Japan

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SUMMARY

Japan gives a high priority to food security. Fisheries demand in Japan is stable, but with decreases in Japanese fisheries production, the country has increasingly relied on imports over the past 30 years. Imported fisheries products made up 57 percent of total fisheries products in 2003.

Mariculture production makes up about 20 percent in quantity of total fisheries production. The gross value of mariculture production amounts to around US$3.8 billion. The significance of mariculture in Japan is increasing. Major mariculture species are seaweed (laver), yellowtail, red seabream, Japanese oyster, greater amberjack, common scallop and others. Recent target species are bluefin tuna, barfin flounder and grouper. In seaweed farming, *mozuku* is a remarkable species with a high content of fucoidan. The tendency for newly targeted species reflects both the expensive tastes and the health interests of consumers. Production of fisheries products for human health is particularly expected to increase in the future.

The present and future priorities for mariculture development and research in Japan are the following:

- development and refinement of aquatic animal breeding techniques;
- development of efficient feeding methods and artificial food;
- prevention of fish disease;
- polyculture systems (including integrated culture);
- utilization of deep-sea water;
- promotion of aquaculture without artificial food; and
- closed recirculation aquaculture systems.

Lately, there are also some problems with mariculture, of which the most serious is self-pollution by net cages. Some reports suggest mariculture net cages contribute up to 70 percent of the total nitrogen discharged into Japanese coastal waters. One report estimates that the level of pollution by mariculture in Japan is equivalent to 5–10 million people. Such findings clearly show that environmental pollution by mariculture has reached serious proportions in Japan and management should be carried out quickly.

From the viewpoint of protection of the coastal environment, closed recirculation systems have been highlighted as potential rearing technologies. Complete system

control would lead to environmental benefits as well as potential cost savings, increased survival rates and better biosecurity. This system is considered the future aquaculture system in Japan.

Closed recirculation systems developed by the Fisheries Research Agency (FRA) consist of a foam separation system, a biofiltration system and a sterilization system. The main characteristics of this system are improved environmental protection because of limited discharges, a high nitrification ability and space-saving, high productivity via high-density rearing and maintenance of water quality. Trials of closed recirculation aquaculture systems have just started in Japan. In some trials by a private company, fish farmed in closed recirculation systems were evaluated as high value because of their traceability and food safety.

Japanese fisheries production comes from three sources: capture fisheries, aquaculture and stock enhancement. The aim of stock enhancement is recovery and increase in fish stocks by release of artificially produced seedlings. The system of stock enhancement consists of selecting target species, managing broodstock, securing eggs and larvae and producing seed in public hatcheries, and releasing seedlings into natural waters. After release, the hatchery-produced seedlings mix with wild juveniles and a comprehensive stock management programme is operated for the fishery that includes both stocked and wild fish. Knowledge of the ecological characteristics of the target species is necessary, and it has emerged that the ecological fitness of stocked and wild fish is a key factor in stocking effectiveness. In some species (e.g. chum salmon and common scallop), stock enhancement has been shown to be highly effective, as clearly reflected by increased fishery production. However, although these stocking measures have been successful, mariculture production will be necessary for future food production. New technologies such as recirculation systems will be essential to farm fish and other aquatic products without environmental impacts.

SUPPLY AND DEMAND OF FISHERY PRODUCTS IN JAPAN

Domestic fishery production (fishery and aquaculture production)

In 2003, Japan saw its fishery and aquaculture production increase 3 percent in volume from the previous year to 6.08 million tonnes (Table 1) and shrink 8 percent in value to ¥ 1.6 trillion.

TABLE 1

Fishery and aquaculture production volume (1 000 tonnes) (Source: Annual statistics of fishery and aquaculture production. Ministry of Agriculture, Forestry and Fisheries, Japan)[1]

	1993	1998	2002	2003	Percentage change 2003/2002
Marine fishery	726	531	443	472	6
Far seas fishery	114	81	69	60	12
Offshore fishery	426	292	226	254	13
Coastal fisheries	186	158	149	158	6
Marine aquaculture	127	123	133	125	6
Inland water fisheries and aquaculture[2]	18	14	11	11	3
Total	871	668	588	608	3

1 Due to fractional rounding, component figures may not add up to the exact totals shown.

2 Inland-water fishery and aquaculture production in and after 2002 covers catch amount at 148 major rivers and 28 lakes and amount of production of cultured trout, ayu (sweetfish), carp and eel.

Fishery product trade

Japan's fishery product imports in 2003 declined both in volume (weight of products upon customs clearance, hereinafter the same) and value. In volume terms, the year's imports declined by 496 000 tonnes or 13 percent from the previous year to 3.325 million tonnes. In value, they dropped by ¥ 193 billion or 11 percent to ¥ 1 569.2 billion.

However, Japan remains the world's largest fishery product importer both in volume and value, accounting for 14 percent of the world's total fishery product import volume and 22 percent of total import value (as of 2002). The People's Republic of China has been the largest fishery product exporter to Japan since 1998. However, in 2003 such imports from China decreased by 120 000 tonnes or 16 percent in volume terms from the previous year and by ¥ 22.9 billion or 7 percent in value terms.

On the other hand, Japan's fishery product exports in 2003 increased by 63 000 tonnes or 21 percent to 370 000 tonnes in volume terms from the previous year, while decreasing by ¥ 1.1 billion or 1 percent to ¥ 135.4 billion in value. The above figures on volume and value for 2003 were calculated on the basis of 2002 statistics (Table 2).

TABLE 2

World fishery product trade: five largest exporters and importers in value (US$ million) and volume (10 000 tonnes) in 2002 (Source: FAO Fishstats – Fisheries Commodities Production and Trade, 1976–2002, FAO)

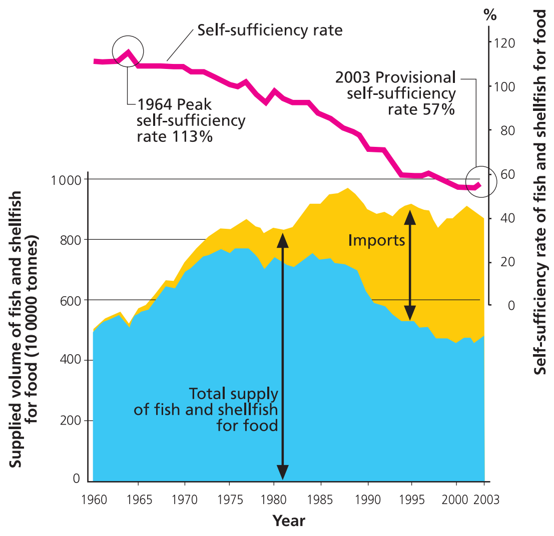
Import		World total	Japan	USA	Spain	France	Italy	-
	Value	62 318	13 863	10 150	3 867	3 237	2 917	-
	% Share	100	22	16	6	5	5	-
		World total	**Japan**	**China**	**USA**	**Spain**	**Denmark**	**-**
	Volume	2 774	382	248	207	146	140	-
		100	14	9	7	5	5	-
Export		**World total**	**China**	**Thailand**	**Norway**	**USA**	**Canada**	**Japan (23rd)**
	Value	58 500	4 601	3 692	3 601	3 319	3 052	818
	% Share	100	8	6	6	6	5	1
		World total	**Norway**	**China**	**Peru**	**USA**	**Denmark**	**Japan (28th)**
	Volume	2 742	210	206	186	136	127	31
	% Share	100	8	8	7	5	5	1

Consumption of fishery products and self-sufficiency rate

In 2003 the fish and shellfish (on an original weight basis) supplied for domestic consumption decreased 2 percent to 10.98 million tonnes from the previous year, of which about 80 percent was supplied for human consumption, down 2 percent to 8.39 million tonnes. Per capita annual fishery product consumption came to 65.7 kg on a crude food weight basis and to 36.2 kg on a net weight basis.

The "self-sufficiency" rate of fish and shellfish for food consumption in 2003 rose by 4 percentage points to 57 percent as domestic production increased and imports decreased (Figure 1).

Figure 1
Changes in self-sufficiency rate of fish and shellfish for human food
(Source: Food Balance Sheets, MAFF, Japan)



MAJOR MARICULTURE SPECIES AND FARMING TECHNOLOGIES

Status of farming of selected species

Target species and their production

In Japan, farming of oyster and laver has been prosperously practiced since the early seventeenth century. The gross of mariculture production amounted to ¥ 435.6 billion in 2004 (MAFF, 2005a). Fish, seaweed, shellfish, pearl, prawn and the others showed 196.5, 118.5, 72.5, 19.9, 8 and ¥ 20.2 billion, respectively (Table 3). The major mariculture species are as follows: fish – yellowtail, greater amberjack, red seabream, coho salmon, torafugu, Bastard halibut and white trevally; crustaceans – kuruma prawn; shellfish – common scallop, Japanese oyster and Japanese pearl oyster; and seaweed – laver, *konbu* tangle and *wakame*. The top five mariculture species in terms of production value were, in order of value: yellowtail and amberjack, laver, red seabream, common scallop and Japanese oyster. These species are very popular in Japan and important as the food for Japanese traditional cooking.

TABLE 3
Major mariculture species and production in Japan (Source: MAFF, 2005a)

Target species		Annual production in 2004	
Common name	**Scientific name**	**Value (¥ billion)**	**Volume (1 000 tonnes)**
Yellowtail	*Seriola quinqueradiata*	72.87	100
Greater amberjack	*Seriola dumerili*	36.43	50
Red seabream	*Pagrus major*	50.72	81
Torafugu	*Takifugu rubripes*	10.82	4
Bastard halibut	*Paralichthys olivaceus*	7.71	5
White trevally	*Pseudoaranx dentax*	4.27	3
Coho salmon	*Oncorhynchus kisutch*	3.57	10
Japanese jack mackerel	*Trachurus japonicus*	1.85	3
Other fish	-	8.24	7
Subtotal in fish	-	196.46	261
Pacific oyster	*Crassostrea gigas*	36.78	236
Common scallop	*Patinopecten yessoensis*	33.99	215
Other shellfish	-	1.69	2
Subtotal in shellfish	-	72.46	453
Kuruma prawn	*Penaeus japonicus*	8.04	2
Sea-squirt	*Halocynthia roretzi*	0.96	16
Other aquatic fauna	-	0.47	0
Nori	*Porphyra* sp.[1]	97.91	359
Wakame	*Undaria pinnatifida*	9.70	62
Konbu	*Laminaria* sp.[1]	8.49	47
Mozuku	*Nemacystus* sp.[1]	2.03	16
Other seaweed	-	0.36	0
Subtotal in seaweed	-	118.48	484
Pearl	*Pinctada fucata*[2]	19.85	31
Seed for aquaculture	-	18.84	– –
Total		435.55	1 216

[1] Representative species.
[2] Mother shell.

Remarkable species

One of the most remarkable species in Japan is bluefin tuna, *Thunnus thynnus* (MAFF, 2005b), because of:

- its high demand and high market value;
- the depletion of wild stocks and tighter regulation for pelagic fisheries;
- the technical development for production of high-quality fish; and
- the production of artificial seed through research progress.

Barfin flounder, *Verasper moseri*, is another important species whose culture is growing rapidly. It grows to a large size with a high commercial value (Andoh, Watanabe and Matsubara, 1999). Aquaculture of barfin flounder has been expanding in the cold waters of northern Japan, especially in Hokkaido and Iwate Prefecture. Aquaculture of grouper, *Epinephelus* sp., has been practised in the western part of Japan; however, the culture of this species is not so successful because of its vulnerability to viral nervous necrosis (VNN) (Furuta, 1996).

Among seaweeds, *mozuku* (*Nemacystus* sp.) and Okinawa *mozuku* (*Cladosiphon okamuranus*) are remarkable species with a high content of fucoidan, a kind of glycan (Noda, 1994). It has been reported that fucoidan is an effective substance for enhancing human immune response, and production of Okinawa *mozuku* is rapidly increasing in Okinawa Prefecture due to trends towards consuming healthy foods.

The establishment of aquaculture species in the country is influenced by the consumer's lucrative taste preference and a market trend towards consuming healthy products. The demand for commodities that are consumed directly, such as *mozuku*, or that are used as ingredients in health supplement products especially seem likely to increase in the future.

