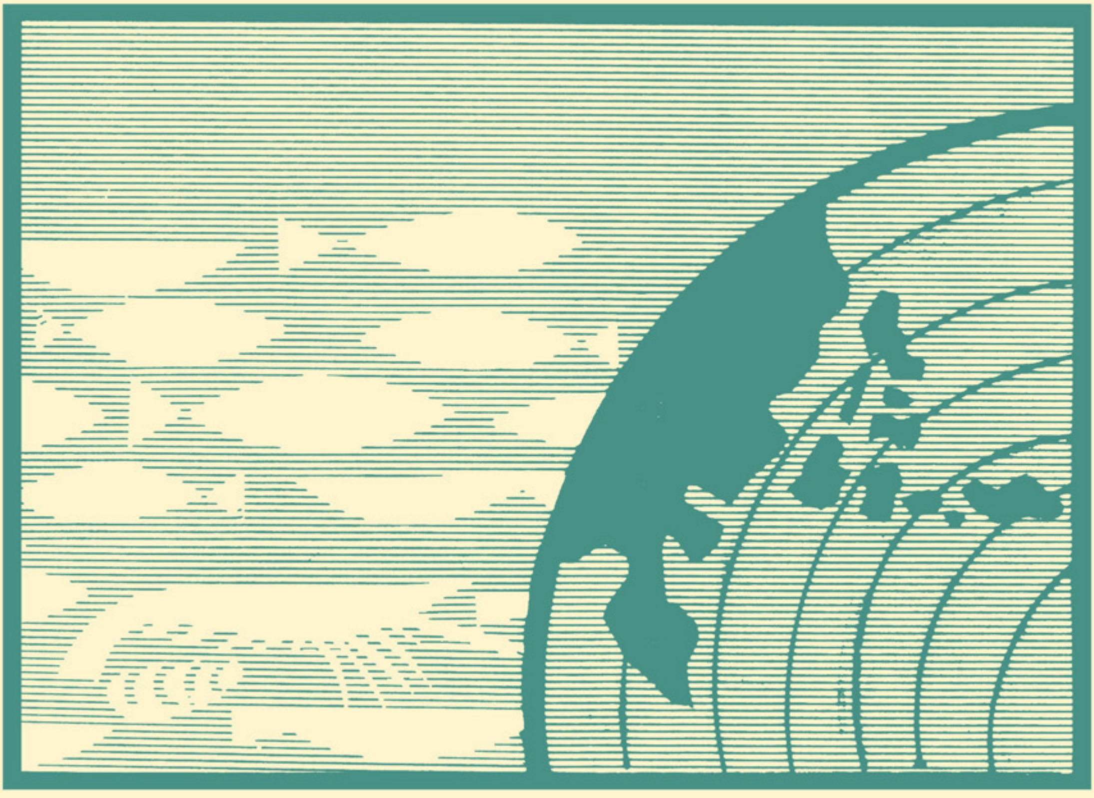
Perspectives in Aquaculture Development in Southeast Asia and Japan

Contribution of the SEAFDEC Aquaculture Department



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FOREWORD

Traditional aquaculture has been practised by fish farmers of Southeast Asia for centuries. In the last 15 years or so, however, the introduction and development of modern and innovative aquaculture technologies have transformed this age-old occupation into a major industry that has increased the national fish production, produced much-needed export earnings, and generated employment and business opportunities.

Acknowledged worldwide is the role of the Southeast Asian Fisheries Development Center (SEAFDEC) in promoting the growth of aquaculture in the region. SEAFDEC performs this role through its Aquaculture Department (AQD) which it established in 1973 in the Philippines with the mandate to undertake research and provide training for aquaculture manpower.

A great deal of aquaculture progress and success has been accomplished since the birth of SEAFDEC and AQD 20 and 15 years ago, respectively. But these must be assessed in the light of present and future needs and challenges. This was the rationale for the regional Seminar on Aquaculture Development in Southeast Asia (ADSEA '87) held in Iloilo City, Philippines, on 8-12 September 1987. Also convened to commemorate the 20th foundation anniversary of SEAFDEC, the conference was attended by senior aquaculturists from Japan, Thailand, Singapore, Malaysia, and the Philippines, together with representatives of various international organizations, Philippine government agencies, academic institutions, and the private sector, including fishfarmers' associations.

The seminar reexamined the existing aquaculture technologies in Southeast Asia, evaluated the contribution of AQD to these technologies, and identified future directions for aquaculture in the region which include areas in research and training where closer collaboration between AQD and SEAFDEC Member Countries should be strengthened.

This Proceedings is a comprehensive account of the seminar. It contains the papers read and discussed at the sessions, and the recommendations reached and formulated.

It is our hope that through this publication AQD is again able to effectively disseminate valuable information for the benefit of aquaculturists, researchers, planners and decision-makers, resource managers, and the general public as envisioned by the founders of SEAFDEC.

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DEVELOPMENT OF AQUACULTURE INDUSTRY IN SOUTHEAST ASIA: AN OVERVIEW

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ABSTRACT

Southeast Asia, a Subregion of the Asia-Pacific Region, is composed of countries of diverse socio-economic circumstances. Fisheries production, particularly that of the aquaculture sector, is relatively developed and is important to the economy of this area. Some 80 economic aquatic species are the subject of culture. Many of these species, which include fin fish, crustaceans, molluscs, and seaweeds, are produced in consequential quantities.

Total production from the Subregion in 1983 amounted to about 880 000 mt which represented nine percent of total world aquaculture production in said year, and a 100% increase in the area within the decade (1975-1983). Unit production is comparatively low as it is usually done with the use of the extensive level of management developed after long years of experience by fish farmers. Higher rate of production in recent years is a trend especially for high value and exportable species like the penaeid shrimps. Aquaculture production tends to have accelerated growth while capture fisheries production tends to increase very gradually or levels off.

Technical and non-technical constraints occur which hinder rapid progress of aquaculture in Southeast Asia. This will require the attention of research institutions and governments. However, bright prospects for future increase in production in this industry are developing in the area. Specific instances to support this forecast are discussed.

INTRODUCTION

Available statistics show that fisheries production is important to the economy and food supply of most countries of the world. Aquaculture production is an important aspect of this production sector.

The Asia-Pacific Region is the center of development of world aquaculture and its Southeast Asian Subregion can be considered the gem for this type of production development (Fig. 1).

Fig. 1. Definition of the Southeast Asian Subregion as employed in this paper

The nine countries included in the Southeast Asian Subregion vary greatly in their socio-economic conditions (Table 1). These circumstances have an impact on the general economic and fisheries/aquaculture development of the countries. In area, the countries vary from as small as 618 km^2 (Singapore) to 1.9 million km^2 (Indonesia). The total land area of the countries in the region is 3.8 million km^2 or close to 2% of total world land area. However, the population of 360.9 million is equivalent to about 7% of total world population. In population density, the countries vary from as sparse as 19 persons/km^2 (Laos) to as dense as 4 000/km^2 (Singapore). The population growth rate also varies considerably with Singapore registering the lowest at 1.5% and Brunei the highest with 3.3%. The economic condition of the countries as indicated by per capita GNP also varies considerably. Based on equivalent US dollars, this ranges from US$85.00 (Laos) to US$22 150.00

Table 1. Vital socio-economic statistics of Southeast Asian countries

Country	Area (km^2)	Population (1000)	Population density (No./km^2)	Population growth rate (%)	Per capita GNP (US$)	Fisheries production[3/] 1983 (mt)	Per capita fish consumption[4/] (kg/year)	No. of fishermen[4/]	No. of fish-farmers[5/]
Brunei	5 765[1/]	221[1/]	38	3.3[1/]	22 150[1/]	2 949	40	2 069	
Indonesia	1 919 443[2/]	165 150[2/]	86	2.3[2/]	540[2/]	1 672 355	11.8	1 713 425	834 655
Kampuchea	181 035[2/]	7 420[2/]	41	*	100[1/]	63 750	24.4	*	*
Laos	236 800[2/]	4 440[2/]	19	*	85[1/]	20 000	3	*	*
Malaysia	329 749[2/]	15 680[2/]	48	2.8[2/]	1 990[2/]	725 898	40-43	107 273	16 967
Philippines	300 000[2/]	54 670[2/]	182	2.8[2/]	660[2/]	1 319 674	41	817 660	210 039
Singapore	618[2/]	2 560[2/]	4 142	1.5[2/]	7 260[2/]	19 099	43	1 321	*
Thailand	542 373[2/]	51 300[2/]	95	2.5[2/]	850[2/]	2 104 577	23.1	82 597	*
Viet Nam	329 556[2/]	59 460[2/]	180	*	189[1/]	505 000	10-12	*	*
Total for SEA countries	3 845 339	360 901				6 433 302		2 724 345	1 061 661
World total	207 495 243	5000 000				77 256 500			
Percent, SEA on world	1.85	7.20				8.33			

[1]World Almanac, 1987 (The per capita income, not GNP, is given)
[2]Asian Development Bank, Key Indicators of Developing Member Countries of ADB, Vol. 17, 1986
[3]FAO 1985 Yearbook of Fishery Statistics, Vol. 60, 1987 (Figures for 1983 were taken for comparative purposes)
[4]Mainly from FAO Data Base taken from national statistics
[5]Southeast Asian Fisheries Development Center (SEAFDEC), 1983 Fishery Statistical Bulletin for South China Sea Area (1985)

*Data not available

(Brunei) with the others registering very wide-ranging intermediate values. Fisheries is important in the region varying from 2 949 mt (Brunei) to 2 104 577 mt (Thailand) in 1983. This situation also has some bearing on the per capita consumption of fish in each country which varies from 3 kg/yr (Laos) to 43 kg/yr (Malaysia and Singapore). Indonesia has the largest number of fishermen (1.7 million) and fish farmers (800 000) followed by the Philippines with 800 000 fishermen and 210 000 fish farmers.

World fisheries production from 1938 to the present has gradually increased from 21 million mt (1938) to 84.9 million mt in 1985 or an increase of over 300% in 46 years equivalent to about 7% increase per year. Of this, 6 to 10 million mt or about 10% come from aquaculture. The world aquaculture production by kind of resource in 1983 consists of the following:

Kind of resource	*Production (mt)*
Finfish	4 447 946
Crustaceans	123 445
Molluscs	3 245 530
Seaweeds, etc.	2 393 782
Total	10 210 703

The distribution of world aquaculture production by region in 1983 is as follows:

Region	*Production (mt)*	*Percent of total*
Asia-Pacific (A-P)	8 412 131	82.4
Europe and Near East (E-NE)	1 221 511	12.0
North America (NA)	312 691	3.0
Latin America and the Caribbean (LA-C)	220 505	2.2
Africa (AF)	43 865	0.4
Total	10 210 703	100.0

Of the Asia-Pacific aquaculture production, the Southeast Asian Subregion produces over 800 000 mt or 10% of the production from this region.

In the Southeast Asian countries, the total fisheries production has been growing gradually. From 1981 to 1985, this increased from 7.1 million mt in 1981 to 7.9 million mt in 1983 but declined slightly to 7.6 million mt in 1985 (Table 2). This subregional production composes 9-10% of the total world production. In aquaculture, the countries produced from 150 mt (Brunei) to 440 000 mt (Philippines) in 1983, with the Southeast Asian countries producing a total of about 885 000 mt or equivalent to about 9% of the total world aquaculture production (Table 3).

PROFILE OF SPECIES BEING CULTURED IN SOUTHEAST ASIA

It is extremely difficult to prepare a comprehensive checklist of species that are the subject of aquaculture in Southeast Asia. There are species that are mainly used for human food (finfish, molluscs, and crustaceans), species that are used mainly in industry (industrial seaweed, pearl, and window pane oyster), species that are used as food organisms for the culture of other species (phytoplankton, zooplankton, brine shrimp, etc.), and species used as cash crop for export (ornamental fish). For purposes of this paper, species used for human food and for industry, either consumed locally or exported are discussed. These consist of finfishes, crustaceans, molluscs, seaweeds, and others. In the region, it is estimated that over 80 species are cultivated consisting of 48 species of finfish, 13 species of crustaceans, 13 species of molluscs, 5 species of seaweeds, and 5 species of other vertebrates (Tables 4, 5).

Finfishes

It is estimated that there are close to 50 species of finfish cultivated in Southeast Asia. This includes freshwater, brackish and marine species. The major marine and brackishwater species include milkfish, sea bass, grouper, snapper, sea bream, rabbitfish, mullet, jack, eel, and gobies. The freshwater species include carps and related cyprinids, tilapias, clarias catfishes, gouramies, snakehead, certain eels, and certain gobies. In 1983 about 595 000 mt of finfish were produced through aquaculture in the region. Highest production by species include milkfish, with over 300 000 mt; carps and related cyprinids with over

Table 2. Fisheries production of Southeast Asian countries, 1981-1985 (in mt)

Country	1981	1982	1983	1984	1985
Brunei	2 367	2 357	3 055	2 226	2 986
Indonesia	1 918 758	1 982 159	2 204 816	1 992 535	2 067 090
Kampuchea	68 700	58 650	63 750	65 000	68 000
Laos	20 000	20 000	20 000	20 000	20 000
Malaysia	804 094	682 569	741 089	664 967	632 185
Philippines	1 686 636	1 787 744	1 977 580	1 935 399	1 867 701
Singapore	16 112	19 346	19 549	25 468	23 032
Thailand	1 989 025	2 120 133	2 260 024	2 134 846	2 123 600
Viet Nam	622 000	640 00	710 000	765 000	800 000
SEA production	7 127 692	7 312 958	7 999 863	7 605 441	7 604 594
World production	74 840 400	76 762 900	77 256 500	83 096 000	84 945 300
Percent SEA production to world production	9.52	9.53	10.35	9.15	8.95

Source: FAO Yearbook of fishery statistics, 1985, Vol. 60 (1987)

Table 3. Fisheries and aquaculture production in Southeast Asian countries, 1983

Country	Total fisheries production[1/] (mt)	*Capture fisheries* Production[1/] (mt)	% of total	*Aquaculture* Production (mt)	% of total
Brunei	3 055	2 905	95	150[3/]	05
Indonesia	2 204 816	1 937 917	88	266 899[2/]	12
Kampuchea	63 750	62 850	99	900[3/]	01
Laos	20 000	19 640	98	360[3/]	02
Malaysia	741 089	687 749	93	53 340[2/]	07
Philippines	1 977 580	1 532 507	77	445 073[2/]	23
Singapore	19 549	17 510	90	2 039[2/]	10
Thailand	2 260 024	2 168 299	96	91 725[2/]	04
Viet Nam	710 000	685 000	96	25 000[3/]	04
Total for Southeast Asian (SEA) countries	7 999 863	7 114 377		885 486	
World totals for same period	77 256 500	67 045 797		10 210 703	
Percent SEA production on world production	10.4	10.6		8.7	

[1/] FAO 1983 Yearbook of Fisheries Statistics, Vol. 56 (1985)
This includes both capture and culture fisheries

[2/] Source: SEAFDEC, 1983 Fishery Statistical Bulletin for South China Sea Area (1985)

[3/] From recent publications and previous estimates from a survey by the author

100 000 mt; the tilapias with 51 000 mt; gouramies with 18 000 mt and catfishes with over 10 000 mt (Table 5).

Crustaceans

World fisheries production of crustaceans is relatively low in tonnage but very high in value. The total crustacean production through aquaculture in Southeast Asia in 1983 is about 60 000 mt. This is equivalent to almost 50% of total world crustacean production through culture. Most of these species are high value species that are exported to major importing developed countries. There is a continuing demand and persistent relatively high price for this commodity. It is estimated that there are about 13 crustacean species cultured in Southeast Asia. The major species belong to the penaeid shrimp which include the *Penaeus* and *Metapenaeus* shrimps followed by the non-penaeid shrimps. The giant freshwater prawn has also been cultured and is produced commercially in the Subregion. There is one species of crab, the *Scylla serrata* being cultivated with small amount of production from the Subregion (Table 5).

Molluscs

Most of the molluscs being cultured are for human food but the pearl oysters are cultured to produce precious pearls and shells. Some 98 000 mt of molluscs were produced through culture in Southeast Asia in 1983. There are about 13 species cultured of which the major ones are: the blood cockle *(Anadara granosa)* followed by the green mussel *(Perna viridis)* and the food oysters *(Crassostrea* spp. and *Ostrea* spp.) (Table 5).

Seaweeds and Others

Of the seaweeds, the brown, green, and red seaweeds or macro algae are cultured in certain countries of the Subregion. Red algae belonging to the genus *Eucheuma* is a major source of an industrial product, the carrageenan. Crop of this algae which is cultured is exported from the region. This species can also be used secondarily for human food but the main food species which have been cultured belong to the green seaweed *Caulerpa.* Five species are cultured in the region and the production in 1983 mainly from the Philippines is about 130 000 mt (Tables 4, 5). Other species which are cultured both for food and industry and for the export trade include frogs and other amphibians,

Table 4. Aquaculture production in Southeast Asian countries by resources, 1983

Country	Finfish (mt)	Crustacean (mt)	Molluscs (mt)	Seaweed, others (mt)	Total, by country (mt)
Brunei	*	-	150[1/]	-	150
Indonesia[2/]	238 895	28 004	*	*	266 899
Kampuchea[3/]	900	*	*	-	900
Laos[3/]	360	-	-	-	360
Malaysia[2/]	14 592	218	38 530	*	53 340
Philippines[2/]	270 068	12 985	29 816	132 204	445 073
Singapore[2/]	2 000	39	*	-	2 039
Thailand[2/]	49 139	12 739	29 841	6	91 725
Viet Nam[3/]	19 000	6 000	*	*	25 000
Total for SEA countries	594 954	59 985	98 337	132 210	885 486
World total	4 447 946	123 445	3 245 530	2 393 782	10 210 703
Percent SEA on world production	13.4	48.6	3.0	5.5	8.7

[1/] Author's estimate based on 1985 survey

[2/] SEAFDEC 1983 Data Base (1985)

[3/] From recent publications and previous estimates from survey by the author

* Practiced but data not available

– Practice is not applicable or amount produced is negligible

Table 5. Production profile for species produced through aquaculture in Southeast Asia (1983)
(Based on SEAFDEC 1983 Fishery Statistical Bulletin for South China Sea Area, Bangkok, Thailand, 1985)

SPECIES/SPECIES GROUP	Brunei (mt)	Indonesia (mt)	Kampuchea (mt)	Laos (mt)	Malaysia (mt)	Philippines (mt)	Singapore (mt)	Thailand (mt)	Vietnam (mt)	Total by species (mt)
I. FINFISH										
1. Milkfish (*Chanos chanos*)	-	81 506	-	-	*	240 610	-	*	*	322 116
2. Seabass *dates calcarifer)*	*	1 105	-		227	*	*	1 084	-	2 416
3. Grouper *(Epinephelus* spp)	*	*	-	-		*	*	*	-	*
4. Snapper *(Lutjanus* spp)	-	-	-	-		*	*	*	-	*
5. Sea bream (Sparidae)	-	-	-	-		-	*	*	-	*
6. Rabbitfish *(Siganus* spp)	-	*	-	-		*	-	*	-	*
7. Mullet *(Mugil* spp)	-	4 129	-	-		*	-	223	-	4 352
8. Jacks (*Caranx* spp)	-	*	-	-		*	*	*	-	*
9. Carps and related cyprinids[1/]	*	81 438	-	*	12 387	590	*	7 823	*	102 238
10. Tilapia (*Oreochromis mossambicus and* O. niloticus)	*	23 812	*	-	1 373	13 928	*	12 125	*	51 238
11. Catfish (*Clarias batrachus* and *C. macrocephalus*)	-	592	*	*	3	*		9 924	*	10 519
12. Eels (*Pluta* sp and *Anguilla* spp)	-	3	-	-	*	*	-	70	*	73
13. Gouramies (*Osphronemus gouramy, Trichogaster* spp and *Helestoma temmineki)*		7 394	*	*	*	147		10 260	*	17 801
14. Snakehead *(Ophiocephalus* spp)	-	*	*	*	*	*	-	4 787	*	4 787
15. Marble goby (*Oxyeleotris marmoratus*)	-	*	*		*		*	*	*	*
16. Other brackishwater finfish[2/]	-	19 328	-	-	516	14793	-	2 027	-	36 664
17. Other freshwater finfish[3/]	-	19 588	-	-	86	-	-	816	-	20 490

II. CRUSTACEANS										
18. Penaeid shrimps (*Penaeus* spp and *Metapenaeus* spp)	*	15 866	-	-	166	12 060	39	10 399	*	38 530
19. Non-penaeid shrimps (*Parapaeniopsis* spp, etc)	-	11 729	-	-	*	*	-	1 151	*	12 880
20. Freshwater crustaceans (*Macrobrachium rosenbergii*, etc.)	-	*	-	-	1	-	*	1 153	*	1 154
21. Mud crab (*Scylla serrata*)	-	*	-	-	*	*	*	*	-	*
22. Other crustaceans (brackishwater)[4/]	-	409	-	-	51	925	-	36	-	1 421
III. MOLLUSCS										
23. Flat oyster (*Ostrea* spp)	-	-	-	-	-	-	-	3 461	-	3 461
24. Cupped oyster (*Crassostrea* spp)	-	*	-	-	-	11 310	-	*	-	11 310
25. Sea mussel (*Perna viridis*)	150[5/]	*	-	-	-	18 506	-	19 285	-	37 941
26. Blood cockle (*Anadara granosa*)	-	*	-	-	38 530	-	*	7 095	*	45 625
27. Pearl oysters (*Pinctada* spp)	-	*	-	-	*	*	-	*	-	*
28. Other molluscs	-	*	-	-	*	*	*	*	*	*
IV. SEAWEEDS										
29. Brown, red and green seaweeds/ algae (Phaeophyceae, Rhodophyceae and Chlorophyceae)*	-	*	-	-	*	132 204	-	*	*	132 204
V. OTHERS										
30. Frogs and other amphibians *(Rana spp)*	-	*	-	-	*	*	*	1	*	1
31. Turtles and other reptiles (*Trionyx sp. Crocodilus* sp, etc.)	-	-	-	-	*	-	*	5	*	5

[1/]Include common carp; Chinese silver, grass, bighead and mud carp; *Puntius, Leptobarbus* and *Osteochilus* species; and goldfish

[2/]Include tilapia species, *Scatophagus* species, etc.

[3/]Include anabantids, gobies, *Notopterus* spp, etc.

[4/]Include mysids, other incidental entrants in impoundments

[5/]Based on 1985 survey by the author

[6/]These include mainly *Eucheuma spp, Gracilaria sp* of Rhodophyceae and *Caulerpa* spp of the Chlorophyceae

– Magnitude zero or not applicable

* Data not available

Rana spp.; and turtles and other reptiles (*Trionyx* sp. and *Crocodilus* sp., etc.) About five species of this economic aquatic vertebrates are cultured in the region but the production is still negligible amounting only to about 6 mt in 1983.

PRODUCTION TRENDS IN THE LAST DECADE

Generally for the Subregion, aquaculture productivity has gradually increased with time. This is true with the production for the different systems as well as the different species within the finfish, molluscan, crustacean, and seaweed groups. Of course, there are certain systems and areas, and/or species where setbacks have occurred due to specific reasons or causes.

The interesting thing about aquaculture production is its relation with capture fisheries. While capture fisheries tended to fluctuate or level off in most countries of the region, aquaculture production gradually increased to attain a relatively higher percentage contribution to the total fisheries production in the different countries as well as the region in general (Table 9).

National Production by Species

The total aquaculture production from all countries of the Southeast Asian Subregion is over 880 000 mt in 1983 which is equivalent to 9% of the total world aquaculture production and about 1% of the total world fisheries production. The leading aquaculture producers in the Subregion are the Philippines with over 440 000 mt, Indonesia with 267 000 mt, Thailand with 92 000 mt, Malaysia with 53 000 mt, Vietnam with about 25 000 mt, Singapore with 2 000 mt and small amounts produced by Kampuchea, Laos and Brunei (Table 3).

By resources or species, the major groups produced in Southeast Asia as of 1983 are: milkfish (36%), seaweeds (15%), carps and other cyprinids (12%), penaeid shrimps (6%), tilapia and other cichlids (6%), blood cockle (5%), sea mussel (4%), gouramies (2%), food oysters (2%), catfishes (1%), snakehead (0.5%), mullet (0.5%), and freshwater prawn (0.1%). There are other species belonging to the finfishes, crustacean, molluscan and seaweed groups which are produced to complete the large array of culture species in the Subregion (Table 5), however, the magnitude of production from these minor species is still negligible.

By species, for finfishes, the Philippines produced the most with about 270 000 mt/yr. mainly from milkfish; Indonesia follows with about 239 000 mt/yr. mainly from milkfish and carps and related cyprinids. This is followed by Thailand with about 49 000 mt distributed in a number of species but mainly the tilapias, gouramies, carps and related cyprinids, snakehead, and others (Tables 4, 5). The total production of finfish through culture in the Subregion amounted to about 595 000 mt or 67% of the production in the area and 13% of world production of this crop.

In the production of crustaceans, mainly the penaeid shrimps in brackishwater, Indonesia leads with about 28 000 mt, followed by the Philippines and Thailand with about 13 000 mt each in 1983. There is small production from Malaysia and Singapore. Only Thailand has a consequential amount of production of over 1 000 mt for the giant freshwater prawn. The total production of crustaceans from Southeast Asian countries in 1983 is about 60 000 mt which is 7% of the total aquaculture production but 49% of total world production for this crop (Tables 4, 5).

In the production of molluscs, Malaysia leads solely from the production of blood cockle with over 38 000 mt/yr in 1983 while both the Philippines and Thailand have a production of 30 000 mt in the same period. The production of the Philippines consists of oysters and mussels while that of Thailand consists of mussels, oysters, and blood cockles. Almost 100 000 mt of molluscs are produced from the Subregion in 1983 (Tables 4, 5). This is 11% of the total aquaculture production from this area and 3% of world production of this crop (Table

The culture of seaweeds is still not widespread in the Subregion as natural stocks are still available and are being gathered (e.g., Indonesia, Malaysia, Philippines, Thailand). However, consequential production through culture especially of the *Eucheuma* spp. is produced in the Philippines. The production of *Eucheuma* seaweed in the Philippines in 1983 was about 130 000 mt (Table 4). Frogs and other amphibians, turtles and other reptiles are produced in some countries of the region through culture such as in Thailand but these are still of very small quantities (Table 5).

Production per Unit Area

Data on the average production by species of cultured organisms in Southeast Asia are not readily available. If available, they may be incomplete or if obtained by different agencies or institutions, variations in methodology can be a cause of varying interpretations. However, out of the scanty data in hand, the aquaculture production averages for different culture systems and for some species in the Subregion may be assessed (Table 6). In the Table, Southeast Asian aquaculture may be divided into three major systems, namely: mariculture, brackishwater culture, and freshwater culture. For the countries practicing mariculture for the year 1983, some idea of the average unit production (kg/ha/yr.) can be gleaned for blood cockle in Malaysia and sea mussels/blood cockle/oysters in Thailand. The average production kg/

Table 6. Aquaculture production averages for different systems and species in Southeast Asia (1983)

System/Country	Species	Total area used (ha)	Total production (mt)	Unit production (kg/ha/yr)
I. MARICULTURE				
Malaysia	Blood cockle	4 699	38 530	8 200
Thailand	Sea mussels, blood cockles and oysters	3 033	29 841	9 800
II. BRACKISHWATER CULTURE				
Indonesia	Milkfish, penaeids, mullet, seabass, etc.	193 724	134 073	690
Philippines	Milkfish, penaeids, etc.	1 96 269	183 770	940
Thailand	Penaeids, seabass, mullets, etc.	5 235	14 920	2 850
III. FRESHWATER CULTURE				
Indonesia	Carps, gouramies, tilapias, catfishes, etc.	165 003	132 828	800
Malaysia	Carps, tilapias, catfishes, etc.	5 810	13 850	2 380
Philippines	Milkfish (fishpens), Tilapia (cages/ponds), carps, gouramies, etc. (ponds)	13 770	99 280	7 200
Singapore	Freshwater species	309	541	1 750
Thailand	Tilapias, gouramies, catfishes, carps, snakehead, giant prawn, etc.	41 082	46 966	1 100

Source: Fisheries Statistical Bulletin for South China Sea Area, 1983 Southeast Asian Fisheries Development Center (SEAFDEC), Bangkok, Thailand, (1985)

Note: There are no available data in hand for other systems and species ha/yr for blood cockle in Malaysia is about 8 mt/ha/yr while that for various cultured molluscs in Thailand is about 10 mt/ha/yr (Table 6). There are no complete records to assess the productivity of cage culture of marine finfish and of seaweeds in the Subregion nor of molluscs in the other countries in the area.

In the brackishwater culture, extensive culture system for milkfish cultured with penaeid shrimp and other finfishes and shrimps is extensively practiced in Indonesia and the Philippines. Here the average annual production per hectare in 1984 for Indonesia is about 700 kg/ha/yr , in 1985 for the Philippines, 950 kg/ha/yr (Table 6). The brackishwater pond production in Indonesia which was about 300 kg/ha/yr in 1960 gradually increased to attain a production of over 600 kg/ha/yr in 1984 while in the Philippines, from about 350 kg/ha/yr in 1940, this increased to almost 1 mt/ha/yr in 1985 (Table 7). In Thailand where semi-intensive culture in brackishwater ponds is practiced mainly for penaeid shrimp and sometimes for sea bass, mullets and other finfishes, and shrimps, the average production is between 2 to 3 mt/ha/yr (Table 6). The slow and gradual increase of production for this industry in Indonesia and the Philippines is an indication that they are the results of experience especially by small-scale fish farmers. In the Philippines, for instance, while the national average is about 970 kg/ha/yr in 1985, it is not uncommon that progressive, large-holding farms harvest from 1 to 3 mt/ha/yr. It is well known that the national average in Taiwan is 2 mt/ha/yr.

In freshwater pond culture as exemplified by Indonesia where this system is of long existence, the area used and production showed fluctuations. Within a 25-year period (1960-1984, Table 8) the area used was in the 30 000-ha level during the 60's and 70's but attained 40 000-ha level in the 80's (Table 8). The total annual production fluctuated from about 40 000 mt in 1960 to about 80 000 mt in 1983. Unit annual production varied from about 1 300 kg/ha (1960, 1970) to 1 900 kg/ha (1983). The average unit annual production for a 25-year period (1960-1984) was about 1 500 kg/ha. Gradual increase in total production and unit production with time during the period is indicated although not conclusive (Table 8).

Relationship of Capture Fisheries and Aquaculture Production

World aquaculture production was assessed by FAO in three different years (1975, 1980, 1983). In the area during these three assess-

Table 7. Increase in area and total and unit production of Philippines and Indonesian brackishwater ponds (1940-1985)

Year	Indonesia			Philippines		
	Area used (ha)	Total production (mt)	Unit production (kg/ha/yr)	Area used (ha)	Total production (mt)	Unit production (kg/ha/yr)
1940	*	*	*	60 998	21 349	350
1950	*	*	*	72 753	25 464	350
1960	145 144	43 078	297	123 252	60 120	488
1970	179 911	55 908	311	168 118	96 461	574
1980	188 601	97 898	519	176 231	135 951	771
1981	198 210	112 916	570	195 832	170 431	870
1982	208 695	129 279	619	195 832	180 484	922
1983	220 365	134 072	608	196 269	183 773	936
1984	225 197	142 404	632	206 525	198 729	962
1985	*	*	*	205 000	198 546	969

Source: National fisheries statistics for Indonesia and the Philippines. These ponds are mainly used for raising milkfish

* Data not available

Table 8. Data on freshwater fishponds in Indonesia (1960-1984)

Year	Area (ha)	Total production (mt)	Unit production (kg/ha/yr)
1960	30 179	39 801	1 319
1965	36 102	63 302	1 753
1970	40 023	51 345	1 283
1975	38 914	55 403	1 424
1976	34 235	52 631	1 537
1977	34 033	56 000	1 645
1978	35 555	57 680	1 622
1979	39 785	59 359	1 492
1980	38 501	66 379	1 724
1981	47 085	78 224	1 661
1982	38 909	69 245	1 780
1983	41 783	79 681	1 907
1984	40 942	76 528	1 869

Source: National fisheries statistics by the Directorate General of Fisheries, Indonesia (various years)

ment periods, total fisheries production increased from 6.7 million mt in 1975 to 7.9 million mt in 1983 or a 19% increase in an 8-year period. During the same period, the aquaculture production from the Southeast Asian Subregion increased from 440 000 mt to 885 000 mt or a 100% increase during the same period (Table 9).

In 1975, the aquaculture production from the different countries in the Subregion had from 3 to 9% of their total fish production or an average of 7% while that of capture fisheries constituted 91 to 97% or an average of 93%. The countries that lead in high aquaculture production compared to capture production in 1975 were the Philippines with a ratio of 9:91; Malaysia and Thailand, 7:93; and Indonesia, 6:94. In 1980, the aquaculture production in the Southeast Asian countries ranged from 3 to 18% of the total fish production in the different countries while capture fisheries composed from 82 to 97%. The relative proportion of aquaculture and capture fisheries production was 18:82 in the Philippines, 11:89 in Indonesia, 9:91 in Thailand, and 3:93 in

Table 9. Aquaculture production and capture fisheries production in Southeast Asia (1975/1980/1983)

	1975[1/]				1980[2/]				1983			
	Total fisheries production (mt)	Total aquaculture production (mt)	Aquaculture production on total (%)	Capture production on total (%)	Total fisheries production (mt)	Aquaculture production (mt)	Aquaculture: total (%)	Capture: total (%)	Total fisheries production (mt)[3/]	Aquaculture production (mt)[4/]	Aquaculture: total (%)	Capture: total (%)
Brunei	1 570	—	—	-	2 225	-	-		3 055	150[5/]	4.9	95.1
Indonesia	2 265 875	143 840	6.3	93.7	1 841 814	199 297	10.8	89.2	2 204 816	266 899	12.1	87.9
Kampuchea	84 700	*			51 600	*			63 750	900[5/]	1.4	98.6
Lacs	20 000	*			20 000	*			20 000	360[5/]	1.8	98.2
Malaysia	473 782	34 559	7.3	92.7	736 486	73 741	10.0	90.0	741 089	53 340	7.2	92.8
Philippines	1 442 981	125 008	8.7	91.3	1 556 602	285 502	18.3	81.7	1 977 580	445 073	22.5	77.5
Singapore	17 560	785	4.5	95.5	16 044	536	3.3	96.7	19 549	2 039	10.4	89.6
Thailand	1 552 836	106 300	6.8	93.2	1 797 960	160 962	9.0	91.0	2 260 024	91 725	4.1	95.9
Viet Nam	872 000	30 000	3.4	96.6	613 000	*			710 000	25 000[5/]	3.5	96.5
TOTAL FOR SEA	6 731 304	440 492	6.5	93.5	6 695 731	720 038	10.9	89.1	7 999 863	885 486	11.1	88.9
WORLD TOTAL	66 000 100	6 102 289	9.2	90.8	72 089 600	8 707 363	12.1	87.9	77 256 500	10 210 703	13.2	86.8
% SEA ON TOTAL	10.2	7.2			9.2	8.3			10.4	8.7		

[1/] After Pillay (1976) and FAO Data Base

[2/] After Pillay (1981) ami FAO Data Base

[3/] FAO Data Base

[4/] SEAFDEC (1985)

Estimates based on available references and previous estimates from survey by the author

— Magnitude zero or not applicable

* Data not available

Singapore. The average proportion of culture to capture fisheries production for the Subregion is 11:89.

In 1983, the aquaculture production in the different countries in the Subregion ranged from 1 to 23%, while that of capture fisheries from 77 to 99%. The leading aquaculture producers have the ratio of aquaculture to capture fisheries production as follows: Philippines, 23:77; Indonesia, 12:88; Singapore, 10:90; Malaysia, 7:93; and the rest with 5% or less in their aquaculture production. The average ratio of aquaculture to capture fisheries production during this period is 11:89. Aquaculture production from the Subregion constituted about 9% of the total world aquaculture production in that year increasing by 2% from that of 1975 which was 7% (Table 9).

Contribution of Different Species to Total Production

The milkfish is the single most important species produced through aquaculture in Southeast Asia with over 300 000 mt in 1983. Of course, it is realized that this species is produced mainly in Indonesia and the Philippines where it is an important food fish. The total production of milkfish constituted 36% of the total aquaculture production in the Subregion (Table 10).

Following milkfish but quite far behind is the cultured industrial seaweed, the *Eucheuma* species which contributed over 130 000 mt (15%) in 1983 exclusively from the Philippines (Tables 5, 6). Third in magnitude are the cultured carps and other cyprinids with over 100 000 mt or about 12% of the total aquaculture production from the Subregion (Table 10). This group of species also constitutes the highest among the freshwater forms cultured in this area. Saltwater shrimp and tilapia follow next with over 51 000 mt each (6%). The saltwater shrimps are valued export crops and their culture is rapidly growing and spreading in this area while the tilapias are important local food fish in most countries of the region (Table 10).

Of the molluscs, the blood cockle, almost exclusively produced in Malaysia with a little amount in Thailand and perhaps Indonesia, registered the highest tonnage in this group with over 45 000 mt or 5% of the total subregional production. This is followed by sea mussel with about 38 000 mt (4%); gouramies, 18 000 mt (2%); oysters, 15 000 mt (2%); catfishes, 11 000 mt (1%); snakehead, 5 000 mt (0.5%); mullet, 4 000 mt (0.5%); and freshwater prawn, 1 000 mt (0.1%) (Table 10).

Table 10. Production of different species through aquaculture in Southeast Asia, arranged by production size, 1983

Species/species group	Production (mt)	Percent of total
Milkfish	322 116	36
Seaweed	132 204	15
Carps and other cyprinids	102 238	12
Penaeid shrimps	51 387	6
Tilapias	51 238	6
Blood cockle	45 625	5
Sea mussel	37 941	4
Gouramies	17 801	2
Oysters	14 771	2
Catfishes	10 519	1
Snakehead	4 787	0.5
Mullet	4 352	0.5
Freshwater prawn	1 154	0.1

Source: Southeast Asian Fisheries Development Center (SEAFDEC), Fishery Statistical Bulletin for South China Sea Area, 1983. SEAFDEC, Bangkok, Thailand (1985)

It is anticipated that these major species being cultured will continue to increase in production in the coming years but more particularly those that have high market demand and especially those for export. The saltwater shrimps and some marine finfish as well as the freshwater prawn belong to this category. Local food fish species like milkfish, the tilapias, carp, and other cyprinids will increase only slightly or level off. The cultivated molluscs like the sea mussel, blood cockle, and oysters will rise depending on market demand and maintenance of good consumption qualities. Likewise, miscellaneous freshwater and marine finfishes will undergo increased use for culture in specific areas. The culture of novelty items like crabs, frogs and other amphibians, and turtles and other reptiles will tend to increase because of their market demand.

CULTURE SYSTEMS AND LEVEL OF INTENSITY FOR MAJOR SPECIES

The level of production in the aquaculture industry depends on the species and their cultural characteristics, the system used for the culture, and the intensity applied in the culture system. Different species are adapted to specific types of culture system (e.g., blood cockle in open sea water, penaeid shrimp in ponds, etc.). Sometimes certain species can adapt to more than one type of culture system (e.g., finfish in ponds, pens, or cages).

Culture Systems

There are different types of culture systems that have developed in Southeast Asia and in many other areas of the world. This can be enumerated as follows:

1. Culture in ponds or impoundments
2. Culture in pens or enclosures
3. Culture in cages
4. Culture in open water, and
5. Ranching

Culture in ponds or impoundments is widely practised and can be applied to most aquaculture species. Two types of culture are used under this system, namely: 1) the stagnant or semi-stagnant pond or impoundment and 2) running water system. Stagnant and semi-stagnant ponds are used for freshwater finfishes as well as for the giant freshwater prawns, brackishwater and marine finfish, and penaeid shrimps. Running water pond culture has been developed mainly for the common carp especially in Indonesia.

Fishpens or enclosures were initially tried in the early 70's in a shallow eutrophic freshwater lake in the Philippines using milkfish for stock. This has proven to be very successful and the practice rapidly attained commercial scale and consequential production in a period of five years. Similar attempts to introduce the system in other bodies of water in the region have not been very successful but tests in more water bodies continue to be conducted.

The use of cages consisting of nets or bamboo and wood is practised in certain areas in the region. These are mainly for finfish such as tilapia and carp in freshwater; and seabass, grouper, bream, snapper and crabs, and shrimps in sea water.

Open water culture system is practised for certain species especially those that require wide areas for culture. These include sea mussels, oysters, blood cockles, and various species of seaweeds. The species used in this culture require constant change of the water medium from which they derive their main source of nutrition.

Ranching is a recent development in aquaculture where the established reproductive habits of the cultured species is taken advantage of. Typically, species used in this system are those that reproduce in specific sites that are known but the juveniles migrate and return to the same site to repeat their life cycle. By augmenting through human management the reproduction of such species the amount of the returning marketable-sized forms can be increased to commercial levels. In other words, the species put under culture are harvested only during the stage when they return to the sites which can be managed by aquaculturists. Actual active stocking of such sites by suitable species may also serve this purpose. Although this system is not yet practiced in Southeast Asia, it is mentioned here because of its potential.

Intensity of Culture

The level of intensity of culture under the different culture systems in the Southeast Asian region may be classified under the following, categories:

1. Traditional management
2. Extensive management
3. Semi-intensive management
4. Intensive management

To describe the characteristics of these levels of culture intensities, the following criteria are considered:

1. Species used and stocking rates
2. Engineering design and layout
3. Use of fertilizers
4. Use of pesticides and elimination of metabolites
5. Food and feeding regime
6. Rearing duration and cropping frequency
7. Quantity and quality of production
8. Post harvest technology and marketing.

Traditional management. The traditional management is the lowest level of intensity of culture. It is the simplest to undertake and the one with no inputs or the least inputs during operations; also, the one with the lowest production. With this management, the stock is very variable with many extraneous species and no specific stocking rate is observed. If the operation uses ponds, usually very big ponds, which may be uncleared and with makeshift dikes, are used. The depth of the pond water can be variable with some portions sometimes unwatered. Equipment such as pumps and aerators are not used and there is no feeding nor use of pesticides with the crop depending mainly on the natural fertility of the area. The production is usually of good quality but is generally variable and there is no special requirement for post-harvest technology and marketing. Traditional brackishwater fish farms in the Philippines which existed but are fast disappearing may produce from 100 to 400 kg/ha/yr.

Extensive management. The extensive management may originate from traditional operations that are improved in their engineering design and management practices. Instead of multi-species culture, monoculture stocking of a definite species or polyculture with planned combination is usually adopted. These ponds are fully cleared and levelled and properly laid out to provide means for water entrance, circulation, and drainage for water management. Pumps or aerators can be useful but are not usually necessary as the level of stocking is usually moderate. Fertilizers are used to enhance farm fertility but feeds are only used as needed to supplement natural food production or whenever required by the cultured stock. The level of harvest is higher than the traditional system with the stocked species dominant while some of the extraneous species may still be found in the harvest. For instance, in extensive brackishwater ponds where milkfish and tiger shrimp are reared in polyculture, the milkfish and the tiger shrimp predominate in the harvest, but other species like tilapia, other species of shrimps, finfishes, and crabs may also exist. The production is usually of good quality and is usually more uniform so that post-harvest technology and harvesting can be planned and implemented. Typical production from extensively managed brackishwater ponds in Indonesia and the Philippines may have a production of 500 to 2 000 kg/ha/yr.

Semi-intensive management. As the areas for expansion for the practice of aquaculture become more limited, increase in production can only be attained through intensification. In Southeast Asia where sites are abundantly available, this increase in production during the initial period of the industry was achieved through area expansion. Within recent years, however, especially during the last decade, sites started to be limited so that production increase can be better achieved through intensification. The semi-intensive level of management can utilize areas formerly used for the extensive system or entirely new areas can be developed. In either case, the appropriate engineering design which consists of reducing large-sized culture units to smaller manageable sizes, providing facilities for effective water control and circulation, and perhaps excavation and levelling of the ponds to attain appropriate depths required in the culture are implemented. The stocking rate is relatively higher compared to that of the extensive management. Application of fertilizers, lime, and pesticides are regularly practised under this system. Feeding using good quality formulated feed to supplement natural food is a regular feature of this management. Pumps and aerators should be available for use when necessary. The harvest is of good quality usually confined to the species under culture which are produced in uniform sizes. Very little or no extraneous species should occur and a pre-planned post-harvest procedure and marketing are generally arranged. An example of semi-intensive brackishwater pond system such as that devoted for the raising of tiger shrimp in the region would require from 50 000 to 100 000 shrimp post-larvae (PL) per hectare per crop. For a culture period of 100 to 150 days, a harvest ranging from 1 to 2.5 mt/ha/crop may be derived. Of course, feeding in this case, as mentioned, is a must in the operation where 2 to 3 t of feed is generally used to produce 1 mt of the crop. The annual crop can be 2.5 to 6 mt/yr.

Intensive management. The intensive management is the result of further intensification in the level of management from the semi-intensive operation. This management requires size units which can provide complete control of water management in terms of quantity and essential qualities. The maximum stocking rates are utilized for the species under culture, aeration using artificial aerators, pumping and strict filtration of the water supply are practised especially if open water sources are used. High-quality feeds appropriate for the species under culture and applied in adequate quantities are used to maintain growth and produce quality crop. Provision for water replenishment whenever needed and facility for the elimination of metabolites are necessary. Facility for easy harvesting and pre-planned post-harvest technology and marketing should be provided. In between harvests, prophylactic treatment of the aquaculture system using lime and organic pesticides as well as bottom cultivation or tilling are practised. As practised in tiger shrimp intensive brackishwater ponds, stocking rates consisting of 100 000 to 300 000 PL/ha/crop for 100 - 150-day culture period is practised. Yields of 3 to 9 mt/ha/crop and with the possible 2.5 crops per year or an annual yield of 7 to 20 mt/ha/yr may be achieved (Table 11).

Table 11. Elements of different intensity levels of management of penaeid shrimp culture in Southeast Asia (Based on Philippine experience, 1985-1986)

Type	Development/ equipment cost (P/ha)	Annual operating cost (P/ha/crop)	Stocking rate (PL/ha/crop) (No. of crops/year)	Production (Kg/ha/year)
Traditional	20 000-50 000	5 000-10 000	Variable, mixed species (variable)	100-400
Extensive	50 000-100 000	10 000-75 000	10 000-50 000 (2)	500-2 000
Semi-intensive	200 000-500 000	75 000-250 000	50 000-100 000 (2.5)	2 500-6 000
Intensive	500 000-1 000 000	250 000-500 000	100 000-300 000 or over (2-5)	7 000-20 000

P or Philippine pesos 20 = US $1

Source: National survey made with a consultancy group by the author (1985-1986). The figures are estimates and varies from place to place and can easily change with time. Above designations as proposed are arbitrary and can have overlaps.

Comparative Costs

Something must be mentioned about the relative costs for development and operations under the different intensity levels of management. It is well agreed that development costs including essential equipment and annual operational cost in the traditional management would be minimal and can be estimated at P20 000 to P50 000/ha and about P5 000 to P10 000/ha, respectively. (Current exchange rate is about US$1=P20, Philippine pesos). The cost for extensive system for development/equipment and for annual operation will be higher though not too much higher. These can be as much as P50 000 to P100 000/ha and P10 000 to P75 000/ha, respectively. As the management level shifts to the semi-intensive and the intensive levels, considerable increase in cost will be required. For semi-intensive the development/equipment cost can be as much as P200 000 to P500 000/ha and for annual operations about P75 000 to P250 000/ha. In the intensive system these values can be P500 000 to P1 000 000/ha and P250 000 to P500 000/ha, respectively (Table 11). Estimates are based on current costs during 1985-1986 under Philippine conditions.

The above figures are estimates based mainly on the different intensity levels for penaeid shrimp culture as practiced in the Philippines. Based on the above, the cost of production for a kg of the crop under the semi-intensive and intensive management levels is estimated to be about P70 to P90/kg which are in turn being sold at P120 to P200/kg.

CURRENT PRODUCTION CONSTRAINTS AND THE ROLE OF RESEARCH INSTITUTIONS AND GOVERNMENTS

The production constraints for the accelerated development of aquaculture in Southeast Asia may be classified into two types:

1. Technical constraints
2. Non-technical constraints

Technical Constraints

A number of technical constraints have slowed down the development of the industry in the Southeast Asian Subregion. These are the following:

1. Inadequate knowledge of the biology of the cultivated species

2. Inadequacy or lack of seeds
3. Lack or poor understanding of the technology of suitable culture system to be used
4. Inadequacy or lack of the required inputs for management operations
5. Inadequacy or lack of properly trained managers, technicians, and skilled labor
6. Diseases and other causes of mortality.

Lack of knowledge of biology of cultivated species. Most aquaculture practices in Southeast Asia have developed through the experience of the fish farmer. Very little, if any, specific culture has evolved through research by concerned development or research institutions. Under these circumstances, technical knowledge on the biology of the cultured species is very inadequate with the result that the improvement in the culture of said species has become very slow as this is only gained through long and painful experiences. For instance, it was only after the reproductive cycle of the jumbo tiger shrimp *(Penaeus monodon)* was studied that hatcheries to produce post-larvae for culture were implemented. Many other species now used for culture still depend on wild fry (e.g., milkfish). Also, very little if any is presently being done on genetic studies and breeding for improvement of cultured species.

Inadequacy of seeds. The critical lack of seeds for stocking purposes in aquaculture is a very serious constraint to most of the species utilized in this production sector. Until this is adequately solved through the production of seeds under controlled conditions, this problem will continue to limit production through aquaculture. Reducing mortalities of available fry and mass production of fry from hatcheries will be needed.

Technology of appropriate culture system. The technology of the efficient culture system that should be used for a particular cultured species is still inadequate and, in fact, is lacking for some species. Also, unless more efficient culture system is adopted, especially for export species, the quantity produced and the cost of production cannot be competitive in the international market. The use of less efficient culture system would naturally increase the cost of production resulting in less competitiveness of the crop.

Inadequacy of manpower. Aquaculture manpower from the managerial or supervisory, the technician as well as the skilled labor levels are generally inadequate in the region and, in most cases, entirely lacking. This is true even where there are suitable resources and sites for the practice of aquaculture and there is need for production from this sector. Support for regional and international training will be required while local national training especially of applied or practical nature will be necessary.

Lack of operational inputs. Application of essential inputs and facilities required for the proper management of aquaculture projects especially those used to enhance production is being practised. Fertilizers, both organic and inorganic, are not only lacking but are being utilized preferably for other uses (e.g., agriculture). Feeds to support aquaculture intensification may be inadequate, and if available, may not be of the proper quality. Pesticides and other chemical products to control pests, predators, and diseases are generally produced outside the region and therefore have to be imported using valuable foreign exchange. Essential facilities such as water pumps, blowers, and aerators are still not locally fabricated in the aquaculture-practicing countries thus providing a constraint in this aspect. Also, as aquaculture intensification progresses the need for environmental monitoring devices increases. Again, as these are fabricated outside the region, they have to be imported at relatively high cost.

Diseases and other causes of mortality. The aquaculture environment should be kept in good quality as environmental deterioration can be a cause for the appearance of diseases. Reduction in the habitat characteristics to levels below the tolerance limits of the cultured organisms can result in mass mortalities. Likewise, with intensification there is more likelihood that parasite and disease-causing micro-organisms will occur. The harmful effects of these unwanted organisms can further be aggravated by crowding of the stock which can result in stress or weakening of the cultured species. Wholesale mortalities can occur due to bacterial or viral infection in crowded aquaculture environment. If not properly remedied, critical oxygen deficiency, extremely low pH, or excessive turbidity can also be causes of mass mortalities. In the cases of the occurrence of parasites in the culture habitats, mass mortalities may not occur but depredation by parasites can result in inferior quality crop. All the above causes can result in a continuing constraint in the attainment of maximum productivity in the aquaculture industry.

Non-technical Constraints

The non-technical constraints include the following:

1. Lack of demand or market for the cultured product
2. Lack or inadequate source of financing for development and operation
3. Limitation of space in terms of water and land for the establishment or expansion of aquaculture
4. Conflict in the utility of land and water or other natural resources needed in aquaculture
5. Legal and institutional constraints
6. Socio-economic and political constraints

Demand and market constraint. A serious constraint in some developed cultures of specific species is the lack of demand or market for the crop with the result that their culture would be uneconomic. Sometimes, this can be remedied through proper processing and utilization but in case of over-production, the culture of species with poor market demand will be a losing proposition.

Competition in land and water use. The use of land and water for aquaculture production competes with other land and water uses. In the case of land, it was generally conceived that poor and waste lands may be appropriated for aquaculture. However, this is a mistaken notion as aquaculture land should be fertile, clayish, and with good source of water. These are the same characteristics needed for good agricultural land resulting in conflict of interest. Likewise, inferior water areas with rocky, sandy, and boggy soils are readily released for aquaculture. These areas, however, are least suitable for this purpose. There is also a conflict of interest in the use of coastal as well as inland waters for wild cropping or fishing with that for aquaculture.

Financing constraints. The establishment of aquaculture projects requires high overhead expenses. Prospective fish farmers with low or moderate income cannot afford to venture into this industry unless financial assistance through easy-term, low-interest credit is provided. It is generally agreed, however, that aquaculture ventures once established are quite stable and sometimes can be very profitable. In many cases, these are not clearly understood by financing institutions and even by the fish farmers resulting in the slow pace of development in this sector.

Limitation in area available. Land and water areas in most countries of the Subregion are generally still available for use in aquaculture. However, there are a number of places where land and coastal water areas are almost fully utilized (e.g., Singapore) or used for a priority industry like oil extraction (e.g., Brunei) so that aquaculture sites can also be limited.

Legal and institutional constraint. There are certain legal and institutional aspects that have also hampered aquaculture development. For instance, since aquaculture is a relatively young industry, there are no statutes nor laws nor are there specifically designated government agencies that will cater to the needs of aquaculture. In many instances, the sites being used for aquaculture cannot be delimited, titled, leased or awarded to practitioners for lack of the statutes and agency for this purpose. Institutionally also, the specific agency that would have the manpower to extend extension services or to issue licenses and permits may be inadequate if not lacking.

Socio-economic and political constraint. On the socio-economic and political aspects, aquaculture has been hamstrung because of many factors. For example, areas which are prospective sites for aquaculture are generally very depressed communities. As aquaculture is a capital-intensive venture especially initially, the population in these areas may not be suitable for undertaking the desired aquaculture development. Another serious socio-economic and political problem in existing as well as prospective aquaculture areas is peace and order condition or security problems in such areas (e.g., Philippines). Although this condition may be temporary, its deterioration or prolonged existence can greatly hamper development or completely erase some projects.

Technical institutions involved in aquaculture research and training are usually available which may be functioning as regional or national projects. In order to maximize the utility of these institutions their short as well as long-range programs should be frequently reviewed and modified so that they can cater to the most relevant problems of the industry. If the resources of these institutions are limited, priorities in their work should be properly set and cooperative work with related institutions should be sought. Frequent dialogues with the industry that these institutions serve should be conducted to update the most pressing needs that require solution. Research personnel need to be properly compensated and rewarded for good achievements and the institutions should be afforded wide level of autonomy and assisted to free them from strife.

Governments need to support the industry by avoiding bureaucratic obstacles in their administrative requirements. Additional support can be rendered by concerned government agencies in looking for sources of financing, locating markets and facilitating the marketing of aquaculture crops and in removing other institutional and legal constraints that may beset the industry. Law and order and security for the industry at the aquaculture sites is another major responsibility of government which should be looked into with dispatch.

PROSPECTS FOR GROWTH AND EXPANSION OF THE AQUACULTURE INDUSTRY IN SOUTHEAST ASIA

The potentials for further growth and expansion of the aquaculture industry in this Subregion can be predicated on the following conditions existing in the area:

1. There are still available areas for the expansion of the industry.
2. Recently developed systems can be applied in existing as well as new areas.
3. More utilization of the potential increase of production through intensification.
4. Concentration of development for the most economic or profitable species.
5. Promotion of the growth of mariculture where expansion is almost unlimited.
6. Presence of dynamic private sector producers.
7. Closing the gap between capture and culture fisheries such as through ranching.

Expansion in Area

Aquaculture development in different areas in the region varies considerably. There are countries where aquaculture is fairly developed and areas for certain production systems have become crowded (e.g., brackishwater ponds in Philippine mangrove swamps, brackishwater areas for shrimp farms in Thailand). On the other hand, there are certain areas for possible development (e.g., Laos, Brunei, Kampuchea). Still large areas can be developed for various culture systems in Indonesia, Malaysia, Vietnam, and Kampuchea.

Application of New Culture Systems

Patterns of recently developed culture systems exist in some countries in the Subregion. These can serve as models for development in other countries where such systems are not yet used. Examples of this system include such methods like the running water culture system for common carp in Indonesia; the culture of finfish in freshwater lake fishpens as practised in the Philippines; the integrated aquaculture, plant crop and animal husbandry as practised in Thailand; cage culture of marine finfish in Singapore; and blood cockle culture in open tidal flats in Malaysia. All the above systems besides others are especially developed in the mentioned countries which could be exchanged with the other countries of the region.

Production intensification

Even, without expanding in area, production from existing aquaculture projects can be increased through intensification. A good example of this system is the development of semi-intensive and intensive culture management for brackishwater shrimp farms. These types of management have now been developed and can be disseminated in different areas of the region.

Special development for the most economic and profitable species

Rapid growth of penaeid shrimp culture in the region as well as other areas in the world is dictated by the availability of export market and the high price paid for this product. This is a definite trend and will continue as long as the profitability of the product and availability of market continue. Other crops that have shown good profitability include high-priced marine species raised in cages such as the sea bass, grouper, snapper, and bream. Market potentials for mangrove crabs fattened in cages or ponds and the raising of novelty crops like the soft-shelled turtle, frog, and crocodile also show good promise.

Mariculture

Mariculture or sea farming is a relatively more recent initiative in aquaculture. However, its prospects is particularly bright in Southeast Asia where extensive available and suitable sites for the culture of several cultivable resources exist. The system that can be adapted to carry out the practices of mariculture can range all the way from the use of ponds or impoundments, pens or enclosures, net cages, and open water system. The resources that can be used vary greatly including various species of finfish, molluscs, crustaceans, and seaweeds.

Dynamic Private Sector Producers

A major factor in the accelerated expansion of aquaculture production in most of the countries in Southeast Asia is the presence of a very dynamic group of private sector producers. Aquaculture people in the private sector in this Subregion have been great initiators. Instead, of depending on government technical and financial assistance, they have ventured to make full use of their past experiences to expand or intensify their own projects. They often get together and organize among themselves in order to gain knowledge from each other. If new technologies are noted outside, the country, they have been ready to make study tour to these centers of development. It is not uncommon to see people in the industry from Indonesia, Philippines, and Thailand attending international or regional aquaculture meetings, seminars, or symposia or they themselves organizing specific local workshops. If the new technology is not readily available, some of the local private aquaculture concerns have gone into joint ventures or actually imported technology and technicians in order to pursue the desired development. Problems of adaptations and modifications to local conditions have occurred, but the transplantation of such technology has generally, so far, yielded positive results.

Ranching

Although this system is not yet used in this Subregion, it has all the potentials for utilization especially for the various diadromous species like milkfish and mullets. In Japan, where penaeid shrimp PL's are now produced in quantities beyond the needs of the controlled culture farms, the excess shrimp seeds are stocked in natural waters and later harvested through capture fisheries. In this sense, the stocking of hatchery produced stock in natural waters practically becomes a means of closing the gap between culture and capture fisheries. Ranching can be the means to achieve this aim and enhance overall fisheries production.

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AQUACULTURE DEVELOPMENT IN JAPAN

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ABSTRACT

Along with the growth of the national economy, aquaculture in Japan has steadily developed in recent years. From 1976 to 1985, production of cultured fish and shellfish increased by 28% from 927 thousand mt to 1184 thousand mt. The contribution of aquaculture to total domestic production constituted 22% in value and 9.7% in weight for 1985. Increase in aquaculture production may be attributed to stronger domestic consumer demand for high grade fish products.

The principal species for culture include sea bream *(Pagrus major),* black sea bream *(Acanthopagrus schelegi),* yellowtail *(Seriola guinqueradiata),* Japanese flounder *(Paralichthys olivaceus),* pufferfish *(Takifugu rubrives),* Kuruma ebi *(Penaeus japonicus),* abalone *(Nordicus discus),* blood ark shell *(Scapharca broughtonii)* and edible seaweeds *(Porphyra, Undaria, Laminaria).* Rapid strides in improved culture techniques have been attained in seed production, grow-out, harvest and disease control in these various species.

Present trend show increasing reliance on cultured rather than fishery products to meet market demand. In some species, e.g., coho salmon, rainbow trout, oyster and laver, production depends entirely on culture. In other species, production by aquaculture contribute a significant portion to total production. However, to maintain the balance between supply and demand for certain principal aquaculture products, controlled production is now being practised for certain species. In addition to these trends, technical improvements in aquaculture has led to a decrease in the number of management units and area of facilities devoted to production.

In the future, greater efforts will be directed to diversify the species cultured to suit consumer preference. Emphasis will also be placed on improving taste and texture of cultured products. New types of feed that will not pollute areas around the culture facilities will be developed. Remarkable achievements in biotechnology will also be applied in aquaculture to improve seed quality.

Parallel with developments in aquaculture, Japan is exerting greater efforts to propagate fishery resources in coastal waters through stock enhancement activities. This is aimed at establishing a multiple fish and shellfish propagation system in the seas surrounding Japan to maintain or increase production from fishery resources.

PRODUCTION AND DEMAND FOR FISH AND FISH PRODUCTS

The total supply of fish and shellfish was 13.7 million mt in 1985. Of this total, the domestic production accounted for 11.4 million mt (excluding seaweeds) and the balance of 2.3 million mt was imported. The domestic consumption was 13.5 million mt with human consumption accounting for 8.4 million mt. Non-human consumption, mainly material for fish meal and food for aquaculture, totalled 3.8 million mt. A total of 1.3 million mt was exported, and there was an increase in stock amounting to 0.2 million mt. As a result, the per capita annual net food supply increased by 0.3 kg from the previous year to 35.8 kg.

The production of fisheries and aquaculture in recent years is shown in Table 1.

PRESENT STATUS OF MARINE AND FRESHWATER AQUACULTURE

Aquatic animals and plants have long been regarded as common properties in Japan. However, with the development of stock enhancement, the aquatic organisms which are protected in a restricted area or released artificially into the water area are now being recognized as intermediate between common property and private property. Consider fisheries from this viewpoint, and aquaculture can be defined as the activities of growing edible aquatic organisms whose ownership is clearly established. Therefore, feeding them or controlling their life histories to some extent are of no concern in the definition of aquaculture. Growing inedible animals such as pearl oyster and gold fishes is usually considered as aquaculture in Japan.

