular, the CABI Aquaculture Compendium<sup>1</sup> and the FAO species profiles<sup>2</sup> will provide useful summary data on the status of a range of farmed species. Rather than dealing at the specific level, this paper seeks to assess some overall issues and constraints to the development of sustainable mariculture in the Asia-Pacific region.

<sup>1</sup> [www.cabi.org/compendia/ac/](http://www.cabi.org/compendia/ac/)

<sup>2</sup> [www.fao.org/figis/servlet/static?dom=root&xml=aquaculture/cultured\\_search.xml](http://www.fao.org/figis/servlet/static?dom=root&xml=aquaculture/cultured_search.xml)



TABLE 1  
Continued

Country	1995	1996	1997	1998	1999	2000	2001	2002	2003	Value (US\$m)
Saudi Arabia	201	201	830	1 758	1 898	2 003	4 212	4 695	9 209	69
Singapore	3 554	3 459	3 942	3 304	3 393	4 397	3 702	4 304	4 371	7
Solomon Islands	13	13	13	13	13	15	15	.	.	.
Taiwan PC	33 237	34 889	31 354	26 035	24 034	28 281	26 982	29 037	33 507	113
Thailand	92 833	80 183	66 408	106 155	158 247	147 972	145 300	145 300	145 200	39
Tonga	.	.	.	.	.	.	.	.	3	0
Turkey	8 494	15 241	18 150	23 410	25 230	35 646	29 730	26 868	39 726	181
Tuvalu	.	.	.	.	.	.	.	.	5	0
United Arab Emirates	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	2 300	7
Viet Nam	21 320	19 651	29 578	33 270	43 629	55 000	70 000	100 000	130 000	115
Total	14 639 974	15 232 039	15 451 251	17 428 377	19 511 876	20 854 551	21 920 862	23 583 292	24 900 599	21 770

### Marine finfish

Marine finfish aquaculture is well established in the Asia-Pacific region and is growing rapidly. A wide range of species are cultivated, and the diversity of culture is also steadily increasing.

Japanese amberjack (*Seriola quinqueradiata*) makes up 17 percent of marine finfish production in Asia, with just under 160 000 tonnes produced in 2003 (FAO, 2005b). Nearly all of this production comes from Japan, where production levels have been relatively stable at 140 000–170 000 tonnes per annum since the 1980s. Other carangids that are becoming popular for culture are the snub-nosed pompano (*Trachinotus blochii*) and silver pomfret (*Pampus argenteus*).

Seabreams are a mainstay of Asian finfish mariculture production, and a range of species are currently cultured.

Barramundi or Asian seabass (*Lates calcarifer*) is cultured in both brackishwater and mariculture environments, though most production is from brackishwater. Global production has been relatively constant over the past ten years at around 20 000–26 000 tonnes per annum, although production has decreased in Asia and increased in Australia over this time.

Grouper culture is expanding rapidly in Asia, driven by high prices in the live fish markets of Hong Kong SAR and the People's Republic of China, and the decreasing availability of wild-caught product due to overfishing (Sadovy *et al.*, 2003).

Southern bluefin tuna (*Thunnus maccoyii*) is cultured in Australia using wild-caught juveniles. Although production of this species is relatively small (3 500–4 000 tonnes per annum in 2001–2003), it brings very high prices in the Japanese market and thus supports a highly lucrative local industry in South Australia (Ottolenghi *et al.*, 2004). The 2003 production of 3 500 tonnes was valued at US\$65 million (FAO, 2005b).

Cobia (*Rachycentron canadum*) is a species that is engendering much interest for tropical marine finfish aquaculture. Most production currently comes from China PR and Taiwan Province of China, totaling around 20 000 tonnes in 2003 (FAO, 2005b). However, 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 is set to become a global commodity, in the same way that salmon has become a global commodity in temperate aquaculture.

Milkfish (*Chanos chanos*) has a long tradition of aquaculture in the Philippines, where it is an important food item. Indonesia is a major producer of seed, much of this coming from “backyard” or small-scale hatcheries, but a significant proportion of the milkfish produced in Indonesia is used for bait by the Japanese tuna fishery. There are traditions 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 mariculture cages where the fish are fed pellets or trash fish.

### Seedstock production

Hatcheries are producing greater numbers and a wider range of marine finfish species, but the industry is still heavily reliant on capture of fingerlings for grow-out, particularly for species that are difficult or costly to raise in hatcheries, such as grouper or Napoleon wrasse (Sadovy, 2000; Estudillo and Duray, 2003) or for which there is no established hatchery technology, such as tunas (Ottolenghi *et al.*, 2004). In general, the availability of seed from wild sources is in decline through over-fishing and habitat destruction (Sadovy, 2000; Ottolenghi *et al.*, 2004). Consequently, there is a need to develop sustainable technologies for seed production, particularly hatchery production.

Hatcheries range in size and technology. In Asia there has been considerable development of small-scale or backyard hatcheries that have only a couple of larval rearing tanks. These hatcheries use basic but effective techniques to produce large numbers of seedstock of a range of marine finfish species. Traditionally, much of



their production has been of milkfish, but production is diversifying to include more difficult to rear species such as groupers (Sim *et al.*, 2005a).

At the other end of the spectrum are the large technology-dependent hatchery systems that have been developed in Australia and Japan. Much of the hatchery technology in use in Australia has been adopted from Europe and modified to meet local conditions (Battaglione and Kolkovski, 2005). A major focus in developing hatchery technology in Australia in particular is the need to reduce labour inputs because of high labour costs.

Taiwan PC has established itself as a major seedstock production centre for the Asia-Pacific region, with around 1 000 farms involved in producing fry and juvenile marine finfish (Kao, 2004; Su, 2005). Marine finfish production in Taiwan PC is typified by highly specialized production sectors: e.g. one farm may produce 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 (Liao, Su and Chang, 1994; Kao, 2004).

### *Nursery*

There is substantial mortality of juvenile seedstock captured from the wild (Estudillo and Duray, 2003). Cannibalism among hatchery-reared juveniles is a major cause of losses in many species. Transportation of fingerlings also results in losses (Ottolenghi *et al.*, 2004).

### *Grow-out technology*

Grow-out technology employed in the Asia-Pacific region ranges from small floating or fixed cages used by small family-run operations, to extremely large cages (15x15x15 m) used for amberjack grow-out in Japan or 30–50 m diameter circular cages used for southern bluefin tuna grow-out in Australia (Ottolenghi *et al.*, 2004; Rimmer, McBride and Williams, 2004).

Much of the marine finfish aquaculture production in the Asia-Pacific region is from small to medium-scale farms. Many farms use relatively simple technologies, with wooden or bamboo cages and plastic barrels or polystyrene blocks to provide buoyancy. However, Japan and Australia in particular use larger and more sophisticated cage systems. In the case of Australia, these are based on European technologies.

The traditional Asian cage system is suited to sheltered inshore waters. As coastal sites have become increasingly crowded, several countries have begun to adopt cage designs that can withstand more open water. These offshore cages have been based on Japanese and European designs. The ability to site farms in more open water has opened up more coastal area for farming.

A major issue regarding the continued proliferation of marine finfish aquaculture in the Asia-Pacific region is the environmental impact of such operations. Although there is now a good understanding of the environmental impacts of cage aquaculture in temperate environments, there has been relatively little work done in tropical systems. This issue is discussed further below.