PRIORITIES FOR DEVELOPMENT AND RESEARCH

Present and future priorities for research and development of mariculture in Japan are presented below.

Development of breeding techniques

The application of molecular biological methods to aquaculture is an important subject, especially to develop improved breeds having high growth and strong tolerance to disease. In Japan, selective breeding has been practiced in goldfish and carp for a long time. Recently many trials of breeding technology (e.g. hybridization; production of diploids, triploids and clones) have been conducted in Japan for parrotfish, red seabream, bastard halibut, laver, Japanese oyster, etc. (Taniguchi and Aoki, 1994). Rapidly advancing new genetic research, especially marker-aided selection by microsatellite DNA markers, is leading to a new level of possibilities in breeding technologies.

Development of efficient feeding methods and artificial feeds

Self-pollution by mariculture is causing serious damage to the coastal environment in Japan. Therefore, development of artificial feeds for higher food conversion efficiency and introduction of on-demand fish feeding systems are necessary for environmental conservation. An on-demand feeding system is an effective management method for reduction of waste feed, and trials have been undertaken for some marine fish such as red seabream, yellowtail, grouper, torafugu and rainbow trout (Kohbara *et al*., 2000).

Disease prevention

It is reported that the annual loss of Japanese aquaculture production due to fish disease amounts to ¥ 15–25 billion (3–6 percent of total production). Therefore, development of preventive measures against disease is a matter of great urgency. Several viral diseases [e.g. yellowtail ascites virus (YAV), hirame rhabdovirus (HRV), baculoviral mid-gut gland necrosis virus (BMN), and viral hemorrhagic septisemia (VHS)] have caused increasing problems of mass mortality in seed production and grow out. Much research has been conducted on methods for detection of virus, specific viral characteristics, sources of infection, interception of infection routes, development of effective and safe vaccines, and reinforcement of fish immunity by special diets and control of environmental conditions (Muroga, 1994).

Polyculture system

Effective utilization of space and resources to increase productivity is an important subject in Japan. The fundamental concept of the polyculture system is "zero emission" by combining species with different feeding behaviours and ecological patterns, but not those negatively interacting with each other. Some case studies on fish, seaweed, sea cucumber and abalone show positive results with increased productivity.

Utilization of deep-sea water

Utilization of deep-sea water for aquaculture has been studied and tested in recent years, for example in Kochi Prefecture, where deep-sea water is pumped up from a depth below 300 m. Characteristics of deep-sea water are:

- its stable low temperature, typically below 10 °C;
- its purity, especially its low concentration of marine bacteria; and
- its richness in nutrients such as nitrogen, phosphoric acid and silicate.

Technology for the aquaculture of bastard halibut and other deep-sea species can be successfully developed using this water, because it can provide a good environment for cultivation of phytoplankton, kelp and other seaweeds and also contains very few pathogenic bacteria that may cause disease.

Promotion of low-trophic commodities

Aquaculture of shellfish and seaweed is practiced without supplementary feeding. Shellfish grow by consuming phytoplankton and suspended organic particles, while seaweeds grow by the uptake of nitrogen and phosphoric acid. These aquaculture commodities give some benefit to the coastal environment – for example, by direct removal of excess nutrients and suspended organic matter and by the indirect effect of removing nitrogen and phosphorus, leading to their removal from seawater via harvesting of products (shellfish and seaweed) (Matsuda, 2002). Therefore, aquaculture of low-trophic commodities will be promoted, especially considering the status of coastal environments in the country.

Identification of better management practices (BMPs) for existing farmed species and systems to mitigate environmental impacts

Problems of existing mariculture

The self-sufficiency rate, a serious concern in Japan, has decreased considerably in recent years due to decreased domestic supply and increased imports. The self-sufficiency rate in fish and shellfish was reduced by half over the past 30 years, down to 57 percent in 2003 (MAFF, 2005b) (Figure 1). Therefore promotion of aquaculture is important to recover the self-sufficiency rate. However, there are issues to be considered for promotion of mariculture in Japan. Drug residues and environmental pollution in aquaculture areas have led to a negative image for aquaculture among consumers and possibly restrained the consumption of aquaculture products. Environmental pollution, in particular, is a serious problem due to wasted feed, urine, fish faeces and other waste products that are discharged into coastal waters by intensive mariculture operations (Figure 2). The level of mariculture-caused pollution compared to a daily discharge of nitrogen and phosphorus from humans (Maruyama and Suzuki, 1998;, Maruyama, 1999) suggests that pollution from Japanese mariculture is equal to the waste produced by 5–7 million people in terms of nitrogen and 9–10 million people in terms of phosphorus (Maruyama, 1999) (Table 4). These results clearly show that environmental pollution by mariculture has reached a serious condition and needs improved management.

Figure 2
Nitrogen balance in marine rainbow trout cage farming
(Source: modified from Hal *et al.*, 1992)

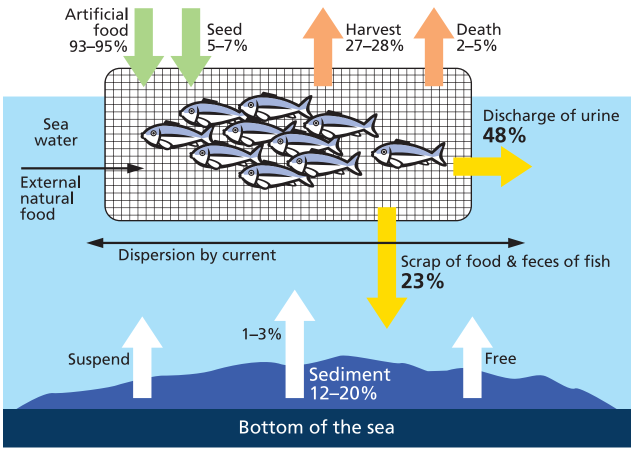


TABLE 4
Trial calculation of the coastal pollution level from aquaculture as compared to that from human population (Source: Maruyama, 1999)[1]

Origin for estimation	Production (1 000 tonnes)	Estimated human population (million)	
		Total nitrogen (TN)	Total phosphorus (TP)
Amount of aquaculture production	325	7.5	10.0
Amount of artificial food production	500	5.4	9.6

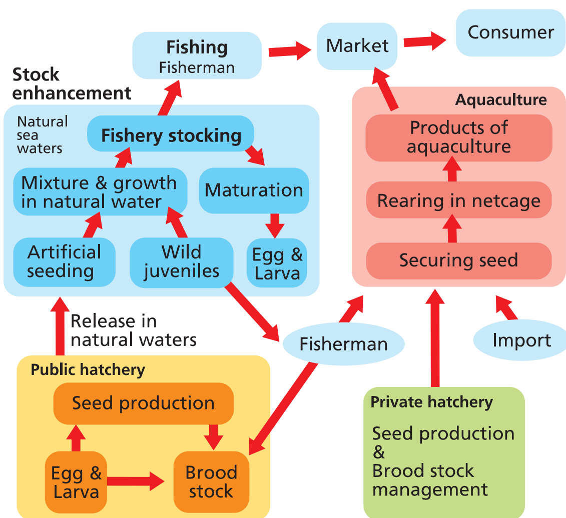
[1] Standard unit for pollution: TN: 100 kg-TN/tonnes – aquaculture production
TP: 20 kg-TP/tonnes – aquaculture production
Standard unit for exchange to people: TN: 12 g-TN/person/day
TP: 1.8 g-TP/person/day

Stock enhancement in harmony with the environment

In Japan, stock enhancement (sea farming) has been practiced in harmony with the environment as a key measure in preserving and enhancing fisheries stocks (Figure 3). The National Center for Stock Enhancement (NCSE) in the Fisheries Research Agency (FRA) started the technical development of stock enhancement in 1963 by releasing artificial seed (juveniles) in a project to actively recover the decreasing fishery stock (Imamura, 1999). Stock enhancement consists of:

- selection of target species;
- broodstock management;
- securing fertilized eggs;
- seed production;
- rearing in nursery and acclimation to the natural environment;
- release;
- comprehensive stock management (released and natural stock); and
- monitoring of stock and evaluating the share of stocked fish in fishery production.

Figure 3
The concept of stock enhancement and system of Japanese fisheries



Many marine species have been released in natural waters. In some species, such as the chum salmon (*Oncorhynchus keta*) and common scallop (*Patinopecten yessoensis*), the effects of stock enhancement are clearly reflected by an increase of fishery production (Imamura, 1999; Kitada, 2001). Recent advances in marker techniques allow better assessments of the effectiveness of stocking, and case studies have reported high return rates (8–50 percent) in red seabream, bastard halibut and abalone (Kitada, 2001).

Knowledge of the ecology of the target species is necessary to support stock enhancement, and it is important that the target species fits into the local ecological system in order to achieve effective results from stock enhancement programmes.

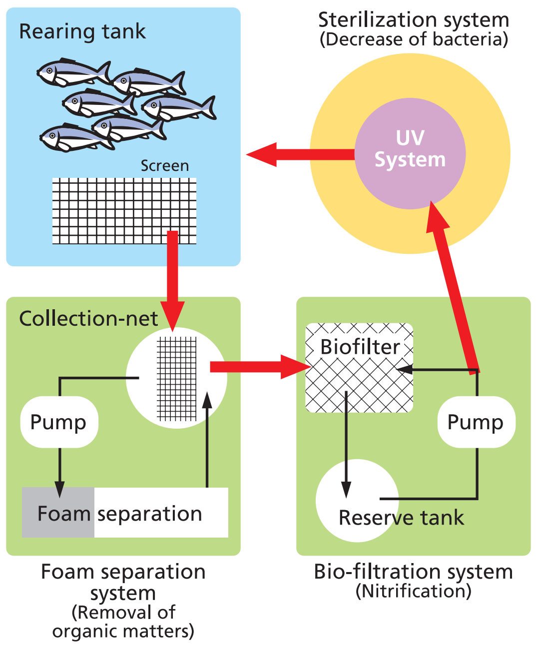
Closed recirculation systems

Considering the need to preserve coastal environments, closed recirculation systems are highlighted as a rearing technology that is a type of "zero emission" fish-rearing system. Research on closed recirculation systems started in the 1950s (Saeki, 1958). Drs Saeki and Hirayama were the pioneers of research for a closed recirculation system through developmental and fundamental research on the biofilter (Saeki, 1958;, Hirayama, 1970). Complete system control leads to many benefits, including:

- reduction of pollution;
- avoidance of external risk (e.g. disease and poor water quality);
- highly stable productivity; and
- energy savings.

Therefore, there is increasing interest in developing hardware and software for such rearing technology. A number of research studies and trials on closed recirculation systems are ongoing, such as high-density rearing of bastard halibut and eel (Kikuchi *et al.*, 1991; Honda *et al.*, 1993; Suzuki and Maruyama, 1999); however, their use by private companies and fishermen has just started. The private sector, academia and government in Japan are cooperating on this topic, and further development and implementation are anticipated.

Figure 4
Seed production in a closed recirculation system at Yashima Station



At Yashima Station, National Center for Stock Enhancement (NCSE), FRA, technical development of a closed recirculation system for seed production in red seabream started in 2000 (Tomoda, Fushimi and Kurokura, 2005). The closed recirculation system developed by this centre consisted of a foam separation unit, a biofiltration system and a ultraviolet (UV) sterilization system. These function for removal of organic matter in rearing water, nitrification and sterilization of water, respectively (Figure 4).

At present, the technical level of seed production by this system is higher than that acheivedachieved by flow-through rearing (Kamoshida, Yamazaki and Yamamoto, 2006). Using the closed recirculation system, survival and production densities from hatched larvae to juveniles of 30 mm in TL are 45–70 percent and 5 000–7 000 individuals per m^3, and those in the case of juveniles of 60 mm in TL are 50 percent and 5 000 individuals per m^3, respectively (Kamoshida, Yamazaki and

Yamamoto, 2006). The water exchange rate is below 0.5 percent per day. Therefore, we can establish the near-perfect, no discharge system for seed production. Water quality during the rearing period from hatching to juveniles of 30 mm in TL (about 50 days) was also investigated. Concentrations of ammonia nitrogen and nitrite-nitrogen in rearing water are kept below 1.0 mg/literlitre and 0.5 mg/literlitre, respectively. Therefore, under a condition of little water exchange, a closed recirculation system can be used to maintain suitable water conditions for seed production and rearing of juvenile red seabream. In the future, this closed recirculation system will be applied to other species for which seed production has proved difficult.