Table 1. Production of fisheries and aquaculture. Upper figures denote weight in 1000 mt., lower figures in parenthesis, value in billion yen including whaling

Year	Total	Marine Fisheries & Culture Method					
		Far sea	Offshore	Coastal	Culture	Fishery	Culture
1981	11 319 (2789)	2165 (584)	5940 (826)	2038 (733)	960 (457)	124 (63)	92 (106)
1982	11 388 (2977)	2089 (641)	6070 (902)	2072 (770)	938 (456)	122 (71)	97 (125)
1983	11 967 (2916)	2132 (640)	6428 (820)	2136 (746)	1060 (519)	117 (62)	94 (117)
1984	12 816 (2947)	2280 (693)	6956 (786)	2265 (752)	1111 (517)	107 (61)	97 (123)
1985	12 171 (2902)	2111 (684)	6498 (757)	2268 (751)	1088 (522)	110 (61)	96 (115)
1986	12 677 (NA)	2262 (NA)	6801 (NA)	2225 (NA)	1190 (NA)	106 (NA)	94 (NA)

Production Trend

Marine and freshwater aquaculture in Japan has steadily developed to meet strong demands for high grade fish as a consequence to improved food habit with the growth of national economy. Production increased from 0.9 million mt in 1976 to 1.2 million mt: in 1985 representing 28% increase in 10 years. In terms of value the production increased by 1.7 times from 374 billion yen in 1976 to 638 billion yen in 1985.

However, stagnating production is being observed in some species in recent years, mainly due to keeping the balance between demand and supply in principal aquaculture products such as yellowtail, red sea bream, eel, oyster, scallop, and laver. Moreover, full use of waters suitable for aquaculture prevents further expansion of production facilities. It is, therefore, anticipated that aquaculture production in Japan will be stable in the coming few years.

Aquaculture production by species together with that fished from the wild is shown in Tables 2 and 3. If viewed by species, production of coho salmon, rainbow trout, tilapia, oyster, and laver depend entirely upon culture, and production from culture are 26.0, 12.2, 4.5, 2.4, and 1.9 times as much as production from fisheries for respective species of eel, *Undaria,* yellowtail, carp and red sea bream in 1985. While production from culture of scallop, sweetfish, Kuruma prawn, and *Laminaria* are between 29% and 48% of the total production of these species, and those of plaice and crucian carp are about 15% of the total production, that of horse mackerel, however, is only 0.3% of the total production. Aquaculture always competes with fisheries in the supply of products, especially that of high-priced ones. Since aquaculture can supply products with equal size and quality regardless of season, it has developed greatly with the decrease in the supply of high-priced fishes by capture fisheries.

The changes in the number of aquaculture management units and the area of facilities are shown in Tables 4-10. Trends of their changes are not always consistent with those of production. For example, in spite of the steady increase of production as observed in eel and scallop cultures, the management units and their areas of facilities have decreased year by year in recent years.

In the beginning, marine aquaculture developed mainly in calm areas less than 20 m deep. However, these waters have been polluted

Table 2. Production trend (in metric tons) by species, cultured and wild

	Horse mackerel		Yellowtail		Plaice		Red sea bream	
Year	Culture	Wild	Culture	Wild	Culture	Wild	Culture	Wild
1976	721	127 704	101 619	42 763		7158	6 453	16 995
1977	772	87 457	114 866	26 915	-	6446	8 120	17 020
1978	815	57 992	121 728	37 414	-	7202	10 844	16 160
1979	1460	82 515	154 872	44 970	-	6818	12 253	15 378
1980	2283	53 664	149 311	42 009	-	7113	14 757	15 170
1981	3229	61 815	150 754	37 774	-	6332	17 953	13 709
1982	3629	105 125	146 304	38 445	-	6387	20 246	14 954
1983	4305	130 230	155 879	41 822	648	6661	25 000	14 699
1984	3710	135 763	152 498	41 212	838	7095	26 156	15 956
1985	5008	152 929	150 961	33 422	1572	8184	28 430	14 723

	Eel		Sweetfish		Carp		Crucian carp	
Year	Culture	Wild	Culture	Wild	Culture	Wild	Culture	Wild
1976	26 251	2040	5726	13 272	26 289	6960	954	10 113
1977	27 630	2106	5875	13 451	29 295	6760	1007	10 316
1978	32 106	2068	7185	13 363	29 160	7376	1292	10 751
1979	36 781	1923	8455	14 822	27 452	7856	1263	10 948
1980	36 618	1963	7989	14 723	25 045	8479	1151	10 066
1981	33 984	1920	9492	15 405	23 784	8108	1289	9138
1982	36 642	1927	10 222	14 872	24 093	8202	1215	8441
1983	34 489	1818	10 318	15 579	22 397	7545	1592	8005
1984	38 030	1573	11 705	14 919	21 071	7594	1492	8034
1985	39 568	1526	10 967	14 492	19 105	7830	1455	7987

	Kuruma prawn		Scallop		Luminaria		Undaria	
Year	Culture	Wild	Culture	Wild	Culture	Wild	Culture	Wild
1976	1042	2579	64 909	30 270	22 089	159 162	126 723	19 337
1977	1124	2440	83 180	43 502	27 249	132 989	125 833	20 180
1978	1184	2673	67 723	59 664	21 890	108 911	102 682	12 213
1979	1480	2468	43 614	79 734	25 291	131 546	103 791	12 131
1980	1546	2307	40 399	83 134	38 562	124 816	143 352	15 759
1981	1666	2864	59 095	91 139	44 221	112 178	91 272	13 993
1982	2000	3068	76 866	99 505	42 980	145 952	118 340	12 155
1983	1949	3578	83 111	128 136	44 345	129 043	112 835	9 565
1984	2037	3356	73 948	135 239	62 756	114 221	114 586	9423
1985	2151	3741	108 509	118 277	53 593	132 903	112 375	7238

or the area may no longer be used due to increased reclamation projects and the expansion of harbor facilities. In view of these developments, culture areas have gradually expanded from bay areas to the outer sea. Newly developed culture techniques such as flowing-current style for laver, middle and bottom layer cage culture for fish, long-line facilities for *Undaria, Laminaria,* scallop, and pearl oyster together with the installation of wave breaker facilities make the expansion of culture areas possible. Accordingly, the area utilized for marine aquaculture has been maintained at around 100 000 ha for the last ten years or so.

Table 3. Production trend (in metric ton) by species, depending entirely on culture

Year	Coho salmon	Rainbow trout	Tilapia	Ascidian	Oyster	Laver
1976		15 322	34	8390	226 286	291 050
1977	—	16 033	56	7463	212 786	279 031
1978	72	17 166	416	5759	232 069	350 471
1979	370	16 714	1526	5287	205 509	325 686
1980	1855	17 698	2392	5749	261 323	357 672
1981	1150	17 819	2465	6909	235 241	340 510
1982	2122	18 230	2640	7382	250 288	263 312
1983	2760	17 817	3233	7889	253 249	360 694
1984	5049	16 773	3544	8903	257 126	396 530
1985	6990	16 324	4180	7660	251 247	351 788

Table 4. Changes in number of aquaculture management units

	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
Horse mackerel	108	149	223	363	599	737	830	821	718	723
Sea breams	1431	1781	2069	2413	2689	2831	2940	2924	2894	3014
Yellowtail	3809	3991	4162	4100	3941	3883	3878	3670	3411	3205
Ascidian	2485	2418	2264	2122	1887	1957	1837	1840	1698	1699
Scallop	8058	7689	6775	6399	5800	5507	5558	5507	5564	5452
Oyster	5522	5695	5973	6157	6211	6135	5977	5911	5781	5781
Pearl	2175	2131	2138	2078	1941	1953	1958	1996	2029	2048
Kuruma prawn	105	104	119	120	121	128	129	134	142	148
Laver	33 625	31 763	30 226	29 560	28 325	26 495	24 436	22 044	21 297	20 405
Undaria	18 887	17 205	16 354	15 337	14 544	14 289	14 142	13 570	13 027	12 985
Laminaria	3110	2828	2991	2882	3270	3913	4052	4037	4352	4451

On the other hand, the water area for major freshwater aquaculture in leading production area decreased from 7997 ha in 1976 to 4948 ha in 1985. In association with the development of intensive culture methods, a sharp decrease in culture area for carp and eel culture has taken place.

Stock Enhancement in Coastal Waters

Until quite recently fisheries meant mainly capturing fish; however, efforts are now being made to develop a new type of fisheries which does not merely catch fish but also increases them naturally. This is similar to the transition from hunting to farming and cattle-raising age.

Within the 200-mile area, it is all the more imperative to develop the seas surrounding Japan to meet the increasing demand for fish and shellfish, especially high-quality ones. However, the production of these high-quality fish and shellfish* has decreased for many reasons. These fisheries resources must not only be maintained, but should also be increased significantly more and more in the future. Along this line, the country is making a very strong effort to promote fish propagation and fishery conservation in all its waters.

Numerous types of stock enhancement technology are being practised, some having been established already as an industry for a long time, and some still being developed at present. For instance, stock enhancement of chum salmon, red sea bream, scallop, and also abalone, prawns, and crabs has been successful. The stock enhancement is conducted mainly by producing large numbers of seedlings of fish and shellfish, releasing them into the sea suitable for their further growth, protecting them until they attain commercial size and harvesting them by the ordinary fisheries methods.

The concept of stock enhancement is to use the wide ocean itself as a pasture for propagating fisheries resources in large amounts, mainly the medium and high-quality species which are widely in demand among the population. The aim of stock enhancement is to create a multiple fish and shellfish propagation system in which different species can be possibly increased when stocked together. To accomplish this, the technology applied to stock enhancement is based on ecological aspects while the technological development of aquaculture has been made through physiological considerations.

Table 5. Aquaculture management units and area of facilities for yellowtail (size in ha, initial number of fish in 1000, food in 1000 mt)

Year	Bank type		Net demarcation		Cage Net		Number of fish	Food	
	No	Size	No	Size	No	Size		Fresh	Others
1976	10	51	99	109	22 394	198	81 132	964	5
1977	7	42	93	111	23 635	205	76 007	966	6
1978	6	14	107	128	27 002	243	83 574	1125	11
1979	6	14	97	129	29 172	249	80 602	1316	8
1980	4	9	82	95	28 878	267	75 327	1296	2
1981	3	7	71	91	27 669	273	80 409	1306	6
1982	2	5	75	85	32 313	299	85 142	1303	5
1983	2	5	66	78	29 452	305	83 803	1344	8
1984	2	5	59	49	27 395	272	66 887	1382	10
1985	2	5	60	72	25 720	248	68 364	1256	24

Table 6. Aquaculture management units and area of facilities for seabream (size in ha, initial number of fish in 1000 mt, food in 1000 mt)

Year	Bank type		Net demarcation		Cage Net		Number of fish	Food	
	No	Size	No	Size	No	Size		Fresh	Others
1976	6	NA	7	NA	6066	NA	18 813	69	NA
1977	4	NA	3	NA	7869	NA	21 577	106	NA
1978	3	NA	26	NA	9128	NA	29 364	154	NA
1979	4	NA	7	NA	10 862	NA	28 231	147	NA
1980	2	NA	2	NA	14 243	112	36 084	194	NA
1981	6	NA	2	NA	15 499	125	34 007	256	NA
1982	16	NA	4	NA	15 644	136	42 052	221	NA
1983	4	12	6	5	17 228	173	47 512	206	22
1984	7	13	7	7	17 698	139	55 182	244	35
1985	6	12	7	6	19 274	151	56 230	261	42

Table 7. Aquaculture management units and area of facilities for pearl (standard size of raft 6.35 × 45 m with 3000 pearl oysters, one unit of long rope 60 m, size in ha)

Year	Raft		Long rope	Production	
	No	Size	Unit	Weight (kg)	Value (mill yen)
1976	112 299	163	NA	33 774	22 158
1977	114 282	176	NA	38 565	26 456
1978	123 803	172	NA	37 586	22 128
1979	117 668	160	NA	40 137	32 176
1980	49 783	216	81 452	42 345	46 062
1981	47 013	203	79 487	45 861	48 925
1982	36 136	138	93 515	51 856	47 817
1983	33 891	140	97 346	57 520	65 682
1984	37 326	129	98 059	64 160	65 682
1985	36 602	126	93 114	61 655	57 833

Table 8. Aquaculture Management Units and Area of Facilities for Oyster (standard size of raft 18.2 × 10.9 m, one unit of long rope 54.54 m, size in ha)

Year			Long rope	Simple hanging	Sticks	Sown on ground
	No	Size	Unit	Size	Size	Size
1976	14 615	NA	12 942	270	21	126
1977	15 388	NA	14 244	174	23	126
1978	15 782	NA	15 420	164	22	133
1979	16 642	NA	15 312	159	22	133
1980	16 509	329	16 778	130	22	141
1981	16 851	335	19 740	117	22	143
1982	17 769	347	17 899	114	16	140
1983	17 585	447	24 792	281	24	141
1984	17 128	340	26 662	282	26	140
1985	20 235	401	25 997	282	26	140

Table 9. Aquaculture Management Units and Area of Facilities for Laver (number in 1000 units, standard size of net 18.2 × 1.5 m, size in ha)

Year	Sticks held Net		Floating Net	
	No	Size	No	Size
1976	1830	11 084	1302	5229
1977	1854	11 120	1165	5054
1978	1876	11 268	1273	5483
1979	1952	10 189	1378	5689
1980	1966	10 108	1421	5505
1981	1854	10 057	1356	5299
1982	1763	9486	1277	4971
1983	1615	8896	1221	4839
1984	1683	8951	1322	4752
1985	1609	8654	1263	3852

Contribution of Aquaculture to Fish Production

The proportion of aquaculture products to the total fisheries production in Japan is considerably high in terms of value although it is still low in volume. In 1985, the production of aquaculture constitutes 22.0% in value and 9.7% in volume of the total fisheries production. When these figures are compared with those of combined coastal and inland fisheries production, they become as high as 41.0% in value and 32.4% in volume in coastal fisheries. As the production of aquaculture for principal species exceeds that of fisheries, aquaculture is taking an important role in the supply of these species. With the expansion of market for restaurants, aquaculture becomes extremely important in providing materials for them. As a result, aquaculture is asked to further increase its link with the restaurant industry by supplying the latter with such products to meet its needs.

FUTURE STATUS OF AQUACULTURE

Judging from the general trend of consumers' preference for food, aquaculture can produce many varieties of species of desired quality. Therefore, the culture of puffer, striped jack, tuna, black sea bream, sea bass, parrot fish, octopus, cuttle fish, and abalone will develop in the near future. At the same time, improvement in taste and

Table 10. Changes in the number of management unit and size of facilities of freshwater aquaculture in leading production area (size in ha)

Year	Carp		Eel		Salmonids		Crucian carp		Sweetfish	
	Unit	Size	Unit	Size	Unit	Size	Unit	Size	Unit	Size
1976	3621	3106	2735	2570	1353	164	333	2108	322	49
1977	3358	2986	2656	2485	1234	165	312	1972	318	44
1978	3849	3394	3218	2477	2007	291	972	2205	498	64
1979	2745	2440	1959	1719	1142	153	231	2043	295	44
1980	2393	2259	1816	1606	1137	156	223	1949	293	43
1981	2240	2000	1682	1421	1143	151	242	2265	285	43
1982	2031	1928	1564	1269	1126	137	234	2152	271	45
1983	1901	1399	1435	1148	1153	160	257	2383	283	48
1984	1712	1573	1569	1199	1136	150	252	2233	295	46
1985	1593	1473	1478	1125	1094	135	249	2181	279	44

texture of aquaculture products is being taken into account to meet the consumers' demand. In this connection, successive efforts will be made to develop assorted feeds like the pellet, and culture facilities for deeper and outer waters. The development of a new type of feed is also expected to prevent water pollution around the aquaculture site.

With the remarkable development of high technologies in such fields as biotechnology, electronics, and new material technology, expectations are placed on the development and application of these high technologies to aquaculture for its further expansion. Since most of the species cultured are wild, great hardships are encountered in keeping them under control. Efforts to improve the seeds suitable for culture by the application of biotechnology, such as cell fusion and chromosome technology, are being made.

FINFISH CULTURE

Broodstock Production

Rearing facilities. Parent fishes of marine species are usually maintained in a concrete tank. The tank capacity depends upon size and swimming and feeding habits of the species. About 20-100 m^3 circular and rectangular tanks are commonly employed as spawner reservoir. There are no rational bases for the choice of shape and dimension of tanks. They might be determined by land space, ease of maintenance, and water supply system. Tanks less than 3 m deep are preferred relative to pump capacity and maintenance procedures. The tank is usually roofed or covered with sheets to protect against sunlight and to avoid unexpected stress.

Rearing method. A sex ratio of one female to one male or one female to two males is widely adopted for mating and spawning in most hatcheries because poor fecundity resulting from unbalanced sex ratio has been proven experimentally. Then parental fish larger than about 600 g are generally maintained at a density of 1-1.5 fish/ m^3 and smaller fish at 0.8-1.5 kg/ m^3 Sea water is supplied by a pumping system through filtration. Pelagic eggs spawned in tank are collected through water overflow by fine mesh net set at the outlet. Heated sea water is used sometimes to induce early maturation in Sparid fish and Japanese flounder. Warm effluent from a thermal power station is utilized to ensure the early maturation of the commercially valued broodstock. Photoperiod control, which has been used in Ayu fish (sweet fish), has recently been applied to effect the natural spawning of Japanese flounder. The pituitary of grass carp and human chorionic gonadotropin (HCG) are occasionally used to obtain viable eggs from sea bass, yellowtail, and Japanese flounder.

Feeds and feeding. Various low-priced fishes are preferably fed by hand to spawners. Sardines, anchovies, sand lance, mackerel, and *Euphausia* are popular feeds. In addition, formulated feeds are also used together with these raw materials. The parental fishes are fed at the rate of 2 to 8% of body weight every morning. Many species anticipate feeding time at a particular part of the tank. Regular feeding schedule has effects on the acclimation of spawners in captivity, resulting in high fecundity of the broodstock.

Capture, handling, and transport. Spawners are captured from the wild or raised from larval stage in the hatcheries. They are usually cultured in floating net-cages, except during the spawning season, and transferred to spawning tanks 4 or 6 weeks before spawning. This procedure is advantageous for the effective utilization of facilities, in reducing cost of broodstock culture and in avoiding accidents in the water supply system during breeding.

No reliable methods are known for monitoring gonad maturation and sex identification. However, spawning behavior in captivity and the temperature at which spawning begins are well investigated to predict the spawning season in various species. Only in few species is sex distinguishable by body color and swelling of abdomen.

Diseases and Parasites. No serious mortality has been generally observed in spawning tanks as broodstock for many species is maintained at low density under good feeding conditions.

To utilize the hatchery facilities economically and effectively, various fish larvae must be reared throughout the year. Therefore, running and maintenance costs are needed to culture numerous broodstocks of different fish species in each hatchery. The utilization of HCG which often results in unstable hatchability must be worked out to obtain viable eggs for yellowtail since the techniques for natural spawning is not yet established.

Seed Production and Nursery Operation

Rearing facilities. Rearing tanks of larvae vary widely in size, shape, and materials. For mass production of fry the smallest tank is 0.5 m^3 the largest, 400 m^3 Most tanks are from 20-100 m^3 with depths of 1.0-1.5 m. Recently, plastic material (polycarbonate and fiber-reinforced plastic) is used to make circular and rectangular tanks from 0.5-4.0 m Simplified tanks of canvas sheet are also employed for larval rearing as well as phytoplankton culture because these are cheaper. All these tanks are commercially available anywhere.

Large tanks with more than 100 m^3 capacity in Hiroshima Prefectural Fisheries Center equipped with automatic feeder and vacuum cleaner were used to save on labor and to mechanize the rearing procedure. The use of an automatic pilot is gradually gaining acceptance in the fisheries centers run by the central and federal government for large-scale production.

Smaller net-cages are commonly used for nursery breeding in the sea. The net-cages measure 2-4 m^2 with depths of 1.5-3 m. Some facilities are installed for electric lighting to attract zooplankton to caged fry at night. A cover net is usually set on the raft to avoid bird predation. The stocking density is controlled relative to fish size and their growth. Fry 1-1.5 cm are kept at a density of 10 000-30 000 ind/m^3 ; 2-3 cm fry at 1000-2000 ind/m^3 and over 4 cm fry at 700-1000 ind / m^3.

Rearing method. Naturally spawned eggs are preferred for mass production because of its high hatchability. Naturally spawned eggs are frequently transported from power station or fish centers in warm districts, where spawning occurs earlier, to fisheries centers and farmers' hatcheries. Vinyl bags filled with oxygen are practical and cheaper as means of transporting eggs and larvae.

Newly hatched larvae, before the mouth-opening stage, are transferred from incubation net enclosures to rearing tanks, after which the density of larvae is estimated volumetrically by taking aliquots from the aquaria. Pelagic eggs are introduced directly to rearing tanks. Egg number is determined by multiplying its number in fixed volume or weight. Stocking density of newly hatched larvae and eggs are dependent largely on tank capacity. About 25 000-40 000 larvae or eggs are maintained in the smaller 0.5-50 m^3 tanks. Stocking density decreases with increasing tank capacity. The larvae and eggs are maintained at lower density of 5000-10 000/ m^3 in tanks larger than about 70 m^3.

During the initial phase, larvae are reared in a static system with aeration, and afterwards in a semi-static system where the water column is replaced partly. Flow-through system is employed when the fish swim actively or approach the transitional stage from larvae to juveniles.

Feces and sediments at the bottom are siphoned everyday. Some fish culturists inoculate *Chlorella* sp. into the rearing tank at the concentration of 30-500 × 10^4 cells/ml as a "water conditioner", which reduces the deterioration of rearing water and prevents starvation of rotifers.

Feeds and feeding. Rotifers, *Brachionus plicatilis,* are well known as useful food for fish larvae. This organism is initially fed to most marine fish larvae from the time of mouth-opening to about 4 weeks after hatching. Rotifer density given in tanks varies widely from 3-10 animals/ml due to the swimming and feeding activities of larvae. *Artemia* nauplii, subsequently, are given with overlapping of feeding period of the previous foods. *Artemia* is provided in 2-6 weeks after hatching. Adult *Artemia* enriched by fatty acid is often used as a supplemental food for metamorphosed flatfish and plaice. Cultured copepod, *Trigriopus japonicus* and wild zooplankton are also used as substitutes for *Artemia* nauplius to save on production cost because *Artemia* cyst is expensive. Formerly, oyster trochophores *(Crassostrea gigas)* were fed to larvae of fish such as grouper and whiting. Recently, however, oyster larvae are no longer used because of the difficulty in mass producing it. Weaning to dry pellets is done when fish reaches the juvenile stage or is completely metamorphosed. The formulated pellet is also provided with minced fish meat (sardine, anchovy, and sand lance) and *Euphausia* and fed 2-4 times daily, depending on fish size and species.

General composition of the pellet is 50-60% crude protein, 5-20% crude fat, 10-2% crude ash, 3-4% calcium, 2-3% phosphorus, and doses of vitamins and fatty acids. Recently, weaning experiments with pellets have been carried out vigorously at the early larval stages of the red sea bream and Japanese flounder as well as Ayu fish.

In the nursery, the fish is usually fed with minced fish meat and *Euphausia* more frequently than before, 4-6 times, at a ration of 10-20% body weight per day. Uniform fish size usually ensues from frequent feeding at early phase of transfer from indoor to outdoor facilities.

Disease control. Vertebral malformation which is frequently found in hatchery-reared red sea bream has been overcome through technical improvement in feeding and aeration methods. The feeding of rotifers cultured with baker's yeast resulted in high mortality and malformation. The quality of the yeast has been improved by the addition of highly unsaturated fatty acids, especially of the ω3 type. Light aeration of less than 100 ml/min/m^3 is commonly used to ease the initial inflation of the air bladder which prevents the abnormal development of the vertebrae.

Fish larvae and fry in hatcheries often contract diseases caused by *Vibrio* spp., *Flexibacter maritimus, Edwardsiella tarda,* and others. Diagnosis and treatment are generally performed by qualified pathologists allocated to each prefecture. They also recommend drugs for the optimal cure based on the symptoms in diseased fishes and suggest the countermeasure to prevent the disease. Generally when the fishes are transferred or handled, they are immersed in 50 ppm Nitrofuran to prevent infection.

Harvesting. Initial rearing conducted indoors usually terminates in 30-100 days following hatching, about 30-40 days for most fishes spawned in spring to summer and 100 days for winter species, Ayu fish and flat fishes. About 30-60% of initial stock is obtained consistently at the termination of the indoor rearing for sea breams, Japanese flounder, Ayu fish, puffer, and plaice. The yield of more than 4000 one cm fish/m^3 is satisfactory for culturists. Fish fry raised indoors are transferred to the floating net cages as well as to outdoor tanks. Size sorting, selection of malformed individuals, and determination of survivors are conducted at transfer. Hatchery-bred fry are siphoned directly into the net-cage or scooped. Overall survival of more than 30% from egg stage to fry of 3 m is well achieved. Fish fry after nursing are utilized for aquaculture projects and for intensive aquaculture by fish farmers.

Production constraints. Main obstacles in seed production might be attributed to abnormality in morphological characters and in pigmentation. Vertebral deformity has been solved by improvement of feeding and rearing techniques. Albinism, however, occurred at high percentage, usually in plaice and Japanese flounder. Supplemental feeding of wild plankton, mainly copepods, is well known to decrease incidence of albino fish; however, the cause of albinism and the effect of diet is still under study. Various diseases occur during the course of rearing, and fish culturists use drugs for treatment. More studies are needed to find optimal rearing conditions to prevent the occurrence of diseases.

Fry raised in the hatchery are used both for cage culture and restocking program. In the latter case, survival capability and size should meet the necessary criteria before releasing fish to achieve success in the restocking activity. No biological information and criteria for releasing fish are known at present.

Automation of counting the fish fry and mechanization of rearing procedures are highly required to increase the harvest in the hatchery.

Production of Marketable Fish

Rearing facilities. Floating raft, consisting of net-cages, bamboo, anchors, and styrofoam buoy, is a typical facility in the culture of marine animals for commercial purpose. The size and materials of net-cages depend on fish species and farming grounds, for instance, depth, current velocity, and topography. Fish younger than one year are maintained in square cages ranging from 4-6 m. The surface of the cages are covered with fish net to prevent bird predation, and they are generally rafted four or more abreast, anchored to the bottom. Adult fish are stocked in larger cages from 6-8 m^2 with 4-6 m depth. Circular floating cages 12-14 m in diameter, constructed of steel frame and wire net are used in the southern part of Japan to cultivate yellowtail weighing 2-5 kg. These facilities are generally located in bays or inlets. In the gulf area, where more rough oceanographic conditions occur, a fish coral measuring about 8 m^2 is commonly employed for cage culture. The fish coral is equipped with a device that sinks it during typhoons. Adoption of this device widens the farming area for culture.

Rearing method. Tremendous strides in yield of yellowtail in Japan are due to the ease of obtaining wild seeds. Other species, however, are cultured from hatchery-reared seeds. Demersal species, flatfishes, and rockfish are cultured at a density 4-5 kg/ m^3 lower than the pelagic ones. A stocking density of 5-9 kg/m^3 is standard for culturing sparid fish and yellowtail in net cages. The wire net system is capable of stocking yellowtail at 10-15 kg/m^3 because the surface of the wire net is smooth enough to prevent the settlement of fouling animals and is, therefore, effective for water flow. Cage capacity and mesh of fish net is changed with fish growth and when fouling organisms settle on the surface of the net. A few omnivorous fish are often cultured together to help the removal of fouling animals, barnacles, seaweeds, and ascidian.

Feeds and feeding. Different species and types of material are utilized for feeding. Sardine, anchovy, sand lance, mackerel, and *Euphausia* are popular food given fresh or frozen. The composition of anchovy and sardine is 3-5% crude fat, 16-20% crude protein, and 70-75% water, and that of sand lance is about 10% crude fat, 20% crude protein, and 65% water. These contents change with seasons and storage methods. Minced and chopped meats mixed with the diet increase nutrient contents of feeds. Feeding of adult fish is less frequent than that of the young. They are fed twice daily, morning and afternoon when active feeding behaviors are observed. Yellowtail and red sea bream are fed every 3-4 days in winter. Table 11 shows a summary of the feeding and growth rates of marine finfish.

Table 11. Daily feed and conversion ratio of major species cultured with raw material

Species	Daily feeding rate*			Conversion ratio**		
	0yr	1yr	2yr	0yr	1yr	2yr
Yellowtail	8-20	4-6	3-5	5-7	6-9	10-14
Red seabream	8-12	6-8	4-6	6	9-12	16-20
Japanese flounder	8-20	4-10		2-5	4-6	

Each value varies considerably with rearing conditions of food items, temperature, feeding strategy, etc.

* = percentage to body weight
** = amount of food fed divided by weight gain.

The composition of formulated pellet resembles that of fingerlings: 45-47% crude protein, 15-18% crude ash, 3-5% crude fat, 2-4% calcium, and 1-2% phosphorus. The pellet is given at 1-3% body weight, one to four times a day, depending mainly on water temperature. Recently, moist pellet, which consists of raw fish, mash pellet, and binder, has been gradually used to culture yellowtail and sea breams. The moist pellet is considered beneficial in preventing pollution, nutrient enrichment, feeding strategy, and production cost.

Disease control. Most cultured finfishes contract diseases from various bacteria, virus, fungi, parasite, food, and stress. Disease increases markedly with increment of farming facilities and aquaculture production, suggesting over-stocking and environmental deterioration. *Pasteurella pisciciba* and *Streptococcus* sp. are the most common and critical pathogens damaging yellow-tail crops. *Benedenia seriola* and *Axine heterocerca* are often observed in cultured yellowtail. Immersing parasitized fish in increasing or reducing salinity is effective and less costly than using drugs. Various disease reports include 162 pathogens for cultured finfish, 98 for freshwater, and 64 for marine fish. Diagnosis of diseased fish and identification of disease agents are usually conducted by qualified technician and optimal use of prophylactic drugs (Antibiotics, Sulfa drugs, Nitrofuran derivative) and supplemental nutrient is suggested to the fish farmer. Appropriate stocking density, feeding, transfer, and other culture techniques are also suggested to prevent infestation and spread of epizootic.

Harvesting. Most marine species are cultured from 1-2 years. Japanese flounder weighing 600-800 g is harvested in less than one year. Commercial fish farmers harvest periodically or seasonally. Caged fishes are harvested for hauling by narrowing the fish net or scooping. Fish hauling differs somewhat from harvesting for the market. Quantities of fish are generally hauled on ice to the wholesale market. Cultured products particularly sea bream, parrot fish, and Japanese flounder have been transported recently to restaurants and other markets by placing the fishes in live-hauling tanks in trucks. Fish hauled alive command a price of 30-60% higher than fish caught the conventional ways.

Production constraints. The development of intensive aquaculture has contributed partly to the effective conversion of trash fish to high protein foods. Feeding of trash fish, in turn, is one of the causes of pollution and environmental deterioration around the farming ground. It also causes mortality and retards the growth of caged fish.

Red tide is the most serious danger to fish aquaculture, especially to yellowtail because of the physiological weakness of this fish to the bloom of red tide organism, *Chattonella* spp., *Gymnodinium* sp., and others. Disease control is also a critical problem preventing stable production. Suitable management method, for instance, optimal stocking density, number of facilities, and feeding method in finfish culture must be pointed out before the use of drugs is suggested to the fish farmer. Recently, various studies on feed material and culture strategy have been carried out to reduce the fat content of cultured finfish which is disliked fairly by individual markets.

Table 12 lists the finfish species cultured in Japan.

SHRIMP AND PRAWN CULTURE

Broodstock Production

Rearing facilities. A total of 17 crustacean species are artificially reared for the restocking program and 9 of these are shrimps. Only the Kuruma prawn is cultivated commercially. An indoor tank made of concrete is commonly used to hold the parent prawn. The tank capacity varies between 60-200 m^3 with depth of 1.5-3 m, either square or rectangular. The tank is provided with an aeration system and heating facilities. The bottom is inclined slightly for complete drainage at harvest.

Rearing method. Only gravid females are introduced to the indoor tank. One female weighing 70-130 g per m^3 is a common stocking density in the breeding tank. The breeding tank is filled with filtered sea water at half level, and the sea water is heated to about 25°C immediately after the spawners are stocked in the tank. Ablation of eyestalk and spawner breeding in earthen pond have been experimented in the Japan Farming Fisheries Center. In both trials, viable nauplii are obtained in small numbers and are still being studied for mass production.

Feeds and feeding. No feed is given to the spawners in the tank. The mother shrimps are removed from the tank for a couple of days after spawning.

Capture, handling, and transport. All females are captured by fishing gears and their maturation level determined with naked eyes. Only gravid females are hauled to the shrimp hatchery by sawdust cartons of fish-hauling tanks. During transfer, 100 kg females are stocked in 1 m^3 capacity tank.

Table 12. Finfish species cultured by hatchery breeding and cage culture

	Clupeidae			Serranidae			Sebastes inermis	CR
Δ	Clupea pallasi	R		Epinephelus septemfasciatus	C	A	Sebastes schlegelii	CR
	Carangidae			Epinephelus akaara	CR		Seastes pachycephalus	R
	Tranchurus japonicus	CR		Epinephelus moara	R		Sebastiscus marmoratus	R
	Caranx delicatissimus	CR		Plectropomus leopardus	R		Synanceiidae	
	Caranx speciosus	R		Epinephelus microdon	R		Inimicus japonicus	R
	Seriola quinqueradiata	CR		Sillaginidae			Paralichthyidae	
Δ	Seriola aureovittata	CR		Sillago japonica	R	O	Paralichthys olivaceus	CR
	Seriola dumerili	R		Sparidae			pleuronectidae	
	Girellidae		O	Pagrus major	CR		Limanda yokohamae	R
	Girella punctata	C		Evynnis japonica	CR		Pleuronichthys	
							cornutus	R
	Lethrinidae		O	Acanthopagrus schlegeli	CR		Eopsetta grigorjewi	R
	Lethrinus nebulosus	R		Acanthopagrus latus	R		Hippoglossidae dubius	R
	Lutjanidae			Sparus sarba	R		Kareius bicoloratus	R
	Lutjanus sp.	R		Acanthopagrus sivicolus	R		Limanda herzensteini	R
	Oplegnathidae			Trichodontidae			Liopsetta obscura	R
	Oplegnathus fasciatus	CR		Arctoscopus japonicus	R		Microstomus achne	R
	Oplegnathus punctatus	R		Scombridae			Tanakius kitaharai	R
	Percichthyidae			Scomberomorus niphoninus	R		Monacanthidae	
	Lateolabrax japonicus	CR		Thunnus thynnus			Stephanolepis	
							cirrhifer	C
	Pomadasyidae			Siganidae			Navodon modestus	C
	Parapristipoma trilineatum	CR		Siganus fuscescens	R		Aluterus monoceros	R
	Hapalogenys nitens	R		Siganus guttatus	R		Tetraodontidae	
	Plectorhynchus cinctus	R		Platycephalidae		Δ	Takifugu rubripes	CR
	Sciaenidae			Platycephalus indicus	R			
	Nibea mitsukurii	R		Scorpaenidae				

R indicates species reared in hatchery and C species cultured commercially in net cage.
Open circles indicate species reared at 10-million level and triangles at a million level at seedling size (15-80 mm).

Disease control. No specific treatment can prevent disease among broodstock. It is important, however, that contamination be avoided by washing spawners well with filtered sea water before introducing them into the tank and by immediately removing dead spawners after spawning. The breeding tanks are used not only for spawning, but also for the culture of diatom and nauplii in succession.

Production constraints. The supply of spawners is entirely dependent on the wild stock in southern Japan. The scarcity of gravid females greatly influences the market price of mother shrimp and the success of broodstock production. The number of viable eggs spawned by the mother shrimp is highly variable. Only 10-50% of the initial stock will spawn resulting in unstable yield of shrimp fry.

Seed Production and Nursery Operation

Rearing facilities. The same tank used for spawning female is used to rear the larvae until P_{20} (about 12-16 mm long) or more developed stage. A small earthen pond is usually used as nursery.

Rearing method. Nauplius density varies between 10 000 and 80 000/m^3 in the tank, depending on the spawning capacity of the female.

Nauplii are cultured in standing water with heavy aeration and slow agitation until the postlarval stage. Exchange of rearing water or running water are introduced after the postlarval stage when ground meat of short neck clam or *Euphausia* and pellet are fed. The rearing sea water is drained through a strainer. The mesh of the strainer is changed relative to larval growth.

Feeds and feeding. Diatoms, *Chaetoceros* spp. and *Skeletonema* spp., are cultured as initial food organisms. The rearing water are enriched by several fertilizers: 15-30 g KNO_3, 2-4 g Na_2HPO_4, 1-1.5 g NaSio , and 7-15 g EDTA per 100 m^3 Under these conditions, diatoms introduced from the sea are inoculated in the tank. The diatoms are cultured at a concentration of 3-10 × 10^4 cells/ml. The diatom culture is a prerequisite for rearing shrimps from nauplius to early postlarval stage. *Artemia* nauplius and meat of marine organisms are fed after the postlarval stage. The percentage of these stuff given to the fry varies from 100-180% of the total biomass in the tank.

In many hatcheries cultured rotifers and formulated pellet are used as substitute for *Artemia* to save on feeding cost.

Disease control. Two diseases are reported to occur in mysis to postlarvae, 6-9 mm in size. Both diseases are caused by *Baculovirus* and *Vibrio* infection, characterized by white intestine and black body surface. Unfortunately, appropriate treatment and prevention are not known.

Harvesting. Survival from nauplius to juvenile shrimp varies between 15% and 40%, yielding 4000-12 000 shrimps/m^3. Duration of indoor rearing usually exceeds 100 days during early spring to late autumn. In harvesting, tank water is removed through a strainer by siphoning or by underwater pump. Juvenile shrimps are held with drained sea water when the water level is reduced to 50-70 cm depth.

Production constraints. Technical development to increase the spawning rate of mother shrimp is requisite for reliable production. Other food items such as pellet, rotifer, and microbial flocks are highly desired as substitute for *Artemia* nauplius.

Production of Marketable Prawn

Rearing facilities. An earthen pond is commonly used for commercial farming. Pond area varies from 500 m^2-10 ha with a depth of about 1-2 m. The pond is usually banked with concrete, and the upper layer of pond bottom overturned partly or completely every year and dried to remove fish predators. Air supply is provided from a blower through a PVC pipe or propeller-driven aerator. A water gate is installed with a screen in the earthen pond to supply sea water from the outside.

Rearing method. Shrimp fry are released into earthen ponds. The stocking density is dependent on shrimp size: 50-90 shrimps/m^2 for 20 mg and 15-30 ind/m^2 for 1-2 g shrimp. Shrimps are fed with various marine animals and pellets. Sea water in the earthen pond is exchanged partly by a pumping system or tidal movement through the water gate.

Feeds and feeding. Food used are meat of short neck clam, mussel, *Mysis, Euphausia,* and formulated pellet. Shellfishes are given crushed; *Mysis* and *Euphausia,* chopped. Feeding rate varies largely with shrimp size, temperature, food quality, and other factors. The following feeding rates are widely used: 100-200% body weight for 20-100 mg, 40% for 1-3 g, 20% for 5-10 g, about 10% for 18-20 g shrimp, respectively.

Formulated pellet is fed from the zoea stage in combination with live food.

Disease control. A disease due to the fungi, *Fusarium* sp., is known to cause losses in shrimp aquaculture, and *Baculovirus* infection is also observed occasionally in shrimps cultured in tanks. No techniques to prevent and cure these diseases have been established yet.

Harvesting. The growing procedure lasts from 100-200 days, depending on fry size when released into the pond. Overall survival from releasing to harvest varies from 60-80% which yield roughly 350 g/m^2.

Various methods are employed to harvest shrimp from the grow-out pond. A pound net to trap and pump-net were used before and a pulse net utilizing electric shocks has been often used recently. Harvested shrimps are packed in cartons with cooled sawdust for transport. Culture shrimps are marketed between 8-100 g. Shrimp of higher price weighs between 25-30 g.

Production constraints. Shrimp culture might be using the most sophisticated techniques in marine aquaculture. Any obstacle along the various production processes influences directly the yield in tanks and ponds. The problems in induced spawning are still to be solved. Production cost must be reduced by modifying present feeding and breeding techniques. For comparison, yield per m^3 per annum is 5-10 kg for finfish, 10 kg for oysters, but only 400 g for shrimp.

MOLLUSC CULTURE

Broodstock Production

Rearing facilities. The total number of hatchery-reared shellfish is 19 species but only 12 species of the 19 are propagated artificially for aquaculture. Culture of edible mollusc is classified as to source of seeds as follows: wild seeds — short neck clam, oyster, half-crenata ark, pecten, and scallop; hatchery-bred seeds — blood ark shell, noble scallop, hard clam, top shell, and abalone. Blood ark shell and noble scallop are cultured artificially from egg stage to marketable size. Hatchery-raised abalones are usually released into the sea and harvested after grow-out.

Rearing facilities of broodstock are needed only for the latter species. A tank smaller than 3 m^3 is generally used for stocking shellfish. Some substrates (sand and/or mud) are occasionally provided in tanks.

Rearing method. Generally wild spats, except for clams, are collected in the sea by different kinds of collectors, namely, shells, plant leaves, and synthetic filaments. For the clam, burrowed seeds are collected at shallow coastal waters, then transplanted to the grow-out area.

Spawners caught in the wild are transferred to broodstock tank, and maintained at a density of 10-50 ind/ m^3 Various manipulations are conducted to induce natural spawning. UV irradiation and temperature are widely used to induce spawning in abalone and blood ark shell in hatcheries.

Feeds and feeding. Usually no feeding is carried out in breeding bivalve broodstock. However, if necessary, cultured phytoplankton (*Pavlova lutherii* and *Chlorella* sp.) are given. The gastropods are fed with *Laminaria, Undaria, Ulva,* and other seaweeds.

Capture, handling, and transport. Most spawners are caught by capture fisheries during the maturing season, then transferred to the hatcheries. Handling and transport are easier for shellfish than for finfish and crustaceans. Sex is determined only when spawners are dissected or to eliminate the gametes.

Disease control. No particular procedures are conducted to prevent diseases. Physically damaged individuals and moribund ones are immediately removed to avoid unexpected infestation.

Production constraints. With the development of fishing techniques, larger spawners have become scarce year by year. It has become increasingly difficult to procure sufficient number of spawners.

The techniques of inducing maturation are desirable for shellfish. In addition, predicting the settling of spats is a prerequisite for stable production of each species.

Seed Production and Nursery Operation

Rearing facilities. Larval culture of the blood ark shell is carried out in indoor tanks of 0.5-1 m^3 capacity. Small and circular tanks made of polycarbonate are preferred by culturists because these tanks arc effective in keeping a high density of diatoms and in distributing larvae evenly in the tank. Light aeration is provided with an air filter. Light intensity is controlled by covering the tank with sheets. Rectangular rearing tanks used in abalone culture vary between 1 and 6 m^3 with 1 m depth. Different kinds of facilities are employed for nursing. Lantern net is popular for the culture of scallop, pecten, and single oyster, and wire of vegetable cages, for the blood ark shell.

Rearing method. Naturally spawned eggs of the blood ark shell and abalone are collected by fine-meshed net, and washed well with filtered sea water. Fertilized eggs then are maintained at a density of 1-2 eggs/ml. Either no exchange, or 10-30% of rearing water is changed during breeding. The rearing water is aerated at 100-200 ml/ min.

Larvae are fed with cultured phytoplankton at an optimal concentration according to size or age of larvae. Spat collectors are introduced to the rearing tank when larvae of the blood ark shell have attained about 240 µm. The plastic plate on which the diatoms grow is placed 5-7 days after hatching in the case of the abalone. Nursery breeding of the blood ark shell starts when the larvae are about 1-2 mm, 60-70 days after spawning. Small seeds of the blood ark shell are maintained in the cage, then hanged from the raft or buoy in the sea. More than 10 000 seeds of 1-2 mm are stocked per m^2 at beginning of nursing, and stocking density, cage size, and mesh size are changed as shell length increases. Hardening is always necessary to avoid high mortalities during summer and autumn in nursing oyster seeds.

Feeds and feeding. Diatoms used for rearing shellfish larvae are *Pavlova lutheri, Chaetoceros gracilis, Chaetoceros calcitrans, Skeletonema* sp. etc. These phytoplankton are cultured purely in high density using chemical nutrients. Cultured diatoms are given solely or mixed. Larvae of blood ark shell are fed in the early stages about 5000 cells/larva and the density is increased with larval growth. No feed is given to the blood ark shell during the nursing period when they reach more than 1.0 mm. For the abalone, seaweeds *(Ulva* and *Undaria)* are usually given in the nursery and grow-out in the sea. No food is given to bivalves after transfer to the sea.

Disease control. In the rearing tank of the blood ark shell, contamination by protozoans especially *Hypotrichida* occurs. The use of sodium hypochlorite solutions is effective in removing the harmful organisms . Rearing water is usually changed completely when harmful organisms are found in the rearing tank.

Harvesting. The survival rate of the cultured blood ark shell is about 10% from egg stage to 10 mm size, and 30-50% afterwards until 20-30 mm. On the other hand, about 1% survival is obtained from egg to 10 mm length for the abalone, then 50-80% until 20-30 mm.

Transport and counting of shellfish are easier than with other cultured animals because they can be moved separately and they settle individually on the substratum.

Production constraints. Survival among shellfish at early stage of development is very low especially in abalone. This may be due to the poor techniques used in induced spawning and poor quality of spawner and egg. To increase shellfish production in aquaculture, the common problems of obtaining sufficient quantity of viable eggs and the mass production of phytoplankton have to be overcome. In addition, techniques to rear cultured seeds to spawner must be developed to ensure high production.

Production of Marketable Shellfish

Rearing facilities. The oyster raft is the most sophisticated facility. It measures 10 × 20 m with 600-800 hanging strings, each 10 m long. The blood ark shells are maintained in large iron-framed cages (1 × 1.5 × 0.3 m) at the sea bottom. A cone net, 50 cm dia and 2 m height, is widely used at a density of 15-18 shells/level for culturing 10 cm scallop in northern Japan.

Rearing method. Blood ark shells, about 3 cm, weighing 5.0 g, are caged at 1500-2000 ind/ m^3 Stocking density is reduced with shell growth. Bottom culture is also carried out in the natural farming ground when the blood ark shell attains a length of 40 to 60 mm. Before releasing, starfish should be removed frequently by bait trap. The wild spats collected artificially are cultured by hanging methods (raft and long-line) for the oyster. The transplantation of the short neck clam is the common method performed in the coastal waters by fishermen. About 1 cm seeds of short neck clam are sown on tideland and cultured to marketable size.

Feeds and feeding. Short-term culture of the abalone for commercial purposes lasts a couple of months or more with *Undaria* and *Laminarta* as food.

Disease control. Diseases are relatively rare in shellfish aquaculture in the sea. About 15 years ago, mass mortalities of cultured oyster by adhesion of the annelid, *Hydroides elegans,* occurred. *Polydora* sp. and *Asterias* spp. are also harmful to various shellfishes cultured by the hanging and sowing methods. The harmful animals are usually removed by hand, drying, and bathing alternately in fresh water and high concentrated salty water. Generally, eradication of fouling animals, such as barnacle and mussel, is conducted by predicting the spawning and settling season around the farming ground.

Harvesting. The blood ark shells are harvestable in about one year following nursery operation. They grow to about 60 g with 50-60% survival in one year, and more than 150 g weight with 10-20% survival in two years. Released seeds for sowing culture are harvested by small dredge net. Yield of oyster meat per raft of 200 m^2 amounts to 2.0-2.5 mt. It takes about 1.5-2 years from spat hanging to harvest. Shellfishes are marketed shucked or with shells.

Production constraints. The eradication of predators and fouling animals is of primary importance in the shellfish aquaculture industry. Bait trap is effective and other practical measures are used to remove the starfish during the bottom culture of the blood ark shell in the natural ground. Unexplained phenomena of oxygen deficiency which is lethal for caged and liberated shellfish occur incidentally not only in the fisheries ground but also in the farming ground. Recently, high density cultivation has resulted in decreasing yield per unit of facilities or area and has retarded the growth of oyster culture in Hiroshima and of scallop culture in Aomori. How to keep the ecological balance between the total crop of cultured animals and the natural productivity is a common problem that should be solved to stabilize production in mollusc aquaculture.

Table 13 lists the shrimp and shellfishes cultured in Japan.

SEAWEED CULTURE

Rearing facilities. Nori (*Porphyra*), Wakame (*Undaria*) and Konbu *(Laminaria)* are typical, edible seaweeds in Japan. Indoor facilities are used in the culture of these species to obtain buds for further cultivation. The facilities for Nori and Wakame culture consist of a concrete tank 2-3 m with 70-80 cm depth, square and rectangular, a roof curtain for regulating illumination, a temperature control system and ventilation. A smaller container of about 100 1 is used for Konbu. Growing operation is carried out in the facilities at sea; floating-net system and stick method for Nori, and raft and long-line method for Wakame. Longer rope, more than 100 m, is used for Konbu culture.

Rearing method. Seaweed cultures are initiated by collecting spores released from the mature plants. The seedling is transplanted by using synthetic material when the temperature goes below 24°C for Nori, 20°C for Wakame, and 10-15°C for Konbu. The string and net with young buds are transferred to set them on the facilities at sea in autumn. Farming grounds suitable for Nori culture are the littoral zone and coastal waters of 10-30 m depth with slow current. Wakame is cultured in farming grounds with waves and fast current. The Nori, Wakame, and Konbu grow well during winter.

Diseases and parasites. The prevention and treatment of two diseases caused by *Olpidiopsis* sp. and *Pytium porphyrae* are well known. Nori buds are generally stored at freezing temperature to make them resistant to diseases. In Wakame culture, damages caused by bacterial diseases and predation of young buds by isopods and gastropods are often observed.

Harvesting. The first Nori harvest begins when the buds are 15-20 cm in length and the second crop is harvested 2-3 weeks later. Thus, harvest is repeated during winter between November to March or April. Collected Nori plants are processed usually into dry product. As for Wakame, full-grown weeds more than 1 m are harvested when the temperature goes below 15°C. The yield of Wakame varies between 5 kg and 10 kg/m rope. The harvested Wakame is processed by drying, raw pack, and salting. The cultured Konbu is harvested from July to August and dried as a product.

Production constraints. Seaweed culture is largely influenced by weather conditions and disease which in turn cause large fluctuations of annual yield. Technical development and genetic research are expected to solve these problems. Expansion and conservation of suitable farming grounds are needed to increase production. Deterioration of farming ground is usually found in areas of high density culture and where culture activity is maintained for a long time.

Table 13. Major shrimp and shellfish cultured by hatchery techniques and their production status

Species		Annual production (million)	Seed size (mm)
Kuruma prawn	*Penaeus japonicus*	715	10-60
Abalone	*Nordotis discus discus*	30	10-40
	Nordotis discus hannai		
	Nordotis madaka Habe		
	Nordotis gigantea		
Blood ark shell	*Scapharca broughtonii*	15	1-20
Pecten	*Pecten albicans*	3	5-40
Scallop	*Patinopecten yessoensis*	3	5-60
Noble scallop	*Chlamys nobilis*	4.5	10-30
Top shell	*Turbo (batillus) cornutus*	0.6	1-30

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AQUACULTURE DEVELOPMENT IN MALAYSIA

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ABSTRACT

Malaysia is a fish-consuming country with fish representing 60% of a total animal protein intake. At an annual per capita consumption of 32 kg some 560 000 mt of fish is required for the projected of 17.5 million people in year 2000.

Coastal marine capture fisheries, the mainstay of Malaysia's fish supply, has not shown any increase in landings over the last few years. In fact in 1985 there was a decline of 3.7% compared to 1984 fish landings. This declining contribution of marine fisheries is compensated by an increase in aquaculture production. In 1985, aquaculture contributed 51 709 mt to the total fish supply. This represents 10% of the total fish landings of 514 570 mt or 13% of total table (edible) fish landings.

Malaysia does not have a long standing aquaculture tradition unlike its neighbours in the Indo-Pacific. Even then, the industry has seen rapid growth in the last few years. Today there are 19 species of finfishes, crustaceans and shellfish cultured in the country. The main freshwater fish species bred and cultured are bighead carp *(Aristichthys nobilis),* grass carp *(Ctenopharyngodon idella),* common carp *(Cyprinus carpio),* Indonesian carp *(Punctius gonionotus),* catfish *(Clarias macrocephalus* and *Pangasius* spp), snakefish gourami *(Trichogaster pectoralis)* and tilapia (mainly *Oreochromis niloticus).* Marine finfishes bred and cultured are sea bass *(Lates calcarifer),* grouper *(Epinephelus* sp.)

and snapper *(Lutjanus johni). Penaeus monodon* is the dominant marine prawn species bred and cultured but culture of *P. merguiensis* is receiving considerable interest. *Macrobrachium rosenbergii* is the only freshwater prawn cultured commercially. Molluscs cultured are the blood clam *(Anadara granosa)* and the green mussel *(Perna viridis).*

In 1985, blood clam and mussel culture accounted for 87% of all aquaculture production of Malaysia, freshwater fish 12%, floating cage culture of marine fish 0.7% and brackishwater pond culture 0.3%. In terms of value blood clam and mussels represented 30% (M$15M) of total value (M$49.5M), freshwater fish 57% (M$28M),cage culture of marine fin fishes 7% (M$3.4M),and brackishwater pond production 6% (M$2.1M).

Aquaculture in Malaysia has considerable growth potential. It is projected that 22 000 ha of mangrove will be opened by the year 2000 for shrimp culture. Some 330 000 m^2 of protected coastal waters have been identified for cage culture. Some 6500 rafts can considerably expand the present capacity. In freshwater culture about 8000 ha of land and 17 500 ha of mining pools can be developed while 200 000 ha of artificial lakes and impoundments for freshwater fish cage culture are available. Yet such development is not without constraints. Freshwater finfish culture is hampered by lack of good quality broodstock. There is also a limited market for freshwater finfishes. Marine finfish culture is limited by lack of fingerlings and good quality compounded diet to replace trash fish which is deteriorating in quality and quantity. Marine prawn culture is heavily dependent on wild spawners, the supply unpredictable and inadequate. Acid sulfate soil continues to cause the deterioration of brackishwater ponds. Cockles and mussels can be sold to export markets only if they meet specific quality standards.

PRODUCTION AND DEMAND FOR FISH AND FISH PRODUCTS

Malaysia is essentially a fish-consuming country. Fish plays a major role in the average diet of Malaysia, accounting for 60% of total animal protein intake.

Two noteworthy attempts have been made to project the demand for fish. A projection offers a "high" and "low" option. The "high" demand projection starts with a base per capita consumption of 26.8 kg for 1973 increasing to 30.9 kg for 1995. The "low" demand project takes 26.6 kg as constant throughout the period. In 1981 the Fisheries Development Authority published a similar study indicating the capita consumption as 43.4 kg in 1980, 49.0 kg in 1985, and 54.1 kg in

1990. The methodology employed in both these formulations are essentially similar. The only difference lies in the value of the parameters adopted.

A recent survey conducted by the Research Survey Malaysia (RSM) for the Federal Agricultural Marketing Authority has produced empirical data to show that the per capita fish consumption (unweighted) for Malaysia as a whole is approximately 21 kg. This suggests a daily intake of 6.2 g/head which represents about 17.6% of the animal protein intake (of 35.3 g) of an average person. In the light of the RSM findings it may be necessary to revise the earlier demand projections. As a rough approximation, assuming that the per capita consumption is 32 kg, an annual production of 560 000 mt fish is required to meet the requirement of the projected population of 17.5 million people in the year 2000.

The coastal marine capture fisheries, hitherto the mainstay of Malaysia's fish supply, however, has shown no increase in landings over the last few years. The quantity of marine fish landings in 1985, for example, actually declined by 3.7% over the preceding year, while the wholesale and retail value of marine landings decreased by 0.8% and 3.3%, respectively. Exports also declined both in terms of weight as well as value. On the other hand, value imports increased by 4.4% although the quantity imported remained somewhat stable. Aquaculture production was also on the upswing, contributing 51 709 mt to total fish supply.

Most aquaculture products find a ready domestic or export market. Freshwater fish is consumed almost entirely by the domestic market although some are exported to Singapore. The market base is small and variable. Different communities consume different species in different forms and freshwater fish is not staple among any of them. The urban market is dominated by Chinese carps for the fresh fish market while tilapia and cat fishes are consigned to the live fish trade. Outside major urban areas, demand is for fresh tilapia, Indonesian carp and catfish. There is no live fish market. The marine finfish industry also caters largely to the live fish trade. Shellfish, both the blood clams as well as mussels, are sold at wet markets throughout the country. Most cultured shrimps are channeled to the export market. Live shrimp is exported to Singapore but the bulk is frozen and exported to Japan. Some of the small farms do, however, dispose of their produce in local markets.

PRESENT STATUS OF THE AQUACULTURE INDUSTRY

Malaysia does not have a long standing aquaculture tradition unlike its neighbors in the Indo-Pacific Region. In spite of that, the industry has seen rapid growth in the last few years.

Aquaculture began only in the early 1900's with the culture of Chinese carps in mining pools. In the mid-1930's, shrimp trapping ponds developed as a major industry in the southern state of Johore. The culture of blood clams began only as recently as 1948.

While semi-intensive culture of freshwater organisms and extensive culture of blood clams dominated the 1950's and 1960's, things began to change in the last two decades. Cage culture of marine fish and raft culture of mussels began in the early 1970's. More significantly, is the growing corporate involvement in the aquaculture industry, particularly in shrimp farms. Today there are over 19 species of finfish, crustaceans, and shellfish cultured in the country.

In 1985, some 51 709 mt of aquaculture products with a total value of M$49.5 million (US $1 = M$2.50) was landed by the industry. This amounted to about 10% of total fish landings (514 540 mt). However, a comparison of this nature is highly misleading, given the fact that aquaculture deals with table products. Landings from marine capture fisheries consist substantially of trash fish which has no human food value. On the basis of edible fishery landings, the role of aquaculture is much enhanced, accounting for 13% of total table fish landings. The growth rate of productive assets of the industry also indicates how far it has progressed within the last few years. Blood clam culture areas grew by 25% from 4000 ha to 5000 ha in 1980-1985. The freshwater fishpond culture, however, recorded a negative growth of 18% in area (5158 ha to 4226 ha) although there was a positive growth of 25% in the number of ponds operated (14 459 to 18 087). Brackishwater ponds grew rapidly from 100 ponds (30 ha) in 1980 to 481 ponds (455 ha) in 1985, representing a 381% increase in the number of ponds and 1400% increase in area. The growth rate of floating cage culture was similarly impressive. Starting with only about 100 units with an effective culture area of 1204 m^2 in 1980, the industry grew to 6835 units with a net area of 82 339 m^2 in 1985. Similarly, mussel culture grew by 1000% over the same period from 20 to 200 rafts.

In terms of production volume, the culture of blood clams and mussels is the most significant rearing activity undertaken. In 1985, these molluscs accounted for 87% of all aquaculture production. The culture of freshwater fish weighed in next at 6362 mt or 12% of total production. The cage culture of marine fish was the third largest, amounting to 408 mt or 0.7%. Brackishwater pond production which landed 180 mt or 0.3%, ranked last.

In terms of value, however, the figures change considerably. Blood clams and mussels, despite their volume, were estimated at M$15 million or 30% of total value. The freshwater fish production was estimated at M$28 million or 57% of total value. Cage culture of marine finfish contributed a creditable M$3.4 million (7%) while brackishwater pond culture production was valued at M$ 4.1 million or 6%.

In terms of the number of people gainfully employed in the industry, again the freshwater aquaculture industry takes the lead. In 1985, a total of 13 047 culturists were employed in the production of a variety of freshwater fish in ponds or cages. This represented 93% of the total workforce of the aquaculture industry. However, there were few employed full-time. Most were farmers involved in agriculture, animal husbandry, or both, who undertook fish culture part-time. The blood clam culture sector employed only 199 full-time culturists or 1.4%. Cage culture of marine finfish employed 503 (3.6%) while mussel culture, 60 (0.4%). The brackishwater pond culture employed only 1.6% of the workforce underscoring its essentially capital intensive nature.

Malaysia has considerable growth potential for aquaculture. The government, in fact, has identified aquaculture as a priority industry and efforts are being made to actively promote investment. Among the major growth sectors, the following stand out:

1. *Shrimp culture in ponds.* Malaysia has over 570 000 ha of mangroves that can be developed for shrimp culture. Given the vital role that mangroves play in coastal ecosystems, development will be limited to a maximum of 20% of the existing area. This means that over 110 000 ha can be made available for shrimp culture purposes. It is anticipated that by the year 2000, about 22 000 ha of mangroves will have been developed for shrimp culture.

2. *Cage culture of marine finfish.* *A* total of 330 000 m^2 of protected coastal waters have been identified for cage culture of marine finfish.

3. *Mussel culture.* The growth of this sector is limited to areas of mussel spatfall. Studies indicate that present capacity may be extended by another 6500 rafts.

4. *Freshwater fish culture in ponds and mining pools.* The resource potential for this sector is good. It has been estimated that there are over 8000 ha of land and 17 200 ha of mining pools that can be developed for freshwater fish culture.

5. *Freshwater fish culture in floating cages.* The prospects for this sector is even more encouraging. By the year 2000, it is expected that there will be over 200 000 ha of artificial lakes and impoundments in which cage culture may be developed.

In short, the resource base for aquaculture is very large and the prospects for development are excellent. The government has instituted numerous fiscal policies ranging from credit with subsidized interest rates, tax exemption, pioneer status, and other factors to encourage investment. Steps are being taken to facilitate land and resource alienation to ensure low-entry costs.

PRESENT STATUS OF PRODUCTION TECHNIQUES

Freshwater Finfish Culture

Broodstock production. The main species commercially bred are the Chinese and Indonesian carps followed by the snakeskin gourami, tilapia, and the catfishes. Fry supply for the culture of these species is mainly from government hatcheries but a small number of private hatcheries also carry out the natural breeding of selected species such as the common carp *(Cyprinus carpio)* and the tilapia *(Oreochromis* spp.*)*

Government hatcheries undertake artificial propagation of some Chinese carps, specifically the big head carp *(Aristichthys nobilis)* and grass carp *(Ctenopharyngodon idella).* Other species similarly bred include the Indonesian carp *(Puntius gonionotus)* and the catfishes *(Cla-*

rias macrocephalus and *Pangasius* spp.). Natural propagation of the snakeskin gourami *(Trichogaster pectoralis),* common carp *(Cyprinus carpio)* and tilapia (mainly *Oreochromis niloticus)* is also undertaken by these hatcheries.

The size of broodstock ponds depend on the species cultured. For carps, pond size of about 0.2 ha are common and for snakeskin gourami and tilapia, much smaller ponds of 0.1 ha or less are used. Broodstock of *Clarias* spp. are also kept in 100 mt tanks. Depending on the species of broodstock both monoculture and polyculture are practised. In polyculture, the common combinations are the common carp/bighead carp and grass carp/bighead carp. Generally, broodstock are kept at low densities of 1500 kg-2500 kg/ha.