### **Crustaceans**

Although there is substantial production of marine shrimps in the Asia-Pacific region, effectively all of this production is undertaken in coastal ponds and thus does not meet the definition of “mariculture” given above. There has been some experimental culture of shrimp in cages in the Pacific (Y. Harache, personal communication), but this has not yet been commercially implemented. Similarly, most crab aquaculture is carried out in coastal ponds and does not meet the definition of mariculture used here.

Tropical spiny rock lobsters (Family Panuliridae), and particularly the ornate lobster (*Panulirus ornatus*), are cultured in Southeast Asia, with the bulk of production

in Viet Nam and the Philippines. Lobster aquaculture in Viet Nam produces about 1 500 tonnes valued at around US\$40 million per annum (Tuan and Mao, 2004).

Tropical spiny rock lobsters are cultured in cages. In Viet Nam, fixed, floating and submerged netcages are used, the former in shallow sheltered areas where the cages can be fixed to the substrate. Submerged cages are mainly used for nursing juvenile lobsters and are located in shallow water. A feeding pipe allows feed to be dropped into the cage, and limits the depth at which this system can be used. Floating cages may be used in depths up to 20 m (Tuan and Mao, 2004).

Seedstock is obtained from the wild. In Viet Nam, coconut logs are drilled with holes to provide an artificial substrate for puerulus/juvenile settlement. Once settled, the juveniles are removed from the logs and placed in nursery cages.

Lobsters are fed exclusively on fresh fish and shellfish, using about 70 percent fish and 30 percent shellfish. Vietnamese farmers show a strong preference for lizardfish (*Saurida* spp.) as a feed item and are willing to pay a higher price for these fish. Juvenile lobsters are fed with chopped fish 3–4 times per day. Larger lobsters are fed 1–2 times per day and fish is fed whole. The food conversion ratio (FCR) for lobsters fed this diet (fresh weight basis) is around 17–30:1 (Arcenal, 2004; Tuan and Mao, 2004).

In the Philippines, the preferred size at stocking is 100–300 g, and it takes 6–15 months for the lobsters to grow to the optimum size of 0.8–1.3 kg (Arcenal, 2004). Survival is around 90 percent, although stocking smaller lobsters (30–80 g) reduces survival to less than 50 percent (Arcenal, 2004). In Viet Nam it takes 18–20 months to culture juveniles (1–2 g) to the preferred harvest size of about 1 kg (Tuan and Mao 2004).

Although *P. ornatus* is a hardy species, there have been several recorded diseases associated with the use of poor quality seedstock in Viet Nam. These include the bacteria *Aeromonas hydrophyla* and *Proteus rettgeri*, the fungi *Fusarium solari* and *Lagenidium* sp. andl. *Zoothamnium* and *Vorticella* (Tuan and Mao, 2004).

Mariculture of tropical spiny rock lobster in Viet Nam is highly profitable, yielding a profit margin of 50 percent (based on a farm-gate price of US\$26.75/kg). More than 4 000 farmers/households are involved in lobster farming in Viet Nam, so it makes an important contribution to coastal communities where it is practiced (Tuan and Mao, 2004). In contrast, farm gate prices for lobster in the Philippines are much lower, US\$12–15 per kg, which limits profitability (Arcenal, 2004).

As seedstock supply is limited and likely to remain so in the short to medium-term, and demand remains strong, farming of tropical spiny rock lobsters is likely to remain highly profitable for the foreseeable future. To enhance the sustainability of the industry, there is a need to ensure that seedstock supplies from the wild are conserved to support this valuable mariculture sector. This may be done by setting up marine protected areas specifically to conserve adult breeding stocks of lobsters.

In the medium to long-term, it is necessary to develop hatchery production technology for seedstock for tropical spiny rock lobsters. There is currently considerable research effort on developing larval rearing technologies for tropical spiny rock lobsters in Southeast Asia and Australia.

There is a need to develop less wasteful and less polluting diets to replace the use of fresh fish and shellfish. Other research priorities are to develop improved cage designs, assess the environmental impacts of tropical spiny rock lobster culture and assess the carrying capacity of coastal environments.

## Molluscs

Bivalves are a major component of aquaculture production in the Asia-Pacific region. Much of this production is based on the culture of mussel, which is a high-volume, low-value commodity. In the Asia-Pacific region, Thailand and the Philippines are large producers of farmed mussels (Mohan Joseph, 1998; FAO, 2005b), primarily the green mussel (*Perna viridis*) (Lucas, 2003).

At the other end of the spectrum, there has been substantial production of pearl farming, which produces an extremely low-volume but high-value product, cultured pearls.

Despite the fact that hatchery production technologies have been developed for many bivalves, most tropical bivalve culture still relies on collection of seedstock from the wild. Artificial settlement substrates such as bamboo poles, wooden stakes, coconut husks or lengths of frayed rope are used to collect bivalve spat at settlement. The spat may be transferred to other grow-out substrates (“relayed”), or cultured on the settlement substrate (Mohan Joseph, 1998; Lucas, 2003).

There are three major systems commonly used for bivalve culture (Mohan Joseph 1998; Lucas, 2003):

1. Within-particulate substrates – This system is used to culture substrate-inhabiting cockles, clams, etc. Predator-excluding devices, such as mesh covers or fences, may be used.
2. On or just above the bottom – This culture system is commonly used for culture of bivalves that tolerate intertidal exposure, such as oysters and mussels. Rows of wooden or bamboo stakes are arranged horizontally or vertically. Bivalves may also be cultured on racks above the bottom in mesh boxes, mesh baskets, trays and horizontal wooden and asbestos-cement battens.
3. Surface or suspended culture – Bivalves are often cultured on ropes or in containers, suspended from floating rafts or buoyant long-lines.

Management of the cultures involves thinning the bivalves where culture density is too high to support optimal growth and development, checking for and controlling predators, and controlling biofouling (Mohan Joseph, 1998; Lucas, 2003).

Tropical mussels grow to market size (about 5–7 cm shell length) in less than one year, and in many cases 6–7 months, after settlement. Production can reach 1 800 tonnes per ha annually but may be lower in some areas. With a cooked meat yield of around 20 percent, this is equivalent to 360 tonnes of cooked meat per ha per year (Mohan Joseph, 1998). In Asia, farmed mussels are generally sold as whole fresh product. Some products are simply processed, e.g. shucked and sold as fresh or frozen meat. There has been some development of longer-life products, including canned and pickled mussels (Mohan Joseph, 1998).

China and Japan are the largest producers of cultured scallops, with the bulk of production being the yesso scallop (*Pecten yessoensis*) (Lucas, 2003). Production in 2003 exceeded 1.1 million tonnes of yesso scallop (FAO, 2005b). Preferred harvest size (>10 cm shell length) is reached in 2–3 years (Lucas, 2003).

Giant clams (Family Tridacnidae) have been cultured in many Pacific Island countries. Their relatively slow growth rates make tridacnid clams suitable only for extensive aquaculture or stock enhancement. Much of the tridacnid aquaculture production is sold to the marine ornamental market, which provides higher and more rapid returns.