CONCLUSIONS

Fishery production in Japan consists of capture fisheries, aquaculture and stock enhancement (sea-farming). Relatively closed coastal waters are considered as large-scale farming grounds; and stock enhancement (sea farming) and sea ranching, intermediate between capture fisheries and aquaculture, are operating in those locations. Fisheries management in the country is comprehensive, involving stocked resources and wild resources and with rational fisheries regulations in place (e.g. limits on catch, fishing gear and fishing period). In other words, the fundamental productivity of the marine environment is being effectively enhanced for fishery production. However, the productivity of natural coastal waters is exhausted by the disappearance of tidelands, seagrass and seaweed beds (Shibagaki, 2002).

National policy aims to increase self-sufficiency in fish and shellfish products, and mariculture is an important means of achieving that goal. The switch in aquaculture systems to closed recirculation systems that preserve the environment will become an increasingly important part of future mariculture production. We consider it necessary for the government to support aquaculture companies that switch to more sustainable aquaculture production methods, such as using the closed recirculation system.

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INTRODUCTION

The Republic of Korea is a peninsula with a coastline of almost 9 000 km and an archipelago of some 3 000 islands. Consequently, fishing has always been a national industry of major economic importance. However, a continuous decrease in capture production in recent years has led to an increased attention to aquaculture, with an attendant increase in culture production. The total national fisheries production in 2003 was 2 492 545 tonnes, comprising capture and culture production of 1 652 700 and 839 845 tonnes, respectively. This indicates a shift towards aquaculture when compared with the capture and culture production quantities of 1 838 018 and 667 883 tonnes, respectively, in 2000. Korean aquaculture is dominated by the marine species. Marine aquaculture contributed 98 percent (826 245 tonnes) of the total aquaculture production of 839 845 tonnes in 2003.

Despite the decline in capture production, the demand for aquatic products has been on the increase. The Republic of Korea recorded a trade deficit in fishery products for the first time in 2001. To meet the demand for aquatic products, further development of the aquaculture sector is needed, especially the marine subsector, which produces most aquatic foods.

MARINE AQUACULTURE PRODUCTS DEMAND, TRADE AND MARKETS

An analysis of marine aquaculture products demand, trade and markets trend, locally and nationally

Since the Republic of Korea is a peninsula, marine products are a major constituent of the food of the people. However, in recent years there has been a marked increase in consumption of marine foods in line with a general increase in consumption of aquatic products. This trend is attributed to the concern for health; consumers now prefer eating aquatic products as alternatives to red meats due to their health benefits. As a result of the improved purchasing power of consumers with concomitant improved standard of living, the demand for high-value species has also increased. There is an increased demand for high-value fish species such as Korean rockfish and olive flounder. Demand for shrimps has equally increased.

Imports and exports of fishery products by major countries and the trends of export, import and trade balance of fishery in the Republic of Korea are shown in Tables 1 and 2, respectively. Unfortunately, data on mariculture trade flows are not available, as trade figures are reported for total fishery products and not individually for the various subsectors. From the tables, it can be seen that there has been a continuous increase in trade deficits (in both quantity and value) in recent years. The Republic of Korea recorded the first trade deficit (in value) in 2001. However, with the government's policies to encourage aquaculture production and the shift towards production of high-value marine species such as Korean rockfish, olive flounder, oysters and fleshy shrimp, it is expected that the trend in balance of trade for marine aquaculture as well as total aquaculture will be reversed.

TABLE 1
Imports and exports of fishery products by major countries (tonnes and US$1 000)

	2000		2001		2002		2003	
	Weight	Value	Weight	Value	Weight	Value	Weight	Value
Imports								
Total	749 191	1 410 598	1 056 252	1 648 372	1 186 400	1 884 417	1 238 603	1 961 145
China	283 420	486 841	474 045	634 449	491 315	719 314	461 971	713 538
Russia	81 265	125 031	92 856	153 756	189 464	215 638	269 918	299 252
USA	75 588	145 366	93 969	158 520	89 603	173 774	82 485	152 677
Japan	67 741	185 109	69 679	139 129	74 536	146 497	69 257	148 699
Viet Nam	33 374	72 240	49 107	101 486	61 504	121 733	67 416	129 878
Others	207 803	396 011	276 596	461 032	279 978	507 461	287 556	517 101
Exports								
Total	533 824	1 504 470	435 691	1 273 619	429 884	1 160 435	424 785	1 129 385
Japan	215 479	1 125 248	179 335	924 873	179 069	823 117	150 155	740 447
China	93 134	84 090	53 673	55 709	44 290	48 345	55 708	70 769
Thailand	44 805	22 691	47 256	32 943	46 295	34 492	55 304	38 354
EU	35 749	64 596	49 429	75 159	39 912	63 760	46 605	78 089
USA	29 215	78 712	27 281	82 210	25 462	77 625	22 964	80 385
Others	115 442	129 133	78 717	102 725	94 856	113 096	94 049	121 341

TABLE 2
Trends of export, import and trade balance of fishery in the Republic of Korea (US$m)

	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Export	1 643	1 518	1 496	1 647	1 722	1 635	1 493	1 369	1 521	1 504	1 274	1 160	1 129
Import	576	506	542	726	843	1 080	1 045	587	1 179	1 411	1 648	1 884	1 961
Trade balance	1 066	1 012	954	921	879	555	447	782	342	94	-375	-724	-832

Role of aquaculture vs. fisheries as supply

Capture and aquaculture production quantities over two decades and in the year 2003 in the Republic of Korea are summarized in Table 3. The total national production in 2003 was 2 492 545 tonnes, comprising capture and culture production of 1 652 700 and 839 845 tonnes, respectively. This indicates a shift towards aquaculture when compared with the capture and culture production quantities of 1 838 018 and 667 883 tonnes, respectively, in 2000. The increase was a result of the government's aquaculture promotion policy and fleet reduction programme. The 2003 aquaculture production figure comprises marine production of 826 245 tonnes and freshwater production of 13 600 tonnes. The total aquaculture production value was US$1.06 billion.

TABLE 3
Capture and aquaculture production in the Republic of Korea (tonnes) (Source: FAO, 2004)

	1980	1985	1990	1995	2000	2003
Marine capture	1 840 938	2 268 584	2 471 584	2 333 525	1 830 878	1 647 974
Freshwater capture	22 290	34 463	25 325	8 765	7 140	4 726
Total capture	1 863 228	2 303 047	2 496 909	2 342 290	1 838 018	1 652 700
Mariculture	544 402	787 571	772 729	996 889	654 440	826 245
Freshwater aquaculture	731	3 198	15 836	20 365	13 443	13 600
Total aquaculture	545 133	790 769	788 565	1 017 254	667 883	839 845
Grand total	2 408 361	3 093 816	3 285 474	3 359 544	2 505 901	2 492 545

Consumer trends, preferences and buying patterns

As previously mentioned, there has been an increase in demand for aquatic products, including marine foods. Similarly, the demand for high-value species among the marine products has been on the increase. This increase is due to increased purchasing power of consumers, concern for health, popular beliefs and other factors. For instance, many consumers prefer raw fish (mainly olive flounder) for its nutritional value. In the same manner, many Koreans eat Japanese eel, one of the popular species, for the purported aphrodisiac properties of the species.

Besides the preference for high-value species of fish, there has also been a trend towards selection of value-added products. To respond to the buying pattern of consumers, efforts are now made to establish a consumer-oriented cultivated marine products supply to develop the processing method to produce high value-added products.

Market chain organization, market trends and vulnerability

Distinctions are hardly made between culture and capture marine products in the analysis of marketing channels of fishery products. As most of the marine aquaculture farms are located in the coastal areas due to their reliance on natural seawater, it can be seen that marine aquaculture products basically follow the same distribution systems as the fishery products that are also available in these areas. Marketing and distribution of the products at landing ports take place through fishery cooperative auction markets and the Busan common fish markets, which are always located at water fronts, but distribution to consumption areas is made through wholesale markets, inland joint-sale and direct-sale markets and retailers. The final consumers usually get their supplies from conventional markets, supermarkets, discount stores, department stores and seafood wholesale markets.

Since marine aquaculture products basically follow the same distribution systems as the capture products, trends in marketing of capture and aquaculture products are the same. Several measures are being taken by the Korean government to ensure stable market prices for fishery products through the establishment of the "Price Stabilization Fund". The fund is intended to cover ten fishery products items, including dry seaweed, frozen squid and frozen hair-tail fish. Fishery marketing systems have been improved through the expansion of market facilities and the upgrading of the consignment system on landing sites and the distribution capacity at areas with large consumer populations. Since October 1997, the government has liberalized the consignment system at landing sites. This policy has been a part of a two-stage free market system first introduced in 1996. Five direct-sale market facilities have been established at large urban areas to strengthen the distribution and handling capacity in areas where large populations of consumers are found. The improvement includes the reduction of distribution and handling steps and marketing margins, and the promotion of direct shipping to consumers by fishermen's cooperatives.

The Republic of Korea imports aquatic products from the People's Republic of China, the Russian Federation, the United States of America, Japan and Viet Nam for domestic consumption and re-export. No difference is ever made between imported and domestically cultured products while reporting the total export quantities and values. In 2003, a total of 424 785 tonnes of fishery products valued at US$1.13 billion was exported, while the import was 1 238 603 tonnes yielding US$1.96 billion (Table 1). The Republic of Korea exports processed aquatic products to Japan, the United States of America and Europe.

LIVELIHOOD OPPORTUNITIES AND MARICULTURE

Since 1975, coastal communities have been allowed to obtain licences for aquaculture in fishery sites. Coastal communities began actively participating in finfish aquaculture in the late 1990s. At that time, finfish aquaculture was seen as a high-profit business in fisheries but personal licenses were not easily available to private farmers. In addition, fisheries agreements between the Republic of Korea, Japan and China adversely affected coastal communities. Part of the government's efforts at reviving coastal communities was approval of licences for mariculture, which led to the explosive growth of finfish aquaculture. This rapid growth caused a decrease in the market price of live fish due to over-production and importation of low-cost live fish from China. As a result, many coastal community farmers became bankrupt.

According to the Korea National Statistical Office, the number of persons employed in the aquaculture industry in 2004 was 63 570, and they constituted around 33.2 percent of the total number of fishermen employed in the fishery sector. These people are concentrated around the major production cities including Busan, Incheon, Ulsan, Kyonggi, Kangwon, Chungnam, Chonbuk, Chonnam, Kyongbuk, Kyongnam and Jeju. Three of these cities are the highest employers of labour in the aquaculture industry; they are Chonnam, Kyongnam and Chungnam, in that order. Mariculture makes the highest contribution to employment of labour. About 92 percent of the people employed in the aquaculture industry in 2004 were involved in mariculture, while only 8 percent were involved in freshwater aquaculture. Of those employed in marine aquaculture, 49.7 percent were engaged in production of molluscs. Seaweed, finfish and crustacean production contributed 29.1, 9.05 and 0.3 percent, respectively. About 1.5 percent of the people were employed in hatcheries. Apart from people directly involved in aquaculture, many others are engaged in subsidiary industries, including feed manufacturing, product processing, transportation, sales and export, and research and development.

Currently there are 1 951 coastal communities around the country, and the annual income per household is US$21 200, less than that of stockbreeders and farm workers (US$50 000 and US$35 000, respectively). It is necessary that actions be taken to improve the income of communities engaged in aquaculture. Loans and grants should be made available to the farmers. Low-cost, high-efficiency and low-pollution feeds should be developed. Programmes to increase the competitiveness of culturing strategic species should be established. Fallowing years for farming sites should be established, and formulated feeds should be subsidized to discourage farmers from using raw fish-based feeds.

EXISTING AND POTENTIAL MECHANISMS FOR TECHNOLOGY TRANSFER

Training centres of excellence

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 coastal areas. The role of these organizations 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.

Existing mechanisms for technology transfer and mechanisms for effective dissemination of R&D to farmers and other stakeholders

For workers in the industry to remain relevant in this information age, 13 890 people were trained in 2004. In the future, intermediate and higher-level courses will be held to educate fisherman thoroughly. Computers, connected to the Internet, together with printers and other accessories were installed in the homes of fish farmers in 100 model fishing villages. The information-sharing systems constructed in 31 different locations (MOMAF, NFRDI and local governmental agencies) allow fisherman to have remote access to essential information about fisheries. Fishermen can communicate effectively through a specialized homepage (www.badaro21.net).