In most establishments static water conditions with regular water exchange of 5-10% a day is common management practice. To ensure optimal conditions, water quality is monitored regularly. The desired fecundity of broodstock is achieved by using formulated pellet feed with a protein content of 32-40% containing mainly fish meal, rice bran, and maize, fed at 3 to 5% of body weight. Freshly prepared ground nut meal and grass are also used. Wet feeds consisting of trash fish and boiled rice as well as pelleted feeds, are fed to *Clarias* spp. The broodstock are checked weekly for gonadal development. Spawning is induced by HCG (Human Chorionic Gonadotropin) and Carp Pituitary Extract.

Spawners are handled carefully to prevent injury and subsequent bacterial infections. Prior to capture, spawners are pre-stressed. Parasitic diseases such as *Oodinium* sp., *Lernaea* and *Ichthyophthirius* sp. are common. *Oodinium* is treated with methylene blue, *Lernaea* with salt and Abate, and *Ichthyophthirius* sp. using biological methods such as flushing.

One of the major constraints delimiting the hatcheries is the lack of good quality broodstock. Aside from the Chinese carps which are imported from Taiwan, breeding of other species rely on a limited broodstock that owes its origins to stock imported during the late 1950's. The Department of Fisheries is currently working to broaden the genetic pool by importing brood fish from other countries. In particular, Indonesian carp *(Puntius gonionotus)* and common carp *(Cyprinus carpio)* have been imported from Indonesia and crossed with local strains. Tilapia *(Oreochromis niloticus)* stock has also been imported from Thailand. Efforts are underway to similarly import brood fish of different species from diverse sources to prevent inbreeding from existing stock.

Seed production and nursery operations. In the seed production of freshwater finfish, simple facilities such as earthen ponds and to a limited extent concrete, high density polyethylene and fiberglass tanks are used for spawning and nursery rearing. These facilities are normally small to accommodate 4-6 breeders. Larval rearing is usually carried out partly *in vitro* and partly in well prepared and fertilized ponds, about 0.1 ha in size. Outside of micro-encapsulated egg, no formulated larval feeds are used. The pond-rearing phase depends entirely on natural pond productivity. The average size of fry harvested is 2.5 cm. Fry are transported in oxygenated plastic bags.

The breeding of grass carp has posed problems particularly in obtaining gonadal maturation. Nevertheless, attempts to breed this species is still going on because of the demand for fry. Culture of local cyprinids has a good potential but fry production is hampered by lack of knowledge of the biology and larval grow-out. Even for currently cultured species, fry production (nursery stage) is still dependent on natural food. To intensify production, development of formulated feeds for larvae is necessary.

Production of table fish. The total production of freshwater finfish in 1985 was 6362 mt valued at M$28 million. This figure is, in fact, thought to be somewhat pessimistic, since collection of accurate production data from many semi-commercial farms is somewhat problematic. Production of freshwater fish is probably closer to 15 000 mt. Production is mainly from excavated ponds (17 424 ponds; 2962 ha) followed by culture in mining pools (663 pools; 1236 ha), floating cages (862 units; 14 321 m^2). Pond culture is carried out generally in small ponds, 0.2 ha-1 ha, and managed on extensive and semi-intensive system, or even on a subsistence level. In pond systems, polyculture and stocking densities of 1000-5000 fish/ha in various combinations is a common practice. The stocking density can increase to 15 750 fish/prawn/ha in the polyculture of the freshwater prawn *(Macrobrachium rosenbergii)* and finfish.

Mining pools are irregularly shaped bodies of water, 0.4-10 ha, a consequence of Malaysia's huge tin-mining industry. Serving as water resource ponds to active mines, they are, however, left abandoned after the mine is exhausted. These pools have been, for decades, used for fish culture. The commodities cultured have been limited to species such as grass carp, bighead carp, and tilapia. Demersal species such as the common carp and freshwater prawn are not generally cultured given the extremes of depth (20-40 m) mining pools are likely to have. Stocking densities of cultured fish is about 1500-2000 grass carp in about 500-600 ha. Both ponds as well as mining pool culture are undertaken in consonance with complementary agriculture and animal husbandry activities. Tri-commodity integrated farming consisting of crops (vegetable, tapioca, bananas, etc.), livestock (pigs, cows, goats, chickens, ducks) and freshwater fish, is, in fact a major feature of Malaysian freshwater aquaculture.

Floating cage culture of freshwater fish is also undertaken particularly in the Cenderoh hydroelectric impoundment and the Durian Tunggal reservoir. Both water bodies are huge, man-made impoundments enough to sustain this system of culture. The culture is intensive and centers around monoculture of grass carp and catfish *(Pangasius* spp.), both about 12 pieces/m^2 Indonesian carp and tilapia, both about 36 pieces/m^2.

Wet feeds such as chicken intestines and broiler mash combined with ground nut meal and grass are commonly used in all three systems. Some commercial culturists use formulated pelleted feeds. The common parasites encountered include *Trichodina* spp., *Piscinoodinium* sp., *Lernaea* sp., bacterial infections caused by *Aeromonas hydrophila* and *Pseudomonas* sp. are also prevalent. Among the commonly cultured species, the Indonesian carp is the most susceptible to parasitic and bacterial infection. Other species such as grass carp and tilapia are also susceptible but to a lesser degree. For the treatment of *Piscinoodinium* sp. in the Indonesian carp, copper sulphate at 1.0 ppm is effective on adult fish.

Harvesting of marketable fish is commonly carried out by the fish buyer who supplies nets and manpower for harvest. Harvested fish are transported live in aerated fiberglass containers.

Finfish production on a commercial basis is being encouraged by the government to ensure self-sufficiency in fish production. The strategy involves more comprehensive use of existing water such as impoundments and reservoirs and the application of intensive production technologies. The biggest constraint holding back the industry is market. At present the market is limited to specific communities with small volume. Thus, to expand the industry there is a need to develop new markets through campaign as well as product development to diversify the existing market base.

Marine Finfish Culture

Broodstock production. A substantial amount of fry for marine finfish farming is imported. Of late, however, the government hatchery at Tanjung Demong, Trengganu has started production of sea bass, *Lates calcarifer* seed. Preliminary runs for the production of grouper *(Epinephelus* sp., fry have also been started. There are, at present, no commercial hatcheries producing marine finfish fry.

Broodstock for the Tanjung Demong facility is obtained from the center's own cages and/or purchased from fishermen. This combination of cultured and wild broodstock will obviate any inbreeding in fry produced. Each brood fish weigh about 4-7 kg. They are maintained in 100-t circular concrete tanks. Feeding is entirely with trash fish at 1-2% body weight.

Neither maturation nor spawning is induced artificially. Spawning occurs naturally during full moon and eggs are collected and hatched. There is minimal handling of spawners, and fish are treated only if injury is observed after spawning.

There is a need, however, as in the case of freshwater fish, to maintain a broad genetic base by constantly supplementing the existing broodstock pool with individuals from diverse population. While, at this point in time, no genetic aberration due to inbreeding of existing stock has been observed, nonetheless, given the fecundity of sea bass, that kind of scenario is probable in the near future.

Seed production and nursery operation. Eggs collected from spawning tanks are transferred to the hatchery and stocked in 500-1 fiberglass containers. Hatching occurs within 12-16 hr. The day-old fry are fed with rotifers grown on *Chlorella* and *Tetraselmis* cultures. Around the 8th-9th day, the fry is fed with *Artemia* nauplii. This continues for about 30 days when the fry are about 1.5 cm. Weaning to trash fish then begins. The fry is reared to 2.5 cm and sold to farmers. There are a number of nursery operators who purchase yolk-sac or 8 days old and rear them to commercial size.

No disease of any consequence has yet been reported. However, given the rapidly growing demand for sea bass fry, the existing capacity of the Tanjung Demong hatchery is stretched to the maximum. The growth of a viable nursery industry would, in fact, substantially reduce the load of the hatchery and free its facilities for spawning. However, the nursery operators are still beginners and have yet to attain the production level of the station for them to effectively take over its seed production function.

Production of table fish. Cultured fish include mainly sea bass *(Lates calcarifer),* grouper *(Epinephelus* sp.), and snapper *(Lutjanus johni).*

Farming of marine finfish is normally carried out in cages (5973 units, 68 018 m^2) and, to a limited extent, in ponds (30 ponds, 20 ha). The latter is confined mainly to the East coast of Peninsular Malaysia where suitable sites for cages are limited by rough seas particularly during the monsoon seasons.

Cage culture sites are limited to protected coastal waters with appropriate water quality. Each floating cage system consists of the net-cage and the frame supporting it. The frame is kept afloat usually by plastic drums or styrofoam blocks coated with fiberglass. The system is held in position by anchors, usually of concrete blocks, or wooden pegs.

Depending on their use, net-cages can be of different dimensions and meshes and can usually be classified into 3 classes (Table 1). Each cage system can be from 1 unit (4 cages) to a maximum of 15 units (60 cages).

Both tidal as well as levee ponds are used for finfish culture. Pond sizes are small, about 0.4 ha each.

In cage culture, rearing is divided into 3 phases; the hapa stage, nursery, and the grow-out stages. The technique reduces cannibalism in culturing fish.

In pond culture, the nursery stage is normally carried out in smaller ponds; the fish are transferred later to another pond for grow-out. Size grading is thus carried out only once. Since this method is ineffective in substantially reducing cannibalism, stocking densities are relatively low.

Table 1. Types of nets commonly found in cage system

Net Type	Dimensions	Mesh Size	Uses
Hapa net	2 × 2 × 2 m	8 mm	for nursing fingerlings of 10 cm or less
Nursery net	2 × 2 × 2 m	25 mm	for nursing fingerlings up to 15 cm
Grow-out	5 × 5 × 3 m	20-50 mm	for grow-out to marketable size

After each culture cycle the net-cages are cleaned of biofoulants by using strong water jets. Torn nets are replaced and repaired during this period.

Before the next culture cycle is carried out, ponds are flushed daily to remove excess sediments and waste from the last culture. Upon starting the next culture, the pond is drained and teaseed cake is applied to water left undrained to ensure effective eradication of potential predators or competitors. After application of lime and rice bran, the pond is filled with water again to about 50 cm and fertilized with triple superphosphate and urea to induce plankton bloom. A day or two before stocking the fry, the water depth in the pond is increased up to a meter.

Stocking is normally done early in the morning after the fry have received prophylactic treatment against diseases. Stocking density varies with the type of culture system practised. The fry, which normally are transported from quite a distance, are first conditioned to the local conditions before stocking. The stocking density in nursery cages is 300-350/m^2 initially. Stock is gradually thinned out, both to reduce its density and to size-grade the fry to reduce cannibalism. The fish, each weighing about 300 g, are transferred to the rearing or grow-out cages normally in about 3 months. The stocking density is thus reduced from 300-350/m^2 to about 100/m^2.

In pond culture the fish fry are stocked at a much lower density. In nursery, the stocking density is normally only about 25 fish/ m^2 and reduced further to 1-3 pieces/m^2 when they are transferred to the grow-out pond after about 2 months. Grading is carried out only during transfer from nursery to grow-out pond.

At present the feed given to cultured species is trash fish. A newly formulated feed meant for sea bass is still being tested with encouraging results. Feeding to satiation is done once or twice daily at 3-10% depending on fish weight.

High mortality normally occurs during early stages, especially in the first few days after stocking. This is mainly due to stress from transport and handling.

Diseases encountered in fish culture are bacterial fin rot, vibriosis, streptococcosis, saprolegniasis, and ichthyosporidosis. Some of the major parasites found in cultured fish with substantial frequency are crustaceans and flatworms. Cultured fish reach market size of about 500 g in 6-8 mo. Average survival per stocking is about 50-60% in cages and 30-70% (at lower stocking) in ponds. The greater range in survival rate in pond culture is due mainly to cannibalism which occurs at higher stocking. The expected harvest from cage culture is about 600 kg/cage compared to an average of 500 kg/ha of pond.

The main constraint setting back finfish culture at the moment is the supply of fingerlings. Even though the hatchery technology for sea bass has progressed so much so that it can ensure adequate supply of hatchlings, the nursery technology, for the production of juveniles having the right size for stocking in ponds and cages, still lags behind. Aside from sea bass seed, the supply for other species such as grouper and snapper still depends on the natural source. Disease is the other factor that needs to be looked into to increase production in finfish culture. The use of trash fish in finfish culture is a problem since supply is deteriorating both in quantity and quality. There is a need therefore to formulate a suitable fish feed. The production of finfish per hectare in pond culture is still very low compared to that of cage culture. The main problem in finfish pond culture is the inability to conduct feeding and grading of fish and other activities that require close supervision and efficient management.

Prawn Culture

Broodstock production. Among the marine prawns, *Penaeus monodon* is extensively cultured with *P. merguiensis* also receiving considerable interest. The giant Malaysian freshwater prawn *Macrobrachium rosenbergii* is the only freshwater prawn cultured on a commercial scale. The marine prawn industry is still heavily dependent on spawners caught from the wild by trawlers. To ensure better survival, the trawling duration is considerably reduced. Spawners are usually collected from the sea by middlemen who rush the spawners to landing points by speed boats. They are then sent to hatchery operators in plastic bags at reduced water temperature by road or air depending on the distance involved. A significant number of small hatcheries are still completely dependent on wild gravid females and have no maturation facilities. The bigger hatcheries generally carry out eyestalk ablation and are, therefore, willing to accept non-gravid spawners from the wild. Hence, there is no rearing of broodstock in the real sense. Wild non-gravid females of adequate size are kept in maturation tanks with more or less equal number of males. The maturation diet consists mainly of squid, mussel, chicken liver, oyster, and maturation pellet. The prawns are fed twice a day; the feed adjusted regularly depending on the left-over from previous feeding. Eyestalk ablated females may spawn up to five times, although the average number of spawning per female is two. The first spawning may occur on the third day after ablation.

As mentioned earlier the industry is heavily dependent on wild spawners, the supply of which cannot be assured at all times. While the pond-grown males mature spontaneously in captivity, the pond-grown females do not respond even with eyestalk ablation so that further work is needed to ensure adequate supply of spawners for the industry.

On the other hand, *Macrobrachium rosenbergii* broodstock supply is not a problem as the pond-grown prawn mates and spawns readily in tanks or ponds throughout the year. To reduce inbreeding, however, wild prawns are also used as broodstock whenever available. Overfishing and water pollution have resulted in the decline of the natural prawn resource. To overcome the problem, the government has initiated an open water stocking program and released large numbers of fry in the riverine system. As a result, even spawners caught from the wild may in fact, really come from the stocked prawn. The intention of using 'wild spawners' to increase the genetic pool and to reduce inbreeding may not be achieved. Aside from this consideration there is no major constraint to broodstock production of the freshwater prawn.

Seed production and nursery operation. Rearing facilities for seed production of the marine prawn vary from hatchery to hatchery depending both on the scale of operation and the culture system adopted. Generally, either rectangular or cylindrical tanks are used. The tanks are either of concrete or fiberglass. The size of tanks varies considerably for extensive system where spawning, hatching, and larval rearing all take place in the same tank. The tanks are large and may be in excess of 50 t. For hatcheries adopting the intensive culture system, where stocking density may be over 100/1, smaller tanks (2 t) are used. Larval feed consists of live phytoplankton initially followed by brine shrimp nauplii toward the later stages. Depending on the system adopted, the phytoplankton may be cultured in pure form in separate tanks under controlled conditions or in outdoor tanks where mixed endemic species of diatoms are maintained. The larval rearing tanks may also be fertilized to maintain a healthy phytoplankton population. While Baker's yeast is used to some extent, artificial larval feeds are still costly and thus not widely accepted. Formulated feeds are generally introduced only at PL_5 to supplement brine shrimp nauplii.

Bacterial contamination which result in necrosis of the larvae and often heavy mortality is common. Chloramphenicol and furazolidone are used for both prevention and control. Contamination of larvae by fungi (*Lagenidium* sp., *Sirolpidium* sp., and *Fusarium* sp.) is common and Treflan is generally used as a preventive measure.

Besides the supply of wild spawners, the major constraint to hatchery production of marine prawn fry appears to be the heavy dependence on phytoplankton as the early larval feed. Intensive culture of phytoplankton under controlled conditions is laborious and costly and not readily adopted by commercial hatcheries. On the other hand, extensive culture which utilizes endemic species is weather-dependent and hence the required phytoplankton may not be available when needed. There is thus a need to develop reliable formulated larval feed to overcome such problem and to reduce production cost.

Most *Macrobrachium rosenbergii* hatcheries are still small. The tanks used are generally not bigger than 10 tons and may either be cylindrical or rectangular. Stocking density is 30-100/1 depending on the culture system. Water management varies from practically no change of water in the static green water system to near daily complete renewal of water in other systems.

There is heavy dependence on brine shrimp nauplii as larval food although fish flesh, cockle meat, egg custard, and formulated feed are also given as supplement. The culture of *M. rosenbergii* has not really taken off compared to that of the marine prawn. There is no great demand for fry; hence, hatchery production is still limited. However, should there be an increased demand, it is foreseen that such demand could be met by increased production from both public and private hatcheries.

Production of table shrimp prawn. Shrimp pond culture in Malaysia originated from the traditional trapping ponds which were subsequently phased out and replaced by the present culture pond system. This was mainly due to the declining supply of natural shrimp seeds or fry.

As in marine finfish culture, both tidal and levee ponds are employed. Pond sizes vary from the very small to as big as 5 ha each, although the majority are 0.25-10 ha and are usually rectangular. In 1985, there were 451 ponds with a total area of 445 ha.

There are three main types of culture systems: extensive, semi-intensive, and intensive. The main differences among these systems are their stocking densities, management techniques, and expected harvest (Table 2).

Pond preparation is broadly similar to that of finfish except that minimal water exchange is done within the first month to retain the natural productivity of the pond and to avoid injury to the still fragile post-larvae. In the later stages, after about one month culture period, water is changed practically everyday especially with the semi-intensive and intensive systems.

In extensive culture, food supply comes from the natural food enhanced through periodic pond fertilization throughout the culture. In intensive and semi-intensive operations, feeding is with pellets made especially for shrimps which are already manufactured locally. At the moment research is being conducted to substitute as much as possible the raw ingredients used in these pellets with local feedstuffs.

Usually after one month, the amount of supplementary feed is increased and further increments in feed is carried out at a 10-day interval as the body weight increases. Feeding frequency is 3-4 times daily depending on the stocking density and the amount of feed given daily.

Table 2. Systems of shrimp culture

Culture Systems	Stocking Density (no/m^2)	Management Technique	Expected Harvest (tons/ha/culture)
Extensive	5	Fertilization with minimal water change and no supplementary feeding	0.3-0.5
Semi-intensive	10-15	Fertilization only for the 1st months, minimal water change in the 1st month; 30% water change almost everyday and supplementary feeding needed; mechanical aeration required during later stages.	1.0-2.5
Intensive	20	Fertilization in the 1st month; water change minimal in the 1st month; 30% water change everyday and compulsory pellet feed even at start of culture.	3.0-6.0

Some of the common diseases and factors of economic importance in shrimp culture are bacterial black spot, vibriosis, yellow gills, and viral diseases. Factors that can also contribute to heavy losses of cultured shrimp include algal bloom, e.g., *Hornellia, Anabaena, Gonyaulax* (Dinoflagellate), and the protozoans *Epistylis, Vorticella, Zoothamnium.*

Culture periods vary from one culture system to another. At lower stocking densities shrimps grow faster and reach marketable size within 60 days. In semi-intensive and intensive culture, shrimps are harvested after 3-4 months. Where partial harvest is practised, the first harvest can be done from the second month onwards. Shrimps harvested are normally graded to appropriate market size either manually or by grading machines.

One of the main challenges shrimp farmers face is the problem of acid sulfate soils especially in excavated ponds. Correction of acidity may take several years at which time farmers are likely to face acute cash flow problems. Another significant problem is the non-availability of credit and financing for investors. Being capital intensive, a large fund base is required for a start in the industry. However, financiers and venture capitalists are hesitant in committing funds because of high risks. Even though the technology exists there is still a lack of skilled and experienced manpower since a number of newly set up farms still have to train their workers. Disease is one of the greatest threats in shrimp farming and to date very little information about this is available. Market outlets are also constraints at this stage of transition when total production already exceeds the local market demand but has yet to meet the export market.

Mollusc Culture

The culture of the blood clam *Anadara granosa* and the green mussel *Perna viridis* depend on natural spats for its seed stocks. In the case of the cockle, the spatfall areas are located in the 4000-5000 ha of mudflats along the West Coast of Peninsular Malaysia. Although there is a high degree of unpredictability as to where spats will settle, the spats settle in large quantities and is sufficient to meet the demand of culturists. Seed collection is done by fishermen who sell them to buyers who in turn transport them to culture areas. Cockle spats are spread over the nursery areas of cockle farms at varying densities depending on seed size. Farmers regularly cull and harvest the cockle about 6-7 months after initial stocking.

Culture of the green mussel requires rafts with hanging ropes of jute or polyethylene as a substrate for spat settlement. Culling is also carried out to ensure even growth. A raft area of 1 ha can produce 3 150 000 kg of green mussel in one year. In 1985, 44 561 mt of blood clams and 200 mt of mussel were produced.

Current legislation pertaining to seed collection, production and marketing can ensure the development of the blood clam industry. However, a constraint to its further development is the marketability of fresh cockles in the export market which demand that cockles and mussels meet specific quality standards through depuration. To expand the domestic and export market for the green mussel, some secondary processing of the product is essential as the demand of the mussel in its fresh form is very limited. Pollution in the Johore Straits where the culture of the green mussel is dominant and along the West Coast of Peninsular Malaysia for cockle culture could be a future constraint.

THE PHILIPPINE AQUACULTURE INDUSTRY

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ABSTRACT

The aquaculture sector of the Philippine fishing industry registered the highest growth rate of 12.5% in 1977-1986. The contribution of aquaculture to the total fish production was equivalent to 24% in 1986 compared to only 85 in the early 1970's. In terms of quantity, the mariculture subsector registered the highest growth rate of 10.2% in 1982-1986, whereas in terms of value the brackishwater fishpond subsector showed the highest growth rate of 33%. Meanwhile, freshwater aquaculture production exhibited a negative growth rate due to reduction of activities in Laguna de Bay and the slow expansion in hectarage of the commercial freshwater fishponds.

Research by several agencies concentrated heavily on the culture of milkfish *(Chanos chanos),* tilapia *(Oreochromis niloticus),* Chinese carps *(Aristichthys nobilis* and *Hypophthalmichthys molitrix),* tiger prawn *(Penaeus monodon),* and sea bass *(Lates calcarifer).* Innovations in seaweed, oyster, and mussel farming are also discussed.

Research directions are presented to assure an ecologically sustainable growth in aquaculture with emphasis on countryside development.

PRODUCTION AND DEMAND FOR FISH

Fish is a major source of protein for the Filipinos. Per capita availability based on domestic production is 32-36 kg per year for the last five years (Table 1).

Table 1. Per capita availability of fish based on Philippine production

	Total Fish Production (mt)	Food Fish Production Component (mt)	Per Capita Availability (kg)
1982	1 896 983	1 591 409	33
1983	2 110 230	1 788 873	36
1984	2 080 268	1 731 587	34
1985	2 052 111	1 701 021	32
1986	2 089 484	1 732 000	32

In 1986 total fish production was 2.1 million mt valued at US $1.7 billion, and contributed 5% to GNP. Of this total the contribution of commercial and municipal fisheries and aquaculture is 26%, 51%, and 23%, respectively. In the early 70's the contribution of aquaculture was only 8%.

Of the three sectors, aquaculture exhibited the highest growth rate of 12.5% from 1977-1986 (Table 2).

Fish, aside from being a staple food and a principal source of protein, is a generator of foreign exchange. From 1982-1986 the export of fish and fishery products registered a growth of 10.3% in quantity and 44% in value, with aquaculture posting a higher growth of 15.4% in quantity and 65% in value for the same period. In 1986 alone the share of aquaculture in the total quantity of exports was 37% while in value its share was 53%.

STATUS OF AQUACULTURE

Recent developments adversely affecting the country's fishing industry such as the devaluation of the peso, the escalation of fuel prices, and the tapering off of catch from traditional marine fishing grounds challenged the industry to shift to aquaculture in an effort to maintain fish production at a level which can meet the increasing demand for fish protein. Aquaculture gained importance because of its fast profit turn over, the stability of its output, the higher value and export potential of its products, and its ability to provide the much needed alternative employment in farming communities.

Table 2. Production of fisheries and aquaculture in the Philippines

Year	Total (000 mt)	Commercial (000 mt)	Municipal Marine (000 mt)	Municipal Inland (000 mt)	Aquaculture (000 mt)
1977	1 509	518	711	116	164
1978	1 580	506	687	171	217
1979	1 581	501	683	204	241
1980	1 672	488	647	247	289
1981	1 773	495	710	229	339
1982	1 897	526	708	270	392
1983	2 110	519	771	375	445
1984	2 080	513	790	299	478
1985	2 052	512	785	260	495
1986	2 089	546	807	265	471
Growth Rate	3.7%	0.6%	1.4%	9.6%	12.5%

Contribution of Aquaculture to Fish Production

The most widely practised type of aquaculture in the country is the growing of milkfish in brackishwater fishponds. Within the last 10 years culture for *P. monodon* alone or in combination with milkfish became very popular. Mariculture production is dominated by seaweed production as well as oysters and mussels. The production from fish-pens and cages in lakes, rivers, and reservoirs is very significant and the use of freshwater fishponds as a medium of production is gaining momentum. Quantity-wise from 1982 to 1986, of the subsectors of aquaculture, mariculture exhibited the highest growth of 10.2%; brackishwater fishponds, 3.5%; while freshwater production exhibited a negative growth due to the reduction of activities in Laguna Lake. In terms of value, the highest growth was exhibited by the produce from brackishwater fishponds, explained by the fact that fish species produced in these areas, particularly shrimp/prawns and milkfish, command higher prices both in the local and foreign markets.

AQUACULTURE DEVELOPMENT PLAN AND FRAMEWORK

Long Term National Goals

The long-term objective of the government and the Department of Agriculture is to lay the foundation for an equitable, efficient, and ecologically sustainable growth in agriculture. The objective is not only to achieve production targets on a competitive basis, but also increase the real income of the poor in rural agricultural households.

Government creates the policy and institutional framework and provides the necessary incentives for investments, infrastructure, research, and technology. The private sector has been called upon to propel the economic recovery in the countryside. People's participation through farmer institutions are recognized as a key factor in bringing about agricultural development.

The government is trying to achieve these objectives through the creation of a healthy economic environment for farmers to maximize their profits. It provides farmers with land, appropriate technology, adequate infrastructure and irrigation, and an effective market information service. It is providing the landless households and other elements of the rural economy with greater employment opportunities. It is decentralizing government decision-making to the grassroots level.

General Objectives for Fisheries Development

Consistent with the national objective of increased rural incomes, policies in fishing are directed at increasing fishing incomes and providing fishermen/fish farmers with more equitable access to resources and an opportunity to be more productive. However, policies directed towards increased production will likewise be pursued in view of the important role fisheries products played in satisfying the country's nutritional requirements and the need for generating foreign exchange.

Rationale for Aquaculture Development

The potential for expanding aquaculture production in the Philippines is extremely high for the following reasons:

1. There are a significant number of hatchery and grow-out operators with the experience necessary to take the lead in the development of the industry;
2. The aquaculture support service/companies including input suppliers, processors, buyers, and exporters are already beginning to organize and expand their operations to meet the future needs of the industry;
3. Ideal climatic, soil, and water quality conditions exist in many areas;
4. Many indigenous species have life histories which make them ideal for culture;
5. Industry is supported by many academic, research, and training institutions and information services which, if reorganized and refocused to improve their effectiveness, could serve to promote and support accelerated development of the sector; and
6. Available fishery resources can be tapped.

Objectives for Aquaculture Development

The government's objectives for aquaculture development in the next 5-10 years have taken into account the potentials of the sector for future expansion both in (1) meeting the nutritional requirements from fish in the event marine production tapers off at present levels and (2) improving the country's foreign exchange position through the export of major aquaculture products like shrimps and seaweeds. These objectives are:

1. Increased aquaculture contribution to total food fish requirement;
2. Improved incomes for rural families;
3. Improved and efficient utilization of culture areas and accelerated development of underutilized fishponds;
4. Increased utilization of lakes, rivers, other inland bodies of water, and coastal areas appropriate for mariculture; and
5. Increased export of aquaculture produced products.

Strategies and Production Plan

To achieve these objectives, several production, post-harvest, conservation-oriented strategies directed by the private sector are to be adopted:

1. Expansion of culture operations to high value species;
2. Intensification of production in existing brackishwater ponds through improved culture technology;
3. Implementation of efficient post-harvest technology and marketing arrangements;
4. Increasing the productivity of lakes, rivers, and other bodies of water; and
5. Expansion of the participation of the private sector in all aspects of aquaculture.

Actual production from aquaculture in 1986 totalled 471 000 mt. By 1900 planned production is 601 000 mt at a 6.3% growth rate. By 1995 target production is 851 000 mt and is expected to increase annually at 7.2% from 1990-1995.

STATUS OF PRODUCTION TECHNIQUES

Milkfish

Breeding and Seed Production. The artificial propagation of milkfish was a subject of investigation as early as 1973-1974 beginning with experiments on hormonal induction of gonadal maturation (Lacanilao 1973), followed by methods of capturing and holding spawners from the wild conducted by the research team of the USAID-assisted Inland Fisheries Project (Anon. IFP 1974). Vanstone et al (1977) and Chaudhuri et al (1977) succeeded in inducing the breeding of wild spawners and described for the first time the embryonic development of milkfish beginning with the fertilized egg. Juario et al (1984) in summarizing the results of induced breeding and larval rearing works at SEAFDEC AQD between 1978-1981 reported an actual fry production of a little over 12 000.

Meanwhile, researchers at SEAFDEC AQD monitored the growth of wild-caught fry obtained in 1975-1977 and hatchery-produced fry obtained in 1979-1980, using large floating cages in a marine cove at the final stage of culture. Sexual maturation and spontaneous spawning occurred among the resulting two distinct broodstocks. Spontaneous spawning was observed twice in August 1980, 8 times in May-July 1981 and 14 times in May-June 1983 (Marte and Lacanilao 1986) but the recovery of eggs was very poor. In May-December 1986, however, the research team reported that 27.3 million eggs were collected from 58 spawnings of 180 six-seven year old milkfish with the use of various egg collecting devices. The number of eggs collected from 52 spawnings of the same broodstock in May-June 1987 was 31.3 million by a particular gear composed of an egg sweeper and a hapa nets (Anon. 1987). SEAFDEC AQD is currently developing the technology package that will enable prawn hatchery operators to integrate milkfish fry production using the same facilities. Adopting the Taiwanese technology on spontaneous spawning and fertilization of milkfish in small earthen ponds (Lin 1985) will strongly complement this effort and will bring us closer to the goal of replacing wild fry with hatchery-produced milkfish seeds. Nutrition studies will probably play a greater role in both broodstock and hatchery operations before the end of the century.

Nursery and Grow-out Operation. Milkfish culture in brackishwater ponds follows the traditional practice of providing for nursery, transition, and rearing operations. In some cases, formation ponds are used for additional growth or stunting of fingerlings prior to stocking in grow-out or rearing ponds. The nursery ponds comprise about 1-4% of total production area while the transition and formation ponds constitute about 6-9% of the total production area. Figures 1 and 2 show the lay-out of conventional and modular pond systems adopted by milkfish farmers. Both systems, however, require a good supply of unpolluted water and an elevation adequate to maximize the use of local tidal fluctuations (Fig. 3).

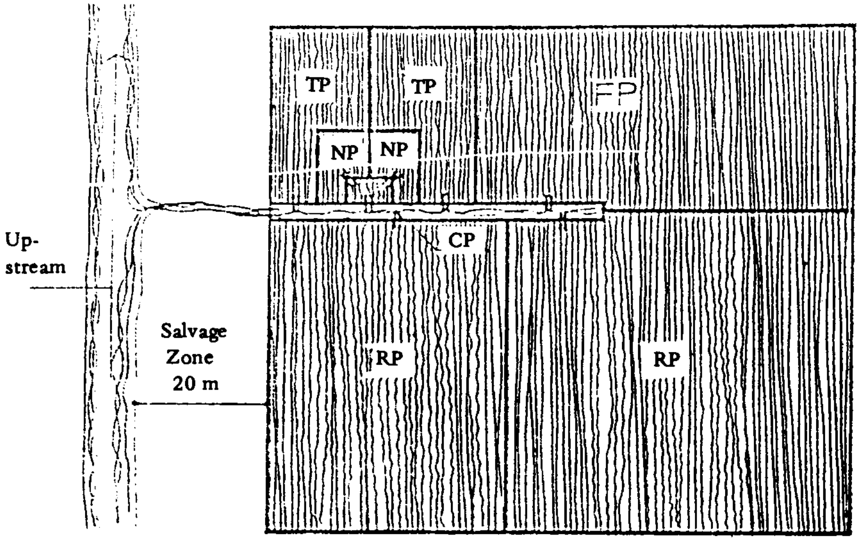

Fig. 1. Conventional system
(Gopa 1983)

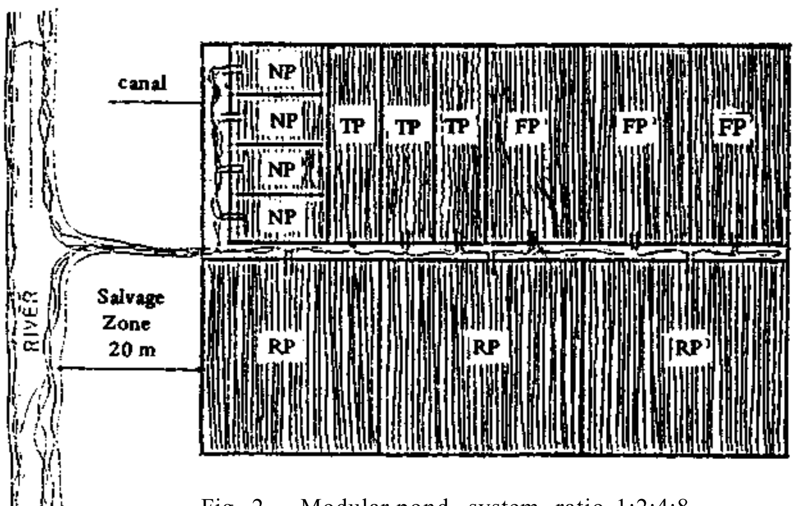

Fig. 2. Modular pond system, ratio 1:2:4:8
(Gopa 1983)

LEGEND:

NP — Nursery pond
TP — Transition pond
FP — Formation pond
RP — Rearing pond

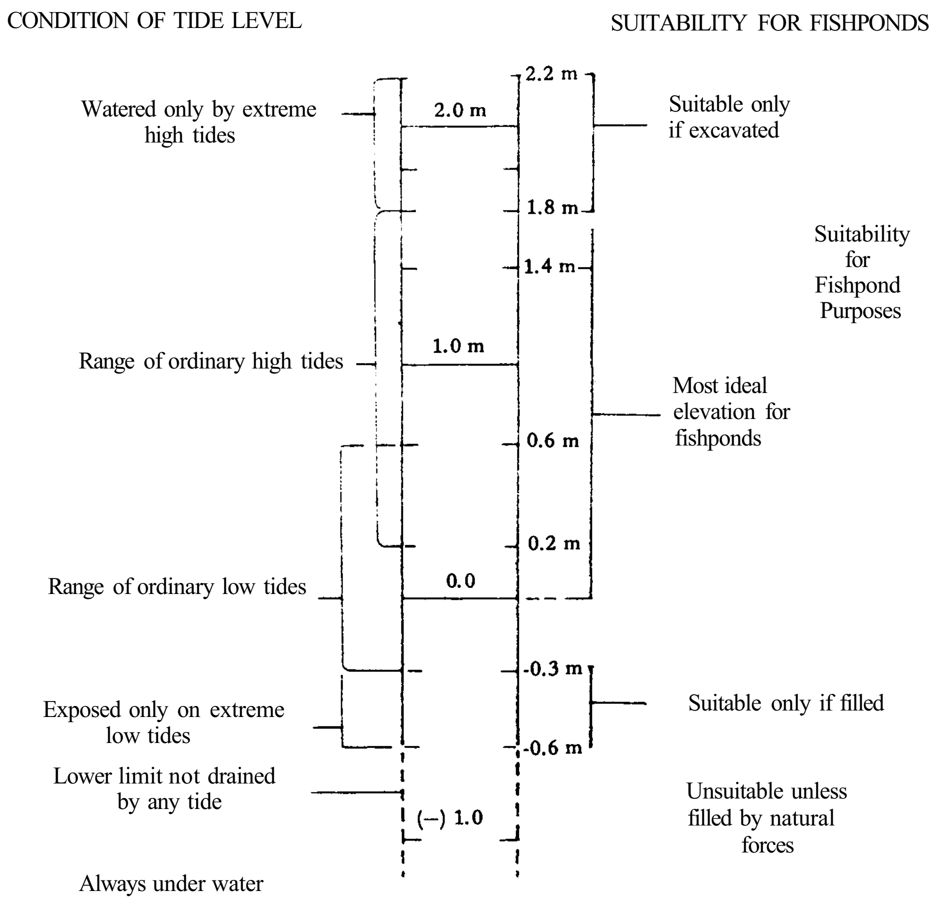

Fig. 3. Relationship between pond elevation and tidal fluctuation (Rabanal pers. comm.)

Milkfish pond aquaculture is basically at the fertilization level of management using *lablab,* a microbenthic plant-animal complex, as food base. In places where salinity ranges are much lower than sea water (less than 10 ppt), *lumut,* a filamentous green alga, is also grown with appropriate N-P-K dosages. The fertilization regimen known to progressive fish farmers is a combination of organic and inorganic fertilizers (Anon. 1976) preceded by lime application particularly in areas of high soil and water acidity. Application of inorganic fertilizer varies in many places and use of chicken manure appears not to be universally accepted by fish farmers (GOPA 1983).

Predator control is considered essential in both nursery and grow-out operations. Drying the bottom after each harvest and the use of fine-mesh nets in sluice gates or pipes are common precautionary measures although the application of chemical pesticides like gusathion, brestan and aquatin is widespread. Biological control using predatory species is recommended but has not been practised on a wider scale.

Milkfish fry stocked at $50/m^2$ in nursery ponds with luxuriant growth of *lablab* will reach fingerling stage of 2-5 g average weight in 4-6 weeks. To grow fingerlings to marketable size of 4 fish/kg would take another 2.5-3.0 months at stocking rates varying from 3 000-5 000 fingerlings/ha. In some of the better-managed fish farms average milkfish yield would reach 1.5 mt/crop. With an organized program of stocking and holding of fry and fingerlings in the modular system it is possible to have 3-6 crops in a year.

Production technology in milkfish farms has brought about significant increases in fish yield and it is believed that further and immediate improvements are attainable with (a) a more systematic arrangements of ponds, (b) renovation or installation of more efficient water control structures of canals, gates, pipes, pumps, (c) repair and reinforcement of dikes, and (d) levelling of pond bottom, excavation of silted areas and clearing ponds of tree stumps (GOPA 1983).

Milkfish is also raised in fishpens especially in Laguna de Bay either in monoculture or polyculture with other species, notably tilapia. At one time fishpens occupied some 34 000 ha of the lake area and contributed about 130 000 mt to the lake's annual output (Mane 1987). Capital investments are considered sizable and yet one could see that there is hardly any real management control over the whole operations. Runoff from the watershed laden with nutrients and agricultural by-products as well as industrial and domestic wastes that are washed into the lake are, however, considered vital factors that enhance lake fertility for fishpen culture. The average annual yield of milkfish from Laguna Lake fishpens was reported to have reached 4 mt/ha/yr at stocking densities of $3\text{-}4/m^2$ of enclosed lake area. The current problems and issues associated with pen culture are chemical pollution, massive siltation, allocation of benefits between fishermen and fishpen operators, and the rationalization of multiple uses such as for domestic water supply and flood control (Davies et al 1986).

Tilapia

Breeding and Seed Production. The rapid establishment of small and medium-scale tilapia hatcheries within this decade is a concrete indicator of the growing importance of this species in the country's food production efforts. The current annual fingerling production capability is estimated at 300×10^6 annually (Guerrero 1986) consisting mainly of Nile tilapia *(Oreochromis niloticus).* The ease of spawning is characteristic of tilapia species in general so that earlier research works were concentrated in solving overpopulation (Guerrero 1982).

Nile tilapia fry production methods using net enclosures, concrete tanks, rice paddies, and earthen ponds have been reported (Table 3) and practised by private operators although the efficiency of one system over the other would have to be clarified. Bautista (1987) reported that the use of concrete tanks is the most efficient method except that capital costs and operational expenses are higher. No expanded fry production figures were, however, given. Meanwhile, Guerrero (1987) stocked Nile tilapia breeders in three earthen ponds with areas of 324-415 m^2 at $4/m^2$ and sex ratio of one male to three females. Total fry production after 30 days was 80 450 or 6.5 $fry/m^2/day$, which may not be an economical operation as actual fingerling production may even be much lower. Earlier studies did not also indicate the spawning potential of each female. Seed production in Laguna de Bay using net enclosures with minimum measurements of $3 \times 2 \times 2$ m appears to be the most accepted scheme considering the natural fertility of the lake. The only drawback here will be the onset of the typhoon season which limits the production cycle.

Genetics and selective breeding will be crucial in the further expansion of tilapia farming. A selection procedure at CLSU Freshwater Aquaculture Center (FAC) has identified a high growth line which was subsequently spawned to produce a new Nile tilapia strain that exhibited a superior growth rate compared with the unselected stock (Abella 1987). The value of interspecific crosses will also be pursued in the near future.

Nursery and Grow-out Operation. The fry production facilities described earlier may also be used to rear the fry to fingerling stage after segregating the parental stock and transferring them into another enclosure or pond. A useful guide regarding stocking densities in the nursery facilities is as follows: 300-500 fry/m^2 in fine-meshed net (hapa), 1 000 fry/m^2 in concrete tanks, and $40\text{-}50/m^2$ in earthen

Table 3. Comparative production of tilapia hatchery systems (Tilapia Committee 1985)

Type	Size	Stocking rate (no. of breeders)	Sex ratio (male:female)	Production (no. of fry)
hapa	1.5 × 1 × 1 m	4/hapa	1:3	500/hapa/2 weeks
hapa	3 × 3 × 2 m	48/hapa	1:3	25/m /month
ponds	1 000-5 000 m^2	4/m^2	1:3	25/m^2 /month
paddy	200-400 m^2	1/m^2	1:4	100/spawner/month
concrete tank	40 m^2	4-6/m^2	1:7	80-100/spawner/month

ponds (Bautista 1987). Fry to fingerling production requires a vitamin and mineral fortified artificial diet containing 30-45% crude protein (Anon. 1985).

Tilapia is raised to marketable size in cages, earthen ponds, and fishpens. Fish cages of the floating or fixed type would vary in size the smallest unit having a dimension of 1 × 1 × 1 m and the larger ones 25 × 50 × 5 m. The cages used in Laguna de Bay consist of bamboo frames and nylon nettings with mesh of 0.6-1.3 cm. Stocking rates of 10-15 g fingerlings vary from 20-25/m^2 with supplemental feeding. The fish reach marketable size of 100 g each in 4-6 months (Mane 1979). A supplemental feed consisting of 25% fish meal and 75% fine rice bran is offered in dry mash or pelleted form (Anon. 1985). Tilapia is also grown in lake fishpens at densities of 20-50/m^2 .

Commercial culture of Nile tilapia in freshwater ponds is concentrated in the Central Luzon area where extensive irrigation canals for rice-farming provide the bulk of the water supply. The length of the culture period is 4-6 months with an average yield of 900 kg/ha/yr. Annual farm inputs per hectare include 1.8 t of chicken manure, 250 kg of 16-20-0 inorganic fertilizer, and 1.3 t of rice bran and 50 kg of fish meal as supplemental feeds. Stocking rates are 9 000-20 000 fingerlings/ha in a single crop (Guerrero 1987). The technology for rice-fish culture is undergoing some evaluation and refinement considering the incompatibility with the use of agricultural pesticides in rice farming.

The greatest potential for the expansion of tilapia culture is indicated in recent experiments that showed the feasibility of raising Nile tilapia in brackishwater fishponds either in monoculture or polyculture with milkfish (Fortes 1987). Genetic manipulation would someday firm up the prospects of saltwater tilapia culture.

Carps

Breeding and Seed Production. The technique of induced spawning of Chinese carps (bighead carp, *Aristichthys nobilis* and silver carp, *Hypophthalmichthys molitrix)* which was successfully demonstrated in China in 1958 became the subject of further experimentation in a number of countries in the succeeding decades. These carps were introduced in the Philippines in the late sixties but limited knowledge on their seed production and the lack of private sector interest in their commercial culture did not allow the full establishment of a major carp industry. The propagation of Asiatic carps by hormone injection was first demonstrated in 1970 by fishery biologists of the Philippine Fisheries Commission (now Bureau of Fisheries and Aquatic Resources) and the Food and Agriculture Organization of the United Nations under the Freedom from Hunger Campaign working with two private hatcheries in Candaba, Pampanga and Dingle, Iloilo (Osborn and Anderson 1971). In 1983-1984 the Binangonan Freshwater Station (BFS) of SEAFDEC AQD concentrated its efforts in the artificial propagation of the bighead and silver carps, using the Chinese technique. During this period 24-year old breeders of bighead carp reared in floating cages and weighing 2.3-2.5 kg each were induced to spawn through injections of 1 800-2 000 IU HCG/kg body weight. Common carp pituitary homogenate was also added at 2-3 pieces of pituitary gland per female. The average fecundity was 150 000 per female with an average fertilization rate of 84.4% but a low hatching rate of 10-30%. It was also found that hatching of eggs was more efficient at 300-500 ppm $CaCO_3$ hardness. A total of 300 000 fry were produced in the 1984 trials (Anon. 1984). Meanwhile, 25 bighead carps (average weight 3.8 kg) spawned in August-December 1985 producing 577 160 fry. Eggs were fertilized and hatched at the rate of 72% and 25%, respectively (Anon. 1985).

Nursery and Grow-Out Operation. There appears to be no standard prescription regarding techniques of nursing the fry and in the case of Laguna de Bay practices the system used for milkfish is adopted for bighead or silver carps. Raising fry to fingerlings of 1-3 g each in net enclosures (hapa) will take approximately 2-4 weeks taking advantage of the natural food sources of the lake. There is also very little information on nursery management in freshwater ponds, except that the usual application of inorganic fertilizer in combination with manures which was proved to be successful in milkfish works just as well for Chinese carps.

Preliminary data on grow-out operation of pens and cages in Laguna de Bay are available. In one trial (Lijauco and Paraan unpublished), cages made of bamboo frames and B-net (0.6 cm mesh) materials and measuring 5 × 5 × 4.5 m were stocked with bighead carp (12), silver carp (12), common carp (5), and nile tilapia (250). The initial weights of the fish were: bighead carp (90-197 g), silver carp (0.9 g), common carp (1.0, 9), and Nile tilapia (5.0 g). After 90 days mean weights were recorded for bighead carps at 320-2600 g, silver carps at 100-150 g, common carps at 150-283 g, and tilapia at 48-250 g. The highest growth of bighead carp was close to 19 g/day or 5 times the best recorded growth rate of milkfish.

Another trial (Castro et al 1981) showed the feasibility of culturing milkfish or silver carps as major species in Laguna de Bay fishpens in combination with bighead carp and tilapia. Stocking rates were 3-5/m^2 for silver carp and milkfish and a constant of 0.1 for bighead carp, 0.5 for common carp, and 1.0 for tilapia. After a period of 4-5 months, the bighead carp exhibited the highest growth of 7.1-10.0 g/day followed by silver carp (5.3-5.7 g/day), milkfish (1.8-2.1 g/day), tilapia (1.1-1.7 g/day) and common carp (0.8-1.3 g/day). The polyculture system with the ratio of 5 silver carp: 1.0 tilapia: 0.1 bighead carp and 0.5 common carp gave the highest net production equivalent to 25.5 mt/ha.

Sea Bass

Breeding and Seed Production. The artificial propagation of sea bass *(Lates calcarifer),* first achieved in Thailand in 1971 by stripping wild-caught spawners, has provided great impetus for its commercial culture. Broodstock from the wild, 2-6 years old and weighing 3-5 kg, are initially transferred and acclimatized under cage or tank conditions for at least 6 months before actual spawning tests (Kungvankij 1987).

Floating cages of variable sizes, 10-100 m^2 and 2 m deep, may be stocked with broodfish at the rate of 1/m^3 of water. Meanwhile, concrete tanks with volumes ranging from 100-200 t can be used with the prescribed stocking rate of 1 fish/2 m^3 of water. Good water quality in concrete tanks is usually kept by changing about 30-50% of the water volume daily (Kungvankij 1987). Broodstocks are fed with live or fresh fish during captivity. At SEAFDEC AQD, sea bass broodstocks are maintained in aerated concrete tanks equipped with a special drainage to simulate tidal fluctuations. Fish whose eggs have a diameter of 0.4-0.5 mm, are injected with combinations of homogenized pituitary gland (2-3 mg/kg) and human chorionic gonadotropin (HCG) at 250-1 000 IU/kg. Successful induced spawning was also demonstrated using LH-RHa in both injection and pellet implantation experiments (Nacario 1986). Further work is being conducted to improve larval rearing techniques, particularly the methods of culture and preservation of natural feeds such as rotifers (e.g., *Brachionus),* phytoplankton (e.g., *Chlorella, Tetraselmis),* and *Artemia.*

Nursery and Grow-Out Operation

Nursery and Grow-Out Operation. In most culture operations the fingerlings are obtained from the wild, although attempts are being made to mass produce fingerlings from fry produced in hatcheries (Fortes 1987). In one experiment, 7-21 day old sea bass larvae were fed with different types of natural food in an indoor recirculating system. Another study is concerned with the response of fry to formulated diets. Results of the experiments will augment current efforts to culture sea bass fry to the fingerling stage in earthen nursery ponds.

The difficulty of obtaining sea bass fingerlings was met during preliminary growth trials in brackishwater ponds that had to use at least 3 size-groups with mean weights of 8, 24, and 53 g and fewer replicates. In this experiment the slow rate of growth was attributed to delayed response to feeding, i.e., about 49 days from the time the fish were stocked. Low survival rate (35%), meanwhile, was attributed to varying individual sizes of fish which might have led to cannibalism (Fortes 1985).

In another experiment (Fortes 1985) post-fingerlings were raised in cages (2 × 1 × 1.2 m) for 90 days at stocking densities of 15, 30, 45, 60, and 75/cage. All fish attained sizes adequate for the market at mean harvest weights of 155-240 g.

Prawn

Breeding and Seed Production. In a complete-cycle prawn *(Penaeus monodon)* aquaculture the process begins with 4-6 month old marketable size specimens with 30-35 g average wt, which are further stocked in *broodstock ponds* until the prawn is one year old with an average weight of 9-120 g (Platon 1979). Otherwise, most hatcheries use wild spawners. The biggest and healthiest in the batch are transferred to maturation tanks approximately 12 m^3 and 80 cm deep at the minimum stocking rate of 20 ablated females. When ready to spawn as indicated by the condition of the ovary, each female is transferred to spawning tanks 2 m^3 and 60-80 cm deep that are shielded from direct sunlight and provided with moderate aeration. Temperature and salinity regimes are kept within 27-29°C and 32-33 ppt, respectively. Ablated females in good condition are reported to lay 20 000-500 000 eggs at a time of which 50% will hatch (Primavera 1979).

Ten to fourteen hours after spawning, eggs are carefully transferred to 2-20 t larval rearing tanks at stocking densities of 50-100 nauplii/1. The nauplii undergo several larval molts to reach the post-larval stage within 2-4 weeks. Given adequate natural feeds (Table 4), the resulting post-larvae are stocked in nursery ponds or nursery tanks (Anon. 1984).

Table 4. Recommended feeding scheme for P. *monodon* larval rearing (Working Committee on Prawn Hatchery 1984)

	Nauplius	Protozoea	Mysis	Postlarvae
Stages	$N_I\ N_{II}\ N_{III}\ N_{IV}\ N_V\ N_{VI}$	$Z_I Z_{II} Z_{III}$	$M_I M_{II} M_{III}$	$PL_1 PL_2 PL_3 PL_4 PL_5 PL_6$ . . PL_N
No. of Days	1.5 days	5-6	4-5	First day of postlarvae is termed PL_1 & 2nd day PL_2 & so on
Scheme 1	no feeding	*Skeletonema* or *Chaetoceros;* -5 000-10 000 cells/ml		
		Egg yolk particles; 5-15 particles/ml		
			Artemia nauplii; 2-5 *Artemia*/ml	
Scheme II	no feeding	*Tetraselmis;* 2 500-5 000 cells/ml		
		Egg yolk particles; 5-15 particles/ml		
			Artemia nauplii; 2-5 *Artemia* /ml	
Scheme III	no feeding	Mixed diatoms; 5 000-10 000 cells/ml		
		Egg yolk particles; 5-15 particles		
			Artemia nauplii; 2-5 *Artemia/ml*	

Nursery and Grow-Out Operation. Prawn nursery ponds 1 000 m^2-1 500 m^2 may be stocked with P_{15}-P_{20} postlarvae at 50-100/m^2, using the same natural food for milkfish. Platon (1979) stocked nursery ponds at 150 P_5/m^2 with supplemental feeds.. At water salinity of 20-25 ppt the expected recovery rate of juveniles, P_{35} with average weight of 1-2 g after 30-40 days, is about 60%. Floating nursery cages, measuring 2 × 5 × 1.5 m, were stocked with P_5-P_{16} post-larvae at 4 000-16 895/m^3 with an average survival rate of 41% (de la Pena et al 1985).

Shrimp grow-out ponds, representing 10-15% of the existing brackishwater fishponds, were originally constructed for milkfish culture. Unique prawn culture requirements, however, would necessitate some form of renovation such as increasing the height of dikes to allow a pond water depth of 1 m, conversion of large units into 5-10 ha sizes, improvement of control gates and the provision of a two-phase nursery grow-out pond systems (IFC 1984). At present, newly constructed shrimp ponds in the Visayan region are small units of 0.5-1.0 ha which are actually converted rice, sugar, and coconut land dramatizing the rapid expansion of the hectarage for prawn production. As shown in Table 5, shrimp farming systems are classified into 3 types, namely, extensive, semi-intensive, and intensive systems (Camacho and Corre 1986). The stocking density for each is much higher than that reported by Apud (1985), indicating that the limits of production technology cannot be determined accurately at this time. The semi-intensive and intensive systems perhaps should be employed with great caution under the present economic situation. Relative to this, a recent study shows that the extensive monoculture of prawn and the extensive polyculture of prawn with milkfish are the only profitable culture systems (Israel 1985).

With greater investments in prawn culture at present, it is important to examine very closely the foreign market situation since under current costs of production domestic per capita consumption has steadily decreased (Camacho and Corre 1986).

Farming of Seaweeds

Only a few members of the green (Chlorophyta), red (Rhodophyta), and brown (Phaeophyta) seaweeds are used for commercial food production or for export. In case of *Eucheuma* and *Gracilaria,* there was intensive harvest of natural stocks especially in the 1960s to fill the

Table 5. Comparison of the three major methods of shrimp culture (Camacho and Corre 1986)

	Extensive Culture	Semi-Intensive Culture	Intensive Culture
Pond Size	5 hectares or larger	1-8 hectares	0.25 ha
Pond Dikes	Concrete or Earthen	Concrete or Earthen	Concrete
Stocking Density (PL)	10 000-30 000/ha	60 000-160 000/ha	180 000-300 000/ha
Fry Source	Wild	Wild or Hatchery	Hatchery
Fry Size	PL20-PL_{35} (25-35 day-old postlarvae)	PL_{20}-PL_{35} (20-35 day-old postlarvae)	PL_{20} (20 day-old postlarvae)
Water management	Tidal exchange, no aeration	Tidal exchange and pump with aeration	Pumps, filter, pre-mixed water, paddle-wheels for aeration and water circulation
Feed Used	Natural & occasional supplemental feed	Pelleted supplemental feed/ natural feed	Formulated complete feed ration
Culture Period	4-6 months	3-4 months	3-4 months
Harvest size	25 pcs/kg	25-30 pcs/kg	32 pcs/kg
Production (kg/ha/yr)	500 or less	3 000-8 000	10 000-20 000
Survival Rate	50% or less	70-80%	70-80%
Crops/yr	1-2	2-3	2.5-3.0

demand for raw materials in Japan and USA (Trono and Fortes 1985). *Eucheuma* culture was accordingly undertaken in the 1970s to prevent the depletion of resources and to sustain the multi-million industry. The viability of cultivation in Sulu attracted many entrepreneurs and fishermen in the South to engage in the operations such that production of dried *Eucheuma* soared from 400 mt in 1970 to 10 000 in 1974 (Bernardino 1985). At the height of *Euchema* culture in Tawi-tawi in 1974 more than 10 000 people were engaged in seaweed farming in more than 1 000 family-type farms ranging from ¼ ha to 1 ha in size (Yutuc and Trono 1977). A family farm covering 0.5 ha of reef area and using nylon monofilament lines to support 7 500 *E. cottonii* plants had a total harvest of 22.5 t wet weight equivalent to a dry saleable weight of 2.2 mt. Each plant grew from 200 g average weight to 3 kg in 90 days (Deveau and Castle 1979).

Seaweed culture represents a very simple system that requires only slight modification of the environment. The farmer provides no control over such factors as water flow and nutrient inputs. Most of the successful farms are located in coral reef areas in Southern Philippines where environmental conditions are relatively stable throughout the year. The net farm installed under water consists of basic net units, usually 2.5 × 5 m, attached to four poles parallel to the bottom. Local farmers have improved the system by using monofilaments rather than polyethylene lines (Deveau and Castle 1979).

The possibility of farming seaweeds in ponds has been explored but the details of commercial application are not well understood (Trono and Fortes 1985).

One serious problem that has faced the industry is the cyclical price fluctuations in the market for *Eucheuma* (FAO 1983). It was reported that buyers, i.e., wholesalers and agents, obtain their annual needs from farmers only early in the year, thereby pushing up prices during that period. These buyers often withdraw abruptly from the market once the annual quota are filled. Other problems confronting the industry in Southeast Asia are presented by Doty (1977).

Oyster and Mussel Farming

Farming methods for oysters and mussels are well established and recent developments are concerned with methods of collecting spats and developing the techniques of growing in areas different from where natural beds are found. Mussels were almost exclusively farmed with the stake method until the rope-web method was introduced which consists of two 5 m parallel ropes tied 2 m apart between bamboo poles. A 40-m rope is then tied in a zigzag fashion at intervals of 40 cm between knots along the parallel ropes (Anon. 1983). Meanwhile, four methods are used in oyster cultivation: stake, hanging, broadcast, and lattice.

Total production of oyster exceeds 10 000 mt a year predominantly contributed by small farms of less than 1/3 ha thereby indicating the significant contribution of oyster farming in coastal communities (Young and Serna 1982). A single oyster farm with an area of 2 460 m^2 can produce as much as 4.3 mt or the equivalent of almost 18 mt/-ha/year. On the other hand, an average mussel farm of 1 784 m^2 harvested close to 3 mt equivalent to 8.3 mt/ha/yr (Librero and Nicolas 1979). Young and Serna (1982), however, reported that the productivity in mussel farms, 0.025 — 1 ha, is generally higher than that of oyster farms of 20-68 mt/ha from stake culture to about 300 mt/ha from the hanging method.

The shellfish industry as a whole is facing the problem of environmental deterioration and direct displacement of farming areas by housing and industry. The export potential and to some extent, even local consumption of oysters and mussels, are constrained by lack of adequate sanitation standards and methods.

SUMMARY AND RECOMMENDATION

It could be inferred that were it not for the foresight and dedication of men and women in the academe, government, and the private sector to undertake development research, the aquaculture industry would not be where it is today.

In spite of the numerous research activities completed and presently being conducted there is still a need to intensify and expand these activities. The government's thrust to intensify production of existing and new aquaculture areas would require additional studies on the following:

1. Formulation of appropriate fertilizers for ponds which are suitable to climatic changes, types of soils, and desirable food organisms;
2. Improvement of fishpond design and engineering to provide efficient water management and stock manipulation;

3. Economic viability of various designs of fishponds, fishpens, and fish cages;
4. Research on genetics, genetic engineering, and broodstock development for tilapia, carp, and shrimp considering the importance of fry supply to the development of the industry;
5. Research on culture technologies of high value species, i.e., sea bass, grouper, crab, and abalone as alternatives to presently cultured species like milkfish and shrimp;
6. Culture of non-traditional species low in food chain such as rabbitfishes and mullets;
7. Nutrition, feed formulation, and disease control for larval and grow-out stages;
8. Fry gathering, handling, storing, and stocking to reduce mortality;
9. Use of locally available materials and recycling of wastes to reduce production cost;
10. Post-harvest handling, processing, and marketing to maximize utilization, minimize wastage of fish, and increase returns from aquaculture operations;
11. Culture of fishes, invertebrates, and seaweeds in coastal areas;
12. Expansion of aquaculture areas in freshwater, brackishwater, and marine environment taking into consideration proper land or resource utilization and maintenance of environmental quality; and
13. Stock assessment of fishery resources in coastal and inland waters to complement fish dispersal activities.

Aquaculture research, however, should continue its orientation toward the needs of the industry. Research results should be translated into useful and practical information for the extension workers, industry users, policy makers, and planners. Government and academic research institutions should be encouraged to engage in research that will have a direct impact on the industry's productivity and maximize the profitability of small fish farmers who are the subjects of government's thrusts and programs. The academic, national and international fisheries research institutions must be able to constitute a coherent and coordinated network that pursues specific research goals in conjunction with the commercial, social, and economic development goals of aquaculture.

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AQUACULTURE DEVELOPMENT IN SINGAPORE

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ABSTRACT

The trend of fish production in Singapore is towards increasing contribution from marine and brackishwater aquaculture. Aquaculture production in 1986 represented 6.8% of local fish production. It is envisaged that this sector will provide about 37.5% of production by 1995. Freshwater aquaculture will focus mainly on production of ornamental fish. Production from farming of freshwater food fish is not likely to increase significantly.

Commonly farmed marine finfishes are groupers *(Epinephelus tauvina),* sea bass *(Lates calcarifer),* and golden snapper *(Lutjanus johni).* Crustaceans include prawns *(Penaeus merguiensis),* crabs *(Scylla serrata)* and mussels *(Perna viridis).* Of the freshwater finfishes, the most commonly cultured are the grass, silver and bighead carps, red tilapia *(Oreochromis niloticus* hybrid), Lampam jawa *(Puntius gonionotus),* marble goby *(Oxyleotrix marmorata)* and the snakehead *(Channa* sp.).

Aquaculture systems use a combination of floating and shore-based techniques. Earthen ponds are utilized for the culture of freshwater carps, floating netcages for marine finfish, ponds and floating netcages for marine crustaceans, and rope culture for mussels. Some research and development studies conducted presently include maturation studies to solve the problem of inconsistent supply of prawn spawners, experiments or use of dry formulated feed to do away with dependency on trash fish as main feed for grow-out marine finfish, and investigations on diseases of prawns under intensive culture.