Pearl oysters are farmed in Japan, China, Australia, Indonesia and in several Pacific Island nations, notably French Polynesia and the Cook Islands. Pearl culture is technically intensive, particularly the process of inserting a nucleus to promote formation of a pearl. The period between nucleus insertion and harvest generally ranges between nine months and three years. The quality of the pearl is related to the length of the culture period, but many insertions are unsuccessful, resulting in the death of the pearl oyster or ejection of the nucleus (Lucas, 2003). Pearl oysters are usually grown out using suspended culture systems in which oysters are usually suspended below rafts or on long-lines.

Due to their filter-feeding nature and the environments in which they are grown, edible bivalves are subject to a range of human health concerns, including accumulation of heavy metals, retention of human health bacterial and viral pathogens, and accumulation

of toxins responsible for a range of shellfish poisoning syndromes. One option to improve the product quality of bivalves is depuration, which is commonly practiced with temperate mussels, but rarely used in the tropics (Mohan Joseph, 1998; Lucas, 2003).

A major constraint to the development of tropical mussel culture is limited demand and low price (Mohan Joseph, 1998; Lucas, 2003). Although prices are higher in Australia and New Zealand, mussels are still relatively low-priced compared with other seafood commodities. The low economic value of mussels is compensated for by their ease of culture and high productivity (Lucas, 2003). Bioeconomic evaluations of mussel culture in the Philippines indicated a low return on investment for mussel farming, although farming in Thailand and Malaysia compared favourably with other forms of aquaculture (Mohan Joseph, 1998).

### Sea cucumbers

The most commonly cultured sea cucumbers are the temperate Japanese sea cucumber (*Apostichopus japonicus*) and the tropical sandfish (*Holothuria scabra*) (Yanagisawa, 1998). Aquaculture production of *H. scabra* is low and is generally still in the experimental phase. However, there is substantial production of *A. japonicus* from both land-based aquaculture and mariculture in China and Japan. Chen (2004) estimated Chinese production of *A. japonicus* in 2003 at 6 335 tonnes, of which 5 865 tonnes (93 percent) were from cultured production and only 470 tonnes from the wild fishery.

Farming of *A. japonicus* is well established in northern China. Most production is from earthen ponds, but there is also some mariculture using sea cages on the substrate or suspended below rafts. The sea cucumbers are fed *Sargassum* and other macroalgae (Chen, 2004; Renbo and Yuan, 2004). In contrast, sea cucumber farming in southern China is only beginning and is likely to utilize the species *Holothuria scabra*, *H. nobilis* and *H. fuscogilva* (Chen, 2004). In Japan juveniles of *A. japonicus* are stocked in coastal waters to replenish local stocks or to develop new harvest fisheries (Yanagisawa, 1998).

In Indonesia, *H. scabra* is farmed in cages of 20x20 m or 40x20 m in shallow (0.75–1.0 m deep) coastal areas or in coastal fish ponds (Tuwo, 2004). Organic material (such as rice bran and animal dust) is added at 0.2–0.5 kg per m<sup>2</sup> every two weeks (Tuwo, 2004). *Holothuria scabra* grow relatively slowly and it takes approximately six months to reach the preferred harvest weight of 200–250 g (Tuwo, 2004). Seedstock supply is mostly from the wild, although there is some hatchery production of juveniles (Tuwo, 2004).

### Production technology

Seed production technology for several sea cucumber species is well established in China. Since the 1980s approximately 6–8 billion juvenile *A. japonicus* have been produced (Chen, 2004). In 1994, 2.6 million seeds were produced in Japan (Yanagisawa, 1998).

Techniques for production of *H. scabra* have been developed in India, Indonesia, the Solomon Islands, New Caledonia, Viet Nam and Australia (Purcell, 2004). Tuwo (2004) identified difficulties in accessing suitable broodstock and low rates of survival to juvenile as constraints to hatchery production of *H. scabra* in Indonesia.

Sandfish require large areas for nursery and grow-out phases because growth rapidly becomes limited as density increases (Pitt and Nguyen, 2004). For this reason, there has been considerable focus on their use for sea ranching (Purcell, 2004).

### Market

The demand for sea cucumber products, particularly from China, dramatically exceeds supply. Chen (2004) notes that this is because the Chinese view sea cucumber as having medicinal properties, as well as being a delicacy. This high level of demand has pushed the price of *bêche-de-mer* (*A. japonicus*) from RMB 500 per kg in the 1980s,

to RMB 600–1 000 per kg during the 1990s, to around RMB 3 000 (approximately US\$400) per kg in 2003.

### **Other invertebrates**

#### *Sponges*

Sponge aquaculture is generating considerable interest in the research community, but commercial production of farmed sponges in the Asia-Pacific region is low. There is a small commercial farm in Pohnpei (Federated States of Micronesia) and several experimental operations in Australia, New Zealand and the Solomon Islands.

Sponge aquaculture is similar to seaweed culture in that sponges can be propagated vegetatively, and little infrastructure is necessary to establish farms. The harvested product (for bath sponges) can be dried and stored and does not require infrastructure such as refrigeration. Consequently, like seaweed culture, sponge culture may be ideal for remote communities, particularly in the Pacific.

However, the market acceptance and economic viability of commercial sponge farming has not yet been established. Further assessment of basic biological parameters such as growth and survival, as well as development of marketing channels, is necessary before large-scale sponge aquaculture can be developed.

#### *Corals*

There has been some small-scale development of coral farming in the Pacific Islands. Both soft and hard corals have been cultured, primarily for the marine aquarium trade, although some hard corals are sold as curios or used for restoration of degraded areas on coral reefs.

Corals are propagated vegetatively. Small pieces of live coral are glued to bases, and these are placed on underwater “tables” fitted with galvanized wire mesh. Growth is reportedly rapid, with aquarium corals reaching harvestable size in 3–12 months.

Because of the low level of capital investment needed and the relatively simple propagation methods used, coral culture is suitable for remote coastal communities where infrastructure may be lacking.

### **Seaweeds**

Aquatic plants are a major production component of mariculture in the Asia-Pacific region. About 13.5 million tonnes of aquatic plants were produced in 2003 (FAO, 2005b). China is the largest producer, producing just less than 10 million tonnes. The dominant cultured species is Japanese kelp (*Laminaria japonica*) (Lüning and Pang, 2003; Tseng and Borowitzka, 2003).

There are around 200 species of seaweed used worldwide, of which around ten species are intensively cultivated, including the brown algae *L. japonica* and *Undaria pinnatifida*, the red algae *Porphyra*, *Eucheuma*, *Kappaphycus* and *Gracilaria*, and the green algae *Monostrema* and *Enteromorpha* (Lüning and Pang, 2003).

Seaweeds are grown for:

- direct consumption, either as food or for medicinal purposes;
- production of the commercially valuable polysaccharides alginate and carrageenan;
- use as fertilizers; and
- feed for other aquaculture commodities, such as abalone and sea urchins.

#### *Production technology*

Because cultured seaweeds reproduce vegetatively, seedstock is obtained from cuttings. Grow-out is undertaken using natural substrates, long-lines, rafts, nets, ponds or tanks (Tseng and Borowitzka, 2003).