Books providing culture standards for each aquaculture species have been published by NFRDI. Furthermore, the Fisheries Outlook Review, providing general information on the status, prospects, monthly market prices, production, exports and imports of Japanese flounder and laver, is published by the Korea Maritime Institute and Fisheries Outlook Center.

Present training activities and likely future requirements

In 2004, Wando Maritime and Fisheries Office, one of the branch offices of Mokpo Regional Maritime Affairs and Fisheries Office, organized a seminar, inviting the chief executive officer (CEO) of SAMYANG Co., Ltd. as the guest speaker to enlighten seaweed farmers and train them on how to collect seeds of laver under indoor culture conditions.

Buan Fisheries Technology Institute, one of the branch offices of Gunsan Regional Maritime Affairs and Fisheries Office, established test farms for clam (*Meretrix lusoria*) aquaculture in four locations around the Buan area. Education of local aquaculture farmers on optimal management systems, activation and resource enhancement of clam and the development of locally specialized products for the Buan area was carried out from 2003 to 2004.

Pohang Regional Maritime Affairs and Fisheries office carried out two projects with local aquaculture farmers. One of the projects was the polyculture of Japanese flounder and abalone in land-based tanks. A continuous decrease in market price of flounder, a high-value species, led to the search for a new technique to produce high-value-added species. An experiment for the production of flounder and abalone, another high-value species, in a polyculture system was carried out by the office and the local aquaculture farmers in a test farm. Results showed the possibility of making profits with polyculture. Another project was the establishment of a new aquaculture farm for the production of sea squirt (*Halocynthia roretzi*) in 22–30 m deep sea. Saturation of sea squirt farms in 10–20 m deep sea area had resulted in low productivity; however, high productivity was recorded following the establishment of new farms in the deeper water.

Programmes to raise work efficiency for mariculture are carried out with other parts of fisheries by the governmental agencies and national institutes.

Due to the industrialization and development of the service industry, most youths are not interested in the fisheries industry; they prefer to find white-collar jobs in urban areas, leading to a reduction in workforce in the fisheries sector. This calls for measures to attract the population to the fisheries sector in order to increase the sector's productivity. Governmental agencies introduced programmes to provide support to students to meet their educational needs and to help them become established in the aquaculture industry. From 1981 to 2004, a total of US$360 million was disbursed and 16 029 people were supported and specially trained by local governmental agencies and the Division of Human Resources Development, NFRDI.

As part of measures to reduce the deficiency of work force in the fisheries industry, US$95 000 was distributed to four of the fisheries high schools by the governmental agencies to support entrance and tuition fees in 2004.

EXISTING MAJOR MARICULTURE SPECIES AND FARMING TECHNOLOGIES

Status of farming of selected species

Total mariculture production by major product groups in the Republic of Korea over two decades and in the year 2003 is shown in Table 4. Seaweed has always topped the total mariculture production followed by molluscs and finfish, in that order, while crustaceans are the least important group in terms of production quantity. Seaweed contributed 55 percent (452 054 tonnes) of the total mariculture production of 826 245 tonnes in 2003. Of interest, however, is the sharp increase in finfish and crustacean production in this millennium.

Table 5 shows the seaweed mariculture production by species in the Republic of Korea in 2003. Sea mustard and laver made up 44 percent and 43 percent, respectively, of the total seaweed production of 452 054 tonnes in 2003. Other species cultured include fusiforme and kelp. These species are cultured using fixed and semi-floating culture systems.

Mollusc production is dominated by oysters, which made up 79 percent (238 326 tonnes) of the total production of 301 540 tonnes in 2003 (Table 6). Oysters are cultured mostly in the south coast of the country by the long-line hanging culture technique. Other species of mollusc cultured in the Republic of Korea are short neck, sea mussel, ark shell, scallop, pen shell, cockles, venus clam, abalones and hard clam.

Marine finfish culture is a major subsector of the mariculture and overall aquaculture industry in the Republic of Korea, although the contribution by this subsector in terms of quantity is relatively low. Furthermore, it is encouraging that the subsector has experienced a sharp growth in recent years in terms of total quantity and value, with the production topped by two high-value species, olive flounder and Korean rockfish, as shown in Table 7. Olive flounder is cultured in onshore tank farms, while rockfish is farmed in offshore floating net-pens.

Although the Republic of Korea produces a number of crustaceans, only the fleshy shrimp was cultured in 2003 to a significant quantity, as reported by the Fisheries Association of Korea (Table 8). Fleshy shrimp is cultured in ponds, mostly along the west coast of the peninsula.

TABLE 4
Total mariculture production in the Republic of Korea (tonnes) (Source: FAO, 2004)

Group	1980	1985	1990	1995	2000	2003
Finfish	4 468	20 988	34 958	35 100	56 217	80 804
Crustaceans	86	87	312	438	1 158	2 324
Molluscs	281 587	369 035	325 590	312 252	222 609	291 063
Seaweeds	258 261	397 461	411 869	649 099	374 456	452 054
Total	544 402	787 571	772 729	996 889	654 440	826 245

TABLE 5
Seaweed mariculture production by species in 2003 (Source: The Fisheries Association of Korea, 2004)

Species	Quantity (tonnes)
Sea mustard	198 172
Laver	193 553
Fusiforme	33 661
Kelp	25 259
Others	1 363
Total	452 054

TABLE 6
Mollusc mariculture production by species in 2003 (Source: The Fisheries Association of Korea, 2004)

Species	Quantity (tonnes)
Oysters	238 326
Short neck	27 494
Hard clam	15 785
Sea mussel	13 653
Cockles	3 842
Ark shell	2 440
Others	-
Total	301 540

TABLE 7
Finfish mariculture production and species in 2003 (Source: The Fisheries Association of Korea, 2004)

Species	Quantity (tonnes)
Flounder	34 533
Rockfish	23 771
Common seabass	2 778
Yellowtail	114
Mullet	4 093
Red seabream	4 417
Others	
Black porgy (*Acanthopaagrus schlegeli*)	1 084
Parrot fish (*Oplegnathus fasciatus*)	-
Puffer (*Takifugu obscurus*)	14
Fill fish (*Monacanthus* sp.)	-
Convict grouper (*Epinephelus septemfasciatus*)	39
Okhostk atka mackerel (*Peurogrammus azonus*)	-
Total	70 843

TABLE 8
Crustacean mariculture production and species in 2003 (Source: The Fisheries Association of Korea, 2004)

Species	Quantity (tonnes)
Fleshy shrimp *(Penaeus chinensis)*	2 324
Kuruma prawn *(Penaeus japonicus)*	0
Others	
Chinese mitten crab (*Eriocheir sinensis*)	-
Mitten crab (*Eriocheir japonicus*)	-
Blue crab (*Portunus trituberculatus*)	-
Snow crab (*Chionoecetes opilio*)	-
Total	2 324

PRIORITIES FOR DEVELOPMENT AND RESEARCH

Due to the dwindling capture production, efforts are made to encourage aquaculture production, and there have been positive results, with mariculture as the leading subsector, as indicated in Table 3. However, Korean mariculture still faces some problems, and it is necessary that these be solved so that the subsector can grow to meet the ever-increasing demand for marine products.

One important issue is the imbalance between the level of production and the prioritization of research for the different cultured species. There are wide disparities in output of the same species between the different locations, and these need to be explained and resolved.

Cultivation of some species still relies on the collection of wild larvae and supplies can barely meet the demand. This practice, in turn, has a negative impact on the prevention and treatment of the common diseases such as lymphocystis, *Edwardsiella* and *Vibrio* in fish culture, *Marteilioides chungmuensis* in oyster culture, and viral diseases in shrimp culture. There is the need to improve seed production technology, establish disease control centers, develop cheap and highly efficient vaccines, develop natural immunostimulants, improve culture facilities and introduce species with short production cycles and high productivity. There are also problems in the manufacture and improvement of feeds, and there is a great need for effective environmental protection and monitoring systems.

Identification of better management practices for existing farmed species and systems to mitigate environmental impacts

Regrettably, although marine aquaculture in the Republic of Korea has recorded a huge increase in recent years, there has been a marked decline in the quality of the products due to the deteriorating environmental conditions of aquaculture farms. Initiatives have been taken by the government to address this issue of deteriorating product quality through the introduction of new coastal mariculture maintenance programmes consisting of three components: general mariculture ground maintenance, special mariculture ground maintenance and demonstration mariculture ground maintenance. The benefits of the coastal mariculture maintenance programmes were clearly demonstrated by the regeneration of aquatic micro-organisms and increased production per unit area, as well as improved quality of products.

On 29 January 2000, the Farming Ground Management Act was enacted to build a sustainable fishery and to improve the productivity of farm sites. The act introduced a system of recess years for the mariculture sites to increase their productivity. The act also introduced the inspection and standardization of environment of farm sites.

The Fishery Promotion Act, which was enacted on 14 January 2002, enables the government to establish a framework to promote aquaculture every five years. One of the functions of the act is to control and manage a fish health programme that can help aquaculture farmers to control diseases. However, much still has to be done to educate the farmers on the early diagnosis and prevention of diseases.

Currently, efforts are being made to further develop offshore aquaculture technology in the Republic of Korea. Other technologies and techniques need to be introduced and the existing ones improved. The optimal stocking densities for the existing species and systems should be established, and farmers should be encouraged to adopt polyculture where necessary and applicable. At present most Korean farmers use formulated feeds, but farmers need to be encouraged to maintain this practice, stressing the negative impacts of the use of raw fish on the environment. High-energy-density feeds with high digestibility should be formulated and used to reduce the nutrient load in effluents.

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Malaysia

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INTRODUCTION

Malaysia is located in the heart of Southeast Asia. Consisting of 330 200 km^2, the country is divided into two main regions: Peninsular Malaysia, which lies south of Thailand, and East Malaysia, which can be found north of Indonesia on the Island of Borneo. Although East Malaysia occupies the larger portion of Malaysia's total area, it is primarily comprised of undeveloped land and jungles. Hence about three-quarters of Malaysia's population of 23 million live in Peninsular Malaysia.

Being surrounded by sea, Malaysia has a coastline of 4 800 km. Within the coastal area, mangrove forests cover about 641 000 ha. Most mangrove forests are located in Sabah (57 percent), with 26 percent in Sarawak and only 17 percent in Peninsular Malaysia. Beyond the shore are over 200 islands with warm, clear waters and teeming marine life that have delighted tourists and divers.

The climate of Malaysia is tropical. The average temperature is between 21–32 °C. Humidity is high. Rain tends to occur between November and February on the east coast of Peninsular Malaysia, in western Sarawak and in northeastern Sabah. On the west coast of Peninsular Malaysia, the rainy seasons are April to May and October to November. With its favourable climate supported by vast natural resources, Malaysia has a great potential for aquaculture development.

Malaysia has the vision to become a developed country by the year 2020. The country recognizes the significance of sustainable aquaculture as an integral part of efforts to develop its natural resources. Malaysia is therefore giving high priority to increasing its aquaculture production, with most attention being given to shrimp and marine finfish aquaculture. Various institutions and governmental agencies have been given the task of commercializing this sector, getting involved in research, training and development. On the other hand, mindful of the rising labour shortage in Malaysia, the government's policy is to promote capital-intensive large-scale commercial shrimp farming. Mechanization and automation are promoted whenever feasible. Farms are encouraged to operate on an integrated and self-sustaining basis. Fry and feed production, processing and packaging, as well as marketing are built into vertically integrated systems. Malaysia is encouraging partnerships to achieve its aquaculture development objectives. The government is interested in attracting foreign capital and appropriate know-how to develop the sector through environmentally friendly technologies.

