Technological and Economic Adaptations in Aquaculture Development in Taiwan

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Declaration

I hereby declare that this thesis has been composed entirely by myself and had not been previously submitted for any other degree or qualification.

The work of which it is a record has been performed by myself, and all sources of information have been specifically acknowledge.

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Abstract

In Taiwan, the history of aquaculture spans over three hundred years and the breakthroughs in the artificial propagation of finfish and shrimp effectively reduced the industries' reliance on wild fry, thereby stabilizing commercial operations and overcoming the barriers for expansion. Taiwan is located very close to Japan, one of the biggest seafood importers in the world, which has also benefited the development of aquaculture. However, the growing problems of water pollution and the increasingly high environmental costs generated by aquaculture ventures have made Taiwan experience a declining trend in recent years.

To overcome those constraints, three main areas are described, which then form the basis of this study.

(1).Adjustment of existing production practices - Milkfish culture, one of the most vulnerable sectors suffering from price fluctuation is used as an example to understand both the production cost, market attributes and the ways in which impacts of variations between production and price can be reduced.

(2). Improving existing systems- One of the methods to reduce the use of underground water is to use super intensive culture in which high densities are stable and water use minimised, and has been tried in Taiwan for eels. However, the cost and benefits must be evaluated and as most eel products are exported to the Japanese market, it is very important to examine the comparative advantages against other countries.

(3). Develop new systems- One of the solutions to the constraints of land-based aquaculture in Taiwan is to develop seawater-based cage culture. This has been developed in a limited degree in Ping-Tong and Pen-Hu counties but the feasibility and profitability have not been investigated.

Based on 274 milkfish farms, 63 traditional eel farms, 5 intensive eel farms, 22 cage culture farms and 133 consumers from different zones, constituted the primary data, which combined with other secondary data constructed this investigation.

The milkfish sector was not economically sound. Farm size in the categories of 4 - <5 ha could appear to be more profitable. Cold weather and unstable in price made this industry more risky. The price was very unstable and strongly correlated to seasonal variation of production.

The various forms of average financial appraisal have shown that intensive eel culture has a slight advantage over traditional eel culture. However, traditional eel culture has a higher distribution and the financial advantage of intensive culture is primarily due to the cheaper eel seed. The mass production of eel from China has caused Taiwan to lose the comparative advantage in roasted eel for the Japanese market.

Cage culture is a new aquaculture venture in Taiwan. The structure of cages, feed and other facilities still need to be improved. Although Dumerils's Amberjack (*Seriola dumerili*) and red porgy (*Pagrus major*) can make higher profits than other species, fish farmers still have great expectation for cobia (*Rachycentron canadus*). As Taiwan's market is not big enough, there is great hope that the Japanese market can be developed and cobia can become a candidate for sashimi (raw fish).

For sustainable development, aquaculture must be economically viable, ecologically sound and socially acceptable. To attain these goals, production and marketing groups, and production area were suggested. Proper administration and management could help the industry to be sustainable.

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Chapter 1

General introduction

1.1 The role of aquaculture

Aquaculture is the farming of aquatic organisms, including aquatic animals and plants, for food or for commercial purpose. Farming implies some forms of intervention in the rearing process to enhance production, such as regular stocking, feeding, maintaining water quality, protection from predators, etc (Pullin 1993), that increase the yield to a level above that naturally found in the environment. Therefore, a natural food-producing system is changed to a more productive, artificial, or manipulated ecosystem. Part of the natural functions usually performed by ecosystems such as decomposition of wastes, exchanges of gases and production of oxygen (by photosynthesis) are accomplished or supplemented artificially by mechanical aeration or flushing.

Aquaculture may be undertaken with full or partial culture operation. In full-culture operation, all phases of a life cycle, which include breeding, seed or larval rearing, and feeding the various stages from fry to fingerlings to adults are under control. In partial culture, there are two varieties; stocking seed without attending to subsequent growth at various levels of intensity, and caring for the cultivars to various levels of their life cycles (Bardach 1997). Suitable environments for aquaculture include fresh, brackish and marine water. The historical evidence of aquaculture is reported to go as far back as 2500

BC in Egypt and 500 BC in China (Pillay 1990), although it is over the last few decades that aquaculture become a rapidly expanding, and globally recognized food production sector.

When compared to alternative sources of protein, such as terrestrial livestock, fish have several advantages. Firstly, they have a better feed conversion ratio. According to Lovell (1989), the ratio of weight gain per gram of dry feed consumed averages 0.84 for channel catfish, compared to 0.48 for broiler chickens and 0.13 for cattle. Efficiency is greater, as fishes are poikilothermic and do not have to maintain a constant body temperature. They need less energy to maintain position and to move in water than animals do on land. They also excrete most nitrogenous wastes as ammonia rather than urea and uric acid, therefore, energy loss in protein metabolism is much lower (Ackefors *et al.* 1994). Secondly, fish protein is of better quality as it is associated with a low calorie content, a low saturated fatty acid content, and a high content of poly-unsaturated fatty acid (Ω3). Thirdly, many fish have a higher percentage of consumable lean flesh. In dressed catfish for example, the consumable lean flesh is 81% compared to 60, 50 and 65% for beef, pork, and chicken, respectively (Lovell 1989).

The production and consumption of fish has made larger gains over the last four decades (Williams 1997). However, the contribution of fish to sustainable food security is now undergoing a transition to increasing scarcity, and capture fisheries have been relatively stable over recent years. Natural aquatic ecosystems are photosynthetically driven systems with relatively long food chains and have high energy losses which ultimately result in a low yield per unit area. For example, overall biomass yield for the earth's ocean is less than 2 kg per hectare per year (kg/ha/year) (Ackefores *et al.* 1994).

About 70% of the world's marine stock is fully exploited, overexploited, depleted or in the process of rebuilding as a result of depletion (Karnicki. 1995), while most of the other 30% of stocks consist of low market-value species. For the two decades following 1950, world capture fisheries production increased on average by 6 percent annually. However, during the 1970s and 1980s, the average rate of increase declined to 2 percent per year, falling to almost zero in the 1990s (FAO 2001). Many management regimes have not been adequate to sustain the fishery resource, or to counteract the negative impacts created by heavy fishing, habitat degradation and habitat loss. Encouraging more people to catch fish for food or profits is no longer an option in most parts of the world. Instead, encouraging people to grow their own fish or participate in artificial stock enhancement is an increasing option (Williams 1997). By contrast with the lower yields from capture fisheries, by adding and controlling inputs the range of production from aquaculture is on the order of 1,000 to 1,000,000 kg/ha/year (Ackefores *et al.* 1994).

Many factors have acted positively on the demand for fish, e.g. growing affluence and growing population numbers. Economic and social factors such as greater disposable income, the price of fish relative to other animal proteins, trade opportunities, and dietary and health preferences all contributed to changing fish consumption patterns. Furthermore, an ever-growing human population exacerbates the situation. The world's population has been growing at a rate of 1.8 % per annum (FAO 2001) and it is estimated that the population will attain 7 billion by the year 2010. To satisfy the world annual demand, at an average of 13 kg per capita, it will be necessary to reach a supply level of 91 million tonnes of fish. It is widely considered that deficiencies of supply can be compensated through aquaculture, i.e., from hunting to farming fish.

The aquaculture industry has undoubtedly seen great success over the last few decades, with world production rising from 2.6 million tonnes in 1970 to more than 45 million tonnes in 2000. Production is dominated by Asia, in 2000, accounting for more than 91% of total production and 82.1% of total value. From 1980 to 2000, the annual average growth rate of quantity and value were 9.5 and 10.2%. The highest growth rate of quantity was in South America, attaining 19.5%, followed by Africa, Asia, North America and Europe, attaining 13.8, 10.0, 6.5 and 4.1%, respectively. The highest growth rate of value was in Africa, attaining 24.5%, followed by, South America, Asia, North America and Europe, attaining 14.5, 10.6, 7.9 and 6.4%, respectively (Table 1.1). The average price was highest in South America, followed by Europe, North America and Africa, and lowest in Asia (Table 1.2).

Table 1.1 World aquaculture production statistics and forecast.

Unit: Millions of tonnes
Millions of US$

Year	Asia		Europe		America, North		America, South		Africa		Total	
	Amount	Value	Amount	Value	Amount	Value	Amount	Value	Amount	Value	Amount	Value
1980[a]	6.2 (84.3)		0.9 (12.5)		0.2 (2.5)		0.02 (0.2)		0.03 (0. 4)		7.4	
1982[a]	6.7 (82.1)		1.1 (13.4)		0.3 (3.4)		0.04 (0.5)		0.03 (0.4)		8.2	
1984[a]	8.5 (83.6)	9.3 (78.0)	1.2 (11.8)	1.7 (14.5)	0.4 (3.5)	0.5 (4.4)	0.06 (0.6)	0.3 (2.6)	0.04 (0.4)	0.03 (0.2)	10.2	12.0
1986[a]	10.7 (84.7)	13.3 (79.5)	1.4 (10.9)	2.4 (14.3)	0.4 (3.2)	0.6 (3.4)	0.07 (0.6)	0.4 (2.4)	0.06 (0.4)	0.04 (0.3)	12.7	16.7
1988[a]	13.4 (86.6)	19.2 (79.8)	1.4 (9.2)	3.2 (13.3)	0.4 (2.7)	0.7 (2.9)	0.1 (0.9)	0.8 (3.1)	0.07 (0.5)	0.1 (0.4)	15.5	24.0
1990[a]	14.5 (86.2)	21.4 (78.7)	1.6 (9.6)	4.0 (14.8)	0.4 (2.4)	0.8 (3.0)	0.2 (1.1)	0.7 (2.5)	0.08 (0.5)	0.2 (0.6)	16.8	27.2
1992[a]	18.8 (88.9)	26.4 (81.1)	1.4 (6.5)	3.6 (11.1)	0.5 (2.4)	1.0 (3.1)	0.3 (1.4)	1.2 (3.7)	0.1 (0.5)	0.2 (0.6)	21.2	32.5
1994[a]	25.3 (90.9)	34.3 (83.8)	1.5 (5.3)	3.7 (9.1)	0.5 (1.9)	1.2 (2.9)	0.3 (1.2)	1.3 (3.2)	0.1 (0.3)	0.2 (0.5)	27.8	40.9
1996[a]	30.9 (91.1)	39.7 (83.8)	1.7 (4.9)	3.9 (8.2)	0.6 (1.7)	1.3 (2.7)	0.6 (1.6)	2.0 (4.2)	0.1 (0.4)	0.3 (0.6)	33.9	47.4
1998[a]	35.5 (90.8)	41.6 (82.5)	1.9 (4.9)	4.3 (8.5)	0.7 (1.7)	1.5 (2.9)	0.7 (1.7)	2.4 (4.8)	0.2 (0.5)	0.4 (0.9)	39.1	50.4
2000[a]	41.7 (91.3)	46.3 (82.1)	2.0 (4.4)	4.6 (8.2)	0.7 (1.5)	1.7 (3.0)	0.7 (1.6)	2.6 (4.5)	0.4 (0.8)	1.0 (1.7)	45.7	56.5
2010[b]											51.8	
2025[b]											92.6	
2035[b]											123.9	
Growth rate	10.0	10.6	4.1	6.4	6.5	7.9	19.5	14.5	13.8	24.5	9.5	10.2

Data source: a: FAO (2002). www.fao.org/fi/figis/tseries/index.jsp
b: New (1997)

The figures in this table are undeflated

Figures in parentheses represent the percentages of annual total.

The growth rate of quantity is from 1980 to 2000, and value is from 1984 to 2000.

Table 1.2 The average prices (US$/kg) of aquaculture products of different continents.

Year	Asia	Europe	America, North	America, South	Africa	Total
1984	1.09	1.42	1.25	5.00	0.75	1.18
1986	1.24	1.71	1.50	5.71	0.67	1.31
1988	1.43	2.29	1.75	8.00	1.43	1.55
1990	1.48	2.50	2.00	3.50	2.50	1.62
1992	1.40	2.57	2.00	4.00	2.00	1.53
1994	1.36	2.47	2.4	4.33	2.00	1.47
1996	1.28	2.29	2.17	3.33	3.00	1.40
1998	1.17	2.26	2.14	3.43	2.00	1.29
2000	1.11	2.30	2.43	3.71	2.50	1.24

Data source: calculated from Table 1.1.
The figures in this table are undeflated

It is also proposed that aquaculture can mitigate against overfishing of certain species, for example, Atlantic salmon. To demonstrate in theoretical terms, in fig1.1, curve C represents the price-supply characteristics of a common-property fishery. The supply quantity increases when the price increases but after the catch effort exceeds the maximum sustainable yield, the supply quantity will decrease and the price will still increase. Curve A, represents the aquaculture supply; curve A+C, is then the horizontal sum of the aquaculture supply and common property supply and Curve D, the demand quantity. Without aquaculture, the common-property equilibrium output will be Q1 and price will be P1. With such a high price, biological overfishing will take place. However, the introduction of an aquaculture supply to the market will lower the equilibrium price to P2, raise the equilibrium quantity to Q2 and lower the risk of overfishing. At price P2, the harvesting level of open access fishing on Q3 is lower than the maximum sustainable yield on Q4.

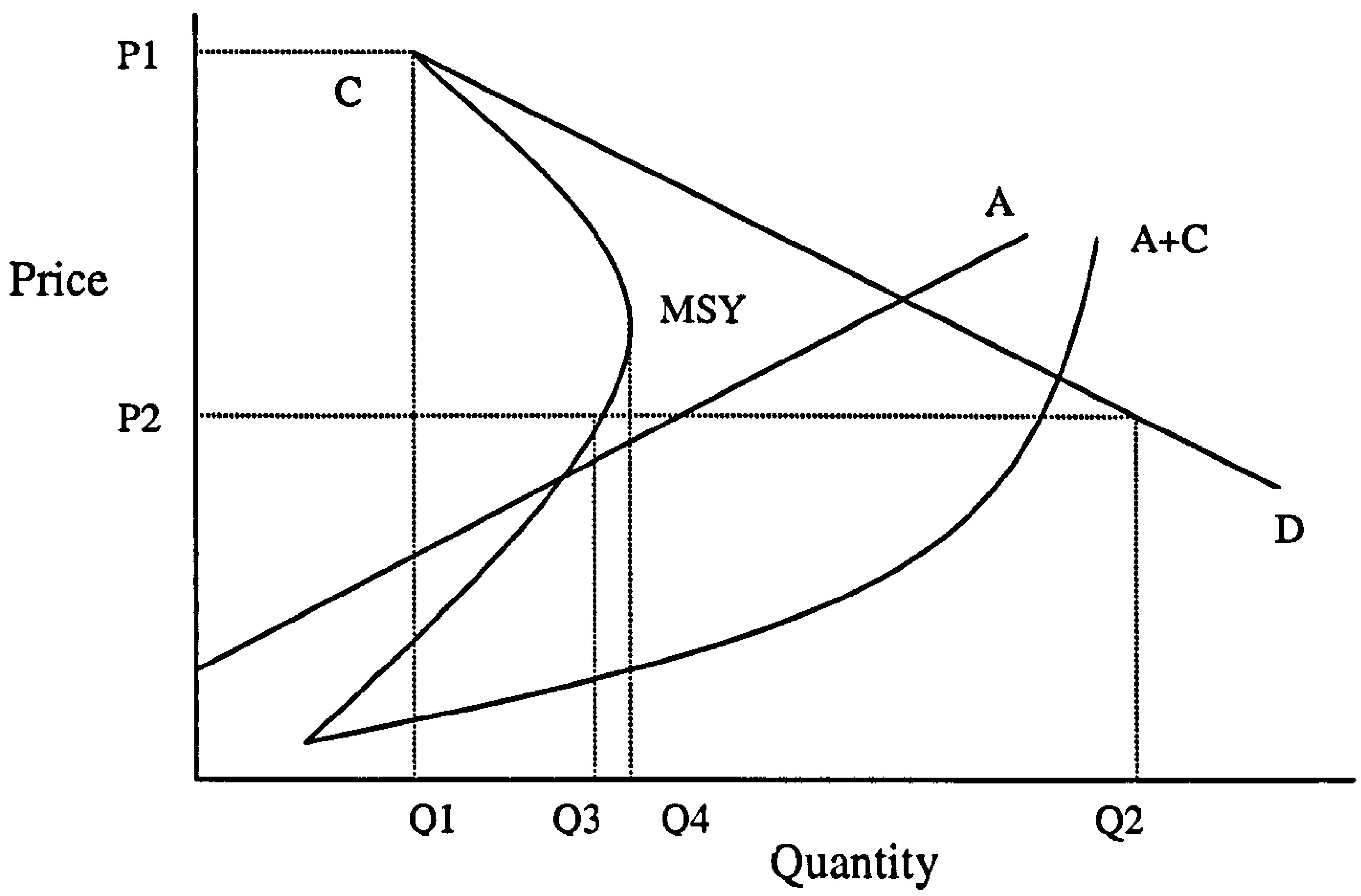


Fig.1.1. Market interaction between common property fishery and aquaculture (Adapted from Ridler, N. B. and M. Kabir 1988).

Apart from generating employment, income and foreign exchange, aquaculture provides markets and raw material input to food manufacturing (Lee 1997). The demand of input materials (backward linkages) and the supply of output commodities (forward linkages) by aquaculture drive a chain of economic activities, which enhance further growth of economy. The demand of input materials like seeds, feeds, nets, fertilisers, chemicals, etc. increases the income of input producers and entails the ancillary activities, such as hatcheries, fingerling grow-out, fry collection from nature, feed processing, pharmaceuticals, specialist engineering services and suppliers, harvesters, post-harvest processing, marketing and storage. The supply of fish products can depress the prices of fish to benefit the consuming public, increase foreign exchange reserves through export of fish to other countries and save foreign exchange by increasing the consumption of locally produced rather than imported fish. Against this generally positive background, the evaluation of the aquaculture industry in Taiwan, the focus of this study can be set out.

1.2 Aquaculture background in Taiwan

With the Tropic of Cancer passing through its southern part, Taiwan is a subtropical area. Monsoons prevail from October to March, and from April to September, periodic typhoon and thunderstorms bring abundant precipitation. Over the period from 1949 to 1986, the average precipitation was 2504 mm, about 3.5 times the world average (Hsiao, 1994a). The average temperature is 23°C and is higher than 20 °C for 9 months after April (Hsiao 1994b). In the southern part of Taiwan, water temperature rarely drops below 10 °C (Liao 1995a).

Though the climate is very suitable for developing aquaculture, Taiwan still faces a shortage of water resource. Its high population density means that each individual can only share about 4,500 m^3 of water, about one-sixth of the world average, from precipitation sources, per year (Hsiao, 1994a). The uneven distribution of precipitation over different seasons makes the problem of water shortage even worse. Most of the precipitation, about 78%, is from May to October. In the southern part of Taiwan, the share of precipitation during this period can be as high as 90% (Hsiao 1994a).

Because of the deteriorating environment (Huang 1997), increasing resource and energy cost of exploitation, and, because of increasing application of control over Exclusive Economic Zones (EEZ) in the world, there are not expected to be any significant wild catch increases for most commercially important species. In Taiwan also, current records suggest that the wild fish catch has reached a plateau (Taiwan Fisheries Bureau 1987-1998) (Table 1.3). Among the sources of fishery products, distant water fisheries* have the highest production quantity, accounting for more than 50%, followed by aquaculture, offshore fisheries and coastal fisheries, accounting for about 20%, 20% and 3% respectively. Table 1.3 shows that except for slightly increased distant water catches, outputs from other fisheries (offshore and coastal fisheries) have declined. The growth rates were 1.2, -3.8, -2.1 and -2.9 in distant, offshore, coastal fisheries, and aquaculture, respectively. Thus, as in the global situation, aquaculture may also be promoted to compensate and supplement fisheries supply.

Production from aquaculture is similar to other fisheries, and has been stable at about 250 to 340 thousand tonnes from 1990 to 1999. As a consequence of its development to date, aquaculture is a valued industry in Taiwan, and is second only to distant water fisheries in terms of its total value produced when compared with other fisheries. In 1999, it accounted for 19% of total quantity of fishery production, but 26% of its total value (Table 1.3). The average prices of products from aquaculture are between 90-130 NT$, far higher than those from distant water fisheries and offshore fisheries, but similar to those from coastal fisheries.

*Distant water fisheries, offshore fisheries and coastal fisheries refer to the fisheries which beyond 200 miles, between 200 and 12 miles and within 12 miles respectively.

Table 1.3 The quantities and values of distant water fisheries, offshore fisheries, coastal fisheries and aquaculture in Taiwan. Unit: 10^3 t/ 10^6 NT$
1US$=32NT$

Year	Distant Water Fisheries			Offshore Fisheries			Coastal Fisheries			Aquaculture		
	Q	V	V/Q	Q	V	V/Q	Q	V	V/Q	Q	V	V/Q
1990	767.0	35249	46.0	292.4	18235	62.4	48.4	3960	81.9	344.3	31531	91.6
	(52.8)	(39.6)		(20.1)	(20.5)		(3.3)	(4.5)		(23.7)	(35.4)	
1991	714.3	32204	45.1	266.9	17457	65.4	41.2	3517	85.3	291.9	30256	103.7
	(54.3)	(38.6)		(20.3)	(20.9)		(3.1)	(4.2)		(22.2)	(36.3)	
1992	737.6	34622	46.9	280.5	16394	58.4	45.4	3327	73.3	261.6	29292	112.0
	(55.7)	(41.4)		(21.2)	(19.6)		(3.4)	(4.0)		(19.7)	(35.0)	
1993	835.0	42701	51.1	258.6	17286	66.8	43.4	3271	75.3	285.3	29816	104.5
	(58.7)	(45.9)		(18.2)	(18.6)		(3.1)	(3.5)		(20.1)	(32.0)	
1994	683.8	36047	52.7	242.3	16084	66.4	39.8	3430	86.2	288.0	33566	116.6
	(54.5)	(40.4)		(19.3)	(18.0)		(3.2)	(3.8)		(23.0)	(37.7)	
1995	709.5	43084	60.7	256.0	16931	66.1	43.5	3976	91.4	286.6	36514	127.4
	(54.8)	(42.9)		(19.8)	(16.8)		(3.4)	(4.0)		(22.1)	(36.3)	
1996	669.0	43828	65.5	256.7	16586	64.6	41.0	4256	103.7	272.5	32727	120.1
	(54.0)	(45.0)		(20.7)	(17.0)		(3.3)	(4.4)		(22.0)	(33.6)	
1997	748.3	49041	65.5	247.6	16673	67.3	40.6	4524	111.5	270.2	26944	99.7
	(57.3)	(50.5)		(18.9)	(17.2)		(3.1)	(4.7)		(20.7)	(27.8)	
1998	839.2	49205	58.6	209.7	14504	69.2	43.6	4382	100.4	255.2	27382	107.3
	(62.3)	(51.5)		(15.6)	(15.2)		(3.2)	(4.6)		(18.9)	(28.7)	
1999	856.7	48914	57.1	205.6	13182	64.1	39.9	4181	104.8	263.1	23508	89.4
	(62.7)	(54.5)		(15.1)	(14.7)		(2.9)	(4.7)		(19.3)	(26.2)	
Growth rate	1.2%	3.7%		-3.8%	-3.5%		-2.1%	0.6		-2.9%	-3.2%	

The figures in parentheses are percentage of total quantities/values.
Data source: Fisheries Administration (2000).
The figures in this table are undeflated

Although production from aquaculture and other fisheries has broadly stabilisied, the population, national and average income is still increasing. From 1987 to 2000, the population increased by more than 2 millions (0.9% per year), and the national (5.96% per year) and average per capita income (4.96% per year) increased by 112.2 and 87.6%, respectively (Table 1.4). The potential demand for fishery products may be increased by these factors. However, the total output (-0.7% per year) and value (0.1% per year) of fisheries did not change to a similar degree.

Table 1.4 The population, national and average income in Taiwan.

Year	Population (Thousand people)	National income (Million NT$)	Average income (NT$)
1987	19,725	4,116,645	210,420
1988	19,954	4,445,103	224,636
1989	20,157	4,757,383	237,798
1990	20,401	4,999,236	247,120
1991	20,606	5,407,640	264,368
1992	20,803	5,724,912	277,173
1993	20,995	6,128,190	293,943
1994	21,178	6,448,149	306,546
1995	21,357	6,734,717	317,451
1996	21,525	7,142,414	333,948
1997	21,743	7,690,149	356,398
1998	21,929	8,159,200	374,669
1999	22,092	8,475,919	386,103
2000	22,277	8,736,165	394,853
Growth rate	0.9%	5.96%	4.96%

Data source: Directorate General of Budget Accounting and Statistics Executive Yuan, R.O.C. (www.dgbas.gov.tw)
The figures are inflation-adjusted and the base year is 1996.

In Taiwan, the history of aquaculture spans over three hundred years. In its development, three major breakthroughs have been commonly recognized. First, the technique for propagation of freshwater finfish was set up after the success of induced spawning of grass carp (*Ceteuopharyngodon idellus*) and silver carp (*Hypopthalmichthys molitrix*) in 1963. Second, in 1968, the development of the artificial propagation of tiger prawn (*Penaeus monodon*) provided a good foundation for the culture of other prawn species. Finally, the successful inducing of spawning and larvae rearing of grey mullet (*Mugil cephalus*) in 1969 established a solid foundation for artificial propagation techniques for other marine finfish species (Liao et al., 1995a). These breakthroughs in the artificial propagation of finfish and shrimp effectively reduced the industries' reliance on wild fry, thereby stabilizing commercial operations and overcoming the barriers for expansion.

Advanced techniques allowed the industry to diversify culture species. In 1970, the industry was already successfully culturing 44 species, including freshwater and marine finfish, crustaceans and shellfish. This reached 105 species in 1991 (Liao 1991). This diversification of aquaculture also helped to satisfy the growing needs of the domestic seafood market.

One of the reasons suggested for the success of aquaculture in Taiwan over the past few decades has been the diligence of the producers. According to a survey on fisheries and aquaculture households in 1992, around 59.1% of aquaculture operators held only an elementary school diploma, while 36.7% graduated from junior and senior high school (Taiwan Fisheries Bureau 1994). Despite this, they were quick to learn and adapt the techniques transferred through training programs and technical support provided by the extension services. These are currently available from a range of sources including the Taiwan Fisheries Research Institute (TFRI), Academica Sinica, some colleges and universities, the national Fisheries Administration and fishermen's associations. Apart from this external technical delivery, fish farmers also developed innovations of their own. For example, the first natural spawning of milkfish was performed by a fish farmer (Lin 1984). The application and innovation of farmers was thus an important factor in the rapid growth of the industry (Liao et al. 1995a).

Taiwan is also located very close to Japan, one of the biggest seafood importers in the world. In 1999, Taiwan exported 418,755 t of fishery products to Japan. It accounted for 32,610 million NT$ (~1,000 US$) (32NT$=1US$) (Fisheries Administration 2000). Therefore, the development of aquaculture in Taiwan is very dependent on the changes of Japanese seafood market.

However, in spite of these positive factors, aquaculture has experienced a declining trend in recent years. This could be part attributed to increasing problems of water pollution and the increasingly high environmental costs generated by aquaculture ventures (Huang, 1990).

Because the water quality in major rivers and dams has significantly deteriorated, the main fresh-water resource for aquaculture is now ground water. For example, the length of severely polluted rivers increased from 5.69% of the total river length in 1983 to 10.4% in 1992 (Huang 1997). Aquaculture has become a significant fresh water consuming industry and accounted for 25% of the total ground water consumption in Taiwan, while the other agriculture ventures accounted for 48% (Huang 1997). Due to too much use of underground water, aquaculture generated a huge environmental cost, with serious land subsidence resulting in the late 1980s and early 1990s (Lee 1997). Based on field investigations in 1992, in the southern part of Taiwan, the area of land subsidence was estimated to extend to1010 km^2. The most serious cases were located in the Ping-Tong area with a local subsidence of 2.5 m vertically (Lee 1997). This very high environmental cost has required limitations to be imposed.

Apart from the environmental problems, marketing constrains and production instability have hampered the development of aquaculture in Taiwan. For example, the Japanese market for eels has stimulated competition from other Asian countries, especially from China, while erratic production of milkfish has induced significant price fluctuation. Such features are considered a hindrance to the orderly growth of the industry. Thus as the domestic market is the major destination for milkfish, if the quantity supplied is too large, the prices may be too low to offset the cost of production. It is clear therefore that if the aquaculture industry in Taiwan is to be sustained, and to grow in the directions which might be suggested, a range of potentially serious impediments may have to understood and overcome.

1.3 The research objective and structure

A number of approaches have been considered for overcoming constraints in the aquaculture sector. Three main areas can be described, which form the basis of this study.

(1).Adjustment of existing production practices - e.g. diversifying productive and marketing strategies in coastal ponds. All the farmers and processors in the aquaculture sector want to predict supply, forecast price and understand what are the most important forces that determine both the quantities supplied and prices. Milkfish culture, one of the most vulnerable sectors suffering from price fluctuation is used as an example to understand both the production cost, market attributes and the ways in which impacts of variations between production and price can be reduced.

(2). Improving existing systems- e.g. intensification of eel culture. One of the methods is to use super intensive culture, which can support high densities and minimise water exchange, reducing the use of ground water. This has been tried in Taiwan for eels, but the cost and benefits of intensifying from traditional methods must be evaluated. As most eel products are exported to the Japanese market, it is very important to examine the comparative advantages against other countries.

(3). Develop new systems- e.g. cage culture. One of the solutions to addressing the constraints of land-based aquaculture in Taiwan is to develop seawater-based cage culture. This has been carried out to a limited degree in Ping-Tong and Pen-Hu counties but the feasibility and profitability have not been investigated.

There are therefore three cases assessing aquaculture development in Taiwan, i.e. milkfish, eel and cage culture. These three cases are described in three chapters. In each chapter, there are three major sections – outline of situation, financial and economic perspectives, and marketing issues. The thesis is divided into seven chapters and. the layout of the study is as follows:

Chapter 1: generalise the situation of world aquaculture and aquaculture background in Taiwan, including its environment, situation, process of development and constraints confronted. Finally, the research objective and structure are described.

Chapter 2: presents the problems and research hypothesis, describes the research methods, including data collection, sample design, data analysis and interpretation, and the selection of research area.

Chapter 3: presents the outline of milkfish culture, including the situation of milkfish culture, characteristic of milkfish producers and farms, financial analysis, marketing channels, relationship between supply and price, consumption level and consumer perspective.

Chapter 4: presents the outline of eel culture, including the situation of eel culture, management of traditional and super intensive eel culture, characteristic of farmers, financial analysis, post-harvesting process, marketing channel, analysis of Japanese market, and Taiwanese market survey.

Chapter 5: presents the outline of cage culture, including the situation of cage culture, legal rights, culture system, financial analysis, marketing channels and constraints.

Chapter 6: brings the findings from each of these cases together to make an overall assessment of sustainability. In this chapter, the sustainability of aquaculture in Taiwan is examined and the ways and methods that might be suitable for the development of aquaculture in Taiwan are suggested.

Chapter 7: provides conclusions and recommendations for further research based on the results from the previous chapters.

Chapter 2

Methodology

2.1 Introduction

The purpose of this research is concerned with diagnosing the current situation, setting objectives, and generating potential alternative strategies for the development of aquaculture in Taiwan. To achieve this, it is necessary to understand the situation, strength, and weakness of aquaculture in Taiwan, from which the future trends and issues can be proposed and proper objectives and potential strategies can be developed. To attain these aims, the collection, analysis and interpretation of data were carried out, from which information could be developed to assist in diagnosing and deciding objectives and potential strategies. The definition of this research is illustrated in Fig. 2.1.

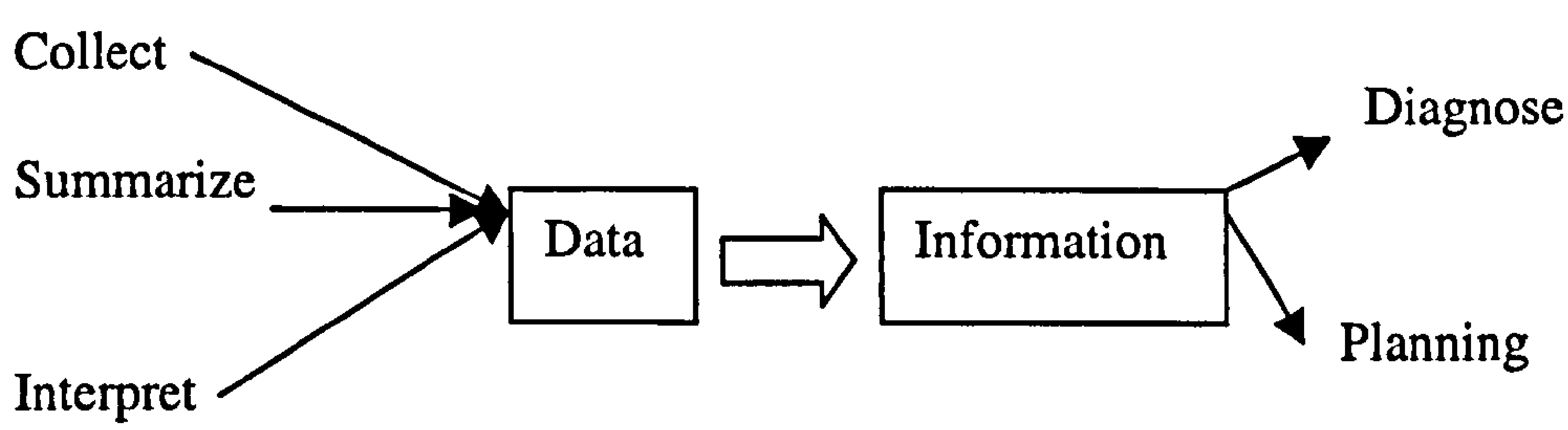


Fig 2.1 The definition of research (modified from Kent.1999).

This chapter describes the research strategy and methodology followed to achieve the objective of the study. There were five basic steps in the research process (Fig.2.2). They are

(1) defining and locating problems,

(2) developing hypotheses,

(3) collecting data with which to test and modify the hypotheses,

(4) analyzing and interpreting research findings, and

(5) reporting research findings.

These five steps were viewed as an overall approach to conducting the research rather than a rigid set of rules. In conducting this research, each of the steps and how they can best be adjusted were considered. It also describes the selection of the research sites.