Production technology for seaweeds is inexpensive and requires only simple equipment. For this reason, seaweed culture is often undertaken in relatively



undeveloped areas where infrastructure may limit the development of other aquaculture commodities, for example in Pacific Island atolls. Existing technologies rely on tying individual plants to lines and are time-consuming and limit production (Ask and Azanza, 2002).

Seaweeds are subject to a range of physiological and pathological diseases:

- “green rot” and “white rot”, caused by environmental conditions, particularly light levels (Tseng and Borowitzka, 2003);
- “ice-ice” disease in *Eucheuma/Kappaphycus*, associated with low light levels and reduced salinity (Ask and Azanza, 2002);
- epiphytes that compete with cultured seaweeds for nutrients and may block light to the thalli (Ask and Azanza, 2002; Lüning and Pang, 2003); and
- several pathogenic diseases that are associated with infections of bacterial and mycoplasma-like organisms (Tseng and Borowitzka, 2003).

In addition, cultured seaweeds are often consumed by herbivores, particularly sea urchins and herbivorous fish species such as rabbitfish (Family Siganidae) (Ask and Azanza, 2002).

Selective breeding for specific traits has been undertaken in China to improve productivity, increase iodine content and increase thermal tolerance to better meet market demands. More recently, modern genetic manipulation techniques have been used to improve temperature tolerance, increase agar or carrageenan content and increase growth rates. Improved growth and environmental tolerance of cultured strains are generally regarded as priorities for improving production and value of cultured seaweeds in the future (Ask and Azanza, 2002; Tseng and Borowitzka, 2003).

Seaweed aquaculture is well suited for small-scale, household-level business operations run by people living in rural coastal communities. Seaweed fisheries are traditionally the domain of women in many Pacific Island countries, so it is a natural progression for women to be involved in seaweed farming. Seaweed farming in the Philippines is undertaken in some areas where civil disturbances may limit production (Philippines country paper, these proceedings).

### **PRIORITIES FOR RESEARCH, DEVELOPMENT AND EXTENSION**

Mariculture in the Asia-Pacific region is expanding rapidly, and there is widespread concern regarding its sustainability. Priorities for research, development and extension (R,D&E) should be focused on increasing the sustainability of mariculture production.

#### **Seed supply**

Seed supply for mariculture comes from two sources: wild populations, where larvae or juveniles are harvested to provide seedstock for grow-out (capture-based aquaculture), and hatchery production of seedstock.

#### *Capture-based aquaculture*

Capture-based aquaculture is widely practiced in the Asia-Pacific region, and many seedstock fisheries may be drastically over-exploited (Sadovy, 2000; Ottolenghi *et al.*, 2004). In general, there is a need to move away from capture-based aquaculture to hatchery production to improve the sustainability of these aquaculture sectors.

#### *R,D&E priorities include:*

- improved knowledge of biology of relevant species and their fisheries;
- development of specific policies and legal frameworks for capture-based aquaculture that promote interactions between the fishing and farming sectors; and
- spat-fall forecasting for molluscs.



### *Hatcheries*

While hatchery production of seedstock is generally more sustainable than the use of wild seedstock, there remain a range of constraints to widespread adoption of hatchery production.

#### *R,D&E priorities include:*

- developing seedstock production technologies to support a wider range of species, including species where seedstock is currently reliant on wild capture;
- controlling and managing disease, particularly viral diseases;
- promoting small-scale hatchery technology to provide livelihood options for marine finfish aquaculture in coastal areas;
- developing more cost-effective larval rearing techniques, such as the use of compounded larval feeds;
- developing new technologies for effective transport of seedstock (finfish fingerlings, bivalve spat) from hatcheries/nurseries to farms; and
- developing and promoting specific pathogen free (SPF) or high health (HH) seedstock.

### **Genetic issues**

Selective breeding has commenced with a wide range of maricultured species. However, the long-term impacts of selective breeding are not well established, particularly for mariculture systems where there is a high risk of selectively bred organisms escaping to interact with wild populations.

#### *R,D&E priorities*

- There are indications that inbreeding in some species has led to a decline in seedstock quality. Genetic management protocols are required for hatcheries to prevent inbreeding effects in captive populations.
- There is a need to develop selective breeding programmes for a range of maricultured commodities. Some of the desirable selected traits include: disease resistance, high growth rate, increased thermal tolerance, product colour, and biochemical composition (e.g. carrageenan content in seaweeds).
- There is a need to establish the biodiversity impacts of selectively bred organisms contributing to wild populations.

### **Production systems**

Production systems in many parts of the Asia-Pacific are relatively simple and are ideally suited to small-scale or family aquaculture. However, the trend is for the development of large-scale farms incorporating a range of technologies to improve the cost-efficiency of production. Marine finfish aquaculture in Asia is adopting the technologies used in Europe originally developed for large-scale salmon production. These systems are likely to be more cost-effective for some species (such as cobia) than for others (groupers). However, there is also a need to improve production systems for mollusc and seaweed culture.

### **Feeds**

So-called "trash" fish (small, low-value or bycatch fish species) are a major source of feed inputs in aquaculture in the Asia-Pacific region. The term "trash" fish is inaccurate in that these fish species would not necessarily otherwise be wasted; alternative uses include reduction to fish sauce for human consumption, use as protein sources for other agricultural commodities (such as pigs and poultry) or even for direct human consumption (New, 1996; Tacon and Barg, 1998; Edwards, Tuan and Allan, 2004; FAO, 2005a).

The issues associated with "trash" fish usage are well documented, most recently in the report of the APFIC Regional Workshop on Low Value and Trash Fish in the

Asia-Pacific Region (FAO, 2005a). Although pellet diets are available for a range of marine finfish as well as some crustaceans, there remain important constraints to the widespread use of compounded diets for aquaculture:

- Farmer acceptance of pellet diets is often low because of the perception that these diets are much more expensive than trash fish. Farmers often do not appreciate that the food conversion ratios of pellet diets (usually 1.2–1.8:1) are dramatically better than that of “trash” fish (usually 5–10:1, but sometimes higher) and so the relative cost of pellet diets is often comparable or lower than the cost of “trash” fish required to produce the same biomass of fish. Variable product quality may also impact substantially on growth and survival of the cultured fish.
- Lack of farmer experience in feeding pellets may result in considerable wastage.
- Fish fed on “trash” fish may not readily convert to a dry pellet diet, resulting in poor acceptance and perceived lack of appetite.
- Distribution channels for pelleted feed are not widely available in rural areas. As well as limiting accessibility to the feed, this factor increases feed costs.
- Many rural areas have no storage facilities. This can result in degradation of the pellets, particularly vitamin content, resulting in poor growth and disease in fed fish.
- Small-scale fishers or farmers operating fish cages may not have access to the financial resources necessary to invest in purchase of pelleted diets or infrastructure such as refrigeration, finding it easier to collect “trash” fish themselves, or obtain it in small amounts as and when financial or “trash” fish resources are available. For many farmers, “trash” fish collection is an opportunity cost that family-operated farms may easily absorb, whereas the purchase of pellets is a cash cost.