MARINE AQUACULTURE PRODUCTS DEMAND, TRADE AND MARKET

An analysis of local and international demand, trade and market trends

Annually from 2002 to 2004, the production of fish from the marine sector in Malaysia was about 1.4 million tonnes with a value of slightly more than RM 5 billion. The bulk of production (close to 90 percent) came from capture fisheries. An average of 10 percent of the share came from aquaculture, amounting to about 1 200 to 1 400 tonnes, valued at RM 700–900 million annually over the last five years (Table 1). Brackishwater aquaculture contributed on average 70–75 percent of the total aquaculture production. In terms of quantity, about 30–40 percent and 10–20 percent of marine aquaculture production came from cockle rearing and seaweed cultivation, respectively. Pond-based production, which is typical of shrimp aquaculture, and cage systems contributed about 5 and 15 percent, respectively, in terms of quantity. Despite the low volume, products from this sector earn the highest trading values for fishery products.

As a source of cheap animal protein, fish is considered an important food item by the Malaysian people. Due to easy access to fish and fish products, Malaysia is among the countries with the world's highest fish consumption, having an average per capita consumption of 49 kg in the year 2000. This consumption increased to 53 kg per capita in 2005 and is expected to rise further to 56 kg per capita in 2010. The importance of fish as food is further reflected in household expenditure data, which show that on average, expenditures on fish account for about 20 percent of the household food budget (MOA, 2003). With increases in population and health consciousness among the Malaysian people, it is apparent that local production will not be able to meet the goal of self-sufficiency within the coming years. Self-sufficiency was only 89 percent in 2000. This figure was expected to increase slightly to about 90 percent in 2005 and predicted to increase further to 94.3 percent in 2010, if strategies and action plans put in place under the Third National Agricultural Policy (NAP3) new policy thrust are implemented and goals achieved.

TABLE 1
Fish production from marine landings and marine aquaculture, 2000–2004

Year	Landing		Aquaculture		Total	
	Volume (tonnes)	Value (RM million)	Volume (tonnes)	Value (RM million)	Volume (tonnes)	Value (RM million)
2000	1 285 696	4 399.23	117 205.56	665.34	1 402 901.56	5 064.57
2001	1 231 289	4 166.11	133 562.79	958.01	1 364 851.79	5 124.12
2002	1 272 078	4 206.81	145 439.81	843.49	1 417 517.81	5 050.30
2003	1 283 256	4 013.62	146 926.82	931.09	1 430 182.82	4 944.71
2004	1 331 645	4 241.45	146 668.04	903.38	1 478 313.04	5 144.83

The NAP3 (1998–2010) was formulated following the Asian financial crisis of 1997, which put pressure on food and the country's food import bill. In response, government strategies and implementing mechanisms for the NAP3 give special attention to agricultural development and the economy as a whole. Besides its traditional role in supplying food for the country, the sector was expected to enhance food security and increase its production and contribution. Secondly, the fishery sector was to become an engine to contribute to national income and export earnings. Thirdly, the sector was to maximize income of the producers and contribute to poverty alleviation. The expectations and hope put on the fisheries sector in the NAP3 were based on the sector and particularly, aquaculture, being able to produce food in a cost-competitive manner. The country was also recognized as having large areas suitable for the development of the aquaculture industry. Previous earning data also indicate that the fisheries sector is a clear contributor to the national economy (Table 2).

TABLE 2
Food export and import bills, 2004 (Source: MOA)

Commodity	Exports (RM million)	Imports (RM million)	Trade balance (RM million)
Livestock	1 005.2	2 696.3	-1 691.0
Fish products	2 073.0	1 935.0	137.9
Agricultural products	4 337.5	7 778.4	-3 440.9
Others	2 513.8	4 144.8	-1 631.0
Total	9 930.0	16 554.5	-6 625.0

Consumer trends, preferences, buying patterns

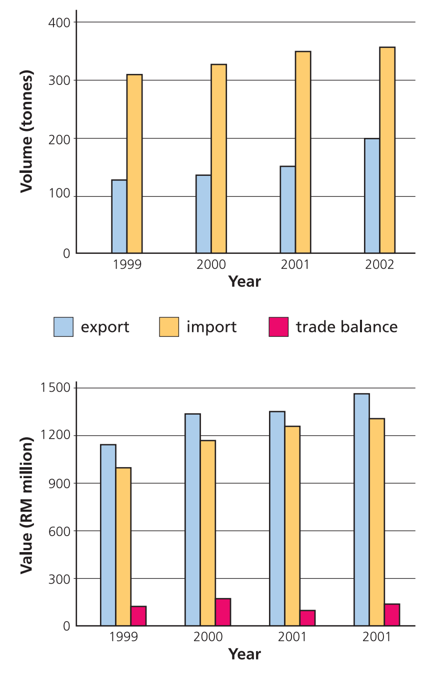
For a long time, most Malaysian consumers have preferred marine fish because of its taste, despite the much lower market price of freshwater fish. However, of late the influx of foreign workers, mainly from Indonesia and Bangladesh, has created a steady demand for freshwater fish. Locals are also starting to show a preference for freshwater fish due to better promotion by the government and dealers alike. As an indication, since 2001 freshwater fish production has shown a yearly increase of 8–12 percent. Most of the freshwater fish supply comes from the aquaculture sector, as Malaysia has little natural productive area. In 2003 the landing from inland fisheries was only 0.27 percent of the total fish production (Table 3). Most freshwater farmed fish are tilapia and African catfish.

Marine fish contributes to more than 70 percent of the local demand. Despite the volume, the species consumed are considered mainly lower grade, such as mackerel, sardines, scad and some tuna. Besides economic reasons, it is also worth noting that the eating habits and dining style of Malaysian people, especially the majority Malay ethnic group, are inclined towards serving small fish. The big or high-value aquatic products, such as crustaceans, are normally served in restaurants and are at high demand during festive seasons and ceremonies, especially among the Chinese community. Except for cockle and mussel, aquatic products from marine aquaculture generally do not supply the needs of ordinary people.

As a result of the continuously high demand for small and lower-grade fish species, Malaysia needs to import fish as a means to ensure enough supply for its people. On average, between 300 000–350 000 tonnes per year of fish and fish products were imported during 1999–2002. The import bills that came with this fish were between RM 1 000–1 300 million (Figure 1). Imported volumes came to about 406 000 tonnes in 2004 (Table 3), with an import bill of RM 1 935 million. The greatest portion of imported fisheries commodities came from neighbouring countries such as Thailand, Indonesia and Singapore, as well as from China (Table 4).

As a source of income, Malaysia exports most of its high-value fish to foreign markets. Among the commodities exported are shrimp, high-grade fish and molluscs (Table 4). The bulk of these commodities was sent to the United States of America (USA), followed by Singapore, Japan, the European Union and China. During the period 1999–2002, 130 000–190 000 tonnes of product were exported, with

Figure 1
Import, export and trade balance of fishery commodities



an export earning of RM 1 100–1 400 million. Subsequently, exports reached more than 238 000 tonnes with a value of RM 2 072 million in 2004. This trade brought in positive net earnings for the country of as much as RM 90–182 million during 1999–2004 (Tables 3 and 4).

TABLE 3
Main export and import fisheries commodities for Malaysia, 2004 (Source: DoF, 2004a)

Commodity	Exports		Imports	
	Volume (tonnes)	Value (RM million)	Volume (tonnes)	Value (RM million)
Live fish	8 332	74 941	4 502	24 792
Fish – fresh, chilled or frozen	79 836	188 526	317 892	980 719
Fish – dried, salted or in brine, smoked	1 495	9 351	1 834	9 254
Crustaceans & molluscs – fresh, chilled, frozen, salted dried	116 992	1 446 864	60 259	772 792
Crustaceans & molluscs – prepared or preserved	31 573	353 267	21 709	147 484
Total	238 229	2 072 229	406 190	1 935 041

TABLE 4
Malaysia's major trading countries, 2004

Export			Import		
Country	RM (million)	Value (%)	Country	RM (million)	Value (%)
USA	527 808	25.46	Thailand	465 146	24.04
Singapore	226 836	10.94	China	272 275	14.07
Japan	210 056	10.13	Indonesia	245 234	12.67
Italy	157 971	7.62	Singapore	161 722	8.36
China	112 297	5.42	Viet Nam	161 093	8.33
Others	837 982	40.42	Others	629 571	32.54
Total	2 072 950	100		1 935 04	100

Role of aquaculture in fisheries supply

Similar to other Asian countries, fish and fisheries products continue to play a vital role as a main source of cheap protein for the population. The fact that there is very little landing from inland fisheries and the preference of Malaysians is for marine fish mean that there is a need to increase production from the marine sector. Marine fisheries are faced with the problem of being exploited to the maximum and are unlikely to contribute further production. Reliance on deep-sea fisheries has not been taken seriously by locals. The deep-sea fishing fleet stood at only 761 units at the end of 2004 and as a small fleet, will not bring any significant changes to marine landings in the near future. Hence, the only option left is aquaculture, and in response the government has prepared strategies to develop marine aquaculture that are clearly defined under NAP3, as indicated earlier. The aquaculture sector is trusted with the task of enhancing food security and creating income to balance out food import bills (BOT), which have long been in deficit.

While recognizing aquaculture as one of the thrust areas for development, the Government of Malaysia is fully aware of the growing concern over sustainability and the environmental impacts of shrimp aquaculture. Human greed, coupled with profit-driven, irresponsible, short-sighted activities, is not to be allowed to tarnish the image of aquaculture. In a step towards realizing sustainable development, the impacts of aquaculture on coastal ecosystems, including mangroves, water and soil quality, as well as the socio-economic linkages in rural communities, are being carefully studied. The government is also interested in attracting foreign capital and appropriate know-how to develop this sector through environmentally friendly technologies.

Malaysia fully supports the initiatives taken by United Nations bodies, such as the Food and Agriculture Organization (FAO) to introduce the Code of Conduct for Responsible Fisheries (FAO, 1997). The government has already initiated steps to zone specific areas for aquaculture and develop standards for sustainable aquaculture practice that do not lead to ecological impacts. Legislative measures on a Code of Practice for Shrimp Aquaculture and establishment of fish health management programmes of international standard are under active consideration (FAO, 2004).

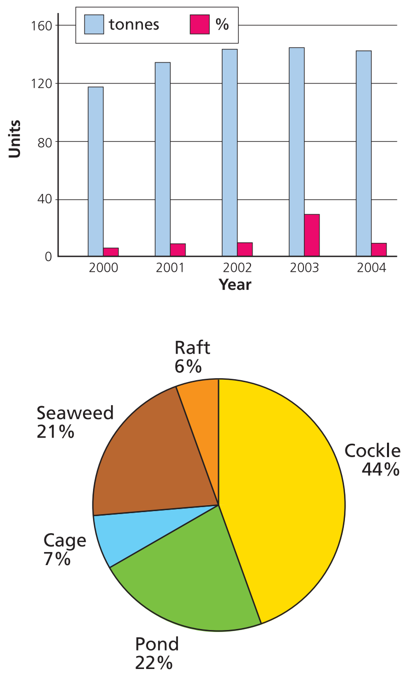
Production status

Marine aquaculture presently contributes about 133 000–146 000 tonnes annually. This represents about 28 to 33 percent of total fish production in the country (Figure 2). There are six major sectors that contribute to the production. The greatest production is contributed by traditional cockle cultivation, which accounted for about 44 percent in 2004. Pond production (mainly shrimp culture) contributed about 22 percent, followed by seaweed cultivation, with a share of about 21 percent. Production from cages (mainly finfish) and rafts (mainly mussels) each contributed about 6 and 7 percent, respectively.

Contribution to food security

Following a decision by the Malaysian government to increase fish production through aquaculture, various strategies were put forward under NAP3 and have been implemented since 1998. Marine shrimp, in particular, are given priority as a commodity with potential to generate income and hence contribute to foreign currency earning. However, the planned development has not met expectations due to problems with disease, land matters, market regulations and price fluctuations, as well as competition from labour-extensive countries. For such reasons, production from marine aquaculture between the years 2000 and 2004 as a whole did not show much development. An annual growth rate of about 20 percent was expected under NAP3; however, after an initial slight jump of about 13 percent in 2000, production from marine aquaculture did not show any further development up to 2004. The contributions were maintained in the range of 133 000 to 146 000 tonnes annually. From an increase of about 8 percent in 2002, the next three years showed an annual increase of only 1 percent (Figure 2).