Constraints for large-scale production of finfish seeds lie in the large tank facilities required for producing live feed; for nursery operations, time and manpower required for grading and feeding; for grow-out systems, disease prevention and control; for prawn production, inconsistent spawner supply; and for mussel production, low consumer demand.

The species with the highest potential for fanning in Singapore is the banana prawn, *Penaeus merguiensis* as its culture can be intensified and high yields can be obtained.

INTRODUCTION

Fish and fish products are popular in the diet of Singaporeans. The per capita consumption of chilled, landed marine foodfish is around 30 kg, while that of fish products like fish cakes and fish balls is about 2-3 kg. Since the introduction of floating net-cage farming in coastal waters in 1981, there has also been increasing demand for marine fish to be sold live in the restaurants.

Total supply of fish in Singapore for 1986 was 111 019 mt, with 98.7% (109 529 mt) chilled and frozen marine foodfish, and the remaining 1.3% (1490 mt) farm fresh, mainly marine foodfish and frequently sold live. Fish products, like fish cakes and fish balls, supplied for the same period was about 7800 mt.

Fresh fish supply is mainly imported from neighboring countries. In 1986, imports accounted for 80.4% (89 250 mt) of the total supply. The other source is local production, mainly from offshore trawling. In 1986, local landings accounted for 18.3% (20 279 mt) of total supply. Production from aquaculture formed only 1.3% (1490 mt).

Fish consumption in 1986 was 82 606 mt or 74.4% of total supply, giving a per capita fish consumption of 31.8 kg. Most of the produce is sold in the local market.

STATUS OF AQUACULTURE PRODUCTION

Production trend is toward increasing contribution from marine and brackishwater aquaculture. It is envisaged that by 1995, this sector will supply about 10% of total supply with about 10 000 to 14 000 mt produced annually. Production from offshore trawling is not expected to increase significantly in the future.

Freshwater aquaculture will be increasingly focused on production of ornamental fish. The export of ornamental fish is a multi-million dollar business in the Republic, with value of export reaching S $51.7 M in 1986. Production from farming of freshwater food fish is unlikely to increase significantly.

CONTRIBUTION OF AQUACULTURE TO FISH PRODUCTION

Aquaculture production in 1986 was 1490 mt contributing 6.8% local fish production of 21 769 mt. Production from marine and brackish aquaculture in 1986 was 1290 mt or 86.6% of overall aquaculture production, while that from freshwater aquaculture was only 200 mt (13.4%).

In 1986 production from marine and brackishwater aquaculture comprised 340 mt finfish, mainly groupers (*Epinephelus tauvina*), sea bass (*Lates calcarifer*), and golden snapper (*Lutjanus johni*), 332 mt crustaceans, mainly prawns (*Penaeus merguiensis*) and crabs (*Scylla serrata*), and 618 mt molluscs, mainly mussels (*Perna viridis*).

Only 200 mt of finfish was produced through freshwater aquaculture in 1986. The species comprised mainly grass carp (*Ctenopharyngodon idella*), silver carps (*Hypophthalmichthys molitrix*), bighead carps (*Aristichthys nobilis*), red tilapia (*Oreochromis niloticus* hybrid), Lampam jawa (*Puntius gonionatus*), Marble goby (*Oxyleotris marmorata*), and tomans and aruans (*Channa* spp.).

PRODUCTION TECHNIQUES

Finfish Culture

The aforementioned species are the commonly farmed finfish.

Broodstock production. There are presently five commercial marine/brackishwater hatcheries, two specializing in the production of sea bass fry/fingerlings, two in marine prawn fry production, and one in both. The finfish hatcheries combine floating and shore-based techniques; the marine prawn fry producers are also planning to start on sea bass fry production; and one floating net-cage operator is collaborating with the Government in raising sea bass fry entirely through floating net-cage methods. The government hatchery premises are used for development of techniques, and studies are carried out on the commonly farmed fish, both freshwater and marine brackishwater.

In breeding marine finfish like sea bass, the breeders are reared in net-cages. Net-cage dimensions vary: in the government floating farm specifications are 4 × 4 × 3 m whereas specifications of nets in commercial farms are 6 × 3 × 4 m to 6 × 4 × 2 m.

Brooders are kept at either 1 male to 1 female ratio, or 2 males to 1 female. Stocking density is around 4-6 kg/m^2 net area. No water management or induced maturation is practised. In the former, water exchange is through tidal currents; in the latter, natural maturation is through the lunar effect.

The breeders are fed with trash fish, consisting of small fish of low economic value, at 1-3% body weight daily during the spawning season. Predominant species is the goat fish, *Upeneus* spp. Feeding is done up to 3 times daily.

The breeders are raised from fingerlings and usually not disturbed unless for net changing. If required for placement in shore-based tanks, e.g., in induced breeding or batch treatment, fish are transported in tanks on the boat during the trip to the shore.

Gonad development and sex determination is monitored through cannulation, or for commercial operators, through visual assessment. Sexing is relatively simple in sea bass because of size dimorphism, while degree of bulging of the abdomen indicates the stage of maturity of the female. Monitoring gonad development through bioassay has been attempted by government researchers.

Very low mortality rates is observed for sea bass breeders. However, grouper breeders may suffer high mortalities caused by swollen air-bladder syndrome. The swelling of air bladder causes the affected fish to swim upside down on the water surface, leading to off-feeding and bacterial infection of the exposed portion of the ventral abdominal region. Puncturing the air bladder with a needle deflates the bladder and helps to right the fish. However, affected fish may re-inflate and revert to upside down position a few days later. Antibiotics like oxytetracycline (20 ppm) and chloramphenicol (10 ppm) can be used as a bath for the affected fish.

Main constraint to the commercial sector holding the broodstock is the vertical-integrated system of farming presently practised by hatchery operators. These people are not only involved in hatchery operations but also in farming. Hence the breeders occupy valuable space in the farm, and considerable effort has to be expended by the farmer to cover both hatchery and farming aspects simultaneously. Over time, operators may specialize in different fields.

Seed or fry production. Larvae of sea bass are reared in fiberglass tanks, either in the floating farm or on land. Tanks are either circular or rectangular, varying from 5 m^3 each in the government hatchery to 10 m^3 each in the commercial sector.

Rearing method of sea bass basically follows that developed by Thailand. Stocking density is 30-55/1. Water exchange starts at 20% daily from D_{3-5} and reaches 50% after larvae attain D_{11}.

Feeding is with rotifers (*Brachionus plicatilis*), brine shrimp (*Artemia* sp), and *Moina* (*Moina micrura*). Feeding regime in government hatchery is as follows: D_2 — rotifers at 2-3/ml; D_{3-10} — rotifers at 3-5/ml; D_{11-12} — rotifers at 5-10/ml and *Artemia* nauplii at 0.2/ml; D_{13-15} — rotifers at 5-10/ml and *Artemia* nauplii at 0.5-1/ml; D_{16-17} — *Artemia* nauplii at 0.5-1/ml; D_{18-20} — *Artemia* nauplii at 0.5-1/ml and *Moina* at 0.10-0.15/ml.

Disease is mainly due to bacterial infection. Treatment is with oxytetracycline at 2-10 ppm once every 2-3 days from D_{15-25}.

Harvesting is done by simply using hand nets.

Constraints to large-scale fry production lie in the large tank facilities required for producing the rotifers and supporting green algae *(Chlorella)* used to feed rotifers.

Nursery operation. Fry can be raised either in tanks, usually fiberglass or in floating net-boxes. In the government hatchery, tanks of 8 m^3 capacity are used. Floating net-boxes 1.8 × 1.2 × 0.9 m are used commercially at the farm site.

Stocking density in tanks starts at 5000/m^3, with gradual thinning at different sizes of the fingerling to a final 2000/m^3 when fingerling is 1.5-2.5 cm total length. The density applied commercially in floating net-boxes is said to be higher, varying from 9000-14 000/m^3 initially.

Where floating net-boxes are used, water exchange is through tidal flow. For tank culture, exchange is 30% daily.

Minced trash fish and minced grago *(Acetes* sp) are fed to fingerlings until satiation, 4-6 days. The fingerlings at this stage can also be weaned over to dry feed. This is being studied by government researchers.

The fry may be attacked by isopods especially if they are held out at sea. A formalin bath of 200 ppm for 1 hour is effective in removing the isopods but may be traumatic for the fry.

Main constraints encountered in the nursery operation are frequent grading required to minimize cannibalism during this stage and feeding the fish to satiation, operations which require time and manpower.

Grow-out production. Marine food fish raised in floating farms are held in net-cages 3 × 3 × 2-3 m or 5 × 5 × 2-3 m. The popular fishes reared are (1) finfish such as groupers, sea bass, snappers, rabbit fish, and red grouper, and (2) crustaceans such as crabs, prawns, and lobsters. A net-cage farm may rear a few types of fish and crustaceans. One farm consists of several net-cage units connected by walkways and anchored within a water space of 5000 m^2.

Freshwater carps are reared in earthen ponds, each usually 0.6-1 ha. Plankton feeding carps such as bighead and silver carps are reared in floating net-cages measuring 7 × 7 × 2 m in the reservoirs. However, rearing of fish in reservoirs are mainly for cropping down on the plankton load and not for fish production.

Freshwater ornamental fish are reared in tanks or in nets held in earthen ponds. In the case of the latter, the nets measure 2 × 2 × 1 m, with pond area ranging from 240 m^2 to 4000 m^2.

Stocking density for marine food fish in net-cages starts at 100-150/m^2 initially when the fish are only 7.5-10 cm TL, then to 44/m^2 when fish attain 12.5-15 cm TL. At harvest when fish reach market-size of 600-800 g or 30-50 cm TL, density is around 40/ m^2. Water exchange in net-cages is through tidal currents. Nets are washed as frequently as monthly to remove fouling organisms like tunicates, mussels, and barnacles, and to clear it of silt. Nets with larger mesh are used as the fish grows.

Stocking density in ponds for bighead carps is around 0.13-0.17/ m^2 and for common carp, 0.5/m^2 For floating net-cages, fish are stocked at 7/ m^2 Red tilapia is stocked at 0.5/m^2 in ponds and around 70 m^2 in sea water under intensive experimental culture. There is very little water exchange in carp ponds. However, ponds stocked with Toman have water exchange of 25% every 2 weeks due to the use of trash fish as feed. Water exchange is also very minimal in ponds holding freshwater ornamental fish.

Marine food fish are fed with trash fish at 3-10% body weight daily. Fingerlings of 50 g are given feeds at 10% of body weight, 100 g at 8%, 300 g at 3-5%, and 500 g at 3%. Feed Conversion Ratio (FCR) is around 4-5. Government researchers are developing dry formulated feeds for groupers, sea bass, and golden snappers. FCRs obtained for dry formulated feeds are around 2.

Freshwater carps are fed with dry formulated diet, either imported or locally produced. Main ingredients are fish-meal, wheat products, rice bran, and bread left-overs. Tomans are fed with trash fish. Freshwater ornamental fish are given dry formulated feed and/or live food like *Tubifex* and *Moina.*

Fish loss during grow-out usually occurs 2-3 weeks after stocking the imported fingerlings in the net-cages out at sea. Survival can be improved considerably through sanitation — a series of 3 treatments done at various stages of shipment of the fish consignment: prior to shipment, i.e., pre-shipment, wherein fish are treated in acriflavine bath of 10 ppm for half an hour; during shipment, i.e., transhipment, antibiotics such as nitrofurazone are added to the packing water at 10 ppm; and at the time of stocking, i.e., post-shipment, fish are further treated in formalin at 100 ppm for 1 hour, followed by nitrofurazone at 10 ppm for 4 hours.

During grow-out of marine food fish, the most common disease problem encountered is that of infestation by protozoans, the most common being the ciliate *Cryptocaryon irritans.* Treatment is through a formalin bath at 200 ppm for 0.5 to 1 hr depending on the fish condition and infestation level. Vibrosis, caused by the bacteria of the *Vibrio* species, like *V. parahaemolyticus* and *V. alginolyticus,* is a common disease occurring mainly as a sequel to protozoan infestation or to physical damage sustained after importation or handling. Treatment at the earlier stages of the disease is by oral feeding of the fish with antibiotics, namely, oxytetracycline (0.5 g active ingredient/kg feed for 7 days), or chloramphenicol (0.2 g per kg feed for 4 days). Bath treatment can be attempted if the fish are off-feed: nitrofurazone at 15 ppm for 4 hours, or sulphonamides at 50 ppm active ingredients for 4 hours.

The main parasites and disease organisms in the freshwater food fish in Singapore are the ciliates. These include *Trichodina,* *Ichthyophthirius, Odinium,* and *Chilodinella* species. The copepod *Lernea* sp. is also a common parasite. Nematodes and trematodes may infest the freshwater ornamental fish.

Harvesting in floating net-cages is done simply by manually lifting the nets. For ponds, harvesting is by seining or draining the pond.

Production constraint, in the case of marine food fish, is the limited availability and high cost of fingerlings of certain popular fish species like groupers, snappers, and siganids. Sea bass is presently the only marine food fish which can be commercially bred in captivity, and the government is therefore working closely with the private sector to help farmers establish sea bass hatcheries by transferring the breeding technology to them. Government researchers are also working on the breeding of groupers and snappers.

Other constraints are the difficulty of getting local labor to work in the farm, and the limited demand for live fish in local restaurants. The government has, in certain cases allowed farms to engage foreign workers and has designated certain land on the main island and outlying islands for intensive, high-technology farming, thereby giving investors an option to establish land-based aquaculture as well. Land-based farms with higher automation will not only be able to attract local workers but will also require less workers. Farmers would have to lower production cost through better management and automation so that price of fish is within the means of ordinary consumers to buy. Exportation of live fish is also being explored by some farmers.

Shrimp/Prawn Culture

The marine prawn species cultured in Singapore is the *Penaeus merguiensis* (banana prawn).

Broodstock production. Commercial hatcheries obtain their spawners from the wild and do not hold any broodstock for maturation. A maturation program on banana prawns has been initiated by government researchers.

Seed production. Larvae are reared in tanks or canvas bags. For land-based hatcheries, larvae are usually reared in circular or rectangular fiberglass tanks of 10-15 m^3 capacity. For floating hatcheries, canvas bags of $2 \times 2 \times 1$ m are used.

Stocking density practised commercially is 100/1. Water change is limited to 30-50% daily.

Skeletonema and *Artemia* are the two organisms fed to the prawn larvae, the former from D_{2-11}, and the latter from D_{4-14}. The feeding regimes are as follows: *Skeletonema* — D_{2-8} at 10 000/ml, D_{9-11} at 5000/ml; *Artemia* nauplii - D_{4-6} at 0.5-1.5/ml, D_{7-8} at 2/ml, and D_{9-14} at 3/ml.

Infections by bacteria, causing reddening of the larval body, and by protozoans, namely, *Zoothamnium,* and fungus, namely, *Lagenidium,* are some of the common diseases encountered during larval culture. Preventive measures include good water and tank management, proper feeding regime, and periodic prophylaxis with antibiotics like oxytetracycline, and with chemicals like Cutrine-Plus®. Jelly fish infestation can also totally wipe out the culture. Treatment with 20 ppm formalin for half hour is only partially effective. However, cultures which are heavily infested have to be discarded.

Harvesting can be by hand nets or by draining the culture contents into a harvesting chamber which concentrates the fry within its screens.

Main production constraint is the present reliance on sourcing spawners from the wild. Supply is sometimes restricted to catch during spring tides. A technique of maturing the spawners under captivity is being looked into by government researchers.

Nursery operation. Fry are raised either in tanks, floating net-cages or ponds. Tanks used are usually fiberglass and of 10 m capacity. Floating net-cages are constructed of plankton nets of 0.5 mm mesh. Ponds are earthen and about 0.5 ha.

Stocking density varies from about 900/m^2 in ponds to 6000-8000/m^2 in floating net-cages. In ponds, daily water exchange is estimated at about 5-10%, being effected by tidal flows. In tanks, exchange is 80% daily, while in floating net-cages, water exchange is continuous by tidal currents.

Diseases common during this process include infestations by *Leucothrix* sp. and ciliates like *Zoothamnium* sp. on the gills, and vibrosis by *Vibrio* spp. in the haemolymph. Treatment for *Leucothrix* is through prophylaxis with copper compound (Cutrine-Plus®) at 2.8

ppm for 3 hours; *Zoothamnium* through a formalin bath at 75 ppm for 4 hours and vibrosis through an oxytetracycline bath at 10 ppm for at least 4 hours or through oral feeding at 0.75 g/kg feed for 8 days.

There are no serious constraints for the production of prawn fingerlings or juveniles.

Grow-out operation. Grow-out is commonly done in either earthen ponds or floating net-cages. A commercial company is also attempting to culture Kuruma prawn *(P. japonicus)* in raised, rubber-lined ponds of 2500 m^2 each. Experiments are conducted by government researchers on the use of 40 m^2 raceways for intensive prawn farming.

Stocking density in ponds vary from 20-30/m^2 and 300-600/m^2 in floating net-cages. In raised, lined ponds, densities are 50-60/m^2 while in raceways, the stocking density is around 600/m^2 Water management in ponds is through tidal exchanges and pumping. In raised, lined ponds, water intake is solely through pumping; resulting in 30% exchange daily- In raceways, exchange is also effected by pumping.

In all cultures, the prawns are fed with formulated dry feed, either imported or produced locally. Ingredients include fishmeal and prawn by-products. In certain cases, as in floating net-cages, prawns are also given trash fish aside from formulated dry feed.

The main loss of prawns in pond culture is due to poor water quality or plankton build-up in the pond due to difficulty in changing sufficient water daily. However, with higher stocking densities there is an expected higher incidence of disease, and prophylactic treatment is necessary.

The causative organisms are bacteria and virus, *Vibrio* spp., which causes vibrosis in the haemolymph (as in nursery stage), chitinoverous bacteria suspected to cause burnspots on the exoskeleton, and Hepatopancreas Parvo Virus (HPV) which causes lesions in the hepatopancreas of the prawn. Treatment for the first is by oxytetracycline bath at 10 ppm for 4 hr at least or through oral feeding at 0.75 ppm feed for 8 days. There is no direct treatment for the second, but oxytetracycline bath at 10 ppm for 4 hr may prevent secondary vibrosis in the haemolymph. No treatment is presently available for HPV infection. Other common diseases include muscle necrosis most likely caused by severe stress due to overcrowding and other environmental stress, white pleura disease of unknown origin, the other diseases described for the nursery stage, namely, *Leucothrix* and *Zoothamnium* infestations.

There is no serious constraint in the production of prawns in Singapore. In fact the culture of prawns has considerable potential in the Republic as it can be farmed intensively and there is tremendous local demand for prawns. More in-depth studies are, however, needed on diseases.

Mollusc Farming

Mollusc culture in Singapore is restricted to farming of green mussels *(Perna viridis).*

Broodstock production. Spats are obtained from natural spatfalls, and no attempts at broodstock management are made by the commercial farms except through retention of some percentage of the grow-out population as broodstock.

Seed production and nursery operation. Spats are usually collected on strips of old netting or nylon ropes, both usually at 2 m long. It is estimated for net strips that a good spatfall could result in the settlement of 10 million spats of 0.5 g each on each strip of rope.

No thinning is practised commercially as this has been found to be too time-consuming and labor-intensive by the farmers. Instead, the spats are allowed to thin out naturally. This, however, results in wasteful drop-out of the spats, and only an estimated 10-15% of spats attain market-size 6-8 months later. This technique can be used in areas which are good spat grounds. However, for poorer spat grounds nylon ropes and nettings are not suitable as spat collectors, and coconut coirs have been found to be better spat collectors. Government researchers have devised a rope called poly-coco for such situations. This type of rope combines both collection of spats on the coconut coir sections, and grow-out on the polyethylene main rope.

Grow-out production. Mussels are farmed on ropes suspended from rafts. Specifications of rafts vary, but all are usually rectangular with the long axis parallel to the direction of the tidal current. Ropes are usually each 2-3 m long in the water, with another 1.5 m for tying on the raft.

Ropes are suspended at 4 ropes/m^2 and are kept about 2 m off-bottom. Water exchange is by tidal flow.

Mussels are filter-feeders, feeding on plankton in the sea. At Lim Chu Kang, where commercial farming of mussels is practised, it has not been necessary to induce plankton blooms as the waters there are relatively eutrophic throughout the year.

There is no serious disease or parasites observed to date.

However, water stagnation in the farming area, leading to low dissolved oxygen in the water, and persistent rainfall resulting in lowered salinity, may at times cause localized high mortalities.

Harvesting is by manual lifting of the ropes. This process can be mechanised. Government researchers have been conducting on-site depuration trials with the mussels.

Main production constraint is not in the farming but in the low consumer demand for the product.

AQUACULTURE DEVELOPMENT IN THAILAND

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ABSTRACT

Aquaculture practised in Thailand is in the form of pond culture and cage culture in freshwater, brackishwater and coastal areas. The main species cultured include freshwater prawns, brackishwater shrimp, cockles, mussels, and various freshwater and marine finfishes. There is good potential for increased production from freshwater, brackishwater and marine aquaculture. However, the 1983 production of 145 000 mt represents only about 6% of Thailand's total fish production and production in this subsector has fluctuated widely. It will be several years before aquaculture production will contribute substantially to total production. Nonetheless, the culture of high value species of shrimp and fish could contribute significantly to export earnings during the next 5 to 10 years.

Conducted primarily by government agencies, research and development are along the lines of increasing seed supply, establishing new culture techniques or improving older ones. The Department of Fisheries (DOF) together with some private companies have ventured into the development and testing of artificial diets for the various cultured species using a variety of indigenous feed stuffs.

It is estimated that with adequate investments and appropriate support, aquaculture production will increase from 145 000 mt in 1983 to 378 000 mt in 1991, showing an annual increase of about 13% over this period. Major increases would come from bivalve mariculture (131 000 mt), brackishwater ponds (36 000 mt) freshwater ponds (46 000 mt) and brackishwater cage culture (20 000 mt).

PRODUCTION AND DEMAND FOR FISH AND FISH PRODUCTS

Fisheries form an important industry in Thailand. Total fish productions in 1982 and 1983 were 2.1 million mt and 2.3 million mt valued at US $857 million and US $916 million, respectively. In terms of gross domestic product the fisheries sector contributed 1.7% in 1982 and 1.6% in 1983. Fisheries is one of the largest foreign exchange earners with export revenue at US $517 million in 1982 and US $551 million in 1983.

Inland Capture Fisheries

Inland capture fisheries has shown slow growth during the past several years. Although production data for this subsector may be inadequate, there are some indications that catch is declining. Continued effort by the Department of Fisheries (DOF) to stock fish and to conserve freshwater fishery resources is required to maintain production at 100 000 mt annually.

Aquaculture

Aquaculture in both fresh water and brackish water is practiced as pond and cage culture and along the coast as mariculture. The main species cultured are brackishwater shrimp, freshwater prawns, cockles, mussels, and various marine and freshwater fish species. There is good potential for increased production in aquaculture. However, the 1983 production of 145 000 mt represents only about 6% of Thailand's total fish production, and production in this subsector has fluctuated widely. It will take several years before aquaculture production can contribute substantially to total landings. Nonetheless, the culture of high-value species of shrimp and fish could contribute significantly to export earnings within the next 5 to 10 years.

With adequate investment and appropriate support, it is estimated that aquaculture production will increase from 145 000 mt in 1983 to 378 000 mt in 1991, an annual increase of about 13% over the present volume. Major increases would come from bivalve mariculture (131 000 mt), brackishwater pond culture (36 000 mt), freshwater pond culture (46 000 mt) and brackishwater cage culture (20 000 mt).

The projected demand for table fish for local consumption is presented in Table 1. Although this is based on a steady increase in demand, actually demand will continue to fluctuate as in the past, particularly in response to climatic factors and variation in the rate of growth of real income. There is no evidence of any long-term shift in underlying demand (i.e., a change in consumers' preference for fish) although it is possible that taste may shift in favor of poultry and red meats as supplies increase.

Table 1. Projected demand for table fish for local consumption 1983-1991 (Minimum estimate)

		Consumption per capita (kg)	Table fish demand + 2% ('000 mt)	+ 3% ('000 mt)
Base period	198-83	20.0	970	970
Required	1983[a]		990	1000
	1984		1010	1031
	1985		1030	1060
	1986		1050	1090
	1987		1070	1120
	1988		1090	1160
	1989		1110	1190
	1990		1140	1230
	1991		1160	1270

a/ Preliminary estimate of apparent consumption is 1 059 000 mt.

PRESENT STATUS OF AQUACULTURE

Freshwater

Latest data indicate that the culture of freshwater finfish in Thailand primarily occurs in about 6000 ha of ponds and 53 000 ha of abandoned rice paddies. Finfish is also cultured in cages suspended in rivers and reservoirs. The yield varies with species and culture system. In ponds it is 1.2-120 mt/ha/yr and in paddies about 1.4 mt/ha/yr. Production from cage culture is 1-2 mt/yr/cage area of 20 m^2 . The principal species cultivated with their corresponding culture systems and yields are shown in Table 2.

Table 2. Principal culture systems of freshwater finfish in Thailand

Species	Culture system M = Monoculture P = Polyculture	Stocking Rate (m^2)	Rearing time Per Crop (mo)	Yield (mt/yr)
Tilapia nilotica	Pond:			
	M or P, fertilized water	3	6	4.8/ha
	M, supplemental feed	3	4-6	6.2/ha
	M, integrated farming	3	4-6	7.2/ha
Carps (common Chinese, Indian)	Pond:			
	M, supplemental feed	0.7	12	1.2-3.6/ha
	P, fertilized water	0.7	12	1.2-2.4/ha
	M or P, integrated farming	0.7	12	4.8/ha
Puntius gonionotus	Pond:			
	M, fertilized water	3-4	6	2.4-4.8kg/ha
	M, supplemental feed	3-4	6	4.8-6.0/ha
	Paddy fields:			
	P	--	12	3-4 kg/ha
Clarias spp.	Pond:			
	M, complete feed	40-100	3.5-5	30-120/ha
Ophiocephalus sp.	Pond:			
	M, complete feed	30-40	8	90/ha
Trichogaster sp.	Paddy fields:			
	M, fertilized water	_	12	0.9-1.4*/ha
Pangasius sp.	Pond:			
	M, complete feed	3	12	30/ha
	Cage:			
	M, complete food	20	12	30 kg/m^2 /crop
Oxyleotris sp.	Cage:			
	M, complete feed	LOO	15	35 kg/m^2/crop

*Includes about 0.5 mt of "wild" fish trapped in ponds and harvested with *Trichogaster* sp.

The *Macrobrachium* culture is growing rapidly in Thailand. Annual production exceeds 3000 mt in 1984 from more than 200 farms ranging in size from 800 m^2 to 40 ha. Average yield is 1000 kg/ha.

Brackishwater

The production of fish through aquaculture has recently acquired significance in Southeast Asia.

Attention is now being focused on the coastal environment primarily because saline and brackishwater have limited use for agriculture but can be used for aquaculture. There are several marine species of economic importance used for coastal aquaculture. Production from fisheries activities in a year was more than 2 million mt: 171 000 mt from aquaculture, 1 900 000 mt from marine fisheries, and 200 000 mt from freshwater fisheries. Aquaculture production is about 8.6% of the total.

The status of coastal aquaculture and mariculture can be seen in the production data in Table 3. Finfish from culture activities is not included as a separate category in official statistics.

Table 3. Production (metric ton) and value (x 1,000 Bahts*) of coastal aquaculture products

Year	Shrimp		Cockle**		Mussel		Oyster	
	Product	Value	Product	Value	Product	Value	Product	Value
1979	4 064	460 586	23 741	61727	49 397	65 698	9 876	91 452
1980	8 063	458 908	17 666	77 735	31 386	129 633	6 015	60 105
1981	10 728	657 264	23 354	81 373	36 746	78 469	8 429	85 951
1982	10 091	765 683	8 636	29 302	65 509	128 263	5 671	39 598
1983	11 550	950 370	16 575	56 095	43 130	106 983	5 322	38 669

* 30 Bahts = US $11.10
* Includes Hoy Krang, hairy cockle, *Scapharca inequivalvis*

STATUS OF PRODUCTION TECHNIQUE

Finfish Culture

The culture systems for various finfish species of greatest economic importance are described below.

Clarias *culture.* The culture of *Clarias batrachus* and *C. macrocephalus* is well established in Thailand. More than 5 000 mt of *Clarias* valued at more than $50 million is being produced annually.

Stocking rates of 3-7 cm fingerlings is 60-300/ m^2. The feed input is a mixture of 9 parts trash fish and 1 part of rice by-products. Marketable fish, 100-350 g, are attained in 3-5 months; most yields are 3-12 kg/m^2 of pond area depending primarily on mortality.

Management practices include liming the ponds to ensure suitable water quality, changing water when necessary, disease control and prevention by using formalin and dipterex to get rid of ectoparasites, and applying antibiotics in feeds to control or prevent bacterial diseases.

High fish mortality are often related to poor water quality due to contaminants. Increasing cost of feeds and unstable market prices are prevailing problems of the industry.

Sepat Siam (Trichogaster pectoralis) *culture.* *Trichogaster* is primarily cultured in abandoned paddy fields modified to form 5 ha ponds by constructing a peripheral ditch and an enlarged dike to maintain water depth greater than what is necessary for rice production. Returns from this culture system are more profitable than rice cropping. Present annual production is in excess of 13 000 mt in 1984 valued at $20 million.

The stock comes from brood fish introduced into the ponds. One pair of spawners is stocked per 16 m^2 of water surface. Resulting fry densities are about 185/ m^2. Emergent vegetation in the shallow central part of the pond is mowed regularly to enrich the water. Water exchange is practised. Fish are harvested when they reach about 100 g in 6-7 months. Yields of *Trichogaster* are usually 0.7-1.1 mt/ha; another 0.3-0.6 mt are obtained from wild fish (e.g., *Ophiocephalus, Anabas, Clarias,* etc.) which accidentally enter the ponds and are harvested along with *Trichogaster.*

Pangasius *spp. cage culture.* Commercial scale culture of *Pangasius* in cages is well established. The present yield is about 9000 mt. In 1984 market prices fluctuated widely and the value of this crop ranged from $1.5 to $3 million.

Cages, mostly 20 m^3, are made of wooden slats usually attached to floating family dwellings. Fingerlings, 8-10 cm, are stocked at 50/m^3 of cage volume. Basic feed consists, of rice bran, broken rice and trash fish mixed at a ratio of 9:1:1, respectively. Additional feed are soya bean and vegetable wastes. The typical feeding rate is 2% or less of the body weight daily. Mortality in cages is low and the normal yield is about 100 kg/m^3 for a 15-month growing period.

Sea bass (Lates calcarifer) *culture.* Seabass has been produced for more than 40 years in shrimp ponds in the coastal areas of Thailand. The method involved collection of sea bass fry from estuaries near the river mouth, mangrove areas, and from shrimp farms. The major problem was lack of fry for stocking which limited the expansion of culture areas. In 1973, the Department of Fisheries succeeded in artificially spawning sea bass. With sufficient fry available, the Department developed culture systems. Cage culture was demonstrated to be effective. Following the Department of Fisheries, the private sector also engaged in commercial breeding and culture of sea bass.

During the last decade the Department of Fisheries succeeded in establishing different techniques for producing sea bass fry:

1. *Natural breeding.* Usually 12-15 pairs of breeders are stocked per 150 t breeding tank. Breeding pairs are about 3 years old.

2. *Hormone injection.* The method was established at Prachuap Khiri Khan Station and is being used by many private farms.

The Fisheries Department can produce more than 30 million fry/yr. After 30-45 days, when the fry are approximately 1-1.5 cm in total length (TL) they are distributed to farmers. The fry can be cultured in brackish or freshwater areas. The culture techniques for sea bass are:

1. *Earthen pond culture.* Fingerlings, 2-3 inches long (50-100/pc), are stocked in ponds. Production period is 6 months to produce 2500 kg/ha.

2. *Cage culture.* Technique is commonly used in the southern and eastern coast of the coastal area. Two cage dimensions are used, namely, 10 × 10 × 2 m and 5 × 5 × 2 m. Average production is 21.8 kg/m^2/yr. Stocking density is 25/m^2 and harvest weight is 500 g. There are at present about 100 sea bass cages in Thailand (Table 4).

Table 4. Sea bass culture in Thailand as of 1983

Province	Rearing Facilities		Surface area	Rearing Facilities		Surface area	Production	Value
	pond	cages	(m^2)	farm	cages	(m^2)	(mt)	(× 1000 Baht)
Chanthaburi	3	4	188	3	4	188	3.48	231.37
Trat	1	3	24					
Krabi	2	3	27	2	3	27	0.42	33.60
Trang	42	77	816	16	20	480	9.17	634.37
Pattani	62	87	235	21	31	835	5.00	349.86
Phangnga	62	284	455	62	284	2445	169.58	13 107.63
Thatthalung	27	70	1827	16	56	1477	1.69	118.26
Ranong	4	15	4136					
Songkhla	363	845	40 527	355	848	39 161	784.28	58 368,78
Total	566	1408		475	1246	44 613	973.62	72 843.87

3. *Pen culture.* This system is not popular in Thailand because of the difficulty in finding suitable production areas.

Thailand is well known throughout Southeast Asia for sea bass. Large numbers of seed are exported to Hong Kong, Singapore, and Taiwan.

Grouper (Epinephelus *spp.) culture.* Grouper is a popular food fish in Southeast Asia. The fish can be cultured in ponds or cages. It grows fast to marketable size of 400-900 g.

The Department of Fisheries succeeded in artificial breeding of grouper by hormone injection in 1981. Other methods of breeding are natural spawning and stripping. In the latter, eggs are fertilized after the dry method. The fry are reared in a net-cage and fed with chopped fish until they reach 5-8 cm. After attaining the desired size, the fingerlings are transferred to a net-cage 3 × 3 × 2 m or 5 × 5 × 2 m at 25 fish/m^2. The stock is fed with trash fish until the fish weighs 400-500 g. The culture period is usually 6-7 months. Production is 25 kg/m^2 /yr.

Cage culture of grouper is practised throughout southern Thailand. There are about 900 cages in the coastal zones. The Department of Fisheries is conducting research on rearing of the larvae to metamorphosis. After the techniques have been established, the technology will be transferred to the private sector. Grouper culture in Thailand is presented in Table 5.

Feed development. A variety of feeds is used in freshwater aquaculture in Thailand. Growth of natural food is often enhanced with organic and sometimes inorganic fertilizers. Rice by-products such as rice bran and broken rice is commonly used as supplemental feed. Trash fish is the primary food for carnivorous species such as *Clarias* and *Ophiocephalus.* The use of artificial diets is gaining momentum with some commercial companies now producing specific feeds. The following diets have been developed by the DOF.

1. Feed formula for Carp and Tilapia broodstock
(Protein = 26%)

Fishmeal	18%
Peanut meal	26%

Table 5. Grouper culture in Thailand as of 1983

	Rearing Facilities		Surface area	Rearing Facilities		Surface area	Production	Value
	pond	cages	(m^2)	farm	cages	(m^2)	(mt)	(× 1000 Baht)
Chanthaburi	1	4	12					
Krabi	67	393	3738	25	225	2025	17.80	1 553.13
Trang	9	38	955					
Phangnga	168	611	5433	152	564	5020	157.59	14 344.04

Fine rice bran	30%
Cassava root meal	20%
Horse tamarind meal	4%
Vitamin & Mineral	2%
	100%

2. Feed formula for carp fry (Protein = 33%)

Fishmeal	30%
Fine rice bran	45%
Peanut meal	24%
Vitamin & Mineral	1%
	100%

3. Feed formula for growing tilapia (Protein = 18%)

Fishmeal	18%
Cassava root meal	41%
Fine rice bran	40%
Vitamin & Mineral	1%
	100%

4. Feed formula for growing *Puntius* (Protein = 23%)

Fishmeal	12%
Peanut meal	23%
Fine rice bran	40%
Cassava root meal	20%
Horse tamarind meal	4%
Vitamin & Mineral	1%
	100%

5. Feed formula for *Clarias* fry (Protein = 36%)

Fishmeal	60%
Peanut meal	8%
Fine rice bran	8%
Alpha starch	16%
Fish oil	6%
Vitamin & Mineral	2%
	100%

6. Feed formula for growing *Clarias* (Protein = 32%0

Fish meal	20%
Peanut meal	14%
Cottonseed meal	16%
Caproc seed meal	10%
Shrimp head meal	10%
Fine rice bran	10%
Cassava root meal	9%
Bone meal	2%
Horse tamarind meal	4%
Fish oil	3%
Vitamin & Mineral	2%
	100%

Seed production. Some seed for culture operations is provided by government hatcheries and many are generated by the farmers themselves. Fry and fingerlings of some species like *Clarias, Trichogaster,* and *Tilapia* are produced by brood fish reared in ponds with some special provisions. *Ophiocephalus* fry are obtained from wild sources. Seeds of certain species are obtained mainly through controlled reproduction by hormone injection. Hormone treatment varies depending on species.

Shrimp and Prawn Culture

Macrobrachium rosenbergii *culture.* The annual production of 3 100 mt in 1984 of *Macrobrachium* is valued at $17.5 million. Some farmers grow their own seed stock in hatcheries ranging from backyard operations production with a few thousand larvae to industrial operations with an output of 10 million larvae. Current postlarvae supply is about 30 million/yr with 6 million originating from government hatcheries. Larval diets consist of egg custard and minced fish fed several times a day and *Artemia* nauplii fed once every evening. Grow-out prawns are fed a variety of diets ranging from farm-produced moist pellets to commercial poultry pellets. Feed conversion of the wet diets averages 1:6-7. Stocking density varies from 5-20/m^2.

Harvesting usually begins on the fifth month when the thinning out process starts and larger prawns are sold. The optimum market weight is 75 g each. The crop is harvested in about 8 months.

Total yield per ha is often less than 1 000 kg/yr. Survival can be as low as 20-40%, particularly when high stocking rates are employed. The low recovery is attributed to predation by crabs, carnivorous fishes, turtles, and poachers. Pond water is not normally renewed continuously but some larger farms replace 20% of the water daily.

Shrimp (Penaeus monodon, P. merguiensis) *culture.* Shrimps are produced in earthen ponds. In most areas the traditional or extensive method of production is used. Methods are normally simple, land is subject to flooding at high tide and wooden sluice gates are installed to control water flow. Excavation is limited to a perimeter area yielding just enough material to make a narrow dike. Fry are allowed to enter the ponds with the incoming tide. They stay in the ponds for some time growing in the rich condition of the swamp. Average yield of *P. monodon* is 3750 kg/ha/year. The existing and potential

Table 6. Existing and potential shrimp farming area in Thailand as of 1983 (Coastal Zone Survey, 1983)

Province	Existing (ha)	Farms	Potential (ha)
Bangkok	881	141	
Samut Sakhon	2321	1039	
Samut Songkhram	5057	527	480
Phetchaburi	1211	106	640
Prachuap Khiri Khan	358	63	280
Chumphon	88	8	600
Surat Thani	1592	233	3200
Nakhon Si Thammarat	8658	1735	4800
Songkhla	58	9	240
Pattani	16	1	2560
Narathiwat	8	10	184
Trat	8	9	3200
Chanthaburi	548	62	480
Rayong	7	5	176
Chon Buri	544	56	320
Chacnoengsoa	681	42	480
Samut Prakan	7841	985	160
Ranong	11	10	576
Phuket	—	—	32
Phangnga	99	10	720
Krabi	16	6	352
Trang	1	1	1040
Satun	256	3	640
Total	36 905	5334	23 160

areas for shrimp culture are listed in Table 6 and production from shrimp farming is shown in Table 7.

Table 7. Shrimp production in Thailand (Fisheries Statistics, 1986)

Year	Area (ha)	Quantity (mt)	Value (million baht)
1979	24 675	1 706 407	460.59
1980	26 036	706 305	458.91
1981	27 459	1 072 787	657.26
1982	30 790	1 009 077	765.68
1983	35 537	1 154 985	950.27
1984	36 792	1 200 675	1 024.01
1985	40 769	1 584 956	1 348.42

Table 8. Production in millions of brackishwater shrimp seeds for 1982-1986

Year	1982	1983	1984	1985	1986
Banana Shrimp	11 000	11 700	14 200	15 800	18 500
Jumbo Tiger Prawn	10 200	12 700	19 400	20 600	21 900
Total	21 200	24 400	33 600	36 400	40 040

Hatchery seed production of *Penaeus monodon* does not meet the demand. Production in 1984 was only 18.8 million postlarvae but demand was over 180 million. Insufficient seed supply is attributed to shortage of gravid females from the wild. Intensive research on brood-stock development using eyestalk ablation has been conducted by the Brackishwater Fisheries Division. The Department of Fisheries is increasing the number of stations providing fry and is extending techno-logical information to private investors to increase seed supply. The target production for shrimp seeds in government hatcheries for 1982-1986 is shown in Table 8.

Mollusc Culture.

Oyster culture. There are 4 species of oysters found in the coastal waters of Thailand. The important species for culture are *Saccostrea* *cucullata, Crassostrea belcheri,* and *Crassostrea lugubris.* The former is distributed along the river mouths and coastal areas of Trat, Chanthaburi, Rayong, Chonburi and Prachuap Khiri Khan Provinces while the latter are found in Krabi, Phangnga, Surat Thani, Pattani and Chumphon. Oyster culture has existed in Thailand for more than 40 years. Several traditional methods have been practised depending on the nature of the substratum. Stones, stakes, or concrete blocks are used as substrates for attachment of oysters. Oyster seeds are small organisms generally suspended in the water. Pairoj (1974) conducted an experiment with *Crassostrea lugubris* on concrete culvert material. The oyster was harvested within 7-12 months. Yield was 250 000-312 500 oysters/ha. The yield of the small oyster (S. *cucullata)* culture in Chantaburi Province was 19 mt/ha.

At present, oyster culture area is approximately 1127 ha (Table 9), while the potential area for development is nearly 6400 ha (Table 10). Recent production figures are 5663, 8442 and 5171 mt for 1980 to 1982.

Mussel culture. Culture of the green mussel has been carried out in Thailand for more than 60 years. The fishermen first collected mussels attached to the stakes of certain types of stationary fishing gear. It was relatively easy to use strong lengths of bamboo or date palm stakes driven into muddy bottoms of shallow water zones as collectors of mussel spats. The method is commonly and successfully used along the coastal areas of Thailand. The attached spats are allowed to grow for 6-8 months before harvesting them for the market. Pairoj (1971) reported that yield of about 62.5 mt/ha could be obtained.

It is believed that the first mussel farming in the south began in Chumphon Province about 16 years ago. Promotion and extension of mussel farming were slow because of lack of natural seed in the coastal areas . of Nakhorn Sri Thammarat, Pattani, Surathani, and Phangnga. The Department of Fisheries introduced adult male and female mussels into other areas. The first introduction was in 1977 at Pattani. Later, mussels were transplanted to Nakorn Sri Thammarat and Phangnga. The results of these attempts have been moderately successful.

At present, mussel farms occupy 661 ha while the potential area is estimated to be 10 605 ha for the 21 maritime provinces (Tables 9 &

10). The production of green mussel is almost entirely from culture activities.

Table 9. Existing bivalve farm (ha) as of 1983

Province	Green mussel	Horse mussel	Blood cockle	Oyster	Total
Samut Sakhorrn					
Samut Songkhram			320		320
Chachoengsao	240				240
Chon Buri	224	240		274	738
Rayong				83	83
Chanthaburi				467	467
Phetchaburi	48		128		176
Prachuap Khiri Khan	12			3	15
Chumphon	119			86	205
Surat Thani			160	79	239
Nahkorn Sri Thammarat			37		37
Phatthalung					0
Songkhla					0.16
Pattani	5				37
Narathiwat					0
Ranong				100	100
Phangnga	11		245	0.16	96
Krabi				2	1.6
Trang			16		16
Satun			300		300
Phuket					0
TOTAL	659	240	1206	1127	3232

Horse mussel culture. The two economically important species of the horse mussel found in Thailand are *Modiolus metcalfei* (Hanley) and *Arcuatuala arcuala.* Culture of these species have been conducted for more than 30 years. There were 117 ha of farming area in 1973. This was increased to 146 ha in 1978. Other species are found on the coast of Andaman Sea in smaller quantities.

Two methods of farming are usually employed. First horse mussel seed 5-10 mm in size are spread over the mud flat at a rate of 56-62/ha. After 8-12 months at the size of 2-3 cm the mussel are harvested by dredging. Production ranges widely at 75-225 mt/ha. In the second method, mussels are spread over the bottom of shrimp ponds. No data on yield/unit area are available.

The horse mussel, 2-3 cm in length, are sold for human consumption at 1.4 baht/kg. Smaller horse mussel are harvested and sold for animal feed at 0.75 baht/kg.

The potential area for horse mussel production is over 4500 hectares.

Table 10. Potential bivalve area (in ha) as of 1983

Province	POTENTIAL AREA					
	Green Mussel	Horse Mussel	Blood Cockle	Oyster	Total	Grand Total
Samut Sakhorn	320	96	320		736	736
Samut Songkhram	640		528		1168	1488
Chachoengsao	800	480	192		1472	1712
Chon Buri	320	320	80	160	880	1532
Rayong	640	160	80	240	1120	1203
Chanthaburi	575			480	1056	1523
Phetchaburi	320		532	160	1012	1188
Prachuap Khiri Khan	640	80	160	320	1200	1215
Chumpohon	608	160	200	150	1118	1324
Surat Thani	640	200	2880	90	3970	4209
Nakhon Sri Thammarat						
Thammarat	1000	300	2272	140	3872	3909
Phatthalung						
Songkhla	160			80	248	248
Pattani	320		320	400	1040	1077
Narathiwat				500	500	500
Ranong	480	500	2000	500	3480	3580
Phangnga	960	2000	2000	1000	5960	6216
Krabi	480	160	752	201	1591	1595
Trang	400		1056	500	1956	1972
Satun	480	150	1000	500	2140	2440
Phuket	160		96		256	256
TOTAL	9944	4616	1447	5749	34 777	37 923

Cockle culture. Cockle farming has been conducted in Thailand for many years with the early farms located in Phetchaburi Province. In that area, approximately 50 cm high bamboo sticks are used to fence each production area which averages 1 ha. Farms are located in mud flats or shore lines and adjacent to river mouth or canal. The site must be intertidal, have sufficient width, and a small gradient.

Cockle seeds are collected from the wild in the same location. The prevailing species is *Anadara nofidera.*

During the last decade a different culture system has developed in the southern provinces, on the Andaman Sea Coast, and the Gulf of Thailand. Production is on mud flat with water depth of 2-5 m. Farm size is 32-320 ha. Farms require a large amount of seed for stocking. More than 4000 mt of cockle seed *Anadara granosa* are imported from Malaysia annually. This is stocked at 3375-6750 kg/ha. The seeds are dredged after a certain growth period to spread them evenly. The market size cockles are harvested after 12-18 months. The culture period depends on initial size of seed.

Seaweed Culture

Thailand does not produce large quantities of seaweed. Harvest is from natural beds. The Department of Fisheries is conducting research and examining the feasibility of mass propagation of seaweed species, especially *Gracilaria* sp. This species of algae is found in Trat, Songkhla, Pattani, and Trang Provinces. Local fishermen collect the seaweed and dry it for sale to middlemen for export. The price is about 20 baht/kg (approximately US $1.10). Total export in 1982 was 68 mt valued at 21 thousand baht.

Laver *(Porphyra* sp.) is collected from natural areas during the cool season (December-January) principally from Songkhla Province. Production is very limited, amounting to only 100-300 kg annually.

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BROODSTOCK MANAGEMENT AND SEED PRODUCTION OF *PENAEUS MONODON* (FABRICIUS)

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ABSTRACT

Research on the maturation of *Penaeus monodon* at AQD has focused on three broad areas, namely, reproductive biology and ecology, induced maturation and broodstock management. Studies on reproductive biology provided information on the life cycle, ovarian maturation stages, courtship and mating behavior, minimum size at sexual maturation (sperm occurrence, first spawning), and morphological egg types. Induced maturation has mainly been done through the eyestalk ablation method. Nutritional and environmental parameters were studied to enhance reproductive performance or as an alternative to ablation. Pond-reared and wild broodstock sources and marine pen and land-based tanks as maturation systems were also tested and compared. Size, shape, color, substrate material and other aspects of tank design and construction, sex ratio, stocking density, water management, and other parameters of the management system were also studied and refined.

Early techniques in larval and postlarval rearing of *P. monodon* at AQD were based on the community culture method of growing natural food in larval tanks. However, low and inconsistent survival led to a shift in rearing methods toward pure phytoplankton culture grown in separate tanks as food for the larvae. Henceforth, refinement of rearing methods have been conducted to improve larval survival through effective water management, nutrition, and disease control. Efforts are continuously being geared toward making the technology affordable to Filipino farmers.

INTRODUCTION

In 1973, when the Aquaculture Department was first established, there was no commercial prawn culture in the country to speak of - prawns and shrimps were harvested as incidental crops from milkfish ponds. Recognition of penaeids as an important aquaculture commodity is evidenced by the start of prawn research that very same year. Since then, continuing research on prawn biology and culture at AQD has generated technology particularly in the areas of maturation and larval rearing which are highlighted in this paper.

BROODSTOCK DEVELOPMENT AND MANAGEMENT

Reproductive Biology and Ecology

Much of the available information on the life cycle of *Penaeus monodon*, can be traced to the five-year study of Motoh (1981) on the fisheries biology of the species. He described five ovarian maturation stages - undeveloped (1), developing (2), nearly ripe (3), ripe (4), and spent (5) - based mainly on progressively increasing mean egg diameter (35-235 μm) and external appearance. Other workers (Santiago 1977; Pudadera and Primavera 1981; Primavera 1982, 1983) also used external and dissected appearance of ovaries and histology to classify maturation stages. More recently, Tan and Pudadera (unpublished) gave a comprehensive classification into four stages using histological (egg diameter, gonadosomatic index) and histochemical criteria:

1. previtellogenic stage - oogonia and oocytes in chromatin nucleolus and/or perinucleolus eosinophilic,
2. vitellogenic stage - eosinophilic yolky oocytes,
3. cortical rod stage - oocytes with peripheral rod-like bodies, and
4. spent stage - remaining oocytes with yolk and/or cortical rods, thicker follicle layer, and few dark irregular perinucleolar oocytes.

Motoh (1981) found that over a three-year period, occurrence of wild *P. monodon* spawners peaked in March and October in Tigbauan, Iloilo (Southern Panay Is.) and in February, July, and November in Batan Bay, Aklan (Northern Panay Is.). Minimum spawner size was 48 mm carapace length (CL) and mean size was smaller (62 mm CL) in Batan Bay, a river mouth, compared to large sizes (64-72 mm CL) in the offshore waters of Tigbauan, Iloilo and Himamaylan, Negros Occidental (Motoh 1981).

Table 1 summarizes data on minimum size of *P. monodon* at sexual maturation: functional maturity or ability to mate of the male (petasma jointed) and female (presence of sperm in thelycum) and physiological maturity or production of eggs and sperm (Motoh et al 1976; Motoh 1981; Primavera 1978). Interestingly, pond stock reached maturity at sizes smaller than wild animals.

Table 1. Minimum size at first sexual maturation of *Penaeus monodon* (Motoh et al 1976, Primavera 1978, Motoh 1981)

Maturity	Male	Female
Functional	jointed petasma = 34 mm CL wild	+ sperm, thelycum = 47 mm CL wild = 39 mm CL pond
Physiological	+ sperm, testes = 37 mm CL wild = 31 mm CL pond = 40 g BW pond	maturation, spawning = 48 mm CL wild = 75 g BW wild

Copulation in closed thelycum penaeids, such as *P. monodon,* requires molting of the female. Primavera (1979) described three stages in the courtship and mating behavior of *P. monodon* starting with the parallel swimming of female and male or males up to the insertion of spermatophores inside the thelycum by one successful male. Such information has been valuable in designing maturation systems.

Based on his observations, Motoh (1981) concluded that first mating occurs at 4-5 mo in brackishwater areas where ovarian maturation also commences but full maturation is completed followed by spawning only after migration to offshore waters at around 10 mo.

A positive correlation was established between fecundity and female size in terms of CL (Motoh 1981) and body weight (Villegas et al 1986). Development of *P. monodon* eggs was described by Motoh

(1981); incubation period or hatching is 12-15 hr after spawning. Incubation period and hatch rate of eggs were observed under different temperature-salinity conditions (Reyes 1981). Time to hatching was inversely proportional to temperature whereas salinity did not affect it. Conversely, salinity affected hatch rate of eggs, but not temperature.

Based on morphology and hatch rates, Primavera and Posadas (1981) developed an egg classification system (Fig. 1) useful in predicting the number of nauplii from a given prawn. There is a highly significant linear relationship between the proportion of good (A_1) eggs and hatch rate.

Spawners are disinfected with 50-100 ppm formalin and spawning water with 10 ppm chlorine. Treatment of spawned eggs with 10 ppm detergent gave significantly higher hatch rates (97.2%) compared to those treated with other fungicides and untreated controls (Po and Sanvictores 1986).

Induced Maturation

Three basic approaches have been employed to induce ovarian maturation in penaeid shrimps: endocrine stimulation by ablation, nuttritional, and environmental. So far, maturation and successful spawning have been reported only for eyestalk-ablated *P. monodon* although diet and environmental parameters may also enhance reproductive performance.

Completion of the cycle of P. *monodon* was first achieved in 1975 (Santiago 1977). Maturation was observed in both unilaterally and bilaterally ablated females but the latter did not spawn and suffered total mortality. Unablated females as controls did not mature.

Although cutting, tying and cautery have been tried the preferred ablation method is by incision-pinching because of its convenience and lack of stress on the prawn (Primavera 1978, 1983).

Monitoring of tagged (Rodriguez 1976) ablated females shows an increase in rematuration rates in 1977-1979 from 10.4 to 23.2% for second spawnings and from 1.6 to 5.9% for third spawnings (Primavera 1982).

Nutrition plays an important role in maturation. In the wild, 85% of ingested food of adult *P. monodon* consisted of small crabs and shrimps and molluscs (Marte 1980). The more frequent occurrence

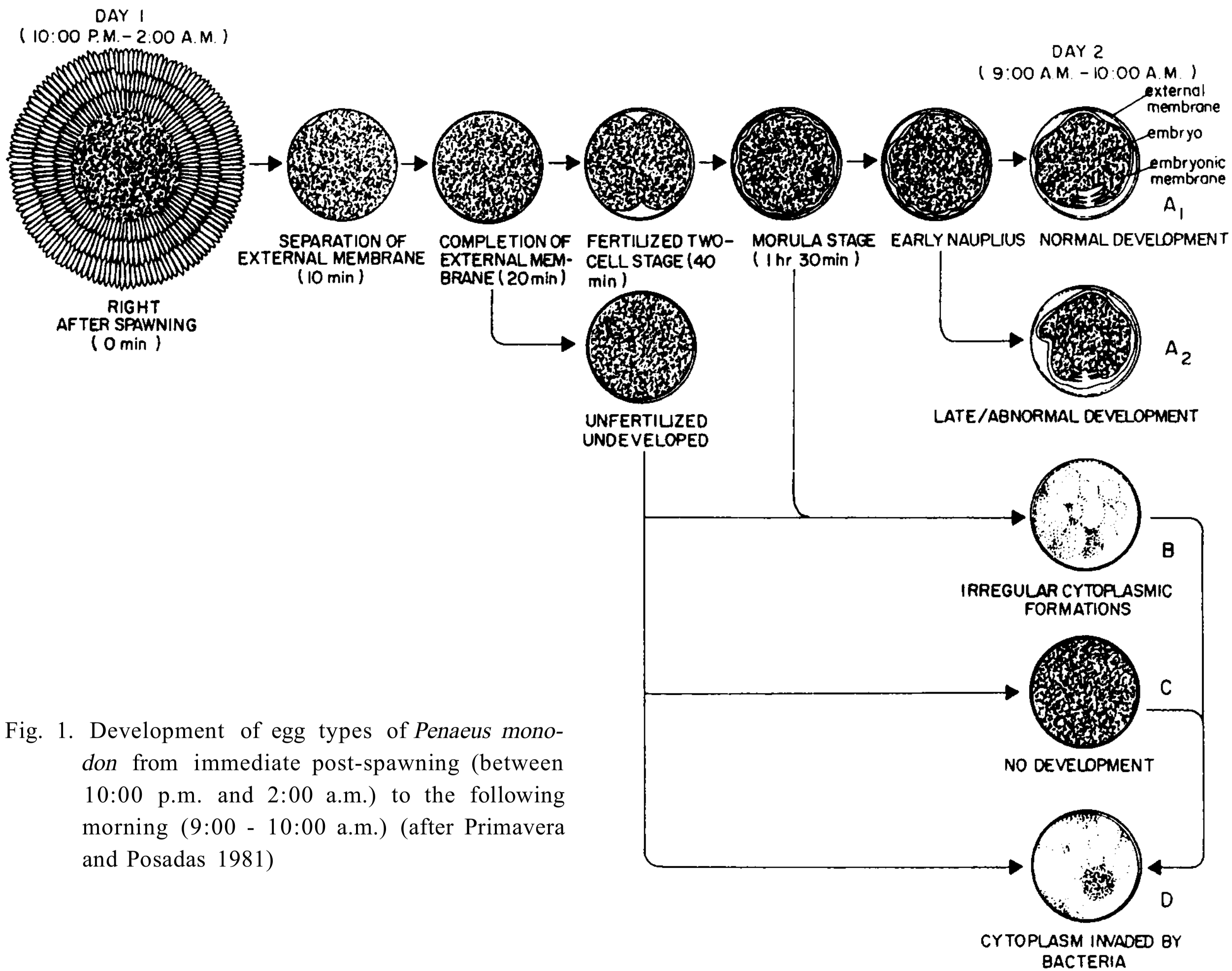

Fig. 1. Development of egg types of *Penaeus monodon* from immediate post-spawning (between 10:00 p.m. and 2:00 a.m.) to the following morning (9:00 - 10:00 a.m.) (after Primavera and Posadas 1981)

of molluscs and other non-crustaceans during months of higher feeding index may reflect changes in dietary requirements related to gonad development during the spawning season (Marte 1982).

Wild immature *P. monodon* females showed an increase in ovarian lipid levels upon reaching full maturity from 5.8 to 17.0% and from 7.5 to 21.9% in unablated and ablated females, respectively (Millamena et al unpublished). The fatty acid profile showed 12.1-24.9% and 11.8-21.5% total fatty acids in unablated and ablated females, respectively, consisting of 20:4ω6, 50:5ω3 and 22:6ω3 fatty acids. The same polyunsaturated fatty acids (PUFA) were reflected in the spawned eggs, indicating their importance in the reproductive process.

A study of different feeding regimes showed highest larval production and hatch rates when ablated *P. monodon* were fed with molluscs (squid, mussel) in combination with a pellet (Primavera et al 1979). More recently, Millamena et al (1986) obtained the best reproductive performance from ablated females given pellets with cod liver oil (longer chain C_{20} and C_{22} PUFA and higher ω3:ω6 ratio) compared to those with soybean lecithin (C_{18} PUFA and lower ω3:ω6 ratio).

A few environmental studies at AQD have focused on light. In an early study, unablated *P. monodon* attained only partial maturation under blue and natural light but not under red light (Pudadera and Primavera 1981). Only ablated females reached full maturation and spawned. An ongoing study incorporating recent improvements in broodstock management and nutrition will verify these results.

Broodstock Management and Maturation System

Broodstock from the wild or pond source may be stocked in maturation tanks or pens, and retrieved as gravid females, eggs or nauplii (Primavera 1985).

Broodstock source. *P. monodon* broodstock may be obtained from the wild or from ponds. Wild broodstock are caught from coastal waters by trawler or motorized pumpboat such as a baby trawler and from estuaries by tide-dependent stationary gear such as fish corrals, lift nets, and lever nets (Motoh 1980, Primavera 1983). Age at ablation from spawning varies from 5 mo (Primavera 1978) to15 mo (Santiago 1977). Satisfactory maturation, spawning, and metamorphosis of larvae to post-larvae have been obtained from females with a minimum age of 8 mo (Primavera 1982, unpublished; Millamena et al 1986). In the wild, *P.*

monodon attains full maturity and spawning at 10 mo (Motoh 1981).

Early studies showed poor reproductive performance of pond stock compared to wild stock with the proportion of good eggs and corresponding hatch rates lowest from pond-ablated followed by wild ablated and best hatching from wild spawners (Primavera and Posadas 1981). Hence for the last three years, studies at AQD have concentrated exclusively on pond stock.

Even with production of good quality larvae and postlarvae from pond-reared *P. monodon,* the state-of-the-art is to use wild broodstock for three reasons. First, the non-availability of pond broodstock-holding the prawns beyond the 3-4 mo cropping period means a loss to the farmers. Second, wild broodstock give a faster turnover producing in 6 weeks the same number of nauplii pond broodstock can yield in 12 weeks. Lastly, pond stock require a maturation pellet often not commercially available (Millamena et al 1986) whereas wild broodstock can be maintained on natural food alone.

Maturation systems. Primavera (1983, 1985) traced the evolution of a suitable maturation system for *P. monodon* dating back to the Igang pens in 1975 through varying sizes of land-based tanks to the present 12 m^3 tank. The tank system offers advantages of security and convenience in maintenance and broodstock sampling over the pen.

Tanks may be made of cement, ferrocement, fiberglass, and plastic or canvas-lined aluminum or wooden tanks. Tank size is a compromise between the biological requirements of the broodstock and the convenience of the hatchery personnel as can be seen in the popularity of the 10-12 m^3 circular tank. In a recent study, Primavera et al (unpublished) observed consistently higher total egg and nauplii production and hatch rates from females in a black-walled tank compared to those in unpainted tanks. A white sand substrate gave significantly higher nauplii production and hatch rates from ablated *P. monodon* compared to black sand (Pudadera et al 1980a).

Ideally, maturation tanks should have a flow-through water system with 100-400% daily exchange rate. However, water should be recirculated when flow-through is not feasible as when sea water is polluted or turbid during typhoons (Primavera 1983).

Depending on water quality and exchange rate and prawn size, stocking density of P. *monodon* is 2-7/m^2 (Primavera 1985). Sex ratios of 1-2 females to 1 male are more economical because they maximize egg and larval production per tank (Pudadera et al 1980b).

Although ablated *P. monodon* can mature and spawn at a salinity range of 15-32 ppt, full salinity is required for incubation and hatching of eggs (Posadas 1986).

Monitoring and Retrieval

Nauplii collectors have been tested for *P. monodon* (A.T. Young pers. comm,), but spawner retrieval gives the advantages of individual records of body measurements, egg numbers and hatch rates, and easier processing of eggs (Primavera 1983). Examination of broodstock and retrieval of spawners is more manageable in 10-12 m^3 tanks than in tanks larger than 20 m^3 ,and more efficient with frequent monitoring of broodstock. Nightly checking of a 12 m^3 tank yielded 48 spawnings producing 6.8×10^6 nauplii compared to only 3.0×10^6 nauplii from 29 spawnings with thrice weekly monitoring (Pudadera et al 1980a).