#### *R,D&E priorities*

- The nutritional requirements of farmed species have to be determined in order to develop cost-effective diets. Research has demonstrated that different species often have different nutritional requirements. Consequently, there will be a range of diets required for various species or species groups. There is a need to define the nutritional requirements of farmed aquatic species, often at the generic or even specific level.
- There is a need for R&D into alternative protein sources for aquafeeds, including terrestrial meat meals and vegetable meals to replace fish protein.
- Changing from “trash” fish to pellet feeds may impact on product quality. The real and perceived impacts of compounded feeds on product taste and texture need to be established in view of consumer preferences. For some species, this may not be important, but this is an issue for high-value marine finfish, e.g. groupers.
- Enhanced information exchange and coordination of nutritional information would benefit the development of compounded aquafeeds.
- Participatory research and extension is a valuable mechanism for promoting the uptake of compounded feeds. The various drivers towards/away from pellet feeds need to be better understood and documented.
- There is a need for feed companies to become actively involved in on-farm trials and to independently evaluate their products. There is no doubt that some batches of pellets perform poorly due to problems with formulation, manufacture or storage. There is a need to work with feed companies to improve product quality and identify areas where improvements can be made.
- National aquaculture development strategies need to incorporate a policy for feeds development.
- There is a need to better quantify the environmental impacts of both “trash” fish and pellet feeds, both in terms of nutrient impacts and as particulate matter

that may cause impacts to benthic communities beneath sea cages. The impacts of feed type need to be integrated with aquaculture planning, farm siting and coastal management.

### **Environmental impacts of mariculture**

Although mariculture production in the Asia-Pacific region includes a substantial quantity of low-trophic-level species such as seaweed and bivalve molluscs, there is a significant production of commodities that require feed inputs, in particular, crustaceans (lobsters) and marine finfish. Environmental impacts associated with marine finfish and lobster cage aquaculture derive mainly from nutrient inputs from uneaten fish feed and fish wastes (Phillips, 1998). For example, studies carried out in China, Hong Kong SAR indicate that 85 percent of phosphorus, 80–88 percent of carbon and 52–95 percent of nitrogen inputs (from “trash” fish) to marine finfish cages may be lost through uneaten food, faecal and urinary wastes (Wu, 1995). These nutrient inputs, although small in comparison with other coastal discharges, may lead to localized water quality degradation and sediment accumulation. In severe cases, this “self pollution” can lead to cage farms exceeding the capacity of the local environment to provide inputs (such as dissolved oxygen) and assimilate wastes, contributing to fish disease outbreaks and undermining sustainability.

However, the impacts of sea-cage aquaculture on coastal waters may be relatively insignificant compared with the terrestrial inputs. In one of the few studies of nutrient impacts of marine cage aquaculture in tropical systems, Alongi *et al.* (2003) found that although fish cages theoretically contributed 32–26 percent of nitrogen and 83–99 percent of phosphorus to the coastal water studied, there was no evidence of large-scale eutrophication due to the cages, and the effects of the cages were largely swamped by large inputs of organic matter from mangrove forests, fishing villages, fish cages, pig farms and other industries within the catchment.

The use of dry pellets rather than wet feeds reduces nutrient inputs through better feed utilization. Other solutions to self-pollution of sea cage sites (Phillips, 1998; Feng *et al.*, 2004) are:

- ensure adoption of better management practices (BMPs), including efficient feed formulation and feeding practices;
- keep stocking densities and cage numbers within the carrying capacity of the local environment;
- use chemicals minimally and responsibly;
- ensure adequate water depth below cages and sufficient water movement to disperse wastes; and
- move cages regularly to allow recovery of the sediments of affected sites.

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

The Philippines is establishing mariculture parks to promote finfish mariculture within a designated area. The park development is controlled by an Executive

Management Council that governs the establishment of “community” mooring systems and clusters of sea cages. This approach attempts to limit uncontrolled development of sea cages, and limit expansion, encroachment and interference with other marine infrastructure (Philippines country paper, these proceedings).

#### *R,D&E priorities*

- There is a need for appropriate environmental assessment systems to support site selection and assess the assimilative capacity of the local environment.
- Aquaculture planning and development should be implemented, taking into account other resource users.
- Regulations that limit aquaculture development within appropriate levels should be developed and enforced, and environmental monitoring should be ensured.
- Robust and cost-effective environmental monitoring systems that are appropriate to tropical mariculture need to be developed.
- Improved knowledge of the role of wild fish communities as potential disease vectors and as sinks for excess feed and wastes is needed.
- The fate and impacts of antibiotics and other pharmaceuticals needs to be better understood.

#### **Post-production**

Both the supply of, and demand for, aquatic products are changing rapidly in the Asia-Pacific region. While fisheries production is relatively stable, aquaculture production is increasing steadily. The region contains the two largest national populations on the planet: China and India. Demand for quality seafood products is expanding in line with growth in affluence in many parts of Asia. In the light of this rapidly changing environment, the ability to match supply and demand in terms of both quantity and quality of products is critical.

#### *R,D&E priorities*

These include the need for:

- improved harvesting and handling techniques to improve product quality;
- improved post-harvest handling, processing, and food safety, including depuration for bivalves;
- development of new products (“value adding”);
- development of new market strategies and new market segments; and
- improved market intelligence, particularly to allow farmers to diversify or change production strategies.

#### **Socio-economics**

The country papers in these proceedings provide information on the extent of the importance of both coastal aquaculture and mariculture to coastal communities throughout the Asia-Pacific region. However, there is still limited information on how coastal communities will respond to changes in mariculture production trends, such as the trend away from low-input commodities (e.g. seaweeds) to more intensive farming systems (e.g. finfish) in China.

#### *R,D&E priorities*

These include the need for better information on:

- the socio-economic impacts of mariculture on coastal communities, both positive and negative;
- the role of mariculture in alleviating poverty in developing countries; and
- the impacts of “urban drift” in rapidly developing economies – many younger

people are looking for employment opportunities in the cities rather than taking traditional roles in sectors such as fisheries and aquaculture (see the Republic of Korea country paper, these proceedings).

### **POTENTIAL FOR INCREASING THE ROLE OF LOW-TROPHIC-LEVEL SPECIES**

There is interest in promoting the cultivation of low-trophic-level marine species to alleviate some of the impacts of culturing animals that require high levels of organic inputs, such as marine finfish. There are two approaches to promoting the cultivation of low-trophic-level species:

- direct replacement of high-input species with low-input species (e.g. replacing production of carnivorous finfish such as groupers with omnivorous species like milkfish and rabbitfish); and
- promotion of low-trophic-level species that may act as “sinks” for the waste products from high-input aquaculture.

#### **Direct commodity substitution with low-trophic-level species**

As noted above, there is already substantial mariculture production of low-trophic-level species in the Asia-Pacific region. Low-trophic-level species include bivalve molluscs, sea cucumbers and seaweeds. Among marine finfish, both milkfish and rabbitfish can be considered low-trophic-level species. Milkfish are cultured throughout the Asia-Pacific region, although most production is from the Philippines and Indonesia, and most of this production is from coastal ponds rather than from mariculture. Rabbitfish are cultured only in small quantities.

One of the drivers against adoption of low-trophic-level species in mariculture is price. Many low-trophic-level species are relatively low-price commodities, the notable exception being sea cucumbers. In China, production of seaweeds has proportionally declined since 1981 because of proportionally greater production of molluscs, shrimps and finfish (Feng *et al.*, 2004). The major reason for this shift is that animal cultivation is more profitable (Feng *et al.*, 2004).