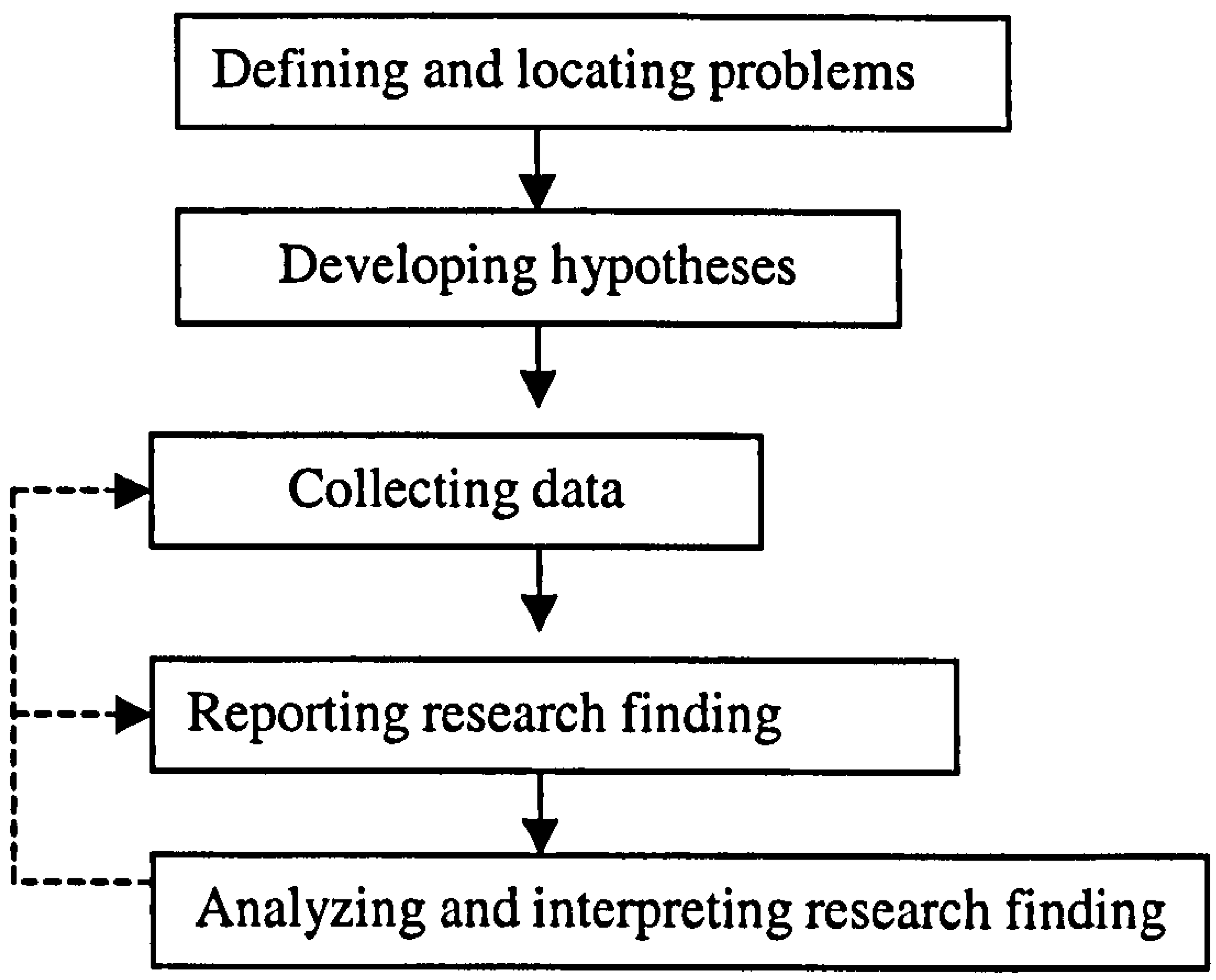


Fig 2.2 The five steps of the research process.

2.2. Defining and locating the problems

Taiwan has had a history of Chinese traditional fish farming for at least three centuries. The development can be divided into three distinct stages. In the traditional stage 1661-1962 (Liao, 1992), the first recorded cultured fish was milkfish (*Chanos chanos*). In this period, production from aquaculture was low with total output of no more than 20,000 t per annum in the 1930s and 1940s (Sheeks, 1989). Production gradually increased, peaking at 53,453 t in 1961. A more prosperous stage developed from 1963 to 1991. With systematic promotion, diversification (Liao, 1992) and modernization in the 1960s and 1970s, output increased more than ten-fold, to reach 201,925 tons in 1981, accounting for 22 percent of the total weight and 33 percent of the total value of all fisheries production. In 1990, the peak year to date, total production reached 344,263 t, valued at 31,530,575,000 NT$, with an average sale value per t of about 92,000NT$ (2875 US$).

The rise in output was largely due to several revolutionary breakthroughs in research during the 1960s and in subsequent decades, as earlier described. However, the collapse of tiger prawn rearing, the competition from other countries (such as China and Malaysia) in exporting eel to Japanese market and the shortage of eel fingerlings (elver) made these industries decline. Limited land and water resources also started to restrict development of aquaculture in Taiwan. For example, the excessive draw down of underground water had caused a serious problem with the water table, resulting in a partial settling of land and salinisation of underground water in the vicinity of aquaculture areas (Liao 1992).

In 1990, Taiwan commenced a process of transformation to address these constraints, and to attempt to sustain the industry. There have been various directions for the aquaculture in Taiwan to change. The first direction has been to go back to traditional fish culture, such as milkfish and Chinese carps. The second direction has been to apply new techniques from other countries, such as using water recirculating systems for eel culture to reduce the usage of fresh water. The third direction has been to shift the culture area toward the ocean, using systems such as sea cages. The aim of this research is to examine each of these strategies, to assess their relative potential. As potential directions, 3 cases were identified, i.e. milkfish culture in traditional style, eel culture in recirculating style and marine fish culture in sea cages.

2.3 Hypothesis

To develop and structure the research work, an objective statement was set out including hypotheses drawn from both previous research and expected research findings. In this sense, the hypothesis can be considered as an informed proposal or assumption about a certain problem or set of circumstances which can then be subject to test and evaluation, following which a clearer range of actions or potentials could be recognised (Dibb et al., 1997). The basic hypothesis of this research concerns whether aquaculture is capable of continuing and developing, and whether the change of structure and operation in aquaculture is feasible. The fundamental hypothesis is that it is feasible to go back to traditional fish culture, to apply new technology from other countries and to shift the culture area toward the ocean. Three cases are used to test this linked hypothesis. To do this, some factors must be understood. They are the biotechnical, social economic background, and from these, the definition of opportunities, goals, strengths, weakness, threats and strategies. The three stages for attaining this are illustrated in Fig. 2.3. In the first stage, must be understood the basic situations, which include the input, market, environment, infrastructure and structure of aquaculture in Taiwan. These include what, where, how much (capacity), who and how to operate. The second stage is to understand how are they changing, why are they changing and when are they changing? The third stage is to predict how will it go in the future and how to adjust?

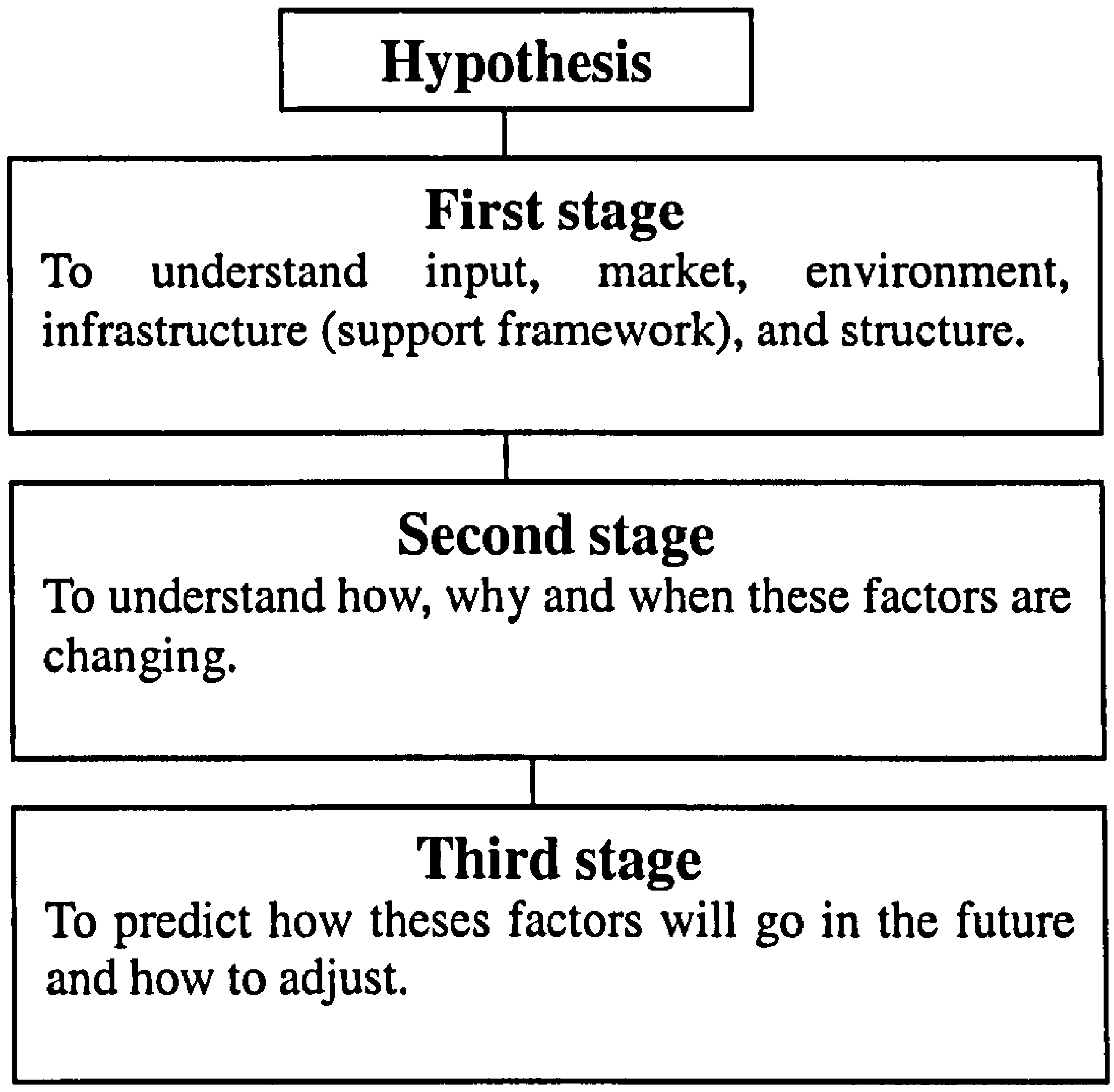


Fig 2.3 The three stages to fulfill the test of the study hypothesis.

2.4 Data collection

2.4.1 Data source

Both primary and secondary data were collected. Primary data were observed and recorded or collected directly from respondents. This included interview by questionnaire, discussing with key informants (fish farmers, marketing traders and school teachers etc.) and personal contacts. There are three main categories of questionnaire- interview, telephone and postal surveys. To avoid misunderstanding of questionnaires, interview surveys were used. However, some farmers only accepted telephone surveys. Four versions of questionnaires were used for each producer group: milkfish farmers, traditional eel farmers, super intensive eel farmers and cage farmers.

Secondary data refers to information and statistics that are already collected, and processed to varying degree. These include government reports, such as the Year Book of the Taiwan Fishery Bureau; unofficial published statistics, the result of previous in-depth research, and the statistics from internet (such as global production of milkfish; population; national and average income in Taiwan) etc. Secondary data can be uneven in coverage, availability and accessibility. It may focus only on specific topic and sometime, it can also be unreliable. However, secondary data still have advantages, often providing information that is not available elsewhere and that cannot be collected in a project context.

2.4.2 Sample design

Two kinds of sample design can be identified- purposive and representative samples. Purposive samples are generated when the case is chosen by the researchers' own judgement. The selection may be deemed to be the most important, reflect a variety of extremes, or those they are typical. Representative samples are chosen in a way that reproduces the structure and features of the population through cases from which the samples were drawn. They are used to make estimates of a population's characteristics (Kent 1999). In this research, representative samples were chosen.

Lists of fish farmers were obtained from fishery agencies of local governments and local fishermen associations, and respondents were selected by simple random sampling. The sampling points are carefully chosen in such a way to obtain a representative cross-section of types of areas. Before interviews, they were contacted by telephone in advance. Face-to-face and telephone interviewing methods were used.

In the area of marketing research, three approaches can be defined- exploratory, descriptive and causal marketing research. Exploratory research is aimed at generating insight, idea and hypotheses rather than measuring or testing them. However, descriptive research is characterized as being concerned with measuring or estimating the size, quantities or frequencies. Causal research is typically seen as concerned with establishing cause-and-effect relationships in an attempt to explain why things happen (Kent, 1999). In this study, consumer surveys were carried out and were descriptive in nature. 2 kinds of questionnaires were used for consumers' survey- for milkfish and for eel consumers. The reason that the consumers' survey for cage culture was not performed is that some species from cage culture (such as grouper) overlapped with those from land based aquaculture.

Before the survey, pre-tests were implemented on pilot groups of respondents to see how they worked. As a consequence of the pre-test, some redesigns of questionnaires were conducted. The questionnaires are presented in Annex A1- Annex A6.

2.4.3 Quantitative and qualitative data

Both qualitative and quantitative information was sought. Qualitative research does not seek to establish absolute values but rather to build up an accurate interpretation of what is being researched, through many different descriptive sources. They are therefore, non-numerical records and arise as words, phrases, statements, narrative, text or pictures (Kent. 1999). Qualitative data can be obtained from interviews, discussion and observation. Qualitative research is usually used for exploratory purposes, in areas where little research has been done, and may be used to diagnose problems in detail.

Quantitative research seeks as far as possible to place firm, absolute levels or values on the investigation. Quantitative data are numerical records arising from a process of measurement. This may be done by using simple count (such as members in family, numbers of farms), economic calculation (such as cost and benefit analysis, net income) and statistical inference techniques (such as inference of the trend of price/production). Table 2.1 shows the comparative strengths and weaknesses of quantitative and qualitative research.

Table 2.1 The strength and weaknesses of quantitative and qualitative research.

Type of research	Strengths	Weaknesses
Qualitative	Provides the initial basis for further quantitative work (may be sufficient on its own) More participatory Can be quick and low cost Good for social processes and context Can explain causes of quantitative finding	More prone to bias because of reliance on interpretation Difficult to infer population characteristics from a small sample Can be very time consuming
Quantitative	Can be more concrete, systematic Can infer population characteristics from a small sample Can test the significance of quantitative findings	Concreteness can be misled Can be very extractive Tendency to collect too much data and to produce over-complex analysis

Adapted from DFID (Department for International Development). In the website: www.livelihoods.org

Effective research in this context needs a combination of qualitative and quantitative research methods, the combination of which will vary according to the tasks. Here, each of the three cases contains qualitative and quantitative data, with qualitative data being used for the basis of each case and quantitative data for economic and statistic inference.

2.5 Analyzing and interpreting research findings

Three activities can be defined in data analysis - display, reduction and statistical inference (Kent, 1999). For qualitative data display, quoted text extracts checklists or tables were used, while for quantitative data, table or chart formats were used. Qualitative data reduction involved paraphrasing and summarizing statement, classifying responses into categories, using quasi-statistics (e.g. the data from questionnaires of consumers' opinion transferred to frequencies). Quantitative data reduction used statistical methods, such as calculating averages, to reduce the data to a few key summary measures, after they were analyzed. Statistical inference focused on what was typical or what deviated from the average. Variables included descriptors, independent variables and dependent variables, indicating how widely responses varied (such as Chi-square test) and how they were distributed in relation to the variables (such as regression) being measured. In this study Excel, Minitab and SPSS were used to perform the statistical analysis.

2.6. Research locations

2.6.1 Milkfish farms

Because milkfish are better acclimated to warmer water, most milkfish farms are located on southwest part of Taiwan, which has therefore been the major research area. This includes Cha-I and Tainan county, Tainan City, and Kaoshung and Ping-Tong county (Fig 2.4). A total of 286 milkfish farms were surveyed.

2.6.2 Eel farms

Similar to milkfish farms, most traditional eel farms are located on southwest part of

Taiwan. The research areas for eel farms were in Jang-Hwa, Yun-Lin, Cha-I, Tainan, Kaoshung and Ping-Tong county (Fig 2.4). In total, 63 traditional eel farms were surveyed. The indoor intensive eel culture is an infant industry in Taiwan, and therefore, only 5 farms were surveyed, located in Taipei, Tao-Yen and Tainan county.

2.6.3 Cage culture

Most cage farms are located in Pen-Hu Island and Ping-Tong county (Fig 2.4), and therefore, only these 2 areas were surveyed. A total of 17 traditional fish farms and 5 submersible fish farms were surveyed.

2.6.4. Consumers' opinion

In 1999, 132 consumers were surveyed to understand their opinion on milkfish and eel by questionnaires. The consumers' opinions from 3 areas are surveyed. The three areas were Taipei City (52 consumers), Taichung City (45 consumers) and Tainan City (35 consumers). These represented the northern, central and southern parts of Taiwan respectively (Fig.2.4).

2.7 Discussion

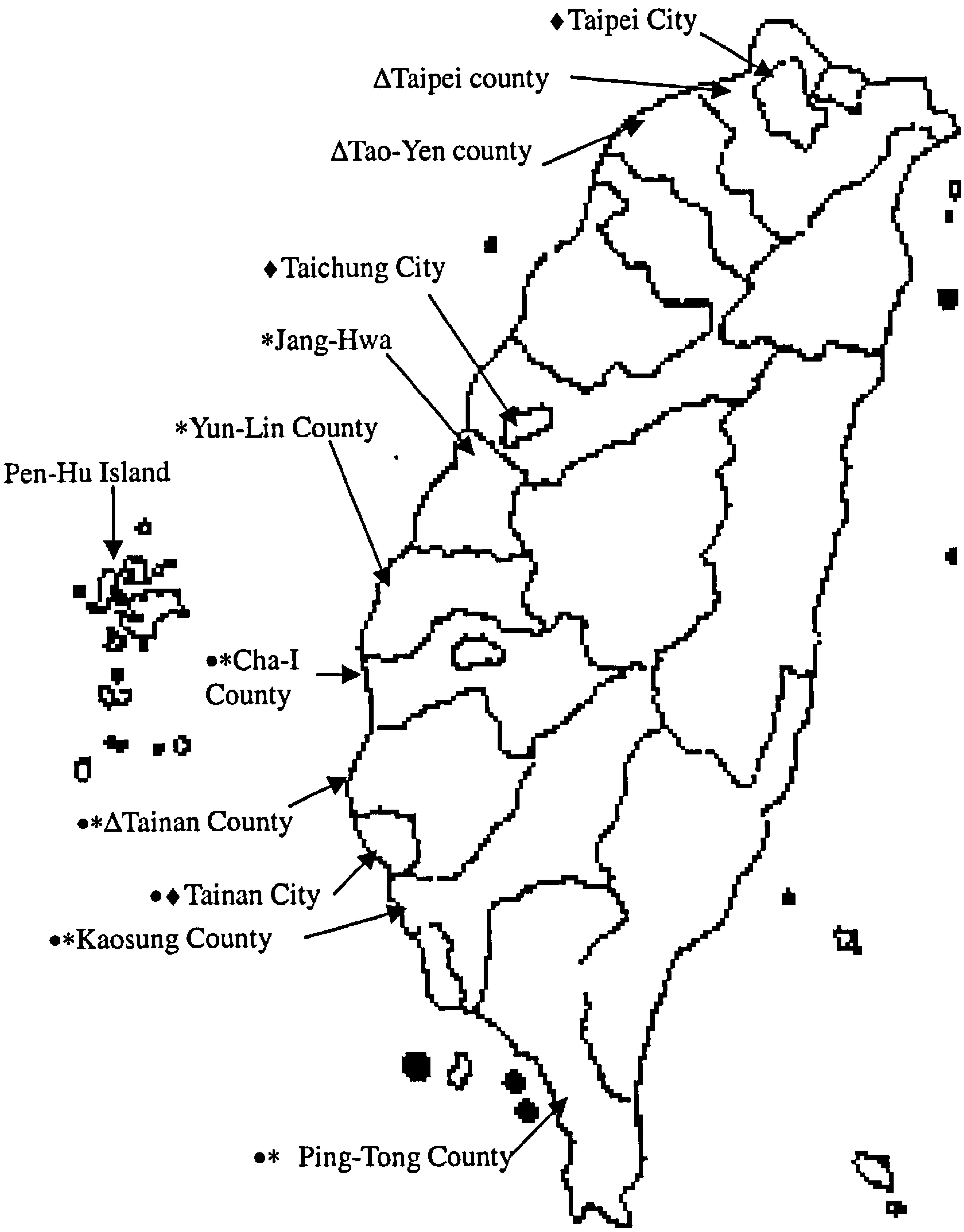
In Taiwan, people dislike to be interviewed and are becoming increasingly aware of their rights and are sensitive about the invasion of their privacy. Some interviewees only accepted telephone interviewing and some just rejected the interviews. The most serious drawback of random samples perhaps is there is a degree of non-response. The disadvantage of postal questionnaires is the low response rate. Some people are reluctant to answer some sensitive questions. In these circumstances, broad categories may be more suitable for these questions, and more personal demographic questions may be better asked at the end of questionnaire. When drafting questionnaires there is a tendency to put in all questions that might seem relevant. This can result in a very long questionnaire that may have an impact on the respondent's willingness to finish. Therefore, a pre-test was carried out to ensure that questionnaires were appropriate. These were also helpful in understanding the real situation and in wording the questionnaire properly. Questionnaire wordings need to be clear, to help respondents understand the questions and be willing to provide answers. In spite of these drawbacks there are some advantages in using questionnaires.

- Detailed information can be collected from small samples about a population, so minimizing costs and source requirements.
- Standardization of questions and answers allows for comparisons to be made.
- They help reveal whether sample populations are relatively uniform or highly heterogeneous, thereby improving the design of programmes.

However, there are also other disadvantages.

- Researchers may underestimate the time taken to process and derive results from that data. This can result in much unutilized data and great delays between collecting the information and being able to act on the data.
- Researchers may feel impelled to skip simple data analysis in favor of sophisticated statistical routines. In the process, more obvious insights can be overlooked and valuable interpretation may be neglected.
- Asking for information about incomes, some assets and intra-household issues can be very sensitive (and sometimes cannot be done at all).

Where research is based on asking people questions, response errors may arise. These may be because of dishonesty, forgetfulness, faulty memories, unwillingness or misunderstanding the questions being asked. In addition to response errors, sampling errors might be made (Kent 1999). These errors might be reduced by increasing the sample size. However, larger samples will cost more and take more time to complete in a very practical issue.



•Locations for milkfish farms
*Locations for traditional eel farms
Δ Locations for super intensive eel farms
Locations for cage culture farms
♦Locations for consumers' opinion

Fig 2.4 Research locations.

Chapter 3

Milkfish culture

3.1 Introduction

The Milkfish (*Chanos chanos*) is one of the most extensively farmed marine bony fishes in the world and is an important culture species in Southeast Asia (Liao, 1993). It has a broad geographic distribution, existing virtually throughout the entire tropical Indo-Pacific Ocean and is found as far east as the Pacific waters off Central America (Lee, 1995). The large-scale culture of milkfish is carried out in the Philippines, Indonesia and Taiwan (Boonyaratpalin 1997), where it has had a long history. It is generally stated that milkfish farming started in Indonesia at least 500 years ago (Schuster, 1952), though Ronquillo (1975) considers that the culture can be traced back 700 years. In the 16th century, milkfish culture was introduced to the Philippines and Taiwan, and in the 17th century in Hawaii (Ling, 1977).

Milkfish have a number of advantages in coastal aquaculture. They can tolerate salinity changes from 0 to 150 ppt (Crear, 1980), and are resistant to disease and handling. According to FAO (2001), there are only 6 countries (Guam, Indonesia, Kiribati, the Philippines, Singapore and Taiwan) recording the aquaculture production of milkfish. Indonesia, the Philippines and Taiwan are the major producing countries, accounting for more than 95% of world production. Total annual production from milkfish culture has exceeded 300,000 tonnes since 1981 (Lee, et al 1997) and in 2000, culture in the three major milkfish farming countries yielded 461,857 tonnes (Table 3.1). The annual production fluctuates, and was more than 400,000mt in 1990, 1991, 1999 and 2000.

The production quantity and value from Taiwan accounted for ~ 6.3-20.9% and 7.5-17.4% of global production quantity and value, respectively. The highest production from Taiwan was in 1990 and 1994, reaching 90,000 and 66,000 t, accounting for 20.9 and 17.5% of world production, respectively. However, the production has gradually declined since 1994, and in 2000, production from Taiwan reduced to 39,700 t, accounting for 8.6% of world production. The Philippines and Indonesia produced more than 80% of global production quantity and value (Table 3.1), while that from the Philippines was unstable, the highest quantity reaching 23,400 t, in 1991 accounting for 52.2% of world production. Production from Indonesia showed an increasing trend and reached 21.7 thousand t in 2000, accounting for 47.0% of world production.

The average prices of milkfish fluctuated and were 1.15-2.32 US$/kg in Taiwan, and1.23-2.22 US$/kg in the Philippines from 1988 to 2000. The ratios of highest to lowest price were 0.50 and 0.55 in Taiwan and the Philippines, respectively. However, the average price was stable in Indonesia and ranged from1.50-1.90 US$ (Table 3.2). The ratio of highest to lowest price was 0.79. Compared to Taiwan and the Philippines, year to year price fluctuation in Indonesia were insignificant.(Table 3.1 and Table 3.2).

Table 3.1 The production quantity and value of milkfish in three major milkfish farming countries (Taiwan, the Philippines and Indonesia). Unit: mt/ US$

Year	Taiwan		Philippines		Indonesia		Global Total	
	Q	V	Q	V	Q	V	Q	V
1988	39853 (11.5)	68428 (14.2)	187877 (54.3)	237818 (49.2)	118001 (32.1)	177001 (36.6)	345823	483460.8
1989	21157 (6.3)	38047 (7.5)	192896 (57.8)	252693 (50.0)	119339 (35.8)	214810 (42.5)	333495	505789.3
1990	90716 (20.9)	104560 (16.4)	210882 (48.6)	294628 (46.2)	132432 (30.5)	238377 (37.4)	434123	637808.3
1991	41298 (9.9)	52535 (8.6)	234123 (52.2)	286969 (47.2)	141024 (33.9)	267945 (44.1)	416520	607651.5
1992	25146 (7.3)	58263 (9.6)	171116 (49.8)	266607 (44.1)	147032 (42.8)	279360 (46.2)	343359	604410
1993	45524 (12.7)	72819 (12.0)	148965 (41.5)	239373 (39.3)	164448 (45.8)	296006 (48.7)	359012	608398
1994	66784 (17.5)	110616 (15.8)	161006 (42.3)	312469 (44.7)	153093 (40.2)	275567 (39.4)	380938	698812
1995	63254 (17.3)	106819 (15.4)	150858 (41.3)	315004 (45.4)	151256 (41.4)	272260 (39.2)	365408	694211.5
1996	58453 (15.8)	129998 (17.4)	150151 (40.5)	333684 (44.6)	162127 (43.7)	283722 (38.0)	370765	747522
1997	62749 (15.4)	93287 (14.1)	161426 (42.8)	309437 (46.9)	142709 (38.9)	256876 (38.9)	367286	660463.3
1998	58349 (15.4)	74807 (13.1)	162401 (42.8)	209766 (36.8)	158666 (41.8)	285598 (50.1)	379593	570473.9
1999	50824 (11.8)	72427 (10.5)	170677 (39.5)	238949 (34.7)	209758 (48.6)	377564 (54.8)	431678	689501.8
2000	39730 (8.6)	64585 (9.0)	204204 (44.2)	258644 (36.2)	217208 (47.0)	390974 (54.7)	461857	715090.1

Data source: FAO, 2001 (www.fao.org/fi/figis/tseries/index.jsp)
The figures are undeflated.
Figures in the parenthesis are the ratios to total global production

Table 3.2 The ratios of production value to production quantity of milkfish in three major milkfish farming countries. Unit: US$/kg

Year	Taiwan	Philippines	Indonesia	Global Total
1988	1.72	1.27	1.50	1.40
1989	1.80	1.31	1.80	1.52
1990	1.15	1.40	1.80	1.47
1991	1.27	1.23	1.90	1.46
1992	2.32	1.56	1.90	1.76
1993	1.60	1.61	1.80	1.69
1994	1.66	1.94	1.80	1.83
1995	1.69	2.09	1.80	1.90
1996	2.22	2.22	1.75	2.02
1997	1.49	1.92	1.80	1.80
1998	1.28	1.29	1.80	1.50
1999	1.43	1.40	1.80	1.60
2000	1.63	1.27	1.80	1.55

Data source: Calculated from Table 3.1.

In Taiwan, although a range of other species has now been developed, milkfish remains one of the most important species, with farms distributed along the SW coast of the island. It is generally believed that the culture was already practised in Taiwan during the reign of Cheng, Cheng-Kung (known in the west as Koxinga) in the 1640s who set up his court and government near Tainan , in SW Taiwan, where a milkfish farm was built and named in his honour (Liao 1992). The area of milkfish farming had increased to 12,545 ha by 1990 (Annex B.1), though this was due to the collapse of tiger shrimp culture, after which some shrimp farmers adapted their ponds to cultivate milkfish. In 1990, output reached 90,673 mt i.e. about 26.3% of total aquaculture production (Annex B.2).

However, overproduction had created some economic distress for milkfish farmers with market price dropping from 60-100NT$/kg to 40-45NT$/kg (32NT$=1US$) i.e. 1.9-3.1, to 1.3-1.4 US$/kg (Liao.1993), as a results of which, some producers started to de-commission their farms. In 2000, the remaining actual culture area was about 13,000 ha and production was about 40,000mt (Annex B1 and Annex B2). Compared with 1990, the highest year of production, the real culture area increased 4.0% by 2000, and this was an increase of 60.7% over the area in 1987, before the collapse of tiger shrimp. Regarding output, compared with 1990, the highest year of production, this decreased 56.16% by 2000. Though low, this was an increase of 37.8% over the production level in 1987. The reason why the production reduced while culture area increased (i.e. yields dropped) was due to cold weather in 2000.

Table 3.3 shows that there is an increasing trend in the ratio of polyculture area to monoculture area. In 1987, this was only 20.79%, increasing to 68.72% in 1996 and 105.27% in 1997, but returning to 70.65% in 2000. The ratio of fresh water to brackish water area had also been increasing. In 1987, the ratio was 19.42%, attaining 56.17% in 1997, but returning to 36.3% in 2000 (Table 3.3). It appears that the ratio of polyculture area to monoculture area, and the ratio of fresh water area to brackish water area have had a positive relationship. The change of the ratio of production value to quantity describes the change in average price. Table 3.4 demonstrates that this ratio is very unstable. Comparing average values per t between brackish and fresh water systems that from brackish water is not always higher. Although people considered there to be risks of off-flavor from fresh water ponds, milkfish cultivated in fresh water using feeds can be fatter and look better (Ding 1994), and can therefore fetch higher price.

Since 1993, the ratio of milkfish culture area to total national aquaculture area has ranged from 11.2-21.3% and that of milkfish to total aquaculture output has ranged from 15.5-23.2% (Annex B1 and Annex B2), indicating its comparatively high productivity. This is possibly due to the introduction of the deep water system (see later) in the 1980s, in which farmers intensified production by using feed instead of just using fertilizers. In 1987, average productivity was about 3.47 t $ha^{-1}yr^{-1}$, rising to 6.73 t $ha^{-1}yr^{-1}$, in 1997. By contrast, the ratio of milkfish to total aquaculture output value ranged from 6.4 -10.9% since 1993 (Table Annex B2), and the ratios of production value to quantity were far lower than that of total aquaculture products (Table 3.4), confirming that, milkfish is not a high value species in Taiwan.

Table 3.3 The ratios of polyculture area to monoculture area and fresh water area to brackish water area of milkfish culture in Taiwan.

Year	Ratios of polyculture area to monoculture area	Ratios of fresh water area to brackish water area
1987	20.79%	19.42%
1988	31.10%	31.65%
1989	51.95%	41.45%
1990	38.99%	42.89%
1991	50.54%	43.28%
1992	52.59%	33.86%
1993	45.21%	41.64%
1994	44.96%	39.14%
1995	49.45%	41.09%
1996	68.72%	49.40%
1997	105.27%	56.17%
1998	60.28%	53.10%
1999	55.30%	43.52%
2000	70.65%	36.29%

Data source: Calculated from Annex B 1 and are real culture area.

Table 3.4 The ratio of production value to production quantity of milkfish in Taiwan.

Year	Brackish water pond	Fresh water pond	Total milkfish	Total Aquaculture
1987	54.34	54.53	54.40	115.35
1988	50.44	47.05	49.03	114.56
1989	45.80	49.24	47.19	106.20
1990	30.99	31.22	31.03	91.59
1991	36.16	30.29	34.15	103.66
1992	60.74	54.32	58.30	111.95
1993	45.14	40.39	42.15	104.52
1994	43.86	43.82	43.83	116.56
1995	51.87	54.00	53.05	127.39
1996	51.68	69.60	61.08	120.09
1997	42.26	42.42	42.34	100.32
1998	45.40	40.50	42.88	106.75
1999	48.76	46.88	47.72	90.40
2000	54.13	48.53	50.82	101.06

Data source: Calculated from Annex B 2.

3.2 Methods of milkfish culture

The procedure for milkfish culture includes fry acquisition, nursery stage production, grow-out, overwintering and harvest. The procedure is shown in Fig 3.1. and will be discussed in the following paragraphs.

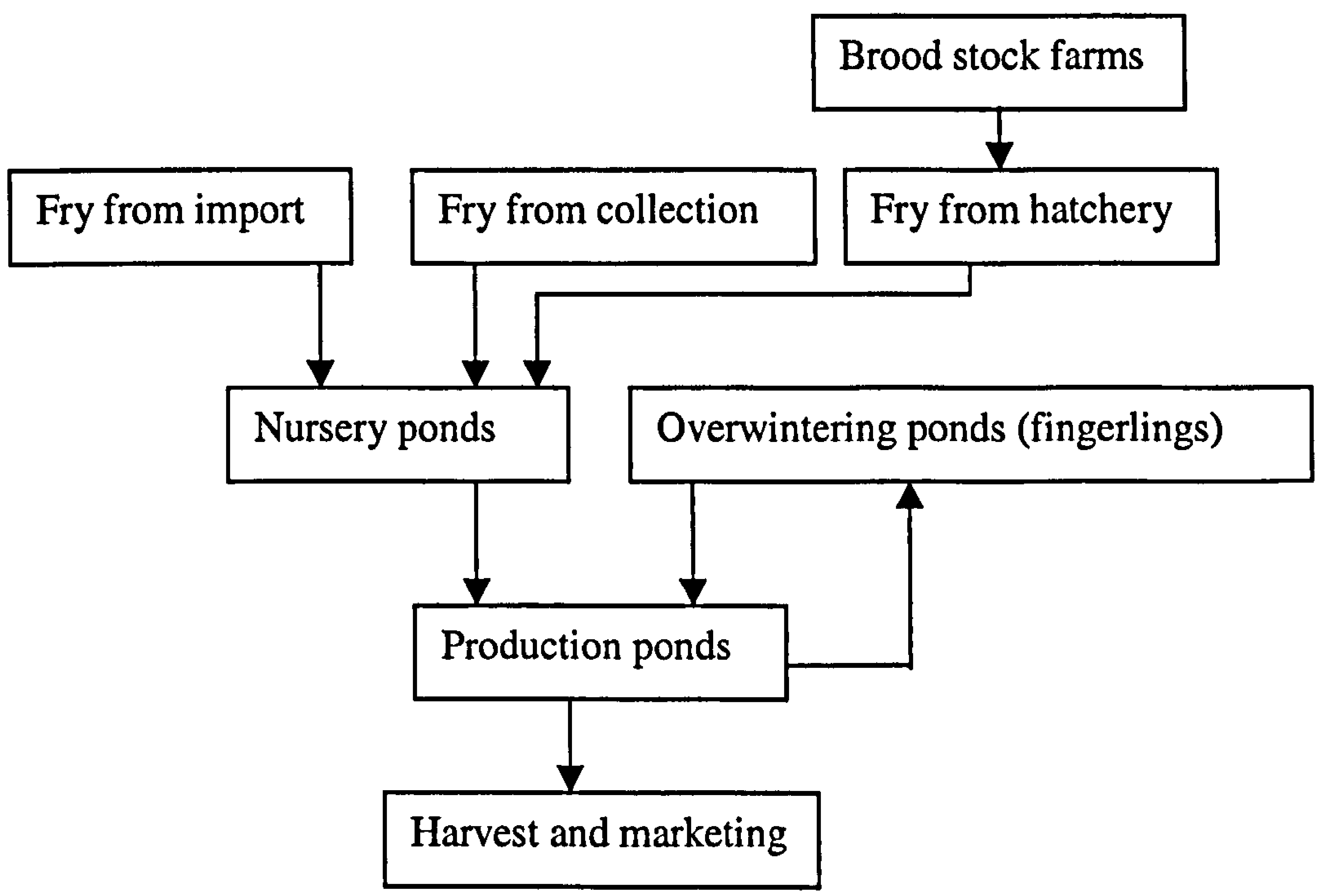


Fig 3.1 The production procedure for milkfish culture in Taiwan.