The maturation requirements for *P. monodon* including size and age, feeding and tank parameters are summarized in Table 2.

Table 2. Summary of maturation requirements for *Penaeus monodon,* SEAFDEC Aquaculture Department, 1975-1987

Size	70-150 g female, 45-120 g male
Source	Pond or wild
Age, pond	Minimum 10 mo (from spawning)
Ablation	Required
Feeding	
Regime	Pellet + natural food (mussel, squid, annelids)
Lipid source (pellet)	6% cod liver oil
Light intensity	Reduced (~ 100 lux)
Light quality	Ongoing study
Tank size	12 m^3 tank, circular
Tank color (inner walls)	Black
Substrate	White sand
Water	100-400% flow-through
Density	3-5/m^2 (300-400 g/m^2)
Sex ratio	1-2 females to 1 male

LARVAL AND POST-LARVAL REARING

Rearing Facilities

Seed production of *Penaeus monodon* in SEAFDEC AQD started in 1975 with rearing techniques similar to those used in the MSU-IFRD. Larvae were reared in rectangular 50, 120, and 200-t concrete tanks installed under a structure with translucent plastic roofing (Platon 1979). With the barangay hatchery concept, a more compact hatchery model was introduced in 1977. The basic unit consisted of 2-t larval rearing tanks, 2 units 1-t algal tanks, 2 units 1-t *Brachionus* culture tanks, and 1 unit 1-t *Chlorella* culture tank, a small compressor or blower for aeration, and 2 sets of water pump. Larval tanks were made of marine plywood shaped into a cylinder with an octagonal cross section and a conical bottom fitted with a drain valve to facilitate draining and harvesting (Platon 1978).

In 1981, the use of shallow (not more than 1 m deep) bathtub-shaped larval tanks made of concrete, wood or fiberglass was recommended. Instead of gate valves, 2 inch PVC drain pipes were installed for draining and harvesting. *Brachionus* and *Chlorella* culture tanks were no longer necessary as the feeding scheme was modified. Aeration was provided by portable electric aerators (Gabasa 1981).

The continuous search for low-cost materials for tanks led to the use of locally-available materials such as bamboo and wooden slats with polyethylene plastic sheet linings (Anon. 1984). There was more flexibility in the materials and shapes of larval tanks to be used as shown in Table 3.

Rearing Methods

Seed production of *P. monodon* at SEAFDEC AQD started with techniques adopted from the community culture method where phytoplankton was allowed to bloom in the larval rearing water as food for the animals. A modification in the system was the hatching of eggs in the spawning tank and not in the larval tank (Anon. 1975). Water was introduced to the larval tanks to a depth of 2 m and was fertilized so that there will be a diatom bloom by the time animals molt to the zoea stage. Nauplii were stocked at a density of 6 000/t as mass mortality occurred at densities beyond this. Baker's yeast was introduced at the zoea and *Artemia* nauplii or rotifers *(Brachionus)* at the mysis stage

Table 3. Comparison of larval tanks used in the seed production of *Penaeus monodon.*

Category	Capacity	Material	Description
Large-scale hatchery[a]	50-200 t	concrete	rectangular
Barangay hatchery[b]	2 t	marine plywood	cylindrical with an octagonal cross-section and a conical bottom; with gate valve for draining
Small-scale[c]	preferably 1.5-12 t	concrete, wood, or fiberglass	bath-tub type; about 0.8 m deep with 2" PVC drain pipe
Small-scale[d]	preferably 3-5 t	concrete, fiberglass, marine plywood, or locally-available materials such as bamboo or wood slats with plastic sheet lining	circular, rectangular or square; sloping bottom; with drain pipe

[a]Platon (1979)
[b]Platon (1978)
[c]Gabasa (1981)
[d]Anon. (1984)

(Table 4). About 20% of the total water volume was changed daily starting at mysis stage. Survival rate at harvest (P_9) was very low and inconsistent, attributed to the non-selective production of natural food and uncontrolled blooms that fouled the water.

An important innovation in the feeding method was initiated in 1976. Diatoms such as *Chaetoceros* or *Skeletonema* were grown in separate algal tanks and concentrated with the use of a sand filter before feeding (Yap 1979). This lessened the possibility of unwanted algal blooms and allowed the culturist to choose the species of phytoplankton to be fed.

To scale down the hatchery technology to a level which can be adopted by local farmers with a minimum of financial and technical input, the barangay hatchery was conceptualized in 1977. Smaller tanks and a more compact hatchery model was used (Platon 1978). Stocking density of larvae was increased to 30-50/1 and harvest was at P_5. The 1977 barangay hatchery feeding scheme in Table 4 was used. However, the basic concern was the culture of natural food which needs specific technical skill and which involved use of more tanks and synchronization of mass production of food with larval rearing. Studies on optimization and simplification of production techniques were thus conducted.

Optimization studies included testing of media for phytoplankton production (Anon. 1977) and screening of phytoplankton species for larval food (Aujero et al 1983). Simplification of production techniques involved studies on the use of preserved natural food so these may be cultured during off-culture periods of larvae.

The use of 100 ppm alum or lime or NaOH to raise the pH of the phytoplankton medium and cause floc formation was tried. The harvested phytoplankton were successfully preserved by freezing at -20 to -22°C with a cryoprotectant but had to be neutralized before use (Aujero and Millamena 1981). This technique was not adopted by private operators as this entailed use of a pH meter which is quite costly. Frozen rotifers and sun-dried phytoplankton were also tested as food but did not perform as well as live phytoplankton (Anon. 1979).

Other attempts in lessening phytoplankton requirement or dependence on this were made by testing possible phytoplankton supplements such as baker's yeast (Villegas and Kanazawa 1980), marine yeast (Aujero et al 1984), whole egg, brown mussel meat, trash fish, soybean cake (Quinitio et al 1983) and egg yolk (Quinitio and Reyes 1983).The

Table 4. Feeding schemes used in the larval rearing of *P. monodon* at SEAFDEC AQD

	ZI	ZII	ZIII	MI	MII	MIII	P1	P2	P3	P4	P5
1. Modified community culture method[a]											
Phytoplankton											
+Baker's yeast											
+*Artemia* or *Brachionus*											
2. Barangay hatchery scheme[b]											
Skeletonema or *Chaetoceros* (x 10[3] cells/ml)	30	50		80							
+*Tetraselmis* (x 10[3] cells/ml)		5	10		20			5 –	10		
+*Brachionus* (ind/ml)				5	8	10					
+*Artemia* (ind/ml)									5		
3. Small-scale hatchery scheme[c]											
Tetraselmis (x 10[3] cells/ml)			5								
+Egg yolk (particles/ml)			15	25							

+*Artemia* (ind/ml)		10 – 15	15 – 20
+Baker's yeast (if not *Tetraselmis*)	0.1-0.3/t/day		
4. Modified egg yolk feeding method[2]			
Skeletonema or *Chaetoceros*	5 – 10		
or *Tetraselmis*	2.5 – 5		
or mixed diatoms (x 10^9 cells/ml)	5 – 10		
or mixed diatoms (x 10^9 cells/ml)	5 – 10		
+Egg yolk (particles/ml)	15-25		
+*Artemia* (ind/ml)		2 – 5	2-5
5. Present feeding scheme[a]			
Skeletonema or *Chaetoceros* (x 10^9 cells/ml)	20 – 50		
+Microparticulate diet (g/t/day)	1 – 3		
+*Artemia* (in/ml)	0.5 – 5		

most popular among those tested was the eggyolk introduced by Gabasa (1981). Using the feeding scheme in Table 4, an average survival rate of 52.9% (P_5) was obtained while only 2.5% resulted from the previous scheme (Gabasa 1981). The stocking density of nauplii was increased to 50-100/1, so more larvae could be reared in a given volume of the tank. Furthermore, tanks for *Chlorella* and *Brachionus* cultures were no longer necessary. The ratio of algal tank to larval tank volume, therefore, decreased (Table 5). With this technology, rearing of P_5 for 10-15 more days in nursery tanks before transferring to ponds was recommended. A further modification of this culture method (Anon. 1984a) is presented in Table 4. This allowed more freedom in selecting the phytoplankton species to be given as food to the larvae.

Later studies, however, revealed that egg yolk was deficient in polyunsaturated fatty acids which was shown to be an important component of larval diet (Millamena and Quinitio 1984.) This was one of the causes of the shift toward the use of commercially available micro¬particulate diets (Table 4 present feeding scheme). Use of locally available feed such as powdered *Acetes* also gave promising results (Kungvan¬kij et al 1983). However, feeding of these artificial diets still involved use of natural food (Table 4). With the carageenan-microbound diet formulation, preliminary results showed that this could be used as a total phytoplankton substitute (Bautista and Millamena unpublished).

The Aquaculture Department has also probed into the possibility of using substitutes for *Artemia.* But *Brachionus, Moina* sp. and *Tisbintra* as food for mysis and postlarvae did not perform as well and were not as convenient to use as *Artemia* (Anon. 1982). To make this expensive food item available locally, *Artemia* culture in tanks (Sorgeloos et al 1980) and in salt ponds (De los Santos et al 1980; Primavera et al 1980; Jumalon et al 1983) has been successfully undertaken.

Studies on biology and larval stage identification by Motoh (1979) were valuable as feeding and water management in a hatchery system vary with larval stage. Investigation of the larval tolerance to various environmental factors such as salinity (Reyes 1981) and nitrite and ammonia (Catedral 1977) also contributed to the determination of optimal rearing conditions.

Diseases and Parasites

Research on the prevention and control of diseases and parasites includes (1) isolation and identification of possible pathogens, (2) screening

Table 5. Feeding schemes at SEAFDEC AQD

Feeding Scheme	Food Items Used Until P_5 Rearing	Ratio of Tanks for Natural Food Culture to Larval Tanks
Modified Community Method (Anon. 1975)	Phytoplankton Baker's yeast *Artemia* or *Brachionus* or Copepods	No separate tanks for natural food culture
Barangay Hatchery Method (Platon 1977)	Diatoms *Brachionus* (to be fed with *Chlorella)* *Tetraselmis* *Artemia*	1-1.5:1
Small-scale Hatchery Method (Gabasa 1981)	*Tetraselmis* sp. Egg yolk *Artemia*	0.5:1
Small-scale Hatchery Method (Anon. 1984)	Diatoms or *Tetraselmis* sp. Egg yolk *Artemia*	0.17-0.2:1
Present Method	Diatoms Microparticulates *Artemia*	0.17-0.2:1

for a suitable prophylactic (prevention or chemotherapeutic (control), and (3) bioassay experiments to test larval tolerance to the chemotherapeutic.

Several microorganisms have been identified to cause mortalities in the larval stages. These include the suctorean parasite *Ephelota gemmipara* (Gacutan et al 1977), the ciliates *Zoothamnium, Vorticella,* and *Epistylis* (Gacutan 1979), fungi of the *Lagenidium* (Baticados et al 1977) and *Haliphthoros philippinensis* (Hatai *et al* 1980) species, and bacteria such as *Leucothrix* and *Vibrio* (Anon. 1985). Infestation by ciliates were, in many instances, cast off by successful molt. These pathogens were not very lethal to *P. monodon* (Gacutan 1979).

Lagenidium and *Haliphthoros* were the most prevalent causes of larval mortalities in prawn hatcheries in the late seventies (Gacutan 1979). Several chemicals were tested for the prevention and control of these mycotic agents. At its effective dose, malachite green was tolerated only by mysis and post-larvae (Lio-Po et al 1978) while furanace not only caused reduction in phytoplankton population (Baticados and Gacutan 1977) but also caused deformities in the larvae (Gacutan et al 1978). Mycostatic and mycocidal chemicals were identified by Lio-Po et al (1982 and 1985) as potential control agents. Tolerance experiments indicated that Treflan-R at a dose of 0.2 ppm was effective against both pathogens and did not cause significant reduction of larval population (Lio-Po and Sanvictores 1986).

SUMMARY

Based on techniques used in the community culture and the Galveston (separate culture of natural food) methods, SEAFDEC AQD has adopted the technology to suit local conditions. It has also scaled down the hatchery technology to a level local farmers can afford.

Despite the achievements of the Department, several production constraints could be identified:

1. lack of spawner or nauplii supply
2. lack of technicians, and
3. occurrence of disease.

Research must, therefore, be directed toward improvement of the reproductive performance of pond-reared or wild broodstock and the optimization of rearing conditions for increased survival rate.

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BROODSTOCK MANAGEMENT AND SEED PRODUCTION OF MILKFISH

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ABSTRACT

Milkfish *(Chanos chanos* Forsskal) remains one of the cheapest sources of protein for developing countries in Southeast Asia, particularly in the Philippines. The unpredictable supply of wild fry, the only source of seed for the milkfish farmer, contributed largely to the slow growth of the milkfish industry. Research on the artificial propagation of this fish was, therefore, given emphasis.

Major research achievements in milkfish breeding of the SEAFDEC Aquaculture Department in the last decade include: (1) successful induced spawning of wild and captive breeders using gonadotropin preparations and gonadotropin-releasing hormone analogues (GnRHa); (2) spontaneous maturation and spawning of captive breeders; (3) completion of the life cycle of milkfish in captivity; (4) development of a simple egg-collecting method; and (5) development of techniques for mass production of milkfish fry.

Information on fry ecology and behavior, larval morphology and physiology were also gathered. These published data constitute the bulk of current knowledge on milkfish biology and natural history.

Milkfish breeding technology is currently being pilot-tested in several breeding sites of the Bureau of Fisheries and Aquatic Resources (BFAR). Spontaneous maturation and spawning of milkfish have been verified in four sites which differ in environmental characteristics. The economic feasibility of producing milkfish fry and the socio-economic impact of artificial propagation of milkfish are now being assessed.

INTRODUCTION

Of the finfish species cultured in Southeast Asia, milkfish contributes 56.2% to total fish production from aquaculture (Rabanal 1987, this Proceedings) thus, emphasizing its economic importance. In the

Philippines and Indonesia where milkfish has been cultured for centuries, fry collected from the wild is the only source of seed for the farmer. The relatively slow growth of the milkfish industry has been, in part, due to unpredictable and seasonal supply of fry. Research on the artificial propagation of milkfish was initiated at the SEAFDEC Aquaculture Department in 1976 to ensure an adequate and steady fry supply.

As part of an overall effort to fully understand the biology of milkfish and to document practices related to its culture, ecological studies to identify and characterize milkfish spawning grounds, fry grounds, and nursery grounds were undertaken. The results of these studies have been reviewed by Kumagai (1984) and Bagarinao and Kumagai (in press). Traditional methods used in fry capture, handling and storage have also been documented (Kumagai et al 1980, Villaluz 1984). This paper presents the achievements and results of studies on milkfish breeding and artificial propagation at the SEAFDEC Aquaculture Department.

BROODSTOCK DEVELOPMENT AND MANAGEMENT

The methods of rearing milkfish to maturity are described in Marte et al (1984). Pond-reared stock (BW = 250 g) are collected from brackishwater ponds and transported to the rearing site in canvas holding tanks filled with sea water and provided with aeration. Transport is by van and pumpboat and may take from 2-8 hr.

Broodstock rearing facilities used at SEAFDEC AQD are floating cages, concrete and canvas tanks. The floating net-cage, however, is preferred for reasons of economy and convenience. The fish are initially reared from 1-3 years in smaller net-cages (4-5 m diameter) or stocked directly in 9 or 10 m diameter cages. Stocking densities normally do not exceed 1.5 kg/m^3. Broodstock reared in small cages are transferred to large cages (6-10 m diameter) on the fourth year of rearing.

The floating net cage facilities at Igang Substation, Guimaras Island, are located about 100 m from shore in an area protected from the open sea by small islands. It has a sandy-muddy substratum and a water depth of 7-10 m. Water transparency is about 5 m; annual salinity and temperature ranges are 26-34 ppt and 25-32°C, respectively. A limited number of broodstock used for various experiments are also reared in canvas or concrete tanks.

One- to three-year old fish are given commercial feed pellets containing 23-32% protein at 1.5%-2% body weight. On the fourth year of rearing or the year before the fish are expected to mature, commercial feed pellet containing 43% protein are fed at 3-5% body weight. The proximate composition of the commercial feed pellets is given in Table 1. The floating net cages are periodically checked for damage and fouling.

Table 1. Proximate composition of milkfish broodstock feed

	Fish Pellet[a]	Crustacean Feed[b] No. 2
Crude protein (%)	35.86	44.26
Crude fiber (%)	6.10	2.26
Crude fat (%)	5.12	4.62
Nitrogen-free Extract (%)	43.18	37.88
Moisture (%)	11.56	8.03
Ash (%)	9.76	10.97

[a]Fed to 1-3 year old milkfish at 1.5-2% body weight

[b]Fed to 4-year old and older milkfish at 3-5% body weight

Reproductive Biology of Captive Milkfish

Captive milkfish sexually mature at 3.5-5 years (Lacanilao and Marte 1980, Marte and Lacanilao 1986). Hatchery-bred fry reared from artificially fertilized eggs from a wild adult female caught in 1978, sexually matured and spawned in 1983 marking the first completion of the life cycle of milkfish in captivity (Marte et al 1983, Marte and Lacanilao 1986). Subsequently, several stocks of milkfish from wild-caught or hatchery-bred fry have matured and spawned at five years.

The results have been verified at four breeding sites of the National Bangus Breeding Program (NBBP) of BFAR located in different regions of the country. Milkfish also matured and spawned at five years in these sites under different environmental conditions.

Captive milkfish undergoes an annual reproductive cycle (Marte and Lacanilao 1986). Sexual maturation occurs during the natural breeding season of wild fish. Gonad development starts in February or March and peaks in April-June (Fig. 1). All fish sampled during these months were maturing or mature (Fig. 2a and 2b). Most fish sampled in July-September were spent. Only regressed and immature fish were obtained in October-December. Sexual maturation appears to coincide with rising seawater temperature and lengthening photoperiod.

Milkfish held in cages smaller than 6 m in diameter have never matured or spawned although fish from the same stock held at the same stocking density but in larger cages spawned (Marte personal observation).

Gonadosomatic index (GSI) of milkfish at different maturity stages is shown in Table 2. GSI for mature females is 1.24-8.12; for mature males, 0.32-3.95. Fecundity is estimated at 250 000-350 000/kg body weight.

The involvement of the pituitary gland in gonad development is well documented in many fish species. In milkfish, the changes in the pituitary during gonad development have been described (Tan 1985), providing a morphological basis to assess the effects of hormonal manipulation on gonad maturation ana spawning.

The number of natural spawnings from various broodstock observed from 1980-1987 has increased (Table 3). Spawnings of a hatchery-bred stock from 1985-1987 indicate that the month of peak spawning varies and may be influenced by the condition of the broodstock. In 1985, peak spawning from Cage 43 occurred in June and July while in 1986 the spawning peak was in September and October. Some fish in this cage were transferred to another cage in March 1986 when gonad development was in progress. The disturbance caused by the transfer may have induced gonadal regression of maturing fish resulting in delayed maturation of the stock. The number of spawnings from Cage 43 (Fig. 3) with 10-16 females from July-October 1986 (23) and June-August 1987 (30) also indicates that milkfish spawns at least twice during the breeding season. Data from fish sampled from various cages since 1980 indicate that a sex ratio of 1 female to 1 male is the norm.

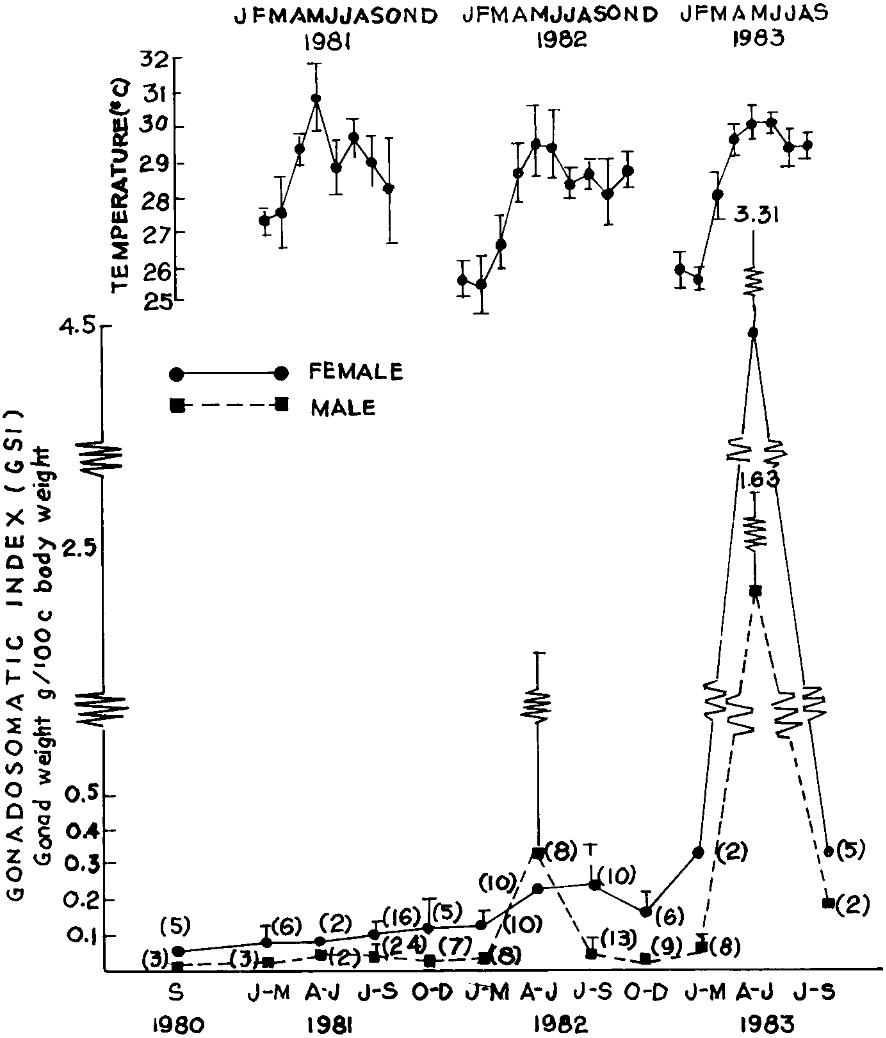

Fig. 1. Mean gonadosomatic index (GSI) of hatchery-bred milkfish sampled in 1980-1983. Points are means, vertical lines represent standard deviation, bracketed numbers denote sample size. Mean surface temperatures are shown on top of figure (From Marte and Lacanilao 1986)

Natural spawning of captive broodstock occurs around midnight although occasional spawnings have been observed at daytime. Wild milkfish was also reported to spawn at around midnight (Senta et al

Table 2. Fork length, body weight, gonad weight and gonadosomatic index (GSI) of Hatchery-bred milkfish at different maturity stages. Values are means ± standard error (From Marte and Lacanilao 1986)

Maturity Stage	N	Folk Length (cm)	Body Weight (kg)	Gonad Weight (g)	Gonadosomatic Index (%)
			FEMALE		
Immature	34	53.0 ± 0.47	2.6 ± 0.07	5.7 ± 0.58	0.21 ± 0.02
Maturing	3	54.8 ± 1.56	2.8 ± 0.10	20.8 ± 8.22	0.74 ± 0.29
Mature	7	55.8 ± 0.62	3.5 ± 0.10	193.6 ± 30.64	5.58 ± 0.94
Spent	5	56.3 ± 1.04	3.0 ± 0.10	9.7 ± 0.04	0.33 ± 0.01
			MALE		
Immature	27	51.2 ± 0.49	2.5 ± 0.09	0.9 ± 0.12	0.03 ± 0.004
Maturing	6	53.7 ± 0.78	2.7 ± 0.11	12.9 ± 5.31	0.51 ± 0.23
Mature	6	56.8 ± 2.09	3.3 ± 0.20	105.9 ± 12.95	3.23 ± 0.32
Spent	7	55.4 ± 0.86	2.9 ± 0.10	4.2 ± 0.77	0.14 ± 0.02

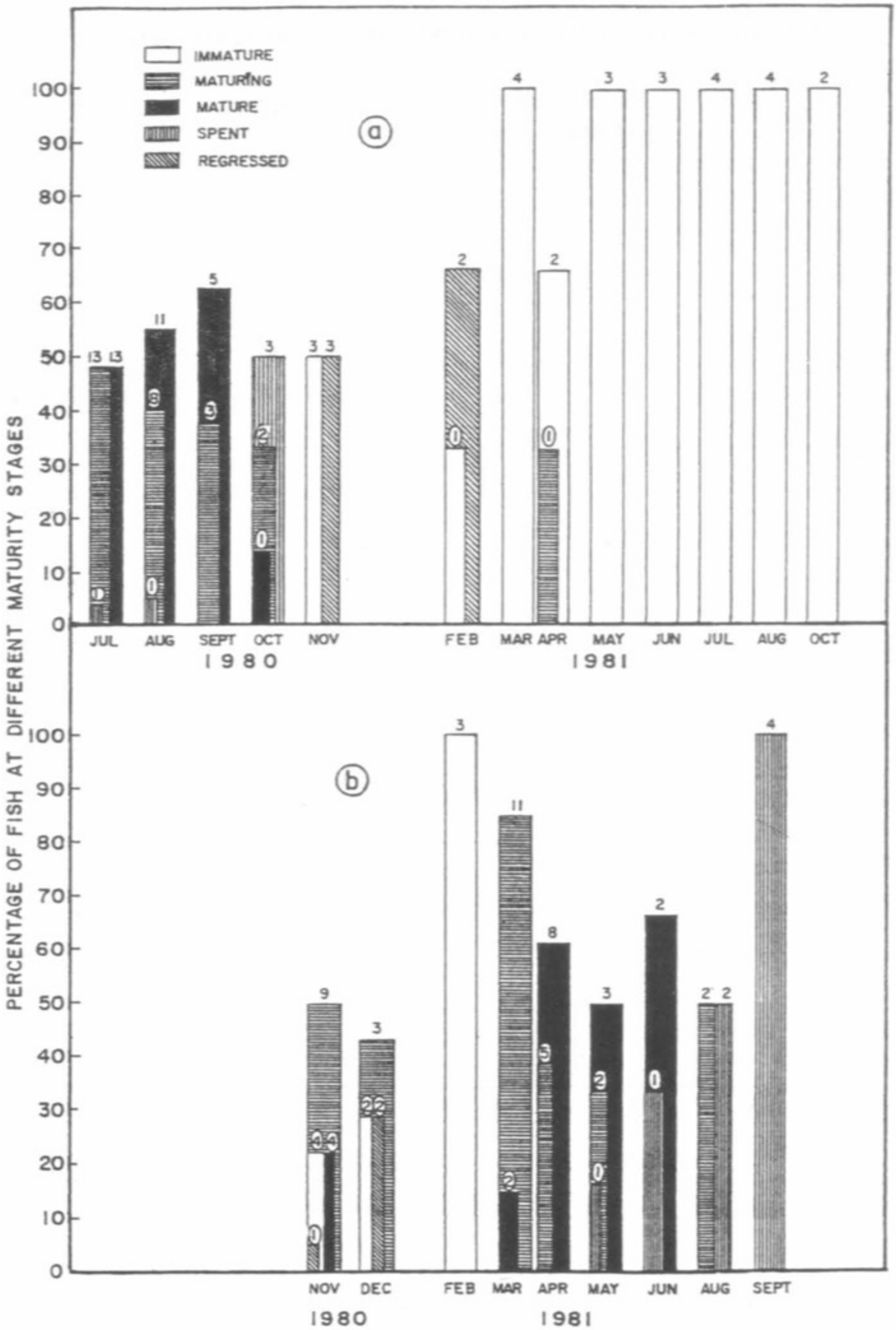

Fig. 2. Milkfish broodstock from wild-caught fry at different maturity stages: a. fish from Cage 5 sampled July 1980-October 1981; b. fish from Cage 6 sampled November 1980-September 1981. *'Maturing or mature gonads in atresia. Numbers denote sample size (From Marte and Lacanilao 1986)

Table 3. Natural spawnings of milkfish 1980-1987 in floating net cages

Year	No. of Spawnings	No. of Cages	No. of Eggs Collected	Range (In Thousands)
1980	2	1	1 400	0. 50- 0.90
1981	8	1	15 765	0.342- 6.293
1983	14	1	315 421	0.770- 114.00
1985	41	4	6 317 132	1. 50- 143.00
1986	64	6	29 196 500	1. 20-2 226.00
1987 (May to Aug.)	61	4	49 279 801	21. 00-2 928.00

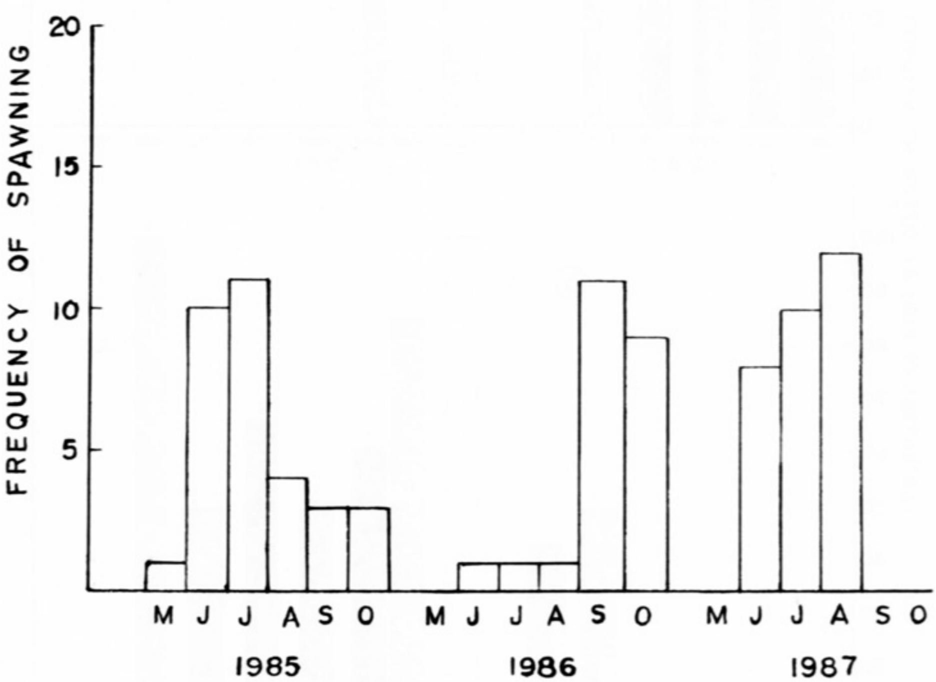

Fig. 3. Monthly spawning of 1980 hatchery-bred milkfish from Cage 43

1980). This observation was based on the developmental stage of milkfish eggs obtained by plankton tows in ecological studies done to identify and characterize milkfish spawning grounds. From the number of eggs collected from the wild and the frequency of fry occurrence, spawnings of wild milkfish were reported to be influenced by lunar phase (Kumagai 1984). The observed spawnings of captive milkfish from floating cages, however, do not indicate a similar lunar periodicity (Table 4).

Table 4. Moon phase and frequency of spawning of milkfish reared in floating cages

	New Moon	First Quarter	Full Moon	Last Quarter
1985	6	11	15	9
1986	6	14	14	17
1987	19	13	12	17
	31	38	41	43

Egg Collection

Although milkfish spawns spontaneously in net-cages, collection of spawned eggs was a technical problem. Various methods of collecting eggs were tried from 1980-1983 with only limited improvement in the number of eggs collected (Table 5, Marte et al 1987b). Eggs were lost through the cage bottom and from predation by other fishes that had easy access into the cage. Recently, a nylon net-cage of 1 mm mesh (hapa) installed inside the broodstock cage partially solved the problem (Marte in press). The number of eggs collected by manual seining in the

Table 5. Egg collector type, spawning frequency, and egg collection (1980-1985) (From Marte et al 1987b)

Egg Collector Type	Year	Cage No.	Number of Spawnings	Number of Eggs Collected
Type A stationary plankton net	1980	C-5	2	500 - 900
Type A stationary plankton net	1981	C-6	8	342 - 6 293
Type B Stationary plankton net	1983	C-2	14	770 - 114 000
Type C stationary plankton net	1985	C-5	1	1 050
Seine net	1985	C43	35	1 500-769 000
Egg sweeper	1985	C-42	5	4 280 - 212 000

hapa enclosed cage increased more than tenfold (Table 6). Manual seining, however, is laborious and requires at least two persons to do the collection at dawn. Recently, a manually operated "egg sweeper" has considerably facilitated egg collection (Garcia et al 1988). The total number of eggs collected from May-August 1987 in four cages holding about 120 fish was 45 115 000. This is a marked improvement over the number of eggs collected in 1986 from 5 cages during the same period (Table 7).

Egg Transport

Milkfish eggs are transported from the spawning site at Igang Substation to the hatchery at Tigbauan Research Station. Duration of transport is from 2-5 hr. Estimate of hatching rates of eggs after transport was consistently lower compared to hatching rates of eggs from the same batch retained at Igang. In addition, a high percentage of abnormal larvae was observed from several batches of eggs indicating that conditions during transport may have adversely affected early embryonic development. Eggs are transported at gastrula to neurula stages. Preliminary results of simulated egg transport experiments indicated that eggs may be transported: (1) at densities of 7 000/1, (2) at salinities of 20-32 ppt, and (3) at ambient temperature of 28°C (Garcia and Toledo in press). Lowering the temperature of the transport water resulted in significantly higher egg mortality and decreased hatching rate. Eggs are routinely transported in oxygenated plastic bags inside *pandan* bags at densities of 100 000 eggs/15 1 of sea water.

Induced Spawning

Initial efforts to breed milkfish focused on the development of techniques to spawn wild adults or sabalo. Methods of capturing and techniques of handling wild adults have been developed (Vanstone et al 1976). A method for sexing wild spawners based on the external appearance of the urogenital apertures has also been reported (Chaudhuri et al 1976). To confirm the sex of breeders, gamete samples are obtained by inserting a polyethylene cannula (Clay-Adams PE 100) through the abdominal or urogenital pore. Yolky eggs obtained in this manner are measured to determine readiness of the female for induced spawning. Salmon pituitary homogenate (SPH) alone or in combination with human chorionic gonadotropin (hCG) were used for spawning wild adults or captive breeders (Vanstone et al 1977, Liao et al

Table 6. Number of eggs collected from two milkfish broodstock cages with and without "hapa" net cage (From Marte in press)

	Without "Hapa"			With "Hapa"		
	No. of Spawns	Range of Eggs Collected	Total Eggs Collected	No. of Spawns	Range of Eggs Collected	Total Eggs Collected
Cage 42	17	3 340 - 668 000	2 141 000	14	330 000 - 2 040 000	10 902 000
Cage 43	9	6 400 - 200 000	329 500	14	292 000 - 2 942 000	15 355 000
TOTAL	26		2 470 500	28		26 237 000

Table 7. Monthly spawning from different milkfish broodstock cages from 11 May to 24 October 1986 (From Marte in press)

Cage Number	34*	38*	41	42	43	44*	
Number of Fish	23	31	60	39	35	30	
Age of Fish (Yrs)	8	10	5	6	6	6	
Month							No. of Eggs Collected
May	2	3		4			1 484 400
June		2		10	1	1	1 135 200
July				2	1		31 500
August				2	1		810 000
September			1	8	11		11 976 800
October			1	5	9		13 758 500
TOTAL	2	5	2	31	23	1	29 196 500

*Fish in these cages were used for induced spawning and rematuration experiments in May-September 1986.

1979 and Juario et al 1984). The results of these early experiments are summarized in Table 8. The hormone solution was injected intramuscularly (IM) from two to four times at intervals of 6-24 hr. Ovulation occurred 6-15 hr after the last hormone injection. The ovulated eggs were stripped and artificially fertilized by the "wet" or "dry" method from milt obtained from 1 to 3 males. Mature males were induced to spermiate with injections of SPH or testosterone. In these experiments, females with oocyte diameter of 0.66 mm or greater were found to respond to the hormone injections. Often, wild adult females and males were not caught together. To partially solve this problem, experiments to prolong spermiation in males by administration of long-acting hormone preparations were done. Durandron forte (Organon), a long-acting testosterone preparation, was found to prolong spermiation for as long as seven days (Juario et al 1980). Experiments to cryopreserve sperm were also carried out. Milkfish serum was reported to be a good extender for cryopreserving milkfish sperm (Hara et al 1982). Fertilization rate of ovulated eggs from a hormone-treated wild female was comparable with eggs fertilized with fresh sperm.

Difficulty in obtaining wild adults and the few available captive broodstock hampered efforts to define an effective spawning regime using fish gonadotropins or hCG. Wild fish were always in a badly damaged condition after capture and handling, and this greatly affected response to the induced spawning treatment.

With the availability of captive broodstock, recent methods for inducing ovulation and spawning fish using synthetic analogues of luteinizing hormone releasing hormone (LHRH-a) and salmon gonadotropin releasing hormone (sGnRH-a) were tried. A single injection, pellet implantation, or osmotic pump implant of LHRH-a and sGnRH-a were effective in inducing ovulation and spawning in maturing milkfish (Fig. 4, Marte et al 1987a). A single injection of 1000 IU/kg hCG was also as effective as the LHRH-a treatments (Marte et al in press). Spontaneous spawning occurred from 16-32 hr after treatment with the analogues of LHRH. Fertilization rate ranged from 20-88%.

Induction of Gonad Development

Early attempts to induce gonad development in fish younger than 5 years old and in refractory fish were unsuccessful. Chronic administration of gonadotropins in cholesterol pellets (SPH, SG-G100 or hCG)

Table 8. Successful spawning attempts of wild adult and captive milkfish

BW (kg)	Initial oocyte diameter (mm)	Total Dose SPH (mg) + HCG (IU)	Weight-Specific Dose	Fertilization (%)	Source
?	?	60 + 4000			Vanstone 1977
		90+6000		ND*	
?	?	60 + 4000			
		90 + 6000			
		90 + 6000		ND	
6.5	0.75	42 + 2600	6.5+ 430.8	38	Liao et al 1979
		42 + 4200	6.5+ 646.2		
7.0	0.77	70+ 10000	10+1428.6	59.0	Juario et al 1984
		70+ 10000	10+1428.6	36	
7.0	0.66	70+10000	10+1428.6		
10.0	0.74	100+ 10000	10+1000	25	
		100+20000	10+2000	28	
4.0	0.76	40+5000	10+ 1250	9	
		40+10000	10+2500	32	
				10	

*ND — not determined

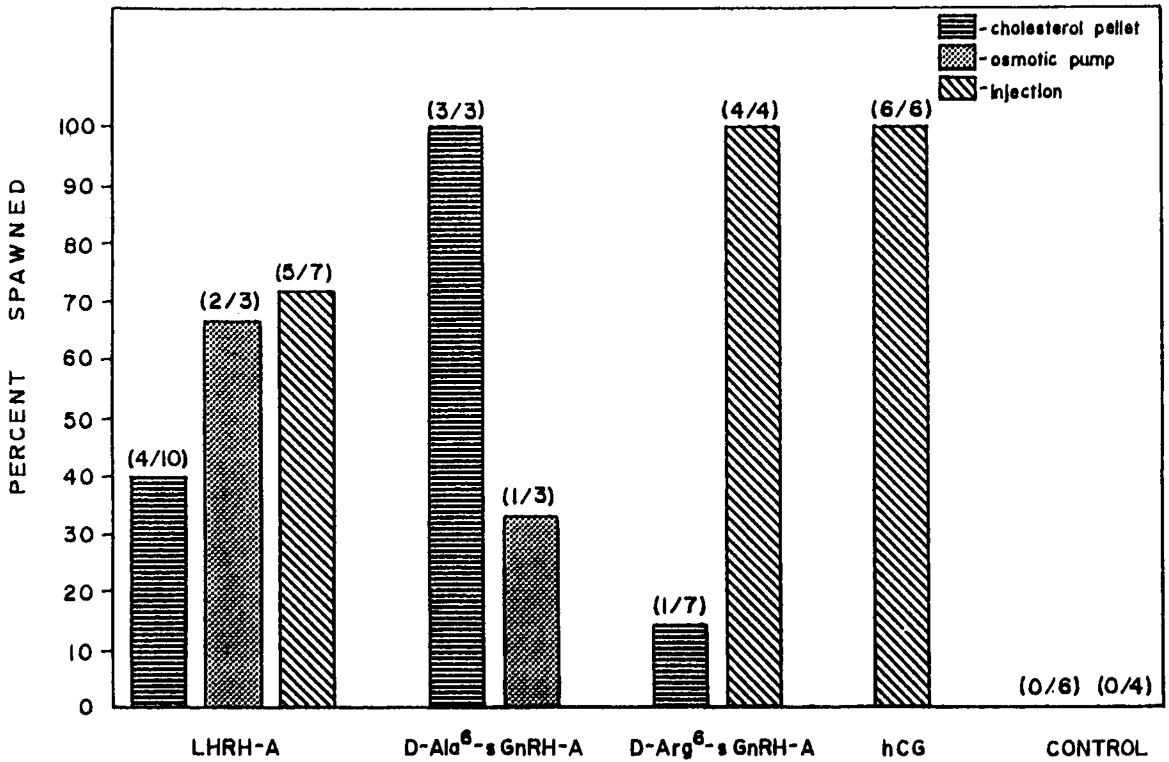

Fig. 4. Percentage of maturing milkfish that spawned following a single treatment of gonadotropin releasing hormone analogues (GnRH-A) and human chorionic gonadotropin (hCG). Hormone dosages were: Chlolesterol pellet-100 µg/pellet; LHRH-A and sGnRH-A Osmotic pump; LHRH-A and sGnRH-A injection-10 µg/kg; hCG injection-1000 IU/kg (From Marte et al 1987)

alone or in combination with estradiol or oral administration of thyroxine failed to induce gonad development in 3-5 years old fish or wild-regressed adults (Lacanilao et al 1985). Factors which may have contributed to the negative response include stress, unfavorable holding conditions, and ineffective hormone preparations. The expected slow and sustained release from the gonadotropin-cholesterol pellet was not obtained even at the highest dose given. Gonadotropin levels were elevated in hormone-implanted fish one day after treatment but dropped to control levels after 2 or 3 days (Marte and Crim 1983).

Recently, maturation of 4-year old fish was enhanced with chronic administration of testosterone and LHRH-a (Marte et al in press). Testosterone (1 mg) and LHRH-a (100 µg) incorporated in cholesterol pellets were implanted intramuscularly to 4-year old fish held in tanks. More mature 4-year old males were obtained in the hormone-implanted groups than in the controls and the two hormone-implanted females that matured were induced to spawn with LHRH-a. The females (BW= 1.8 and 2.5 kg) were about half the size of captive spawners. This is the first report of maturation in fish younger than 5 years. A single intraperitoneal implant of 1 mg testosterone together with monthly implants of 100 µg LHRH-a pellet also induced rematuration from 2-4 times in three regressed females.

Diseases of Broodstock

Good water exchange in the floating cage site and low stocking densities have ensured healthy rearing conditions for milkfish broodstock. A few cases of localized infections at hormone implantation sites in fish repeatedly implanted with hormones have been reported (Lio-Po et al 1986).The causative organism was tentatively identified as *Vibrio parahaemolyticus,* a normal bacterial flora of seawater. The same organism was associated with the occurrence of opaque eyes in transport-stressed milkfish and in some fish cultured in earthen ponds (Muroga et al 1984). Milkfish broodstock often develop opaque eyes after capture from the net cage during hormone induction experiments or whenever they are transferred or disturbed. The histological changes found in the cornea ("adipose membrane"), iris, retina, and lens in fish with the opaque eye syndrome were described (Tamse et al 1983).

Broodstock held in canvas or concrete tanks have occasionally been infected by the parasitic copepod *Caligus.* The recommended treatment is a gradual change from sea water to fresh water (Lio-Po, pers. comm.). *Caligus* can also be controlled by a dilute solution of 90 ppm formalin (Lio-Po pers. comm.) or 0.25 ppm Neguvon (Laviña 1978).

SEED PRODUCTION

The fish hatchery facilities at SEAFDEC AQD include 250-1 to 1.5- ton fiberglass tanks, 2.5-5-ton canvas tanks and 3.0-12.0-ton concrete tanks. These are used for rearing larvae and for production of natural food such as *Chlorella* and *Brachionus.* The layout of a pilot hatchery for the NBBP now currently used for verification trials is shown in Fig. 5.

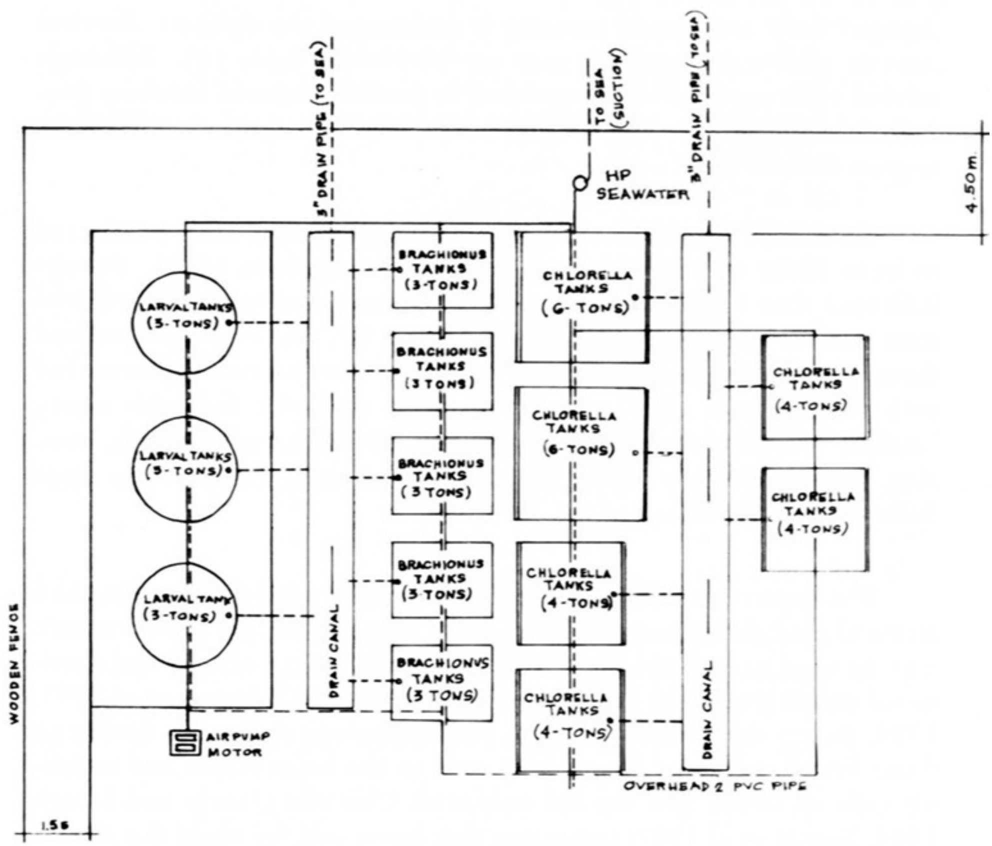

Fig. 5. Lay-out of the National Bangus Breeding Project Pilot hatchery at SEAFDEC, Aquaculture Department, Tigbauan, Iloilo

Food and Feeding

Larval rearing procedures for milkfish were described by Juario and Duray (1983). Several feeding schemes have been tried with success (Table 9). Survival rates of up to 71% in larvae fed with a combination of the algae *Chlorella virginica, Isochrysis galbana,* and *Tetraselmis chuii* together with the zooplankton *Brachionus plicatilis* (BP) and *Artemia salina* (AS) were reported (Juario et al 1984). Stocking densities used, however, were relatively low. The feeding scheme currently adapted is shown Fig. 6. This involved feeding larvae with *Chlorella*-fed *Brachionus* at 15 individuals/ml from day 2 to day 15 and at 5 individuals/ml from day 16 to day 21. Green water or *Chlorella* is maintained in the larval rearing tank to condition the water and maintain *Brachionus.* Brine shrimp nauplii is introduced only at day 15. Water is changed daily and gentle aeration is maintained throughout. Survival rates in pilot-scale hatchery runs are 11-90.6% (Table 10). Although survival rates are relatively lower than in previous reports, hatchery production using this feeding scheme is simpler and requires less facilities to grow natural food.

To reduce dependence on live feed, experiments were conducted to wean larvae to artificial diets (Duray and Bagarinao 1984). Results indicated that 14-day old larvae may be weaned abruptly to artificial diets such as the artificial plankton AS and BP, SEAFDEC-formulated diets, commercial feed, and moist egg diets. Survival rates of larvae fed with the different diets were comparable to larvae fed with newly hatched *Artemia* nauplii and was higher in BP-fed larvae. Growth, however, was significantly higher for *Artemia*-fed larvae compared to those fed with artificial diets.

The hepatocyte ultrastructure of milkfish fry fed different live and artificial feed differ markedly indicating that hepatocyte ultrastructure may be used to evaluate the quality and acceptability of feed and nutritional condition of the fry (Storch and Juario 1983; Storch et al 1983, 1984; Juario and Storch 1984). Histopathological changes similar to those found in starved larvae were seen in the hepatocytes and intestinal cells of larvae and fry fed only with *Chlorella* (Juario and Storch 1984, Segner et al 1987) indicating that larvae and fry could not directly utilize *Chlorella.* Milkfish, however, could utilize *Tetraselmis* and *Isochrysis* but these algae when fed alone were nutritionally inadequate to support growth (Juario and Storch 1984).

Table 9. Larval survival of milkfish under varying conditions of density and using different live food organisms, 1978-1980 (after Juario et al 1984)

Year	Live Food[a] Used	Tank Vol. (l)	Mean Stocking Density Larvae/l	Mean Survival Rate (%)	No. of Tanks
1978	C+O+R+BS	600	20	18.0 (7-30)	6
1979	C+R+BS	600	27.7	7 (3-17)	6
1980	C+Iso+T +R+BS	600	22.3	43 (8-71)	6

[a]C: *Chlorella virginica,* 2-5 × 10^5 cells/ml
Iso: *Isochrysis galbana,* 2-5 × 10 cells/ml
T: *Tetraselmis chuii,* 2-5 × 10^4 cells/ml
O: Oyster trocophore, 30-300 ind/ml (Dl-6)
R: *Brachionus plicatilis,* 20-30 ind/ml (Dl-10), 10-20 ind/ml (Dl1-21)
BS: *Artemia salina* nauplii

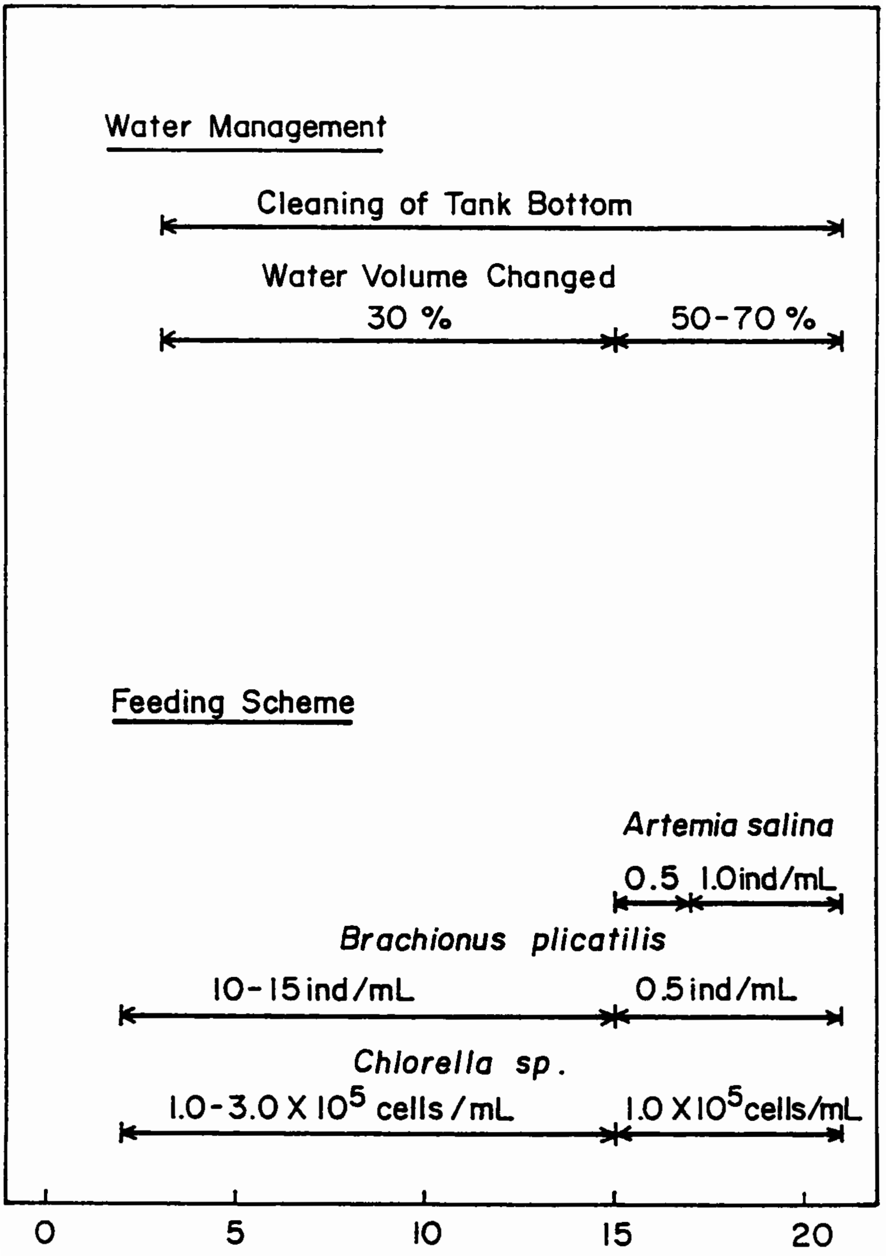

Fig. 6. Feeding and water management scheme followed in the larval rearing of milkfish (Juario and Duray, personal communication)

Table 10. Larval survival of milkfish, pilot-scale production runs, 1987

Live Food	Tank Vol. (1)	Stocking Density ((Larvae/1)	Survival Rate (%)	No. of Runs
C+ R + BS	2 500[b]	30	16 - 90.6	9
	3 000	30	11 - 39	5
	5 000	30	12 - 30	5

[a]C: *Chlorella,* 1-3 × 10^5 cells/ml (Dl - D15), 0.5 × 10^5 cells/ml (D16 - D20)

R: *Brachionus,* 15 ind/ml (Dl - D15), 5 ind/ml (D16 - D21)

BS: *Artemia* nauplii, 0.5 - 1.0 ind/ml (D15 - D21)

[b]NBBP pilot-hatchery

Histochemical and ultrastructural observations on fry fed with different artificial diets support previous observations on survival and nutritional effects of these diets. Degenerative changes in the hepatocytes were seen in fry fed with egg yolk and rice bran, indicating that these feeds are nutritionally inferior (Segner and Juario 1986). Egg yolk is commonly used as feed for fry by milkfish concessionaires while rice bran is given as supplemental feed in nursery ponds. From growth and hepatocyte ultrastructure, mixed diet consisting of a SEAFDEC artificial diet (43.2% crude protein, 9.4% crude fat, 32.8% carbohydrate, 7.1% ash and 7.5% water) fed together with *Artemia* gave the best results (Storch et al 1984). The fry, however, can be successfully reared on the artificial diets.

Larval Development

Artificially fertilized or naturally spawned eggs hatch 25-32 hr after fertilization at a water temperature between 26.4 and 29.9°C (Liao et al 1979, Chaudhuri et al 1978). The embryonic and post larval development of milkfish was described by Chaudhuri et al (1978) and Liao et al (1979).

In unfed larvae, yolk is completely resorbed at 138.8 hr, time after hatching (TAH), while first feeding occurs as early as 77.0 hr TAH. All larvae start to feed by 125.0 hr TAH (Bagarinao 1986).

Five phases of larval development are recognized based on early morphological changes and transition from endogenous to exogenous feeding (Kohno et al in press). These are:

1. rapid early growth due to rapid resorption of yolk (hatching at about 10 hr TAH),

2. rapid growth with a relatively slow slope and organogenesis based on utilization of yolk (to about 75 hr TAH),

3. slow growth and organogenesis owing to yolk (to about 75 hr TAH),

4. slow growth based on yolk and exogenous food (to about 120 hr TAH), and

5. accelerated growth from exogenous food only (beyond 120 hr TAH).

Development of fin supports and branchial system were described and correlated with mode of swimming and feeding in larvae and fry (Taki et al 1986, 1987). Milkfish larvae acquire efficient swimming ability at around 10.5 mm standard length (SL) when major components of the caudal skeleton develop and ossify. This supports the view of active shoreward migration of milkfish larvae in the wild and corroborates earlier drift card experiments which indicated that surface currents are not the major factor in the shore-ward transport of milkfish larvae (Kumagai and Bagarinao 1979).

Fry gathering is an important industry in many coastal villages. These are caught with a variety of catching gears (Kumagai et al 1980, Villaluz 1984). Behavioral studies of milkfish larvae were conducted to explain phenomena of fry distribution, recruitment, and mass appearance near the shore of fairly uniform-sized larvae (10-17 mm). Milkfish larvae initially exhibits strong rheotactic but weak optomotor response. Positive optomotor reaction becomes pronounced as larvae transforms into the juvenile phase ("metamorphic stage" .) The well-developed optomotor response and the histological structure of the larval eye support the view that milkfish larvae feed primarily by vision (Kawamura and Hara 1980). Abrupt changes in optical behavior during the "metamorphic stage" is also thought to be related to the abrupt disappearance of larvae from the shore.

Diseases and Parasites

Incidences of larval mass mortalities have been frequently observed. Low hatching rates and mortalities during the early rearing stage seem to be related to unfavorable conditions during egg transport. Some mortalities are due to the presence of gas bubbles in the abdominal cavity or within the digestive tract (Lio-Po et al 1983). Gas bubble disease appears to be associated with high level of oxygen in the rearing tanks during periods of plankton blooms. These observations emphasize the need to improve methods of transporting eggs including water and tank management procedures during larval rearing.

Milkfish Seed Production Constraints

With proper management and adequate feeding, milkfish matures and spawns at five years. Care for the broodstock entails huge investments which can discourage most fish farmers from rearing milkfish for hatchery production of fry. Various means to reduce the cost of rearing broodstock are possible but still have to be tried. Recent results in the hatchery indicate that low survival is, in part, due to inadequate nutrition of broodstock. The nutritional requirement of milkfish broodstock is not known. This needs to be investigated to obtain the information needed to formulate a practical diet which can provide the nutrients for better-quality eggs and fry.

The hatchery technique developed for rearing milkfish larvae is adequate for small quantities of eggs. Mass production techniques to accommodate the large number of eggs spawned by a few females still need to be tested. Improvements in hatchery rearing such as increasing stocking densities of larvae and adopting more efficient water management procedures are being investigated.

Artemia is still an important component of larval diet. Artificial diets, however, are being developed and tested to replace or at least reduce the dependence on this costly imported larval food.

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BROODSTOCK MANAGEMENT AND SEED PRODUCTION OF THE RABBITFISH *SIGANUS GUTTATUS* (BLOCH) AND THE SEA BASS *LATES CALCARIFER* (BLOCH)

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ABSTRACT

This paper reviews results of studies conducted on the rabbitfish, *Siganus guttatus* (Bloch) and the sea bass *Lates calcarifer* (Bloch) at the Aquaculture Department of the Southeast Asian Fisheries Development Center. Studies include broodstock development and management, induced breeding, effect of handling stress and diet on egg quality, early life history, food, feeding strategy, weaning to artificial diets, effect of stocking density and salinity on egg development, larval growth and survival, and advancement of metamorphosis in sea bass by using thyroxine.

A seed production technique had been developed for rabbitfish with survival rates ranging from 5-35% while the seed production technique for sea bass developed in Thailand had been modified to suit local conditions. Based on results from recent morphological and physiological studies, the stocking density, water management, and feeding scheme for the production of rabbitfish and sea bass fry had been modified to reduce cannibalism and improve survival.

INTRODUCTION

Rabbitfish and sea bass are two of the major marine and brackish-water species cultured in Southeast Asia (Rabanal, this volume). The major constraint to increase production of rabbitfish is seed supply (Juario et al 1985) while that of sea bass is availability of economically feasible weaning and grow-out diets and cannibalism in the hatchery production phase. The Department, therefore, started to conduct studies on the rabbitfish, *Siganus guttatus,* in 1980 to develop an economically feasible seed production technique and on the sea bass, *Lates calcarifer,* in 1982 to develop an appropriate and economically feasible weaning diet and to reduce cannibalism. This paper reviews the results of these studies.

BROODSTOCK MANAGEMENT

Rearing Facilities

Hatchery-bred or captive juveniles of *S. guttatus* and sea bass are reared to sexual maturity in floating net-cages at the Igang Substation, Guimaras Island. The cages are either rectangular (4 × 4 × 2 m) or circular (10 m dia × 3.0 m deep) and are made either of galvanized iron pipes or bamboo. Each cage is provided with cylindrical styrofoam floats. Fine-meshed net (0.5 cm) is used for fish weighing 50 g or less, 1.0 cm mesh net for 100-300 g, and about 3.0 cm for over a kg fish. Fish is stocked at a density of 2-3 kg/m^3, thinned, and size-graded every 3-4 months. Nets are regularly cleaned of fouling organisms.

In Tigbauan, fish are reared to sexual maturity in 4-10 m dia × 1.0 m deep (15-40 t capacity) canvas tanks or in 6-50 t rectangular concrete tanks. The tanks are provided with aeration and flow-through system. A drain pipe is installed either at the center or periphery of the tanks. Bottom sediments are siphoned out weekly for *S. guttatus* (feeds are given on trays) and daily for sea bass. Tanks are thoroughly cleaned weekly for sea bass, monthly for siganids, or as the need arises. Broodstock tanks are either provided with green plastic roofing or covered with black sack cloth to prevent diatom or algal blooms.

Rearing Method

Juvenile guttatus are stocked at 20 fish/m^3; sea bass juveniles at 10 fish/m^3 in floating cages. The density is gradually thinned out as the fish grow. Rearing temperatures and salinity range from 26.1-30.9°C and 31.1-34.7 ppt, respectively. Siganids are fed *ad libitum* twice daily with filamentous green algae or at 3-5% BW, with commercial fish pellets containing 35% protein or a combination of both. For spawning purposes, the breeders are fed with SEAFDEC lipid-enriched formulated diet at the same feeding level and frequency. Sea bass, on the other hand, are fed once daily with trash fish at 8-10% body weight (BW) if they are less than 100 g and 3-5% BW if bigger. Ration is reduced to 1-2% BW during the peak of spawning season.

Guttatus spawners are stocked at 1 female to 1 male ratio. Six pairs are stocked in each 6 m dia canvas tank provided with a flow-through system and aeration. For spawning, a pair is transferred to 500 1 fiberglass tanks during the first lunar quarter. Sexes are determined by cannulation. Spawners are not fed during the spawning period lasting 5-7 days. In sea bass, breeders with a sex ratio of 1:1 or 1:2 are transferred to spawning cages (1.5 × 3 × 2 m). As in guttatus, sexes are determined by cannulation in the absence of reliable external features that distinguish males from females.