Figure 2
Mariculture production and culture system contribution in 2004



Contribution to national economy

According to a recent fisheries statistical report (DoF, 2004a), fisheries production as a whole contributed between 1.37 to 1.73 percent to national gross domestic product (GDP) during the period 2002–2004. More than 85 percent of the contributions were from marine fisheries landings, and the contribution from the aquaculture sector as a whole was about 15 percent over the past four years or so. The majority or slightly more than 70 percent of the share originated from marine aquaculture. Further analysis estimates the GDP from marine aquaculture production at about 0.11–0.14 percent. These monetary gains were mainly generated from the trading of 145 000 to 147 000 tonnes of fish and fishery products with a wholesale value of RM 843.5 million to 931.1 million. In addition to generating income, the marine aquaculture sector provided job opportunities to about 4 000 to 4 200 people (Table 5 and 6), representing about 20 percent of the workforce in aquaculture-related activities during the last four-year period.

TABLE 5
Production, income (wholesale value) and labour involved in aquaculture activities, 2002–2004

	2002			2003			2004		
	1 000 (tonnes)	RM (million)	Labour	1 000 (tonnes)	RM (million)	Labour	1 000 (tonnes)	RM (million)	Labour
Inland	46.40	237.7	17 074	49.95	241.2	16 679	55.57	255.1	17 298
Marine	145.44	843.5	4 090	146.93	931.1	4 435	146.79	903.4	4 209
Total	191.84	1 081.3	211 644	196.87	1 172.3	211 144	202.24	1 158.5	2 507

TABLE 6
Contribution of marine aquaculture (in percentage) to fisheries and national economy, 2002–2004[1]

Parameter	2002	2003	2004
GDP	0.13	0.11	0.14
Employment in aquaculture	19.3	21.0	19.5
Fisheries	20.0	13.3	13.2
Volume (tonnes)	75.8	74.6	72.5
Value (RM)	78.0	79.4	78.0

[1] Note: Fisheries to GDP – 1.5% (2002), 1.37% (2003), 1.73% (2004).

The market chain organization, trend and vulnerability

Shrimp

Shrimp is considered marketable after a culture period of 120 days. Harvesting is usually done by draining the pond and attaching a net around the outlet pipe to trap the shrimp. The harvested shrimp is then washed using the waste water from the pond. The shrimp left in the pond are collected manually. Before harvesting, the buyers take a random sample to determine the average size and the price. The ex-farm price of black tiger shrimp (*Penaeus monodon*) of 40 pieces/kg ranges between RM 20–25, while that for white shrimp (*Litopenaeus vannamei*) of standard size (70 pcs/kg) bring an ex-farm price of between RM 12–15. Buyers provide ice, boxes and also transportation for the shrimp to be sent to processing plants. The distribution channel for cultured shrimp is straight forward; buyers are also processors or exporters. Most of the products are for the export market, and only a small quantity goes to local markets such as restaurants, hotels and retail chains. Despite the vast market, as elsewhere in Asia, the industry is vulnerable to threats from disease and the impact of fluctuating prices on the world market. There are also the issues of market regulation and traceability, which may slow down production from small-scale farmers. In terms of new area, not much can be developed if there is a boycott of shrimp from mangrove areas. Shrimp farming is further hindered by competition in terms of production cost among major producing countries. Malaysia is at a disadvantage in terms of labour. Most of the farms employ foreigners to run their operations, and as the government is tightening the entry procedure, the industry may have little space to remain competitive. One option is if Malaysia could make more efficient use of fuel to reduce costs of production.

Finfish

Marine finfish are considered marketable at about 500 g. However, different markets may require different sizes. Consumers in China, Hong Kong Special Administrative Region (SAR) prefer a size of 600 g to 1.2 kg for live grouper. There are two marketing channels, one to local markets and the other to overseas markets, mainly China, Hong Kong SAR. Species cultured for the local market are mostly seabass, various species of snapper and black grouper. The ex-farm price for seabass is between RM 12–14 per kg, while that for black grouper and snapper is between RM 18–25 per kg. The local market for live marine finfish is limited mainly to festivals, and the peak season for consumption is around January to March, coinciding with the Chinese New Year. On ordinary days the main outlets are Chinese seafood restaurants. The price of fish in restaurants is at least double that of the farm. Export markets are for fish of high-value such as tiger grouper and mouse grouper. The price reflects international market prices.

For live finfish, handling and packaging are given serious attention to ensure the best price. Shipment of fish from cages to local markets or to holding tanks or nets is done using trucks equipped with aerated seawater tanks. Shipment of live fish is done in two ways, either by packing in plastic bags or (typically involving large quantities) by live fish transport vessel (LFTV), usually owned by China, Hong Kong SAR importers. Fish in plastic bags are commonly transported as airfreight. They are placed at about 4–5 kg per bag in a four-layer plastic bag followed by a final packing into a styrofoam or cardboard box.

Fish farming for the live-fish market will not see a drastic scale up of production in the near future, as expected by the government and stipulated in NAP3. Foremost, it is constrained by seasonal demand and secondly, by the problem of meeting changing market demands that require multi-species production. In addition, the industry is vulnerable to shortages in supply of seed and space to expand operations. Disregarding the ever-changing species and seasonal demands, seed is still a major constraint in development of traditional fish such as seabass. While the number of suppliers is sufficient, most of them use a pond-based production system that is vulnerable to disease outbreaks and poor survival; hence the quality of seed delivered to farmers is poor. Seasonal demand and multi-species fish culture operations also affect the seed supply and the hatchery business; the seed producers thus are in a dilemma about upgrading their systems. Concerning the space available for grow-out, inshore areas are restricted and vulnerable due to their limited carrying capacity and increasing coastal water pollution. Deep-sea cages or land-based systems are needed for future development.

Molluscs

Cultivated cockles, green mussels and oysters are sold at local markets through middlemen. The retail price of a kg of cockle is RM 1.50–2.00. Raw mussels usually have a retail price of about RM 5.00/kg, while the dried form may fetch a retail price of about RM 12–15/kg. In terms of volume, fresh oyster is still small and mostly sent direct to seafood restaurants and hotels. Cockle cultivation depends largely on availability of suitable mudflat areas free of water pollution. Future plans to expand cockle, mussel and oyster culture will need to address constraints in seed supply, effects of harmful algal blooms and food safety issues. Food safety issues need to be addressed by rigorous environmental monitoring and quality controls.

Seaweed

Singularly a Sabah product, the main species used for commercial culture is *Eucheuma cottonii*. Environmental conditions around the Sabah coastline are generally favourable for culture of the species. Many of the operators are of Filipino ancestry. Seaweed is sold as a dried item. It takes approximately 9 kg of seaweed to produce a kilo of its dried form. Seaweed culture involves low capital investment and has a fast turn over. In general, seaweed production is still profitable at the steady production volume recently recorded (DoF, 2004a). Most seaweed from Sabah is sold for export, mainly to Denmark. Its dried form is sold directly to the exporter without using any middlemen. Usually the exporter assists farmers by providing aquaculture facilities, creating an obligation to sell the product back. The price of the dried form is about RM 1.50 per kg. Of late however, not many people want to get involved in seaweed culture because of better opportunities available in other sectors. Beside price incentive, commercial seaweed production is quite risky because of price fluctuations and the harvest being largely dependent on good sun-drying conditions. Future expansion needs to take into consideration conflicts with other resources users, including the tourism industry.

LIVELIHOOD OPPORTUNITIES RELATED TO MARICULTURE DEVELOPMENT

Information on coastal communities

Most coastal communities earn a living from activities related to fisheries. The most common occupation of coastal inhabitants is that of fisherman. Other economically important activities include small-scale aquaculture and food processing related to fish products. Fishermen still dominate the traditional fishing sector. An unofficial estimate is that about 10 percent of the total of more than 80 000 fishermen fall into the "poor" category or are below the poverty level (RM 529 per month) (Table 7). People in this category are mostly employed on commercial fishing boats or as helpers on traditional fishing boats. They remain in these occupations because of their educational background. Data from reliable sources indicate that 50 percent of workers from coastal communities who are involved in the fishing industry have only a primary-level education. Close to 20 percent do not have any formal education or have never attended school at all. Due to their poor economic situations, about 20–25 percent do not own their own houses.

TABLE 7
Monthly income of various categories and levels of fishermen (RM)

Category	Owner	Skipper	Worker	Diver
Commercial	3 326.27	1 631.54	507.41	1 118.27
Traditional	816.15	623.17	417.47	266.25

The role of mariculture in poverty reduction

The implementation of commercial-scale aquaculture projects in coastal areas has good potential to contribute to food production and poverty alleviation in coastal communities, besides earning income for producers and generating foreign exchange for the country. Aquaculture activities can create employment for communities and hopefully provide workers with much better take-home pay and a less risky job than the capture fishing industry. In addition, infrastructure such as electricity supply and communication and road access can spur related economic activities that can have a direct impact on coastal communities. As envisaged by government, if the targeted aquaculture production is fulfilled, there is a possibility that the percentage of the population falling into poverty will drop drastically within the next few years (Table 8) and that poverty may be totally eradicated by the end of 2009, or before the final date of the Ninth Malaysian Plan.

TABLE 8
Predicted annual increment in aquaculture and poverty reduction in coastal fishermen (Source: MOA, 2003)

Subject	2004	2005	2006	2007	2008	2009	2010
Aquaculture production (tonnes)	200	200	300	400	500	600	600
Below poverty level (%)	20	15	10	5	2	0	0

EXISTING AND POTENTIAL MECHANISMS FOR TECHNOLOGY TRANSFER

Training centres of excellence

Presently the Department of Fisheries (DoF) has two training centres to cater to marine aquaculture-related activities (DoF, 2006). Another such centre will be built within the next one to two years with a specialization in brackishwater grow out. Besides catering to local requirements, both centres also train overseas participants, mainly those under the Malaysia Technical Cooperation Programme (MTCP), which was established for aquaculture in 1989. One of the centres, which is situated in the north of Peninsular Malaysia (Kampong Pulau Sayak, Kedah), is the Institute of Marine Aquaculture (IAM), which started operation in 1987. Among the courses offered at the centre are 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 on-farm feed formulation (DoF, 2006). The second training centre for marine aquaculture in Malaysia is the Marine Finfish Production and Research Centre (MFPRC) at Tanjung Demong, Besut, Terangganu, located at the east coast of Peninsular Malaysia. Marine finfish fry production and cage-culture operations are offered as courses at MFPRC.

Existing and proposed alternatives for technology transfer mechanisms

In making a concerted bid to develop aquaculture into a major industry by 2010, the Government of Malaysia through DoF has put emphasis on acquisition of technology through research and development (R&D) and training mechanisms to acquire and transfer that technology.

Technology acquisition through R&D

Realizing that the private sector plays a critical role in spurring aquaculture development, but may not be keen to invest in research, the Government of Malaysia promotes the concept of joint research projects. The area where R&D support is most needed is in quality seed production, an example being the production of specific pathogen free (SPF) broodstock. The government has a commitment to provide high-grade broodstock to farmers as a means to facilitate farming with high-quality seed. To facilitate research on such topics, the government will develop the capability and skills of its staff in priority areas of biotechnology, genetic engineering, breeding and disease. At the same time, an out-sourcing mechanism may be adopted to bring in knowledge from outside of the country.

Training as a mechanism of transfer of technology (TOT)

The DoF is traditionally involved in providing knowledge and technology to current and potential aquaculturists. With an increase in demand from the industry and to fulfil the manpower requirements for future development, existing facilities are being upgraded and new ones will be built to enable more participant enrolment and improve access to knowledge. The training syllabus is improved and personnel are also being improved. The latest development is cooperation between DoF and the National Vocational Training Authority (MLVK) to launch a training school to produce qualified skilled manpower in various aquaculture fields.

Present training activities and likely future requirements

Currently DOF is officially conducting eight training programmes in brackishwater/marine aquaculture at two training stations (Table 9). The syllabus of these training programmes includes subjects such as disease diagnosis and water quality management. Future topics that most likely will be included are finfish broodstock management and spawning, and management and application of recirculating systems.