3.2.1 Fry collection and distribution

Traditionally, milkfish fry were caught from the wild, annually during natural spawning. This was the sole source for culture until natural spawning in captivity and mass larval rearing in hatcheries were achieved in the late 1980s. Milkfish larvae are pelagic. Younger larvae (less than 10mm TL) occur mostly near the surface, but also down to 20-30 m, while older larvae (≥ 10mm TL) occur only near the surface. Younger larvae are found both far from and near the shore, but older larvae occur only inshore (Bagarinao, 1994). In the past, milkfish fry collection was an important source of extra income for many fishermen. Usually, wild fry are considered stronger than cultured fry and command a higher price (Chang et al., 1993). However before the success of natural spawning in captivity, fry supply from wild source was unpredictable and fluctuated significantly, with fry shortages occurring in some years, in which case, Taiwanese farmers imported fry from the Philippines, Indonesia and Malaysia.

Milkfish fry can be collected from March to October, but the peak season is between April and July. Newly caught milkfish fry of about three weeks age are 12-16 mm in length, 0.03-0.11g in weight and are nearly transparent. The traditional gear, still commonly used, is a triangular scoop net, pushed forward in chest-high water (Chen 1990). A more efficient method uses a modified seine with an open-end net bag, pulled at the same depth of water by two fishers, or by one in the water and another on a bamboo raft. Fishermen stop their operations periodically to dip the fry out through the opening at the end of the net bag, which is suspended on the water surface by a float. Since the late 1960s, motorised boats have also been used to tow the scoop net or seine net, extending the fishing area further off shore and increasing capacity.

Collectors sell fry to buyers who accumulate them in shaded tanks, with 10cm water depth, sited near the collecting area. Fry are then sealed in oxygen-filled plastic bags, one-third filled with 10-15 ppt salinity water, and delivered to fry dealers. The dealers then hold the fry in concrete tanks, and feed twice daily with wheat flour and occasionally egg yolk. The water in the tanks has to be changed at least daily (Chen 1990). However, after the success of natural spawning, the availability of cheaper hatchery-produced fry has made some fishermen lose interest in collecting wild fry. In turn fish farmers have fewer options but to accept cultivated fry.

3.2.2 Hatchery reared fry

Boodstock

The prime market size for milkfish throughout most countries in Asia is about 300 to 400 g, usually less than one year old. Liao and Chen (1984) reported that milkfish in captivity showed gonadal maturation in 5-year-old males and 6-year-old females but satisfactory spontaneous spawning only occurred from the age of 10 years (Lin, 1984). Thus, traditional milkfish farming has had little emphasis on producing sexually mature and reproductively active fish in captivity. In Taiwan, the first successful induced spawning was in 1979 (Tseng and Hsiao 1979; Hsiao and Tseng 1979, and the first success of spontaneous spawning was achieved in 1983 (Lin 1984). Although spawning can be induced by hypophysation or hormone implantation (Lee et al. 1986, Liao and Chen 1984, Lin 1982, Marte et al. 1987), there are drawbacks, with inconsistent success in fertilization. Frequently, males do not release sperm at the same time that females spawn, and stripping the ovary is not very effective, as it can injure or even kill the fish and, the resultant fertilization rates are relatively low. Spontaneous spawning is therefore preferred.

To reduce cost, brood stock milkfish are commonly cultured in ponds in lower densities with other main culture species in ponds, such as mullet, grouper or tilapia, before they reach maturity. Because the spawners easily get injured and may even die after poor handling, the harvest of other species must be done with extreme caution. Spawners with well-developed gonads are very sensitive to low dissolved oxygen and bigger fish usually die faster than others when oxygen is sharply depleted (Chang et al. 1993). Spawners are usually transferred into spawning ponds two months before the spawning season, with a recommended stocking density of 0.5 fish/m^2 surface area and a sex ratio of 3 female to 1 male (Lee 1995). Spontaneous spawning usually occurs after midnight and seems to be a significantly related to the intensity of moonlight. Mating activity such as chasing before sunset is a strong predictor of spawning after midnight. During strong chasing behavior, the dorsal and caudal fins of spawners come out of the water (Chang et al 1993). The first spawning usually starts in early April and the peak of spawning frequency and egg production occurs from May to July, declining between August and October.

Generally, milkfish can spawn two to four times in one season (Kelly and Lee 1991) and have asynchronous spawning behavior in captivity (Lin 1987). This is different from the observation of wild milkfish in Hawaii by Kuo and Nash (1979). Water temperature and salinity are important environmental factors affecting milkfish maturation and egg quality, spawning occurring within 26 to 34.5°C. At the peak season, water temperatures are usually within the range of 29 to 33°C. Egg quality was found to be better at salinity higher than 30 ppt. Although artificial fertilization can be achieved at 5ppt (Lee 1985), effective spawning was difficult to observe at salinities lower than 26 ppt as eggs sink gradually to the bottom of the pond a few hours after spawning (Chang et al 1993).

Egg collection and incubation

After spawning, a 0.8 mm mesh plankton-net is stretched across a corner of the pond. Paddlewheels are then used to generate currents that pass through the plankton nets, trapping the eggs drifting in the current inside the plankton nets. If the salinity is lower or the price of fry is higher, guarding is done rotationally and the eggs are collected very soon after spawning. Most of the fertilized eggs float at salinities of over 30 ppt. Live fertilized eggs are about 1.2 mm in diameter, translucent with some yellow tinges and are suspended in the water column, while dead eggs normally sink to the bottom and are opaque. The fertilized eggs are usually collected before dawn to prevent them being eaten by other small fish or by the spawners themselves.

After collecting the fertilized eggs and separating and removing detritus, the eggs are transferred to well-aerated tanks. They are then stocked into plastic bags and distributed to larval rearing farmers for incubation. Because broodstock are rarely caught in the wild and are not available from commercial grow-out ponds, fry producers must raise their own. Because broodstock farmers do not have enough facilities and labour to hatch all the spawned eggs, and want to make efficient use of eggs, one central broodstock farmer usually keeps the broodstock and provides fertilized eggs to several satellite hatcheries. The organization and operating systems are shown in Fig. 3.2.

Broodstock farmers offer fertilized eggs, technology, financial support and marketing service to the satellite hatchery farmers and the hatchery farmers provide facilities and labour for hatching. Total earnings from fry sales are typically shared by broodstock farmers and satellite hatchery farmers at a ratio of 4:6 (Lee et al 1997 and Chang et al 1993). The stocking density of fertilized eggs for incubation is about 2 kg eggs m^{-3}, or 1.6 million eggs m^{-3} (1600 eggs/cubic) (Chang 1993). Key management consists of the removal of various suspended substances and dead eggs from the incubation tank. The fertilized eggs will hatch in less than 24 hours at 30°C. Below 30 ppt, increased aeration is required to keep eggs suspended in the water column, and so, the preferred salinity range is about 30-40 ppt.

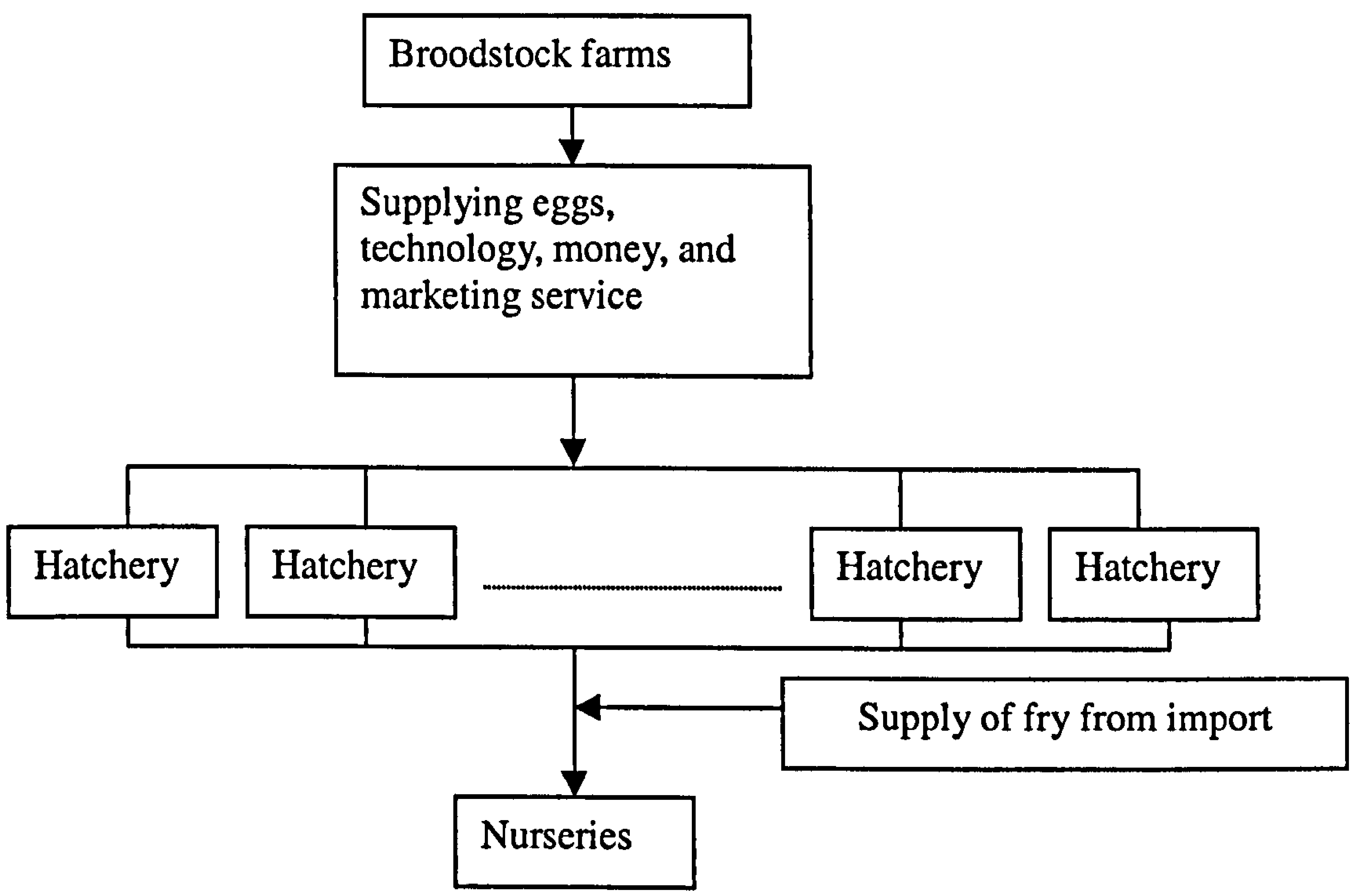


Fig 3.2 Organization and operational systems involved in milkfish fry production in Taiwan (Modified from Chang et al 1993 and Lee et al 1997).

Larval rearing

Outdoor (semi-intensive) ponds covered with black plastic shading are normally used for larvae rearing. The larval density is about 2-3 larvae l^{-1} and aeration is provided at every 2.5 m interval. After hatching, the fry start feeding in about two days and to ensure survival, exogenous feed must be provided before yolk absorption. Green water is introduced into the larvae rearing ponds on the second day after hatching to reduce transparency, since larvae have a phototactic behavior, and it is harmful for them to aggregate in schools and swim up to high light intensity (Chang et al 1993). Larvae can be fed on oyster eggs and smaller rotifers after first feeding, but survival rate can be increased by supplying oyster eggs directly at first feeding. Oyster eggs are supplied for seven days after first feeding and rotifers are supplied on the fifth day or later after hatching. Rotifers can be cultured by using minced trash fish, yeast powder and chicken dung. On the fifteen day after hatching, a start can be made in using fishmeal, eel feed in powder form, or micropellet to feed larvae, and the rotifers gradually replaced.

3.2.3 General layout of shallow-water milkfish culture farms in Taiwan

Traditionally, milkfish farmers used fertilizer (such as chicken manure) to produce benthic algae as food for milkfish. For producing benthic algae, the water depth cannot be too deep (about 30 cm), to prevent the growth of phytoplankton. This method of milkfish culture referred to as the shallow water milkfish culture system, started to be amended in the 1980s, as some milkfish farmers applied the deep water system, in which, the water depth is usually more than 1 m and feed is used (Ding 1994).

Production ponds

Production ponds are usually 3 to 8 hectares in size, rectangular, with the long axis running from east to west to reduce wind-driven waves. Ponds are usually built in the coastal area, and water is supplied by tide or pumped, and salinity changed with the rainfall and evaporation. Water depth is 30 to 40 cm and even in the deepest area; only 45 cm deep. To prevent water being spilled out by waves or heavy rain, the height of the dyke is about 80cm. The bottom of the pond is flat and has a slope of about 3cm per 100m (0.03%) from inlet to outlet.

Overwintering canals

Except in Pingtung, the southernmost county in Taiwan, overwintering canals are necessary components of milkfish farms. These are 100-300m long ditches, 5-8m wide on the surface and 1.2-1.5 on the bottom, with water depth of 1.5-2m, also aligned across the direction of the prevailing wind. Traditionally, windbreaks made of straw, canvas or polyethylene plastic, held together by bamboo sticks, are constructed on the north side of the canals during the winter period. The windbreak has an angle of 30-60 degrees from the horizontal to deflect the winter wind. There are generally 1m×0.5m windows in the windbreak at 20-25m intervals, kept open in warm days to facilitate air circulation and enhance input of air into the water.

Nursery ponds

One nursery pond is connected to each overwintering canal with a gate allowing fish to swim between them. The nursery pond is about 18-25m wide and 20 cm deep, and can serve as a grazing and swimming ground for overwintering fingerlings on a warm day, and can be used as a rearing pond for new fry. When the cold weather is coming, farmers drive the fish into overwintering canals and close the gates between the canals and nursery ponds.

Water supply canals

Every production pond has sub-canal, connected to the main canals for filling and draining water. These serve as acclimatisaton areas for fingerlings and temporary emergency shelters for fish when the production ponds are being dried in the sun. The water canals are 30-40 cm deeper than the production ponds and about 6-8m wide.

Pond preparation

After harvest in late November, the fish of under market size are driven into overwintering canals and the main pond is prepared for the next growing season. The organic debris in the ponds is raked and spread evenly over the bottom and the ponds left to be sun-dried till the mud on the bottom starts cracking. After sun-drying, fertilizers are applied to develop the benthic algae. These include chicken or pig manure and rice bran. Next, the canals are also drained, cleaned and dried. At the end of February, tea seed meal is used as a pesticide to kill the pests and predators, and finally the ponds are left to let the benthic algae grow.

Nursery management

Before milkfish fry are stocked in the grow-out ponds, they are usually kept in nursery ponds. To recover from transport stress or to be acclimatized to the new culture environment, fry are first put into an acclimatization pool with a gate connected to the nursery pond. The gates are opened a few hours after stocking and the fry gradually swim into the nursery pond after they have become used to its salinity. Nursery ponds vary in size from 100 to 5000 m^2 or 1-3% of the total farm water surface. The stocking density is about 40-50 fry/ m^2. Usually, nursery ponds have easy access to water and aeration in case of emergency. Eel feed and wheat flour are supplied to the fry. After 4-6 weeks, the fry can grow to 5-8cm fingerlings, the ideal size for releasing to grow-out ponds.

Pond management

At the end of March or the start of April, fish in the overwintering canals are driven in to the production ponds. These fingerlings are of different sizes and the density is about 3500-4500 ha^{-1}. If the fingerlings available are not sufficient, the shortage is purchased from an outside source. Then, wild caught or hatchery reared fry are stocked in the nursery ponds and released to the production ponds after they attain fingerling size. After that, the nursery pond is restocked immediately, and this cycle repeated monthly 3 or 4 times until July. The different sizes of fingerling are cultivated together to avoid all the fish attaining market size at the same time, in which case, the amount of fish could exceed the carrying capacity of the on-growing pond. The key point in shallow-water milkfish culture is to maintain the benthic algae. If this is overgrown, the algae in the bottom layer will die and the algal mat may detach from bottom of the pond, after which, the phytoplankton may dominate, followed by the production of zooplankton, making the water in the pond yellowish-green. This will inhibit the growth of benthic algae and could lead to anoxic conditions and mass fish kills. To avoid overgrowth of the algal mat, ponds must be stocked with enough fish to graze on it. However, overstocking can deplete the algae mat, and to avoid overgrazing, supplemental feeding (rice bran) is used, typically at 30-50 kg every two days per hectare (Ding 1994). If the phytoplankton take over the benthic algae, fish are driven from the production pond into the canals. The production pond is then drained, manure applied and sun-dried to grow another crop of benthic algae before the fish are reintroduced into the pond.

3.2.4 Harvest

The market size of milkfish in Taiwan is about 200-500g. When this size is attained, partial harvesting can be done. This is usually done once a month, usually 4 times, from late May or early June to October. By late May or early June, the biomass will reach 700-800Kg ha^{-1} which is about the carrying capacity in the pond. After partial harvest, the biomass can be reduced to about 250Kg/ha, after which, supplemental restocking and partial harvest can be repeated.

To prevent the algal mat from being damaged, a gill net is used for partial harvesting. A gill net with a very large mesh red twine is used first to threaten the milkfish and to make them empty the contents of their digestive tract. About 2-3 hours later, a smaller mesh gill net is used for harvesting. At the end of November, a complete harvest is made and the undersized fish driven into the overwintering canals.

3.2.5 Overwintering

Prior to the year-end harvest at the end of October, fish farmers start preparation of the overwintering canals. This is similar to that for the production ponds, and includes draining, cleaning, sun drying, applying manure, killing pests and then growing algae. Then, the windbreak is repaired and installed. After driving the fish into the overwintering canals, the fish can be fed with rice bran or fish meal/ eel feed meal on the warmer days. Stocking density is usually less than 1.3 Kg m^{-3} and the temperature in the overwintering canals can be 3-5°C higher than the water in the production ponds during a cold spell.

3.2.6. Deep-water culture

In response to declining profit, and the limited and increasing value of land and manpower resources, deep-water culture of milkfish was developed. Most deep-water milkfish ponds are created by converting the larger shallow-water ponds by subdividing them into smaller and deeper ponds or converting them into small fresh water ponds. The management of deep-water ponds is similar to that of traditional pond procedures, and includes pond preparation, fry stocking, harvesting and overwintering. After harvest, ponds are sun-dried and limed. Deep-water ponds are typically about 2m in depth. The average stocking density is about 22,000 fish ha^{-1}. Every hectare is equipped with 2-4 paddlewheels to increase the dissolved oxygen. Benthic algae are present during the initial culture period, but feed pellets are the main source of nutrition during the main growing phase. One to two blower-type stationary automatic feeders are used to distribute pelletized feed onto the surface of each pond from 0800 to 1800.

Daily feeding rate is about 3-5% of fish biomass, the protein content is about 23-27% and food conversion ratio about 1.3-1.6. If fresh water is used, fry must be acclimatized or else packs of coarse salt put into the ponds near the bank before releasing fry into the ponds. As with the shallow-water system, milkfish are selectively harvested with a gill net. Ideally, to fetch higher prices, the harvesting schedule would differ from the peak production season from August to November. Milkfish usually can command a higher price during the December to May period, especially in April. Using feed, the milkfish can continue to be grown during the winter months, and can be harvested later. If the survival rate is higher, the annual productivity the deep-water pond can be 12 ton/ha.

Table 3.5 Socioeconomic characteristics of milkfish farmers.

Socioeconomic characteristics	Number	Percentage
Age (years)		
21-30	9	3.14%
31-40	71	24.83%
41-50	99	34.62%
51-60	85	29.72%
61 and above	22	7.69%
Average	46.54 years	
Education attainment		
None	14	4.91%
Elementary	131	45.96%
Junior high school	55	19.30%
Senior high school	73	25.61%
College	12	4.21%
Average years of schooling	8.24 years	
Experience in milkfish culture		
1-10 years	48	16.84%
11-20 years	110	38.60%
21-30 years	64	22.46%
31-40 years	47	16.49%
41 years and above	16	5.61%
Average years of experience	22.70 years	
Source of family income		
Milkfish production only	69	24.13%
Milkfish production and other source	217	75.87%
Household size		
1-5	180	63.16%
6-10	100	35.09%
11 and above	5	1.75%
Average household size	4.95 peoples	

3.3. Characteristics of milkfish producers

In 1999, 286 fish farmers who also managed their farms were surveyed by questionnaire. Most farms (> 97.6%) were owned by single proprietors. On average, milkfish producers were 46.5 years old. The majority of the respondents achieved elementary education (about 46%) and the average years of schooling was about 8.2 years (Table 3.5). Most had many years of experience in milkfish culture, averaging 22.7 years. Less than one-fourth (24.1%) stated that milkfish farming was their only source of family income. More than half of respondents (63.2%) had a household size of ≤ 5 people, the average household size being 4.95.

The education attainment is correlated to the age. Younger group had higher education attainment. The average education attainments in different age categories were 11.3, 10.2, 8.1, 7.0 and 5.7 years in the categories of 20-<30, 30-<40, 40-<50, 50-<60 and 60->60 years old, respectively. The average household sizes were similar in different age groups, being 4.8, 4.6, 5.0, 5.0 and 5.2 in the categories of 20-<30, 30-<40, 40-<50, 50-<60 and 60->60 years old, respectively. The percentage of each group with outside income was correlated to the age. The younger group except 20-<30 age group, had a higher percentage with an outside income, accounting for 55.0%, 92.0%, 79.6%, 72.5% and 68.1% in the categories of 20-<30, 30-<40, 40-<50, 50-<60 and 60->60 years old, respectively. The high percentage of farmers with outside income suggests that milkfish farming might be generally a part-time occupation. The percentage of each group using monoculture for milkfish production was correlated to the age. The younger group, with the exception of the 20-<30 age group, had a higher percentage of monoculture use for milkfish production, accounting for 37.5%, 70.4%, 56.7%, 46.9% and 46.2% in the categories of 20-<30, 30-<40, 40-<50, 50-<60 and 60->60 years old, respectively (Table 3.6)

Table 3.6 Averages of education attainment, household size, percentages of farmers with outside income and percentages of monoculture in different age categories.

Age category	20-<30	30-<40	40-<50	50-<60	60->60
Education attainment	11.3	10.2	8.1	7.0	5.7
Household size	4.8	4.6	5.0	5.0	5.2
Outside income	55.0%	92.0%	79.6%	72.5%	68.1%
% of monoculture	37.5%	70.4%	56.7%	46.9%	46.2%

3.4. Characteristics of milkfish farms

According to the survey, most of the traditional shallow milkfish farms have been transferred to deep-water systems and some fish farmers also use polyculture, i.e. with other species in the ponds. Those species were fed by additional feed or the detritus of milkfish feed.

Three types of milkfish culture could be defined, i.e. monoculture, polyculture and a mix of monoculture and polyculture. In the first two cases the fish farmers used all their ponds either for monoculture or for polyculture, respectively. In the mixed approach, farmers used some ponds for monoculture and others for polyculture. The survey showed that 58.0 % of farms used monoculture, 33.6% polyculture and 8.4% used mixed culture (Table 3.7). Most (69.93%) of farm sizes are < 3 hectare (Table 3.7). Species for polyculture with milkfish include tiger prawn (*Penaeus monodon*), sand prawn (*Metapenaeus ensis*), fresh water prawn (*Macrobrachium rosenbergii*), tilapia (*Oreochromis spp*), mullet (*Mugil cephalus*) and other fishes. Among these, tiger prawn and sand prawn are the most popular (Table 3.8).

Table 3.7 The number of farm sizes and status of milkfish farms surveyed in Taiwan.

Farm size	Mono-culture	Poly-culture	Mixed mono- and poly-culture	Subtotal
< 1 ha	48	13	3	64 (22.38)
1-< 2 ha	44	31	1	76 (26.57)
2-< 3 ha	38	17	5	60 (20.98)
3 -< 4 ha	13	14	6	33 (11.54)
4 -< 5 ha	9	5	3	17 (5.94)
5 -> 5 ha	14	16	6	36 (12.59)
Subtotal	166 (58.0)	96 (33.6)	24 (8.4)	286 (100)

Figures in parentheses are the percentages of ratio to total surveyed number.

Table 3.8 The frequencies of species in poly-culture with milkfish ponds.

	Number	Percentage
Tiger prawn	54	43.9%
Sand prawn	45	36.6%
Fresh water prawn	7	5.7%
Tilapia	5	4.1%
Mullet	5	4.1%
Other fishes	7	5.69%

Three kinds of water source were observed, seawater, ground water and river or reservoir water. For faster growing, fish farmers usually used fresh water to mix with seawater, or even fresh water alone (Table 3.9) as the fish do not need to expend so much energy in osmotic regulation. When farm size is < 1 ha, most farms tried to use more fresh water (ground, and river or reservoir water), and accounting for more than 39% of farms. However, when the farm size was > 1 ha, the percentage of farms using fully fresh water reduced, accounting for less than 25% of farms (Table 3.10).

Table 3.9 The frequencies of water sources that were used by farmers for cultivating milkfish.

Water source	Number	Percentage
Seawater	76	26.6%
Ground water	47	16.4%
River or reservoir water	31	10.8%
Mixed seawater and ground water	40	14.3
Mixed seawater and river or reservoir water	59	20.6%
Mixed ground water and river or reservoir water	8	2.8%
Mixed all 3 kinds of water	25	8.7%

Table 3.10 The use of water sources by different farm sizes.

Farm size	Seawater	Ground water	River or reservoir water	Mixed seawater and ground water	Mixed seawater and river or reservoir water	Mixed ground water and river or reservoir water	Mixed all 3 kinds of water
< 1 ha	11 (17.2)	22(34.4)	3 (4.7)	2 (3.1)	17 (26.6)	1 (1.6)	8 (12.5)
1-< 2 ha	24 (31.6)	10(13.2)	8 (10.5)	11(14.5)	14 (18.4)	2 (2.6)	7 (9.2)
2-< 3 ha	15 (25.0)	4 (6.7)	10 (16.7)	12(20.0)	10 (16.7)	4 (6.7)	5 (8.3)
3 -< 4 ha	11 (33.3)	5 (15.2)	3 (9.1)	7 (21.1)	6 (18.2)	1 (3.0)	0 (0.0)
4 -< 5 ha	3 (17.6)	2 (11.8)	2 (11.8)	1 (5.9)	7 (41.2)	0 (0.0)	2 (11.8)
5 -> 5 ha	12 (33.3)	4 (11.1)	5 (13.9)	7 (19.4)	5 (13.9)	0 (0.0)	3 (8.3)
Subtotal	76	47	31	40	59	8	25

The figures in parentheses are the percentages of water sources in different categories of farm sizes.

Usually, tiger prawn, mullet and sand prawn were reared in the water sources with higher salinity. In the 54 farms using tiger prawn for polyculture with milkfish, only two farms did not use seawater or mix seawater. Of 45 farms using sand shrimp for polyculture 14 did not use seawater or mix seawater. All the farms using mullet for polyculture used seawater or mixed seawater. However, except for one farm mixing sea water for fresh water prawn, all the farm using fresh water shrimp, tilapia and other fish for polyculture used fresh water as water sources(Table 3.11).

Table 3.11 The frequencies of species in poly-culture with milkfish in different water sources.

Water source	Tiger prawn	Sand prawn	Fresh water Prawn	Tilapia	Mullet	Other fish
Seawater	38	14	0	0	2	0
Ground water	2	9	6	3	1	2
River or reservoir water	2	5	0	2	0	2
Mixed seawater and ground water	7	11	0	0	2	3
Mixed seawater and river or reservoir water	2	3	0	0	0	0
Mixed ground water and river or reservoir water	2	2	0	0	0	0
Mixed all 3 kinds of water	1	1	1	0	0	0
Subtotal	54	45	7	5	5	7

When monoculture farms were used to compare the average yield level in different farm sizes, it shows that smaller farms had higher productivity, with higher yield level at farm sizes of less than 3 ha. The highest average yield levels were found in farm sizes of < 1ha, attaining 18.6 t/ha, followed by 1-< 2 ha and 2-< 3 ha, attaining 11.7 and 11.3 t/ha, respectively. However, when farm sizes were bigger than 3 ha, the relationship between size and yield was not so clear, with insignificant difference of average yield levels. The average yield levels of farm sizes in the categories of 3 -< 4 ha, 4 -< 5 ha and 5 -> 5 ha were 8.2, 7.3 and 8.8 t/ha (Table 3.12). Although farm sizes of < 1 ha, 1-< 2 ha and 2-< 3 ha had higher yield level, the variation was relatively larger, the highest and lowest yield level ranged from 4.6-33.3, 3.4-14.9 and 4.7-18.0 t/ha respectively.

The variation of yield levels of farm sizes of 3 -< 4 ha, 4 -< 5 ha and 5 -> 5 ha were relatively smaller, ranged from 5.7-12.9, 4.8-13.5 and 4.9-15.0 t/ha, respectively. These suggested that when farms were < 3 ha, more intensive management might be used, however the differences between better and poorer performance were greater.

On the contrary, when farms were > 3 ha, more extensive management were used, and the variation of performance were smaller.

Table 3.12 The average yield levels in different farm sizes.

Farm size	Productivity (t/ha)
< 1 ha	18.6 (4.6-33.3)
1-< 2 ha	11.7 (3.4-19.6)
2-< 3 ha	11.3 (4.7-18.0)
3 -< 4 ha	8.2 (5.7-12.9)
4 -< 5 ha	7.3 (4.8-13.5)
5 -> 5 ha	8.8 (4.9-15.0)

The figures in the parentheses are the range of highest and lowest yield levels.

3.5 Economic analysis

To assess the profitability of milkfish farming in Taiwan, 262 milkfish farmers were surveyed in 1999, excluding those which mixed mono- and poly-culture. In this section, the cost and benefit analysis of different sizes of farms and different styles of culture (monoculture and polyculture) are compared.

3.5.1.Cost catagories

Two cost components can be identified, capital and operating cost. Capital costs comprise costs of buildings, pond construction, power generator, feeder, paddlewheel and pump (Table 3.13 and Table 3.15). Operating costs consist of costs of fingerling, feed, electricity, chemicals, wages, miscellaneous, land rent, depreciation and interest (Table 3.16). As most fish farmers have their own land, land rent is estimated at 100,000 NT$ (3,100US$) ha^{-1} yr^{-1}. Usually, fish farmers do not hire labor for routine work, wages only being paid for harvesting.

Three important assumptions are:

(1) investment costs are covered by a loan at an annual interest rate of 8%

(2) facilities and equipment are taken as having a straight line depreciation during their useful lifetime;

(3) the useful lifetime of the building and pond construction is 20 years, the power generator and feeder is 10 years, and the paddle wheel and pump is 5 years.

Because spending on operating costs is spread throughout the culture period, the interest is charged on only 50% of the total amount. Total expenditure on variable costs is not paid out at the beginning, so will not incur full interest costs for the entire period. However, the interest is charged on 100% of the capital cost.

3.5.2 Capital cost characteristics

The average capital cost of monoculture system was shown in Table 3.13. Comparing capital cost of different farm sizes, average capital cost per hectare reduced with increased farm size up to < 4 hectare, suggesting that the 3 -< 4 ha size category is the most capital efficient for monoculture. In contrast, capital cost per hectare of polyculture is highest at >1 ha and is very similar at sizes from 2 to 5 hectare, only reducing at > 5 ha, suggesting possible economies of scale beyond that level (Table 3.14).

Comparing monoculture with polyculture, capital cost for the latter is higher by average 58.8% The capital cost of polyculture were especially higher in the items of pond construction and paddlewheel than that of monoculture. It implies that more capital is needed to modify the ponds and paddle wheel to accommodate other species.

Table 3.13 The average capital costs of monoculture milkfish farms of different sizes.

Unit:NT$, 32 NT$ = 1 US$

Item	Cost					
	< 1 ha	1 - < 2 ha	2 - < 3 ha	3 - < 4 ha	4 - < 5 ha	5 - > 5 ha
No. sampled	48	44	38	13	9	14
Building	125350	157280	199740	133500	217140	370420
Pond construction	176670	225770	261110	283000	378400	900000
Power generator	100910	111770	121150	122730	135200	240420
Paddlewheel	48540	139630	142960	188540	211110	499190
Feeder	15940	20940	42860	45080	101670	119580
Pump	34580	34980	47635	53540	116890	159310
Total	501980	690360	815440	826380	1160410	2288910
Cost per hectare	910390	538680	355960	269520	278720	346090

Table 3.14 The average capital costs of polyculture milkfish farms of different sizes.

Unit:NT$, 32NT$ = 1 US$

Item	Cost					
	< 1 ha	1 - < 2 ha	2 - < 3 ha	3 - < 4 ha	4 - < 5 ha	5 - > 5 ha
No. sampled	13	31	17	14	5	16
Building	155560	137830	179333	245390	260000	326430
Pond construction	387500	334000	775000	1175000	1250000	1263330
Power generator	120000	121920	126000	156090	194000	195000
Paddlewheel	99580	114130	151530	213360	510800	343380
Feeder	15460	26570	35530	41570	116400	88930
Pump	34540	33690	58270	113180	56000	78130
Total	812640	768140	1325660	1944580	2387200	2295200
Cost per hectare	1345100	584210	588410	607680	568380	352090

The average capital cost for producing per tonne of milkfish of monoculture is shown in Table 3.15. The average capital costs to produce per tonne of milfish reduced with increased farm size up to < 4 hectare, after that the costs increased with increased farms size. The average cost for producing one tonne of milkfish were 85.3, 64.9, 41.3, 32.7, 33.4 and 50.3 thousand NT$/t in the size categories of < 1, 1 - < 2, 2 - < 3, 3 - < 4, 4 - < 5 and 5 - > 5 ha, respectively. Pond construction was the highest cost component in production, per tonne of milkfish, the average cost in producing one tonne of milkfish reduced with increased farm size up to > 5ha. The average costs of pond construction in producing one tonne of milkfish were 31.1, 25.7, 14.1, 10.3, 6.7 and 21.8 thousand NT$/t in the size categories of < 1, 1 - < 2, 2 - < 3, 3 - < 4, 4 - < 5 and 5 - > 5 ha, respectively.

The ranges of the highest and lowest cost of pond construction were 15.9-66.7, 6.7-54.5, 3.8-20.0, 8.6-13.9, 3.5-12.5 and 13.3-30.0 thousand NT$/t in the size categories of < 1, 1 - < 2, 2 - < 3, 3 - < 4, 4 - < 5 and 5 - > 5 ha, respectively. Next to pond construction was building, the average cost in producing one tonne of milkfish reduced with increased farm size up to > 4ha, after that the cost increased with increased farm size. The average costs of building in producing one tonne of milkfish were 24.7, 14.5, 8.5, 5.5, 5.8 and 7.5 thousand NT$/t in the size categories of < 1, 1 - < 2, 2 - < 3, 3 - < 4, 4 - < 5 and 5 - > 5 ha, respectively. The ranges of the highest and lowest cost of building were 5.2-33.3, 3.1-31.3, 2.8-17.8, 1.7-10.0, 3.5-9.6 and 2.7-16.7 thousand NT$/t in the size categories of < 1, 1 - < 2, 2 - < 3, 3 - < 4, 4 - < 5 and 5 - > 5 ha, respectively. The variation of the cost of pond construction in producing one tonne of milkfish may be due to the site of farms and performance of yield level (Table 3.12). The variation of the cost of building in producing one tonne of milkfish may be due to the source the farmers bought them from, their size, the year they have been used and performance of yield level.