Gonadal Maturation and Sexual Maturity

Captive wild guttatus matures at 200 g with a fork length (FL) of 34.0 cm (Soletchnik 1984). Hatchery-bred males mature in 10 months at 19.0 cm FL (Juario et al 1985) and females in 12 months at 21.5 cm FL (Soletchnik 1984, Juario et al 1985). One gonadal cycle is complete within 27-28 days (Soletchnik 1984, Hara et al 1986). Fish spawns every month throughout the whole year.

Gonadal development of sea bass is monitored every month by cannulation. Males mature ahead of females. Males mature when they are two years old, weighing about 1.5 kg with a TL of 45.0 cm, females at three years old, weighing 2.0 kg with a TL of 50.0 cm (Tan pers. comm.). Sexual maturation begins in January and peaks in February to August. The number of mature individuals decrease from October to November. Males appear to undergo gonadal regression earlier (October) than females (November), (Anon. 1985). Rematuration in the same season and multiple spawning were observed if gonadotropin-releasing hormone (GnRH-A) pellets are implanted in the breeders (Almendras pers. comm.).

Food abundance and diet quality proved to be important factors for guttatus maturation (Soletchnik 1984). Most of the females fed with commercial diet containing 43% protein spawned monthly for 11 consecutive months. However, Juario et al (1985) observed a decline in the fertilization and hatching rates and in larval quality with age of spawners fed with a commercial diet containing 43% protein.

Fecundity and Gonadosomatic Index (GSI)

A 400 g captive guttatus broodstock with GSI of 13.8% had 0.8 million eggs, while a 520 g with a GSI of 12.6 had 1.2 million eggs (Soletchnik 1984). About 400-500 g captive females spawned 0.45-1.3 million eggs. Hara et al (1986b) reported 0.2-1.2 million eggs from captive females averaging 410 g.

A 2.7 kg female sea bass had 3.6 million eggs; a 2.8 kg, 4.9 million eggs (Garcia pers. comm.).

Spawning

Natural or induced spawning for both species is not a problem. Guttatus spawns naturally the whole year 2-3 days after the first lunar quarter (Soletchnik 1984, Hara et al 1986b). Females mated for the first time spawned without failure. Weekly sampling of guttatus collected from Cebu and Bohol, Philippines from April to June 1986 showed that a fish with a GSI value of 7.0 may spawn during the new to full moon period with a peak at the first quarter (Hara et al 1986d).

Guttatus having oocytes with an average dia of 0.46 cm spawned after one injection of human chorionic gonadotropin (HCG) at 2 IU/g body weight while those having oocytes with an average dia of 0.43 mm did not spawn or spawned only after several injections (Juario et al 1985). Harvey et al (1985) reported that LH-RH pellet implantation advanced spawning in both the first and second gonadal cycles after treatment. Stress due to routine hatchery operation also enhanced spawning but did not affect survival performance of resulting larvae (Ayson 1987).

Sea bass reared to sexual maturity in floating net-cages at the Igang Substation also spawn naturally (Anon. 1985). LH-RHa administered as saline injections or as cholesterol implants were comparably effective in inducing sea bass to spawn while osmotic pump triggered successive spawnings at 24 hr intervals (Harvey et al 1985). The same response was exhibited by females injected with LH-RH analogue D-ala^{6}-D-Gly^{10}-ethylamide at 100-400 μg /fish (Nacario and Sherwood 1986). An LH-RH dose of 150-300 μg/kg body weight induced a lower spawning frequency in sea bass, whereas lower dosages of 37.4-75.0 μg/kg induced higher spawning frequencies in mature females. At all doses tested, the total number of eggs collected per spawner decreased after four daily spawnings. Mean fertilization and hatching rates from four sequential spawnings of fish treated with 300 μg LH-RH were relatively lower compared to those implanted with lower doses. A dose with a range of 4.7-38.0 μg/kg increased spawning frequencies (Garcia pers. comm.).

The use of mammalian or salmon LH-RH during the new or first lunar phase was not clearly different. Although 1:1 sex ratio is effective, a ratio of 1 female to 2 males gave better fertilization and hatching rates. Pellets, pumps, and repeated injections induced multiple spawnings in sea bass, but the pellets proved to be more reliable, cheaper and less stressful to the fish (Almendras pers. comm.).

Spawning Behavior

Spawning behavior of guttatus is characterized by male chasing the female, nudging her abdomen, continuous swimming close to her nudging the operculum, anal region and caudal peduncle in sequence. After a minute of male display, female releases a small quantity of eggs and male releases milt. They stay quiescent for a time and another display is exhibited. Then more eggs and milt are released by both (Hara et al 1986c).

Active swimming of sea bass at night wherein male chases the female, characterizes their spawning behavior (Garcia pers. comm.).

Sperm Preservation

Significant results were obtained on the effect of pH, type of extender, dilution rate, and concentration of cryoprotectant on sperm viability of guttatus at 0.4-19.6°C (Anon. 1984).

After 24 hr in liquid nitrogen and cryogenic preservation in 150 mM KCl, 150 mM NaCl, and freshwater teleost Ringer's solution adjusted by tris-citric acid, good sperm motility was observed from pH 6.0-7.0. For 125 mM citrate, best sperm motility was at 6.5-1.0 pH, while glucose adjusted by HCl and NaOH at 4.0-10.0 pH.

Extenders like 100-200 mM KCl, 100-200 mM NaCl, 200-400 mM glucose, 75-175 mM Na citrate, freshwater Ringer's solution and Cortland medium yielded good results. Sera of tilapia, silver carp, milkfish, marine teleost Ringer's and Mounib medium yielded lower motility scores for cryopreserved sperm after thawing.

Cryoprotectant concentrations were best between 5-20% for dimethyl sulfoxide (DMSO) and 5-20% for glycerine. Ethyl alcohol yielded considerably lower scores than DMSO and glycerine.

Diseases

The ectoparasite, *Caligus epidemicus,* commonly infest captive *S. guttatus* spawners. This is effectively eradicated if salinity is kept at 0 ppt at least for 24 hr. Captive fish were also infected with nematodes leading to poor appetite.

No mortality due to infection or parasite have been reported for sea bass.

SEED PRODUCTION

Rearing Facilities

Larval rearing tanks vary in size and shape and are made of different materials. Size of experimental tanks ranges from 200-500 1. They are either circular or conico-circular and made of fiberglass. Pilot and large scale production tanks range from 3-10 t and are either circular, conico-circular or rectangular and are either ferroconcrete, concrete, or canvas. All tanks are housed in a roofed hatchery to protect larvae from direct sunlight or heavy rain. The roof is made of transparent corrugated plastic sheets.

Conico-circular concrete tanks are easier to clean than rectangular tanks; the former, however, are more expensive to construct and occupy more space. It is easier to maintain good water quality and to prevent harmful effects of aeration on young larvae in larger tanks. Thus, it is generally assumed that better survival rates are obtained in larger tanks. For rabbitfish results are contradictory (Juario et al 1985, Hara et al 1986b).

Egg Collection and Handling

Guttatus eggs are adhesive and demersal. Egg collectors consisting either of plankton nets or plastic sheets are placed at tank bottom prior to spawning. After spawning the collectors are removed and transferred to incubators.

Sea bass eggs are pelagic. Eggs from broodstock reared in floating net-cages are collected as follows: A day or two prior to quarter moons, cages are lined with hapa net (mesh size, 150 μm) to prevent loss of eggs. If spawning occurs, eggs are collected by using a net with a mesh size of 150 μm. Eggs spawned in tanks are collected in the same manner.

Sea bass eggs collected from floating net cages at Igang Substation arc packed in doubled oxygenated plastic bags at a density of 100,000 eggs/10 1 of sea water. Plastic bags with eggs are placed in *pandan* bags and transported to Tigbauan Research Station where they are reared to fry or until metamorphosis.

Incubation

Eggs are incubated in 500 l tanks or directly in 3 or 10 ton larval rearing tanks. A maximum stocking density of 400/l may be used for the former and 100 for the latter. Water is changed 1 or 3 times by allowing it to flow through for 30 min to 1 hr depending on water quality (Juario et al 1985). The total number of incub?ted sea bass eggs are estimated by collecting five samples from different parts of the tank by using a PVC pipe. Depending on temperature, incubation for guttatus ranges from 18-26 hr; and for sea bass, 15-18 hr, (Juario et al 1985, Duray et al 1986, Hara et al 1986b).

A comparative study on the effects of salinity on guttatus egg development and hatching showed that naturally spawned eggs are more tolerant to salinity changes than inductively spawned ones (Duray et al 1986). Higher hatching rates and greater number of viable larvae were obtained when eggs were transferred at the gastrula stage than at the blastomere stage. Highest total hatching and percentage of viable larvae were obtained at 24 ppt and lowest at 8 ppt. Larvae that hatched at lower salinities (8, 16 ppt) were relatively longer than those at 32 ppt and 40 ppt (Duray et al 1986).

Larval Rearing

Both guttatus and sea bass larvae are reared in semi-static system with aeration. Sediments and detritus that settle on tank bottom are siphoned out daily. Water management and feeding schemes in rearing guttatus and sea bass larvae to metamorphosis are presented in Fig. 1 and 2. The phytoplankton *Chlorella, Tetraselmis,* or *Isochrysis* are added to rearing tanks as water conditioners and as food for rotifers.

Newly hatched guttatus larvae were more resistant to low and high salinities (8-37 ppt) than 7-14 days old larvae while older larvae are more resistant to abrupt salinity (2-55 ppt) changes (Anon. 1984). Survival of larvae reared at 20-32 ppt salinity from 0-21 did not differ significantly (Hara et al 1986b). First-feeding larvae reared under continuous lighting grow and survive better than those reared under daylight (Duray and Kohno in press).

Survival of sea bass larvae reared at a density of 15, 30, and 45 ind/l did not differ significantly from each other. By day 21, however, the mean weight of larvae stocked at 5/l and 30/l were significantly larger than those stocked at 45/l. Based on size and weight of larvae,

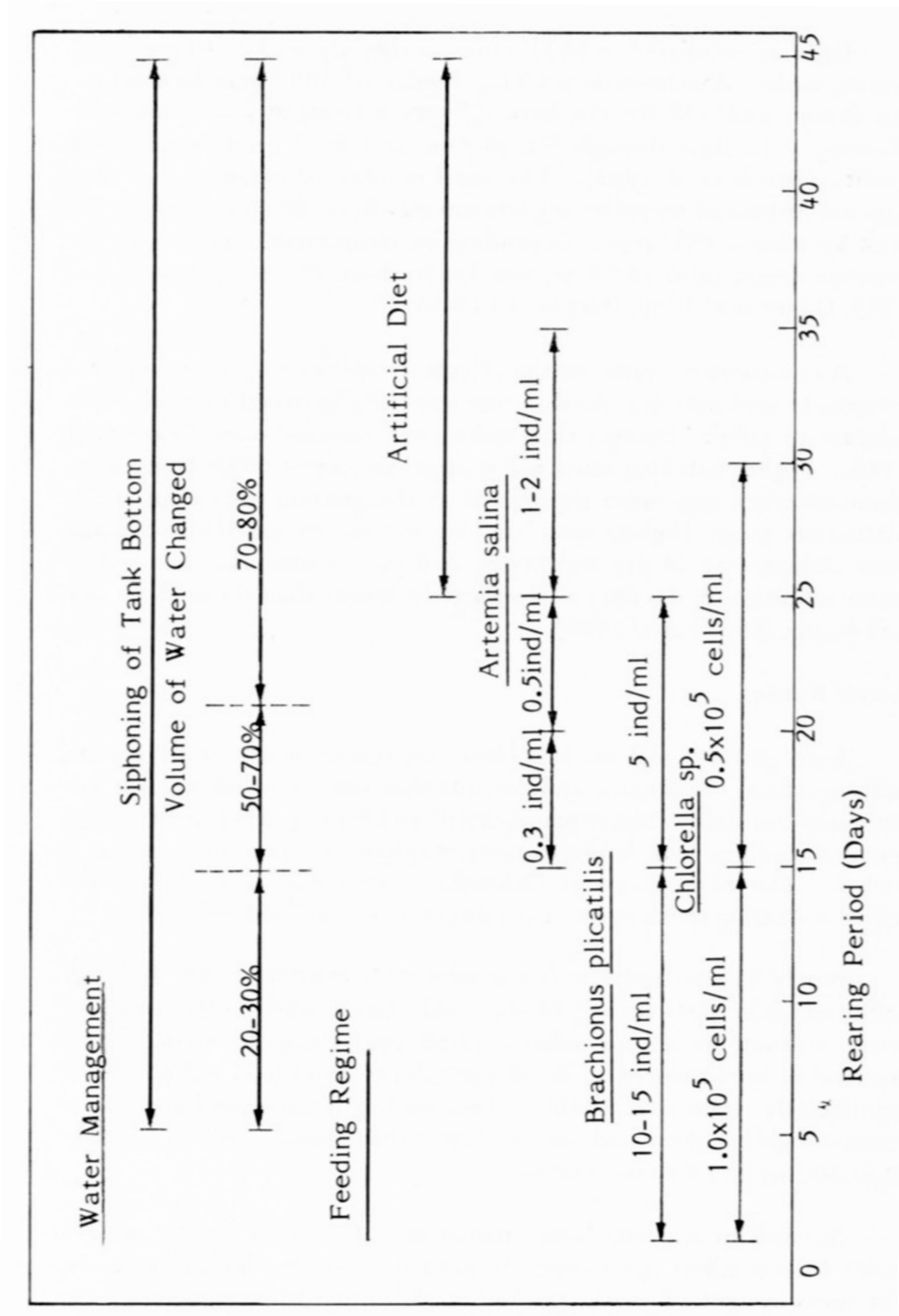

Fig. 1. Feeding scheme and water management for *Siganus guttatus*

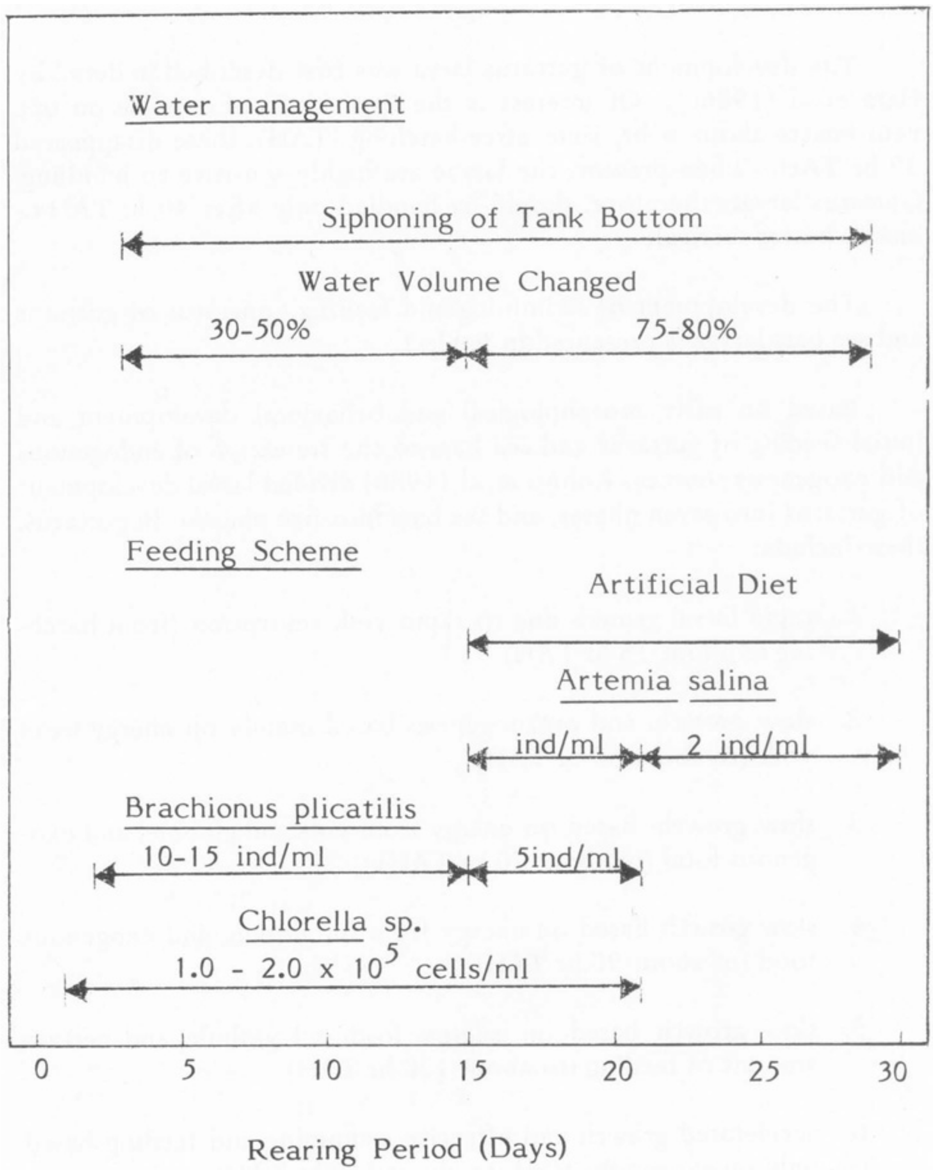

Fig. 2. Feeding scheme and water management for *Lates calcarifer*.

the stocking density of 30 ind/1 is the most appropriate in mass producing sea bass fry (Juario and Duray unpublished).

Larval Development

The development of guttatus larva was first described in detail by Hara et al (1986c). Of interest is the appearance of cupulae on free neuromasts about 6 hr, time after hatching (TAH); these disappeared 39 hr TAH. When present, the larvae are highly sensitive to handling. Guttatus larvae, therefore, should be handled only after 40 hr TAH to ensure better survival.

The development of swimming and feeding apparatus of guttatus and sea bass larvae is presented in Table 1.

Based on early morphological and behavioral development and initial feeding of guttatus and sea bass to the transition of endogenous and exogenous sources, Kohno et al (1986) divided larval development of guttatus into seven phases, and sea bass into five phases. In guttatus, these include:

1. rapid larval growth due to rapid yolk resorption (from hatching to about 15 hr TAH)

2. slow growth and organogenesis based mainly on energy from yolk (to about 50 hr TAH)

3. slow growth based on energy from yolk, oil globule, and exogenous food (to about 70 hr TAH)

4. slow growth based on energy from oil globule and exogenous food (to about 90 hr TAH)

5. slow growth based on energy from oil globule and certain amount of feeding (to about 120 hr TAH)

6. accelerated growth and effective swimming and feeding based only on exogenous food (to about 150 hr TAH); and

7. same mode as in the preceding but with increased feeding (beyond 120 hr TAH)

In sea bass, these include:

1. rapid early growth due to rapid yolk resorption (from hatching to about 15 hr TAH)

Table 1. Size of siganid and sea bass larvae at the first appearance and completion of morphological characters related to swimming and feeding (Kohno et al 1986, unpublished data)

Morphological Characters		Siganid		Sea Bass	
		Size at 1st Appearance	Size at Completion	Size at 1st Appearance	Size at Completion
A. Swimming-Related:					
Dorsal:	Fin Supports	3.7	10.99	3.74	4.26
	Fin Rays	3.93	8.04	4.23	5.30
Anal:	Fin Supports	5.10	6.03	3.74	4.49
	Fin Rays	5.94	8.54	4.45	5.85
Caudal:	Fin Supports	4.14	8.94	2.95	8.40
	Fin Rays	4.83	6.44	3.27	7.70
Pectoral:	Fin Supports	2.52	10.80	2.06	2.52
	Fin Rays	6.29	9.74	5.30	10.25
Ventral:	Fin Supports	3.70	_	5.30	—
	Fin Rays	3.93	7.44	5.30	7.09
Vertebrae		6.29	7.17	-	-
Notochord end flection		4.97	6.50	3.27	6.5-7.5
B. Feeding-Related:					
Upper Jaw Teeth		4.49	7.5	2.57	5.85
Lower Jaw Teeth		4.12	5.94	3.20	_
Upper Pharyngeal Teeth		3.26	6.00	2.57	—
Lower Pharyngeal Teeth		7.08	—	3.84	—
Maxilla		2.52	—	1.92	_
Premaxilla		4.12	-	2.57	-

2. morphological differentiation and slow growth based on energy from yolk until yolk is exhausted (about 50 hr TAH)

3. slow growth with initiation of feeding and swimming activities, based on energy from oil globule and from exogenous food (to about 110 hr TAH)

4. accelerated growth and effective feeding and swimming based on the same two sources of energy as in the preceding stage until the oil globule is exhausted (to about 120-140 hr TAH); and

5. accelerated growth, effective feeding and swimming, and further development based solely on exogenous energy (beyond 140 hr TAH). The energy sources during the developmental phases are the yolk, oil globule, exogenous food, or any combination of these.

Sea bass eggs and larvae are bigger than guttatus (Bagarinao 1986, Avila and Juario 1987). At similar ambient temperatures (26-30°C), guttatus larvae grow much faster than sea bass in the first 24 hr TAH. This appears to be a compensatory mechanism for survival. Full eye pigmentation and opening of the mouth occur at 32-36 hr TAH for both species; sea bass larvae learn to feed earlier than guttatus.

Sea bass larvae of different ages were immersed in 0, 0.01, 0.10, and 1.0 ppm thyroxine to advance metamorphoses (Ordonio 1987). Growth, survival, and yolk resorption were not affected but fin differentiation and epidermal thickening in treated larvae were enhanced. Abnormalities in vertebral column were observed only among larvae exposed to a concentration of 1.0 ppm from day 7-14 and 0.1 and 1.0 ppm from day 15-21. Metamorphosis without deleterious effects was advanced in larvae exposed to T_4 from day 21-28. The absence of thyroid follicles from day 0-35, i.e., until metamorphosis, suggests that the thyroid gland may not be directly involved in the early development of sea bass larvae.

Food and Feeding

Guttatus larvae are reared on rotifers, newly hatched brine shrimp nauplii and artificial diet (Juario et al 1985, Hara et al 1986b). Initially they feed on rotifers at a total length (TL) of 2.6 mm (day 2) and on brine shrimp at 4.4 mm TL (day 12). A change in feeding habits occur at about 7.0-9.5 mm TL with rotifer as prey and at 7.2 mm TL with brine shrimp as prey. Preference for brine shrimp over rotifers was observed in 8.0-9.0 mm TL or longer larvae. These changes in feeding habits coincide with the full osteological development of the feeding apparatus in 7.0-8.0 mm TL larvae.

In sea bass, initial feeding on rotifer was observed at 2.5 mm TL (day 2) and on brine shrimp at 4.0-4.5 mm TL (day 10). The amount of food consumed increased exponentially with larval growth. Food preference shifted from rotifers at 4.5 mm TL to brine shrimp at 6.0-7.0 mm TL.

The timing of events related to the onset of feeding in both species is presented in Table 2. Although sea bass larvae are about the same size as guttatus at the onset of feeding, mouth size of the former is twice larger than that of the latter. Thus, availability of food with appropriate size is critical to the survival of guttatus larvae during the first feeding period. Feeding guttatus larvae with rotifers less than 90 μm at a density of 10-20 ind/ml improved survival (Duray 1986). This was confirmed later by Hara et al (1986b).

The phytoplankton, *Chlorella, Tetraselmis,* or *Isochrysis* when given as the only food for guttatus larvae will not support life during the first-feeding days (Duray 1986). A feeding combination of the three phytoplankton and small-sized rotifers resulted in better survival although this was not significantly different from a feeding combination of *Isochrysis* and small-sized rotifers. A feeding combination of *Chlorella* and rotifers resulted in poor survival. Survival of larvae fed with rotifers at a density of 10-20 and 20-30 ind/ml did not differ significantly but differed significantly from those fed with rotifers at a density of less than 10/ml.

Guttatus larvae exhibit a diurnal feeding pattern. The percentage of larvae with food in the gut decreased in the evening and reached zero at 2200 hr. The time of active feeding shifted earlier in the day with larval growth. Satiation occurs at 0800-1000 hr (Hara et al 1986a).

Under natural illumination, the amount of rotifers in the gut of 10-day old sea bass larvae decreased from 1800 hr and started to increase at 1500 hr. No food was found in the gut at 0100 hr. The maximum food intake was 0800 hr at 20 rotifers/larva. Under artificial illumination, only 30-50% of the larvae had 0.5-11.0 rotifers in their guts from 2200-0500 hr. Maximum food intake was at 1300-1600 hr with 24-27 rotifers/larva (Anon. 1982).

Table 2. Some of the early life history characteristics of sea bass and siganid reared at 26-30°C (Bagarinao 1986)

Characteristics	Siganid	Sea Bass
Usual time of spawning	Midnight	Evening
Incubation period (hr)	20	14
Fertilized egg, type	Demersal	Pelagic
diameter (mm)	0.55	0.80
volume (ul)	0.871	0.2681
Larval length at hatching (mm)	1.50	1.72
Yolk volume at hatching (ul)	0.0251*	0.0859*
Maximal larval SL attained on yolk reserves (mm)	2.55	2.45
Time from hatching to attainment of maximal SL on yolk (hr)	24	24
Yolk volume remaining when maximal larval SL attained (ul)	0.0032*	0.0072*

*Total of yolk plus oil globule

Delayed feeding experiments showed that mortality occurred among unfed guttatus larvae in 88 hr while 7-12% of those fed within 32-56 hr survived beyond 88 hr. Unfed sea bass larvae died 144 hr TAH (Bagarinao 1986).

Guttatus larvae fed with newly hatched San Francisco Bay (SFB) brine shrimp nauplii for three days followed by SELCO-enriched Great Salt Lake (GSL) brine shrimp nauplii thereafter have significantly longer TL than those fed only with newly hatched GSL brine shrimp nauplii throughout the experimental period or newly hatched GSL brine shrimp followed by SELCO-enriched GSL brine shrimp nauplii (Duray unpublished). For sea bass larvae, better growth and survival are obtained if newly hatched GSL brine shrimp nauplii are fed on day 15 or 18 rather than on later stages (Kohno pers. comm.). A feeding level of 1.0 ind/ml is better than at lower (0.5/ml) or higher concentration (2.0/ml) (Gallego pers. comm.).

Diseases

Red spots sometimes appear on sides and bottom of rearing tanks. These red spots consist primarily of the bacteria, *Vibrio* sp. Continuous direct application of fresh water for 2-3 days effectively controls the infection. Bacterial (*Vibrio* sp.) diseases observed in 22-25 days old sea bass larvae often result in total mortality of sea bass reared in outdoor tanks at high ambient temperatures (26-32°C), salinity (35-37 ppt), illumination, and dense diatom bloom (Bagarinao and Kungvankij 1986).

Transport and Handling of Fry

Fry are transported in doubled oxygenated plastic bags placed in *buri* or *pandan* bags for further protection. The density in each bag depends on fry size. Survival is better if sea bass fry are transported by day 21 when they are about 1.0 cm TL at a density of 3 000-5 000 fry/ 10 1 water/bag (Juario pers. comm.).

Production Constraints

Although a technique to mass produce guttatus fry had already been developed, more work needs to de done before artificial propagation can be carried out on a routine basis. Survival rates are still very variable and there is no diet for guttatus broodstock that will lead to production of good quality eggs. In addition, practical diets for rearing guttatus larvae to metamorphosis and for its nursery phase still needs to be developed.

Although an appropriate diet had already been developed to successfully rear as early as 10 days old sea bass larvae to metamorphosis, its economic feasibility should be assessed and the most appropriate time and way of weaning the larvae to artificial diets should be determined. Cannibalism is still a serious constraint to sea bass fry and fingerling production. A technique to minimize it has to be developed.

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BROODSTOCK MANAGEMENT AND SEED PRODUCTION OF TILAPIA AND CARP

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ABSTRACT

Bighead *(Aristichthys nobilis)* and silver *(Hypophthalmichthys molitrix)* carps were reared in ponds, pens and floating cages in Laguna Lake until maturity. Spontaneous gonadal maturation and rematuration of carp broodstock occurred within 2-2.5 years with average weight of 3-4 kg. Under lake conditions, broodstock were not given supplemental feeds. Induced spawning of gravid females was done by intraperitoneal injections using HCG combined with either common carp pituitary homogenates or LHRH-A. Stripping and dry-fertilization of eggs were done 6-8 hr after the final injection. Eggs were incubated in water containing 300-500 ppm Total Hardness. Fertilization and hatching rates were 23-88% and 7-36%, respectively. Post-larval carps were reared in tanks and fine-meshed nylon net cages installed in manured ponds. Tank-reared post-larvae were fed with *Brachionus plicatilis* and subsequently with *Moina macrocopa* in combination with powered formulated feeds containing 40% crude protein. Fry were harvested and stocked in nursery cages after 30-45 days of rearing in tanks.

Four-month old 50-100 g tilapia *(Oreochromis niloticus)* stocked in hapa net cages, tanks or ponds were used for breeding. Egg and fry production was significantly high at 4 females/m^2 stocking density Different sex ratios, however, did not affect fry production. Spawning frequency and total growth of broodstock was highest in fry fed formulated diets containing 50% crude protein. Harvesting of fry was done every 15 days during summer months and every 21 days during cold months. Fry were reared in tanks and hapa cages and fed diets containing 35% crude protein. Supplemental feeding in the lake was suspended when productivity reached 3 gC/m^2 /day.

TILAPIA

Introduction

Tilapia culture in the Philippines started in the 1950's with the introduction of *Tilapia mossambica* (also known as *Oreochromis mossambicus)* from Thailand (Guerrero 1986). The fish, due to its prolific nature, did not gain much popularity because the ponds where the fishes were stocked became overpopulated with small fishes.

In the early 1970's, there was a renewed interest in the growing of tilapia. *Tilapia nilotica* (also known as *Oreochromis niloticus)* was introduced from Thailand and Israel in 1972 (Guerrero 1985). The culture of Nile tilapia was readily accepted by farmers because of its fast growth and lighter color compared to the Mossambique tilapia. Government as well as private institutions has taken much interest in *O. niloticus* culture.

Since 1977, the Binangonan Freshwater Station (BFS) of the Southeast Asian Fisheries Development Center (SEAFDEC) has undertaken researches on tilapia farming in Laguna Lake. Studies were done on stocking density (Basiao 1986), supplemental feeding (Santiago et al 1982), natural feeding (Pantastico et al 1985), broodstock development and production of high-quality fry and fingerlings (Bautista 1986), among others.

Today, tilapia ranks second to milkfish in economic importance. The annual production of tilapia from inland waters, i.e., fresh and brackishwater ponds, lakes and reservoirs, was estimated at 50 200 mt (Guerrero 1985). In 1984, about 13 111 mt of tilapia were produced from 15 311.46 ha of fishponds in 12 regions of the country.

Broodstock Development and Management

Rearing facilities. Among the various rearing facilities used for breeding tilapia, the three most commonly used are: hapa net cages installed in the lake, concrete tanks, and earthen ponds. Hapa net cages with mesh of 0.5 mm are 3 × 3 × 2 m. The cages in the lake are suspended from either fixed bamboo posts or floating bamboo modules arranged in series. The cages are submerged at a depth of at least 1.0-1.5 m, leaving an allowance of 0.5-1.0 m of the net above the water surface. The cages may or may not be covered.

Concrete tanks are constructed in series, each measuring 4 × 5 × 1 m. The series of tanks is not less than 20 tanks to minimize water temperature fluctuations. Each compartment is designed with a catch basin occupying about 15-20% of the floor area with depth of about 10-12 cm. This serves to collect both the breeders and fry during harvest. Water is drained through a removable PVC (polyvinylchloride) stand pipe (about 7 cm dia) which also maintains the water level at 50-75 cm.

Earthen ponds with rectangular shape have an area of 100-320 m^2 (10 × 10 m or 16 × 20 m) per compartment. Each compartment is provided with water inlet and outlet, both of which are protected with a net barricade. Water level in the pond is maintained at a depth of at least 70 cm.

Rearing methods. Four-month old tilapia with weights ranging from 50-100 g are used for breeding. The stocking density varies according to rearing facility used.

In hapas, the breeders are stocked at 5 females/m^2. In concrete tanks, a density of 4 females/m^2 is used without aeration and 6 females/m^2 with aeration. A lower density of 2 females/m^2 is used in earthen ponds. The sex ratio for all types of breeding facility is 1:4 or 1:7 male to female (Bautista 1987).

A study was conducted on the effects of the different stocking densities and sex ratios on egg and fry production of *Tilapia nilotica* bred in hapa cages and in concrete tanks (Bautista 1987). Results showed that both lake-based hatchery using hapas and land-based using concrete tanks, the highest average production of egg and fry were obtained at the lowest stocking density of 4/m^2. The most efficient sex ratio for both hatcheries was 1:4, male to female, although it was not significantly different from the other ratios used, i.e., 1:7 and 1:10 (Fermin et al 1986). The frequency of spawning per female was highest at 1:4 sex ratio; however, there were no significant differences among the three ratios.

In a related experiment, the effect of varying dietary crude protein of *T. nilotica* breeders were determined. Results showed that spawning frequency and total growth (body weight plus total weight of eggs collected) had a tendency to increase as the dietary crude protein level increased to 50% (Santiago et al 1983)

Size differences among fish are not so great as to minimize aggression especially by the males (Basiao 1981). The premaxilla of the male breeder is removed by clipping with scissors to prevent injury or death of females during courtship (Santiago et al 1983).

The broodstock are fed daily with formulated dry pellets with 50% dietary crude protein (Santiago et al 1983). The feed is given twice daily at 3.0% of the biomass, once in the morning and once in the afternoon.

Capture, handling, and transport. Tilapia broodstock are selected from different grow-out systems like pens, cages, and ponds at BFS and from other government and private institutions. Broodstock from fishpens and earthen ponds are collected by seining. Harvested fish are held in a more convenient container like small cage or tank with aeration for the selection process. From the cage or tank, fish are directly transferred to the transport containers, i.e., plastic bag and *bayong* (buri bag).

Sex is determined during the selection process, by examining the genital papillae located near the anus. Males have pointed papillae with one opening, the urogenital, while females have rounder papillae with two openings, the urogenital and the ovipository. In general, males are larger than females of the same age (Basiao 1981).

At least one day before transport, the broodstock are temporarily held in tanks with aeration for conditioning.

Fish are transported in oxygenated doubled plastic bags placed in *bayongs.* The density of fish varies according to size, from 8-12 breeders (about 100 g each per bag) filled with 10-15 1 of water. The breeders are transported early in the morning or late in the afternoon when ambient temperature is low. A few ice cubes are placed in one or both sides of the outer bag to keep ambient temperature to about 24-26°C.

Diseases and parasites. Newly transported breeders are prone to disease and parasite infestation due to stress. Fish are subjected to disinfection in salt baths, at 1 000-2 000 ppm prior to stocking in the hatchery (Palisoc 1986).

Lernea infestation has occasionally been observed in tilapia broodstock. Infected fish is treated with 0.25 ppm Dipterex.

Constraints to broodstock production. The continued deterioration of tilapia stocks through inbreeding could result in the production of poor quality fry and fingerlings. This leads to slow growth and body deformities of the progenies and adversely affects succeeding generations.

Tilapia broodstock in the lake are constantly subject to environmental hazards especially during typhoons. Unfavorable weather conditions may cause severe damage or complete loss of stocks.

Seed Production

Rearing facilities. Lake and land-based facilities are used for rearing newly harvested tilapia fry. Lake-based nursery consists of floating hapa cages measuring 3 × 3 × 1.5 m with cover. Covered cages may be suspended in fixed bamboo posts or in floating bamboo modules, arranged in series at 1-1.5 m intervals. The set-up is protected from strong waves and water hyacinths during typhoons by a peripheral bamboo barricade constructed at least 10 m away from the set-up.

Land-based nursery is made of concrete or wooden tanks. Nursery tanks are either square or rectangular ranging from 4 × 4 × 1.5 m — 3 × 8 × 1.5 m and arranged in series. Each compartment is provided with inlet and outlet for easy draining of water during cleaning and harvesting. About 120 1 glass aquaria are used to incubate eggs and rear yolk-sac fry until yolk has been resorbed. Aquaria are provided with moderate aeration to keep eggs in suspension throughout the incubation period.

Rearing methods. Newly harvested fry from breeding cages are stocked in hapas at 300-500/m^2 . While in hapas, the fry are given supplemental feeds such as hard-boiled egg yolk, blended trash shrimps, formulated feeds or commercial livestock starter feed (Table 1).

Supplemental feeding of fry is suspended when primary and secondary productivity in the lake is at least 3 g C/m^2 /day.

In tanks, fry are stocked at 1000/m^2. At least 1/3 of the total water volume is changed daily. Fry are fed with formulated dry diets containing at least 35% crude protein (Table 2) (Santiago et al 1982). Feed is given twice daily at 15% biomass. The feed is a mixture of all the ingredients including vitamins and minerals. Oil and gelatinized

Table 1. Types of feed given to tilapia fry reared in hapas in Laguna Lake (Bautista 1986)

Feed Type	Form of Feed	Feeding Rate	Frequency	Feeding Period
Chicken egg yolk	mashed, moist	1 pc/20 000 fry	2×/day	Days 1-3
Trash shrimp	blended, wet	25g/10 000 fry	2×/day	Days 4-7
Formulated feed 35% CP	meal form	10-15% of fish biomass	2×/day	Days 4-7
Broiler starter mash	finely ground	50 g/10 000 fry	2×/day	Day 7 onwards

Table 2. Percentage composition of formulated feeds for tilapia fry (Santiago et al 1982)

Ingredient	%
Fish meal	30.17
Soybean oil meal	25.95
Ipil-ipil leaf meal	8.10
Copra meal	11.48
Rice bran	12.24
Dextrin	2.73
Cod liver oil	1.00
Vegetable oil	1.00
Starch	3.00
Vitamin premix[a]	0.69
Mineral premix[a]	3.60
Butylated hydroxytoluene	0.04
Est. crude protein (%)	35.00
Anal. crude protein (as fed) (%)	36.00
Est. digestible energy (Kcal/100 g)	250.00

[a]For complete and practical diets (Nat. Res. Council 1977)

Based on values for channel catfish: protein, 3.5 Kcal/g; fat, 8.1 Kcal/g; NFE, 2.5 Kcal/g (Nat. Res. Council 1977, Wilson 1977) starch are added last. The mixture is then extruded through 2 mm dies of a heavy-duty meat grinder. The resulting pellets are oven-dried at 70°C until moisture content is about 10% or less. The dry pellets are crumbled and sieved. Feed particles that pass through the No. 60 mesh sieve are fed to fry for the first two weeks. During the 3rd and 4th week, fry are given feeds that pass through No. 45 mesh sieve. Larger crumbles are fed subsequently. Stocks of prepared feeds are kept in a refrigerator.

The rearing tanks are maintained by siphoning uneaten feeds and feces. Water is changed every 10 days by draining at least 1/3 of the total water volume. Growth of phytoplankton in tanks, especially the blue-green algae and diatoms, is encouraged. In some cases, uni-algal cultures of the desired species are used to inoculate the rearing tanks on a regular basis. These serve as food for the growing fry aside from maintaining good water quality in tanks. The blue-green algae *Chlorococcus dispersus* and the diatom *Navicula notha* enhanced growth and survival of tilapia fry (Pantastico et al 1985).

Diseases and parasites. *Tilapia nilotica* fry infected with *Trichodina* and *Dactylogyrus* are treated with salt bath at the concentration of 1 000-2 000 ppm. *Pseudomonas* has also been found in tilapia fry reared in nursery tanks. Aside from salt bath, fry are fed oxytetracycline-treated artificial feeds at 7.5 g/100 kg fish body weight per day for 7-12 consecutive days.

Harvest and transport. Fry are harvested after 21-30 days of rearing in hapa cages in the lake or 30-45 days in tanks. Fry are sorted according to the mesh size of the cage to which they were to be transferred, i.e., A-net (2 mm sq mesh), B-net (4 mm diagonal mesh) or C-C net (20 mm diagonal mesh). Fingerlings measuring about 2-2.5 cm total length are stocked at 200-250/m^2 using A-net or B-net cage in the lake for further rearing. In a related experiment by Tabbu et al (1986), tilapia recovery was highest in breeding hapas than in the ponds. Fry were collected from the ponds either by seining or by means of fine mesh scoop nets. Low fry recovery in ponds was attributed to cannibalism and other factors such as asynchrony of spawning cycles and variable fecundity.

Fingerlings are transported in doubled plastic bags filled with oxygen at a fry density of 500-1 000/bag in 10-15 1 of water.

Production constraints. In general, tilapias are prolific breeders so that the production of fry is not much of a problem. However, some unfavorable environmental parameters in the lake like low water temperature during cold months, scarcity of natural food, and adverse conditions during typhoons could lower their reproductive capacity. Likewise, growth and survival of tilapia fry are affected by these parameters.

CARP

Introduction

Carp culture in the Philippines began in 1966 when fingerlings of Chinese carp, i.e., bighead, silver and grass carps, and the common carp were grown in ponds at the Tanay Experimental Station of the Bureau of Fisheries and Aquatic Resources (Chaudhuri 1979). Subsequently, mass seed production of these species was conducted. In 1969, the first successful induced spawning of bighead and silver carps by hormones was achieved (Reyes as cited in Chaudhuri 1979). Despite these pioneering efforts, the carp culture technology did not flourish due primarily to the limited production of fry and fingerlings.

In the mid-1970's, two enterprising fish culturists ventured into hatchery and grow-out culture of Chinese carps. They developed carp broodstock from the fingerlings obtained from Taiwan (Santos, pers. comm.). However, fry and fingerling production was limited to their own requirements for grow-out.

The potential of bighead and silver carps for cage culture in the lake was further recognized when several studies were undertaken by SEAFDEC AQD in 1980. From the fingerlings of Chinese carp obtained from a private hatchery in Bulacan, broodstock was developed and subsequently induced to spawn for seed production. Studies on broodstock development resulted in the successful gonadal maturation and rematuration of bighead and silver carps in floating cages in the lake all year round (SEAFDEC Asian Aquaculture 1984). The first record of induced spawning of lake-reared carps was achieved at SEAFDEC AQD in 1983. The fingerlings produced were made available to the fishpen and cage operators in Laguna Lake. The following year, more than 100 000 bighead carp fingerlings were made available to several fishpen and cage operators in the lake. The number of fishpen operators has increased to 14 in 1985-1986, operating an aggregate area of 1 862 ha for bighead carp grow-out (Almazora 1987). At the minimum stocking density of 10 000/ha, a total of 18.6 million carp fingerlings are needed for cropping every 6-8 months.

At present, there are about 16 private carp hatcheries around Laguna Lake, ready to supply fingerlings. These hatcheries operate at varying production rates ranging from 0.1 to 1.5 million fingerlings/6-month operation (Almazora 1987). Carp fingerlings (about 4-6 cm length) are sold at the current price of P2-2.50 each.

Broodstock Development and Management

Rearing facilities. Fishpens, cages, and earthen ponds are used to rear bighead and silver carp broodstock. Broodstock pens are 10 × 50 × 2.5 m, each lined with size 20 mm mesh nylon netting. The net is buried at least 0.5-1.0 m deep and held in place with bamboo stakes. It is extended to about a meter above the water surface.

Cages are 4 × 4 × 3 m or 5 × 10 × 3 m covered, and with mesh size of 4-20 mm. The cages arranged in series are suspended in stationary or floating bamboo modules. It is protected from strong waves and heavy growth of water hyacinths during typhoons by a peripheral bamboo and net barricade.

Earthen ponds have each a total area of 500 m^2 (20 × 25 × 1.0 m) with mean water depth of 0.75 m. Each compartment has individual inlet and outlet gates for easy draining and refilling.

Rearing methods. One-year old bighead and silver carps are stocked and maintained at densities of 100-200/500 m^2 fishpen or at 10-20/m^2 in floating cage. The two species are reared separately. In ponds, bighead and silver carps are reared in polyculture in compartments at 25 pcs/500 m^2. A female to male ratio of at least 1:1 to 1:2 is maintained in all rearing facilities.

In the lake, carp broodstock are not given supplemental feeds. Bighead carps feed on zooplankton while silver carp thrives mainly on phytoplankton, both of which grow abundantly in the lake (Carlos et al 1986). Preliminary experiments on the supplemental feeding of carp broodstock in floating cages in the lake were done (Castro et al 1984). The experiments aimed primarily at enhancing the gonadal maturation and subsequently the spawning capacity of the fish. The fish were fed daily, once in the morning and once in the afternoon, at 3% biomass with the dry pellet that contained about 35% crude protein. Initial data, however, showed no significant results. Further investigations are still needed.

Broodstock ponds are prepared by draining, sun-drying, and fertilizing with chicken manure prior to stocking of fish. Chicken manure is applied initially at the rate of 2-3 t/ha and subsequently at 1-1.5 t/ha/ 7-10 days. The breeders are given supplemental feeds twice daily at 3.0% biomass. Pond water is partially flushed and replenished at least twice a week.

Gonadal development. Carp broodstock are sampled monthly to assess gonadal development and growth. During sampling, fish are held in a large rectangular styrofoam box (0.5 × 1.0 × 0.7) m) filled with lake water and aerated.

Fish are anesthetized with 2-phenoxyethanol at the rate of 30-40 ml/100 1 of water. At least 6-8 breeders weighing 3-4 kg each are held in the box at a time during sampling. Broodstock are measured individually for total length, weight, and body girth. Each fish is coded by marking the surface of the head with a lead pencil. The mark could last more than a month and is renewed every sampling time.

Sex of breeders is determined by means of their pectoral fins. A mature male broodstock has rough pectoral pins due to the presence of "ctenoid teeth structures" which appear prominently along the first ray. A male broodstock is selected for induced spawning when it readily gives off milky white milt when press gently along the abdominal portion. A female breeder has smooth pectoral fins. When fully mature, its belly is distended with pinkish genital papilla. Gonadal maturity is assessed by cannulation. Stage IV mature eggs are yellowish in color, easily dispersed in freshwater, and are 1.0-1.4 mm dia. The nuclei of mature eggs are polarized when placed in a petri dish containing FAA solution (9.05% formaldehyde, 4.55% acetic acid, and 86.4% ethyl alcohol) (Fermin 1986a). The fish is then selected for induced spawning.

Gonadal maturation and spawning. Under Laguna Lake conditions, bighead and silver carps attain sexual maturity in 2-2.5 years, each ranging 3-4 kg. They undergo spontaneous gonadal maturation and rematuration throughout the year without hormonal inducement (Fermin 1986b). Carp broodstock maturation rates peak in summer (March-May) when natural food in the lake are most abundant. This gradually declines to its lowest approaching the cold months (December-January) (Fig. 1).

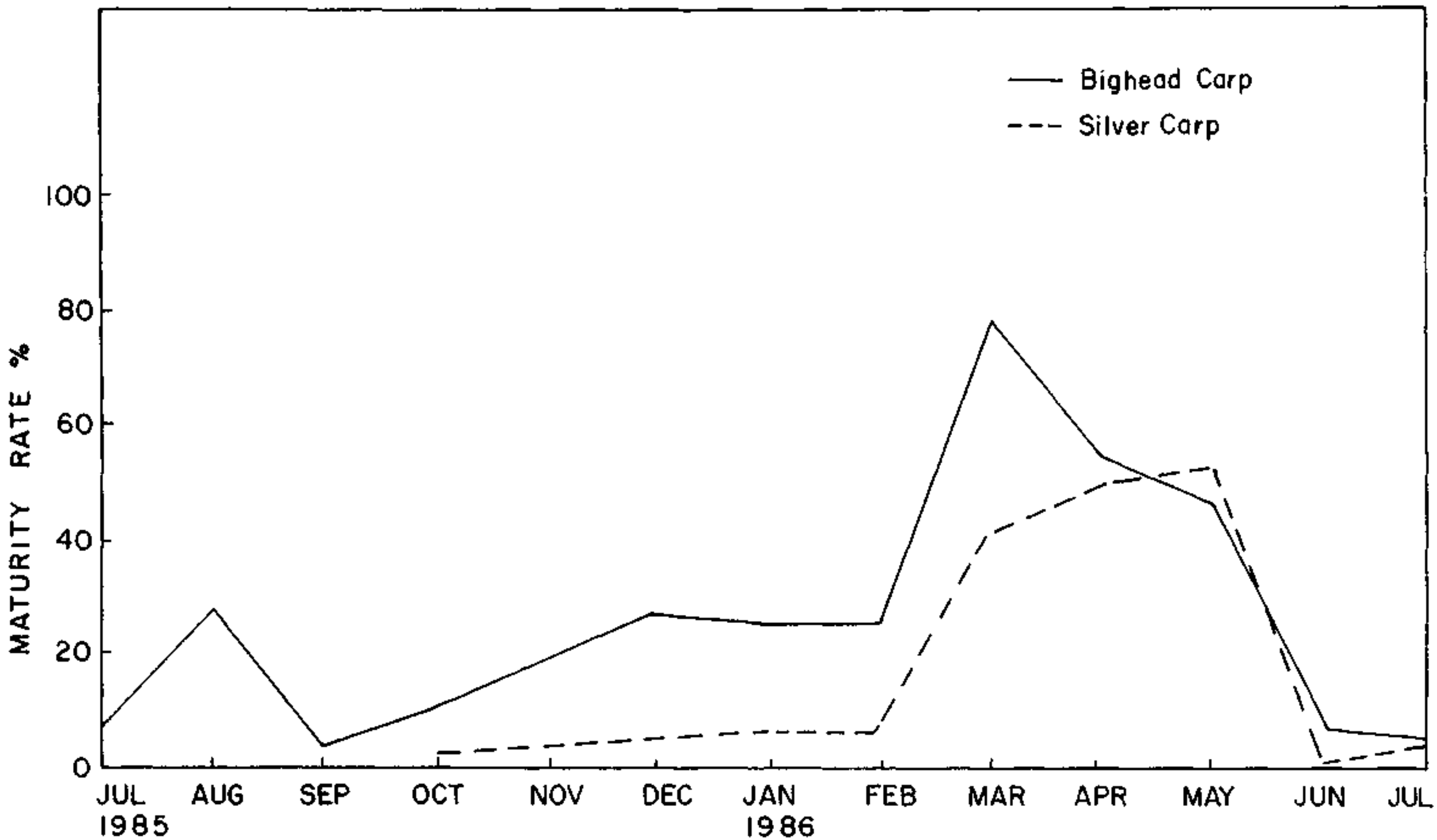

Fig. 1. Percentage maturity rate of bighead and silver carp broodstock reared in floating cages in Laguna Lake from July 1985 to July 1986 (Fermin et al 1986)

Gravid females with mature Stage IV eggs are selected for induced spawning. The fish are conditioned in a circular pool (5 m dia and 1.3 m depth) made of G.I. sheets and lined with plastic canvas. The tank is provided with water jet effecting a continuous circular flow of water. Two to three males are used for every female. The fish are held in the tank for 18-24 hr prior to hormone injection. The hormones used for carp spawning are: Human Chorionic Gonadotropin (HCG), leuteinizing hormone-releasing hormone analogue (LHRH-a) and common carp pituitary gland (PG). The females are injected with an initial dose of HCG at 10% of the total dosage of 2 000 IU/kg body weight. During the second injection, about 6-8 hr later, the remaining 90% of HCG is injected in combination with either 20 μg of LHRH-a or 3-4 pcs of common carp PG homogenized in 1-2 ml of distilled water. At this point, males are also injected with 1 000 IU of HCG/kg body weight. The hormones are given by intraperitonial injections behind the pectoral fin.

During the latency period, about 6-8 hours after injecting the final doses, the fish display aggressive movements causing intermittent rippling on the water surface. The female is then taken out of the tank and stripped of its eggs which are collected in an enameled basin. A 3-kg breeder can spawn about 15 000-200 000 eggs. Simultaneously, 2 or 3 males are stripped of their milt directly into the eggs which are stirred with feather. Fertilization rates vary from 23-88% (Table 3). Eggs are incubated in well water with total hardness of 300-500 ppm (Gonzal et al 1987) (Fig. 2 and Table 4). Lake or underground water with total hardness of about 75-150 ppm may cause premature bursting of carp eggs within 5-8 hours of incubation. The normal incubation period for carp eggs ranges from 13-18 hr at water temperature of 28-30°C. Hatching rates vary from 7-36%. Under favorable conditions, a spent female may remature in 2-3 months in Laguna Lake.

Diseases and parasites. Injuries by handling and crowding during the process of induced spawning sometimes lead to some bacterial and fungal infections of the breeders. Broodstock are subject to indefinite salt bath at a concentration of 1 000-2 000 ppm after spawning and before putting back in cages (Palisoc 1986). *Aeromonas hydrophila* and *Citrobacter micrococcus* have been found in silver carp broodstock used in induced spawning. The fish were injected with oxytetracycline at 7.5 g/100 kg fish body weight/day for 7-12 consecutive days. Parasite infestation has not been observed in carp broodstock reared in the lake.

Table 3. Induced spawning of bighead and silver carps broodstock reared in floating cages, Laguna Lake, 1985 and 1986 (Fermin et al 1986)

Date	Species	No. of Females	Average Weight, kg	No. of Males	Total Amount of Spawned Eggs	Fertilization Rate, %	Hatching Rate, %	Larval Production	Remarks
1985									
Aug. 14	Silver	1	2.8	3	95,000	45	12	5,000	— delayed spawning
	Bighead	2	3.5	3	115,000	74	23	20,000	— incomplete spawning
Aug. 22	Bighead	2	4.0	5	250,000	23	9	6,000	— delayed spawning
Sept. 11	Silver	3	3.1	5	330,000	35	15	18,000	— poor milt discharge by males
Sept 24	Bighead	3	3.1	7	350,000	45	26	40,000	— partially spawned
Oct. 12	Bighead	1	5.2	4	450,000	50	18	41,900	— prolonged incubation
	Silver	1	3.5	2	150,000	60	31	28,000	temp. 26°C
Oct. 16	Bighead	3	4.3	6	800,000	72	7	23,150	
Nov. 12	Bighead	2	3.5	6	450,000	70	26	86,500	— delayed spawning
Dec. 9	Bighead	3	2.0	7	450,000	65	24	68,900	
Dec. 19	Bighead	3	3.7	8	900,000	88	36	288,800	
1986									
Mar. 17	Bighead	4	2.7	8	550,000	75	32	132,000	
Mar. 24	Bighead	4	4.0	7	480,000	83	26	104,000	
June 26	Silver	3	4.5	7	125,000	42	28	14,800	— partially spawned
July 1	Silver	3	3.3	5	460,000	46	8	16,900	— delayed and partially spawning
July 21	Bighead	1	2.8	4	83,000	50	24	9,900	

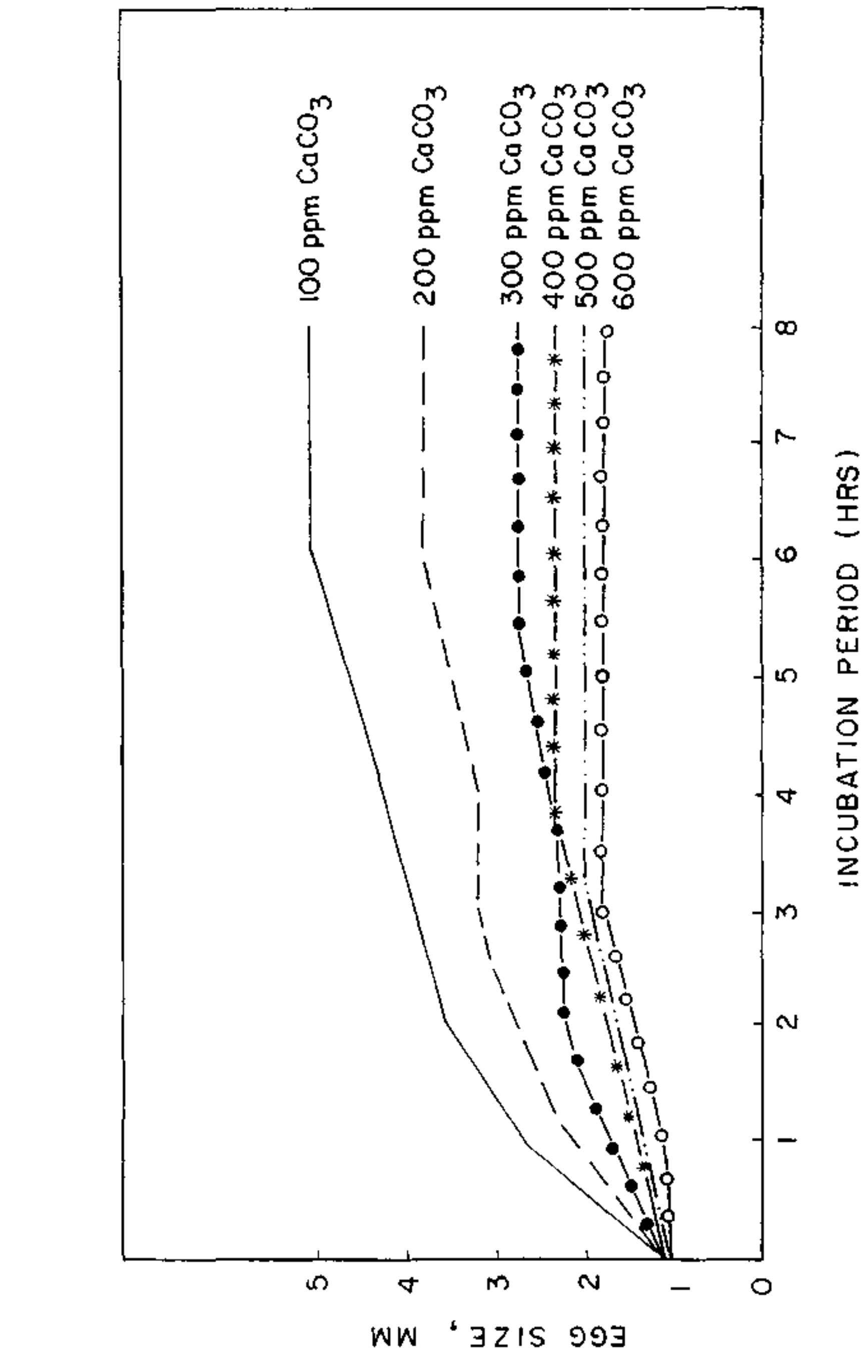

Fig. 2. Enlargement of silver carp eggs exposed to different levels of water hardness ($CaCO_3$) (Gonzal et al 1987)

Table 4. Mean egg diameter, hatching rate and larval production of silver carp spawn after 7-hr, incubation at varying levels of water hardness (Gonzal et al 1987)

Total Hardness	Mean Egg Diameter mm)	Hatching Rate (%)	Larval Production (%)
100	5.0	3.67[b]	7.95[c]
200	3.8	4.50[b]	29.45[cb]
300	2.7	22.50[a]	40.20[b]
400	2.3	27.50[a]	67.50[a]
500	2.0	28.83[a]	71.80[a]
600	1.9	3.67[b]	40.20[b]

[1]Means with the same superscript are not significantly different ($P > 0.10$)

Production constraints. The production of carp broodstock is adversely affected by poor weather conditions in the lake. During typhoons, broodstock cages and pens are prone to destruction by strong waves resulting in complete loss of fish. Poaching is another perennial problem being experienced by hatchery operators. Bighead carp broodstock are easy prey to poachers because of their sedentary nature.

Seed Production

Rearing facilities. Carp fry are reared in indoor tanks made of fiber glass, marine plywood, cement, or plastic canvas. Fiberglass tanks are oval-shaped with total capacity of about 1.3 t each. Water can be kept at a depth of 0.5-0.6 cm. Marine plywood and cement tanks are rectangular measuring 1.2 × 2.4 × 0.6 m and 2.0 × 2.8 × 0.7 m, respectively. Plastic canvas tanks are circular with a diameter of 3 m and water depth of about 0.3 m. Mean water depth of rearing tanks is 0.5 m.

Carp fry are also reared in fine-mesh net-cages installed in earthen ponds. Net-cages of about 80 µ mesh size measure 1 × 3 × 1.5 m or 2 × 5 × 1.5 m. The cages are tied to bamboo or ipil-ipil *(Leucaena leucocephala)* posts spaced about 1 m apart. The cages are arranged in series in the middle of the pond. The pond has an inlet and outlet which permits periodic flushing of water.

Rearing methods. Three to four day old bighead or silver carp fry are stocked in the nursery tanks at 10/1 of filtered lake water or unchlorinated tap water. Each tank is moderately aerated.

During the first 2 weeks of rearing, fry are fed daily in *ad libitum* with small-sized zooplankton like *Brachionus plicatilis* in combination with artificial feeds. *Brachionus,* a marine rotifer, are mass produced in artificial sea water with 10-15 ppt salinity in 120 1 capacity glass aquaria or in 240 1 capacity galvanized iron tanks. The zooplankton are fed daily with freshwater *Chlorella* plus bread yeast (Acosta et al 1986). Harvesting is done starting on the 3rd day of culture up to the 7th day, after which the culture is renewed. *Brachionus* is washed with sufficient freshwater before feeding to fry. Fry can be fed artificial feeds with 40% crude protein (Table 5), (Fermin 1985).

Table 5. Composition of artificial feed used for rearing carp fry (Fermin 1985)

Ingredient	%
Fish meal	40.60
Soybean meal	36.13
Rice bran	15.00
Vitamin-mineral premix	5.00
Cod-liver oil	3.27
Estimated crude protein %	40.066
Analyzed crude protein %	40.21
Estimated digestible energy	270.503

In the next 3-6 weeks the fish are gradually shifted to larger zooplankton such as nauplii and small adults of *Moina macrocopa.* Mixed sizes are given in the latter part of the rearing period. Artificial feed is given in addition to *Moina.*

Moina, a cladoceran, is mass-produced outdoors in circular cement tanks about 1.3 t capacity, using fermented leaves and stalks or water hyacinths *(Eichhornia crassipes)* mixed with filtered lake water at 50:50 ratio (Baldia 1986). Peak production of *Moina* is attained at the 9th day; then it gradually declines. Cultures are renewed every 10th day.

Throughout fry rearing, phytoplankton in the form of "green-water" is added daily to the culture tanks after each water change. Phytoplankton improves the water quality in the rearing tanks and enhances fry survival (Fermin 1985). They have the ability to assimilate nitrogenous end-products of fish wastes and excess feeds.

Fry are stocked in nursery cages installed in the ponds, at the rate of 1 000-1 500/m^2. They are given artificial feed *ad libitum* to supplement the natural food in the pond. Ponds are fertilized every 2 weeks with chicken manure at 0.1-0.2 kg/m^2. The manure is placed in sacks and hanged at different sites within the pond. Water depth in the pond is maintained at 0.5-0.75 m throughout the rearing period. Carp fry are cultured for 21-30 days in cages after which they are released directly in the pond.

Diseases and parasites. Carp fry reared in indoor tanks are vulnerable to disease and parasite infestation particularly under conditions of crowding, handling stress, and poor water quality. Bighead carp fry in tanks were found to be infected with *Pseudomonas.* The fry were treated with indefinite bath of formalin at concentration 15-25 ppm (Palisoc 1986). Preventive measures like daily change of water, and removal of excess feed and other wastes are generally practised.