Economic drivers may be important for farmers choosing which species to cultivate. Yap (2002) found that grouper aquaculture in the Philippines was more accessible to farmers than milkfish culture because of higher margins and the lower level of investment required to achieve the same profit.

Cultivation of low-trophic-level species may not necessarily result in environmental benefits. For example, while milkfish can be farmed extensively with negligible feed inputs, this type of culture is generally being replaced with more intensive styles of culture. Cage culture of milkfish relies on the same high levels of inputs as does any other type of marine finfish aquaculture, albeit with lower protein feeds and thus likely lower nitrogen inputs to the environment. The localized environmental impacts from large-scale milkfish culture do not differ substantially from those of any other marine finfish production.

#### **Promotion of low-trophic-level species as nutrient sinks**

Many authors have suggested that one solution to high levels of nitrogen inputs from aquaculture is to culture organisms that act as nitrogen sinks, particularly seaweeds (Chopin *et al.*, 2001a; Feng *et al.*, 2004). Most work to date, however, has focused on the use of seaweeds as nutrient sinks in land-based systems (Chopin *et al.*, 2001b; Neori *et al.*, 2004).

Feng *et al.* (2004) noted that 50 tonnes of seaweed can fix 1 250 kg of carbon and 125 kg of nitrogen. Using Wu's (1995) data on finfish effluent fed a diet of “trash” fish and an FCR of 8:1, the nitrogen produced from 1 kg of marine finfish production (4.2–7.6 kg N) would require the absorptive capacity of 1.7–3.0 tonnes of seaweed production. Given the economic drivers away from seaweed production towards



more profitable commodities, it is difficult to envisage that large-scale mariculture will incorporate seaweed production at an order of magnitude greater than finfish production.

The dynamic processes that affect utilization of nutrients in tropical mariculture are poorly researched. It is likely that much of the soluble waste from aquaculture production is used up rapidly by bacteria and phytoplankton, and high nutrient levels may not persist far from their source. In this case, there may be limited additional nutrients available for seaweed culture.

An alternative is the use of intermediate organisms to remove phytoplankton that may proliferate because of the nutrient-rich environment adjacent to cages. Pham *et al.* (2004) describe co-culture of green mussels (*Perna viridis*) with tropical rock lobster. Lobsters fed the mussels demonstrated faster growth and better health than those fed “trash” fish. Water quality around cages where mussels were co-cultured with lobsters had reduced concentrations of organic matter in the water column and in the sediment (Pham *et al.*, 2004). The use of filter-feeding bivalves as a nutrient sink that can then be used as a feed source for other cultured species is a potentially valuable option to improve the sustainability of mariculture.

### **Integrated mariculture**

The widespread recognition that aquaculture must improve its environmental performance, both real and perceived, has generated interest in integrated aquaculture. Integrated aquaculture is broadly defined as the culture of a range of trophic-level organisms whereby outputs from one species or group can be utilized as inputs by another species or group. While there has been some research undertaken using land-based systems (Chopin *et al.*, 2001a, 2001b; Neori *et al.*, 2003, 2004; Troell *et al.*, 2003) there has been comparatively little research on “open” or mariculture systems.

While the concept of integrated mariculture is straightforward, there is a paucity of information to assess its effects on the environment. The dynamics of aquaculture-generated nutrients in tropical coastal waters are complex and not well understood. As much of the nutrient input may be absorbed rapidly by phytoplankton and bacteria, the systems used for integrated mariculture may differ substantially from those used in land-based systems, which rely on aquatic plants as nutrient sinks (Neori *et al.*, 2004). With the rapid expansion of mariculture in the Asia-Pacific region, and the need to improve the environmental credentials of mariculture, the topic of environmental impacts and the development of cost-effective amelioration strategies is a high priority.

### **Better management practices for mariculture**

An approach to improving the sustainability of aquaculture has been the development of Better Management Practices (BMPs). To date, BMPs have been most widely used in shrimp culture. More recently, the development of BMPs for mariculture has commenced, particularly with regard to tropical marine finfish aquaculture. The Marine Aquarium Council, together with The Nature Conservancy and with the assistance of the Asia-Pacific Economic Cooperation (APEC) and NACA, has developed Standards for the Live Reef Food Fish Trade, including aquaculture standards. These standards provide a basis for the development of BMP documentation for finfish mariculture.

Two recent publications from the Asia-Pacific Marine Finfish Aquaculture Network (APMFAN) demonstrate the BMP approach to finfish mariculture with respect to the promotion of small-scale marine finfish hatchery technology (Sim *et al.*, 2005a) and the use of compounded feeds instead of “trash” fish to feed groupers (Sim *et al.*, 2005b). These publications are being made widely available in the Asia-Pacific region and have been translated into Thai, Indonesian and Vietnamese to facilitate farmer access to this information. APMFAN plans to expand its range of BMP documentation in future years.



Adoption of BMPs, particularly voluntary adoption, remains problematic. While some BMPs may improve the financial viability of farms, for example through more cost-effective feeds, faster fish growth and improved fish health (Sim *et al.*, 2005b), other BMPs may have associated financial costs that farmers are reluctant to bear (Stanley, 2000). Another issue with regard to adoption of BMPs for mariculture, as noted above, is the paucity of information on the nutrient dynamic processes associated with tropical mariculture. In the absence of detailed research results, it is difficult to develop detailed BMPs, particularly if there are financial costs involved in their adoption.

Different countries in the Asia-Pacific region have BMP or BMP-like information available in a variety of forms. In Australia, there are Codes of Practice for several industry subsectors, including a Harvesting and Processing Code of Practice for barramundi farmers. In the Republic of Korea, the National Fisheries Research and Development Institute publishes culture standards for each aquaculture species (see the Democratic People's Republic of Korea country paper, these proceedings). Information sharing among farmers is supported by the installation of Internet-connected computers in the homes of fish farmers in 100 model fishing villages. Fishermen have access to various information sources, including the ability to communicate through a specialized website ([www.badaro21.net](http://www.badaro21.net)) (see the Republic of Korea country paper, these proceedings).

A useful approach would be the development of BMPs, including the coordination and redistribution of existing information, at a regional level. Most of the issues facing mariculture in the Asia-Pacific region are not country-specific, so a coordinated approach would provide consistency and reduce duplication of effort. As the regional organization with responsibility for coordination of aquaculture activities, NACA is ideally placed to direct this coordinated effort.

## REGIONAL RESOURCE CENTRES

The following is a provisional list of institutions, derived from country papers presented to these proceedings, that are presented as potential resource centers and sources of expertise for a regional cooperation in mariculture. Identification of additional resources is welcome.

### India

#### Indian Council of Agricultural Research

- Central Marine Fisheries Research Institute, Kochi
- Marine Products Export Development Authority
- Rajiv Ghandi Centre for Aquaculture, Chennai and Port Blair

### Indonesia

#### Directorate-General of Aquaculture, Technical Implementation Units (TIUs)

- Centre For Marine Aquaculture Development, Lampung (Sumatera)
- Marine Aquaculture Development Centre, Batam (Riau)
- Marine Aquaculture Development Centre, Ambon
- Marine Aquaculture Development Centre, Lombok (West Nusa Tenggara)
- Brackish Water Aquaculture Development Centre, Jepara (Central Java)
- Brackish Water Aquaculture Development Centre Takalar (South Sulawesi)
- Brackish Water Aquaculture Development Centre, Situbondo (East Java)
- Brackish Water Aquaculture Development Centre, Aceh

The role of the TIUs is to conduct technology propagation/extension and develop applied technology. Thus they are equipped with commercial-scale experimental facilities (hatchery, nursery and grow-out facilities) training facilities, dormitories and laboratory services.