Table 3.15 The average capital cost for each tonne of annual output of monoculture milkfish farm of different size. Unit: Thousand NT$

Item	Cost					
	< 1 ha	1 - < 2 ha	2 - < 3 ha	3 - < 4 ha	4 - < 5 ha	5 - > 5 ha
No. sampled	48	44	38	13	9	14
Building	24.7 (5.2-33.3)	14.5 (3.1-31.3)	8.5 (2.8-17.8)	5.5 (1.7-10.0)	5.8 (3.5-9.6)	7.5 (2.7-16.7)
Pond construction	31.1 (15.9-66.7)	25.7 (6.7-54.5)	14.1 (3.8-20.0)	10.3 (8.6-13.9)	6.7 (3.5-12.5)	21.8 (13.3-30.0)
Power generator	10.6 (6.4-14.6)	10.1 (6.5-15.6)	5.3 (2.2-11.1)	4.9 (2.5-6.3)	5.4 (2.9-7.5)	5.2 (2.1-10.0)
Paddlewheel	8.7 (2.4-15.4)	8.8 (3.3-13.3)	8.3 (3.1-12.5)	8.1 (4.3-10.1)	6.9 (2.7-10.9)	10.1 (5.2-14.0)
Feeder	3.3 (1.1-7.4)	2.1 (0.9-4.7)	2.6 (0.9-4.3)	1.9 (1.1-2.8)	3.7 (1.4-6.0)	2.4 (1.0-4.8)
Pump	6.9 (1.0-15.6)	3.7 (0.8-9.1)	2.4 (0.6-6.3)	2.1 (0.8-3.8)	4.8 (1.1-6.9)	3.4 (0.8-9.1)
Total	85.3 (48.7-132.0)	64.9 (32.6-102.9)	41.3 (28.9-64.5)	32.7 (28.2-42.0)	33.4 (22.3-48.0)	50.3 (35.2-73.0)

The figures in the parentheses are the range of highest and lowest cost.

3.5.3 Operating cost characteristics

The average operating cost of monoculture is shown in Table 3.16. Within this, the cost of feed is highest, accounting for 30.3% to 35.4%, after which is land rent, accounting for12.4% to 20.3%. The third highest cost is fingerling, accounting for 10.31% to 14.83%. As with monoculture, the highest operating cost of polyculture is feed, accounting for 31.6% to 42.5% (Table 3.17), after which is fingerling, at 12.2% to 23.6% and land at 9.1% to 16.4%. The operating costs of polyculture included the costs of the other species in the polyculture system.

Table 3.16 The average operating costs of monoculture milkfish farms of different sizes. Unit:NT$

Item	Cost					
	< 1 ha	1 - < 2 ha	2 - < 3 ha	3 - < 4 ha	4 - < 5 ha	5 - > 5 ha
No. sampled	48	44	38	13	9	14
Fingerling	45920	86490	135660	190120	304280	476450
	(10.31)	(11.62)	(11.45)	(12.04)	(14.83)	(11.94)
Feed	141170	255070	419290	551620	622940	1316220
	(31.70)	(34.26)	(35.38)	(34.94)	(30.36)	(32.98)
Electricity	57460	65560	100860	128860	205780	474180
	(12.90)	(8.80)	(8.51)	(8.16)	(10.03)	(11.88)
Chemicals	5190	8620	9280	17100	10080	23180
	(1.16)	(1.16)	(0.78)	(1.08)	(0.49)	(0.58)
Wage	21200	19090	33870	77690	65830	272000
	(4.76)	(2.56)	(2.86)	(4.92)	(3.21)	(6.82)
Land rent	55140	128160	229080	306620	416330	661360
	(12.38)	(17.21)	(19.33)	(19.42)	(20.29)	(16.57)
Miscellaneous	21760	35130	74090	99640	143720	215850
	(4.89)	(4.72)	(6.25)	(6.31)	(7.01)	(5.41)
Depreciation	43410	67350	77560	86020	119060	231220
	(9.75)	(9.04)	(6.55)	(5.45)	(5.80)	(5.79)
Interest	54070	79150	105320	120980	163590	320680
	(12.14)	(10.63)	(8.89)	(7.66)	(7.97)	(8.03)
Total	445310	744630	1185000	1578640	2051610	3991140

The figures in parentheses are the percentages of total operation cost.

Table 3.17 The average operating costs of polyculture milkfish farms of different sizes. Unit:NT$, 32 NT$ = 1 US$

Item	Cost					
	< 1 ha	1 - < 2 ha	2 - < 3 ha	3 - < 4 ha	4 - < 5 ha	5 - > 5 ha
No. sampled	13	31	17	14	5	16
Fingerling	99720 (15.00)	118500 (13.54)	171140 (12.47)	533630 (23.64)	383500 (12.18)	732410 (16.15)
Feed	224000 (33.69)	293870 (33.58)	503180 (36.67)	713690 (31.61)	1226800 (38.98)	1926590 (42.48)
Electricity	50790 (7.64)	62010 (7.09)	86440 (6.30)	112660 (4.99)	278000 (8.83)	240040 (5.29)
Chemicals	10550 (1.59)	13030 (1.49)	12450 (0.91)	37590 (1.66)	32000 (1.02)	44070 (0.97)
Wage	31540 (4.74)	43510 (4.97)	45410 (3.31)	44640 (1.98)	142000 (4.51)	195060 (4.30)
Land rent	60420 (9.09)	131480 (15.03)	225290 (16.42)	320000 (14.17)	420000 (13.34)	651880 (14.37)
Miscellaneous	34950 (5.26)	54510 (6.23)	71740 (5.23)	108950 (4.83)	149000 (4.73)	209720 (4.62)
Depreciation	67520 (10.15)	68010 (7.77)	105830 (7.71)	156090 (6.91)	219900 (6.99)	192180 (4.24)
Interest	85490 (12.86)	90130 (10.30)	150680 (10.98)	230410 (10.21)	296230 (9.41)	343610 (7.58)
Total	664960	875050	1372170	2257670	3147430	4535550

The costs of fingerling and feed include the species for polyculture.
The figures in parentheses are the percentages of total operation cost.

The average operating cost of monoculture milkfish farms of different sizes in producing 1 kg of milkfish is detailed in Table 3.18. This shows the most effective size of farm is 4 - < 5 ha, the operating cost for producing 1 kg of milkfish was only 27.2 NT$. Followed by < 1 ha, 2 - < 3 ha and 1 - < 2 ha, the average operating costs are 44.1, 45.2 and 48.2 NT$, respectively. The most inefficient farm sizes in operating cost are 3 - < 4 ha and 5 - > 5 ha, the average operating costs are 63.1 and 66.7 NT$, respectively. The ranges of the highest and lowest operating cost for producing 1 kg of milkfish were 29.6-58.8, 32.6-62.2, 30.1-58.0, 50.1-79.4, 20.4-39.9 and 50.7-81.1 NT$/kg in the size categories of < 1 ha, 1- < 2 ha, 2 - < 3 ha, 3 - < 4 ha, 4 - < 5 ha and 5 - > 5 ha, respectively.

The key factors contributing to the operating cost for producing 1kg of milkfish were feed, land rent and fingerling. The costs of feed for producing 1kg of milkfish were 14.0, 16.5, 16.0, 22.1, 8.3 and 22.0 NT$/kg, the highest and lowest cost of feed ranged from 10.0-18.8, 11.5-23.7, 10.0-23.1, 18.2-29.2, 5.6-12.5 and 19.1-28.3 in size categories of < 1 ha, 1- < 2 ha, 2 - < 3 ha, 3 - < 4 ha, 4 - < 5 ha and 5 - > 5 ha, respectively. In the farm size of 4-< 5 ha had the most efficient FCR, it might be because of the economies of scale and the supply of natural food. However, when a farm size exceeded 5ha it become more difficult for a family to manage.

The costs of land rent for producing 1 kg of milkfish were 5.5, 8.3, 8.7, 12.3, 5.5 and 11.1 NT$/kg, the highest and lowest cost of land rent ranged from 1.4-11.0, 2.6-13.9, 3.6-13.9, 8.6-19.3, 3.6-10.2 and 6.2-18.9 NT$/kg in size categories of < 1 ha, 1- < 2 ha, 2 - < 3 ha, 3 - < 4 ha, 4 - < 5 ha and 5 - > 5 ha, respectively. As most farmers have their own land, the land rent is estimated at 100,000 NT$ ha^{-1} yr^{-1}, therefore the costs of land rent for producing 1 kg of milkfish were related to the yield levels (Table 3.12).

The costs of fingerling for producing 1 kg of milkfish were 4.5, 5.6, 5.2, 7.6, 4.0 and 8.0 NT$/kg, the highest and lowest cost of fingerling ranged from 1.9-8.9, 2.5-10.1, 2.5-9.2, 3.7-11.8, 2.5-9.6 and 4.3-11.7 NT$/kg in size categories of < 1 ha, 1- < 2 ha, 2 - < 3 ha, 3 - < 4 ha, 4 - < 5 ha and 5 - > 5 ha, respectively. The costs of fingerling were related to the survival rate, therefore better management may lower costs of fingerling for producing 1 kg of milkfish.

Table 3.18 The average operating costs of monoculture milkfish farms of different sizes in the production of 1kg of milkfish. Unit:NT$

Item	Cost					
	< 1 ha	1 - < 2 ha	2 - < 3 ha	3 - < 4 ha	4 - < 5 ha	5 - > 5 ha
No. sampled	48	44	38	13	9	14
Fingerling	4.5 (1.9-8.9)	5.6 (2.5-10.1)	5.2 (2.5-9.2)	7.6 (3.7-11.8)	4.0 (2.5-9.6)	8.0 (4.3-11.7)
Feed	14.0 (10.0-18.8)	16.5 (11.5-23.7)	16.0 (10.0-23.1)	22.1 (18.2-29.2)	8.3 (5.6-12.5)	22.0 (19.1-28.3)
Electricity	5.7 (3.3-9.1)	4.2 (3.2-6.4)	3.8 (2.3-5.9)	5.2 (3.9-7.7))	2.7 (1.8-5.9)	7.9 (4.6-12.5)
Chemicals	0.5 (0.2-0.7)	0.6 (0.2-0.8)	0.4 (0.2-0.6)	0.7 (0.3-1.0)	0.1 (0.1-0.2)	0.4 (0.2-0.6)
Wage	2.1 (0.9-3.6)	1.2 (0.7-1.8)	1.3 (0.7-1.8)	3.1 (2.3-3.9)	0.9 (0.6-1.2)	4.5 (2.9-5.6)
Land rent	5.5 (1.4-11.0)	8.3 (2.6-13.9)	8.7 (3.6-13.9)	12.3 (8.6-19.3)	5.5 (3.6-10.2)	11.1 (6.2-18.9)
Miscellaneous	2.2 (1.0-3.4)	2.3 (1.1-3.4)	2.8 (1.3-4.1)	4.0 (2.7-5.1)	1.9 (0.9-2.8)	3.6 (2.5-4.8)
Depreciation	4.3 (2.1-6.0)	4.4 (2.4-5.9)	3.0 (1.8-4.9)	3.4 (1.9-5.2)	1.6 (0.9-2.4)	3.9 (2.0-5.3)
Interest	5.3 (3.8-7.3)	5.1 (3.8-7.2)	4.0 (3.2-5.6)	4.8 (3.6-6.2)	2.2 (1.3-3.1)	5.4 (3.9-7.3)
Total	44.1 (29.6-58.8)	48.2 (32.6-62.2)	45.2 (30.1-58.0)	63.1 (50.1-79.4)	27.2 (20.4-39.9)	66.7 (50.7-81.1)

The figures in parentheses are the ranges of highest and lowest cost.

3.5.4 Benefit analysis

When opportunity cost is considered, the profit (P) is equal to the net revenue (MI) (excluding depreciation and interest) minus operating cost (C). Profitability can be estimated by the benefit-cost ratio (BCR) and the income ratio (IR), where formulas are as follows:

BCR=P/C

IR=P/MI

Where P = Profit

C = Production cost

MI = Revenue

The higher are these values the more financially sound is the operation. This also indicates that the operation is economically sound and further development may be considered.

Table 3.19 and Table 3.20 reveal that in monoculture, the IR values are similar in all size categories, ranging from -35.2% (3- 4ha) to -43.1% (1- 2ha). The IR values of polyculture were even poorer than monoculture, and at pond sizes 3 - 4ha were even below –100% (Table 3.19). However, the IR value in size categories of 4 ha and above were higher in polyculture than in monoculture. The costs and revenues in polyculture include the costs and revenues of the other species in the polyculture system. Based on the survey, milkfish culture was not financially sound, with costs exceeding revenues in all size categories and both types of culture. However, most facilities of farms have existed, farmers have their own farm and farmer usually can get the loan with lower interest rate (about 6.5%), therefore, the costs of capital interest, depreciation and land costs can be neglected.

Table 3.19 Returns and benefit ratios for monoculture milkfish, by farm size.

	< 1 ha	1 - < 2 ha	2 - < 3 ha	3 - < 4 ha	4 - < 5 ha	5 - > 5 ha
Cost (NT$)	445307	744629	1185004	1578640	2051610	3991142
Revenue (NT$)	322649	520443	858774	1167923	1501778	2804286
Profit (NT$)	-122658	-224186	-326230	-410717	-549832	-1186856
BCR	-27.54%	-30.10%	-27.53%	-26.02%	-26.80%	-29.74%
IR	-38.02%	-43.08%	-37.99%	-35.17%	-36.61%	-42.32%

BCR is the ratio of profit to cost and IR is the ratio of profit to revenue.

Table 3.20 Returns and benefit ratio for polyculture milkfish, by farm size.

	< 1 ha	1 - < 2 ha	2 - < 3 ha	3 - < 4 ha	4 - < 5 ha	5 - > 5 ha
Cost (NT$)	664959	875050	1372171	2257665	3147428	4535545
Revenue (NT$)	432154	516113	911276	1000871	2631200	3627438
Profit (NT$)	-232805	-358937	-460895	-1256794	-516228	-908107
BCR	-35.01%	-41.02%	-33.59%	-55.67%	-16.40%	-20.02%
IR	-53.87%	-69.55%	-50.58%	-125.57%	-19.62%	-25.03%

BCR is the ratio of profit to cost and IR is the ratio of profit to revenue.

If the gross profit was considered, i.e., the opportunity costs (interest, depreciation and land cost) are excluded and only expenditure costs were considered, all the monoculture size categories could make profit and the highest levels are in the 4-< 5ha size at 149160 NT$ (Table 3.21). However, in polyculture, only the 2 - < 3 ha, 4- < 5 ha and >5 ha size categories could make profit at 20906, 419900 and 279558 NT$ respectively, though, the size had higher profits than any monoculture size (Table 3.22).

The lowest cost in the farm size of 4-< 5 ha might permit this category to have the highest profit. Table 3.18 shows that farm size of 4-< 5 ha had lower costs to produce 1 kg of milkfish. Feed is an important factor to reduce cost because it accounts more than 30% of production, therefore better management and lower FCR might be the factors of reducing cost and cause higher profit.

Table 3.21 Gross profits and benefit for monoculture milkfish, by farm size.

	< 1 ha	1 - < 2 ha	2 - < 3 ha	3 - < 4 ha	4 - < 5 ha	5 - > 5 ha
Cost (NT$)	292685	469971	773045	1065028	1352622	2777882
Revenue (NT$)	322649	520443	858774	1167923	1501778	2804286
Gross profit (NT$)	29964	50472	85729	102895	149156	26404
BCR	10.24%	10.74%	11.09%	9.66%	11.03%	0.95%
IR	9.29%	9.70%	9.98%	8.81%	9.93%	0.94%

BCR is the ratio of gross profit to cost and IR is the ratio of gross profit to revenue.

Table 3.22 Gross profits and benefit for polyculture milkfish, by farm size.

	< 1 ha	1 - < 2 ha	2 - < 3 ha	3 - < 4 ha	4 - < 5 ha	5 - > 5 ha
Cost (NT$)	451532	585433	890370	1551159	2211300	3347880
Revenue (NT$)	432154	516113	911276	1000871	2631200	3627438
Gross profit (NT$)	-19378	-69320	20906	-550288	419900	279558
BCR	-4.29%	-11.84%	2.35%	-35.48%	18.99%	8.35%
IR	-4.48%	-13.43%	2.29%	-54.98%	15.96%	7.71%

BCR is the ratio of gross profit to cost and IR is the ratio of gross profit to revenue.

When the ranges of gross profit were considered, the highest profit of monoculture was in the size category of 4 - < 5 ha at 180,300 NT$. However the size category of 3 - < 4 ha and 2 - < 3 ha had higher lowest gross profit than that of the size category of 4 - < 5 ha (Table 3.23).

Table 3.23 The ranges of gross profit for monoculture milkfish, by farm size.

	Gross profit			BCR			IR		
	Highest	Average	Lowest	Highest	Average	Lowest	Highest	Average	Lowest
< 1 ha	52436	29964	9117	19.4%	10.24%	2.9%	16.3%	9.29%	2.8%
1 - < 2 ha	79227	50472	31027	18.0%	10.74%	6.3%	15.2%	9.70%	6.0%
2 - < 3 ha	126012	85729	65975	17.2%	11.09%	8.3%	14.7%	9.98%	7.7%
3 - < 4 ha	177208	102895	71381	17.9%	9.66%	6.5%	15.2%	8.81%	6.1%
4 - < 5 ha	180300	149156	41514	13.6%	11.03%	2.8%	12.0%	9.93%	2.8%
5 - > 5 ha	32626	26404	-16364	1.2%	0.95%	-0.6%	1.2%	0.94%	-0.6%

The ranges of gross profit for polyculture were wider than monoculture. Although the size categories of 4 - < 5 ha had highest average gross profit, the highest profit was in the size category of 5 - > 5 ha at 1,283,900 NT$ and only in the size category of 3 - < 4 ha could no profit be made. However, all the size categories of polyculture could not make profit in the lowest range (Table 3.24).

Table 3.24 The ranges of gross profit for polyculture milkfish, by farm size.

	Gross profit			BCR			IR		
	Highest	Average	Lowest	Highest	Average	Lowest	Highest	Average	Lowest
< 1 ha	116082	-19378	-177414	36.7%	-4.29%	-29.1%	26.9%	-4.48%	-41.1%
1 - < 2 ha	106310	-69320	-244950	25.9%	-11.84%	-32.2%	20.6%	-13.43%	-47.5%
2 - < 3 ha	288017	20906	-335242	46.2%	2.35%	-26.9%	31.6%	2.29%	-36.8%
3 - < 4 ha	-84940	-550288	-860520	-7.8%	-35.48%	-46.2%	-8.5%	-54.98%	-85.9%
4 - < 5 ha	1083290	419900	-22360	70.0%	18.99%	-0.8%	41.2%	15.96%	-0.9%
5 - > 5 ha	1283922	279558	-557412	54.8%	8.35%	-13.3%	35.4%	7.71%	-15.4%

Table 3.25 Nominal cash-flow projection for monoculture milkfish farm.

Unit: Thousand NT$

	Year0	Year1	Year2	Year3	Year4	Year5
Cash flow						
Capital cost						
<1 ha	502.0	0	0	0	0	0
1- < 2ha	690.4	0	0	0	0	0
2- < 3ha	815.4	0	0	0	0	0
3- < 4ha	826.4	0	0	0	0	0
4- < 5ha	1160.4	0	0	0	0	0
5->5ha	2288.9	0	0	0	0	0
Operating cost						
<1 ha	0	347.8	347.8	347.8	347.8	347.8
1- < 2ha	0	597.9	597.9	597.9	597.9	597.9
2- < 3ha	0	1002.1	1002.1	1002.1	1002.1	1002.1
3- < 4ha	0	1371.6	1371.6	1371.6	1371.6	1371.6
4- < 5ha	0	1769.0	1769.0	1769.0	1769.0	1769.0
5->5ha	0	3439.2	3439.2	3439.2	3439.2	3439.2
Revenue						
<1 ha		322.6	322.6	322.6	322.6	322.6
1- < 2ha		520.4	520.4	520.4	520.4	520.4
2- < 3ha		858.8	858.8	858.8	858.8	858.8
3- < 4ha		1167.9	1167.9	1167.9	1167.9	1167.9
4- < 5ha		1501.8	1501.8	1501.8	1501.8	1501.8
5->5ha		2804.3	2804.3	2804.3	2804.3	2804.3
Net cash flow						
<1 ha	-502.0	-25.2	-25.2	-25.2	-25.2	-25.2
1- < 2ha	-690.4	-77.5	-77.5	-77.5	-77.5	-77.5
2- < 3ha	-815.4	-143.3	-143.3	-143.3	-143.3	-143.3
3- < 4ha	-826.4	-203.7	-203.7	-203.7	-203.7	-203.7
4- < 5ha	-1160.4	-267.2	-267.2	-267.2	-267.2	-267.2
5->5ha	-2288.9	-635.0	-635.0	-635.0	-635.0	-635.0

3.5.5 Cash-flow and discounted financial indicators

The pattern of cash flow includes capital cost, operating cost (excluding interest and depreciation) and revenue. A 5-year nominal and a discounted cash flow analysis (at 10% discount rate) of monoculture milkfish farm reveal that investment in milkfish is not financially viable (Table 3.25 and Table 3.26). Both nominal and discounted cash flow shows monoculture milksish farms have negative cash flow.

Table 3.26 Discounted cash-flow projection for monoculture milkfish farm.
The discount rate for NPV is 10%. Unit: Thousand NT$

	Year0	Year1	Year2	Year3	Year4	Year5
Cash outflow						
<1 ha	502.0	313.0	281.7	253.6	228.2	205.4
1- < 2ha	690.4	538.1	484.3	435.9	392.3	353.1
2- < 3ha	815.4	901.9	811.7	730.5	657.5	591.7
3- < 4ha	826.4	1234.5	1111.0	999.9	899.9	809.9
4- < 5ha	1160.4	1592.1	1432.9	1289.6	1160.6	1044.6
5->5ha	2288.9	3095.3	2785.8	2507.2	2256.5	2030.8
Revenue						
<1 ha	0	290.4	261.3	235.2	211.7	190.5
1- < 2ha	0	468.4	421.6	379.4	341.5	307.3
2- < 3ha	0	772.9	695.6	626.0	563.4	507.1
3- < 4ha	0	1051.1	946.0	851.4	766.3	689.6
4- < 5ha	0	1351.6	1216.4	1094.8	985.3	886.8
5->5ha	0	2523.9	2271.5	2044.3	1839.9	1655.9
Net cash flow						
<1 ha	-502.0	-25.2	-22.7	-20.4	-18.4	-16.5
1- < 2ha	-690.4	-77.5	-69.7	-62.8	-56.5	-50.8
2- < 3ha	-815.4	-143.3	-129.0	-116.1	-104.5	-94.0
3- < 4ha	-826.4	-203.7	-183.3	-165.0	-148.5	-133.7
4- < 5ha	-1160.4	-267.2	-240.5	-216.4	-194.8	-175.3
5->5ha	-2288.9	-635.0	-571.5	-514.3	-462.9	-416.6
NPV						
<1 ha	-605.1					
1- < 2ha	-1007.6					
2- < 3ha	-1402.5					
3- < 4ha	-1660.6					
4- < 5ha	-2254.5					
5->5ha	-4889.1					

As for monoculture milkfish farms, a 5-year nominal and a discounted cash flow analysis (at 10% discount rate) of polyculture milkfish farm revealed that investment in milkfish is not financially viable (Table 3.27 and Table 3.28). Both nominal and discounted cash flow shows polyculture milkfish farms to have negative cash flow. However, compared with monoculture, polyculture milkfish farm had better financial performance.

Table 3.27 Nominal cash-flow projection for polyculture milkfish farm.

Unit: Thousand NT$

	Year0	Year1	Year2	Year3	Year4	Year5
Cash flow						
Capital cost						
<1 ha	812.6	0	0	0	0	0
1- < 2ha	768.1	0	0	0	0	0
2- < 3ha	1325.7	0	0	0	0	0
3- < 4ha	1944.6	0	0	0	0	0
4- < 5ha	2387.2	0	0	0	0	0
5->5ha	2295.2	0	0	0	0	0
Operating cost						
<1 ha	0	512.0	512.0	512.0	512.0	512.0
1- < 2ha	0	716.9	716.9	716.9	716.9	716.9
2- < 3ha	0	1115.7	1115.7	1115.7	1115.7	1115.7
3- < 4ha	0	1871.2	1871.2	1871.2	1871.2	1871.2
4- < 5ha	0	2631.3	2631.3	2631.3	2631.3	2631.3
5->5ha	0	3999.8	3999.8	3999.8	3999.8	3999.8
Revenue						
<1 ha		432.2	432.2	432.2	432.2	432.2
1- < 2ha		516.1	516.1	516.1	516.1	516.1
2- < 3ha		911.3	911.3	911.3	911.3	911.3
3- < 4ha		1000.9	1000.9	1000.9	1000.9	1000.9
4- < 5ha		2631.2	2631.2	2631.2	2631.2	2631.2
5->5ha		3627.4	3627.4	3627.4	3627.4	3627.4
Net cash flow						
<1 ha	-812.6	-79.8	-79.8	-79.8	-79.8	-79.8
1- < 2ha	-768.1	-200.8	-200.8	-200.8	-200.8	-200.8
2- < 3ha	-1325.7	-204.4	-204.4	-204.4	-204.4	-204.4
3- < 4ha	-1944.6	-870.3	-870.3	-870.3	-870.3	-870.3
4- < 5ha	-2387.2	-0.1	-0.1	-0.1	-0.1	-0.1
5->5ha	-2295.2	-382.3	-382.3	-382.3	-382.3	-382.3

Table 3.28 Discounted cash-flow projection for polyculture milkfish farm. The discount rate for NPV is 10%. Unit: Thousand NT$

	Year0	Year1	Year2	Year3	Year4	Year5
Cash outflow						
<1 ha	812.6	460.8	414.7	373.2	335.9	302.3
1- < 2ha	768.1	645.2	580.7	522.6	470.4	423.3
2- < 3ha	1325.7	1004.1	903.7	813.3	732.0	658.8
3- < 4ha	1944.6	1684.1	1515.6	1364.1	1227.7	1104.9
4- < 5ha	2387.2	2368.2	2131.4	1918.2	1726.4	1553.8
5->5ha	2295.2	3599.8	3239.8	2915.8	2624.2	2361.8
Revenue						
<1 ha	0	388.9	350.0	315.0	283.5	255.2
1- < 2ha	0	464.5	418.1	376.2	338.6	304.8
2- < 3ha	0	820.1	738.1	664.3	597.9	538.1
3- < 4ha	0	900.8	810.7	729.6	656.7	591.0
4- < 5ha	0	2368.1	2131.3	1918.1	1726.3	1553.7
5->5ha	0	3255.7	2930.1	2637.1	2373.4	2136.1
Net cash flow						
<1 ha	-812.6	-71.8	-64.6	-58.2	-52.4	-47.1
1- < 2ha	-768.1	-180.7	-162.6	-146.4	-131.7	-118.6
2- < 3ha	-1325.7	-183.9	-165.6	-149.0	-134.1	-120.7
3- < 4ha	-1944.6	-783.3	-704.9	-634.4	-571.0	-513.9
4- < 5ha	-2387.2	-0.1	-0.1	-0.1	-0.1	-0.1
5->5ha	-2295.2	-344.1	-309.7	-278.7	-250.8	-225.8
NPV						
<1 ha	-294.9					
1- < 2ha	-740.8					
2- < 3ha	-754.6					
3- < 4ha	-3209.6					
4- < 5ha	-2.7					
5->5ha	-1411.4					

If the gross cash flow was considered, i.e., the opportunity cost (interest, depreciation and land cost) are excluded and only expenditure costs were considered, a 5-year nominal and a discounted cash flow analysis (at 10% discount rate) of monoculture milkfish farm reveal that investment in milkfish is not financially viable (Table 3.29

and Table 3.30). Both nominal and discounted gross cash flow shows monoculture milkfish farms have negative cash flow.

Table 3.29 Nominal gross cash-flow projection for monoculture milkfish farm.

Unit: Thousand NT$

	Year0	Year1	Year2	Year3	Year4	Year5
Cash flow						
Capital cost						
<1 ha	502.0	0	0	0	0	0
1- < 2ha	690.4	0	0	0	0	0
2- < 3ha	815.4	0	0	0	0	0
3- < 4ha	826.4	0	0	0	0	0
4- < 5ha	1160.4	0	0	0	0	0
5->5ha	2288.9	0	0	0	0	0
Operating cost						
<1 ha	0	292.7	292.7	292.7	292.7	292.7
1- < 2ha	0	469.8	469.8	469.8	469.8	469.8
2- < 3ha	0	773.0	773.0	773.0	773.0	773.0
3- < 4ha	0	1065.0	1065.0	1065.0	1065.0	1065.0
4- < 5ha	0	1352.6	1352.6	1352.6	1352.6	1352.6
5->5ha	0	2777.9	2777.9	2777.9	2777.9	2777.9
Revenue						
<1 ha		322.6	322.6	322.6	322.6	322.6
1- < 2ha		520.4	520.4	520.4	520.4	520.4
2- < 3ha		858.8	858.8	858.8	858.8	858.8
3- < 4ha		1167.9	1167.9	1167.9	1167.9	1167.9
4- < 5ha		1501.8	1501.8	1501.8	1501.8	1501.8
5->5ha		2804.3	2804.3	2804.3	2804.3	2804.3
Net cash flow						
<1 ha	-502.0	30.0	30.0	30.0	30.0	30.0
1- < 2ha	-690.4	50.7	50.7	50.7	50.7	50.7
2- < 3ha	-815.4	85.7	85.7	85.7	85.7	85.7
3- < 4ha	-826.4	102.9	102.9	102.9	102.9	102.9
4- < 5ha	-1160.4	149.1	149.1	149.1	149.1	149.1
5->5ha	-2288.9	26.4	26.4	26.4	26.4	26.4

Table 3.30 Discounted gross cash-flow projection for monoculture milkfish farm.
The discount rate for NPV is 10%. Unit: Thousand NT$

	Year0	Year1	Year2	Year3	Year4	Year5
Cash outflow						
<1 ha	502.0	263.4	237.1	213.4	192.0	172.8
1- < 2ha	690.4	422.8	380.5	342.5	308.2	277.4
2- < 3ha	815.4	695.7	626.2	563.5	507.2	456.5
3- < 4ha	826.4	958.5	862.7	776.4	698.8	628.9
4- < 5ha	1160.4	1217.4	1095.6	986.1	887.4	798.7
5->5ha	2288.9	2500.1	2250.1	2025.1	1822.6	1640.3
Revenue						
<1 ha	0	290.4	261.3	235.2	211.7	190.5
1- < 2ha	0	468.4	421.6	379.4	341.5	307.3
2- < 3ha	0	772.9	695.6	626.0	563.4	507.1
3- < 4ha	0	1051.1	946.0	851.4	766.3	689.6
4- < 5ha	0	1351.6	1216.4	1094.8	985.3	886.8
5->5ha	0	2523.9	2271.5	2044.3	1839.9	1655.9
Net cash flow						
<1 ha	-502.0	27.0	24.3	21.8	19.7	17.7
1- < 2ha	-690.4	45.6	41.0	36.9	33.2	29.9
2- < 3ha	-815.4	77.2	69.4	62.5	56.3	50.6
3- < 4ha	-826.4	92.6	83.4	75.0	67.5	60.8
4- < 5ha	-1160.4	134.2	120.8	108.7	97.9	88.1
5->5ha	-2288.9	23.8	21.4	19.2	17.3	15.6
NPV						
<1 ha	-391.5					
1- < 2ha	-503.6					
2- < 3ha	-499.5					
3- < 4ha	-447.1					
4- < 5ha	-610.8					
5->5ha	-2191.6					

As with monoculture milkfish farm, a 5-yaer nominal and a discounted gross cash flow analysis (at 10% discount rate) of polyculture milkfish farm revealed that investment in milkfish is not financially viable (Table 3.31 and Table 3.32). Both nominal and discounted cash flow shows polyculture milkfish farms have negative cash flow. Compared with monoculture, polyculture milkfish farm did not have better financial performance.

Table 3.31 Nominal gross cash-flow projection for polyculture milkfish farm.

Unit: Thousand NT$

	Year0	Year1	Year2	Year3	Year4	Year5
Cash flow						
Capital cost						
<1 ha	812.6	0	0	0	0	0
1- < 2ha	768.1	0	0	0	0	0
2- < 3ha	1325.7	0	0	0	0	0
3- < 4ha	1944.6	0	0	0	0	0
4- < 5ha	2387.2	0	0	0	0	0
5->5ha	2295.2	0	0	0	0	0
Operating cost						
<1 ha	0	451.5	451.5	451.5	451.5	451.5
1- < 2ha	0	585.4	585.4	585.4	585.4	585.4
2- < 3ha	0	890.4	890.4	890.4	890.4	890.4
3- < 4ha	0	1551.2	1551.2	1551.2	1551.2	1551.2
4- < 5ha	0	2211.3	2211.3	2211.3	2211.3	2211.3
5->5ha	0	3347.9	3347.9	3347.9	3347.9	3347.9
Revenue						
<1 ha		432.2	432.2	432.2	432.2	432.2
1- < 2ha		516.1	516.1	516.1	516.1	516.1
2- < 3ha		911.3	911.3	911.3	911.3	911.3
3- < 4ha		1000.9	1000.9	1000.9	1000.9	1000.9
4- < 5ha		2631.2	2631.2	2631.2	2631.2	2631.2
5->5ha		3627.4	3627.4	3627.4	3627.4	3627.4
Net cash flow						
<1 ha	-812.6	-19.4	-19.4	-19.4	-19.4	-19.4
1- < 2ha	-768.1	-69.3	-69.3	-69.3	-69.3	-69.3
2- < 3ha	-1325.7	20.9	20.9	20.9	20.9	20.9
3- < 4ha	-1944.6	-550.3	-550.3	-550.3	-550.3	-550.3
4- < 5ha	-2387.2	419.9	419.9	419.9	419.9	419.9
5->5ha	-2295.2	279.6	279.6	279.6	279.6	279.6

Table 3.32 Discounted gross cash-flow projection for polyculture milkfish farm.
The discount rate for NPV is 10%. Unit: Thousand NT$

	Year0	Year1	Year2	Year3	Year4	Year5
Cash outflow						
<1 ha	812.6	406.4	365.7	329.2	296.2	266.6
1- < 2ha	768.1	526.9	474.2	426.8	384.1	345.7
2- < 3ha	1325.7	801.3	721.2	649.1	584.2	525.8
3- < 4ha	1944.6	1396.1	1256.4	1130.8	1017.7	916.0
4- < 5ha	2387.2	1990.2	1791.2	1612.0	1450.8	1305.8
5->5ha	2295.2	3013.1	2711.8	2440.6	2196.5	1976.9
Revenue						
<1 ha	0	388.9	350.0	315.0	283.5	255.2
1- < 2ha	0	464.5	418.1	376.2	338.6	304.8
2- < 3ha	0	820.1	738.1	664.3	597.9	538.1
3- < 4ha	0	900.8	810.7	729.6	656.7	591.0
4- < 5ha	0	2368.1	2131.3	1918.1	1726.3	1553.7
5->5ha	0	3264.7	2938.2	2644.4	2380.0	2142.0
Net cash flow						
<1 ha	-812.6	-17.4	-15.7	-14.1	-12.7	-11.4
1- < 2ha	-768.1	-62.4	-56.1	-50.5	-45.5	-40.9
2- < 3ha	-1325.7	18.8	16.9	15.2	13.7	12.3
3- < 4ha	-1944.6	-495.3	-445.7	-401.2	-361.1	-324.9
4- < 5ha	-2387.2	377.9	340.1	306.1	275.5	247.9
5->5ha	-2295.2	251.6	226.4	203.8	183.4	165.1
NPV						
<1 ha	-884.1					
1- < 2ha	-1023.6					
2- < 3ha	-1254.9					
3- < 4ha	-3972.8					
4- < 5ha	-839.7					
5->5ha	-1264.9					

3.5.6 Price sensitivity

The profitability is sensitive to the changes in the selling price. Here, the relationship between gross profit of monoculture to different selling price is compared. The average farm gate price was 33.8 NT$/kg. The average break even prices were 29.0, 30.4, 29.5, 42.6, 17.9 and 46.4 NT$/kg in the size categories of < 1 ha, 1- < 2 ha, 2 - < 3 ha, 3 - < 4 ha, 4 - < 5 ha and 5 - > 5 ha, respectively. Prices of 25, 30, 35, 40 and 45 NT$ were used to compare the sensitivity of profitability to price. When price dropped down to 25 NT$/kg, only in the farm size of 4 - < 5 ha could make profit. With the exception of farm size of 4 - < 5 ha, all the farms could make profit when the price rose to 45 NT$/kg, the profit of farm size of 4 - < 5 ha could reach 2,041,600 NT$ (Table 3.33)

Table 3.33 The sensitivity of profitability to price. Unit: NT$

Price	25	30	35.	40	45
< 1 ha	-40243	10245	60733	111222	161710
1 - < 2 ha	-83753	-6509	70735	147978	225222
2 - < 3 ha	-117622	13462	144547	275631	406716
3 - < 4 ha	-439576	-314486	-189396	-64305	60785
4 - < 5 ha	533049	910183	1287317	1664452	2041586
5 - > 5 ha	-1281952	-982766	-683580	-384394	-85208

3.6 Marketing channels

The marketing channel for milkfish is very complex (Fig. 3.3). Usually, there are five ways for fish farmers to sell their product and the money was paid by either cash or short term cheque.