Harvesting and transport. Fry are harvested after 30-45 days of rearing in tanks or 25-30 days in cages in the pond. They have a total body length of about 1.5-2.5 cm.

Harvesting is done by slowly draining the water in the tanks leaving at least 1/3 of the total volume. The fry are either scooped out or completely drained into the collecting basins half-filled with water and lined with soft, fine-meshed net.

During transport, fry are kept in 10-15 1 of water in oxygenated doubled plastic bags (60 × 90 × .003 cm) packed in buri bags *(bayong).* Density of fry ranged from 70-100/1. Bags are inflated with oxygen and secured by tying each layer with rubber bands. A few pieces of ice cubes are put on opposite sides of each bag to cool water to about 24-26°C. Transport of fry is done preferably in the morning or late in the afternoon when ambient temperature is low.

Production constraints. The insufficient supply of natural food organism could adversely affect growth and survival of fry reared in indoor tanks. The adverse conditions in the lake especially during the rainy months can cause heavy mortality of fry. Fry reared in ponds have better growth rate. However, recovery during harvest is very low.

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FARMING OF MUSSELS AND OYSTERS

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ABSTRACT

This paper reviews the works on mussel and oyster culture conducted from 1975 to 1985 by the Southeast Asian Fisheries Development Center Aquaculture Department at Tigbauan, Iloilo, Philippines. Innovative techniques developed in increasing collection of natural seeds and in improving farming techniques are presented. Results of the work on artificial seed production, bacterial depuration, uptake and elimination of heavy metals by green mussel, investigations on red tides, and microbiology of spoilage are discussed.

INTRODUCTION

In Asia and the Pacific, bivalves represent a high quality food resource, either harvested from the wild or cultivated in farms. Compared to crustacean culture, annual production of bivalves per ha is higher at 1.5×10^4 kg oysters, 1.0×10^4 kg to 2.5×10^4 clams (depending on market size), and 3.0×10^4 to 5.0×10^4 kg mussels (Utting 1987).

Interest in bivalve culture in Southeast Asia has grown considerably. The most important species are oysters, mussels, clams, cockles, and scallops. Mollusc production, however, has declined significantly in recent years primarily due to the decreasing production in Malaysia and Thailand arising from the rapid depletion of natural breeding stocks of cockle and mussel (Table 1). Nevertheless, molluscs accounted for approximately 35% of the total production of coastal aquaculture in 1984 in terms of gross weight (Shang 1986).

Table 1. Production of molluscs from coastal aquaculture by country, 1975-84 (Csavas 1985)

Country	1975	Unit: 1000 MT 1981	1982	1983	1984	Average annual growth rate 1975-84	 1981-85
						%	%
PR China	248.9	301.6	343.4	309.1	372.6	5.0	5.9
India	0.1	1.8	1.8	4.0	4.0	390.0	30.5
Indonesia	—	—	—	—	—	—	—
Japan	278.0	302.0	335.2	347.1	347.1	2.3	3.3
Malaysia	53.5	121.3	121.3	49.4	49.4	0.1	-5.9
Philippines	—	12.8	25.3	29.8	34.9	—	43.0
Taiwan PC	30.9	44.7	46.2	53.7	59.2	9.2	8.1
Thailand	23.0	53.7	23.9	29.8	29.8	3.0	-11.0
Total	634.4	837.9	897.1	822.9	891.6	4.1	1.6

SEAFDEC AQD started its work on bivalve molluscs in 1975 when a Mussel Research Project was set up with the assistance of the New Zealand Government. The project first undertook a survey of the mussel farming industry. Later, it conducted a baseline study on the biology of local mussels and preliminary experiments on mussel farming (Tortell et al 1978, Yap 1978, Yap et al 1979).

SEED COLLECTION

SEAFDEC AQD started a spatfall-forecasting program in Himamaylan River in Negros Occidental in 1979 for oysters and another in 1981 in Batan Bay, Aklan for mussels. The main activities of the forecasting program were: (1) monitoring of daily counts of oyster or mussel larvae in the plankton and (2) monitoring of actual setting of larvae on standardized collectors installed in oyster-mussel farm sites.

For oysters, series of collectors were set out in the sampling area: one upriver, another located seaward, and a third in-between. The sample collectors are retrieved and examined every week at a designated day. In addition, plankton tows were carried out daily during flood tide at a standard distance of 360 m. For mussels, a set of 5 sample collectors, each consisting of 30 cm lengths of rope collectors strung across a frame hung from a floating raft, was installed. At weekly intervals, 5 new sample collectors were exposed while 5 old ones were retrieved. This provided good indications for cumulative settlement of mussel spat. For analysis, samples were passed through a series of sieves which grade the spat according to size and age.

The preliminary reports (Young et al 1981) are not adequate as yet for formulating a spatfall forecasting scheme, but a few general observations are significant:

1. When the count of mature larvae exceeds 5 oyster larvae/100 sample and persists for at least 3 days, spatfall maybe expected very soon. This spatfall period may last up to 1 month so that the best strategy for collecting oyster spat is to spread out the collection effort over the spatfall period instead of putting out all spat collectors at the same time.

2. For commercial farming operations, a good or substantial set of oyster seed should yield at least 15 spat/shell in a surface area of $40 m^2$. For mussel seed, a count of 200-500 spat/m of

rope or 70-85 spat/30 cm of sample rope collector indicates a good settlement for commercial production.

FARMING TECHNIQUES

Countries which have successfully cultured bivalve molluscs have developed their own system of culture which depends entirely on natural seed stock. Seeds for farming are either gathered from natural seed beds or collected by using suitable materials for collecting seed from natural grounds.

A number of natural and synthetic ropes have been used for spat collection. Natural rope fibers have been found to be attractive to mussel larvae, but they do not last long. On the other hand, synthetic ropes like polyethylene or polypropylene ropes will stand up to several years, but they catch less spat unless a heavy spatfall occurs. The catching qualities of synthetic ropes, however, can be improved by inter-weaving more suitable cultch among the strands of the rope by wrapping fibrous materials externally around or by tying short pieces of fibrous materials into the rope. Coir, a natural coconut fiber, can be interwoven among the synthetic braid during the making of the rope or may be wrapped around it. Coir biodegrades rapidly in sea water but the mussel larvae because of its ability to move will have attached themselves securely before the coir is destroyed. Another is to intermittently insert into the ropes short segments of sacking material or husks segments cut from a mature dried coconut (Yap et al 1979, Sitoy et al 1983). Other materials that can be used are old frayed ropes, polyethylene strands used in making rice sacks, plaited ropes of vegetable fibers, and other fibrous materials (Young 1984).

Farming methods for oyster and mussel in the Philippines make extensive use of bamboo stakes which increase siltation rate in areas occupied by such stake-farms. The bamboo poles serve as cultch for the settling of mussel larvae, and no thinning or transplanting is done during the grow-out. An alternative method is the floating raft culture shown in Fig. 1 (Anon. 1979, Sitoy et al 1983, Sitoy 1984).

Mussel farming using rafts has several advantages: mussel grow faster; regular thinning can be done; rafts can be moved around to prevent siltation. It can easily be constructed out of durable materials

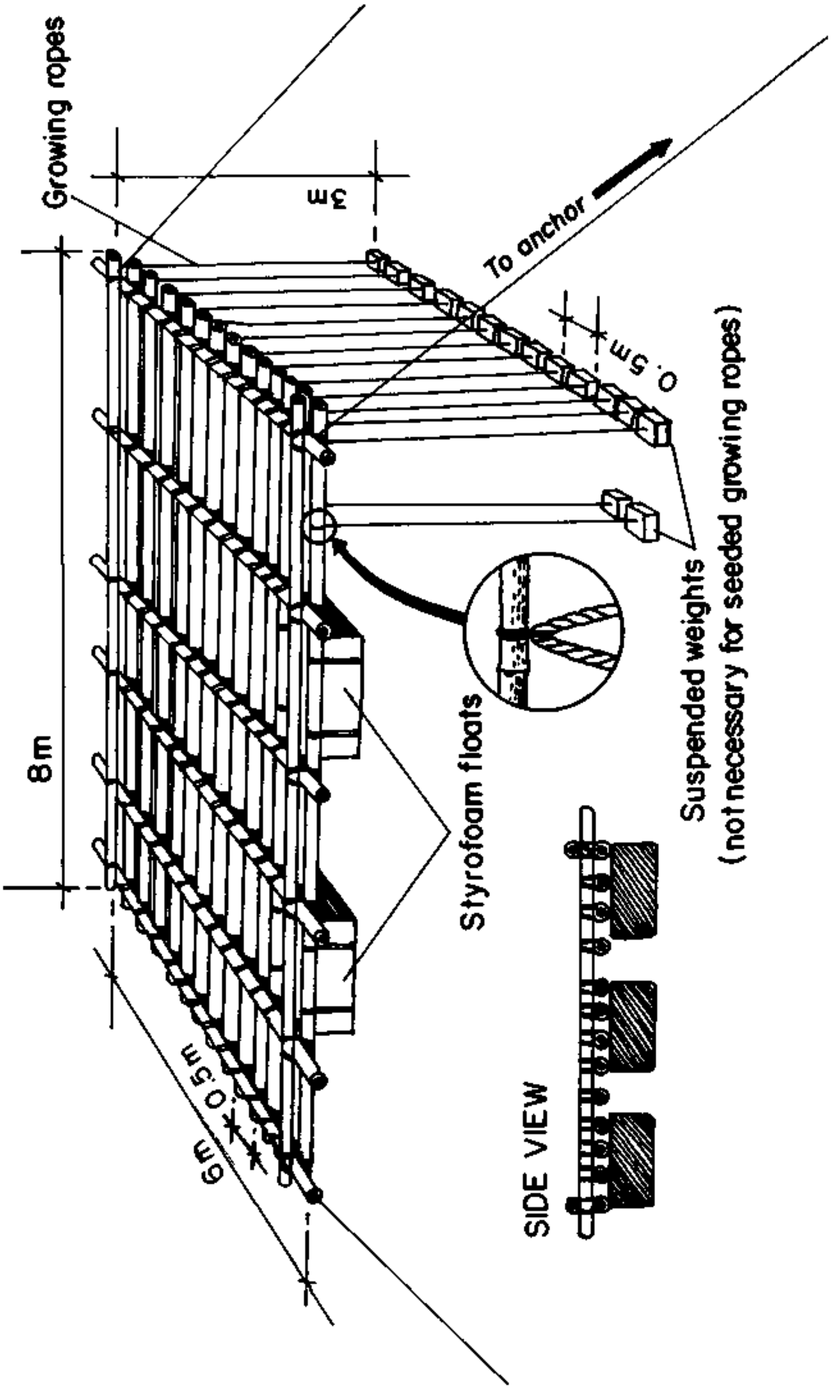

Fig. 1. Diagram of a mussel raft unit (Sitoy et al 1983)

lasting for several years. Aside from providing higher production per unit area the technique offers a convenient method of transplanting seeds to other areas without natural stocks (Aypa 1980; Walter 1981, 1982;Tabbu et al 1983).

SEED PRODUCTION

Seed production of bivalves at AQD started in 1979. Young (1979) successfully spawned the green mussel (*P. viridis*) in the laboratory. The slipper oyster (*C. iredalei*) and the windowpane shell *(Placuna placenta)* were also successfully reared through its larval stages to metamorphoses and settlement. A detailed description of the larval development and morphology of *C. iredalei* is presented in Table 2 and that of *P. placenta* in Table 3. Recently, the Asian moon scallop *(Amusium pleuronectes)* was successfully spawned and the eggs reared through metamorphoses (Young unpublished). Newly developed D-veliger larvae measure 107 µm in length 83 µm high, reaching the umbo veliger stage at 145 µm. Unlike *Placuna,* Asian moon scallop shell is equivalve and broad. Pediveligers average 107 µm in length and show alternate swimming and crawling movements. After day 13 from spawning, prediveligers attach bysally to objects and remain there until they reach an average diameter of 5 mm. As early as 1 mm in size, *Amusium* juveniles already show characteristic jet-propulsion movements in pectinids.

Young (unpublished) successfully reared oyster larvae at a density of 3-5 ind/ml and fed with a combination of *Isochrysis galbana* and *Chaetoceros calcitrans* at $3.0\text{-}5.0 \times 10^4$ cells/ml. The larvae were successfully induced to set on crushed windowpane shells spread on the bottom of a floating screened PVC-frame after 17 days of rearing from hatching. A week from setting, about $5.0\text{-}6.0 \times 10^3$ young oyster spats were retrieved and transferred to an upwelling-type nursery system where they were fed *ad libitum.* But growth in the nursery was limited by insufficient food and less than 3% survived. After a month the remaining spat reach 3-11 cm. A batch of mussel larvae was also reared to metamorphosis. After 19 days, ready-to-settle larvae attached themselves to strips of knotless nylon netting suspended in the tank.

An experiment to assess the suitability of Tahiti's low-density technique (AQUACOP 1979, 1980, 1984) against China's high-density method (Fusui et al 1981) was conducted. Four 750 1 cylindrical tanks were stocked with mussel larvae at 5/ml and two U-shaped

Table 2. Main features of the larval development of *Crassostrea iredalei* (Temperature, 26.5-30°C; salinity, 30-32 ppt) Ver 1986)

Stage	Age	Mean Size (µm)	Range (Mm)	SE (Mm)	n	Remarks
Straight-hinge veliger	22 hr-4 days	L = 74	64-84	0.528	110	D-shaped; shell asymmetrical but equivalved
		H = 67	56-80	0.708	110	
		D = 48	41-61	0.948	41	
		Hinge-line length = 50				
Umbonate veliger	5-22 days		L = 85-275		419	rounded umbo at lengths 85-90Mm; knoblike umbo at lengths 91-150 µm; skewed umbo at lengths greater than 150 µm
			H = 81-305		422	
			D = 62-200			
Pediveliger	16-22 days		L = 210-275		18	alternately creeping and swimming vigorously
			H = 240-305		15	
			D = 171-220		6	
Eye-spotted pediveliger	18-22 days	L 217				larvae nearing metamorphosis; eye-spot diameter, range 8-15
		H 242				
Spat	20 days	L 274				larvae attached on cultches
		H 328				

Table 3. Major features of larval development in *Placuna placenta* cultured at 27°C and 28-29 ppt salinity (Young 1980)

Stage	Age	Size range (Mm)	Shape/distinguishing features
Fertilized egg	0	Dia. 45 µm	Golden yellow, spherical
Straight-hinge	20-30 h	L:50-105 H:43-98 D:25-52 HL:4-55	Smallest veliger 50x43 µm; hinge line commonly 50-55 µm, slightly curved, not increasing in length with growth. Ends of nearly equal length. Shell inequivalve.
Umbo veliger	2-8 days	L: 100-200 H:80-200 D:50-75	Shells inequivalve. Right valve flat with undeveloped umbo. Left valve rounded. At lengths beyond 150 µm umbo of left valve projects well above the shoulders as a prominent knob. Shells nearly transparent; digestive organs situated almost beneath umbo, No byssus notch. Anterior end longer, more pointed. Ventral margin bluntly pointed.
Pediveliger	8-10 days	L: 180-220 H:180-220	Foot functional at L=170 µm. Eyespots at L=150, commonly obscured by opaque mass of digestive gland. Metamorphosis at L: 220-230.
Spat	10-11 days	Typically L:230 H:220	Foot long, well developed. Velum absent. Dissoconch delineated by narrow dark band. Shells nearly transparent.

3-ton tanks with 15 larvae/ml. The tanks were maintained on a 24-hr basis after which about 30-50% of the bottom water was siphoned and replaced by rearing water pretreated with sodium hypochlorite and filtered through a P-5 polypropylene cartridge of the dirt/rust type capable of removing particles of 5 µm and further disinfected through a UV sterilizer. Larvae were fed with *Isochrysis galbana* during the first week and then a combination thereafter of *Isochrysis* with either *Tetraselmis chuii* or *Chaetoceros calcitrans* at 5.0×10^4 cells/ml. Total water renewal was done every fifth day. The high density stocking method yielded an average of 2.36 million ready-to-settle (5.3% survival) mussel larvae in 20 days.

Mass mortalities caused by bacterial population reaching lethal levels in the larval tanks were encountered in the trials. Contaminants were traced to bacterized algal feed from 10 1 plastic carbouys used in mass production of feeds. Poor growth and survival were particularly evident in larvae fed with algae at 7.5×10^4 cells/ml. The production of pseudofeces of overfed larvae promoted the proliferation of bacteria in the cultures, and despite total water renewals, cumulative blooms from residual bacterial populations still prevailed. *Vibrio* sp., a well known pathogenic bacteria, especially virulent to bivalve larvae, was present. Of the anti-bacterials tested, only the mixture of penicillin and streptomycin was found effective in promoting growth and survival of larvae. Sulfadiazine and sulfamerazine were ineffective in depressing bacterial growth.

DEPURATION

Oysters and mussels, which have high bacterial concentrations can be purified by placing them in unpolluted water and allowing such water to be filtered by the bivalves. The bacteria, usually concentrated in the guts are excreted as feces and those in the gill region as pseudofeces. This purification process ensures that bivalves are safe for consumption.

In 1983, a prototype low-cost depuration unit suitable for local conditions was set up in the Tigbauan Main Station (Fig. 2). Experimental tank No. 1 is made of 20 mm marine plywood coated inside with fiberglass resin. Oysters are placed individually in plastic trays at 20 pieces/tray, and loaded on the rectangular depuration tank, (No. 4). Water, prefiltered with a P-5 polypropylene cartridge of the dirt/rust type enters the tank at 7l/min and trickles through a perforated PVC pipe placed at the proximal end of the tank (No. 2).

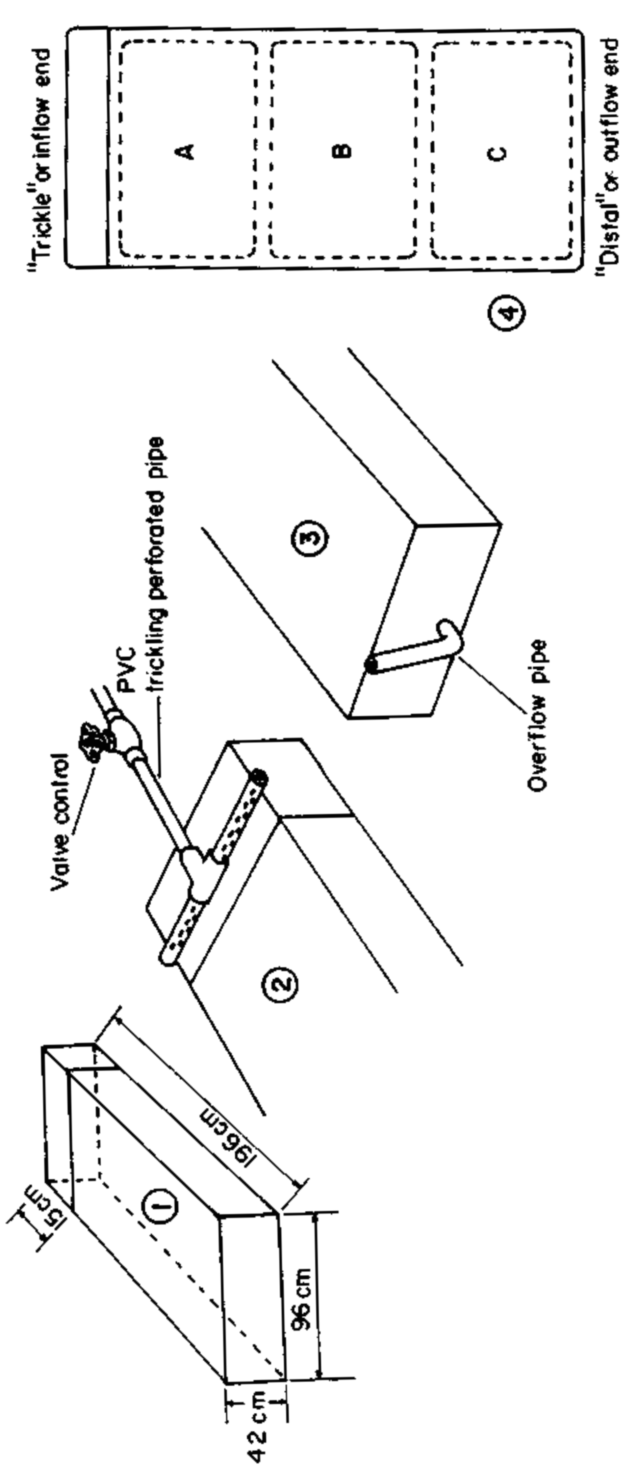

Fig. 2. Experimental depuration unit (Gacutan et al 1986)

Water is disinfected further by passing it through a UV sterilizer. At the distal end, water is drained through a 2.5 cm overflow pipe located at a height level with the tank floor (No. 13). Freshly harvested oysters were depurated by using microbiologically clean sea water sterilized by treatments with chlorine, UV, ozone, polyvinylpyrrolidone-iodide-iodine and sand-filtered in a flow-through system. In terms of bacterial disinfection efficiency, ultra violet-treated water was found to be 99% efficient after 48 h (Gacutan et al 1986). UV radiation may be most suitable for the region as it has no residual effect, is easy to use, and is comparatively inexpensive. Figure 3 shows the changes in the fecal coliform load in oysters during depuration.

Bivalves are known to accumulate heavy metals in their body tissues. In 1981, a sample of the natural population of green mussels in Batan Bay, Aklan was found to contain mercury. A study was therefore conducted to determine mercury uptake by the mussel, its depuration capability, and the possible pathway of mercury bioaccumulation. Results show that the green mussel accumulates mercury rapidly from its surroundings but is very slow in self-cleansing (Fig. 4). This is significant since mussels can be utilized as indicators for presence of trace metals and organochlorines in tropical waters. In July-August 1983, a red-tide occurred in Western Samar and Leyte, covering approximately 300 km of coastlines and lagoons. The causative dinoflagellate was *Pyrodinium bahamense* var. *compressa,* the same organism that caused several red-tide outbreaks in Papua New Guinea, Sabah, Brunei, and Palau.

Average toxicity of red-tide contaminated green mussels was 1165 MU/l00 g (range 945 1, 310 MU/100 g) (Gacutan et al 1984). On the basis of the equivalence of 1 MU to 0.18 μg of saxitoxin, the toxicity was 213 μg/100 g) almost triple the threshold set by the US Food and Drug Administration for closure of shellfish beds (i.e., 80 μg/100 g). When undiluted extracts were injected into mice, killing times averaged 2.5-3.5 minutes. The shortest killing time was recorded at 1.5 min (Gacutan et al 1986).

Preliminary results pointed to the possibility of using ozone and PVP-iodide-iodine to inactivate PSP toxins in green mussels (Gacutan et al 1984).

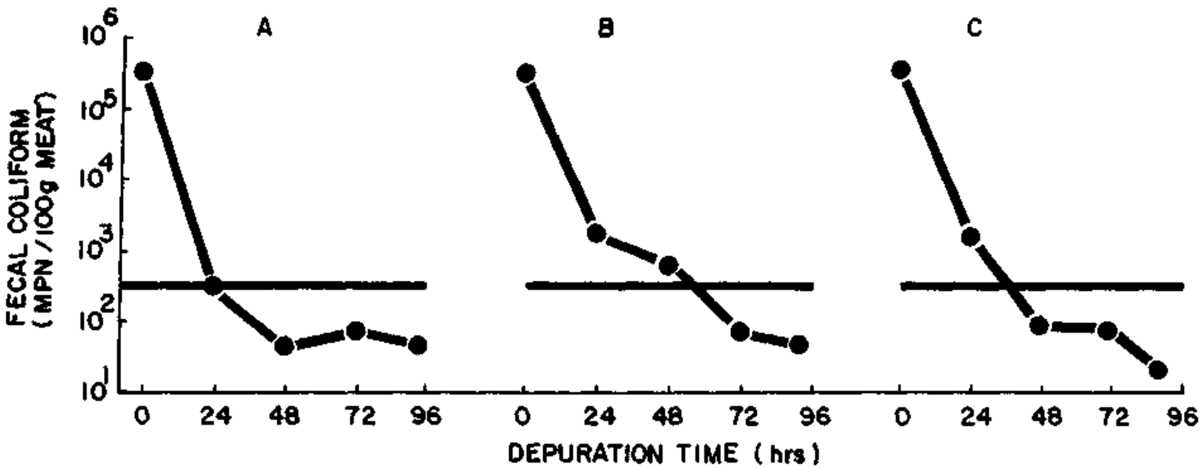

Fig. 3. Changes in the fecal coliform (FC) load (MPN/100 g meat) in the slipper oyster *Crassostrea iredalei* from three areas of a 4 × 8 m wooden tank during depuration of 96 hours (Gacutan et al 1986)

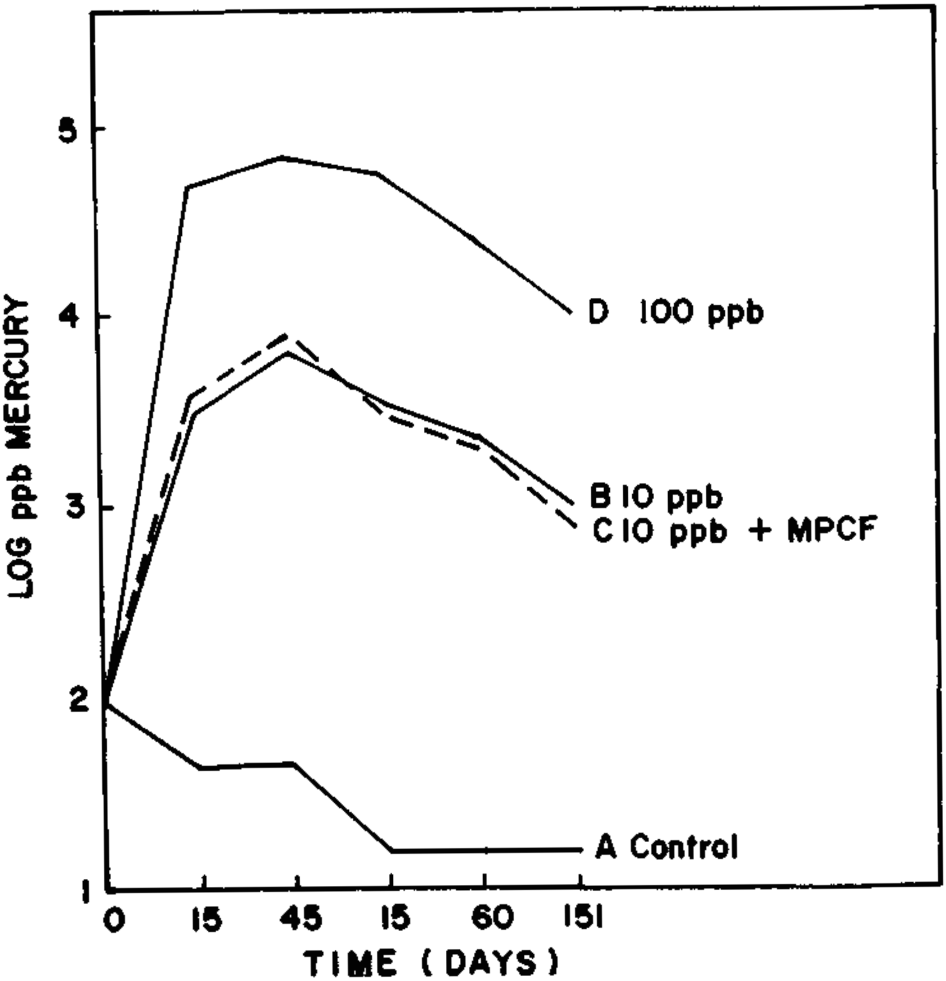

Fig. 4. Accumulation and elimination of mercury by green mussels (Rosell 1985)

TRANSPORT AND HANDLING

In 1976, the Department started conducting experiments on Postharvest handling. Results showed that large mussels are more hardy than small ones and that keeping them wet with sea water prolongs their survival after harvest (Yap and Orano 1980). The bacteriological flora of the slipper oyster was also examined and the results shown in Table 4 (Llobrera et al 1986). A related study showed that while other forms of storage such as freezing and chilling arrest meat spoilage for several days, the most practical storage condition is by placing the meat under a blanket of ice. Oyster meat under a blanket of ice retains its wholesome quality for 14 days, thus extending its marketing possibilities.

Table 4. Percentage distribution of the microbial flora of oysters stored at different temperature (Llobrera et al 1986)

Storage temperature	Day	Pseudomonas	Vibrio	Aeromonas	Flavobacterium	Enterobacteriaceae	Acinetobacter/ Moraxella	Coryneforms	Micrococcus	Bacillus	Streptococcus	Staphylococcus
A	0	10.3	6.9	13.8	6.9	13.8	10.3		6.9	6.9	3.4	13.8
Room temperature	2	30.4	19.6	13.0	6.5	8.7	4.3	10.8	6.5			
24°C												
	0	125	2.5	22.5		12.5	7.5	37.5	2.5	2.5		
8	4	20.0		20.0	10.0	10.0						40.0
Under ice blanket	8	66.6				33.3						
34°C	12	71.4						28.6				
	14	68.4		10.5		5.3		10.5	5.3			
	0	7.7	18.0	38.5		7.7		23.1		5.0		
C	4	12.5		12.5		6.3		31.2				37.5
Chilled	8	28.6	14.3	21.4		14.3		7.1		7.1		7.1
4°C	12		14.3		14.3			28.6	14.3		28.6	
	22								100.0			

	0	36.8	7.9	13.2	7.9	5.3		26.3		2.6	
	4	23.5		17.6	5.9	5.9		29.4			17.6
	8	14.3		21.4	14.3	28.6	7.1	14.3			
	12	8.3		33.3		8.3		8.3		25.0	16.7
	16	36.3			9.1	18.2			18.2		18.2
D	20	20.0				6.6		46.7		26.7	
Frozen	24	16.6							16.6	66.7	
-25°C	28	25.0						16.6	41.7	16.6	
	32	18.2						18.2	36.4	27.3	
	36	6.7		6.7				13.3	13.3	46.7	13.3
	40	25.0						43.8		18.8	6.2
	44	66.7						6.7	13.3	13.3	
	48	26.3					10.5	52.6	5.3	5.3	
	52	21.0		5.3		21.8		26.3	10.5	10.5	
	56	31.7						26.3	10.5	21.0	
	64	30.8		15.4	20.5	5.1		10.2	5.1	7.7	5.1

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NURSERY AND GROW-OUT OPERATION AND MANAGEMENT OF *PENAEUS MONODON* (FABRICIUS)

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ABSTRACT

The results of research on nursery and grow-out rearing of prawn conducted by the SEAFDEC Aquaculture Department for over a decade are reviewed. Different rearing facilities designed to accommodate hatchery-produced prawn fry are presented with corresponding data on growth, survival and production. Studies on stocking density, fertilization/natural food production, water management, feeds and feeding schemes and harvest/post-harvest handling are evaluated and viable technology identified. Diseases, pests and predators and other factors considered as production constraints are also mentioned.

The success in hatchery operation for prawn coupled by the gradual emergence of nursery and grow-out rearing technology have triggered off a technology-dependent prawn industry. When SEAFDEC AQD was established in 1973, there were very few commercial prawn monoculture ventures in the country. Prawn pond production was mostly an incidental crop in milkfish culture. At present, various prawn grow-out techniques ranging from extensive, semi-intensive and intensive culture systems are in practice. SEAFDEC AQD focused its research on the extensive and semi-intensive culture systems which are within the reach of most farmers in contrast to the intensive system that is highly capital-intensive.

There have been much work done in nursery and grow-out operations, but much remains to be done in research, among which are the development of nutritionally-efficient and low-cost feed, control of diseases, etc.

INTRODUCTION

According to the Food and Agriculture Organization, total world shrimp production increased by no less than 32% in 1974-1984. The Philippines ranked 12th among the 14 major shrimp-producing countries of the world. Its production rose from 5.4 mt in 1974 to 52.2 mt in 1984. The Asian region produced 49-61% of the world total (Sjeb von Eys 1986).

More than 75 000 mt of cultured shrimp was produced in 1983 and it is estimated that by the end of this decade, shrimp production will be about 200 000 mt (Feller 1986). Although India, Indonesia, Thailand, and Taiwan are considered the most important countries that culture shrimp, other Asian countries are increasing their production significantly, one of them being the Philippines. Cultured shrimp production in the Philippines was 2700) mt in 1977 and increased to 4250 mt in 1983 (Feller 1986) and is projected to produce about 20 000 mt by 1990. Likewise, Thailand produced 10 091 mt in 1983 and is projected to produce 35 000 mt by 1990.

The demand for shrimps in the world market, particularly in Japan, United States, and Europe, brought about the upsurge in the production of shrimps. Around 90% of the cultured shrimps in the Philippines is exported to Japan while about 5% are exported to the United States and 5% to Hongkong and Europe (Fernandez 1985). Shrimp consumption in the U.S. reported to be 1 000 mt in 1973 and increased to 11 100 mt in 1982. Likewise, Japan consumed around 109 200 mt in 1973 and 162 700 mt in 1982.

This paper reviews results of studies on the nursery and grow-out phases of prawn at the Leganes Brackishwater Station of the SEAFDEC Aquaculture Department (AQD) since its establishment in 1973. Research results and recommendation on the nursery and grow-out phases of *P. monodon* have been disseminated through training, extension, and consultative meetings.

NURSERY OPERATION

Rearing Facilities

About a decade ago, milkfish ponds were utilized for nursing hatchery-produced prawn fry using a similar management method for milkfish fry culture. However, the system could hardly obtain profitable rates of survival. To improve prawn post-larval production, various nursery systems were studied by the Leganes Brackishwater Station, namely, suspended hapa net, earthen pond, concrete tank, and floating cage nursery systems.

In a study by Primavera (1976) using suspended hapa nets as nursery facility, survival of prawn fry at different stages were consistently within the range of 50-70%. The suspension nets measured $3 \times 2 \times 2$ m with a stocking density of 200 fry/m^2. Comparable results were obtained by Apud (1979) when the earthen nursery system consisting of 200 m^2 and 500 m^2 compartments (Fig. 2) were utilized. However, the former was found to be best suited for postlarvae, PL_{15} and older, while younger postlarvae, PL_4 to PL_5, could be reared in the latter system. With the use of concrete tanks for nursery operation, Mochizuki (1979) obtained survival of 70-80%. Likewise, using the tank nursery system with tank sizes of 3-40 t integrated in hatchery system, Gabasa (1982) achieved comparable results. In a preliminary run using marine plywood tanks a much higher survival (96-98%) was obtained by Soeprayitno (1976).

The use of floating cages made of bamboo measuring $2 \times 5 \times 1.5$ m with cement-coated styrofoam sheets as floats was tried by de la Pena et al (1985). These cages were installed offshore where water depth was at least 2 meters during the lowest tide. Based on 25 production runs, an average survival of 41.0% was obtained in a 2-3 week culture period.

Among the nursery systems studied, the tank nursery system has been found to be superior in production output, but it requires relatively higher initial capital investment compared with the other systems. Unlike the earthen or tank nursery, the floating cage nursery system is more economical to operate as it requires no aeration and pumping. It can be installed inside the fishpond just like hapa nets, but is more appropriate in coves with slow currents and other protected areas with suitable conditions.

Rearing Methods

Nursery rearing facilities are necessary and technical knowledge of the rearing method is a prerequisite for higher post-larval production. The unavailability of a good culture method for nursery system some-time in 1974 resulted in very low survival rates of from 0-10% when prawn fry from the hatchery were stocked directly in ponds by fish farmer cooperators of SEAFDEC AQD. Since then, different culture techniques have been tried by the Leganes Brackishwater Station research staff on optimum stocking density, feeding rates, fertilization rates, and proper water management.

Stocking Density

Various stocking densities from as low as 15 fry/m^2 to as high as 150 fry/m^2 have been tried in earthen nursery ponds by (Apud et al 1979). Generally, stocking densities lower than 50 fry/m^2 gave higher survival rates. Higher survival rate at 100 fry/m^2 which tended to decrease as stocking density increased to 150 fry/m^2 were obtained by Tabbu (1984). Both studies showed that prawn fry can be reared at higher than 50 fry/m^2 in earthen nursery ponds with survival rates of 40-80% provided feeding is supplemented with mussel meat at 100-20% body weight or artificial diet at 50-30% body weight and water is frequently renewed.

In 1978, Platon obtained an average survival of 50% at stocking density of 5 000 fry/t of sea water using the tank nursery system. On the other hand, fry survival was very much improved (70-90%) when stocking rates from 2 500 to 3 000 fry/t was used (Gabasa 1982).

In the floating cage nursery system, the highest stocking density tried was 50 000 fry in 10 t of water but the optimum density recommended is 30 000 fry (De la Pena et al 1984).

Feeding versus Fertilization

Prawn fry have been found to prefer natural food or *lablab* which consists of microbenthic organisms such as algae and diatoms. The growth of natural food in pond is influenced by the amount of nuttrients in the water and soil; hence, natural food varies from one pond to another. Problems related to propagation and maintenance of *lablab* have led to the search for alternative feed.

Experiments with prawns fed with mussel meat at various feeding rates showed that fry stocked at 150 fry/m^2, fed 100% of body weight daily for the first 16 days and subsequently reduced to 20% for the rest of the rearing period, attained an average survival of 57.4% (Apud et al 1979). When feeding was abruptly stopped after 16 days, survival dropped to 25.5%. Very low survival (15.5%) resulted when mussel meat was given at 20% body weight daily throughout the rearing period. The storage and erratic supply of mussel meat led Mochizuki (1979) to compare mussel meat with artificial feeds as supplementary feed. He suggested that prawn fry should be fed with artificial feeds twice daily at an adjusted feeding rate of 100%, 50%, and 25% body weight. Results from a study by Tiro et al 1984 showed that there was no significant difference in growth and survival between those fed with fresh mussel meat and those fed with artificial feed containing 40% protein.

With the use of a SEAFDEC AQD formulated-feed given at adjusted feeding rates of 50%, and 30% body weight, better growth and survival of fry compared with those completely dependent on natural food was obtained by Tabbu (1984). The artificial feed contained approximately 35% crude protein and 3 400 kcal of M.E./kg of diet. Natural food was propagated by using chicken manure and inorganic fertilizer/ammonium phosphate (16-20-0) at the rates of 3 t and 50 kg/ha, respectively, with subsequent application of 16-20-0 at 25 kg/ha every 2 weeks to maintain good growth of natural food organisms.

Water Management

Water quality is another critical factor in fry rearing. The common practice of changing pond water by tidal fluctuation is possible only during spring tides which occur at a 2-week interval. This method can not maintain the desired water quality with high stocking densities and artificial feeds, hence, the use of water-moving devices were studied.

Apud (1979) found out that aeration has a significant effect on fry survival. Higher survival was obtained in earthen ponds with aeration compared with those without aeration. Frequent water flow prevented increase in salinity and at the same time replenished water lost through evaporation and seepages. Water flow-through was effected through an adjacent reservoir pond where water was pumped in and flowed out at periods of low oxygen at 0500r800 hr and at 1300-1600 hr when temperature was usually high.

Harvest and Post-harvest Handling

Prawn fry are normally harvested after reaching the PL_{35} - PL_{40} stage or one month after stocking from the hatchery. At this time, the prawn size may vary from 0.5 - 1.5 g depending on the age at stocking,

stocking density, and management techniques. The method of harvesting is similar for tank and earthen pond nurseries except that harvesting from the earthen pond is more laborious and tedious. When *lablab* is abundant, fry is entangled in it, making sorting and counting difficult.

The bagnet and the harvesting box are useful but their effectiveness have to be assessed. The 2-3 days it takes to completely harvest the juveniles in earthen ponds causes some mortality.

The problem of transporting prawn juveniles for stocking in grow-out ponds was solved by Yap et al (1979). Their study on optimum packing density and ice quantity showed that prawns of 40 mg size can be packed to as much as 3 000 per plastic bag containing 8 1 sea water and 16 1 oxygen for a maximum transport period of 15 hours. Packing densities above 3 000 per bag with 8 1 sea water and 16 1 oxygen can be used only for short transport periods. They also found out that about 50 g ice/hr is needed to maintain the packing temperature of 20°C. Packing density depends largely on distance or travel time, fry size, and storage facility.

GROW-OUT REARING OPERATION

Rearing Facilities

Prawn grow-out rearing ponds were mostly developed out of fishponds originally designed for milkfish production; hence, rearing of prawns to marketable size in such ponds was not very efficient. These ponds could hold only 30 cm of water, had only one gate, and were irregular in size resulting in abrupt fluctuations of water temperature and salinity and difficulty in water exchange.

Apud and Sheik (1979) found that milkfish ponds characterized by big and irregular compartments with a single gate could not facilitate total movement of water in the pond because water at the farthest side of the gate remained practically unchanged. Santiago et al (1975) indicated that higher survival rates of *P. monodon* are obtained in compartments with deeper water, close to the gate, and with proximity to fresh tidal water for replenishment. Likewise, Primavera et al (1976) observed that the compartments near the gate had the advantage of being in the direct line of water flow; hence, growth rates of prawn were consistently higher in these compartments than in those with the same stocking densities opposite the gate. The shallow depth affected the growth of prawn because less water volume means less living space for feeding. Mochizuki (1978) observed that milkfish pond which is usually 30 cm deep causes abrupt fluctuations of water temperature and salinity during intense sunlight or heavy rain and is, therefore, too shallow for prawn culture.

Apud et al (1984) studied the effect of water depth on the growth and survival of *P. indicus* stocked at 50 000/ha with supplementary feeding and cultured within a period of 90 days. Favorable results were obtained in ponds with water depth of 70-100 cm compared to those with 40-70 cm depth. Mean survival of 70.4% and production of 343 kg/ha/crop were significantly higher in deeper ponds compared with those in shallow ponds, 37.5% and 180 kg/ha/crop, respectively. This confirmed the need to use ponds of about one meter deep for prawn culture.

Another important factor for the successful production of prawns is pond size. In determining pond size, the ease in water change or movement and the convenience in harvesting are of primary consideration (Apud and Sheik 1978). In addition, the pond bottom should decline toward the outlet gate for convenience in water management, stock manipulation, and harvesting (Esguerra 1979). Mochizuki (1978) found out that the pond size suitable for extensive culture without feeding is 1—3 ha while 3 000 m^2 - 5 000 m^2 was appropriate for intensive culture.

SEAFDEC AQD has recommended an appropriate pond design and layout for prawn culture. Salient features of the design include provisions for a canal and a two-gate systems as supply and drainage facilities. For a 1-ha pond, construction of a diagonal canal of 5-10 meters wide and 0.3-0.5 meters deep extending from inlet to outlet gates was recommended for convenient draining of water and harvesting and as hiding place for shrimps during daytime (Kungvankij et al 1986). In the development of these prawn ponds with earthen dikes, problems related to reconstruction of leaking dikes and erosion were solved by the use of plastic sheets along the dike or by digging a trench along the leaky area and using the excavated materials as reinforcement for the dike (Apud 1984). The pond gate systems introduced by SEAFDEC AQD were the monk type culvert (Fig. 1) and the open sluice gates (Fig. 2) made of ferrocement. These gates are cheaper, more convenient to construct and install, and effective as tertiary and secondary gates.

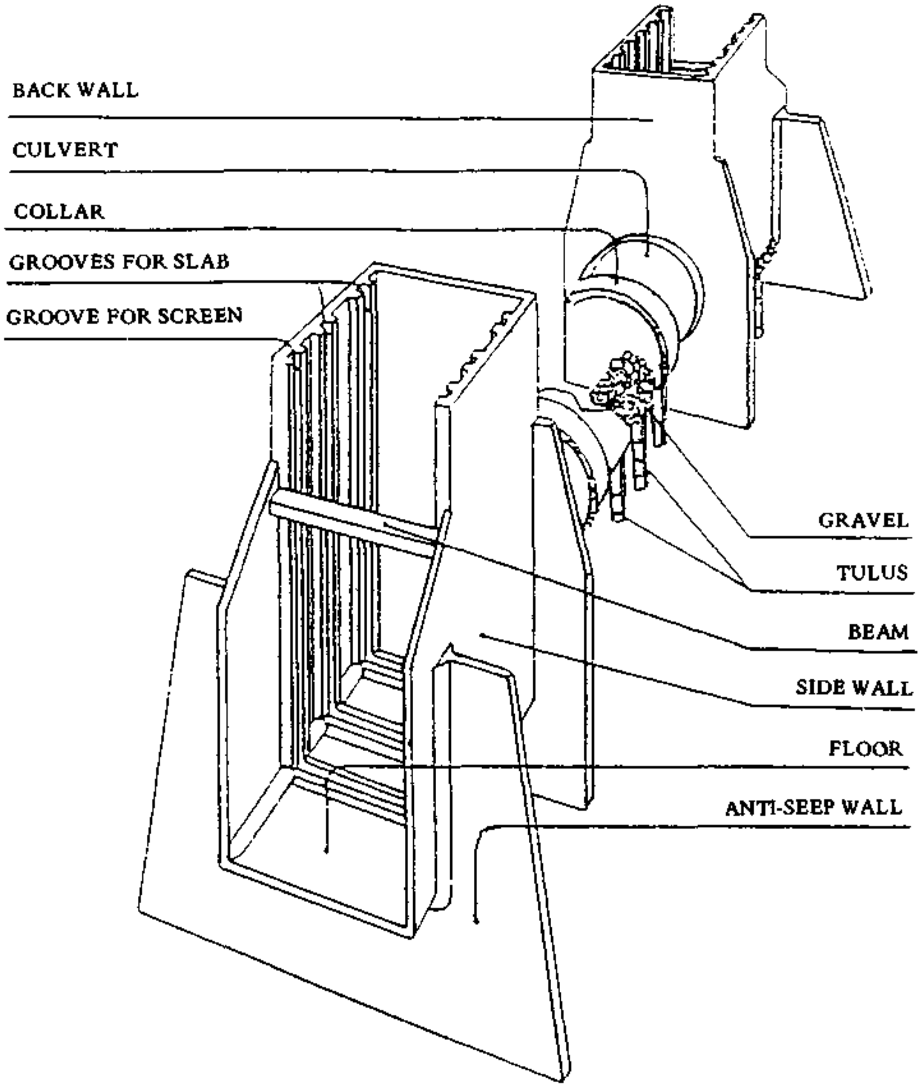

Fig. 1. Ferrocement culvert gate, LRS SEAFDEC AQD (Torres 1983)

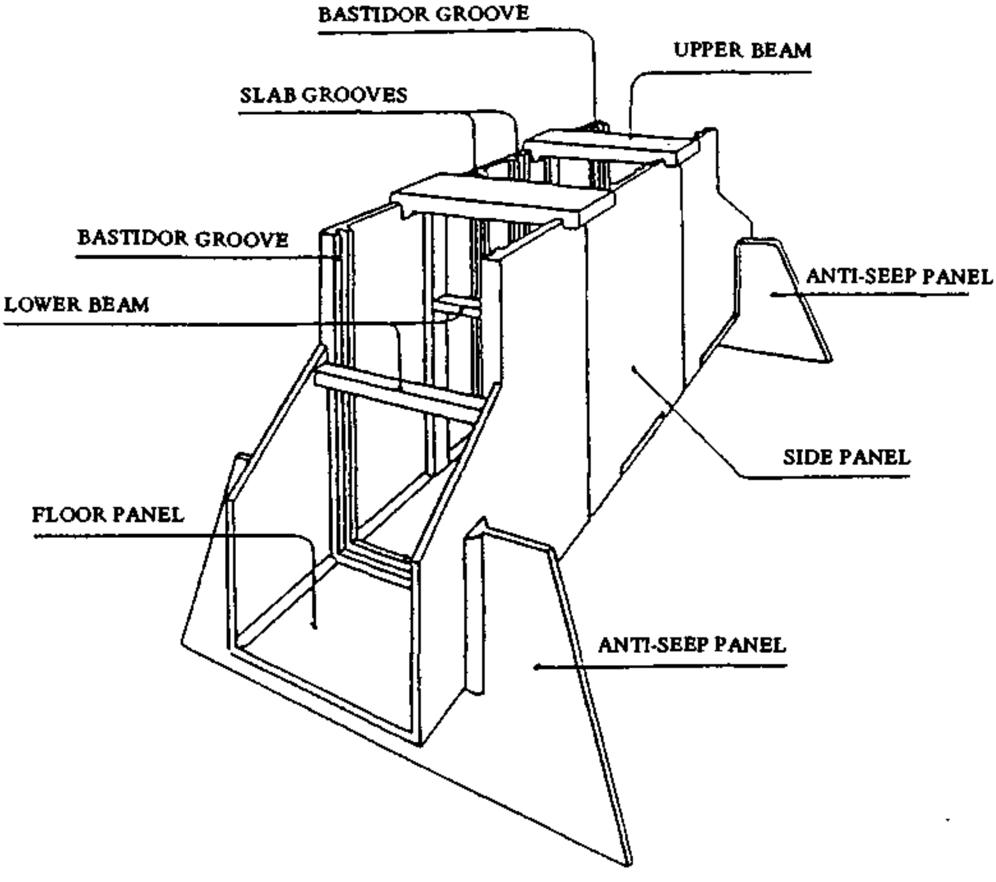

Fig. 2. Ferrocement sluice gate at LRS SEAFDEC AQD
(Torres 1983)

Rearing Methods

The lack of an effective rearing method for prawns was earlier considered one of the main constraints to prawn culture. Fish farmers were hesitant to raise prawns in monoculture, thus, for many years prawns remained a secondary crop to milkfish in brackishwater ponds. Studies have been conducted at the Leganes Brackishwater Station to develop pond culture technology of prawns that can be adopted by the private sector. Studies have been focused on the monoculture of prawn, polyculture with milkfish, stocking density, water management, feed and feeding schemes, fertilization, and other pond management techniques.

Fertilization

The effect of fertilization on the growth of *P. monodon* has been tested through the years. Santiago et al (1975) showed that by fertilizing the pond with an inorganic fertilizer (mono-ammonium phosphate 16-20-0) at 200 kg/ha at a stocking density of 10 000/ha an average survival rate of 72.7%, mean body weight of 16.4g, and a production of 160 kg/ha was obtained in 5 months of culture. However, a comparable production of 150 kg/ha was also obtained in unfertilized ponds. In a related experiment, where chicken manure was applied at approximately 1 200 kg/ha during pond preparation, prawn production reached only 66 kg/ha in 4 months. In contrast, Apud et al (1984) obtained a yield of 105 kg/ha when chicken manure at the rate of 2 000 kg/ha was used. The effect of organic fertilizer in the form of mudpress at 5 t/ha and a combination of 0.5 t/ha chicken manure plus 4.5 t/ha of mudpress was evaluated. Both treatments gave relatively low production (40 and 60 kg/ha, respectively), attributed to inadequate growth of natural food and the presence of competitor and predators. A combination of chicken manure at 1 t/ha and inorganic fertilizer consisting of 15 kg nitrogen and 30 kg phosphorus/ha yielded 180 kg/ha in 86 days of culture; the prawns were stocked at 7 000/ha (Subosa unpublished). The source of nitrogen and phosphorus were taken from chemical fertilizers, di-ammonium phosphate (18-46-0), and urea (46-0-0), applied during pond preparation and subsequently at 15-day intervals following every water exchange by tidal movement.

At present, SEAFDEC AQD recommends that soil analysis should be conducted prior to application of fertilizer to determine the organic matter content of the soil and subsequently the amount of fertilizer to be used. It was reported that when organic matter is higher than 16%, fertilization is not required (Kungvankij et al 1986). Generally, chicken manure is applied at 1-2 t/ha followed by inorganic fertilization at 75-150 kg/ha of mono-ammonium phosphate (16-20-0) and 25-50 kg/ha of urea (46-0-0).

Stocking Density

Results of fertilization studies indicate that the optimum stocking density of prawn is below 10 000/ha for stock completely dependent on natural pond productivity. As pond yield is relatively low, higher density levels from 10 000/ha and above have been tried with supplemental feed and frequent water exchange by tidal movement and by pumps.

Apud et al (1981) obtained good growth and survival at a stocking rate of 25 000-50 000/ha with artificial diet as supplemental feed. Increasing the density from 100 000-200 000/ha did not affect the survival rate but the growth rate significantly decreased. Furthermore, the pelleted feed given twice daily at feeding rates of 10%-5% of biomass resulted in feed conversion ratios (FCR) of 1.5-2.6.

Results from a study by Kungvankij et al (1984) showed best growth performance at 40 000/ha stocking rate of prawn fed with artificial diet at 10% to 3% of biomass per day. Overall yield was high at higher stocking rates, but body weight at 80 000/ha and 120 000/ha was low (mean weight of 11 g) compared to a mean weight of 25 g when stocking density was at 40 000/ha. Higher yield of 284 kg/ha was also obtained by Tiro et al (1986) at stocking rates of 40 000/ha compared with 171 kg/ha at 10 000/ha and 317 kg/ha at 20 000/ha. However, pond yield in 40 000/ha was lower compared with those obtained by other workers probably because supplemental feed was given only after the second month of culture, whereas others started feeding a few days after stocking (Apud et al 1981, Tabbu 1984, Kungvankij et al 1984, Corre unpublished). In general, results indicate that the optimum stocking rate of prawn in monoculture with supplemental feed and improved water management is 40 000/ha with corresponding pond yield of 300 kg/ha-850 kg/ha in 3-4 months culture.

The polyculture of prawn and milkfish at varying stocking combinations has been studied to maximize pond production through efficient utilization of available space and food. A study by Pudadera and

Lim (1980) showed that a stocking combination of 2000 milkfish/ha plus 6000 prawn/ha was economically feasible with combined net production of 463.6 kg/ha in 100 days. Moreover, the polyculture treatments had higher total production than monoculture although prawn production in monoculture (144.3 kg/ha) was significantly higher than in polyculture with 2000 (75.6 kg/ha) and 4000 (49.8 kg/ha) milkfish/ha. Comparable results were obtained by Eldani and Primavera (1981) except that combined net production (492.1 kg/ha) slightly increased at stocking combination of 8000/ha prawn and 2000/ha milk fish.

The possibility of raising prawn with Nile tilapia *(T. nilotica)* has also been tried and results showed that the polyculture of 6 000/ha prawn and 4000/ha tilapia proved profitable (Corre 1983). In this combination, the presence of tilapia is favorable, evidenced by higher production of prawn in polyculture (137.69 kg/ha) compared to monoculture (123.21 kg/ha). Competitive relationship did not exist in the above combination but was evident at a stocking combination of 6 000 prawn/ha plus 6 000 tilapia/ha.

The efficiency of integrating polyculture of shrimp and milkfish with poultry has been evaluated (Apud et al 1983). Results of two successive experimental runs consistently achieved higher net production (80-129 kg/ha) and mean body weight (10-14.6 g) of *P. indicus* culture in ponds with poultry than in those without poultry. The net production did not vary for milkfish which is 401-549 kg/ha.

The problem related to overgrowth of plankton due to continuous manuring of ponds with poultry led to the search for additional species which efficiently feeds on plankton. In a study by Pudadera et al (1986) tilapia *(T. nilotica)* at varying densities were tested with *P. indicus* and milkfish stocked at 50 000/ha and 2 000/ha, respectively, integrated with poultry (chicken broiler). A total production of 680.2-936.3 kg/ha can be attained with best net production of tilapia at 15 000 ha. The poultry operation with chicken broiler production of 1809-2174 kg/ha gave major contributions to the total net earnings and a free source of fertilizer from the droppings.

Baliao (1985) tried the modular method of prawn culture at 5 000/ha and 10 000/ha. Similar growth (39.8 g and 38.4 g,respectively) and survival (96.5% and 90.5%, respectively) were obtained in both stocking densities. However, production at high density (348 kg/ha/crop) was more than double than at low density. At 20 000/ha., Tiro et al (1986) obtained higher yield of 525 kg/ha/crop in 120 days culture when the prawns were transferred 60 days after stocking. A slightly lower yield (422 kg/ha/crop) was obtained when transfer was done every 45 days.

Water Management

Basically, water management in prawn ponds is patterned after that used in milkfish culture. Water change at 20-30% of water volume is done once a week or every two weeks by tidal fluctuation. This method is normally practised in ponds where stocking density is low (10 000/ha) and the stock completely dependent on natural productivity.

The need to increase production by increasing stocking density and supplementing natural food in pond has led to studies to determine effective water management. Yokokawa (1978) earlier suggested that water supply must be checked frequently. Water must be changed frequently with tide and water pump, and whenever there is sudden change in the color of the water and unhealthy prawns are observed, water renewal must be more frequent.

The need for water renewal by tidal movement and pumping and the effect of feeding/artificial pellets at varying rates in prawn culture were studied by Norfolk et al (1982). Increasing water renewal daily at 5-20% of water volume did not influence the growth and survival of prawn but affected the low early morning dissolved oxygen particularly at higher feeding rates. On the other hand, Suemitsu (1983) obtained better growth of prawn in ponds provided with aquamill as a water-moving device in addition to tidal movement in contrast to prawns grown in ponds completely dependent on tidal fluctuation.

Feeds and Feeding

The amount of natural food in pond declines at a certain period depending on stocking density and pond fertility and thus becomes insufficient to meet the growing demand of prawns. Supplementary feeding is needed when stocking density is more than 10 000/ha (Apud 1981). Supplemental feed such as rice bran with trash fish, chopped frogs, snakes, chicken entrails, mussel, and clam meat are commonly used but problems related to their availability and storage have led to the search for alternative feed.

The Feed Development Section of SEAFDEC AQD has been undertaking studies related to the nutritional requirements of *P. monodon.* Results of these studies are used in the formulation of diets screened under laboratory conditions and then tested under pond conditions. SEAFDEC-formulated diets and commercial pellets were tested by Mochizuki (1978). Growth of prawn fed with SEAFDEC diet at 10%-5% of biomass was similar to that obtained with a commercial pellet. Both feeds resulted in high survival 74.7-82.8% and production of 645.6-695.9 kg/ha in 3 months. A comparable yield (518-581 kg/ha) was obtained when SEAFDEC-formulated practical diet containing 40% crude protein was pilot-tested in ponds stocked at 25 000/ha. The artificial diet was given daily one month after stocking at a decreasing feeding rate of 10, 8, 6, and 4% of the biomass; feeding rate was adjusted every 2 weeks. High yield and low feed conversion ratios (1.6-2.1) achieved in this study demonstrated the efficiency of SEAFDEC-formulated prawn grow-out diet in semi-intensive culture (Pascual unpublished). Results from a study by Tabbu (1985) showed that the pelletized feed containing 45% crude protein resulted in better growth than the formulated diet with 35% crude protein, both with high survival of 82.6-91.8%. Better growth (23.96 g mean weight) and yield (839.7 kg/ha) were obtained when pelleted feed (75%) containing 35% crude protein was fed in combination with trash fish (25%) in ponds stocked at 40 000/ha (Corre unpublished).

Supplemental feeds are given either by the broadcast method or by the use of feeding trays or both. In the broadcast method, the feeds are spread over the pond surface. For bigger ponds, a flat-bottom boat is used so that the mid-portion of the pond can be reached. Kungvankij et al (1984) pointed out that the use of feeding tray is very advantageous because it prevents feed wastage, at the same time provides information on prawn condition and feed consumption. A combination of the broadcast and feeding tray methods is being employed to ensure efficient feed utilization.

In computing feed requirement, a decreasing feeding rate is generally used with 10, 8, 4% of the biomass given daily and adjusted every 15 days after the stock are sampled by cast net or prawn trap. The feeds are given 2-3 times a day and daily feed ration is apportioned accordingly.

Harvest and Post-harvest Handling

Prawns are normally harvested upon reaching marketable size (25 g or more or after 3-4 months. Traditionally, harvest is done during full moon or right after the water is changed, thus fish farmers oftentimes harvest molting or soft-shelled prawns. To minimize this problem, a good time to harvest is 2-3 days after the peak of spring tide or 5 days after an abrupt change of water. The stock must be checked or sampled to determine prawn condition before harvesting.

Harvesting may be complete or partial depending on demand. Complete harvest is commonly done with a bagnet attached to the sluice gate while partial harvest is accomplished with bamboo traps, pound nets, or cast nets. The new harvesting technique documented by SEAFDEC is staggered harvesting using an eight-knot pound net (stretched mesh =2-4 cm). Results from a study by Suemitzu et al (1985) showed better growth, survival, and feed conversion rates in staggered-harvest treatment than in a single-harvest treatment. In the staggered harvest, bigger prawns are caught earlier thus reducing competition and giving the smaller ones a better chance to grow.

Upon harvesting, Kungvankij et al (1986) suggest that prawns be washed in clean water and soaked immediately in chilled water (10-15°C) for about 15 minutes prior to packing. The prawns should be packed in styrofoam boxes with alternate layers of crushed ice at a ratio of 1:1. Moreover, if bigger styrofoam boxes are used, the box should be filled up with chilled water, prawns, and ice to avoid physical damage to prawns.

Diseases and Parasites

Very few cases of disease-related problems have been reported in ponds with extensive and semi-intensive methods of culture. There has been a report of "red disease" in prawn. Gram-positive cocci were consistently isolated; however, experiments with the disease have to be replicated to determine other possible factors that influence its incidence (Lio-Po pers. comm.). The incidence rate of black shell syndrome among prawn juveniles in ponds is being checked. The preliminary data are currently being analyzed (Lio-Po and Pitogo pers. comm.).

A field survey of prawn ponds in the island of Panay conducted by the SEAFDEC AQD Fish Health Section staff showed that occurrence of soft-shelled prawns could be predicted with 98% accuracy with poor pond soil and water conditions. In soft-shelled prawns, calcium and phosphorus levels were significantly higher in the hepatopancreas, and phosphorus was significantly lower in the exoskeleton compared to hard-shelled prawns. Chitinoclastic bacteria, *Vibrio* and *Aeromonas,* were isolated from soft-shelled prawns but experimental infection with these species to induce soft-shelling gave largely negative results. Laboratory experiments with an organostannous pesticide revealed that a 96-hr exposure to at least 0.0154 ppm of the pesticide could result in soft-shelling of 47-60% of the prawns and that soft-shelling could be reversed by dietary manipulation (Baticados et al 1986). Successful regrowth and survival were observed in prawns fed with 14% mussel meat.

ECONOMICS

A comparative economic analysis of different culture systems in 1985 showed that all production systems are profitable with integrated production systems generally more profitable than individual production systems (Israel unpublished). The profitability indicators (Table 1) show that the integrated hatchery-nursery system is the most profitable and that the extensive polyculture of prawn and milkfish is the most profitable grow-out culture method. A similar result was obtained in 1986 in a polyculture study by Kuntiyo and Baliao (unpublished). Economic analysis showed a higher annual profitability of US$135.3 net income after tax, 45.2% return on investment (ROI) and payback period of 2.21 years for polyculture of 20 000/ha prawn plus 2 000/ha milkfish as against the monoculture of prawn (20 000/ha) having annual profitability of US$2 660.7, 38.69% ROI and 2.49 years payback period. The most recent culture system introduced which is highly viable is the monoculture of prawn in a modular pond system. Cost and return analysis showed ROI of 69.5 and 72% and payback period of 1.4 and 1.3 years for prawns stocked at 15 000/ha and 20 000/ha, respectively (Pudjatno and Baliao unpublished).