The technology transfer by these institutions includes:

- on the job training, where the participants stay, learn and work with the staff in charge for a certain period depending on the subject and level;
- publication of posters and leaflets;
- on-farm supervision; and
- pilot projects, prototypes and modelling.

#### **Central Research Institute for Aquaculture**

- Gondol Research Institute for Mariculture (Bali)
- Research Institute for Coastal Aquaculture, Maros (Southern Sulawesi)

#### **Islamic Republic of Iran**

The Iranian Fisheries Research and Training Organization ([www.ifro.org](http://www.ifro.org)) affiliated to Shilat is the major source of applied research and training on fisheries and aquaculture. It has ten research centers and two training centers:

- four centers that located by the Persian Gulf and Oman Sea, in Khuzestan, Bushehr, Hormozgan and Sistan –Baluchistan provinces;
- five Fisheries Research Centres that are located by the Caspian Sea, in Guilan, Mazandaran and Golestan provinces; the International Institute of Cold Water in Mazandaran and the International Institute of Sturgeon in Guilan; and
- the Artemia Research Centre, located by Urimia Lake (research on *Artemia* and live feed).

Research outcomes are used for running pilot projects that are modified as needed. The results are then extended to farmers through short training courses and manuals.

#### **Republic of Korea**

Eighteen fisheries subsidiary organizations, including several branch offices of the Ministry of Maritime Affairs and Fisheries (MOMAF) exist in rural areas, mostly located along the coast. Their role is to support fishermen with information, training and government funding. The major government aquaculture research institutes are the National Fisheries Research Development Institute (NFRDI) and Pukyong National University.

#### **Viet Nam**

Resource centers include:

- Research Institute for Aquaculture No.1, Cua Lo and Cat Ba
- Research Institute for Aquaculture No.2, Ho Chi Minh City and Vung Tao
- Research Institute for Aquaculture No.3, Nha Trang
- University of Fisheries, Nha Trang
- Institute of Oceanography, Nha Trang

#### **Malaysia**

Resource centers include:

- The Institute of Marine Aquaculture (IAM), Pulau Sayak, Kedah, which opened in 1987. Courses offered include marine finfish seed production, finfish aquaculture in cages, marine shrimp seed and grow-out programme, seed and grow-out production of oyster and mussel, and feed formulation for farm practice.
- The Marine Finfish Production and Research Centre (MFPRC), Tanjung Demong, Besut, Trengganu. Courses are offered on marine finfish fry production and cage- culture operation.

## REFERENCES

- Alongi, D.M., Chong, V.C., Dixon, P., Sasekumar, A. & Tirendi, F. 2003. The influence of fish cage aquaculture on pelagic carbon flow and water chemistry in tidally dominated mangrove estuaries of peninsular Malaysia. *Mar. Environ. Res.*, 55: 313–333.
- Arcenal, J.M.M. 2004. Sustainable farming of spiny lobster in Western Mindanao, Philippines In K.C. Williams, ed. *Spiny lobster ecology and exploitation in the South China Sea region - Proceedings of a workshop held at the Institute of Oceanography, Nha Trang, Vietnam, July 2004*. ACIAR Proceedings No. 120, pp.19–20. Canberra, Australian Centre for International Agricultural Research.
- Ask, E.I. & Azanza, R.V. 2002. Advances in cultivation technology of commercial eucaematoid species: a review with suggestions for future research. *Aquaculture*, 206: 257–277.
- Battaglione, S. & Kolkovski, S. 2005. A review of new and emerging temperate marine finfish species for farming in Australia: challenges in larval rearing. In C.L. Hendry, G. Van Stappen, M. Wille & P. Sorgeloos, eds. *Larvi 2005 - 4th Fish and Shellfish Larviculture Symposium, Ghent, Belgium, 5-8 September 2005*. Eur. Aquacult. Assoc. Spec. Publ. No. 36, pp.19–20 (Abstract).
- Chen, J. 2004. Present status and prospects of sea cucumber industry in China In A. Lovatelli, comp./ed.; C. Conrad, S. Purcell, S. Uthicke, J.-F. Hamel & A. Mercier, eds. *Advances in sea cucumber aquaculture and management*. FAO Fisheries Technical Paper No. 463, pp. 25–38. Rome, FAO.
- Chopin, T., Buschmann, A.H., Halling, C., Troell, M., Kautsky, N., Neori, A., Kraemer, G.P., Zertuche-Gonzalez, J.A., Yarish, C. & Neefus, C. 2001a. Integrating seaweeds into marine aquaculture systems: a key toward sustainability. *J. Phycol.*, 37: 975–986.
- Chopin, T., Yarish, C., Neefus, C., Kraemer, G.P., Belyea, E., Carmona, R., Saunders, G.W., Bates, C., Page, F. & Dowd, M. 2001b. Underutilized tools: seaweeds as bioremediation and diversification tools and bioindicators for integrated aquaculture and coastal management. *J. Phycol.*, 37: 12–22.
- Edwards, P., Tuan, L.A. & Allan, G.L. 2004. *A survey of marine trash fish and fish meal as aquaculture feed ingredients in Vietnam*. ACIAR Working Paper No. 57, . 56 pp. Canberra, Australian Centre for International Agricultural Research.
- Estudillo, C.B. & Duray, M.N. 2003. Transport of hatchery-reared and wild grouper larvae, *Epinephelus* sp. *Aquaculture*, 219: 279–290.
- FAO. 2005a. *APFIC Regional Workshop on Low Value and 'Trash Fish' in the Asia-Pacific Region*. 32 pp. Bangkok, FAO Regional Office for Asia and the Pacific.
- FAO. 2005b. *FAO yearbook, fishery statistics, aquaculture production 2003. Vol 96/2*, Rome, FAO.
- Feng, Y.Y., Hou, L.C., Ping, N.X., Ling, T.D. & Kyo, C.I. 2004. Development of mariculture and its impacts in Chinese coastal waters. *Rev. Fish Biol. Fish.*, 14: 1–10.
- Kao, C.C. 2004. Development of grouper culture in Taiwan - a solution to reduce destructive fishing practices in coral reefs. *Infofish Intern.*, 3/2004, pp. 24–28.
- Lai, L.W.C. 2002. An overview of research on aquaculture economics and management in Hong Kong. *Aquacult. Econ. Manag.*, 6: 131–152.
- Liao, I.C., Su, M.S. & Chang, S.L. 1994. A review of the nursery and growout techniques of high-value marine finfishes in Taiwan In K.L. Main, & C. Rosenfield, eds. *Culture of high-value marine fishes in Asia and the United States*. pp.121–137. Hawaii, The Oceanic Institute.
- Lucas, J. 2003. 21 - Bivalves In J. Lucas & P.C. Southgate, eds. *Aquaculture – farming aquatic animals and plants*. pp. 443–466. Oxford, Blackwell Publishing Ltd.
- Lüning, K. & Pang, S. 2003. Mass cultivation of seaweeds: current aspects and approaches. *J. Appl. Phycol.*, 15: 115–119.