- Sell product directly to the retail market or restaurants by themselves. Profits can be higher but this is more complicated and time-consuming. Usually, farmers may only sell part of their products directly to retail markets.

- Sell product directly to the processing plant. Usually, the processing plant will sign a contract with the fish farmer and this is often preferred by producers. However, because of factors such as the capacity of the processing plant, the required market size of the processed product or the distance between the plant and the production site, not all the fish farmers can use this method regularly.

♦ Sell product directly to an auction market. In this situation the fish farmer must take the risk of price fluctuation directly, as there is no contract for price. In the auction market, the prices are decided by bidding and sales are organised through agents.

♦ Sell to a middleman, who collect products from farmers or auction markets and re-sell the products to retail markets or consumers (including restaurants). Middlemen may pay a higher price to the producers. However, because the middlemen usually deal not only with milkfish and cannot buy large quantities, except for smaller farms, most producers do not sell their product this way. However some will sell to a middleman because of the pressure of friendship.

♦ Sell to a collector. This is a traditional method and is the most common because although price may not be so high, it is more convenient and farmers can obtain their money quickly. There were another two reasons for farmers usually selling their product to collectors. First, they do not know the marketing channel and are only used to the traditional method of selling their fish. Second, they do not have vehicles to transport their product to the auction market and therefore, they hire the vehicles belonging to the collector for this purpose. However, the fish farmers must take the risk in the sale to the collector.

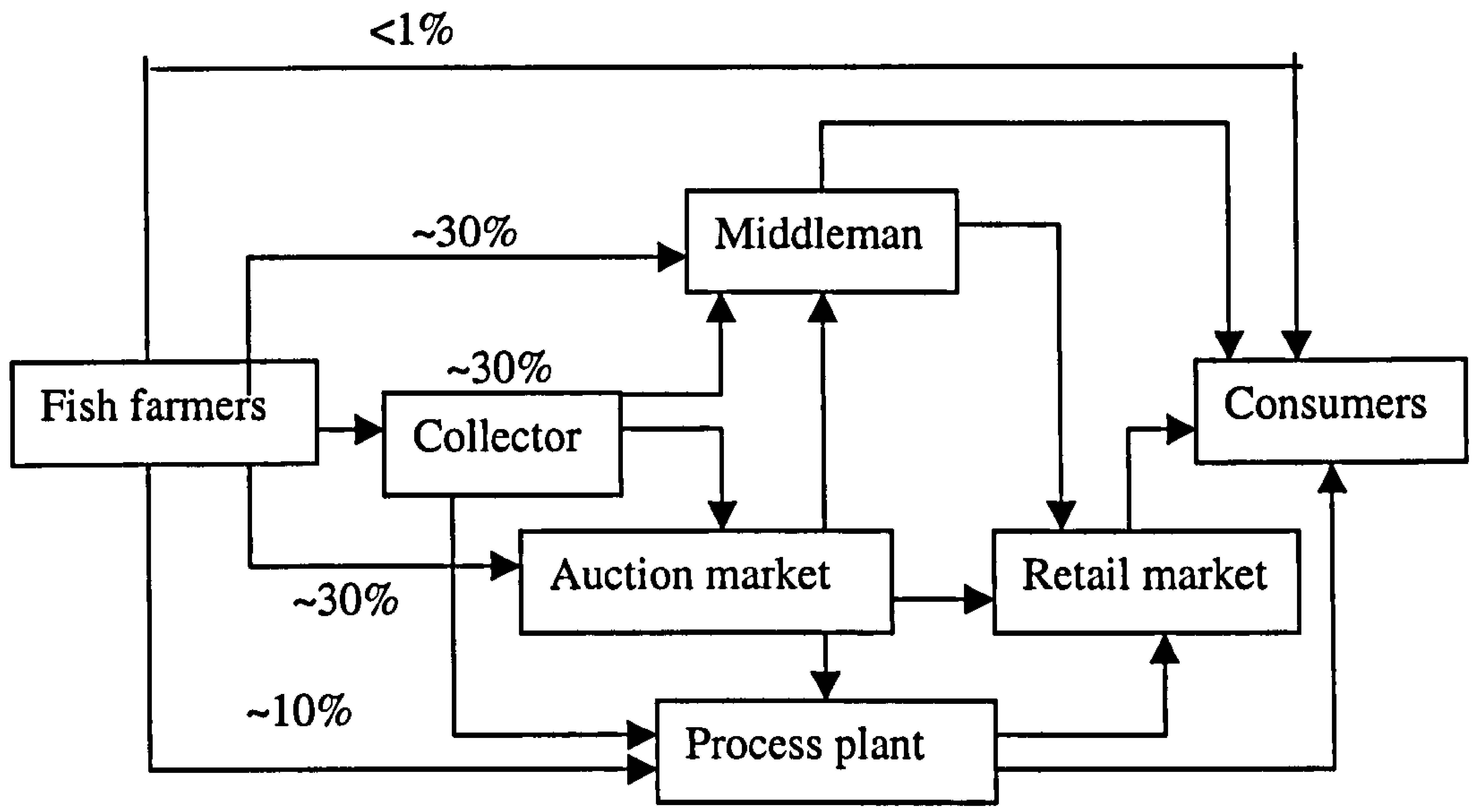


Fig 3.3 Chart of marketing channel for milkfish in Taiwan.
Data source: Tzeng (personal communication 1999).

3.7 Supply and price relationships

For understanding the factors which influence price, data were collected from Chia-I fisheries market (one of the biggest fisheries auction markets in Taiwan). The data is provided in the form of average prices by month. Production data was obtained from the Year Book of the Taiwan Fisheries Bureau (1994-1998) to assess the relation between production quantity and price.

3.7.1 Seasonal variation of production and price

Table 3.26 shows the outlines of production of milkfish in Taiwan over the years 1994-1998 and presents an index of seasonal variation, based on average trends. This shows that the season of highest production centers on June to December when the indices are over 100%, the average peak being in October, with an index of 143% (Table 3.34 and Fig. 3.4.). However, in different years, the peaks of production were in different months, suggesting that farmers have changed the practice of harvesting in different months. In general, the higher production season is from summer to early winter. The index of seasonal price (Table 3.35 and Fig. 3.5) shows that the season of average higher prices centers on January to June, with indices at over 100%, the highest being in April, where the average index is 120.9%. The seasonal indices of prices have a negative relationship with indices of production. The indices of price became higher when the indices of production were lower.

Table 3.34 The seasonal variation of production of milkfish in Taiwan. Unit: ton

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug	Sep.	Oct.	Nov.	Dec.	Ave
1994	3780 (69)	3673 (67)	3419 (62)	3800 (69)	4098 (75)	5883 (107)	8516 (155)	7137 (130)	7903 (144)	10499 (191)	4581 (84)	2515 (46)	5484 (100)
1995	3848 (73)	3983 (75)	3609 (68)	4613 (87)	4024 (76)	4786 (90)	4297 (81)	6819 (129)	6369 (120)	7524 (142)	9228 (174)	4424 (84)	5294 (100)
1996	3974 (81)	3459 (71)	4037 (83)	2752 (56)	3838 (79)	6078 (125)	3933 (81)	4279 (88)	6541 (134)	7153 (147)	7235 (148)	5269 (108)	4879 (100)
1997	3876 (74)	4061 (78)	2142 (41)	4607 (88)	4292 (82)	7870 (151)	6966 (133)	4589 (88)	5448 (104)	6613 (126)	3656 (70)	8625 (165)	5229 (100)
1998	3644 (75)	3663 (75)	3642 (75)	4265 (88)	4528 (93)	7391 (152)	7065 (145)	5468 (112)	5696 (117)	5141 (106)	2845 (59)	5002 (103)	4863 (100)
Ave.	3824 (74)	3768 (73)	3370 (65)	4007 (78)	4156 (81)	6402 (123)	6155 (120)	5658 (110)	6391 (124)	7386 (143)	5509 (107)	5167 (100)	5150 (100)

Data source: Year Book of Taiwan Fisheries Bureau (1995-1999).
The figures in the parentheses are the indices of seasonal variation.

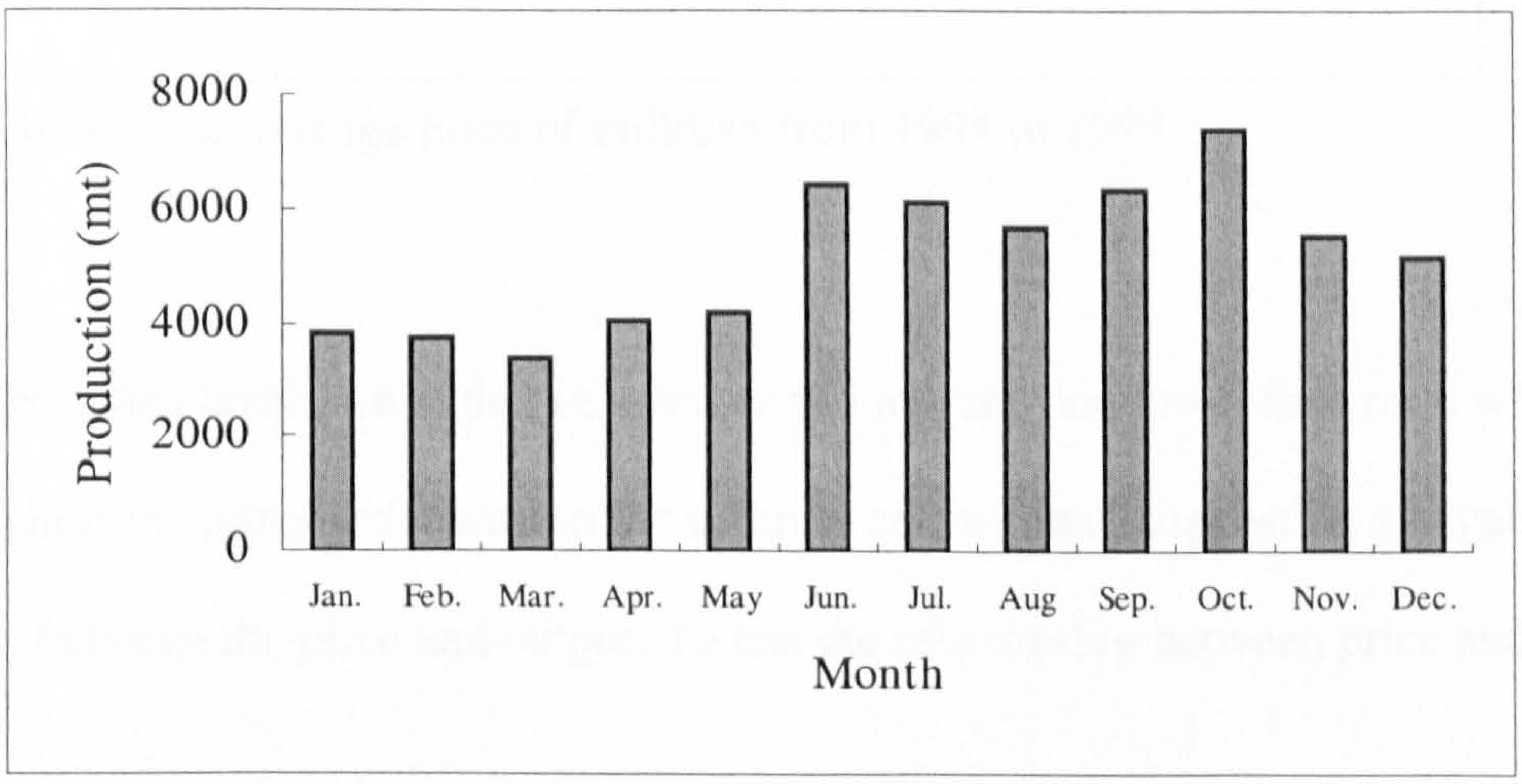


Fig.3.4 The average production quantity of milkfish from 1994 to 1998.

Table 3.35 The seasonal variation of price of milkfish in Taiwan. Unit:NT$

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug	Sep.	Oct.	Nov.	Dec.	Ave
1994	56.9 (112)	57.3 (112)	55.8 (109)	59.2 (116)	55.9 (110)	46 (90)	43.3 (85)	47.7 (93)	43.2 (85)	45 (88)	48.9 (96)	53 (104)	51.0 (100)
1995	53.7 (86)	63.5 (101)	71.3 (114)	68.8 (110)	71.5 (114)	66.1 (106)	62.8 (100)	66.3 (106)	59.1 (94)	54.4 (87)	52.7 (84)	61.4 (98)	62.6 (100)
1996	71 (95)	77 (103)	91.6 (123)	101.1 (136)	104 (140)	90.2 (121)	66.1 (89)	66.4 (89)	54.4 (73)	55.5 (75)	55 (74)	61.6 (83)	74.5 (100)
1997	69.9 (120)	75.1 (128)	72 (123)	71.3 (122)	65.1 (111)	60.1 (103)	48.1 (83)	48.4 (83)	47.2 (81)	44.8 (77)	47.7 (82)	51.7 (88)	58.5 (100)
1998	52.7 (116)	53.3 (118)	51.3 (113)	52.3 (116)	47.4 (105)	42.3 (93)	39.9 (88)	45.7 (101)	40 (88)	40.8 (90)	39.5 (87)	37.9 (84)	45.3 (100)
Ave.	60.8 (104)	65.2 (112)	68.4 (117)	70.5 (121)	68.8 (118)	60.9 (104)	52.0 (89)	54.9 (94)	48.8 (84)	48.1 (82)	48.8 (84)	53.1 (91)	58.4 (100)

Data source: Chai-I Fisheries Market (1999).
The figures in the parentheses are the indices of seasonal variation.

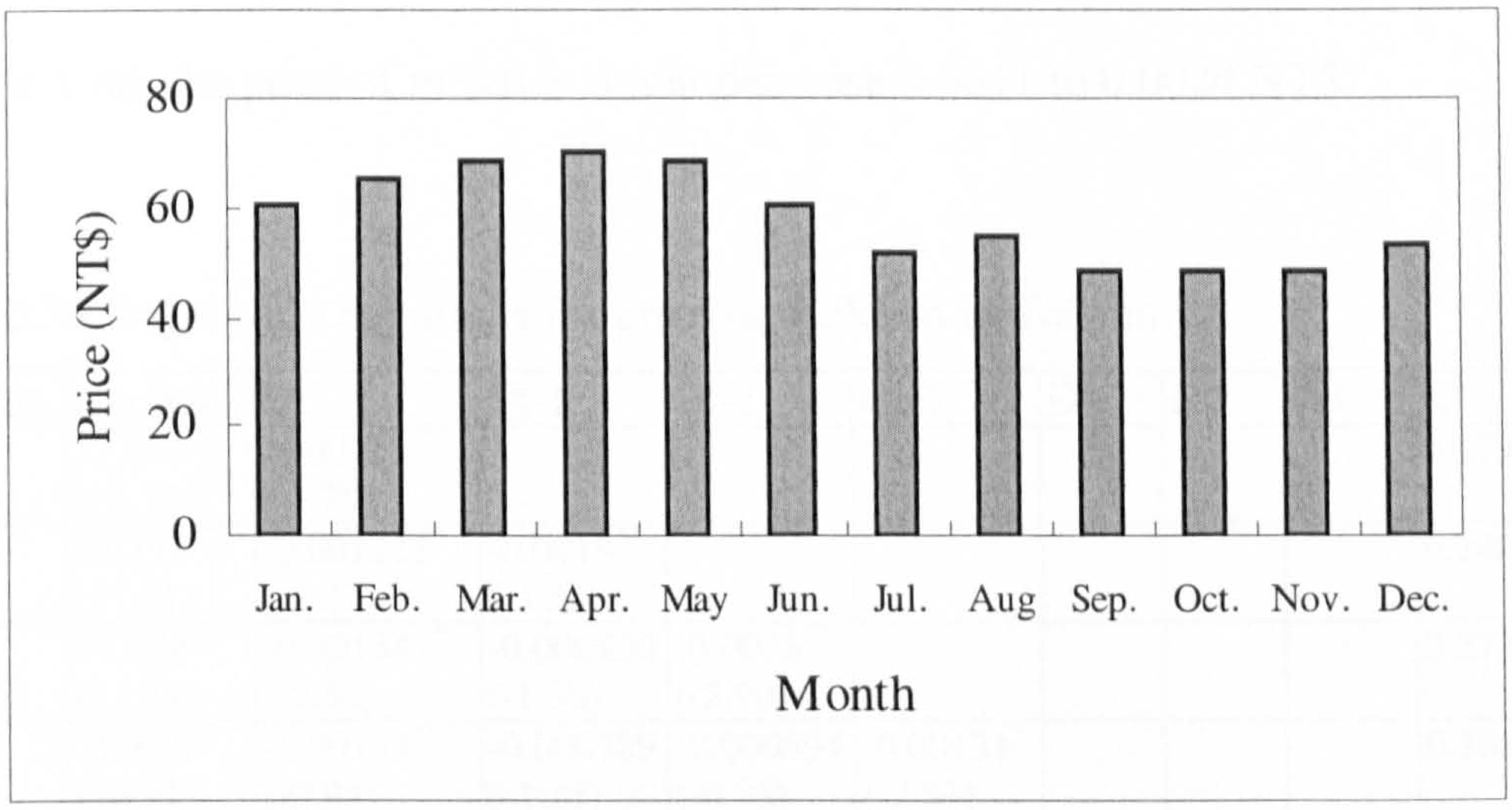


Fig.3.5 The average price of milkfish from 1994 to 1998.

As indicated, sales levels are higher in summer and autumn and lower in spring, while price is highest in spring and lowest in the summer and autumn, suggesting a negative correlation between the price and output. To test the relationship between price and production of milkfish, including lagged quantity and seasonal variation, regressions were determined based on the following function form.

$P_t = f(Q_t, Q_{t-1}, Q_{t-2}, Q_{t-3}, D_1, D_2, D_3)$

In this function P_t is the undeflated price of milkfish in month t, in NT$ per kilogram; Q_{t-1}, Q_{t-2}, Q_{t-3}, are production quantity in months t, t-1, t-2 and t-3, in respectively, in thousand kilogram. D_1 to D_3 are dummy variables which represent spring, summer and autumn. The results of regression were shown in Table 3.36, from which it can be shown that the price of milkfish is strongly affected by seasonal variation and by production quantity in the same month (Qt). The coefficients of Qt in different regressions are from -0.0011 to –0.0024, that means when the national production increase 1 mt, the price of milkfish might decrease 0.0011 to 0.0024 NT$.

Table 3.36 Regression equations for price of milkfish in Taiwan.

Equation	Constant	Qt	Qt-1	Qt-2	Qt-3	D1	D2	D3	R^2	F
A	72.643** (31.72)	-0.00244** (-5.79)							0.179	33.47**
B	75.372** (31.91)	-0.001211* (-2.27)	-0.0019** (-3.57)						0.240	24.03**
C	77.738** (31.35)	-0.001341* (-2.56)	-0.000830 (-1.30)	-0.0015** (-2.90)					0.278	19.24**
D	79.884** (30.21)	-0.00154** (-2.94)	-0.000789 (-1.26)	-0.000594 (-0.95)	-0.00131* (-2.51)				0.302	16.02**
E	61.9** (20.12)	-0.00182** (-4.15)				17.9** (4.69)	13.4** (3.51)	1.07 (0.26)	0.317	17.55**
F	64.601** (19.10)	-0.00107* (-2.51)	-0.0012* (-1.69)			16.4** (4.19)	11.6** (2.98)	0.92 (0.23)	0.343	15.56**
G	67.7** (18.17)	-0.00112* (-2.63)	-0.000579 (-0.68)	-0.00102 (-1.53)		14.7** (3.68)	9.24* (2.28)	-0.07 (-0.02)	0.356	13.57**
H	71.76** (17.44)	-0.00120* (-2.27)	-0.000554 (-0.92)	-0.000282 (-0.46)	-0.00120* (-2.26)	12.5** (3.08)	6.43 (1.53)	-2.89 (-0.69)	0.371	12.24**

Data sources: Chai-I Fisheries Market (1999).
Year Books of Taiwan Fishery Bureau (1988-1999).
The prices used are defalted.
Number in parentheses are t values.

3.7.2 Long-run variation of price and production

The degree of annual fluctuation or instability in the price and production of milkfish can be evaluated by using the Michaely index (f), where

$$f = \frac{\sum_{t=2}^{n} \left| \frac{x_t - x_{t-1}}{x_{t-1}} \right|}{n-1} \times 100$$

The higher the value of *f*, the more instability is implied. If *f* is above 20%, it means extreme instability and slight instability if *f* is less than 10% (Lee 1983). The f value of the milkfish price from 1986 to 1999 was 22.04% and the value of milkfish production from 1987 to 1998 is 60.23%. This shows that the price of milkfish in Taiwan was highly unstable in Taiwan during these periods, and production was even more unstable.

3.7.3 Annual trend of yield and price of milkfish

The trend of production of milkfish in Taiwan from 1987 to 1999 can be expressed as:

$$Y = 35537 + 2094t \qquad R^2 = 0.176 \qquad F = 2.36 \qquad DW = 2.41$$
$$(3.28)^{**} \quad (1.54)$$

Where

Y= annual total production of milkfish in MT

t= number of years from 1987 to 1999

R^2= coefficient of determination

DW= Durbin Watson d test

The trend of price of milkfish in Taiwan from 1986 to 1999 can be expressed as:

$$P= 100.669- 3.6234t \quad R^2= 0.585 \quad F= 16.91^{**} \quad DW= 2.16$$
$$(13.42)^{**} \; (-4.41)^{**}$$

Where

P= deflated average price of milkfish in NT$

t= number of years from 1986 to 1999

R^2= coefficient of determination

DW= Durbin Watson d test

Although DW value shows there is no positive serial correlation, the regression shows the long term trend of increasing production and decreasing price.

3.7.4 Actual apparent consumption

The real consumption level by domestic market can be expressed in kg/capita/year and can be evaluated by using actual apparent consumption (AAC), where

AAC = (Production + Import – Export)/ Number of people

The result of AAC were shown in Table 3.29, from which it can be shown that the highest AAC was in 1990, followed in 1994, reaching 4.4 and 3.2 kg. However, since 1994, the value of AAC decreased gradually and was only 1.4 in 2000. The highest value of AAC might be because of the mass production in 1990. Table 3.26 shows that since 1996, Taiwan developed the export market, accounting for ~ 5-9% of total milkfish production.

Table 3.37 The actual apparent consumption (AAC) of milkfish.

Year	Production (mt)	Export (mt)	Import (mt)	Population (1,000 people)	AAC* (kg/people/year)
1990	90,673	0.12	0.11	20,401	4.4
1991	41,232	2.93	0	20,606	2.0
1992	25,114	0.98	0	20,803	1.2
1993	45,513	2.79	0	20,995	2.2
1994	66,778	5.08	0	21,178	3.2
1995	63,254	26.71	0	21,357	3.0
1996	58,453	6,531.26	0.19	21,525	2.4
1997	62,749	10,765.00	0.01	21,743	2.4
1998	58,349	9,581.67	7.83	21,929	2.2
1999	50,824	9,640.69	0.97	22,092	1.9
2000	39,731	7,509.10	77.06	22,277	1.4

Data source: Fisheries Administration, Taiwan (www.fa.gov.tw).
Directorate General of Budget Accounting and Statistic, Executive Yuan, R.O.C. (www.dgbas.gov.tw).

*AAC refers to actual apparent consumption.

3.7.5 Consumer perspective

To understand better the attitudes of consumers towards milkfish, 132 individuals were surveyed in 1999. 3 areas were surveyed; Taipei (52 consumers), Taichung (45 consumers) and Tainan (35 consumers), representing northern, central and southern part of Taiwan respectively.

As shown in Table 3.38, the majority of respondents (85%) prefer fresh milkfish. Though consumers may not have known that a lot of milkfish (dorsal part) is used for producing fish meat ball or fish powder, fresh fish is clearly their favourite. As canned tuna is ~ 10 NT$ cheaper than canned milkfish per can (~230 g), it is difficult for milkfish to compete in this sector.

Table 3.38 Preferences for milkfish product forms.

Products	Numbers	Percentage	Chi-square value	P value
Fresh fish	130	86.1%	74.42	$1.89*10^{-21}$**
Canned fish	6	4.0%	8.82	
Fish meat ball	12	7.9%	5.78	
Others	3	2.0%	10.58	
Total	151	100%	99.6	

Most of the respondents preferred the belly part of milkfish (Table 3.39) because it is the softest and most oily part. A very small number (5.7%) preferred the milkfish head, while scaled and gutted or whole fish were moderately popular.

Table 3.39 Preferences for fresh milkfish product.

Products	Numbers	Percentage	Chi-square value	P value
Whole fish	34	21.7%	0.307692	0.000264**
Scaled and gutted whole fish	39	24.8%	0	
Head	9	5.7%	7.692308	
Belly part	75	47.8%	11.07692	
Total	157	100%	19.07692	

The survey suggested that consumption of milkfish was not correlated with seasons (Table 3.40), as respondents (>75%) did not buy milkfish in a specific season, though they would buy a little bit more milkfish in summer than in winter. It might be because the price in summer is cheaper.

Table 3.40 Seasonal preference for purchasing milkfish.

Seasons	Numbers	Percentage	Chi-square value	P value
Spring	6	4.4%	5.44	$2.82*10^{-18}$**
Summer	18	13.3%	1	
Autumn	6	4.4%	5.44	
winter	3	2.2%	7.11	
Uncertain	102	75.6%	69.44	
Total	135	100%	88.44	

Most respondents preferred the size of milkfish at about 600g (Table 3.41), though the market size of milkfish is usually about 200-500g. However if the size of milkfish is too big (over 600g), its meat might be too firm and it would be over pan size.

Table 3.41 Preferred purchasing size of milkfish.

Sizes	Numbers	Percentage	Chi-square value	P value
300 g	18	15.38%	1.4423086	$5.62*10^{-8}$**
600g	78	66.67%	27.08333	
900g	12	10.26%	3.39102	
1200	9	7.69%	4.673077	
Total	117	100%	36.58974	

Most respondents expressed that their frequency of buying milkfish was uncertain (48.9%) (Table 3.42), suggesting that they would purchase at will, without pattern. Some respondents like milkfish and will buy it regularly. A good number of respondents (26.3%) like milkfish and will buy it every week.

Table 3.42 The frequencies of buying milkfish.

Frequencies	Numbers	Percentage	Chi-square value	P value
Every week	35	26.3%	1.163636	$4.2161*10^{-6}$**
Every two weeks	24	18.0%	0.072727	
Every three weeks	3	2.3%	6.913636	
Every month	6	4.5%	5.254545	
Uncertain	65	48.9%	16.91364	
Total	133	100%	30.31818	

In Taiwan, the unit of weight is 600g, and therefore 600g, 1200g and 1800g were chosen as purchase quantities. The most common amount of milkfish that respondents report purchasing is about 600g (44.2%) (Table 3.43). Consumers might consider this amount is suitable for a family. If they buy more they may not finish it in one meal.

Table 3.43 The quantity of milkfish purchased each time.

Amount	Numbers	Percentage	Chi-square value	P value
About 600 g	57	44.2%	6.331395	0.02929*
About 1200 g	21	16.3%	1.30814	
About 1800g	20	15.5%	1.40715	
Uncertain	31	24.0%	0.052326	
Total	129	100.01%	9	

When asked why they do not buy milkfish, more than 90% of respondents answered that milkfish was too bony (Table 3.44). That may also be the reason why some consumers just buy the belly part, as there are no tiny bones in this part. The boniness of milkfish appears to be the biggest problem restricting market development of milkfish in Taiwan.

Table 3.44 The reasons that consumers do not buy milkfish.

Reasons	Numbers	Percentage	Chi-square value	P value
Bony	120	90.91%	43.7361213	$5.2587*10^{-15}$**
Too expensive	3	2.27%	12.7381663	
Others	9	6.82%	9.28349693	
Total	132	100%	65.7577846	

More than 77% of respondents considered the price of milkfish to be acceptable (Table 3.45), neither too expensive nor very cheap. Compared to other aquaculture products (Table 3.4) or other protein products, the price of milkfish is not high. However, its boniness is a disadvantage in competition.

Table 3.45 Opinions of respondents concerning the price of milkfish.

Opinions	Numbers	Percentage	Chi-square value	P value
Very expensive	4	3.0%	6.913636364	$7.2238*10^{-19}$**
Expensive	6	4.55%	5.254545455	
Acceptable	102	77.27%	72.16363636	
Cheap	14	10.6%	1.640909091	
Very cheap	6	4.55%	5.254545455	
Total	132	100%	91.22727273	

Regarding the quality of milkfish, most respondents have a positive opinion. More than 55% consider the quality to be good and only ~ 9% consider it to be below acceptability, it might be because it is too bony (Table 3.46).

Table 3.46 Opinions of respondents concerning the quality of milkfish.

Opinions	Numbers	Percentage	Chi-square value	P value
Excellent	9	6.82%	3.822727273	$3.06203*10^{-9}$**
Good	75	56.82%	29.82272727	
Acceptable	36	27.27%	1.163636364	
Bad	9	6.82%	3.822727273	
Very Bad	3	2.27%	6.913636364	
Total	132	100%	45.54545455	

When combining quality and price, most respondents have a positive opinion about milkfish. More than 90% of consumers considered milkfish are acceptable or more than acceptable (Table 3.47). This suggest that consumers might be willing to pay more.

Table 3.47 Evaluations of respondents concerning the price and quality of milkfish.

Opinions	Numbers	Percentage	Chi-square value	P value
Excellent	12	9.09%	2.618181818	$2.5983*10^{-7}$**
Good	57	43.18%	11.82272727	
Acceptable	54	40.91%	9.618181818	
Bad	6	4.55%	5.254545455	
Very Bad	3	2.27%	6.913636364	
Total	132	100%	36.22727273	

Most of consumers considered that they would buy more milkfish if the price were lower (Table 3.48). Milkfish must compete with other species and other food products would also have to be taken into account.

Table 3.48 Situations in which consumers would buy more milkfish.

Situations	Numbers	Percentage	Chi-square value	P value
Price is cheaper	72	52.9%	5.4	0.01713*
Quality is better	33	24.3%	1.066667	
Others	31	22.8%	1.666667	
Total	136	99.99%	8.133333	

3.8 Discussion

In Taiwan, milkfish is a traditional and very important sector in aquaculture, accounting for about 10-20% of total production (Table 3.3). Although fry can be produced in hatcheries, and potential supplies are more than enough to provide for domestic demand, they are still imported from the Philippines because of the seasonal shortage. First spawning usually occurs in early April when the water temperature rises to 26°C and so some farmers import fry to stock before May, to allow harvest before that winter. Therefore, to make broodstock spawn from February to March, and to cope with lower temperature larval rearing outdoors are big challenges for researchers.

Overall, milkfish rank first in fry production among finfish and the potential of supply is more than enough to meet demand in the domestic market. It would therefore be more useful to balance the demand and supply, to try to develop the fry market more widely in Southeast Asia.

Milkfish culture has been developed over more than 300 years in Taiwan, and in general terms, its technology is quite mature, but a number of problems are to be solved. The cold weather is a significant problem in the production of milkfish, as water temperature drops below 10 °C, it causes mass mortality (Ding 1994). Therefore, the accurate weather forecasting is very important in allowing farmers to set up overwintering canals or harvest before the cold weather comes. If possible, a strategy should be developed to set up production areas in the warmer part of Taiwan to avoid cold-kill.

Being concerned about the low profits from monoculture, a number of farmers used polyculture in milkfish ponds with other species, such as tiger prawn, sand prawn, fresh water prawn mullet and other economically valuable species to spread risks and increase revenues (Table 3.2 and Table 3.8). It also contributed to a smoother harvesting pattern, and consequently cash flow, throughout the year. Capacity can also be utilized more evenly. However, this survey showed that in polyculture, only farm sizes in the category of 4-<5 ha had significantly higher profit than monoculture.

This survey suggested that the milkfish sector is not economically sound. This might be the reason that more than 75 % of milkfish farmers have other family income (Table 3.5), and in the age category of 30 < 40 years old, the ratio of other family income was even as high as 92% (Table 3.6). However most milkfish farmers have their own land and have already made investments in facilities for cultivating. As a result, it is difficult for them to change to another usage though the sunk costs also mean that their effective return may be greater than those suggested by net profit calculations. Even in years when the price of milkfish is not high enough to cover costs, farmers still rear milkfish and hope the fish will fetch a better price the next year.

Further understanding the ratio of their labour input on milkfish farming and other jobs, and the earning from milkfish and other job might be helpful in understanding the involvement of farmers in milkfish farming. Farm size in the categories of 4- < 5 ha for monoculture could appear to be more profitable. The lowest cost producer is efficient as a result of economies of scale for family labour. However, when farm size exceeded 5 ha, it was difficult for a family to manage. In polyculture, the range of profitability was wider than monoculture. Farmers with better performance could attain higher profits than in monoculture. In the future, farms might be adjusted to 4- < 5 ha or replaced by better managed polyculture farms.

The marketing channel is very complex. With at least five routes for selling fish and a number of intermediary stages, this suggests inefficiency, and the need over the longer term to shorten the marketing channel. Even though production and marketing groups have been set up, their function was not obvious (Wu 1998), though if these were strengthened, this group might shorten the marketing channel. Production and marketing groups will be discussed further in Chapter 6.

The price of milkfish is easily influenced by production quantity. The fluctuation of production might also cause the variation of price. Overproduction could make the market prices drop dramatically. For example, in 1990, when the tiger shrimp sector collapsed, some shrimp farmers adapted their ponds to cultivate milkfish, which induced overproduction. This overproduction made the price of milkfish drop from 60 to below 45 NT$ (Liao 1993) and caused economic distress to producers. Although this extreme situation is unlikely to happen again in the near future, the high values of Michaely index show that the production and price of milkfish were unstable. Such an unstable situation might make this industry more risky. Therefore, proper information about the production areas and predicted production amount might be helpful to avoid this disaster.

To balance the demand and supply more effectively, better planning of production is required, and market conditions monitored by the government or Fishermen Association to advise farmers if significant unbalances are likely to occur. As price is also strongly correlated to seasonal variation, farmers may be able to do more to adjust the harvest time to match the higher price period in April and harvest size. In the long-term analysis, price was in a decreasing trend. It might be because of the long term increasing trend of production caused by the introduction of deep-water culture.

With respect to the potential for expanding markets, most consumers had positive opinions on milkfish. Generally, consumers preferred the belly part of milkfish and a size of about 600g. The low price of milkfish might be an advantage for market competition with other products, however their boniness is a disadvantage. For expanding market and competing with other products, the technique of boneless preparation from the Philippines might be helpful. Although one processor has learned this technique from the Philippines (China Times, December 22, 2001), it is still a secret technique in Taiwan.