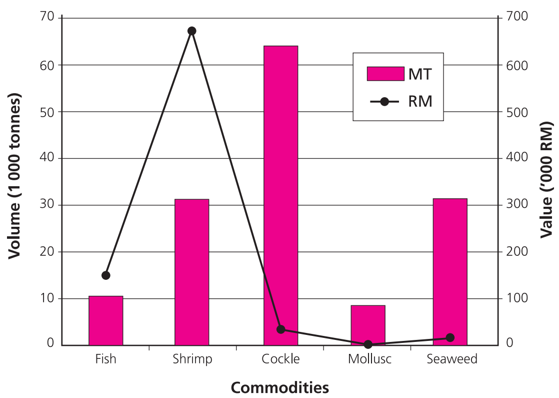
TABLE 9
Training programmes in marine aquaculture conducted by DoF in 2005

Title of training programme	Duration (days)	Intake per year (head)
Fundamental aquaculture practice	7	20
Seed production and management of marine finfish	30	15
Cage culture of brackishwater finfish	5	15
Seed production and management of marine shrimp	20	20
Culture and management of marine shrimp in pond	12	20
Feed formulation and preparation at farm scale	3	20
Seed production and culture of oyster	30	20
Seed production and culture of mussel	14	20
Giant freshwater prawn seed production	30	20

EXISTING MAJOR MARICULTURE SPECIES AND FARMING TECHNOLOGIES

Mariculture activities in Malaysia involve production of products from five major commodities: finfish, shrimp, cockles, other molluscs and seaweeds. Cockle farming produces the highest quantity of aquaculture product in terms of volume, with a production close to 64 560 tonnes in 2004. The next highest production was from seaweed cultivation with 30 960 tonnes. This was followed by shrimp production, which contributed 30 840 tonnes. During the same period, finfish culture brought in about 10 510 tonnes of fish, and harvest from other mollusc culture was 8 170 tonnes. Despite the volume, the income generated from the sale of cockle production was only third or RM 54.2 million. In general, shrimp production continues to dominate the income earned in aquaculture. In 2004 this was recorded at RM 656.5 million. The second highest income was from finfish culture at RM 157.48 million in the same year. Seaweed and molluscs generated an income of RM 15.48 and RM 4.60 million, respectively, in 2004 (Figure 3).

Figure 3
Quantity and value from mariculture production based on commodities, 2004



Status of farming of selected species

Marine shrimp

Species of interest

The sea around Malaysia is home to more than 15 species of shrimp classified as being of commercial importance. Five of these are of very high export value and form the backbone of seafood trading in the country: black tiger shrimp (*Penaeus monodon*), banana shrimp (*P. merguiensis*), Indian white shrimp (*P. indicus*), flower shrimp (*P. semisulcatus*) and greasy back shrimp (*Metapenaeus ensis*). Only *P. monodon* is cultured at commercial scale, although the popularity of this species is slowly being taken over by the white shrimp (*Litopenaeus vannamei*). The illegal introduction of this species was recorded in 2000. Despite being a prohibited species, illegal production during 2003–2005 was estimated at between 5 000 to 7 000 tonnes. Considering the yet unsolved disease problems in black tiger shrimp, the government finally decided to legalize the culture of *L. vannamei* effective from April 2004. Nevertheless, in a step to contain disease transmission, there is still a control on fry and broodstock entry into the country.

In Malaysia as in many countries that are traditional producers of *P. monodon*, *L. vannamei* is expected to play an leading role in the shrimp aquaculture industry in the years to come, unless efforts are made to revitalize the culture operations and disease control for the former. The DoF encourages Malaysian farmers to put interest on the culture of the Indian white shrimp, *P. merguiensis*; this local shrimp species was already being cultured at a small scale prior to the shift to *L. vannamei.* The product was sold as live shrimp and shipped mainly to Singapore. The poor farmer interest in *P. merguiensis* as an aquaculture species is due to its poor growth performance under high culture density. In the long run, however, this problem could be solved through a selective breeding programme. Such practices have proven effective in other shrimp species like *L. vannamei*, *L. stylirostris* and *Fenneropenaeus chinensis*.

Being a great income generator, the government hopes to increase shrimp production through aquaculture. Under NAP3, the target set was to achieve a production of 150 000 tonnes (Table 10) before or in year 2010. Concurrently, various contingency measures were undertaken, of which the most important was to increase the area under culture.

TABLE 10
Shrimp culture status in Malaysia, 1995–2004.

Year	Area (ha)	Farmers (number)	Shrimp production (tonnes)	
			Black tiger	White
1995	2 623	1 010	6 779	NA
1996	2 958	971	7 748	NA
1997	5 910	931	10 385	NA
2000	7 151		17 231	NA
2002	7 813	1 150	23 987	845
2003	7 011	1 239	25 375	804
2004	7 555	1 252	25 721	5 118
2010[1]	30 000	-	150 000	

[1] Projected figure based on NAP3 (1998–2010).

With the targets for production set in NAP3, it is estimated that a total of 30 000 ha of pond area is needed, a four-fold increase over the present area (Table 10). However, this target may take a longer time to achieve, due to land access constraints, diseases, market issues and regulation, plus the ever-increasing production from labour-extensive countries; the target can be partly achieved if a very drastic and holistic action is implemented.

Fry production

Presently there are about 50–60 shrimp fry production centres that supply the seed to shrimp grow-out farmers. They were originally intended for production of *P. monodon* but lately most of them have shifted to production of *L. vannamei*. In 2005, three hatchery facilities were granted permits to import SPF *L. vannamei* broodstock. On the government side, there is the National Prawn Fry Research and Production Centre (NAPFRE), a training and research facility for marine shrimp. There is also one fully biosecure hatchery system capable of production of clean/SPF *P. monodon* postlarvae (PL). In addition, there are also two or three other hatcheries with "partially" biosecure systems belonging to well-established aquaculture companies such as Charoen Pokphand and Grobest that still adhere to production of *P. monodon*. Overall, development in this sector at the small-scale level has been rather static because of inconsistent demand, strict quality requirements for fry and the demand for a warranty after some period in the pond. System-wise, most of the hatcheries are of the indoor type and are capable of producing 20–30 million PL per year.

Besides the use of chlorination to treat water, it is also common to see local hatchery systems equipped with extra gadgets such as ultraviolet light (UV) or ozone facilities. There is also a trend toward application of biotechnology products such as probotic bacteria, bioremediation and enzymes. Due to space limitations, most hatcheries use a single tank system to complete the fry production cycle. Only those few established hatcheries have separate larval and nursery tanks for this purpose.

With regard to *P. monodon*, the local supply of the broodstock is still sufficient. In fact, the interest in *L. vannamei* has seen the demand for *P. monodon* drop drastically from time to time. In terms of volume and quality, stock from East Malaysia, mainly from the waters off Sabah, is sought. Previously, broodstock from the Strait of Malacca were good enough, but lately most shrimp in this stock are found to be carriers of serious pathogens. As a biosecurity approach, it has already become normal practice for shrimp spawners to be screened for monodon baculovirus (MBV), whitespot syndrome virus (WSSV) and Tara syndrome virus (TSV). Except for small-scale operators who do direct spawning or purchase only nauplii, the procedure may not be adhered to so strictly. There are a few wild spawner collecting centres that deliver such products to small-scale operators. The price for a million nauplii of *P. monodon* is around RM 400–600, while gravid broodstock weighing 130–160 g are priced at RM 200–250 each.

Pond operation

In the past, a shrimp pond in Malaysia was synonymous with a mangrove swamp area. However, less critical and better areas such as coastal lands, abandoned coconut estates and paddy fields closer to infrastructure and facilities are now being developed. Water is supplied by means of a pump or via interconnected canals. Commercial farms integrate reservoir and sediment to ensure a supply of good-quality water for their operations. Separate inlet and outlet drains are normally installed. Be it a small-scale or a commercial operation, rectangular ponds of 0.5–1.0 ha dominate the present systems of operation. The depth is usually 1.2–1.5 m. Water exchange is less frequent and reservoirs are commonly used. Pond structure and design are of several types. Earthen ponds are most common, with plastic linings used on a small proportion of farms. Ponds with concrete wall structure are rather rare.

To sustain water quality and increase productivity, farmers invest in various biotechnology products. Some of these are bacteria-dominated compounds, enzymes, yeasts, inert feeds, simple sugars and vitamins. A common practice for tiger shrimp culture is to stock fry at PL stage 15–20; however, for *L. vannamei* this is done at PL 7–10. Under the present system, stocking rates are 30–40 per m^2 for *P. monodon* and up to 120 per m^2 for *L. vannamei*. Prior to stocking, responsible farmers will do acclimatization and selection as a final step to guarantee that only quality and healthy PL are stocked. PL are delivered by means of plastic bags. In a standard plastic bag of 5–8 litres, they are packed at 500–1 000 per litre. As a criteria for PL quality, farmers insist on a disease test and certification, besides adhering to physical, microscopic observation and stress test implementation. In ensuring sufficient oxygen supply, paddle wheels with single or double blades are installed, usually between 4–6 pieces per pond. In addition, long-arm paddle wheels of six or more blades are also installed at some corners to sweep and accumulate leftover feed from the feeding area. Feeding trays of 1 m^2 are commonly used, with between 4–6 per pond. Feeding commences with a rate of two times per day and is increased to four and up to six to eight times daily when shrimp are near harvesting size. During the farming process, various types of lime are applied to stabilize water pH. Harvesting usually commences when the shrimp attain a size of 30–50 pieces/kg for *P. monodon* and about 70 pieces per kilo for *L. vannamei*.

Marine finfish

Although marine fish farming has existed for the same length of time as marine shrimp farming, its development in Malaysia has been slower and less prominent. One of the primary reasons is that it was over-shadowed by the farming of black tiger shrimp, which once attracted many people as a fast and lucrative source of income. The fact that it is not a land-based activity, restricting it to a few suitable areas, has also constrained development. Marine fish farming is still at an infant stage, and thus the industry is still operated with traditional farming concepts. Almost all of the marine fish produced come from open floating net-cages, which are basically small to medium-size cage farms. As a commodity that contributes to national economic and food security, the government has targeted a production of 120 000 tonnes to be achieved by 2010 through aquaculture. Production presently amounts to about 10 500 tonnes (Table 11). In terms of value, the sale of cultured marine finfishes brought in about RM 158 million as income to the country, an increase of about 24 percent from year 2002. Hence, with the targeted and increasing demand for fish, there is a need to change the concept of marine fish farming from that of subsistence farming to a commercial scale.

TABLE 11
Production (tonnes) and wholesale value (RM million) of the main cultured fish species, 2002–2004

	Production (tonnes)		
Fish species	**2002**	**2003**	**2004**
Asian seabass	4 003.73	4 210.93	4 000.54
Mangrove snapper	591.44	706.56	572.97
Yellow snapper	1 556.15	2 351.55	2 263.33
Red snapper	989.68	1 402.09	1 162.85
Grouper	1 210.43	1 977.33	2 283.59
Tilapia	283.97	222.07	264.42
Total	8635.4	10 870.53	10 547.7

	Value (RM million)		
Fish species	**2002**	**2003**	**2004**
Asian seabass	46 220.13	49260.86	46 241.57
Mangrove snapper	6 157.05	8 415.69	7 742.36
Yellow snapper	20 188.00	32 491.55	32 771.81
Red snapper	12 951.31	18 513.27	14 687.02
Grouper	30 385.26	49 954.09	54 628.69
Tilapia	1 683.98	1 049.09	1 387.08
Total (x1 000)	117 585.73	159 684.55	157 458.53

Species of interest

In Malaysia, marine fish farming started with the culture of Asian seabass (*Lates calcarifer*) during the 1970s. As in other Asian countries, this sector is characterized by the culture of a range of fish species regarded as high value. The choice of which species to culture is related to availability of seed and the ever-changing preferences of consumers in China, Hong Kong SAR and Singapore. The species cultured by farmers are also switched when current stocks are affected by disease problems. Over the last five years, the number of species being farmed has increased drastically following the success of breeding programmes, both locally and elsewhere. At least ten species of fish are presently cultured throughout the country. The leading species remains the Asian seabass., followed by the snappers (Lutjanidae), which include yellowstreaked snapper (*Lutjanus lemniscatus*), mangrove red snapper (*L. argentimaculatus*), John's snapper (*L. johni*) and crimson snapper (*L. erythropterus*) (Table 12). The interest in grouper has led to at least six species being introduced for farming. Among the groupers commonly cultured in Malaysia are brown-marbled grouper (*Epinephelus fuscoguttatus*), orange-spotted grouper (*E. coiodes*) and Malabar grouper (*E. malabaricus*). Other minor species are fourfinger threadfin (*Eleutheronema tetradactylum*), cobia (*Rachycentron canadum*), snubnose pompano (*Trachinotus blochii*) and red tilapia (*Oreochromis* sp.).