PRODUCTION CONSTRAINTS

In spite of the headway that AQD made in the culture of *P. monodon* through research, problems continue to beset both the nursery and grow-out phases of the industry. Some of these are:

1. Erratic and insufficient supply of seeds for intensive culture.
2. Lack of knowledge of nutrient requirements.

Table 1. Profitability indicators of individual and integrated prawn production systems

	Payback period (yr)	B/C ratio	IRR
Backyard hatchery	1.1	1.47	123
Pond nursery	2.2	1.08	54
Extensive monoculture	4.5	1.14	29
Semi-intensive monoculture	4.5	1.11	28
Extensive polyculture of prawn and milkfish	3	1.27	45
Extensive polyculture of prawn and shrimp	5.5	1.08	23
Integrated hatchery-nursery system	0.5	1.58	225
Integrated hatchery nursery-grow-out system	1.2	1.38	86

Israel unpublished.

3. Insufficient supply of locally produced good quality feed ingredients.
4. High cost of formulated diets. About 60% of the operational cost of the culture of prawn is due to feed.
5. Financial constraints. Although the intensive method of culture has been found profitable, the development and operational cost is staggering.
6. Shortage of trained and qualified technicians.
7. Absence of effective harvesting devices for *P. monodon.*
8. Unacceptability of shrimps in the world market due to substandard quality resulting from inefficient post-harvest handling of product. Lack of ice plants, lax quality control measures, lack of marketing infrastructure, transport and handling facilities.
9. Lack of systematic technology verification and transfer of prawn culture under different environmental conditions.

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NURSERY AND GROW-OUT OPERATION AND MANAGEMENT OF MILKFISH

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ABSTRACT

This paper reviews the results of studies on the pond culture of milkfish *Chanos chanos* Forsskal at the SEAFDEC Leganes Brackish-water Station, Leganes, Iloilo since its establishment in 1973. Substantial contribution on the nursery system includes increased stocking density and survival through the use of nylon substrates, supplemental feeding with rice bran, the use of hatchery-reared and stunted fingerlings as alternative sources of stocks, and improvements in the acclimation process. Studies on monoculture and polyculture in grow-out ponds investigated the use of stunted fingerlings, kitchen or algal nursery ponds, stock manipulation techniques, increased stocking density using the plankton method, method frequency and quantity of fertilization, modular pond culture system, and initial findings on fish diseases. Constraints setting back increased production in the Philippines are discussed.

INTRODUCTION

Milkfish farming is one of the major aquaculture ventures in the Philippines. Milkfish culture originated centuries ago starting with the enclosure of nipa swamps or inlets indenting the shores with dikes at their narrowest entrance. Stocking was by chance entry of fry carried by the incoming tide. With the conversion of swamp-lands into productive culture areas, it became necessary to dispense with this inadequate and uncertain method of stocking the ponds.

Traditional milkfish farming employed an enclosed portion within the nursery pond which served as acclimation area. The delicate fry were allowed to grow for a few weeks before they were released into the rest of the nursery pond (Pillai 1962). Those in the Visayas and Mindanao, however, were generally without nursery ponds. As a result, only one harvest could be made in one year with an average production of 70 kg/ha/yr (Villaluz 1953). Milkfish fry were stocked at 25-50/m^2 and rice bran was fed at 5-10 kg/ha/day once the natural food was depleted (Pillai 1962). The fry were kept for 1-2 months and could be overstocked to keep them stunted until ready for stocking into rearing ponds.

There was no definite stocking density in rearing ponds as stocking was primarily dependent upon the availability of *lumut* to support the stock (Adams et al 1932). Villaluz (1952) reported that this practice was a real hit-and-miss method as oftentimes *lumut* was depleted long before milkfish were ready for harvest. In some fish farms, a transition pond was used before fish were stocked in rearing ponds. The fingerlings were stocked at 1 500-2 500/ha and reared for 3 months until they have grown to three inches length. They were then transferred to rearing ponds and raised for 4-7 months depending upon the quantity of *lumut* available (Pillai 1962). Some progressive farmers, such as those in Dagupan City, use bigger post-fingerlings, so that culture usually took only 6-8 weeks.

Fertilization was carried out primarily by using organic fertilizers such as chicken, cow and pig manure, human night soil, rice bran, and leaves of leguminous plants (Pillai 1962). Pests and predators were eradicated by thorough drying of pond bottom for 1-2 weeks until it cracked. Screens made of abaca or sinamay cloth were installed at the sluice gates to prevent entry of unwanted species.

Various strides have since then been made and, noteworthy of which was the introduction of the shallow-water method commonly called *lablab* method by a Taiwanese consultant in the 1960's. In 1974, one year after the establishment of SEAFDEC in Iloilo, the first cooperators' program was launched to collect benchmark information on the traditional pond management practices under varied pond conditions (Agbayani et al 1975). Out of 16 cooperators, six applied chemicals such as Aquatin, DDT, and Bayluscide to eliminate pests and predators such as snails, tilapia, ten-pounders, and gobies during pond preparation. Fertilization seemed accepted among cooperators. Nine cooperators applied inorganic fertilizers in different quality and quantity. This suggested that in spite of its long existence, some milkfish farms were extensively managed.

A socio-economic survey of the milkfish industry reported that the average inorganic fertilizer rates varied from two applications of 37 kg/ha/yr of nitrogen to seven applications of 40 kg/ha/yr of phosphorus to somewhere between these two extremes (Librero et al 1977).

Some traditional farms yielded, 50-300 kg/ha/yr (Hopkins and Hopkins 1983). In 1975, the national average production was 605 kg/ha/yr (PCARR 1978). A decade later, it increased to 870 kg/ha/yr (Samson 1985). Milkfish production from brackishwater ponds alone yielded 135 951 mt in 1980 which rose to 198 729 mt in 1984 (BFAR 1984). By 1990, milkfish brackishwater production is projected to be 395 000 mt, a demand at 145 690 mt and exports at 1 129 mt (Samson 1985).

This paper highlights the results of experiments on milkfish nursery and grow-out culture at the SEAFDEC Leganes Brackishwater Station. Other results need refinement before their application while other techniques have already been disseminated to the industry through in-situ training programs, publications, cooperators' programs, and consultative meetings with fish farmers. At these meetings, SEAFDEC researchers come to know the problems of the industry, so that research thrusts of the Department can be geared towards their solutions.

MILKFISH POND OPERATION AND MANAGEMENT

Rearing Facilities

The experimental ponds used for milkfish nursery and growing studies at the SEAFDEC Leganes Brackishwater Station are of 24-144 m^2, 12-350 m^2, and 6-2 000 m^2. Four units of 1 ha each serve as production ponds. The nursery system consists of 4-1 000 m^2 and 2-1 500 m^2 ponds which supply milkfish fingerlings for both research and production. The milkfish modular system consists of 4 sets of modules at sizes 1:2:4. On the other side of Gui-gui Creek, a 1-2 000 m^2 pond serves as transition area for one set of module at sizes 1:3:5. The transfer gates between the modules facilitate the movement of stocks. Generally, the ponds are rectangular and oriented according to the prevailing wind direction to minimize dike erosion by wave action.

Nursery System

An effective method of eradicating predators consists of applying lime at 1 t/ha and ammonium sulfate (21-0-0) at 10 g/m^2 to undrained canals, holes, and gate areas when the water pH is still high. Gobies, tilapia, and shrimps are killed in less than an hour when eradication is carried out under strong sunlight when the air is still, as wind increases ammonia loss considerably (Norfolk et al 1981). Since liming is routine during pond preparation, the only additional cost incurred is that of 21-0-0. This is an improvement over the use of chemical pesticides which leaves residual effects and destroys the pond ecology.

With the breakthrough in the spawning of milkfish in captivity, it was imperative to compare the performance of the hatchery-produced fry with those of the wild-caught ones. Results showed that there was no significant difference in survival and growth in both sources of fry (Baliao et al 1980). This suggests that the hatchery-produced fry can be an alternative fry source to alleviate shortage.

Nursery studies were directed towards improving the survival of 50-60% and stocking density of 25-50 fry/m^2. The highest mean survival of 71.5% was obtained for fry stocked at 75/m^2 and fed with rice bran and the lowest mean survival of 51.7% at 50 fry/m^2 without supplemental feeding (Villegas and Bombeo 1981). High survival rate of 81% at 100 fry/m^2 was attained by installing nylon screen substrates to increase the surface area for attachment of food organisms (Anon. 1982). Rice bran was given at 5% biomass one month after stocking fry. The possibility of mass fry production was investigated in a 1-ha pond using the *lablab* method stocked with 500 000 fry. A high survival rate of 88.7% was largely due to an effective predator control (Anon. 1979).

Stunting of milkfish fingerlings has long been practised in the, industry. However, the effects of stunting duration and stocking density on the survival of stunted fish were poorly understood. Hence, a study was conducted with stocking densities of 15, 20, 25, and 30 fingerlings/m^2 subjected to 6-month stunting. Results showed that highest survival of 86.9% was attained at 20 fingerlings/m^2 although this was not significantly different from those in 15 and 25 fingerlings/m^2. Based on these results, a follow-up study was undertaken with 20 fingerlings/m^2 subjected to various stunting durations. Those stunted for 6 and 9 months were not significantly different in mean body weight and survival. Only the 12-month stunted fingerlings yielded significantly lowest results (Baliao et al 1987). From the economic point of view stunting for 6-9 months at 20 fingerlings/m^2 is most cost effective. This permits the production of milkfish fingerlings at lower cost than they can be purchased (Baliao et al 1987).

It should be noted that acclimation ponds and hapa nets which are tedious and time-consuming methods are no longer used in the stocking of fry in the nursery ponds. Researchers at SEAFDEC Leganes Station realize that acclimation is still a vital process before stocking. However, acclimation is now made simple and easy by the gradual adjustment of salinity and temperature of the fry right inside the plastic bags to that of the pond water. Stocking is done during the cooler time of the day.

Grow-out System

Monoculture. The argument against the use of stunted fingerlings in grow-out ponds rests mainly on whether stunting per se could adversely affect growth of stunted fish. Hence, a preliminary study was carried out to compare growth and survival of stunted and non-stunted fingerlings. Non-stunted fingerlings clipped at the right pectoral fin and stunted ones clipped at the left pectoral were stocked in the same pond. Results indicated that there was no significant difference in the growth and survival between two treatments (Lijauco et al 1978). In a related study, a comparison was made using 2-month old non-stunted fingerlings initially weighing 3.3 g, 3-month old and 6-month old stunted ones initially weighing 7.8 g and 43.1 g, respectively. Results showed that survival, weight gain, and total harvest did not differ significantly among three treatments. This suggested that stunting does not adversely affect growth and production of milkfish and can therefore be practised by fish farmers to provide a year-round supply of fingerlings (Tuburan unpublished).

The use of kitchen algal nursery pond at varying sizes of 3%, 6%, and 12% of the grow-out area was verified. The rationale behind its use was to produce maximum biomass *lablab* for fish in grow-out ponds. Results revealed that the control (without algal nurseries) yielded the highest body weight and survival (Anon. 1982). There is, therefore, no need to employ kitchen pond as this reduces the area for fish production.

The possibility of adopting here the stock-manipulation technique popular in Taiwan was tested with two-size groups of fingerlings comprising 50% each of the total population. The total stock in each treatment was 6 000/ha. The study was on the time intervals in stocking which were programmed at 0 (control), 15, 30, and 45 days. The 45-day stocking interval yielded the highest weight gain of 216.6 g, those in the control the lowest value of 165.7 g (Anon. 1983). A subsequent pilot study was undertaken to refine this technique in a modular pond system. Two production runs at a stocking density of 3 000/ha based on the area of the last module yielded 2.2 mt, 200.8 g, and 93.3% for the first run while the second run yielded 2.4 mt, 198.4 g, and 99.4% for gross production, body weight, and survival, respectively (Anon. 1983).

An attempt was made to increase the usual stocking density of 3 000/ha using the deep water or plankton method. This bears an assumption that as the plankton method requires bigger water volume, more food organisms are produced to support higher stocks. The highest mean weight increment of 1.64 g/day was attained at 4 000/ha while the lowest value of 0.76 g/day was attained at 8 000/ha (Anon. 1983). Based on these results, a subsequent study was made with lower densities of 4 000/ha, 5 000/ha, and 6 000/ha which attained weight increments of 1.4 g/day, 1.2 g/day and 1.0 g/day, respectively (Anon. 1984). In the next run, the stocking density was placed at 4 000/ha and different supplemental feeds such as rice bran, trash fish, a mixture of rice bran and trash fish, and no supplemental feeding were evaluated. Fish fed with a mixture of trash fish and rice bran grew best with a weight increment of 1.4 g/day (Anon. 1985). From the results, it appears that further tests on the plankton method are needed before it is recommended to the farmers. It requires deeper water and pond renovation which is expensive.

Lumut was primarily the natural food base in the traditional milkfish culture. However, it was found out that milkfish trypsin was inhibited by a tryptic inhibitor from *Chaetomorpha brachygona,* a major algal component of *lumut.* This may explain the slow growth rate of milkfish fed with *lumut* (Benitez 1985).

Water exchange in milkfish farming is usually done once every two weeks during high tide. An optimum combination of water exchange and fertilization, however, needs to be determined to maximize production. The biweekly water exchange and biweekly fertilization scheme yielded the highest production of 530.2 kg/ha/crop while the biweekly water exchange and weekly fertilization gave the lowest yield of 414.1 kg/ha/crop. No significant difference existed between the weekly and biweekly water exchange when considered as a single factor. The biweekly fertilization, however, resulted in significantly higher production than that of the weekly application (Tuburan unpublished). It is therefore suggested that farmers combine water exchange and fertilization biweekly as this is less laborious and not time-consuming.

Fertilizer application in brackishwater ponds has not been standardized. The use of 16-20-0 at 50 kg/ha and of 45-0-0 at 15 kg/ha, their half-dosages, chicken manure at 0.5/ha, and MASA organic fertilizer (processed from agricultural and industrial wastes) at 0.5/ha applied biweekly were evaluated in milkfish ponds. Mean body weight, survival, and gross fish production were not significantly different among treatments. The net profit, however, was highest with 16-20-0 at 50 kg/ha and 45-0-0 at 15 kg/ha (Tuburan et al unpublished). During the succeeding dry season these fertilizer dosages, their half-dosages and two levels of 18-46-0, were tested. The best fertilizer treatment was that of half-dosages (Tuburan unpublished). It appears that 16-20-0 at 50 kg/ha and 45-0-0 at 15 kg/ha are more efficient in providing nutrients for primary productivity during the wet season while the half-dosages are effective during the dry season. Results, however, need further tests although it appears that inorganic fertilizer enhances good *lablab* growth enough to support milkfish to marketable size.

The broadcast method of fertilization has been popular among fish farmers. Another method used is the silo wherein baskets containing fertilizers are submerged in pond water, allowing continuous supply of nutrients instead of the single biweekly dose. Results showed no significant difference in growth and survival between the broadcast and the silo methods (Gerochi et al unpublished).

The most widely practised milkfish culture system is the straight culture. Recent innovations, however, lead to the modular system which consists of monthly stock transfers in three modules of increasing sizes. This modular pond system was verified in sizes of 1:2:4 at two schemes: (a) 3 000/ha based on the area of the last module, and (B) based on the total area of all modules. Mean body weight and survival were 251 g and 87% for scheme A and 242.8 g and 89% for scheme B. Net production of 608.5 kg/ha/crop in scheme A was higher than 357.4 kg/ha/crop in scheme B (Anon. 1983). A similar study was made with two sets of modules: one set with 1.47 ha, 2.08 ha, and 3.21 ha and another set with 0.68 ha, 0.76 ha, and 1.27 ha. Three consecutive monthly harvests yielded a total of 10.11 mt for A and 2.57 mt for scheme B. Six croppings per year are likely.

Polyculture. Systematic polyculture was not popular before the establishment of the Department. Milkfish was the main culture species while prawns and shrimps were only incidental products. The first polyculture study was with *Penaeus monodon* at 1 500/ha and milkfish at 3 000/ha which gave the highest combined yield of 432 kg/ha (Santiago and Santiago unpublished). In a related study, highest combined production was obtained at 2 000 milkfish/ha and 8 000 prawns/ha which gave 521.3 kg/ha compared with milkfish only which yielded 286.7 kg/ha. Mean net production of both milkfish and prawns considered singly were highest in a combination of 2 000 milkfish/ha and 8 000 prawns/ha although no significant difference existed among treatments (Eldani and Primavera 1981). In another study, highest combined production of 463.6 kg/ha was attained with 2 000 milkfish/ha and 6 000 prawns/ha. At stocking rates of 2 000/ha and 4 000/ha, monoculture of milkfish yielded slightly higher production than polyculture. The competition of prawn against milkfish was almost negligible while milkfish exerted a greater competition against prawn (Pudadera and Lim 1982).

Use of formulated feeds in milkfish monoculture and its polyculture with prawns was tested. Results indicated that highest total production of 335.7 kg/ha was attained in milkfish alone without supplemental feeding. However, this was not significantly different from those stocked with 2 500 milkfish/ha and 3 000 prawns/ha with and without supplemental feeding (Villegas and Baliao 1980).

A comparative study of milkfish and prawn cultured singly and in combination yielded a production of 923.5 kg/ha/crop in polyculture with return on investment (ROI) of 45%. Chopped trash fish was given daily to prawns at 10%, 8%, and 6% of the biomass adjusted monthly (Kuntiyo and Baliao unpublished).

Polyculture of milkfish with crabs yielded the highest combined production of 661.7 kg/ha with 2 500 milkfish/ha and 5 000 crabs/ha (Table 1). As early as day 60, size and weight of crabs varied widely and some crabs had already attained fairly good marketable sizes. The net production of crab was higher in polyculture than in monoculture but the opposite was the case for milkfish (Lijauco et al 1980). Another study confirmed earlier results that 2 500 milkfish/ha and 5 000 crabs/ha had 500 kg/ha crab production and 600 kg/ha milkfish (Baliao 1983).

Polyculture of 3 000/ha milkfish and 6 000/ha prawns was tested in a modular pond. Milkfish attained a mean body weight of 220.2 g while prawns attained 38.75 g (Anon. 1984).

Table 1. Average Production and Survival in Monoculture and Polyculture of the Mud Crab, *Scylla serrata,* and Milkfish

	Gross Production (Kg/Ha)		Survival (%)		
Treatments	Milkfish	Crab	Milkfish	Crab	Feed Conversion
Milkfish only: 2500/ha	533.4		97.3		
Crab only: 5000/ha	–	336.2		37.0	18.4
Crab only: 10 000/ha	–	445.3	–	26.5	68.1
Polyculture: Milkfish: 2500/ha	372.9		91.3		
Crab: 5000/ha		449.7		56.0	9.0
Polyculture: Milkfish: 2500/ha	395.0		100.0		
Crab: 10 000/ha	–	529.0	–	26.5	37.3

(Lijauco, Prospero, and Rodriguez 1980)

An attempt was made to polyculture sea bass with various stocking densities of milkfish and tilapia. Results indicated that the best combination of sea bass, milkfish, and tilapia was 5 000/ha, 1 500/ha, and 4 000/ha with survival rates of 75.6%, 89.7% and 70.6% and net production of 1 459.4 kg, 229.9 kg and 168.21 kg/ha/crop, respectively (Anon. 1984).

HARVEST AND POST-HARVEST HANDLING

The harvest method is locally known as *pasulang* or *pasubang* which takes advantage of the behavior of milkfish to swim against the current. This involves draining 85-90% of the pond water during low tide and allowing in water at the incoming high tide so that the fish swim against the current through the tertiary gate and into the catching pond. The gates are then closed after a greater percentage of fish has been impounded while the rest swim back to the rearing area. From the catching pond the fish are seined while the remaining ones are handpicked during the total drain.

PRODUCTION CONSTRAINTS

The various problems that beset milkfish production in the Philippines are technical, social, economic, institutional, environmental, and political (Schmittou et al 1985). Typhoons, acid sulphate soils, and other physical factors are also constraints in some areas. Filipino fish farmers are equipped with skills to practice intensive fertilization and extensive feeding in ponds. The prohibitive costs of imported inorganic fertilizers and commercial feeds, however, restrict them from improving their technology. Generally, the farmers are responsive to technological change and may even take risks in ventures that promise quick returns. The major economic constraints, however, are the high capital required and the high cost of credit. Infrastructure, in relation to availability of ice and transportation, are difficult problems especially outside the Manila-Central Luzon area. Research facilities are believed adequate for effective research but well-trained scientists are still insufficient. Generally, budgets barely meet salary requirements, leaving a small portion for research. The well-trained technicians and researchers often join private companies which offer attractive salary, incentives, and the opportunity to learn the intensive prawn culture techniques which is now the trend. Future expansion is also limited by some regulations on mangrove swamp alterations to protect an important ecological resource. The peace and order situation in the country also poses a threat to the further development of aquaculture.

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NURSERY AND GROW-OUT OPERATION FOR TILAPIA AND CARP

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ABSTRACT

Most researches conducted at the Binangonan Freshwater Station of the SEAFDEC Aquaculture Department were directed toward enhancing growth and survival of the young tilapia and carp in the nursery as well as increasing yields in grow-out cages, pens, and ponds. Studies included the culture and evaluation of phytoplankton and zooplankton as feeds of the tilapia and carp fry to fingerlings; determination of protein and amino acid requirements of young Nile tilapia; development of practical dry diets; evaluation of feeding regimes, feeding rates, and feeding frequencies ; and the use of fertilizers in nursery ponds.

For the grow-out aspect, one of the earliest studies demonstrated the profitability of the monoculture of tilapia in cages which triggered the initial proliferation of tilapia cage culture by the private sector in areas near the Station. Subsequently, supplemental feeds were developed and evaluated; non-conventional feedstuffs were tested as feeds or feed components; and the growth rates of Nile tilapia fingerlings in cages at varying stocking densities were evaluated at three distinct rearing periods covering one year.

Prior to the successful mass production of bighead carp fingerlings at the Station, studies on polyculture of tilapia, milk fish, and different species of carp were conducted in cages and pens with remarkable results. This led to the technology-verification projects on polyculture at various areas in Laguna Lake. With the availability of freshwater fishponds for research purposes, studies on polyculture in ponds were also conducted.

INTRODUCTION

The Indo-Pacific Region produced as of 1983 about 83% of the world aquaculture production of 10.5 billion mt (FAO 1985). The largest contribution came from China (56%), India and Japan (11% each). Korea (6.1%), Philippines (4.2%), and Indonesia (1.9%) have also contributed significantly.

On the basis of production, the Chinese carps are the most important food fishes in Asia followed by the Indian carps, tilapias, milkfish, catfishes, and gouramis (Guerrero 1986 and 1987). In terms of distribution, tilapia ranks first followed by common carp *(Cyprinus carpio,* bighead carp *(Aristichthys nobilis),* and silver carp *(Hypophthalmichthys molitrix)* consecutively. The estimated tilapia and carp production in Southeast Asia from 1976 to 1984 showed an increasing trend (BFAR 1980 and 1984) which may also reflect the increasing demand for fingerlings of both groups.

Tilapia culture in the Philippines started when *Tilapia mossambica (Oreochromis mossambicus)* from Thailand was introduced in the country in 1950. However, it was the impressive performance in terms of growth and consumer acceptance of the Nile tilapia *(O. niloticus),* introduced in 1972, which led to the development of tilapia farming in the country. Culture of Nile tilapia in cages in the Philippines was first done in 1974 (Delmendo and Baguilat 1974). Although Indian carps and some species of Chinese carps became available in 1966 through the Bureau of Fisheries and Aquatic Resources (BFAR) (Reyes 1972, Chaudhuri 1979), only the Chinese carps are being commercially produced to date.

The SEAFDEC Aquaculture Department, through the Binangonan Freshwater Station (BFS) which was established in 1976, developed various techniques for tilapia culture which were readily accepted by the fish farmers in the vicinity and eventually in other areas. In 1983, the Aquaculture Department also succeeded in the large-scale production of bighead carp fingerlings.

This paper presents studies conducted at the BFS concerning tilapia and carp nursery and grow-out operations.

REARING FACILITIES

Nurseries

The tilapia and carp fry are reared in tanks, cages, or ponds. For experiments, size of rearing facilities is influenced by construction cost and availability of experimental fish for a given number of treatments. Net cages of various meshes (fine-meshed net, 0.30 cm or A-net, and 0.40 cm or B-net) are used in the lake. The dimensions are 1 × 1 × 1 m, 1 × 1 × 1.5 m, 3 × 1.5 × 1 m. Cages are usually covered with the same netting material used for the other sides. Oval fiberglass tanks (1.3-ton capacity) coated with white epoxy paint and concrete tanks (1 × 2 × 1 m) are used for land-based studies. In 1985, nursery ponds (5 × 10 m) were available for fry to fingerling production.

Grow-Out Facilities

For rearing tilapia fingerlings to marketable size under experimental conditions, cages (1 × 1 × 1 m, 2.5 × 2.5 × 2.5 m, and 5 × 10 × 1.5 m) and fishpens (40 × 20 m) have been used.

The grow-out facilities for carp consisted of pens (10 × 50 m) and cages measuring 5 × 10 × 1.5 m and 5 × 20 × 1.5 m. Nets for the cages or pens have mesh sizes of 0.40 cm (B-net), 0.50 cm (CC-net # 22), 0.70 cm (CC-net # 17), and 1.5 cm (CC-net # 8).

Grow-out as well as nursery cages recommended for commercial operations are usually larger and their actual size is determined primarily by the ease of management and the financial capability of the fish farmer.

REARING METHODS

Nursery

A study showed that sustained supply of phytoplankton as feed for Nile tilapia fry produced higher growth and survival compared to rice bran alone (Pantastico et al 1982). Growth of fry was also enhanced when phytoplankton concentration in the rearing medium was increased from low to moderate (90-120 × 10^3 cells/ml) and high (150-175 × 10^3 cells/ml). The acceptability of five species of fresh water algae was tested and it was found that *Navicula notha* (a diatom) and *Chroococcus dispersus* (a unicellular cyanophyte) as feeds resulted in highest growth and survival of the tilapia (Pantastico et al 1985). *Oscillatoria quadripunctulata,* a filamentous cyanophyte, has limited acceptability to tilapia fry probably because of its larger size compared to *Chroococcus.* In terms of assimilation of ^{14}C-labelled algae, the highest assimilation rates were obtained in fry fed with *Navicula* and *Chroococcus,* whereas only negligible amounts of *Chlorella, Euglena,* and *Oscillatoria* were assimilated by the fry. Another study showed the poor performance of Nile tilapia fry fed with *Chlorella* but it also demonstrated the suitability of *Moina macrocopa* (a cladoceran) as feed for the fry (Baldia 1984). Thus, although phytoplankton in general enhances the growth of young Nile tilapia, some algal species have higher nutritional value.

Cannibalism among the different sizes of tilapia fry and fingerlings has been recognized as a factor that decreases recovery of fish in nurseries. It was observed that cannibalism became more intense as the difference in sizes of fish increased (Pantastico et al 1987). However, feeding with phytoplankton, particularly the blue-geen alga, *Spirulina,* proved effective in reducing cannibalism.

Because tilapias readily take artificial feeds from the first feeding up to adult stage, studies on certain aspects of feeding Nile tilapia with prepared feeds have been undertaken. The protein requirement of Nile tilapia fry was determined under laboratory conditions to be 35% of the diet (Santiago et al 1982). This supplements what was earlier known about the protein requirements of older Nile tilapia and the juveniles of other mouth-brooding tilapia. Subsequently, it was shown that the optimum daily feeding rate for Nile tilapia fry stocked at 5 fry/1 was 30-45% of the fish biomass when a formulated dry diet was the only feed for the fry (Santiago et al 1987a). Moreover, survival rate was higher when the fry were fed with dry pellet crumbles rather than an unpelleted diet of the same formulation.

In the formulation of practical fish diets the quality of protein as reflected by its essential amino acid components is as important as the quantity of protein required by the fish. Recently, the essential amino acid requirements of the Nile tilapia fry were quantified (Santiago 1985). As in other fishes studied so far, the essential amino acid requirement pattern for the Nile tilapia was highly correlated with the essential amino acid pattern of the muscle of the fish.

Stocking rate of 5 fry/1 is used under laboratory conditions. Water in the rearing containers is partially replaced daily to maintain good water quality. Natural food is given *ad libitum* while artificial feeds are given three times a day. In nursery cages, stocking rate of 300 to 500 fry/m^2 is recommended (Bautista 1987). The fry are initially placed in fine-meshed net cages, then transferred to A-net and B-net cages as the fish grow. Supplemental feeds are given when supply of natural food is low.

Silver carp and bighead carp fry are usually stocked in tanks at 500/m^3 with the water replaced daily. The combination of an artificial diet having a crude protein level of 40% and the zooplankton, *Brachionus* and *Moina* given *ad libitum,* was found best for the carp fry (Fermin 1985, Anon. 1985). With an artificial diet alone given 1-3 times/day (Table 1), the suitable daily feeding rate is 30% of the fish body weight (Carlos 1985). On the other hand, the cyanophyte, *Spirulina platensis,* seemed to be the most promising natural food for very young silver carp (Pantastico et al 1986a). Based on assimilation rates of ^{14}C-labelled live food organisms, acceptability of specific phytoplankton to bighead carp fry occurred at a later stage (Baldia et al 1985).

Table 1. Percent composition of formulated feeds for carp larvae/fry

Ingredients	g/100 diet
Fishmeal	56.6
Soybean meal	11.4
Shrimp meal	9.0
Rice bran	10.7
Oil	5.0
Starch	3.0
Vitamin-mineral premix	4.3
Estimated crude protein	40.0

The initial stocking rate in fine-meshed nursery cages (hapas) is 1500-3000 carp fry/m^2. It is reduced to 750-1500/m^2 in A-net cages after two weeks, then to 400-800/m^2 in B-net cages (Fermin pers. comm. 1987). In ponds, the normal stocking rate is 35 fry/m^2. Pond water is fertilized to enhance natural food production by using chicken manure at 60 kg/ha/2 weeks, or an inorganic fertilizer, ammophous

(16-20-0), at 20 kg/ha/2 weeks and *Sesbania* at 60 kg/ha/2 weeks (Anon. 1985).

Studies on tilapia culture were both monoculture and polyculture while carp researches were mainly polyculture with tilapia, milkfish, and sea bass.

The first tilapia species used for cage culture was *O. mossambicus.* The fish, 10 g each, were stocked in B-net cages at 75 pieces/m^2 and were given the combination of rice bran, fish meal and ipil-ipil *(Leucaena leucocephala)* leaf meal (60:20:20), or the combination of rice bran and chopped snails (70:30) as supplemental feed. Results showed that fish given supplemental feeds had much higher growth compared to the controls (Pantastico et al 1979). The feasibility of using ipil-ipil leaf meal as a low-cost feed ingredient was also demonstrated. Subsequently, *O. niloticus* fingerlings, stocked at a density of 150/m^2, were given supplemental feeds consisting of ipil-ipil leaf meal and rice bran in varying proportions: I – 33.3% ipil-ipil: 66.7% rice bran; II – 66.7% ipil-ipil: 33.3% rice bran; III – 100% ipil-ipil; and IV – 100% rice bran. Fish given ipil-ipil leaf meal at varying dietary levels grew faster compared to those given rice bran alone (Pantastico et al 1980). Fresh *Azolla pinnata,* a tiny aquatic fern, was also an effective supplemental feed for tilapia fingerlings in cages, particularly when the primary productivity of the Lake was low (Anon. 1980, Pantastico et al 1986b) while dried and finely ground *A. pinnata* was desirable component of feeds for Nile tilapia fry (Santiago et al 1987b). Within a range of protein required by Nile tilapia fingerlings, practical diets with higher protein content did not necessarily produce better growth than those with lower protein level (Santiago et al 1986). Furthermore, diets with fish meal (18%) resulted in higher weight increases compared to those containing 0 or 5% fish meal.

The growth of Nile tilapia in cages is greatly influenced by the seasonality of natural food and water temperature. Tilapia fingerlings reared in cages in Laguna Lake at different months of the year showed marked differences in growth and survival (Basiao and San Antonio 1987). Fish reared in April-July had much higher growth than those reared in August-December or December-April. Without supplemental feeding, fish stocked at 50 and 100 fingerlings/m^2 in April-July attained a marketable size of over 100 g during harvest. At 150 and 200 fingerlings/m^2 growth was much lower. Information from this study has guided fish farmers as to the time of stocking and the stocking rates of young Nile tilapia in cages in the Lake.

In 1984, an experiment on pen culture of Nile tilapia compared the growth rates of fish at different stocking densities ($5/m^2$, $10/m^2$, and $15/m^2$) (Anon. 1984). Results showed an inverse relationship between stocking rate and mean weight of tilapia. At $5/m^2$, mean body weight after 4 months was 161.35 g. Net yield was only 0.188 kg/m^2 based on a recovery rate of 23%. Better harvesting technique for tilapias in pens has to be developed.

As part of the limnological project at BFS, fish growth was monitored in March-August 1984 (Anon. 1984). Hapa net cages (1 × 1 × 1 m) were installed in the West Cove of Laguna Lake and stocked with 10 fish/cage. After five months, tilapia *(O. niloticus)* attained a mean weight of 145 g. Net yield was 1.4 kg/m^2.

In collaboration with two private fish cage operators in Bo. Kalinawan, Binangonan, Rizal, two stations were established in 1985 at the West Bay of Laguna Lake. Station 1 was inshore and Station 2 was offshore. Tilapia fingerlings with mean initial weight of 0.55 g were stocked in B-net cages (50 m^2) at $16/m^2$. After six months (May to October) without feeding, mean weight of 43.4 g was attained by the tilapia reared in cages in Station 2 compared to only 28.5 g by those in cages in Station 1.

Polyculture of carps with other fish species was done in 1980 using a stocking rate of 6.6 pieces/m^2 at three varying stocking ratios (Castro et al 1980a, Castro et al 1980b). All species reached marketable size after 3 to 4 months. Final mean weights of milkfish and silver carps as the major species were highest at a stocking density of $4.5/m^2$, followed by $3/m^2$, and $5/m^2$. Fastest growth rate was exhibited by bighead carp, followed by silver carp, milkfish, tilapia, and common carp. With milkfish as the primary species, highest average net production of 558.16 kg/500 m^2 was obtained at a ratio of 4.5 milkfish:0.5 tilapia:0.1 bighead:0.5 common carp/m^2. With silver carp, the highest average net production obtained was 1218.85 kg/pen at a ratio of 5 silver:l tilapia:0.1 bighead:0.5 common carp/m^2. The two studies demonstrated locally that polyculture of fish species with complementary feeding habits is an effective means of increasing fish yield per unit area of cage or pen.

Another polyculture was undertaken in 1984, this time in seven areas representing the four distinct areas of Laguna Lake:Central Bay, West Bay, East Bay, and South Bay (Anon. 1984, Lijauco and Paraan 1984). Tilapia were grown with silver, bighead, and common carps at

$13/m^2$ and at a stocking ratio of 10 tilapia:2 common carp:0.5 bighead: 0.5 silver. Mean final weight of tilapia in the various bays was 63-181 g after six months of culture. There was not much difference in the mean final weight of common carp but the mean weight of bighead carp ranged from 699-1600 g while that of silver carp was 325-525 g. Tilapia from the southwestern part of the West Bay had the highest mean final weight of 181 g. Growth of tilapia as well as that of bighead, silver, and common carps in the South, East, and Central Bays was high.

Two technology verification projects were pursued in 1985 to determine the areas in Laguna Lake suitable for polyculture. Tilapia and bighead carps were stocked in CC-net cages (50 m^2) at 10 tilapia: 6 bighead carp/m^2 in the first project (Anon. 1985). The mean final weight of tilapia after 180 days (May to October) was 38.8 g and 41.4 g for the West Bay (inshore) and West Bay (offshore), respectively, from an initial weight of 0.55 g. Mean weight of tilapia from the South Bay (177.5 g) was much higher. The same trend was observed on the growth of bighead carp. Higher mean weight of 770 g was obtained in the South Bay compared to 187 g and 422 g for the West Bay (inshore) and West Bay (offshore), respectively. The second project was conducted simultaneously with the first and fish farmer cooperatives around Laguna Lake were involved in the implementation (Tabbu et al 1986). Bigger CC-net cages were used (200 m^2 and 100 m^2). These were stocked with 10 tilapia, 1.2 bighead carp and 0.6 common carp/m^2. Compared with the first project, higher mean weights of tilapia were obtained: 66 g at West Bay, 108.3 g at South Bay, and 102 g at East Bay Mean weights of bighead carp were: 1540 g (southwestern part of West Bay), 1170 g (South Bay), and 1290 g (East Bay). From the two polyculture studies in 1985, highest fish yield was obtained in the South Bay, followed by East Bay, and the southwestern part of West Bay. Moreover, bigger cages allowed higher fish growth.

Additional researches were subsequently conducted in ponds. Tilapia was cultured singly or in combination with bighead carp and sea bass in cages installed in ponds. Results showed highest yield from tilapia-carp-sea bass combination and tilapia-carp combination after six months (Anon. 1986, Tabbu 1986). On the other hand, the effect of different inorganic and organic fertilizers and their combinations on fish yield was evaluated. A stocking density of $4.6/m^2$ and a ratio of 2.5 tilapia and 2.1 bighead carp were used. Among the fertilizers used, chicken dung alone or phosphorous (0-18-0) alone gave the highest yields (Anon. 1986, Acosta 1986).

DISEASES AND PARASITES

The Fish Health Laboratory at BFS has reported occurrence of parasite infestation and diseases in tilapias and carp (Palisoc 1985). Samples came from land-based hatcheries or nurseries as well as from pens, cages, and open waters. Recommended treatments for affected fish are presented in Table 2. It is impractical to treat infected or diseased fish in cages or pens in large bodies of water. However, valuable fishes such as carp and tilapia broodstock may be harvested and transferred to land-based facilities for treatment.

Table 2. Parasites and disease organisms of tilapia and carp and their treatment

Fish species	Infective organism	Treatment	Dosage	Duration
T. nilotica	*Pseudomonas*	Oxytetracycline	7.5 g/100 kg of fish/day	7-12 days
	Trichodina	Salt bath	1000-2000 ppm	indefinite
	Dactylogyrus	Salt bath	1000-2000 ppm	indefinite
Bighead Carp	*Trichodina*	Formalin	150 ppm	1 hour
	Pseudomonas	Oxytetracycline	7.5 g/100 kg of fish/day	7-12 days
Silver Carp	*Aeromonas*	Oxytetracycline	7.5 g/100 kg of fish/day	7-12 days
	Citrobacter	Oxytetracycline	7.5 g/100 kg of fish/day	7-12 days
	Micrococcus	Oxytetracycline	7.5 g/100 kg of fish/day	7-12 days
	Lernaea	Salt bath	1000-2000 ppm	indefinite
		Formalin	15-25 ppm	indefinite

PRODUCTION CONSTRAINTS

The main problem of tilapia and carp production is the insufficient supply of high quality fingerlings, particularly when these are needed for stocking. Although many hatcheries exist, it is difficult to obtain at one time the desired number and size of fish. For cage culture of both species, poaching is a serious problem. Also, typhoons cause destruction of cage and pen installations, loss of fish to open waters, and fish mortality. Lack of technical knowhow by some fish farmers also affect fish production.

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TRAINING PROGRAMS OF SEAFDEC AQUACULTURE DEPARTMENT

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ABSTRACT

With training as one of its three mandated functions, the SEAFDEC Aquaculture Department offered its first training course in 1974. Since then it has trained some 6 519 participants in various degree and non-degree programs. The degree courses are MS. Fisheries (Aquaculture) and M. Aquaculture in collaboration with the University of the Philippines in the Visayas.

The non-degree programs include regular short-term courses, on-site seminars internship training and practicum for graduating students. The "hands-on" short-term courses cover Prawn Hatchery and Nursery, Marine Finfish Hatchery, Brackishwater Pond Culture, Sanitation and Culture of Bivalves, Freshwater Aquaculture, Aquaculture Management, Aquaculture Engineering, and Aquaculture for Social Scientists. A profile of 637 1982-1986 training participants show 82.3% from Southeast Asia, 79% male and 57.5% from government sector.

The paper discusses planning and implementation of training programs, funding support (Japanese Government, International Development Research Centre of Canada, FAO Network of Aquaculture Centres in Asia), and future trends.

INTRODUCTION

Research, training, and information dissemination are the three mandated functions of the Southeast Asian Fisheries Development Center Aquaculture Department (SEAFDEC AQD).

The strength of the AQD training program is derived from experience in research, training, and exposure to the industry. The Department has some 80 professional staff with masteral and doctoral degrees who have published more than 200 papers in various scientific journals and conference proceedings. It has also sponsored 16 national, regional and international conferences, seminars and workshops on aquaculture research and development.

Parallel to research has been the training program with the first short-term course offered in 1974. Lecturers and instructors are drawn from the research staff. Many of the research facilities including laboratories, hatcheries, nurseries, ponds, pens and cages, and library services are also utilized for training. Moreover, the 13-year lead time has enabled the Department to develop training facilities (audiovisual equipment, training laboratories, and ponds), and manpower (a core training staff) exclusively for training purposes.

In addition, AQD trainees have access to private sector practices in the thriving aquaculture industry in the Philippines. Given the country's extensive coastal areas, the potential contribution of training to aquaculture development cannot be underestimated. At the regional level, training is even more significant as Asia is considered the cradle of aquaculture, and contributed around 80% of the total 1984 world aquaculture production of 10.2 million mt.

TRAINING PROGRAMS

The training programs of SEAFDEC AQD consist of a degree program and four non-degree offerings: regular short-term courses, on-site seminars, internship, and student practicum. The practicum and on-site seminars are exclusively national while internship of degree programs are open to international participants.

The regular short-term courses are "hands-on" 4- to 7-week technician courses conducted in any of the Department stations in Tigbauan and Leganes, Iloilo and in Binangonan, Rizal, and are open to national and international participants.

The 3-day on-site seminar has been designed for fish farmers and other aquaculture entrepreneurs who have neither means nor time to come to AQD. Organized upon the request of local aquaculture associations and in collaboration with the Department of Agriculture Bureau of

Fisheries and Aquatic Resources, this outreach activity aims to bring the latest aquaculture technologies to the farm site.

Internship training is for participants with some aquaculture background either from previous research or industry experience or upon completion of a short-term course and who need further specialization in such areas as nutrition and feed formulation, proximate analyses of feeds, disease diagnosis, plankton culture, and instrumentation. Practicum or "on-the-job" training is designed to complete the 400 to 800 practical hour requirement of the Philippine government for graduating students in fisheries and related fields in order to supplement their theoretical knowledge.

The academic program in collaboration with the University of the Philippines in the Visayas, which grants the degrees, includes the two-year M.S. Fisheries (Aquaculture) program which requires a thesis and the one-year M. Aquaculture program. The latter is also called the Training Course for Senior Aquaculturists in Asia and the Pacific and is supported by the FAO Network of Aquaculture Centres in Asia through fellowships, equipment, and personnel.

Table 1 and Figure 1 summarize the various training programs of SEAFDEC AQD from 1974 to 1986 which show a total of 6776 participants and 6399 man-months. The on-site seminar leads in terms of number of participants trained (51%) but has only around 7% of total man-months because of its short duration. Next are the short-term courses and the student practicum with 29% and 14%, respectively, of the total number of participants.

The degree program has the greatest number of man-months (34%) but constitutes only 3% of the total participants reflecting its 1- to 2-year period. Also ranking high in man-months are the 4- to 7-week short-term courses and the 2-month student practicum at 24% each.

Short-Term Training Courses

Forming the centerpiece of AQD training, the regular short-term courses are characterized by a mix of 80-90% laboratory exercises, practical/field work and field trips, and 10-20% lectures.

Table 1. Summary of participants and man-months of the training programs of the SEAFDEC Aquaculture Department, 1974-1986.

	No.	%	Man-month	%
A. National				
1. Student practicum	925	13.6	1 512	23.6
2. On site seminars	3 481	51.4	434	6.8
3. Short-term courses	1 065	28.7[a/]	469	23.5[a/]
Sub-total	5 471		2 415	
B. International				
1. Internship	191	2.8	748	11.7
2. Degree program	231	3.4	2 201	34.4
3. Short-term courses	883	28.7	1 035	23.5
Sub-total	1 305		3 984	
TOTAL	6 776	100.0	6 399	100.0

[a/]Includes both national and international programs.

Areas

The five areas offered at present are (1) Prawn Hatchery and Nursery, (2) Marine Finfish Hatchery, (3) Brackishwater Pond Culture, (4) Sanitation and Culture Techniques of Tropical Bivalves, and (5) Freshwater Aquaculture. Other courses occasionally offered are Natural Food Culture, Aquaculture Engineering, and Aquaculture Management.

Among the various courses, Brackishwater Pond Culture and Prawn Hatchery lead in both participants and man-months (Fig. 2) reflective of both the extensive coastal areas and the recent heightened interest in prawn culture in the country and the region.

Timetable

The activities of a training course are numerous and varied:

1. *Scheduling.* The choice and scheduling of courses within a

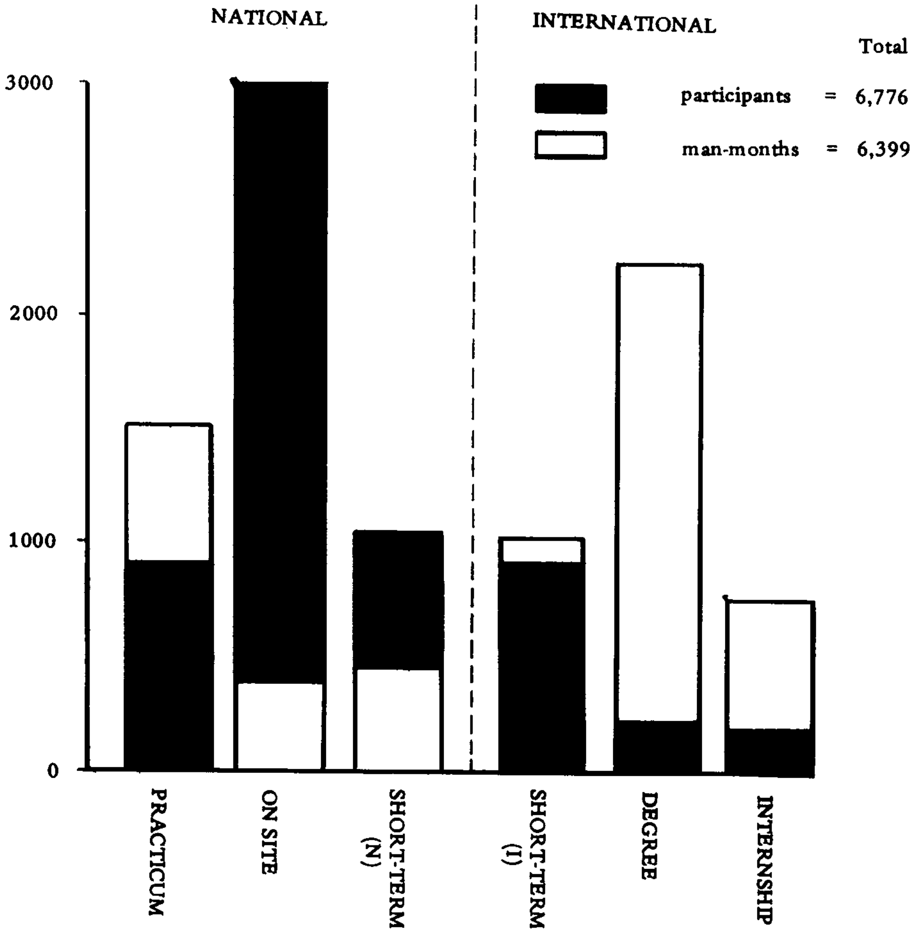

Fig. 1. Summary of participants of the SEAFDEC Aquaculture Department training program, 1974-86

given year are based on demand in terms of industry feedback and the number of applications received in previous year, seasonality of aquaculture commodity, availability of faculty and accommodations. Scheduling is done at least six months in advance to give lead time for announcements.

2. *Circulation.* Announcements of the scheduled training courses are made through an extensive mailing list and through mass media.

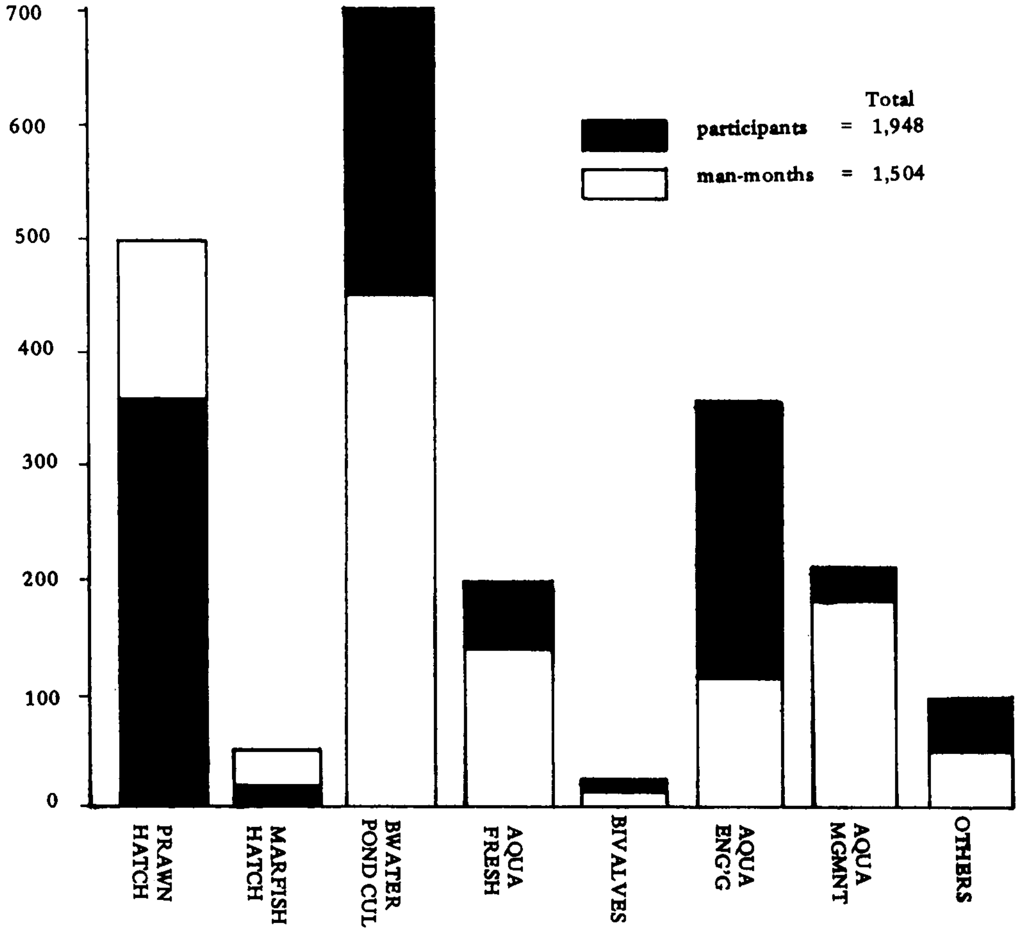

Fig. 2. Summary of participants/man-months of short-term courses, SEAFDEC Aquaculture Department, 1974-86

3. *Screening for admissions/fellowships.* Three basic qualifications for applicants are a college degree in fisheries or related fields or background in aquaculture; proficiency in English, the medium of instruction; and good health. If the number of qualified applicants exceeds the 20-24 slots per course, other secondary factors are considered. These include age (25-55 years), sex (female), and sector (government). The bias for females is because of the predominantly male profile (79% of 637 trainees, 1982-1984) of participants. The preference for public sector applicants is due to the "multiplier effect" of training trainors such as government fisheries extension workers.

At this time, participants are also screened for available fellowships which provide financial support in form of air fare, stipend, and various allowances from such donors as the Government of Japan and the International Development Research Centre (IDRC) of Canada.

4. *Preparation.* Prior to the start of a given course, the assigned Course Officer prepares a schedule of activities (lectures and practical work), equipment, supplies and materials, stocking of a demonstration pond, and other facilities. Lecturers and instructors from the Department research staff and from the outside (academe, private sector) are also selected.

5. *Course proper.* This covers opening ceremonies and orientation; lectures, practicum and field trips; panel discussions; written and oral examinations; course evaluation and closing ceremonies.

6. *Non-technical aspects.* Because of the live-in nature of the short-term courses, the non-technical activities also require attention. These include arrangements for arrivals and departures, travel (visa, tickets), opening and closing ceremonies, stipend and allowances (for fellows), health and accident insurance, accommodations and meals, banking and communications, cultural tours, socials such as picnics and parties, and group dynamics.

7. *Course evaluation.* This includes evaluation of lecturers, instructors, lodging, meals, and overall course assessment.

IMPACT

The impact of AQD's continuing training program may be gauged in terms of aquaculture policy and aquaculture production in the region. Figure 3 shows that out of a total of 1305 participants and 3984 man-months for the international training programs, 76.4% of trainees (997) and 77.3% man-months (3079) came from Southeast Asia.

Policy

Many of AQD's training alumni, particularly from the degree programs now help formulate national and regional policies in aquaculture

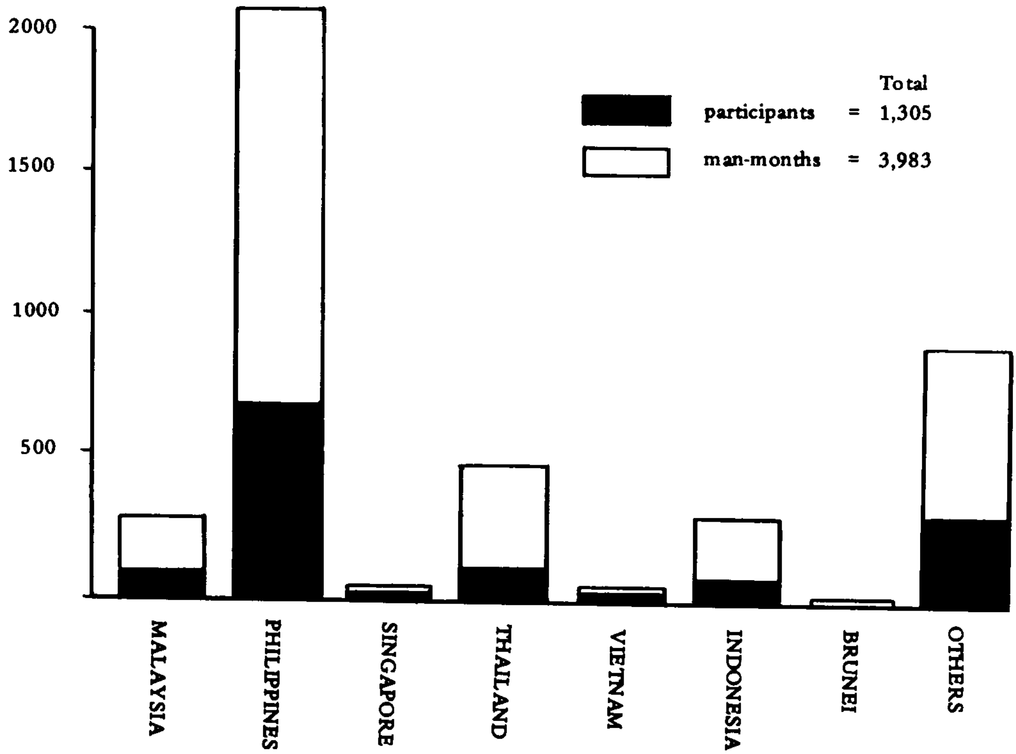

Fig. 3. Summary of participants/man-months of the SEAFDEC Aquaculture Department international training program, 1974-86 by country

and fisheries in their respective countries.

Production

The Southeast Asian region shows a 100% increase in aquaculture production from 1975 to 1983 compared to only 20% from capture fisheries for the same period (Rabanal 1987).

1. *Prawn Hatchery.* In the Philippines, production of prawn *(Penaeus monodon)* fry increased from 3 million in 1974 to approximately 100 million in 1983 (Primavera 1985) to more than 200-300 million at present.

2. *Pond Culture.* Average yearly brackishwater pond production of milkfish in the Philippines has increased from 300 kg/ha in the mid-1970's to more than 1 000 kg/ha at present.

FUTURE DIRECTIONS

Short-Term Courses

There will be a continued demand in the country and the region for the technician courses, particularly Prawn Hatchery and Brackishwater Pond Culture. With intensification of aquaculture, there will be a need for training in such specialized topics as Fish Diseases and Natural Food Culture.

On-Site Seminars

The Philippine Government through the Department of Agriculture and Food has focused on the need of small fish farmers. Therefore, future efforts will emphasize the on-site seminars as a means of reaching out to small farmers in the areas of pond culture and mariculture of seaweeds, bivalves, and finfish.

Major Training Courses in the Region

SEAFDEC AQD's strong offerings in marine seed production (prawn and finfish) and brackishwater culture can be seen from the popularity of these courses (Fig. 2). Singapore is offering courses in net-cage (marine) fish culture and bivalve microbiology while Thailand has courses in freshwater and marine shrimp hatchery.

Perhaps a regional workshop may be useful to evaluate past training programs, to determine future needs, and to rationalize the various training efforts in the region.

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SUMMARY OF WORKSHOP RECOMMENDATIONS

A special workshop among participants was conducted to assess the status of the aquaculture industry in Southeast Asia, particularly in Malaysia, Philippines, Singapore, and Thailand. Although hatchery, nursery, and grow-out culture techniques had already been developed for most of the economically important species cultured in Southeast Asia, the outcome of the workshop showed that there are still major constraints to be able to increase production. Further studies have to be conducted to have greater control of factors that lead to better production. The participants prioritized the economically important species and the research area for each species for the Region.

The summary of workshop recommendations are as follows:

I. FINFISHES

A. Marine and Brackishwater

Priority Species	*Research Areas*
1. Sea Bass	1. Diseases in nursery and grow-out a. ciliates b. bacteria c. virus d. stress-induced 2. Feed development for nursery 3. Feed development for grow-out
2. Grouper	1. Development of hatchery techniques 2. Development of feed for nursery 3. Development of artificial diet for grow-out 4. Diseases in nursery and grow-out a. bacteria b. virus c. stress-induced 5. Diseases in nursery a. ciliates
3. Red Snapper	1. Development of reliable hatchery techniques 2. Feed development for nursery 3. Diseases in nursery and grow-out a. ciliates b. bacteria

- c. virus
- d. stress-induced

4. Development of artificial feed for grow-out

4. Golden Snapper

1. Development of reliable hatchery techniques
2. Development of feed for nursery
3. Development of feed for grow-out
4. Diseases in nursery and grow-out
   - a. bacteria
   - b. virus
   - c. stress-induced
   - d. ciliates

5. Mullet

1. Development of hatchery techniques
2. Development of feed for grow-out
3. Development of feed for nursery
4. Diseases in nursery and grow-out
   - a. bacteria
   - b. virus
   - c. ciliates
   - d. stress-induced

6. Rabbitfish

1. Development of feed for grow-out
2. Development of reliable hatchery techniques
3. Development of feed for nursery
4. Diseases in nursery
   - a. ciliates
   - b. bacteria
5. Diseases in grow-out
   - a. Stress-induced
   - b. Bacterial and ciliate

7. Milkfish

1. Refinement of broodstock management technique
2. Development of practical diets for hatchery, nursery and grow-out
3. Development of disease prevention and control methods for hatchery, nursery and grow-out
4. Economic assessment of hatchery systems

B. Freshwater

Priority Species	*Research Areas*
1. Red Tilapia	1. Selective breeding 2. Refinement of hatchery techniques 3. Feed development for nursery 4. Feed development for grow-out

2. Marble Goby	1. Refinement of hatchery techniques 2. Feed development for nursery 3. Feed development for grow-out
3. *Clarias* sp.	1. Refinement of hatchery techniques 2. Feed development for nursery and grow-out 3. Selective breeding
4. Other Tilapias	1. Selective breeding 2. Feed development for nursery 3. Refinement of hatchery techniques 4. Feed development for grow-out
5. Carps (Grass Carp)	1. Refinement of hatchery techniques

II. CRUSTACEANS

Priority Species	*Research Areas*
1. *Penaeus monodon*	1. Development of captive broodstock 2. Development of economically feasible diets for grow-out 3. Development of economically feasible broodstock and larval diets 4. Refinement of existing hatchery-nursery technology[1] 5. Development of techniques for disease prevention and control in hatchery 6. Water management for grow-out
2. *P. merguiensis/P. indicus*	1. Development of economically-feasible diets for grow-out 2. Water management 3. Development of techniques for disease prevention and control 4. Development of captive broodstock 5. Refinement of existing hatchery-nursery technology 6. Selective breeding
3. *Macrobrachium rosenbergii*	1. Selective breeding 2. Refinement of existing hatchery-nursery technology[1] 3. Water management

[1]Includes feeds, disease prevention and control, and water management.

	4. Development of techniques for disease prevention and control
	5. Feed development for grow-out
	6. Development of captive broodstock
4. *Scylla serrata*	1. Refinement of existing hatchery-nursery technology[1]
	2. Development of captive broodstock
	3. Feed development for grow-out
	4. Development of techniques for disease prevention and control
	5. Water management for grow-out
5. *Metapenaeus ensis/ M. monoceros*	1. Development of captive broodstock
	2. Water management for grow-out
	3. Refinement of existing hatchery-nursery technology[1]
	4. Feed development for grow-out
	5. Development of techniques for disease prevention and control

III. MOLLUSCS AND SEAWEEDS

A. Molluscs

Priority Species	*Research Areas*
1. *Perna viridis*	1. Product development and other uses
	2. Depuration
	3. Resource evaluation
	4. Site identification
	5. Spatfall forecast
	6. Transplantation
	7. Evaluation of culture technology
	8. Refinement of grow-out techniques
2. *Crassostrea* sp.	1. Resource evaluation
	2. Site identification
	3. Depuration
	4. Spatfall forecast
	5. Evaluation of culture technology

Includes feeds, disease prevention and control, and water management

	6. Product development and other uses
	7. Transplantation
	8. Refinement of grow-out techniques
3. *Anadara* sp.	1. Depuration
	2. Resource evaluation
	3. Site identification
	4. Spatfall forecast
	5. Transplantation
	6. Product development and other uses
	7. Development of hatchery techniques
	8. Refinement of grow-out techniques
	9. Evaluation of culture technology
4. *Placuna placenta*	1. Spatfall forecast
	2. Resource evaluation
	3. Development of hatchery techniques
	4. Transplantation
	5. Site identification
	6. Refinement of grow-out techniques
	7. Product development and other uses

B. Seaweeds

Priority Species	*Research Areas*
1. *Gracilaria*	1. Refinement of culture techniques
	2. Basic biology
	3. Product utilization
	4. Screening and characterization of natural products
2. *Porphyra*	1. Basic biology
	2. Refinement of culture techniques
	3. Product utilization
	4. Screening and characterization of natural products
3. *Eucheuma*	1. Refinement of culture techniques
	2. Basic biology
	3. Product utilization
	4. Genetics/selective breeding and establishment of seed banks

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