There has also been some risk due to negative press reporting. Thus when on December 25, 2000, a newspaper reported research results by Chin-Hwa University that milkfish were contaminated by chlorine, the price declined to below 40 NT$ the next day. Therefore, proper management in fish farms to avoid any contamination and appropriate quality control through Fishermen Association and production and marketing groups might improve the image of milkfish.

Since 1996, certain amount of export markets have been developed and about 5-9 % of total production was exported (Table 3.26), it might be benefit for the development of milkfish industry in the long term.

Chapter 4

Eel Culture

4.1. Introduction

4.1.1. Background

Eel culture started in Japan in 1879 (Matsui 1952), and during a similar period in Italy and France (Gousset 1990). The Japanese started to rear glass eels in 1919, and artificial feeds were introduced to the market in 1965. The first experiment of the feasibility of eel culture in Taiwan began in 1952, and in 1958 small-scale commercial eel farming started. The first large-scale expansion of eel farming began in 1964 with the raising of glass eels to stocking size fingerlings for Japanese eel farms. The first export of market size eels to Japan took place in 1970 (Chen1990).

Eel culture has been one of the most important aquaculture sectors in Taiwan. The total value of eel production is the highest among all aquaculture sectors, with almost 90% of production exported to Japan. In 1988, its value had reached 43.2% of total aquaculture value (Table 4.1). Eel culture can be carried out in both of fresh and salt water. However, most farmers use fresh water because of faster growth. Eel is a high value product and farmers usually use intensive monoculture. Since 1988, the ratio of eel culture area to total national aquaculture area has ranged from 6.2 to 2.4% and that of eel to total aquaculture output has ranged from 19.5 to 6.3%. The productivity of aquaculture has ranged from 3.5 to 4.5 mt/ha, while that of eel has ranged from 8.4 to 14.8 mt/ha (Table 4.1 and 4.2), illustrating its highly intensive nature. The ratio of eel to total aquaculture production value has ranged from 43.2 to 18.7% since 1988

(Table 4.1). The average price (V/Q) of eel ranged from 200 to 289 NT$/kg from 1987 to 1993. However, the average prices increased, since 1994 to 1998, the prices were higher than 300NT$ and reached the highest level of 457 NT$/kg in 1995. In 1999, the average price returned to 266 NT$ (Table 4.1). This change might be influenced by the prices of eel seed (Table 4.4). Since 1988, the average prices of aquaculture products have ranged from about 90 to 130 NT$ and those of eel have ranged from 200 to 460 NT$ (about 2 times the average for aquaculture) (Table 4.1), illustrating its high price.

However, because of limited land and water resources, a shortage of eel seed and competition with China for the Japanese market, the sector has been declining (Fig. 4.1 and Table 4.1) and almost 1/3 (33.1%) of culture area was suspended in 1997 (Table 4.2). From 1987 to 1999, the average change of eel output and value has been -61.01% and -64.07% respectively (Table 4.1). To reduce the use of land and ground water, some producers have recently developed indoor super intensive culture. In this chapter, traditional and the super intensive eel culture will be described and compared. The average yield of eel production was highest in 1991, reaching 14.8 mt/ha (Table 4.2). However, it decreased to 8.44 mt/ha in 1999, implying that more intensive culture was not applied widely.

Table 4.1 Output and value of eel culture in Taiwan.

Unit: Quantity: Thousand M.T.
Value: Million NT$

Year	Total aquaculture			Eel culture			R^1	R^2
	Quantity	Value	V/Q	Quantity	Value	V/Q		
1987	305.4	35.23	115.4	42.5	12.23	287.9	13.9	34.7
1988	301.0	34.48	114.6	51.6	14.90	288.8	17.1	43.2
1989	250.0	26.52	106.2	48.0	10.61	220.9	19.2	40.0
1990	344.3	31.53	91.6	55.8	12.36	221.5	16.2	39.2
1991	291.9	30.26	103.7	55.6	11.11	199.6	19.1	36.7
1992	261.6	29.29	112.0	51.0	11.73	229.8	19.5	40.0
1993	285.3	29.82	104.5	40.0	11.15	279.1	14.0	37.4
1994	288.0	33.57	116.6	33.4	12.98	389.1	11.6	38.7
1995	286.6	36.51	127.4	25.5	11.67	456.9	8.9	32.0
1996	272.5	32.73	120.1	25.1	10.52	419.9	9.2	32.2
1997	270.1	27.10	100.3	22.3	8.55	382.8	8.3	31.6
1998	255.2	27.39	107.3	17.2	6.02	349.5	6.8	22.0
1999	263.1	23.51	89.4	16.5	4.39	265.6	6.3	18.7
Average growth rate (1987-1999)	-1.24%	-33.28%		-61.01%	-64.07%			

Data source: Fisheries Year Book, Taiwan Area.

R^1 represents the ratios of total output of eel culture to total output of aquaculture.

R^2 represents the ratios of total production value of eel culture to total production value of aquaculture.

The figures are undeflated

Table 4.2 The area for aquaculture of *Anguilla sp.* Unit: Thousand ha

Year	Total Aquaculture		Eel culture					R^1	R^2
	Area	MT/ha	Mono-culture	Poly-culture	Suspended	Total	MT/ha		
1988	**67.41**	**4.47**	3.51 (99.28)	0.03 (0.71)	-------	3.53	14.60	5.24	5.24
1989	**71.08**	**3.51**	3.92 (97.58)	0.10 (2.41)	-------	4.01	11.97	5.64	5.64
1990	**76.42**	**4.50**	3.95 (99.55)	0.02 (0.45)	-------	3.97	14.08	5.19	5.19
1991	**74.08**	**3.94**	3.72 (99.22)	0.03 (0.66)	-------	3.75	14.83	5.07	5.07
1992	**72.29**	**3.62**	4.43 (99.48)	0.02 (0.52)	-------	4.46	11.44	6.17	6.17
1993	**70.97**	**4.02**	3.20 (81.68)	0.02 (0.48)	0.70 (17.84)	3.92	12.41	5.52	4.54
1994	**69.60**	**4.14**	2.90 (69.13)	0.07 (1.66)	1.23 (29.20)	4.20	11.22	6.03	4.27
1995	**70.08**	**4.09**	2.50 (68.96)	0.04 (1.14)	1.08 (29.90)	3.62	10.05	5.17	3.63
1996	**67.61**	**4.03**	2.17 (65.56)	0.07 (2.13)	1.07 (32.31)	3.31	11.19	4.89	3.31
1997	**63.16**	**4.28**	1.80 (64.02)	0.08 (2.88)	0.93 (33.10)	2.81	11.86	4.46	2.98
1998	**63.19**	**4.039**	1.46 (68.79)	0.07 (3.40)	0.59 (27.81)	2.13	11.23	3.36	2.43
1999	**63.21**	**4.16**	1.91 (78.26)	0.05 (1.93)	0.48 (19.80)	2.44	8.44	3.86	3.10

Data source: Fisheries Year Book, Taiwan Area.
Figures in the parenthesis are the ratios to total area for eel culture.
R^1 represents the ratios of total areas of eel culture to total areas of aquaculture.
R^2 represents the ratios of real areas of eel culture (excluding suspended area) to total areas of aquaculture.

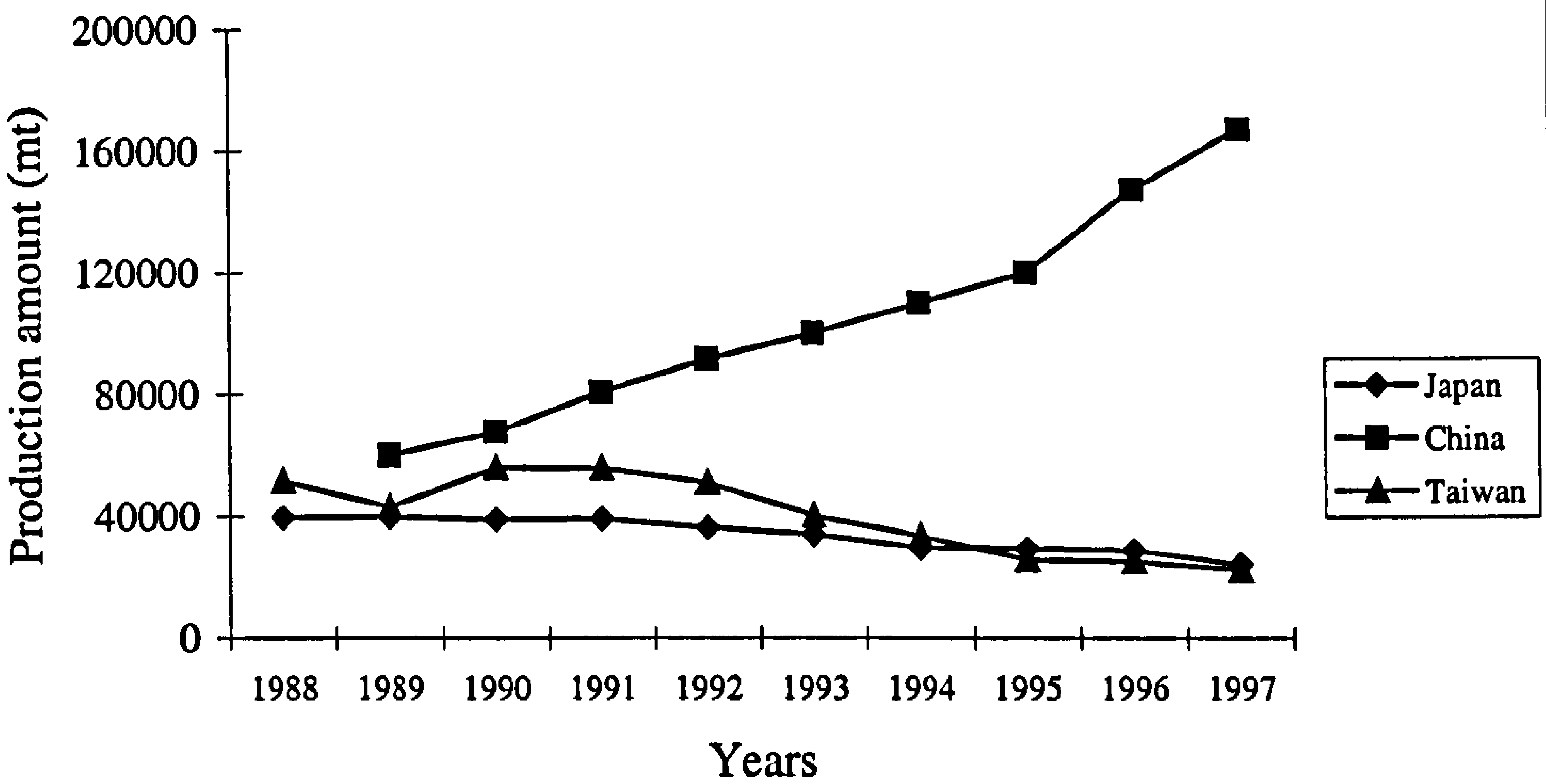


Fig 4.1 The production amount of eels in China, Japan and Taiwan.

Data source: FAO (1999).

4.1.2 Eel seed

In Taiwan, the major species of culture is the Japanese eel (*Anguilla japonica*), a temperate catadromous fish which is widely distributed in the rivers of NE Asia, i.e. China, Taiwan, Japan and Korea (Tesch 1977). The catch levels of glass eel of different countries are shown in Table 4.3 and Table 4.4.

The spawning ground of Japanese eel was discovered in the North Equatorial Current west of the Mariana Islands, 15^0 N, 140^0 E (Tsukamoto, 1992). The leptocephali drift with the North Equatorial Current to the continental shelf of the Philippines, then turn northward into the Kuroshio Current conveyed by the mechanism of Ekman transport (Kimura et al., 1994).

Table 4.3 Catches of glass eel of different countries.*

Unit: mt

Year	Japan		China		Korea	
	Million seed	MT	Million seed	MT	Million seed	MT
1991	255.8	46.5	220	40	49.5	9
1992	225.5	41	198	36	49.5	9
1993	236.5	43	----	----	----	----
1994	155.1	28.2	192.5	35	----	----
1995	191.4	34.8	242	44	44	8
1996	160.6	29.2	82.5-99	15-18	38.5	7
1997	137.5	25	82.5-110	15-20	33	6
1998	68.8	12.5	41.3-48.4	7.5-8.8	9.9	1.8
1999	352.0	64	330	60	27.5	5
2000	93.5	17	275	50	27.5	5

Data source: Japan Aquculture News (2001).
* The figures of million seed are estimated from 5.5 million glass eels per ton of eel seed.

In Taiwan, the fishery season of Japanese elvers is from October to March, peaking in December and January. The glass eel are collected in estuarine waters with traps, seines or scoop nets from boats or by wading (Chen 1990). Quantities caught have been very unstable. From 1987 to 1999, the highest level was 155.1 million pieces in 1991 and the lowest level 8.0 million in 1998, an almost 20-fold variation (Table 4.4). The average price was similarly unstable, ranging from a high of 37.5 NT$ per eel in 1994 to a lowest average price of 5.2 NT$ in 1990, a more than 7-fold difference (Table 4.4). The average prices were influenced by the quantity of capture. Since 1994, average prices were more than 25 NT$ per eel, though, in1999, this dropped to 14.3 NT$ because of the high quantity of capture, and the suspension of production by some farms. According to Chen et al (1994), the fluctuation of Japanese elver catches has a positive relationship with rainfall and a negative relationship with seawater temperature. With total dependence on the natural sources, the supply of seed is limited, unpredictable (Table 4.4), and is one of the bottlenecks in the development of eel culture.

Based on Table 4.4, the relationship between average price and quantities of glass eel caught can be calculated by a simple linear model and presented below.

$$P = 26.5 - 0.13\,Q \qquad F = 3.25$$

$$(5.87)^{**} \quad (-1.80)$$

$$R^2 = 22.8\%$$

Where

P = Deflated average price of glass eel (NT$)

Q = Quantity of glass eel caught (10^6)

Although this is not a significant relationship it showed that the average prices had a negative correlation with capture quantities. The coefficient for Q showed that if the capture quantity increases by 10^6, the price would decrease by 0.13 NT$ per eel.

Table 4.4 The quantity and value of caught glass eel in Taiwan.

Year	Quantity (10^6)	Value (10^6 NT$)	V/Q
1987	21.0	182.8	8.7
1988	38.2	436.8	11.4
1989	137.6	852.8	6.2
1990	24.3	125.1	5.2
1991	155.1	920.1	5.9
1992	40.1	450.8	11.2
1993	12.0	217.3	18.1
1994	30.9	1,158.6	37.5
1995	35.5	1,195.5	33.7
1996	49.2	1,660.1	33.8
1997	12.6	348.1	27.6
1998	8.0	291.6	36.4
1999	47.0	673.3	14.3

Data source: Year Book of Taiwan Fisheries Bureau.
V/Q is the ratios of values to quantities and implied the average nominal prices.

Based on the culture area and capacity in Taiwan, the demand of glass eel is around 250 million (~ 50 t), while the size of the catch is only 50 million (~ 10 t) (Tzeng, 1986). Tzeng (1986) noted that it was effectively impossible to increase local catches of glass eel significantly, as exploitation in coastal Taiwan was 45-75% of the natural population. The shortage must be made up by import from Korea, or from Mainland China through Hong Kong. With China's recent development of a domestic eel culture industry and thus control of its glass eel exportation, the shortage of glass eels has become more serious. Before the introduction of super intensive culture, farmers tried to use European eel (*Anguilla anguilla*) to replace Japanese eel but suffered numerous failures. Compared with Japanese eel, the European eel was rejected by farmers, considered to suffer from a range of deficiencies, particularly that they:

- cannot stand high temperature,
- are easily infected by parasites,
- develop large differences in size between fast and slow growers,
- have weak feeding behaviour and slow growth, and
- require sediment on the bottom of their ponds to be cleaned thoroughly.

Most farmers and researchers believe that in general (Usui 1991), the growth of eels is faster in females than in males but they believe that higher densities support the development of males as an adaptive response to less than ideal living condition. However, Holmgren and Mosegaard (1996) suggest that males display, on average, a higher weight increase than females. More research is needed to explore density and growth interrelationship.

At market size, the Japanese eel has a longer and slimmer body shape and is easy to tell from the European eel. However, they are difficult to distinguish morphologically at glass eel stage. Usually, Japanese glass eel are ~ 5.8 cm in length and ~ 5000 to 6000 individuals to a kilogram; while European glass eel are ~ 7.8 cm and are ~2500 to 3500 to a kilogram. To distinguish the two species, eel farmers can use a 1 mg l^{-1} solution of Giodrin (a pesticide), in which the European eel die in 20 minutes whereas the Japanese eel survive (Chen 1990). However, because of the shortage and supply fluctuation of Japanese eel seed, European eel is now the major species for industrialized super intensive eel culture.

4.2. Traditional eel culture

4.2.1. Introduction

In Taiwan, eel culture can be separated into 2 stages. The first stage is to rear glass eel to fingerling (5-10g), while the second is to rear the fingerling to market size (150-200g) (Fig. 4.2). This two-stage approach, and the subsequent export and marketing will be discussed in the following paragraphs.

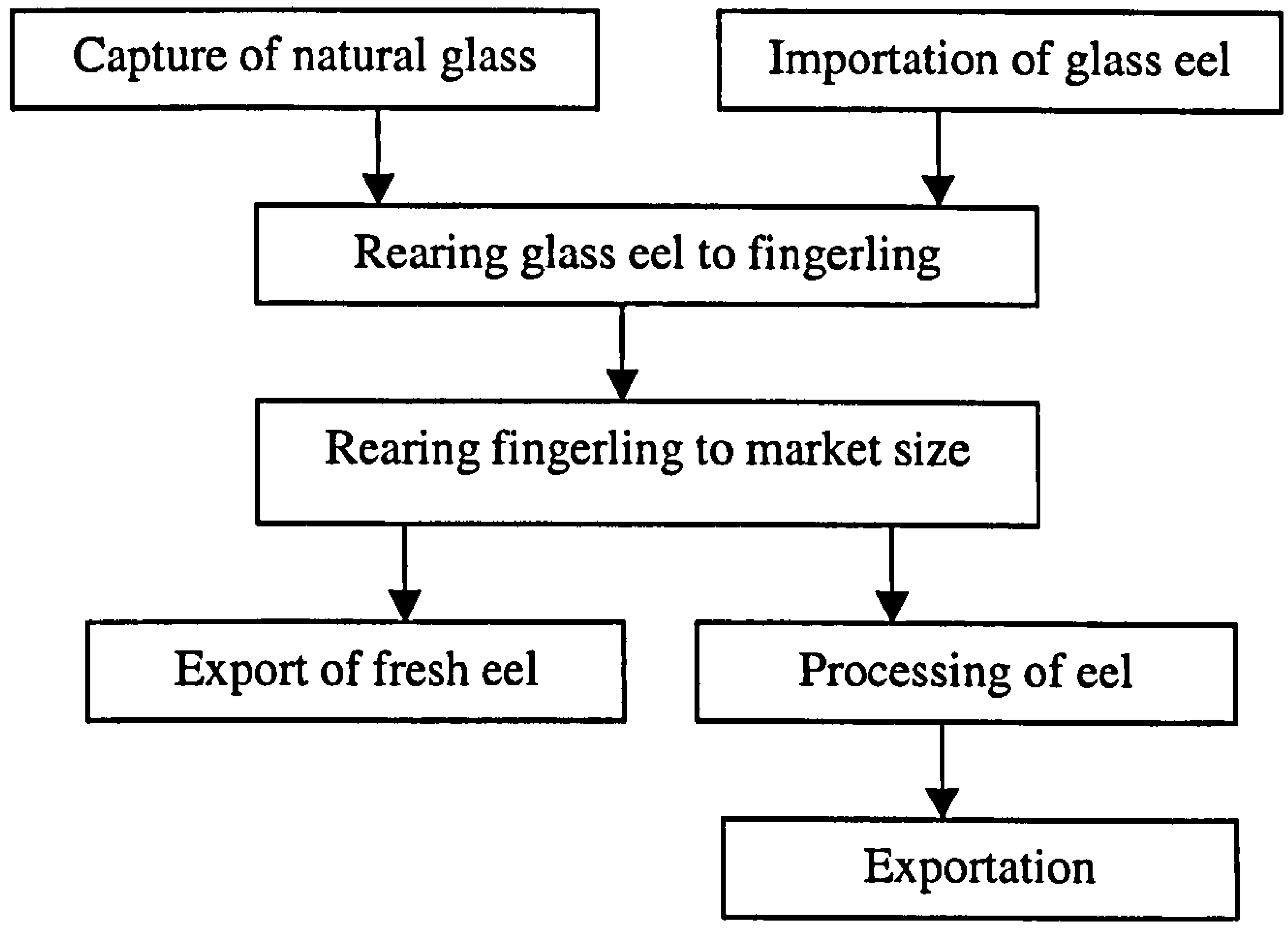


Fig.4.2 The process of eel culture in Taiwan.

4.2.2. Facilities

Traditionally, there are two kinds of eel ponds in Taiwan i.e. "hard" and "soft" ponds. Traditional hard ponds are normally rectangular in shape from 20 m^2 to 3,000 m^2 in surface area, with vertical concrete or brick walls surrounding a clay bottom covered with coarse sand. Usually, soft ponds are converted from milkfish and tilapia ponds, in which fish farmers change inlet and outlet systems to develop eel ponds. Both the walls and bottoms of soft ponds are clay and the area ranges from 0.5 to 0.8 ha. Eel ponds normally also have a wooden feeding platform of up to 10m^2, which provides a shaded area for eel to congregate. At the center of the feeding platform and under its cover, there are one or more feeding cages. These are normally made of plastic-coated wire mesh, with a mesh size, which allow eels to come into the cage. Paddle wheel aerators are usually necessary, typically one per 0.1ha of water surface (= 7.46 KW installed per ha). The paddle wheels are installed along and parallel to the side of the pond to create a circular flow in the system.

4.2.3 Manipulation of glass eel

During the upstream process from seawater to fresh water, glass eels acclimatize to the fresh-water environment. If the glass eels were caught in an area with high salinity, this acclimatization must be done carefully and gradually, as dramatic changes in temperature and salinity should be avoided. Osmotic imbalance, shown by the body of glass eels becoming opaque, can be adjusted by using a water bath in the salt water with 0.5-0.7% salinity (Yu, 1994).

Before stocking the glass eels, ponds are usually sterilized; after clearing out the silt on the bottom of the ponds by flushing and suction pumping, the ponds are filled with water to a depth of 20 to 30cm and around 25 kg of powdered bleach is scattered per 100 m^2 of pond. The ponds are then stirred by a paddle wheel or pump, and drained after 2-3 days exposure. The pH value is then adjusted within a range of 6-9 by liming, the amount depending on alkalinity. One week before stocking with glass eels, the ponds start to be filled with water.

Glass eels acquire a dark pigmentation after several days' rearing, and reduce slightly in size. Those that are freshly collected from the wild only take live food and must be trained to adapt to artificial feed in a designated feeding area. Traditionally, tubifex worms are first used as feed, then after 1g weight, increasing proportions of formulated feed are mixed in, with full weaning on to formulated feed when elvers reach 2g. The tubifex worms are bought from tubifex farmers or collected from the wild and must be stocked in clean water to discharge any contaminating materials from their outer surfaces or at stomachs before being used. If there are not enough tubifex worms, minced oyster and boned fish are used as replacement. At the beginning of feeding, feed is scattered all over rearing pond, and over a few days this is gradually concentrated toward the feeding platform. Initially, feeding must be conducted several times a day in the daylight hours and evening, after which evening feeds are gradually eliminated. The weaning programme starts by placing the feeding basket on the bottom and gradually raising it to the surface. This encourages the eel to feed on the surface or out of the water, to reduce submergence of the feed under water and, thus, minimize loss of feed in suspension or through dissolution. Daily rations of tubifex can be up to 30% of the body weight, divided into three feeds, in a quantity that can be consumed in one hour. After feeding, the basket is lifted out of water. Leftover feed in the pond should be avoided, as it can seriously affect water quality. The stocking density of glass eels is 0.2-0.3 kg/m^2 and thinning is required periodically. The eels reach a weight of 2g in two months and 5-10g in another two months. At 5-10g they are referred to as stocking size fingerlings.

4.2.4 Management of on-growing eels

The initial stocking density for on-growing eels is 0.6-1.0 kg m^{-2}. With a water exchange rate of 20% daily, and after two or three thinnings, faster growing fingerlings can reach the minimum market size of 150-200g (5-6 kg^{-1}) in six months. The slow growers need 18 months to reach the market size. With continuous 20% water exchange daily, the carrying capacity can be 3 kg m^{-2} at harvest and at 40% exchange daily; this can increase to 9 kg m^{-2}. Usually, the aerators are turned on twice every day, once in the afternoon to drive oxygen from the super-saturated surface layers to the lower depths and again from the evening to the next morning, to increase atmospheric oxygen transfer into the pond water.

The survival rate from glass eels to market-size is usually about 60-70%, requires 100,000 glass eels per hectare for a yield of 10 t ha^{-1}, or 10 glass eels per 1kg of market size eels. If 5-10g fingerlings are used, survival to market size is 70-85% and about 70,000 fingerlings are needed for one hectare.

4.2.5 Feeding on-growing eels

Currently, formulated feed is the dominant diet, and trash fish are only added in small quantities as a nutrient supplement. Formulated eel feeds are in powder or floating pellet form. For the former, feeds are usually mixed with fish paste, a small amount of fish oil and an equal amount of water, to form a dough-like consistency before being put into feeding baskets. Feeding baskets are normally made of plastic-coated wire screen. Eels can go through the mesh of feeding basket or climb on to the basket to get the feed. If the eels in the pond are not uniform in size, several feeding baskets of different size are necessary to ensure that small eels can be adequately fed. One hour after feeding, the uneaten paste remaining in the baskets is lifted out of the pond, thus avoiding fouling the pond. By contrast, pelletised feed requires little effort in preparation, does not need feeding baskets and can prevent feeds from losing too much nutrient due to suspension and dissolution. However, it is difficult to add medicine or other additive nutrients into the feed, though some farmers will dissolve additives into fish oil or water and soak the pelletised feed in it before feeding.

4.2.6 Characteristics of traditional eel farmers

In 1998, 63 traditional farmers who also managed their farms were surveyed by questionnaire. On average, producers were 45.59 years old. Regarding education attainment, there were two main groups, those who had completed elementary school

(34.92%) only, and those who had completed senior high school (38.10%). Average years of schooling were 9.1 years. Most had 1-20 years of experience in eel farming, averaging 17.1 years. More than half (57.1%) stated that eel farming was not their only source of family income. The average household size was 7.0 people; more than 60% of respondents had a household size larger than 5 people (Table 4.5).

Table 4.5 Socioeconomic characteristics of eel farmers.

Socioeconomic characteristics	Number	Percentage
Age (years)		
31-40	14	22.22%
41-50	32	50.79%
51-60	15	23.81%
61 and above	2	3.17%
Average	45.59 years	
Education attainment		
None	5	7.94%
Elementary	22	34.92%
Junior high school	6	9.52%
Senior high school	24	38.10%
College	6	9.52%
Average years of schooling	9.05 years	
Experience in eel culture		
1-10 years	20	31.75%
11-20 years	28	44.44%
21-30 years	10	15.87%
31-40 years	3	4.76%
41 years and above	2	3.17%
Average years of experience	17.14 years	
Source of family income		
Eel production only	27	42.86%
Eel production and other source	36	57.14%
Household size		
1-5	25	39.68%
6-10	28	44.44%
11 and above	10	15.87%
Average household size	7.02 peoples	

The education attainment is correlated to the age, the younger groups having higher education attainment. The average education attainments in different age categories were 10.0, 9.5 and 5.4 years in the categories of 30-<40, 40-<50 and 50+ years old, respectively. The average years of experience in eel culture of different age groups were 9.1, 15.2 and 27.1 years in the categories of 30-<40, 40-<50 and 50+ years old, respectively. The average household sizes were similar in different age groups, being 7.8, 6.8 and 6.8 in the categories of 30-<40, 40-<50 and 50+ years old, respectively. The percentage of each group with outside income was correlated to the age. The older group had a higher percentage with outside income, accounting for 42.9%, 53.1% and 76.5% in the categories of 30-<40, 40-<50 and 50+ years old, respectively. The average yield levels in different age groups were 9,832, 15,063 and 13,035 kg/ha in the categories of 30-<40, 40-<50 and 50+ years old, respectively. This implies that older groups had more experience in culture and higher yield level. However, when at ages of greater than 50, more farmers engaged in other business (higher outside income) and the yield level reduced.

Table 4.6 Averages of education attainment, experience, household size, percentages of farmers with outside income and yield levels in different age categories.

Age category	30-<40	40-<50	50->50
Education attainment	10.0 years	9.5 years	5.4 years
Experience	9.1 years	15.2 years	27.1 years
Household size	7.8 people	6.8 people	6.8 people
Outside income	42.9%	53.1%	76.5%
Yield level	9,832 kg/ha	15,063 kg/ha	13,035 kg/ha

4.3 Super intensive eel culture

Because of the shortage of Japanese glass eel, fish farmers and the Fisheries Research Institute tried to import European glass eel as a substitute. At the same time, super intensive fish culture systems were imported. In these, a central control system is installed, which monitors temperature, pH value and dissolved oxygen, and controls the automatic feeder, emergency oxygen-supply system, rotating net brushes and pumps.

4.3.1 Culture tanks

These are made of fibreglass with water inlets submerged at the bottom, with water led in tangentially to create a rotating current. In this way, faeces and other particles are forced to concentrate in the centre and on the bottom of the tanks by gravity. A pipe from the centre of the tank base is connected to a bowl. The bowl is connected to and surrounds the outlet. Through the pipe and the bowl, faeces and feed waste are removed from the tank to the outlet pipe. The outlets are fitted with wire netting to prevent the escape of eels and are continuously cleaned by a brush rotating around the net to keep the net from blocking (Fig. 4.3).

Usually, only pelletised feeds are used in super intensive systems because the powdered form of formulated eel feeds easily fouls the water quality. The feed is loaded in the feeding silo and leaves the feed through a gap onto a plate. There, a rotating scraper scrapes the feed on the plate into the tank (Fig. 4.3). The size of the gap can be controlled and therefore also, the feeding amount in certain time.

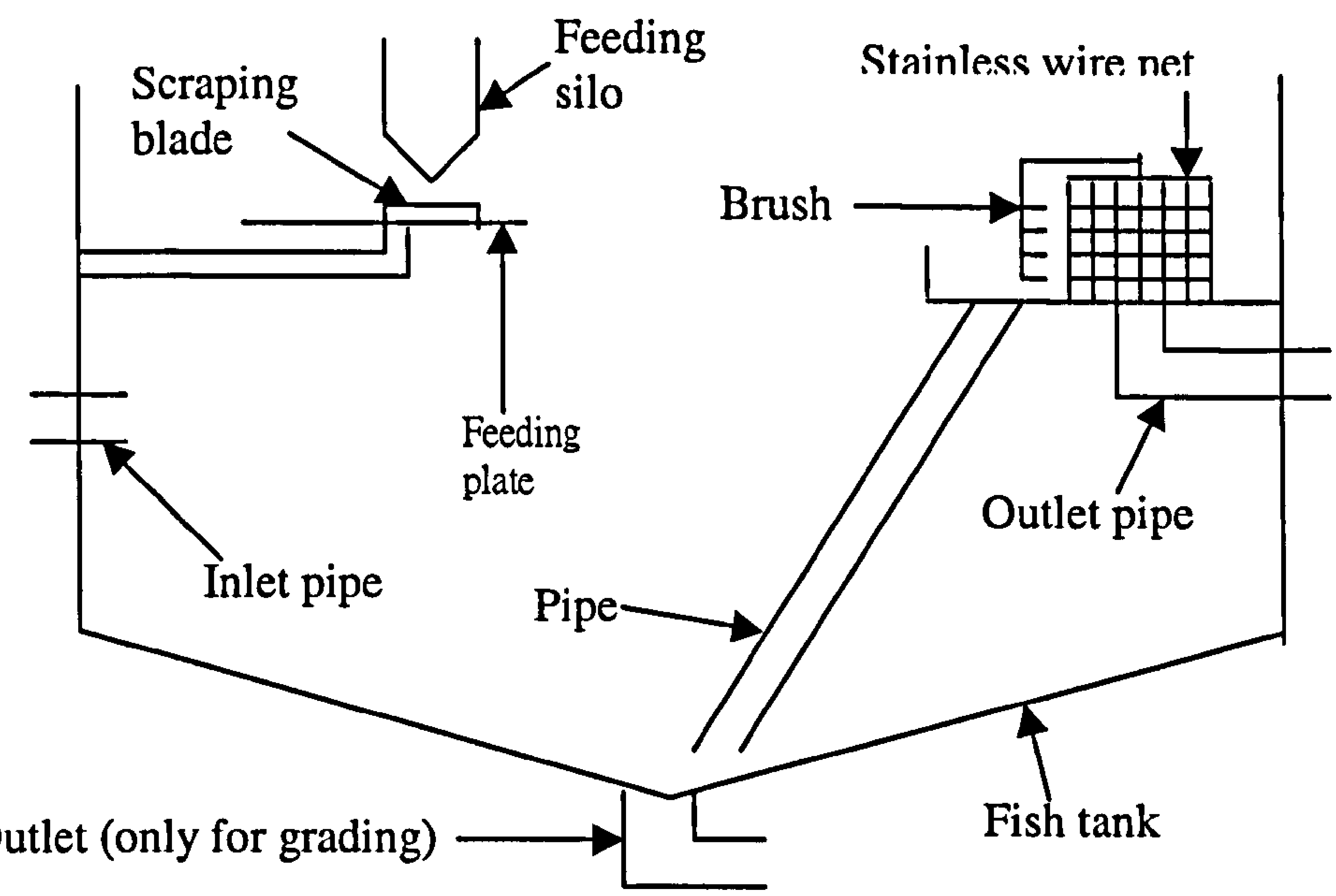


Fig. 4.3 Culturing tank for super intensive eel culture.

4.3.2 The process of water flow

The overflow water is led into a drum filter, which retains particles on the filter screen. The retained particles would eventually block the flow of water and so, after the water level reaches a certain point, a high-pressure water jet is turned on automatically to flush out the particles from the net. In the drum filter, part of the faeces and uneaten feed are eluded, leaving the partially cleaned water to flow through a biological filter tank packed with a biofilter medium with specific surface of $150m^2\ m^{-3}$, on which nitrifying bacteria are encouraged to grow, converting ammonia to nitrite and nitrate. After flowing through the biological filter, an UV system is used to control bacteria levels, though typically penetration of UV light is only 0.7-1.0cm. The useful life of an UV lamp is about 8000 hours. Finally, the water is oxygenated by using an oxygenation cone. At 25 °C, the dissolved oxygen can reach 20 mg l^{-1} dropping to 16 mg l^{-1} at 30 °C. The system flow chart is as shown in Fig.4.4.