TABLE 12
Finfish species of interest for mariculture in Malaysian waters

Species	Common name
Seabass	
Lates calcarifer	Asian seabass
Snapper	
Lutjanus lemniscatus	Yellowstreaked snapper
L. argentimaculatus	Mangrove red snapper
L. johni	John's snapper
L. erythropterus	Crimson snapper
Groupers	
Epinephelus coiodes	Orange-spotted grouper
E. malabaricus	Malabar grouper
E. sexfasciatus	Sixbar grouper
E. fuscoguttatus	Brown-marbled grouper
Cephalopholis leopardus	Leopard hind
Cromileptes altivelis	Humpback grouper
Threadfins	
Eleutheronema tetradactylum	Fourfinger threadfin
Cobias	
Rachycentron canadum	Cobia
Tilapias	
Oreochromis sp.	Red tilapia
Pompanos	
Trachinotus blochii	Snubnose pompano

Seed production

Seed supply is still a constraint to the development of marine fish culture in Malaysia. A significant amount is still being imported from neighbouring countries such as Indonesia, Thailand, Singapore and Taiwan Province of China. Beside seed, eggs are also brought in. At present, local seed production centres are still too small to supply the demand, especially when dealing with the multi-species way of fish production. Additionally, most hatcheries are still crude in approach and hence do not always meet the requirement to supply good-quality seed for sustainable grow-out farms. To supplement the demand, there are two typical seed production systems employed, the tank or hatchery system and the pond-based system. Unofficial records indicate that 12 land-based fish hatcheries are currently in operation. Two of them are government research and training centres that occasionally distribute their produce to farmers. Each private hatchery has a capacity to produce some 0.5–2.0 million fry per year. Some of the hatcheries maintain broodstock, whereas others still need to acquire eggs from outside.

To supplement the seed supply, there are more than 50 fry production units that use earthen or partially concreted ponds as their production system. Each unit employs 3–10 ponds of 0.1–0.5 ha on average. The operation starts with the hatching of eggs in a *hapa* installed in the pond or in separate tanks close to the pond. The fry are released into the pond a few days after hatching, when they are ready to consume outside food. Ponds are enriched with live food by means of organic or inorganic fertilizers before stocking of newly hatched fry. Being low-capital and food-chain based, survival from this production system is on average between 1–5 percent. Sometimes, when natural food availability is not sufficient, nothing is produced. Nevertheless, production from this sector is quite significant, with each farm producing 0.2–1.0 million fingerlings per year.

Broodstock and egg production is another part of the production system that is improving. Currently eggs are distributed by breeders who keep the broodstock in floating cages. Egg production normally comes from the process of natural spawning. The operators need to keep a large number of spawners so that there are sufficient fish ready to release eggs when needed. Upon spawning, the eggs are collected by net. Although wild-caught spawners are preferred for egg production, broodstock often come from normal cage production. The price of a million eggs varies from RM 500–3 000, depending on fish species.

Farm operation and production

The main production system for marine fish is still the floating net-cage. Pond production has not yet been given due consideration, despite the volume it can produce; pond production may yet be suitable for high-value fish species that require water of higher salinity than that found in many inland ponds. However, fish raised by pond culture are susceptible to off-flavour, and thus this method may not be suitable as a system for the live fish market. Seeing the potential, the venture into mass production using deep-sea cages was initiated by the government through the DoF a decade ago. Since then, however, there has not been much development. The main reason seems to be an insufficient supply of fry. The demand in terms of number and quality is not yet matched. Apparently, this is due to this being a multi-species style of production. As of the end of 2005, there were 100 units of square-type cages measuring 6x6 m each and a total of 21 units of round type with a diameter of 15 m each. All of these cages were harboured at Langkawi Island, in northern Peninsular Malaysia. As they still face some technical problems, the cages are operated at under capacity most of the time.

Until a new system of fish production or cage-culture technology is introduced, traditional floating cages will continue to be the core marine fish production system in Malaysia. As of 2003 and 2004, there were a total of 1.0 million m^2 of cage area, an increase of about 14 percent from 2002 (Table 13). These cages were run by about 1 400 and 1 600 operators, respectively, during the production years of 2002 and 2003–04 (Table 13). Most operators are small-scale farmers running small (3x3 m) to medium-size (6x6 m) cage farms. Stocking densities vary from 300–1 000 fingerlings per cage. The culture period extends from 6–12 months, depending on species. Trash fish remains the major feed type, and only on occasion is supplementary commercial feed used. Farmers still find it difficult to change to pelleted feed, which would be a better option for disease control and environmental management. The main reason is the cheap price of trash fish and that the supply is readily available. Many farmers also still believe that feeding with trash fish produces a fish preferred by the market in terms of quality and texture.

In recent years, due to increasing intensification in production and area, cage farming has faced many disease problems. As a result, there were regular records of mass mortality that were related to water quality and oxygen depletion. The die-hard farmers seem to take this for granted and are willing to invest in a new operation for the sake of fish production.

TABLE 13
Facilities and operators involved in marine fish farming, 2002–2004

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

Molluscs

Malaysia has a long tradition of mollusc culture. In terms of quantity, cockle contributes about 40 percent of the harvest from the aquaculture sector. Over the past three years, the annual production from cockle was about 70 000 tonnes (Table 14). The value from the sale of cockle during 2004 was about RM 54 million. The total area used for the cultivation of cockle is presently about 7 000 ha, and there are about 300 operators cultivating this commodity. Mussels, which come next in terms of production, were harvested in the range of 6 000–7 000 tonnes, whereas around 250–285 tonnes of oyster were produced annually during 2002–2004. Both mussel and oyster are cultured in rafts with about 100 000–150 000 m^2 and 100 000 m^2 of area, respectively, being dedicated to their production. The number of operators involved in their culture during the last three years is about 300–350 and 260–300, respectively, for mussel and oyster production (Table 14). In term of revenue, both commodities created income of about RM 5 million during 2004.

TABLE 14
Production, areas and number of operators involved in mollusc aquaculture, 2002–2004

	Production (tonnes)		
Commodity	**2002**	**2003**	**2004**
Cockle	78 706.64	71 067.29	64 564.75
Mussel	5 919.85	7 701.73	7 904.76
Oyster	285.66	256.43	260.68
Total	84 912.15	79 025.45	72 730.19

	Area and operators					
Commodity	**2002**		**2003**		**2004**	
	Area	**Operators**	**Area**	**Operators**	**Area**	**Operators**
Cockle	6 891.2 ha	297	7447.1 ha	311	6662.7 ha	276
Mussel	82 186 m^2	288	109 817 m^2	347	156 799 m^2	357
Oyster	103 145 m^2	264	103 212 m^2	282	104 008 m^2	309
Total		849		940		942

Seaweed

Compared to other marine aquaculture products, seaweed culture is localized in one state, Sabah, and in only one area, Semporna. Culture of the commodity has a long tradition, and between 2002 and 2004 its annual production increased from 26 000 to about 31 000 tonnes, despite a decrease in the culture area from 1 900 ha to about 1 000 ha (Table 15). There was also a drop in the number of operators involved in cultivation, from about 712 in 2002 to about 392 in 2004. In terms of quantity, seaweed cultivation contributed about 21 percent of the share of production from the marine aquaculture sector. The value from the sale of seaweed in 2004 was about RM 15.48 million.

TABLE 15
Seaweed aquaculture, 2002–2004

	2002	**2003**	**2004**
Volume (tonnes)	25 624.92	27 607.90	30 956.90
Area (ha)	1 908.32	1 206.25	986.02
Operators (no.)	712	605	392

PRIORITIES FOR RESEARCH AND DEVELOPMENT

Being a sector that traditionally supplies food and continuously contributes to the national economy, aquaculture was recently given special attention by the Government of Malaysia. The strategy and action plan to develop the sector was clearly spelled out in the Third National Agricultural Policy (NAP3, 1998–2010), a long-term plan for agricultural development. A volume of 600 000 tonnes was set aside for the aquaculture sector to deliver by the year 2010. Based on the annual fisheries statistics, the current achievement is around 202 225 tonnes. Hence, an additional 400 000 tonnes is necessary to achieve the target. With another five years to go, an annual production growth of about 22 percent will be necessary. In the marine sector, the two top-most income-generating commodities, shrimp and finfish, were assigned production targets of 120 000 and 150 000 tonnes, respectively. Presently these commodities have achieved production of only about 10 500 and 32 000 tonnes, respectively; thus, there is a long way to go to achieve the target. While a massive increment in production will no doubt come from increasing the area under culture, most new production will probably be from intensification of existing culture practices.

Marine shrimp

The major constraint in the development of traditional black tiger shrimp culture is disease. Hence, research on the following should be given due consideration:

- production of SPF broodstock and disease-free PL;
- application of better management practices (BMPs);
- automation towards reducing production costs; and
- development of sustainable production systems.

While aquaculture of the traditional shrimp species needs to be scrutinized and its problems solved, the importance of indigenous shrimp species such as the banana shrimp (*Penaeus merguinsis*) should be given due consideration to create interest for commercial production. This will create diversity of choice while slowly getting away from the culture of the exotic *Litopenaeus vannamei*. Promoting commercial culture of the species will mean that research must to go all out to solve the problem of poor growth performance under high density culture and to realize a culture period of 120 days, an established benchmark for many shrimp farmers in Malaysia.

Research on the following should be given due consideration:

- domestication and selective breeding programme;
- development of suitable feed; and
- development of culture technology.

Marine finfish

Being at a pioneer stage in the marine finfish industry, Malaysia can learn a lot from the stories of successes and failures in the shrimp industry. Foremost, seed should be of high quality and if possible free of serious pathogens (SPF). To pursue this goal, a domestication and selective breeding programme should be given high priority, along with improved biosecurity.

With regard to developing the subsector, the foremost priority should be a focus on the specific species to be developed. The live fish market cannot be relied upon to expand the market significantly, and attention should be given to the frozen fish market, the main agenda being to diversify the market through value-added products and to develop varieties to increase consumption by local consumers. Land-based production systems, i.e. ponds or tanks, should be examined as a means of production, as environmental problems may no longer permit the use of waterways for cage operations. Foreseeing the future problems, priorities in research and development (R&D) are considered to be:

- R&D for selected fish species;
- development of a broodstock bank;
- R&D in domestication and a selective breeding programme;
- development of a biosecure fish fry production centre;

- R&D in live food production;
- R&D in grow-out production facilities; and
- R&D in nutrition and feed formulation.

Identification of better management practices to mitigate environmental impacts

As a means to mitigate environmental impacts, the DoF in Malaysia has come out with a Guideline on Good Aquaculture Practices (GAP). Mainly for the shrimp industry at this moment (FAO, 2003), this guideline upholds the standards recommended by international bodies such as the FAO. Similar guidelines soon will be developed for marine finfish aquaculture and other culture systems. A major task for government is to ensure that the guidelines are adopted by aquaculturists, particularly the small-scale farmers. At this stage, the guideline is still difficult to implement because of a "free-for-all" situation that has existed for a long time. Lack of institutional and legal support may jeopardize the action plan or else local governments will have to impose rules for domestic food safety standards from aquaculture, as are being required by many importing countries. Large-scale operators, however, implement good aquaculture practices on their own initiative, so as to comply with the requirements for quality fish and shrimp products for the export market. To be part of the food production chain, one has to have standards and environmentally friendly production protocols.

Along this line, DoF Malaysia has introduced the Farm Certification Scheme or SPLAM (DoF, 2004b). The objective of SPLAM is to provide official recognition to aquaculture entrepreneurs who practice GAP and environmentally friendly concepts to ensure the safety, quality, consistency and competitiveness of their products based on the criteria, guidelines and standards determined by DoF. Farmers can obtain quality certification for their products after a period of quality assessment by authorities. Among the benefits derived from participating in the SPLAM programme are assurances that the farm's aquaculture products meet the food safety standards required by the domestic and international markets. Secondly, the programme assists and expedites the issuance of health certificates and sanitary and phytosanitary (SPS) certificates, so that this does not solely depend on final product testing. The third benefit is to encourage consumer acceptance of aquaculture products from local farms. Finally, the programme will assist the aquaculture industry to develop in a sustainable and environmentally friendly manner.

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