- Mohan Joseph, M. 1998. Chapter 10 - Mussel and oyster culture in the tropics *In* S.S. De Silva, ed. *Tropical mariculture*. pp. 309–360. London, Academic Press.
- Neori, A., Chopin, T., Troell, M., Buschmann, A.H., Kraemer, G.P., Halling, C., Shpigel, M. & Yarish, C. 2004. Integrated aquaculture: rationale, evolution and state of the art emphasizing seaweed biofiltration in modern mariculture. *Aquaculture*, 231: 361–391.
- Neori, A., Msuya, F.E., Shauli, L., Schuenhoff, A., Kopel, F. & Shpigel, M. 2003. A novel three-stage seaweed (*Ulva lactuca*) biofilter design for integrated mariculture. *J. Appl. Phycol.*, 15: 543–553.
- New, M.B. 1996. Responsible use of aquaculture feeds. *Aquacult. Asia*, 1: 3–15.
- Ottolenghi, F., Silvestri, C., Giordano, P., Lovatelli, A. & New, M.B. 2004. Capture-based aquaculture. The fattening of eels, groupers, tunas and yellowtails. 308 pp. Rome, FAO.
- Pham, T.D., Do, H.H., Hoang, T.D. & Vo, T.H.T. 2004. Combined culture of mussel: a tool for providing live feed and improving environmental quality for lobster aquaculture in Vietnam *In* K.C. Williams, ed. *Spiny lobster ecology and exploitation in the South China Sea region - Proceedings of a workshop held at the Institute of Oceanography, Nha Trang, Vietnam, July 2004*. ACIAR Proceedings No. 120, pp. 57–58. Canberra, Australian Centre for International Agricultural Research.
- Phillips, M.J. 1998. Chapter 2 - Tropical mariculture and coastal environmental integrity *In* S.S. De Silva, ed. *Tropical mariculture*, pp. 17–69. London, Academic Press.
- Pitt, R. & Nguyen, D.Q.D. 2004. Breeding and rearing of the sea cucumber *Holothuria scabra* in Viet Nam *In* A. Lovatelli, comp./ed.; C. Conrad, S. Purcell, S. Uthicke, J.-F. Hamel & A. Mercier, eds. *Advances in sea cucumber aquaculture and management*. FAO Fisheries Technical Paper No. 463, pp. 333–346. Rome, FAO.
- Purcell, S.W. 2004. Criteria for release strategies and evaluating the restocking of sea cucumbers *In* A. Lovatelli, comp./ed.; C. Conrad, S. Purcell, S. Uthicke, J.-F. Hamel & A. Mercier, eds. *Advances in sea cucumber aquaculture and management*. FAO Fisheries Technical Paper No. 463, pp.181-191. Rome, FAO.
- Renbo, W. & Yuan, C. 2004. Breeding and culture of the sea cucumber, *Apostichopus japonicus*, Liao *In* A. Lovatelli, comp./ed.; C. Conrad, S. Purcell, S. Uthicke, J.-F. Hamel & A. Mercier, eds. *Advances in sea cucumber aquaculture and management*. FAO Fisheries Technical Paper No. 463, pp. 277–297. Rome, FAO.
- Rimmer, M.A., McBride, S. & Williams, K.C. 2004. *Advances in grouper aquaculture*. ACIAR Monograph, 110, 137 pp. Canberra, Australian Centre for International Agricultural Research.
- Sadovy, Y. 2000. Regional survey of fry/fingerling supply and current practices for grouper mariculture: evaluating current status and long-term prospects for grouper mariculture in Southeast Asia, 120 pp. Hong Kong SAR, University of Hong Kong.
- Sadovy, Y.J., Donaldson, T.J., Graham, T.R., McGilvray, F., Muldoon, G.J., Phillips, M.J., Rimmer, M.A., Smith, A. & Yeeting, B. 2003. *While stocks last: the live reef food fish trade*. 147 pp. Manila, Asian Development Bank.
- Sadovy, Y.J. & Lau, P.P.F. 2002. Prospects and problems for mariculture in Hong Kong associated with wild-caught seed and feed. *Aquacult. Econ. Manag.*, 6: 177–190.
- Sim, S.Y., Rimmer, M.A., Toledo, J.D., Sugama, K., Rumengan, I., Williams, K. & Phillips, M.J. 2005a. *A guide to small-scale marine finfish hatchery technology*. 17 pp. Bangkok, NACA.
- Sim, S.Y., Rimmer, M.A., Williams, K., Toledo, J.D., Sugama, K., Rumengan, I. & Phillips, M.J. 2005b. *A practical guide to feeds and feed management for cultured groupers*. 18 pp. Bangkok, NACA.
- Stanley, D.L. 2000. The economics of the adoption of BMPs: the case of mariculture water management. *Ecol. Econ.*, 35: 145–155.

- Su, H.M.** 2005. Marine fish hatchery production - the Taiwan model. *Aquacult. Asia-Pacific*, 1: 24–26.
- Tacon, A.G.J. & Barg, U.C.** 1998. Chapter 6 - Major challenges to feed development for marine and diadromous finfish and crustacean species. In S.S. De Silva, ed. *Tropical mariculture*. pp. 171–207. London, Academic Press.
- Troell, M., Halling, C., Neori, A., Chopin, T., Buschmann, A.H., Kautsky, N. & Yarish, C.** 2003. Integrated mariculture: asking the right questions. *Aquaculture*, 226: 69–90.
- Tseng, C.K. & Borowitzka, M.** 2003. 13 - Algae culture In J. Lucas & P.C. Southgate, eds. *Aquaculture - farming aquatic animals and plants*. pp. 253–275. Oxford, Blackwell Publishing Ltd.
- Tuan, L.A. & Mao, N.D.** 2004. Present status of lobster cage culture in Vietnam. In K.C. Williams, *Spiny lobster ecology and exploitation in the South China Sea region - Proceedings of a workshop held at the Institute of Oceanography, Nha Trang, Vietnam, July 2004*. ACIAR Proceedings No. 120, pp. 21–25. Canberra, Australian Centre for International Agricultural Research.
- Tuwo, A.** 2004. Status of sea cucumber fisheries and farming in Indonesia. In A. Lovatelli, comp./ed.; C. Conrad, S. Purcell, S. Uthicke, J.-F. Hamel & A. Mercier, eds. *Advances in sea cucumber aquaculture and management*. FAO Fisheries Technical Paper No. 463, pp. 49–55. Rome, FAO.
- Wu, R.** 1995. The environmental impact of marine fish culture: towards a sustainable future. *Mar. Pollution Bull.*, 31: 159–166.
- Yanagisawa, T.** 1998. Chapter 9 - Aspects of the biology and culture of the sea cucumber In S.S. De Silva, ed. *Tropical mariculture*, pp. 291–308. London, Academic Press.
- Yap, W.G.** 2002. Role of mariculture in securing food supply and reducing poverty in the Philippines. In *World Aquaculture 2002 International Aquaculture Conference and Exposition*, p. 864. Beijing, World Aquaculture Society.