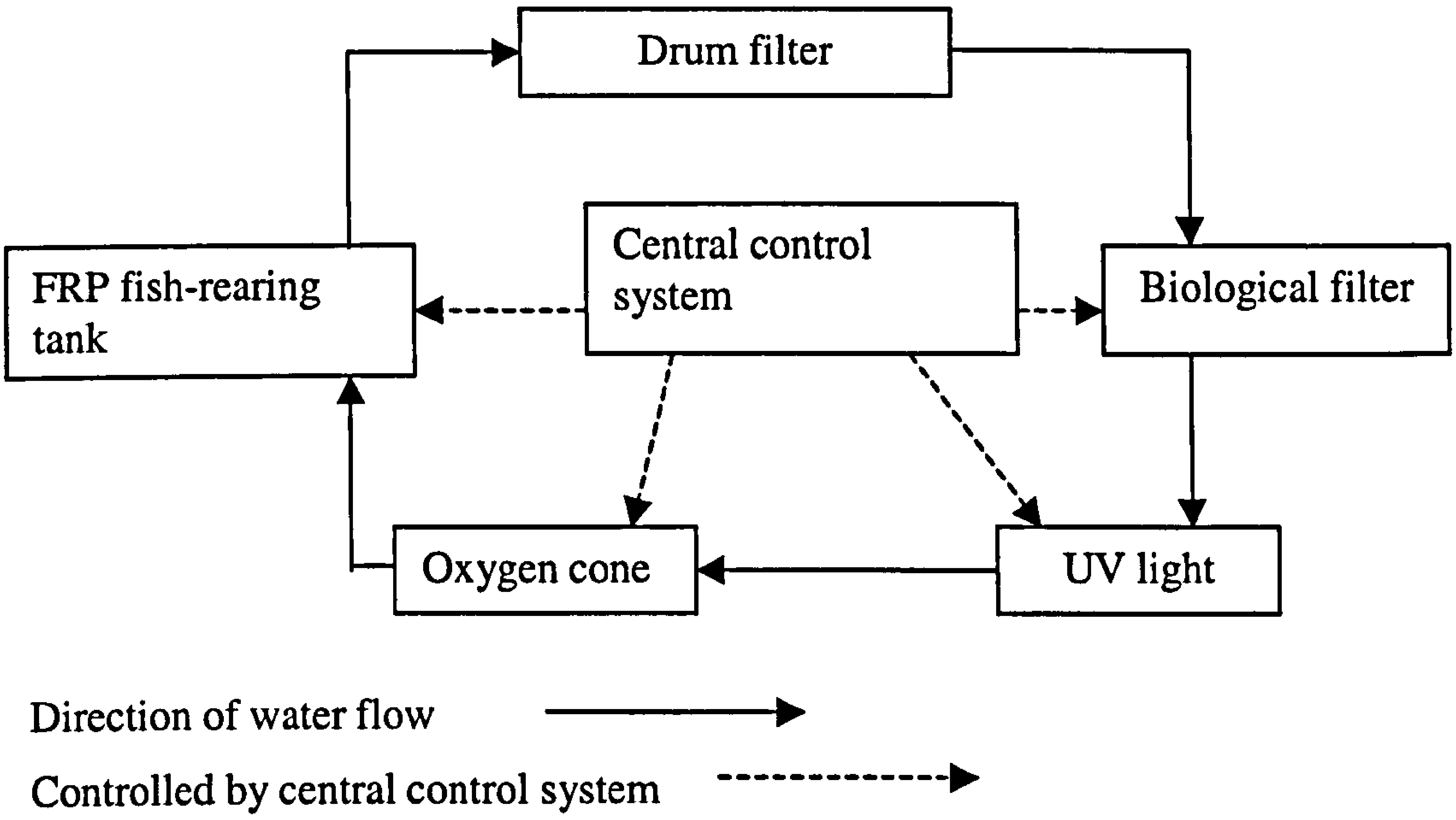


Fig. 4.4 Flow chart of super intensive eel culture system.

4.3.3 Management of water quality

In traditional pond culture, environmental conditions are maintained by balancing the inputs of feed with the assimilative capacity of the ponds. A key to successful recirculating production is the use of cost effective water treatment systems. Water quality maintenance for a recirculating system includes temperature and pH value control, reduced suspended and dissolved waste fraction, oxidized ammonia and nitrite-nitrogen, oxygenated water and effective sterilization etc. The required management of water quality control is summarized in Fig. 4.5.

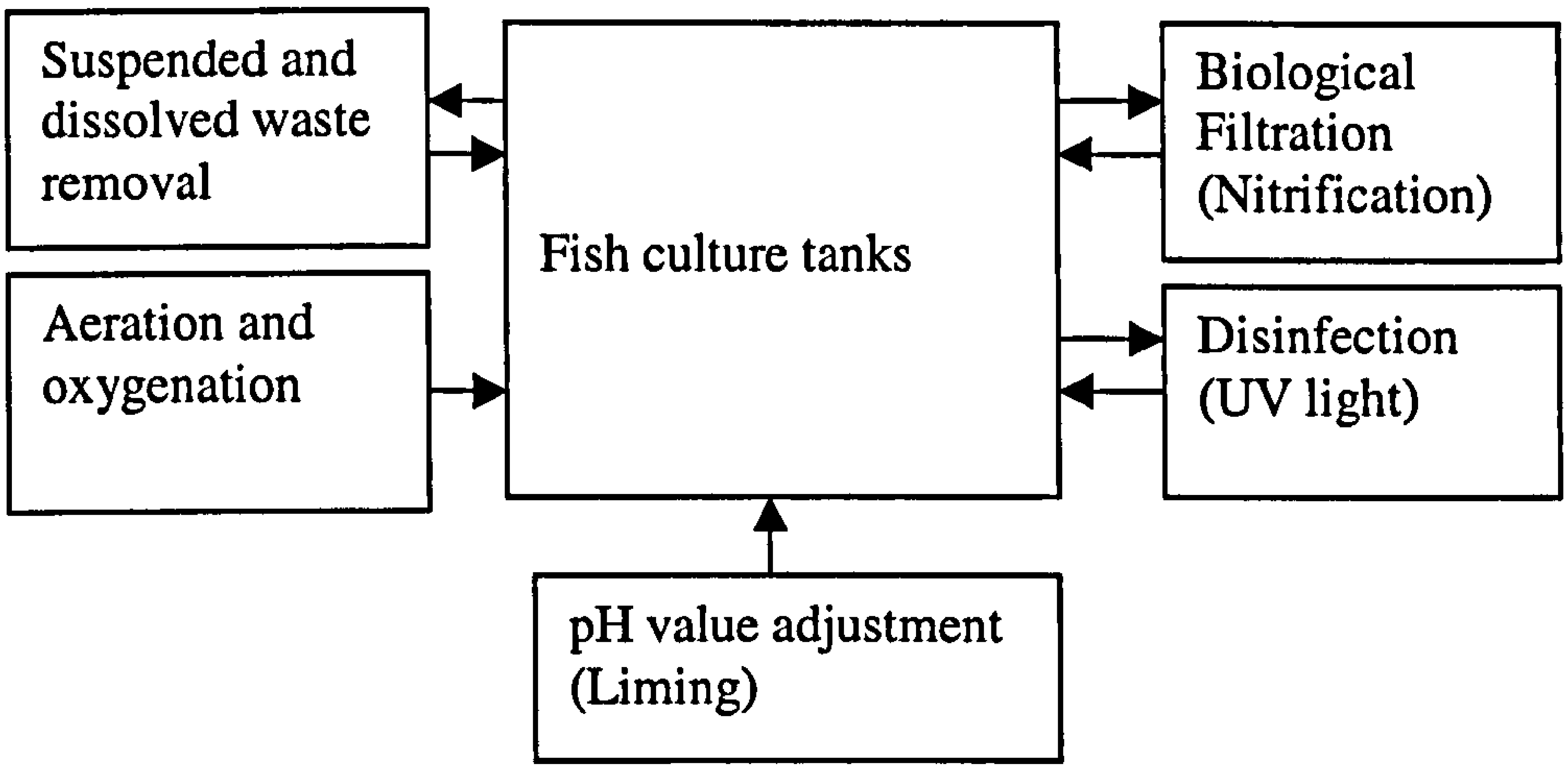


Fig. 4.5 The required management of water quality control.

Temperature

Temperature is critical in growth and survival, with optimum temperature ranges for growth, FCR and disease resistance. In Taiwan, few farmers need to resort to temperature adjustment, but if necessary, this can be done by using submersible heaters or coolers.

Dissolved oxygen (DO)

Oxygen supply is necessary for the eels in the tanks and nitrifying bacteria in the biological filter systems. For maintaining optimum growth, D O in rearing tanks must not be lower than 5 mg l^{-1}, added to which, nitrifying bacteria need at least 2 mg l^{-1} DO to permit adequate conversion of NH_3 to NO_2 and NO_3. To maintain adequate DO level, oxygen must be fed. In recirculating systems a better location to aerate water is in the recycled flow-stream just prior to re-entry into the tanks (Losordo et al., 2001). The water is usually over saturated in oxygen using a specifically designed oxygen cone. This is better led into the bottom of the tanks where it can quickly mix with the main tank water. If the mixing is too fierce, the over saturated oxygen can easily be lost to the air, while if mixing is inadequate, patches of highly over saturated water may cause gas bubble disease, which may hinder the normal physiological functions and cause death. Glass eels and fingerling are more sensitive to this phenomenon. In this system, each fish tank is equipped with an emergency oxygen supply system starting, when the central control system detects the DO as too low.

pH value

pH is a measure of hydrogen ion concentration in water, indicating the degree to which water is acidic or basic. The pH of water affects the state of many water quality parameters and the rates of many biological and chemical processes. The acceptable range for pH is usually from 6 to 9.5, though if the pH value changes by 2 units or more very quickly, it may be harmful, especially, to small fish. The optimum pH value for nitrifying bacteria to mineralize the waste in the biological filter system is about 7 to 8 (Gousset, 1990). However, pH reduces in recirculating systems due to acids produced by nitrifiers in oxidizing NH_3 to NO_3 and due to accumulated carbon dioxide released by the fish. For maintaining the appropriate pH value, lime water is usually added. This is not added into the tank directly as it may causes patchy areas of high pH and damage the eels. The pH value in the system must be monitored and adjusted daily.

Dissolved nitrogenous waste

Ammonia is the major nitrogenous waste in the eel culture system and is converted to NO_2 and NO_3. It exists in two forms in water, un-ionized ammonia (NH_3) and ionized ammonia (NH_4^+). At a pH of 7.0, most of the total ammonia nitrogen (TAN) is in NH_4^+ form, while at a pH of 8.0, the majority is in NH_3 form (Losordo et al., 2001). NH_3 and NO_2 are toxic to eels and elimination is very important. If the concentration of NH_3 is higher than 0.035 mg l^{-1}, gills will be damaged and growth retarded. However, aquatic species can tolerate extremely high levels (>200 mg l^{-1}) of NO_3 (Losordo et al., 2001). NO_2 is a product of oxidation of NH_3 while NO_3 that of oxidation of NO_2. Nitrifying bacteria (eg *Nitrosomonas spp*) utilize NH_3 as an energy source and produce NO_2, while *Nitrobacter spp* utilize NO_2 as an energy source and produce NO_3. Both types of bacteria are present, and as culture develops, large amounts of bacteria adhere to the biological filters and must be cleaned to maintain their efficiency, getting rid of aging bacteria and supplying space for new bacteria. However, the filters must not be too clean, leaving no bacteria on them. When there are problems in the biological filters, feeding must be stopped or reduced.

Suspended solids

Most of this arises from faeces and uneaten feed. Pelleted feeds used in intensive eel culture consist of protein, carbohydrates, fat, minerals etc. The portion not eaten or not assimilated by the fish become highly organic wastes. When those wastes are broken down by bacteria within the system, they will consume dissolved oxygen and generate ammonia. Their rapid removal is very important in the super intensive system, as they will use oxygen and produce ammonia and other toxic gases. Suspended solids can be removed by drum filters, though smaller particles are still suspended in the system. However, although they add to oxygen and ammonia loads, they can also produce a substrate on which nitrifiers can attach, and so a certain amount may be beneficial for the system. However, if levels are excessive, water exchange must be increased to prevent deterioration of the water quality.

4.3.4 Husbandry

Feeds for super intensive system are pelletized, applied at ~ 3-4% per day for fingerlings and 1-2% for on growing. When near harvesting, the total feeding amount will reach its maximum, at which time, feeding continuously is better than 2 or 3 times daily. As the respiration rate increases significantly during feeding, feeding small amounts regularly can prevent the DO from dropping abruptly below 5 mg l^{-1}.

Separating the fast growing eels from the slow growers is very important since it can increase feeding efficiency. In the process of grading, eels are drawn to the upper layer above the rearing tanks by vacuum suction, go through the automatic grading machine with a table of rotating bars and are separated into 3 sizes in plastic bags or baskets. After that, the graded eels are put in the tanks with pipes connected to the different rearing tanks for different sizes. The eels go down to the rearing tanks by gravity. Usually, the eels are graded every 45-60 days. The processes of grading are shown on Fig. 4.6.

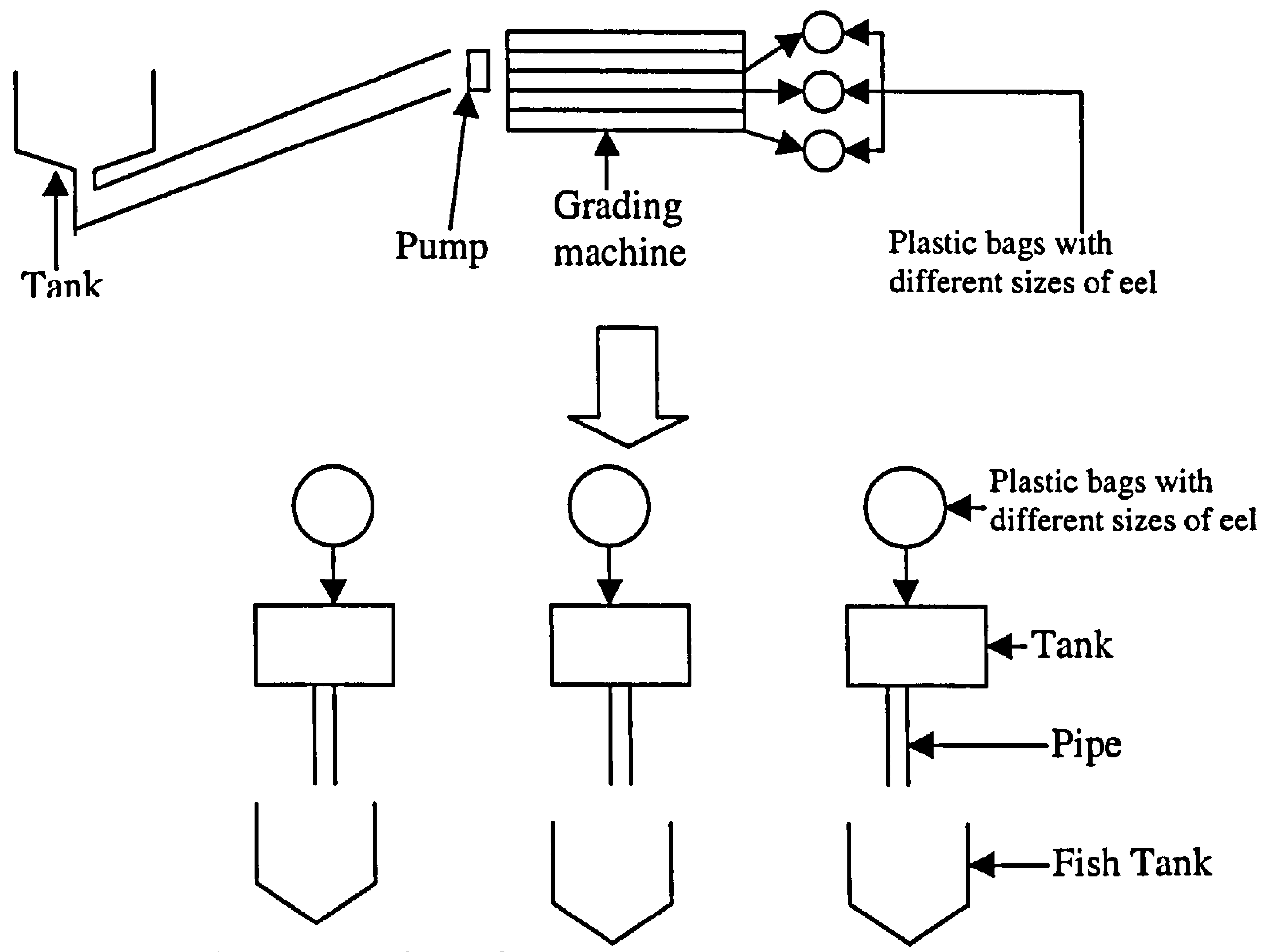


Fig. 4.6 The procedure of grading in super intensive eel culture system.

4.4 Financial analysis of eel culture

4.4.1 Introduction

The eel farming industry has had experience with rising production costs (such as increasing cost of glass eel) in Taiwan, and therefore, super intensive cultivation is applied, using European eel to reduce the cost of eel seed. Here, the feasibility of traditional and super intensive eel culture are investigated and compared, using financial surveys based on questionnaires. The surveyed areas for traditional eel farms were on Jang-Hwa, Yun-Lin, Cha-I, Tainan, Kaoshung and Ping-Tong Counties (Fig 2.4), where 63 farms are surveyed. The survey areas for intensive eel culture were on Taipei, Tao-Yen and Tainan County where only 5 farms were surveyed because there were only a few intensive farms in Taiwan.

Financial viability is analysed by using cost and benefit analysis, pay-back period analysis and discounted cash flow investment appraisal. Additionally, the sensitivity of the price of glass eel and the social costs are examined.

4.4.2 Cost analysis

Traditional eel culture

Two components, capital cost and operating cost can be established. The capital costs comprise the costs of a work shed and storage house, pond construction, preparation and maintenance of the ponds, repair and maintenance facilities, power generator, paddlewheel and pump. The operating costs consist of the cost of eel seed, feed, electricity, chemicals, wage, miscellaneous, land rent, depreciation and interest. Three important assumptions are that:

1) investment costs are covered by a loan at an annual interest rate of 8%;
2) the facilities and equipment are subject to straight line depreciation over the useful lifetime;
3) the useful lifetime of buildings and pond construction is 20 years, of a power generator is 10 years and of a paddle wheel and pump is 5 years respectively.

Because spending on operating costs is spread throughout the culture period the interest is charged on 50% of the outlay. Total expenditure on variable costs is not paid out at the beginning and therefore, it does not incur the full interest charge for the entire period. However, the interest is charged on 100% of the capital costs (Christensen, 1993).

Among the capital costs of traditional eel farm, pond construction is the highest, followed by the work shed and storage house, paddlewheel, and power generator; their ratios to total capital cost are 54.6%, 15.9%, 9.2% and 7.5% respectively. The average capital cost per t of production was 108.74 thousand NT$, the lowest and highest capital costs per t being 45.91 and 195.72 thousand NT$, accounting for 42.2 and 180.0% of average capital cost, respectively. The ranges of capital costs were very large, some items ranged from below 20% to more than 200% of the mean. The items with higher cost variabilities were work shed and storage house, pond construction and pump. This might be related to the sources which the farmers bought them from, their sizes and the years they have been used.

Table 4.7 The average annual cost of eel production of per traditional eel farm.

Unit: Thousand NT$

Item	Cost	Useful life	Percentage
Capital cost			
Workshed and storage house	463.66	20 years	15.9%
Pond construction	1591.30	20 years	54.6%
Preparation and maintenance of ponds	101.70		3.5%
Repair and maintenance facilities	136.46		4.7%
Power generator	218.65	10 years	7.5%
Paddlewheel	268.13	5 years	9.2%
Pump	136.58	5 years	4.7%
Total	2916.48		
Operating cost			
Eel seed	6527.37		60.5%
Feed	1944.80		18.0%
Electricity	314.39		2.9%
Chemicals	128.65		1.2%
Wage	756.57		7.0%
Miscellaneous	7.79		0.07%
Land rent	270.50		2.5%
Depreciation	205.54		1.9%
Interest	639.54		5.9%
Total	10795.15		100%

Table 4.8 Average capital cost of traditional eel farm for producing per t of eel.

Unit: Thousand NT$

Item	Cost	Percentage of average
Work shed and storage house	17.29 (2.14-35.71)	12.4-206.5%
Pond construction	59.33 (16.67-138.89)	28.1-234.1%
Preparation and maintenance of ponds	3.79 (0.67-6.67)	17.7-176.0%
Repair and maintenance facilities	5.09 (1.25-12.78)	24.6-251.1%
Power generator	8.15 (3.43-13.33)	42.1-163.6%
Paddlewheel	10.00 (3.60-16.67)	36.0-166.7%
Pump	5.09 (2.14-11.36)	42.0-223.2%
Total	108.74 (45.91-195.72)	42.2-180.0%

The figures in the parentheses are the range of highest and lowest cost.

The average operating cost per kg of eels is detailed in Table 4.9 and is about 402.6 NT$. This shows the relatively high cost of eel seed at 243.4 NT$ per kg of eel, accounting for 60.5% of total operating costs, followed by feed, at an average cost per kg of 72.5 NT$, accounting for18.0% of total, and labour at 28.2 NT$ per kg, accounting for 7.0% of total. The variation among observations is relatively small. The highest and the lowest operating costs for producing 1 kg of eel were 336.9 and 452.8NT$, accounting for 83.7 and 112.5% of average operating cost, respectively (Table 4.9). Compared to capital cost, the variation of total operating cost was smaller. Although the 'miscellaneous' category had the highest variation (33.3-400.0%) among operating costs, its contribution to total cost was small, the key factors being seed, feed, wages and interest. This suggests the importance of higher survival rate, lower FCR, proper administration and lower capital cost in reducing operating cost.

Table 4.9 Annual average operating cost of traditional eel farm for producing 1kg of eel. Unit: NT$

Item	Cost	Percentage of average
Eel seed	243.4 (178.2-340.1)	73.2-139.7%
Feed	72.5 (51.4-119.7)	70.9-165.1%
Electricity	11.7 (4.0-30.2)	34.2-258.1%
Chemicals	4.8 (1.3-8.9)	27.1-185.4%
Wage	28.2 (9.8-56.7)	34.8-201.1%
Miscellaneous	0.3 (0.1-1.2)	33.3-400.0%
Fee of renting land	10.1 (5.0-16.3)	49.5-161.4%
Depreciation	7.7 (3.9-16.9)	50.6-219.5%
Interest	23.8 (14.5-55.3)	60.9-232.4%
Total	402.6 (336.9-452.8)	83.7-112.5%

The figures in the parentheses are the range of highest and lowest cost.

Cost analysis of super-intensive eel culture in Taiwan

In this system, capital costs comprise cost of buildings and the recirculating system. Operating costs consist of the cost of eel seed, feed, electricity, oxygen, chemicals, wage, miscellaneous, land rent, depreciation and interest. The first and second assumptions are as for traditional systems. The useful lifetimes of buildings and the recirculating system are 10 years. As with traditional eel culture, interest on operating costs is charged on 50%, but interest is charged on 100% of the capital costs.

In super intensive eel farms, most of the capital costs were in the recirculating system, which on average accounted for more than 70% of the capital costs (Table 4.10). Average capital cost of super-intensive eel farm for producing per t of eel was 64.7 thousand NT$. The highest and the lowest capital costs for producing per t of eel were 55.4 and 73.9 thousand NT$, accounting for 85.6 and 114.2 % of average capital cost, respectively (Table 4.11). The lowest cost producer might set up some part of facilities by themselves, instead of purchasing the culture system.

Table 4.10 The average annual cost of eel production for a super-intensive eel farm.

Unit: Thousand NT$

Item	Cost	Useful life	Percentage
Capital cost			
Building	2,000	10 years	28.6%
Recirculating system	5,000	10 years	71.4%
Total	7,000		
Operating cost			
Eel seed	5,066.7		20.4%
Feed	9,441.33		38.0%
Electricity	2,060		8.3%
Oxygen	956.7		3.8%
Chemicals	320		1.3%
Wage	3,048.8		12.3%
Miscellaneous	1,172		4.7%
Fee of renting land	600		2.4%
Depreciation	700		2.8%
Interest	1,494.62		6.0%
Total	24,860.15		100%

Table 4.11 Average capital cost of super-intensive eel farm for producing per t of eel.

Unit: Thousand NT$

Item	Cost	Percentage of average
Building	18.5 (13.9-24.1)	75.1-130.3%
Recirculating system	46.2 (41.6-49.8)	90.0-107.8%
Total	64.7 (55.4-73.9)	85.6-114.2%

The average operating cost of eel culture for a super-intensive farm is shown in Table 4.10. The average cost of producing 1 kg of eels is detailed in Table 4.12 and is shown to be about 229.5NT$. Feed is the highest cost component, the average cost per kg of eels being as high as 87.2NT$ and accounting for 38% of the total operating costs (Table 4.10). Next to feed is eel seed, where the average cost per kg of eels is 46.8NT$ accounting for20.4% of the total. The third highest cost is labor at 28.1 NT$ per kg of eels, accounting for 12.3%. The highest and the lowest operating costs for producing 1 kg of eel were 207.6 and 256.7 NT$, accounting for 90.5 and 111.9% of average capital cost, respectively (Table 4.12). The key factors, which influenced the production cost were eel seed, feed, electricity and wages. Similar to traditional eel culture, higher survival rate, lower FCR and proper administration were the important factors to reduce the operating cost.

Table 4.12 Annual average operating cost for a super-intensive farm to produce 1 kg of eels. Unit: NT$

Item	Cost	Percentage
Eel seed	46.8 (20.8-66.7)	44.4-142.5%
Feed	87.2 (77.1-136.8)	88.4-156.9%
Electricity	19.0 (6.3-26.7)	33.2-140.5%
Oxygen	8.8 (7.7-10.8)	87.5-122.7%
Chemicals	3.0 (1.4-5.8)	46.7-193.3%
Wage	28.1 (13.9-37.8)	49.5-134.5%
Miscellaneous	10.8 (5.4-16.6)	50.0-153.7%
Fee of renting land	5.5 (3.2-7.1)	58.2-129.1%
Depreciation	6.5 (4.9-7.2)	75.4-110.8%
Interest	13.8 (10.6-15.8)	76.8-114.5%
Total	229.5 (207.6-256.7)	90.5-111.9%

The figures in the parentheses are the range of highest and lowest cost

4.4.3 Benefit analysis

The profit (P) is equal to the revenue (MI) minus operation cost (C), profitability can be estimated by the benefit-cost ratio (BCR) and the income ratio (IR)(Chen 1994). The respective formulas are as follows:

$$BCR = P/C$$

$$IR = P/MI$$

Where P = Profit

C = Production cost

MI = Revenue

The higher are these values the more financially sound is the operation. This also indicates that the operation is economically sound and further development may be considered. The average amount of production of traditional eel culture per farm is 26.82 t, the average cost per farm is 10.80×10^6 NT$ with an average revenue per farm of 11.12×10^6 NT$. The average profit per year is 0.33×10^6 NT$. Therefore, the average BCR is 3.05% and IR is 2.96% (Table 4.13). The average cost per super-intensive farm is 24.86×10^6 NT$ and the average revenue per farm is 25.64×10^6 NT$. The average income per year is 0.78×10^6 NT$. Therefore, the average BCR is 3.13% and IR is 3.04% (Table 4.13). This showed that on average super intensive eel farm is a little bit more financially sound than traditional eel farm. The range of profit between best and poorest farms of traditional eel farms (-3.7- 6.6 million NT$) was wider than that of super-intensive culture (-0.7-2.2 million NT$).

Table 4.13 The benefit analysis of traditional eel farm and super intensive eel farm.

Unit: million NT$

	Average cost	Average revenue	Average profit	BCR*	IR*
Traditional eel farm	10.8 (2.6-44.6)	11.1 (1.7-44.8)	0.33 (-3.7-6.6)	3.05%	2.96%
Super intensive eel farm	24.9 (19.3-26.7)	25.6 (20.6-28.1)	0.78 (-0.7-2.2)	3.13%	3.04%

* BCR is benefit-cost ratio and IR is income ratio.

Although super-intensive eel farms had higher average profit, the distribution of profitability shows that it is still possible for traditional eel culture to have a higher profit than super-intensive eel culture (Table 4.14). When attaining economies of scale or having better performance, traditional eel culture can still make better profit.

Table 4.14 The distribution of profitability for traditional and super-intensive eel farms. Unit: NT$

Profit	Number	
	Traditional eel culture	Super-intensive eel culture
< -3 million	1	----
-2 million->-3 million	1	----
-1 million->-2 million	2	----
0- >-1 million	12	1
0- <1 million	26	2
1 million - < 2 million	8	1
2 million - < 3 million	6	1
3 million - < 4 million	4	----
4 million - < 5 million	1	----
> 5 million	2	----

4.4.4 Pay back period

The pay back period defines the time required to recover the initial investment out of the expected earnings from the investment, before any allowance for depreciation (Shang 1981). The method is as follows.

T = C/E, Where

T = the pay back period (number of year)

C = initial investment

E = average annual profit expected from the investment before depreciation

The pay back period is expected after 5.45 years for traditional eel farming and 4.73 years for intensive eel culture.

4.4.5 Cash-flow and discounted financial indicators

A 5-year discounted cash flow analysis at 10% discount rate reveals that investment in both types of eel culture remains viable (Table 4.15). The pattern of cash flow includes capital cost, operating cost (excluding interest and depreciation) and revenue. At 4271.1 thousand NT$, the NPV is higher in intensive eel culture than in traditional eel culture (1534.9 thousand NT$). If the discount rate is increased, the value of NPV will decrease. For those whose capital costs are higher than average and/or have poor initial performance, the value of NPV might be negative.

Table 4.15 Cash-flow projection for a traditional eel farm and an intensive eel farm. The discount rate for NPV is 10%. Unit: Thousand NT$

	Year0	Year1	Year2	Year3	Year4	Year5
Traditional eel farm						
Cash flow						
Capital cost	2916.5	0	0	0	0	0
Operating cost	0	9950.1	9950.1	9950.1	9950.1	9950.1
Revenue	0	11124.5	11124.5	11124.5	11124.5	11124.5
Net cash flow	-2916.5	1174.4	1174.4	1174.4	1174.4	1174.4
Discounted cash flow						
Cash outflow	2916.5	9045.5	8223.2	7475.6	6796.0	6178.2
Revenue	0	10113.1	9193.8	8358.0	7598.2	6907.4
Net cash flow	-2916.5	1067.6	970.6	882.3	802.1	729.2
NPV	1534.9					
Intensive eel farm						
Cash flow						
Capital cost	7000.0	0	0	0	0	0
Operating cost	0	22665.5	22665.5	22665.5	22665.5	22665.5
Revenue	0	25638.8	25638.8	25638.8	25638.8	25638.8
Net cash flow	-7000.0	2973.3	2973.3	2973.3	2973.3	2973.3
Discounted cash flow						
Cash outflow	7000.0	20605.0	18731.8	17029.0	15480.9	14073.5
Revenue	0	23308.0	21189.1	19262.8	17511.7	15919.7
Net cash flow	-7000.0	2703.0	2457.3	2233.9	2030.8	1846.2
NPV	4271.1					

4.4.6 Sensitivity of the price of glass eel in traditional eel culture

Overall profitability is clearly sensitive to relatively small changes in values of certain costs and selling price. Among the operating costs, the cost for fingerling is the highest and the most sensitive item. Here, the relationship between the different cost of fingerling to price is compared. In this study, the average farm size is 2.67 ha, the average density of fingerling is 96970/ha and the average cost of fingerling is 6527365 NT$. With an average price per fingerling of about 25.2 NT$. The average price per kg of eels is 414.85NT$ and the break-even price is 402.6NT$. Prices of 10, 15, 20, 25, 30, 35 and 40 NT$ of per fingerling was used to compare the sensitivity of price (Table 4.16).

Table 4.16 Sensitivity analysis of eel fry price.

Price of per eel fry (NT$)	10	15	20	25	30	35	40
Price of eel fry per producing 1kg eel (NT$)	100	140	190	240	290	340	390
Break-even price per kg eels (NT$)	260	300	350	400	450	500	550
Benefit for each farm (Thousand NT$)	4266.4	2971.9	1677.4	382.9	-911.6	-2206.1	-3500.6
The percentage of fry cost to operating cost (%)	37.8	47.6	54.8	60.3	64.5	68.0	70.8

The benefit of each farm is based on the average selling price, that is 414.85NT$/kg.

From Table 4.16, if the price of eel fry is higher than 30 NT$ each, the price of eels per kg must be higher than 450 NT$/kg, to break even. If the price of eel fry is 35 or 40 NT$, the price of eels must be as high as 500 and 550 NT$/kg (Fig 4.7). Thus traditional eel farmers must confront the pressure of a high price for eel fry. The lack of suitably priced glass eel seed has made many traditional eel farmers stop production. In some cases, some farmers just partially stock their farms and suspend some ponds when the price of glass eel is too high.

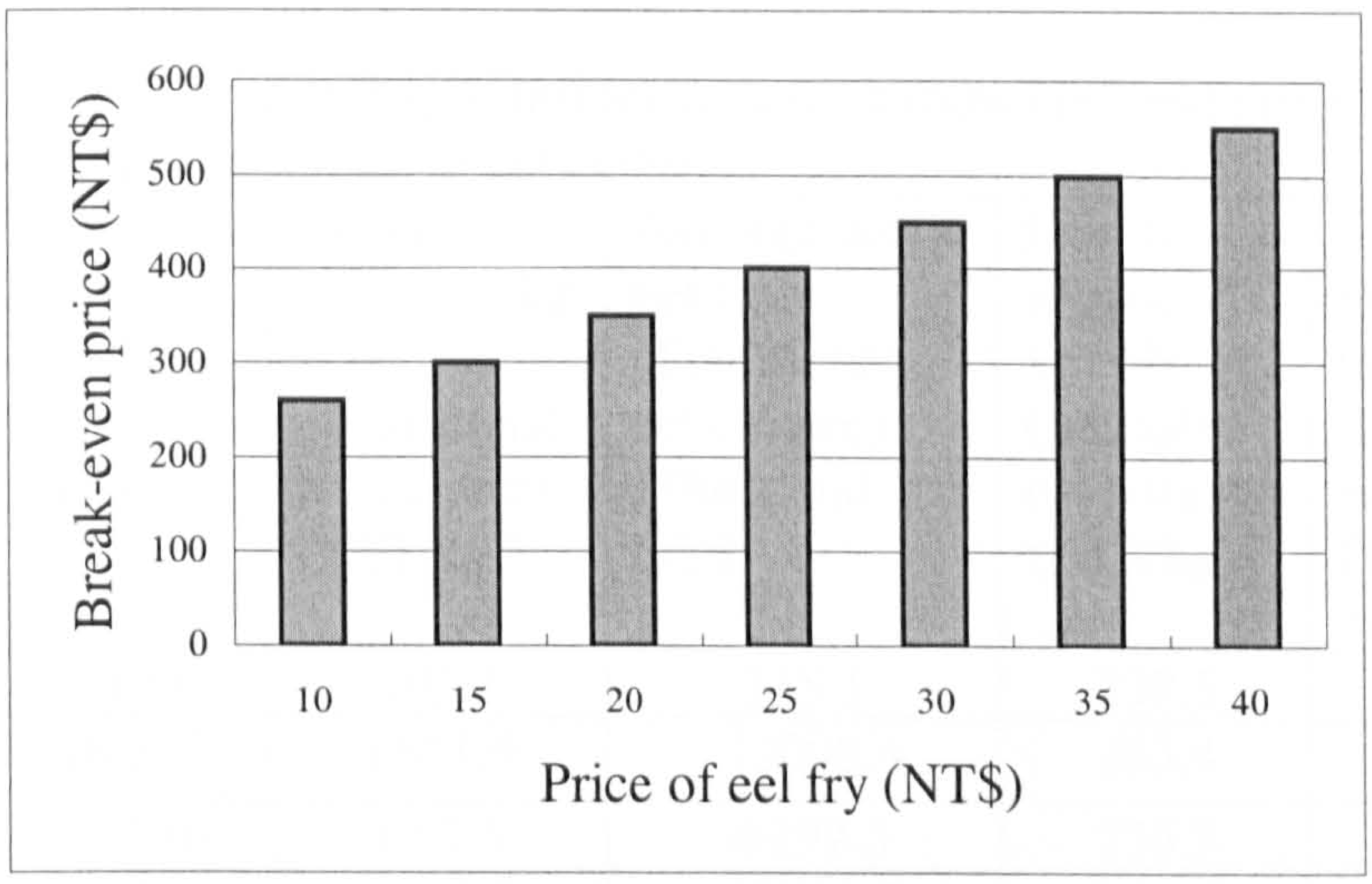


Fig 4.7 The break-even prices in different prices of eel fry.

4.4.7 Social cost

One of the particular reasons for the past prosperity of eel culture in Taiwan may be attributed to the use of pumped ground water, legally or illegally, for which the users had not been required to pay. Huang (1990) evaluated the cost of ground water, revealing that this may vary from region to region. Based on his results, and assuming water use to be the major externality (as evidenced by subsequent impacts) the adjusted social cost of producing 1 kg eels can be estimated.

Table 4.17 Social prices of underground water, and shadow cost and profit of traditional eel culture and intensive eel culture.

Region	Social prices of ground water (NT$/m^3)	Cost to produce 1kg eels (Traditional eel culture) (NT$/kg)[a]	Average profit per farm (Traditional eel culture) (Thousand NT$)	Cost to produce 1 kg eels (Intensive eel culture) (NT$/kg)[b]	Average profit per farm (Intensive eel culture) (Thousand NT$)
Tung-Kang	0.018	403.1	315.1	229.5	778.8
Linpien	48.372	1611.9	-32099.4	263.4	-2893.3
Shuilichum	10.036	653.5	-6399.5	236.5	20.6
Wunfon	65.887	2049.8	-43841.8	275.6	-4214.8
Tachung	9.987	652.3	-6367.3	236.5	20.6
Lichiachun	0.238	408.6	167.6	229.7	757.28
Tonghai	4.039	503.6	-2379.9	232.3	475.5
Pathliao	0.063	404.2	285.6	229.5	778.8
Shuidiliao	0.018	403.1	315.1	229.5	778.8
Sinlong	6.678	569.6	-4149.7	234.2	269.7

a: 25m^3 ground water is needed for producing 1 kg eel in traditional eel culture.

b: 0.7m^3 ground water is needed for producing 1 kg eel in intensive eel culture.

The average prices in 2000 for Japanese eels and European eel were 414.85 NT$ and 236.69 respectively. From Table 4.17, it can be seen that including full costs of water the traditional culture of Japanese eel is only feasible in Tung-Kang, Lichiachun, Pathliao and Shuidiliao and the highest profit is only 11.7 NT$/kg. With intensive eel culture, only in Wufon and Linpein are the adjusted costs higher than the average price of European eel. Here, the highest profit can reach 7.2 NT$/kg.

4.5 Post-harvesting process and marketing of eel

4.5.1 Introduction:

Although, *somen* (Japanese vermicelli), *hiyamugi* (iced noodle) *kakigori* (shaved ice) and watermelon are popular foods in Japan during the summer, eel is also considered a delicacy and good for the health during this season (The Japanese Times, July 1, 2001), and therefore, the greatest consumption is in the summer period.

Recently, production of eel in Japan has been reducing from 40,098 mt in 1991 to 24,904 mt in 2000, (Table 4.18). However, the consumption and imports have increased. Total consumption rose from 114,212 mt in 1991 to 158,049 mt in 2000 (average 3.68 % per year) and imports increased from 74,114 mt in 1991 to 131,352 mt in 2000 (average 6.57 % per year).

More than 90% of eels produced in Taiwan are exported to the Japanese market, in either live or in frozen roasted form. However, in recent years, China and other Asian countries have committed an increasing effort in developing their eel industry (Liao 1996). As cheaper eel from China became available in Japan, the market share of the eel from both Japan and Taiwan started to diminish. The market share of eel produced in Japan reduced from 35.1% in 1991 to 15.9% in 2000 and the market share of the eel produced in Taiwan reduced from 51.5% in 1991 to 18.9% in 2000 (Yu, 2001). The rapid growth in eel culture in China in particular increased competition in the Japanese market, which has had important consequences for the domestic Taiwanese eel industry.

Table 4.18 The production, consumption and imports of eel in Japan. Unit: mt

Year	Production amount of eel in Japan	Total consumption in Japan	Imported amount		
			Fresh	Processed	Total
1991	40,098	114,212	17,687	56,427	74,114
1992	37,397	114,752	16,745	60,616	77,361
1993	34,830	113,867	15,137	63,900	79,037
1994	30,380	111,232	15,832	65,020	80,852
1995	30,030	102,264	11,969	60,265	72,234
1996	29,517	116,796	11,442	75,837	87,279
1997	25,031	130,793	13,635	92,127	105,762
1998	22,845	122,548	13,033	86,670	99,703
1999	23,637	129,794	11,628	94,529	106,157
2000	24,907	158,049	14,355	117,187	131,352
Growth rate	-37.9%	38.4%	-18.8%	107.7%	77.5%

Data source: Yu, 2001.

4.5.2 Post-harvest processing

Two kinds of frozen roasted forms of eels are exported; without seasoning (Shirayaki); and prepared eels (Kabayaki). Both forms are presented whole or sliced skewered. The process is as shown in Fig 4.8 and is discussed below.

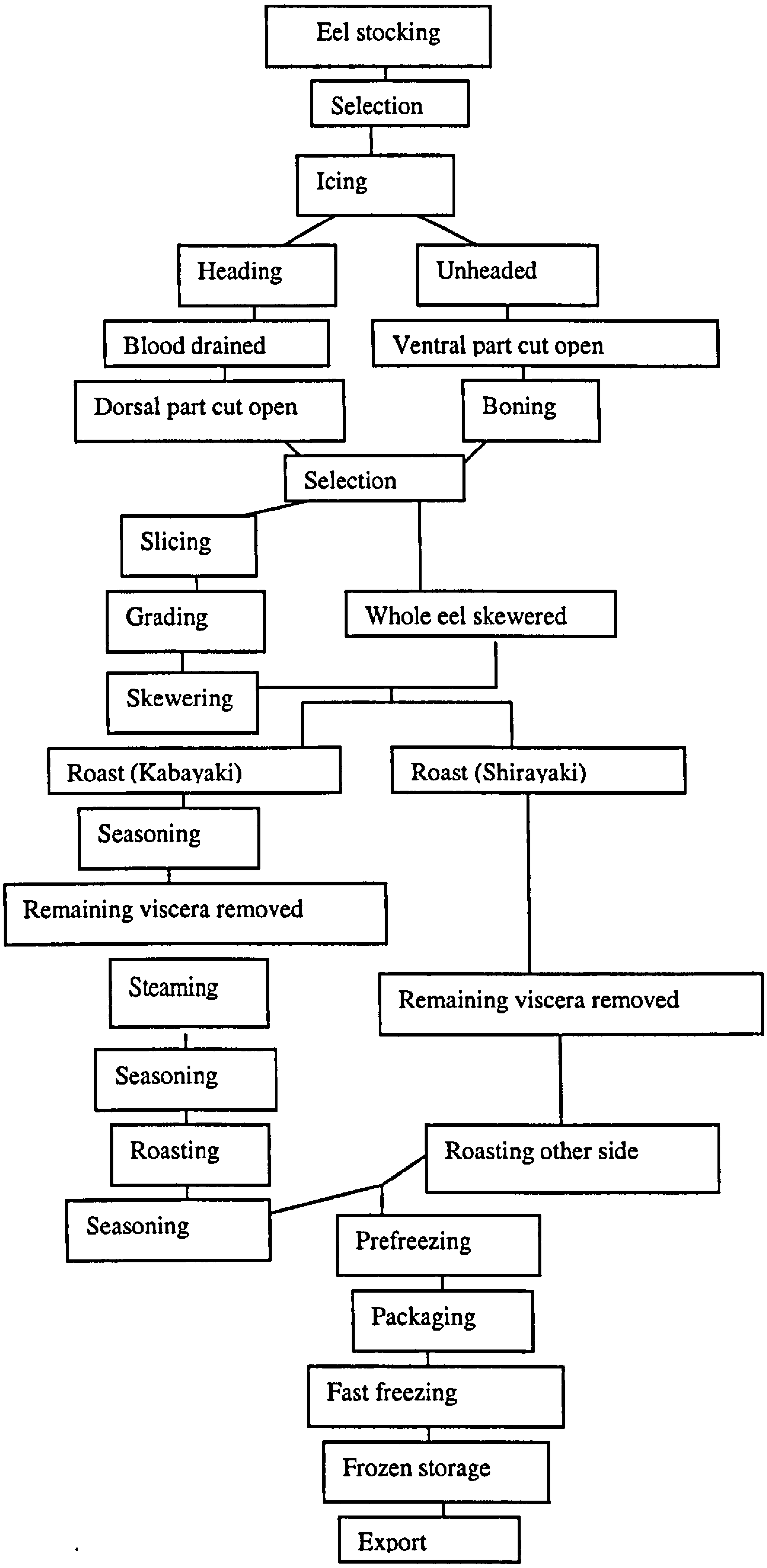


Fig. 4.8 The flow chart of the process for the frozen roasted eel process in Taiwan.

Before processing, eels must be held in stocking ponds with flowing water for at least 24 hours, as far as possible to allow the feed in the eels' stomach to be excreted. In the stocking ponds, total bacterial levels should not be over 10^2 /ml, and during stocking, dead eels must be removed at least twice daily. Selection must then be implemented before processing. This not only size-grades the eels, but also gets rid of eels of unsuitable quality. After selection, the eels are cooled in a water bath with crushed ice, at a temperature of less than 4℃ to anaesthetize them. Icing lasts for 30 minutes, after which they are prepared for dissection. The first step of dissection is beheading and the draining off of blood. They are then gutted, viscera removed, and boned. The next step is to put them into a machine to remove the remaining blood, as the percentage of blood content in the body will affect the taste, the speed of rotation to remove part of the blood is very important.

Slicing and skewering: there are two kinds of roasted eels, whole skewered and sliced skewered. Usually, longer eels are sliced by hand, under highest standards of hygiene, into 4 pieces, and shorter eels into 3 pieces. During the slicing process any eels that do not reach the required standard must be removed. After slicing, the next step is skewering. The pieces of eel flesh must be skewered tightly and cannot be skewered through the skin. The sharp ends of the skewers (bamboo sticks) usually project 5-cm out of the flesh.

Roasting: the skin side of the eels is roasted first. After the skin side is roasted, the fins of the eels are clipped and the eels are turned to the flesh side to roast again. If the process is for Kabayaki, the fins of eels are not clipped during the first roast, but the eels are steamed and the fins are clipped after steaming. Then, the eels are put into a sauce tank and roasted again. The seasoning and roasting must be carried out twice. The products were packed in plastic bag by vacuum and stored below –20 ℃ before export.

4.5.3 Marketing channels

Eel producers are either individual eel farmers or companies, and more than 90% of eels produced in Taiwan are exported to the Japanese market. Companies sell via their own exporting agency or to processing plants, while individual farmers will sell to a producer association or export agency, or to a processing plant through wholesalers. The marketing channel is very stable and shown as Fig.4.9.

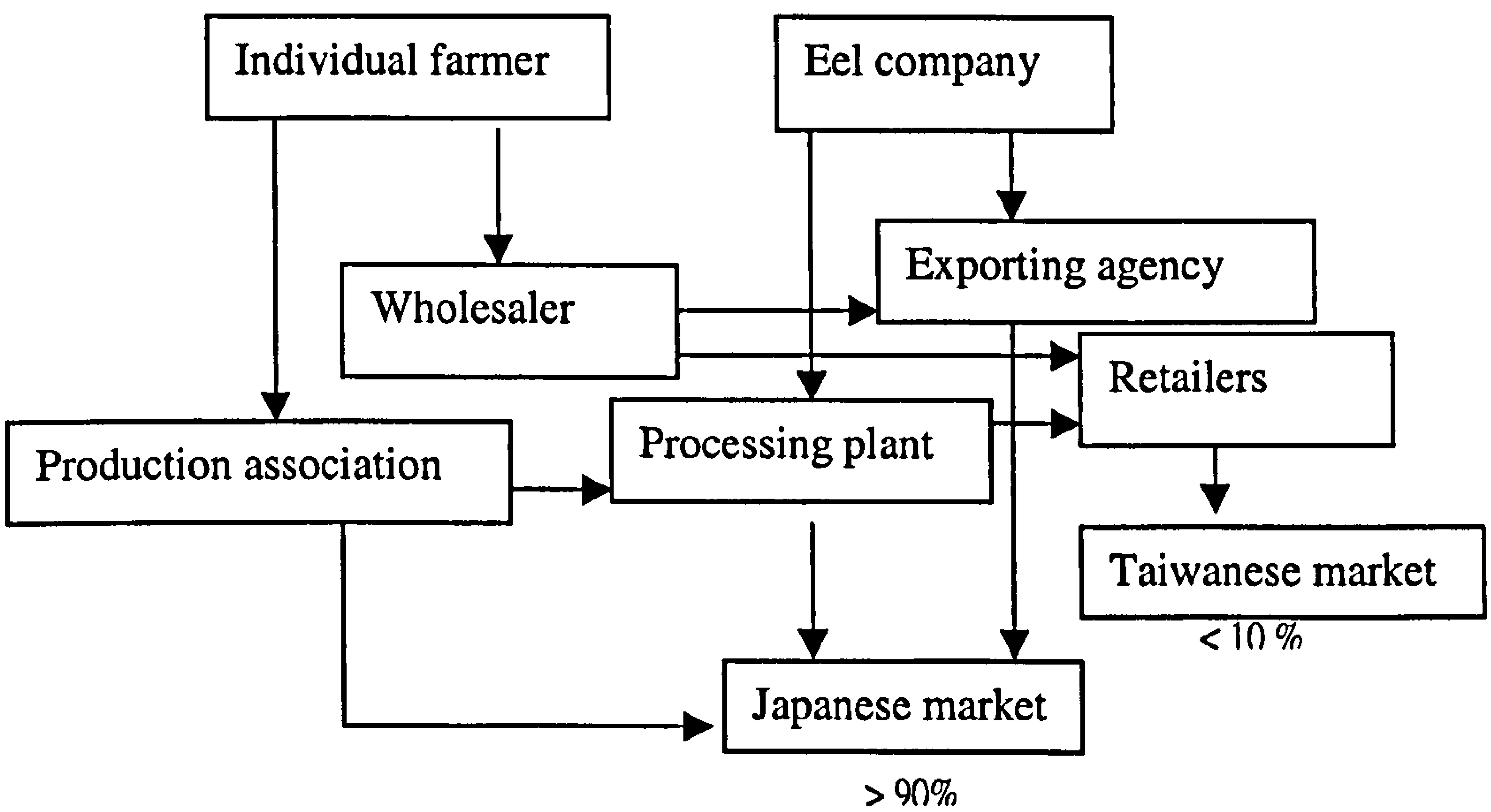


Fig.4.9 The marketing channels of eel.

Data source (Chu 1996).

4.5.4 Import quantity of the Japanese market

In the Japanese market, Taiwanese eels still have the biggest import market share for fresh eels at around 60 to 80%, reaching as high as 88.68% in 1992 (Table 4.19). However, for roasted eels, Taiwan has been replaced by China since 1994. In 1988, Taiwan's market share of roasted eels was 92.85% and that of China only 6.96%, while by 1998, China's share was 91.27% and that of Taiwan only 5.65% (Table 4.20).

Table 4.19 Market share of Japanese imports of fresh eels, by countries. Unit:mt

Year	Taiwan		China		Malaysia		Other countries	
	Quantity (mt)	Market share	Quantity (mt)	Market share	Quantity (mt)	Market share	Quantity (mt)	Market share
1988	12617	66.8%	5569	29.5%	0	0%	709	3.8%
1989	13365	73.7%	3953	21.8%	0	0%	827	4. 6%
1990	16033	79.7%	4027	20.0%	0	0%	47	0.2%
1991	13635	77.1%	4043	22.9%	0	0%	9	0.1%
1992	14850	88.7%	1871	11.2%	16	0.1%	8	0.1%
1993	11963	79.0%	2557	16.9%	553	3.7%	64	0.4%
1994	9319	58.9%	5699	36.0%	158	1.0%	655	4.1%
1995	8464	70.7%	3156	26.4%	122	1.0%	227	1.9%
1996	8067	70.5%	3096	27.1%	265	2.3%	14	0.1%
1997	9446	70.7%	3472	26.0%	268	2.0%	179	1.3%
1998	8122	62.3%	4329	33.2%	534	4.1%	49	0.4%

Data source: Customs bureau, Ministry of Finance, Japan.

Table 4.20 Market share of Japan imports of roasted eels, by countries. Unit:mt

Year	Taiwan		China		Malaysia		Other countries	
	Quantity (mt)	Market share	Quantity (mt)	Market share	Quantity (mt)	Market share	Quantity (mt)	Market share
1988	34142 (20485)	92.9%	2560 (1536)	7.0%	0	0%	70 (42)	0.2%
1989	35775 (21465)	90.1%	3782 (2270)	9.5%	0	0%	132 (79.)	0.3%
1990	41977 (25186)	87.3%	6058 (3635)	12.6%	0	0%	27 (16)	0.1%
1991	45215 (27129)	80.1%	10453 (6272)	18.5%	737 (442)	1.3%	30 (18)	0.1%
1992	44116 (26470)	72.8%	14141 (8485)	23.3%	2324 (1394)	3.8%	39 (23)	0.1%
1993	37591 (22554)	58.8%	22556 (13534)	35.3%	3668 (2201)	5.7%	86 (52)	0.1%
1994	22150 (13290)	34.1%	39374 (23625)	60.6%	3406 (2045)	5.2%	87 (52)	0.1%
1995	11856 (7113)	19.7%	45884 (27530)	76.1%	2445 (1467)	4.1%	81 (49)	0.1%
1996	10750 (6450)	14.2%	63008 (37805)	83.1%	2053 (1232)	2.7%	27 (16)	0.0 %
1997	7886 (4731)	8.6%	82442 (49465)	89.5%	1745 (1047)	1.9	53 (32)	0.1%
1998	4894 (2937)	5.7%	79104 (47463)	91.3%	2147 (1288)	2.5%	525 (315)	0.6%

Data source: Customs bureau, Ministry of Finance, Japan.
The figures in parentheses are quantities of processed eel, where the ratio of processed to fresh eel is estimated at 0.6.

4.5.5 RCA index

Balassa (1965) first developed the concept of revealed comparative advantage (RCA). The relative export performance for a particular product in a particular country can be quantified in the form of an index, which indicates the pattern of revealed comparative advantage in its trade (Ling et al, 1996, Traesupap et al, 1999). An RCA value for the eel sector can be obtained by dividing a country's share in the exports of the type of eel product by its share in the combined exports of eels of the exporting countries. The RCA index is expressed as follows.

$RCA = (X_{ij}/X_{bj})/(X_a/X_b)$

Or

$= (X_{ij}/X_a)/(X_{bj}/X_b)$

where:

X = export quantity of eel product

i = eel exporting country I

j = eel product j

a = all eel products of country I

b = all eel products of all exporting counties

If the RCA index of a country in a given export eel product is higher than 1, it means that the country's share in this product has the comparative advantage, and if is less than 1, it reveals a comparative disadvantage. A value of 1 signifies comparative neutrality.

From 1988 to 1991, China had the comparative advantage in fresh eels, while since 1992, this shifted to Taiwan (Table 4.21), and to Malaysia in 1997 and 1998. Regarding roasted eels, Taiwan lost the comparative advantage to China from 1992 but Malaysia also had the comparative advantage since 1991 (Table 4.22). From the RCA index, Taiwan's comparative advantage can be shown to have changed from processed to fresh eel, while that of China's shifted in the opposite direction. Unstable supply of eel might be the reason that some processing factories stopped their business and caused the comparative advantage changed from processed to fresh eel.

Table 4.21 RCA indices of fresh eel imports in the Japanese market from 1989 to 1998.

Year	Taiwan	China	Malaysia	Other countries
1988	0.794972	2.01828	----	2.680691
1989	0.866877	1.628893	-----	2.749452
1990	0.937031	1.353703	----	2.165942
1991	0.970956	1.168893	0	0.950281
1992	1.163551	0.539859	0.031592	0.783996
1993	1.260511	0.531706	0.683945	2.230713
1994	1.512447	0.645744	0.225578	4.507391
1995	2.513836	0.388408	0.287654	4.443594
1996	3.270161	0.357261	0.872345	2.624151
1997	4.301904	0.318955	1.051292	6.079245
1998	4.773435	0.396883	1.523247	0.653498

(Developed from Table 4.19).

Table 4.22 RCA indices of processed eel imports in the Japanese market from 1989 to 1998.

Year	Taiwan	China	Malaysia	Other countries
1988	1.105352	0.476768	----	0.136396
1989	1.06086	0.712489	----	0.200205
1990	1.026343	0.85203	----	0.512234
1991	1.009103	0.947066	4.19067	1.015582
1992	0.954822	1.127107	4.588525	1.059668
1993	0.938289	1.110932	4.537491	0.708461
1994	0.875238	1.086249	4.88181	0.146077
1995	0.699349	1.121464	5.747539	0.316095
1996	0.657475	1.096977	6.755383	0.754946
1997	0.521007	1.098796	6.842132	0.263175
1998	0.432564	1.090695	6.126725	1.052106

(Developed from Table 4.20).

4.5.6. Seasonal variation

Detailed monthly records of exports are provided in Annex C1, from which indices of seasonal variation can be calculated. The major season for fresh eel exports from Taiwan to the Japanese market is concentrated in June, July and August, the index being over 100, the highest being in August, when the index is 305.4. For fresh eel imported from China, there are 3 months, June, July and December when the seasonal index is over 100. Unlike Taiwan where the market is concentrated in the summer period, China has 2 different peaks for exporting fresh eels to the Japanese market (Annex C2). Compared with that of Taiwan, the Chinese eel supply is also more evenly distributed.

In the case of roasted eels imported from Taiwan to Japan, there are 5 months, March, April, May, June and July, where the seasonal index is over 100 (Annex C3), with a more even distribution for roasted eel than fresh eel. For roasted eels imported from China, there are 4 months-April, May, June and July where the seasonal index is over 100 (Annex C4).

The seasonal indexes show, in the summer time (especially July), the demand for fresh eel in Japanese market attained a peak. However, the demand for roasted eel was more evenly distributed in the whole year. When comparing Taiwan and China, the demand for fresh eel from Taiwan is higher in the summer while that from China is more evenly distributed.

4.5.7 Analysis of export market

A simple econometric model of the export market was developed to outline the factors associated with the performance of Taiwanese processed eels in Japan. This linear model was based on time series annual undeflated data covering the period of 1988 to 1998, and estimated with an ordinary least square procedure. Data sources are from the Customs Bureau, Ministry of Finance, Japan. The empirical equation is presented in the equation below:

$$PIP = 419.5 - 0.000014DI + 46.04EC - 0.003229QPIT + 0.8116PPC$$

(0.46) (-0.01) (0.52) (-0.67) (5.73)**

$R^2 = 90.0\%$ $F = 13.46^{**}$

Where

PIP = Undeflated import price of Taiwanese processed eel (¥/Kg)

DI = Disposable income of Japanese household (¥)

EC = Currency exchange rate of NT$ to ¥

QPIT = Quantity of processed eel imported from Taiwan

PPC = Undeflated import price of Chinese processed eel (¥/Kg)

The empirical equation estimated has an R^2 value of 90.0%, indicating that this specification explains 90% of the variation in the import price of Taiwanese processed eels in Japan. Only the import price of Chinese processed eels has significant effect on import price of Taiwanese processed eels in Japan. The coefficient for PPC showed that if the price of Chinese processed eels increases by 1yen per kg, the price of Taiwanese processed eels would increase 0.81yen per kg in the Japanese market. However, the effect of Chinese processed eel prices in driving that of Taiwanese processed eel needs to be judged very carefully, as other factors might also be involved.

An econometric model for fresh eel was also developed for the Japanese market. The empirical equation is presented below:

$$PIF = 1801.6 - 0.001383DI - 130.85EC - 0.0012QFIT + 0.6585PFC$$

(3.37)* (-1.67) (-1.89) (-0.05) (2.81)*

$R^2 = 96.9\%$ $F = 46.87^{**}$

Where

PIF = Undeflated import price of Taiwanese fresh eel (¥/Kg)

DI = Disposable income of Japanese household (¥)

EC = Currency exchange rate of NT$ to ¥

QFIT = Quantity of fresh eel imported from Taiwan

PFC = Undeflated import price of Chinese fresh eel (¥/Kg)

The empirical equation has an R^2 value of 96.9%, indicating this model explains 96.9% of the variation in the import price of Taiwanese fresh eels for Japan. The import price of Chinese fresh eels has significant effect on import price of Taiwanese fresh eels in Japan. The coefficient for PFC showed that if the price of Chinese fresh eel increases 1yen per kg, the price of Taiwanese fresh eels would increase 0.66yen per kilogram in Japanese market. However, the impacts of Chinese fresh eel prices on Taiwanese fresh eel prices need to be very carefully considered, as other factors might also be involved.

4.5.8 Market survey

Although most eel products are exported to Japanese market, the development of local markets is also considered to be important. Therefore, an understanding of the requirements of domestic consumers is essential. In 1999, in 3 areas, 132 consumers were surveyed. These were in Taipei (52 consumers), Taichung (45 consumers) and Tainan (35 consumers), representing the northern, central and southern part of Taiwan respectively.

As shown in Table 4.23, most respondents (52%) preferred frozen roasted eel, though a significant number preferred fresh eel (36%). Traditionally, the Taiwanese had bought fresh eel and stewed them with Chinese herbs. However, more and more people now preferred convenience foods, and frozen roasted eel are becoming more popular.

Table 4.23 Preference for product forms.

Products	Numbers	Percentage	Chi-square value	P value
Fresh fish	48	36.36%	0.120579	0.003652**
Frozen roasted	69	52.27%	4.729986	
Others	15	11.36%	6.374158	
Total	132	99.99%	11.22472	

The majority of respondents (66%) preferred the size below 300g (Table 4.24), which is similar to demand in Japanese markets, for which the size is usually between 200g to 500g. However, the smaller size (200g group) can fetch higher prices.

Table 4.24 Preferred size of eel for domestic consumers.

Sizes	Numbers	Percentage	Chi-square value	P value
200 g	33	26.83%	0.5215	0.629202
300g	48	39.02%	0.39714	
600g	42	34.15%	0.007966	
Total	123	100%	0.926606	

Although most respondents (66%) stated that the consumption of eel was not correlated with seasons (Table 4.25), 25% preferred buying eel in winter season. Traditionally, Taiwanese consider stewed eel with Chinese herbs in the winter to be wholesome, which is very different from the Japanese, who prefer to eat eel during the hot summer.

Table 4.25 Seasonal preference for purchasing.

Seasons	Numbers	Percentage	Chi-square value	P value
Spring	3	2,27%	6.913636364	$1.584*10^{-13}$**
Summer	3	2.27%	6.913636364	
Autumn	6	4.55%	5.254545455	
winter	33	25%	0.55	
Uncertain	87	65.91%	46.36818182	
Total	132	100%	66	

Most people either stew eel with Chinese herbs or eat them roasted (Table 4.26). To cook eel by roasting is perhaps influenced by Japanese preferences, and some companies roasting eel before export also now sell them in domestic market. Such factors may change traditional cooking habits and consumer preferences.

Table 4.26 Preferred ways of cooking.

Cooking ways	Numbers	Percentage	Chi-square value	P value
Stewed with Chinese herbs	60	44.44%	1.6667	0.03813*
Roasted	54	40%	0.6	
Others	21	15.56%	4.2667	
Total	135	100%	6.53333	

More than 50% of respondents considered that they would buy more eel if the price were lower (Table4.27). However, as the domestic market has been limited because of high prices, most eel were exported to the Japanese market, for which prices might be higher. Another 25% of respondents considered that they would buy more eel if the quality were improved. Therefore, to improve the quality and service, and create new products might be helpful to develop the potential of domestic market.

Table 4.27 Situations in which consumers would buy more eel.

Situations	Numbers	Percentage	Chi-square value	P value
Price is cheaper	69	52.27%	4.729986367	0.028233*
Quality is better	33	25%	0.918125426	
Others	30	22.73%	1.486632584	
Total	132	100%	7.134744376	

A great number of respondents noted that their frequency of buying eel was uncertain (93%) (Table 4.28). Eel consumption is not popular in Taiwan and most consumers did not buy them regularly.

Table 4.28 The frequencies of buying eel.

Frequencies	Numbers	Percentage	Chi-square value	P value
Every week	0	0%	8.8	$6.6822*10^{-31}$**
Every two weeks	0	0%	8.8	
Every three weeks	3	2.27%	6.913636364	
Every one month	6	4.55%	5.254545455	
Uncertain	133	93.18%	117.8227273	
Total	142	100%	147.5909091	

Most respondents also noted that the quantity purchased was uncertain (Table 4.29). As in the preceding question, it seemed that they did not buy eel regularly. Note that as the unit of weight scale is 600 g in Taiwan, units of 600 g and 1200 g were chosen in this survey.

Table 4.29 Purchasing quantities of eel at each purchase.

Amount	Numbers	Percentage	Chi-square value	P value
About 600 g	39	29.55%	0.187967258	0.006279**
About 1200 g	21	15.91%	4.002428377	
Uncertain	72	54.55%	5.95058663	
Total	132	100.01%	10.14098226	

When asked why they do not buy eel, expense was the biggest reason (51%), after which were their boniness (32%) and difficulty of cooking (23%) (Table 4.30). As more than 70% of respondents considered the eel to be expensive (Table 4.31), its high price was likely to be the biggest problem restricting market development. However, there were still 6.8% of respondents do not buy eel because of other reasons (Table 4.30). To improve the quality might be their requirement.

Table 4.30 The reasons that consumers do not buy eel.

Reasons	Numbers	Percentage	Chi-square value	P value
Difficult to cook	30	22.73%	0.090909	0.018566**
Bony	42	31.82%	0.818182	
Too expensive	51	38.64%	3.272727	
Others	9	6.82%	5.818182	
Total	132	100.01%	10	

Table 4.31 Opinions of respondents concerning the price of eel.

Opinions	Numbers	Percentage	Chi-square value	P value
Very expensive	9	6.82%	3.822727273	$8.27367*10^{-13}$**
Expensive	84	63.64%	41.89090909	
Acceptable	36	27.27%	1.163636364	
Cheap	3	2.27%	6.913636364	
Very cheap	0	0%	8.8	
Total	132	100%	62.59090909	

Regarding the quality of eel, most respondents have a positive opinion. More than 65% of respondents considered the quality to be good/excellent. However, almost only 32% considered the quality to be acceptable and 2% considered it to be below acceptability (Table 4.32). It seemed that quality still has some scope to be improved.

Table 4.32 Opinions of respondents concerning the quality of eel.

Opinions	Numbers	Percentage	Chi-square value	P value
Excellent	15	11.36%	1.640909091	$1.77627*10^{-9}$**
Good	72	54.55%	26.25454545	
Acceptable	42	31.82%	3.072727273	
Bad	3	2.27%	6.913636364	
Very Bad	0	0%	8.8	
Total	132	100%	46.68181818	

When combining quality and price, most respondents considered eel to be acceptable (61.4%). Less than 30% of respondents considered eel are good/excellent (Table 4.33). It suggested eel might be an average rather than a good level of value for money.

Table 4.33 Evaluation of respondents concerning the price and quality of eel.

Opinions	Numbers	Percentage	Chi-square value	P value
Excellent	9	6.82%	3.822727273	$1.15787*10^{-10}$**
Good	30	22.73%	0.163636364	
Acceptable	81	61.36%	37.64090909	
Bad	9	6.82%	3.822727273	
Very Bad	3	2.27%	6.913636364	
Total	132	100%	52.36363636	

The market survey suggested that eel is a luxury product in Taiwan, which people did not buy regularly. The biggest problem is the price is too high, and this might be the reason why most of the eel products were exported to Japanese market. However, there was still a certain level of respondents (25%) who considered that they would buy more eel if the quality was improved. To improve the quality to satisfy consumers requirement might be helpful to develop domestic markets.

4.6 Discussion

Although the history of eel culture in Taiwan is less than 50 years old, the technology of eel culture is quite mature. However, problems still exist, including overuse of fresh water resource, lack of eel seed and market competition. To overcome some of these, Taiwan tried to apply new technology from other countries and used European eel to replace Japanese eel.

Traditional eel culture in ponds requires large quantities of water, and in many areas of Taiwan is not feasible because of limited water supplies or an absence of land for pond construction. Recirculating systems may offer an alternative, through water treatment and reuse, requiring only a fraction of the water required by ponds to produce similar yields. These systems usually also use tanks for production, substantially reducing land requirements (Losordo *et al.*, 2001). The level of water renewal in a recirculating aquaculture system depends first, on its efficiency in removing toxic outputs from fish metabolism and secondly, on the amount of water that is lost when removing the accumulated waste product (Chaves *et al.*, 1999). On average, the production of 1 kg eels requires 20 to 30 t of water in traditional eel culture, but only 0.8 t in intensive recirculated culture. Intensive culture is thus also less likely to create adverse environmental impact.

Super intensive recirculating systems were imported during the 1990s, but are still not widely developed in Taiwan. Up to 2000, only 12 farms used this system (Chen personal communication, 2001). Most eel farmers still do not want to invest in intensive culture, and they consider the density to be too high, growth rate too low and the capital cost too high.

Until captive propagation can be successfully achieved, the supply of eel seed depends totally on wild capture, and the shortage of natural seed remains a huge constraint to the development of eel culture, also burdening eel farmers with a higher cost of production (Table 4.7 and Table 4.9). Therefore, any steps to increase the fishery resource of eel seed would be valuable imperative to restore the development of eel culture. The situation is similar to that described by Houvenaghel (1989) concerning the decline of European eel, due to:

- overfishing;
- environmental changes (land reclamation, river banking, dams, etc.);
- water pollution especially in the rivers used by the eels during ascending and descending migration;

- decrease in recruitment.

This situation is even more serious in Asia and for Japanese eel. To overcome such constraints, the Taiwanese government has tried to increase the natural resource by releasing adult eel into ocean, and importing European eel. However, success has been limited.

As Table 4.34 shows the percentage cost of eel seed in producing Japanese eel has increased greatly, from 8.2% in 1975 to 60.5% in 1997. The increasing cost of eel seed makes this industry difficult to develop on a sustained basis.

Table 4.34 The percentage of cost structure for producing Japanese eel in Taiwan.

Item	1975	1977	1979	1981	1983	1985	1987	1990	1997
Eel seed	8.2%	25.5%	10.1%	25.5%	25.2%	25.7%	29.9%	37.9%	60.5%
Feed	40.9%	38.3%	60.7%	37.4%	36.2%	36.1%	34.1%	34.4%	18.0%
Wage	10.6%	9.0%	5.4%	9.0%	9.2%	0.3%	1.7%	8.4%	7.0%
Electricity	5.3%	3.9%	4.5%	3.6%	4.3%	1.8%	1.2%	5.3%	2.9%
Renting land	11.2%	7.0%	5.6%	7.6%	7.9%	4.8%	4.5%	3.1%	2.5%
Interest and depreciation	13.0%	3.0%	9.4%	2.4%	12.4%	7.9%	5.6%	7.9%	7.8%
Miscellaneous	2.7%	3.3%	4.5%	4.5%	4.8%	3.3%	3.1%	3.1%	0.07%

Data source: 1975~1990:(Chen 1997).

1997: this study.

The various forms of average financial appraisal have shown that intensive eel culture has a slight advantage over traditional eel culture. However, the distribution of profitability shows that it is still possible for traditional eel culture to have higher profits than super-intensive eel culture (Table 4.14), the advantage of super-intensive culture being primarily due to the cheaper eel seed. The average prices of eel seed of Japanese eel and European eel are 25.21NT$ and 4NT$ respectively, and as shown in Table 4.9 and Table 4.12, eel seed takes up 60.5% and 20.4% of the operation costs in traditional eel culture and intensive eel culture, respectively. The highest operating cost in intensive culture is feed instead of eel seed. Most eel farmers still do not want to try intensive eel culture as it is difficult for many to invest more than 7,000,000 NT$ (= 218,750 US$) in the necessary facilities (Table 4.10). Farmers also consider that the growth rate of eels in intensive culture is slower than in traditional culture. Although the deficiency of eel seed makes operating costs of traditional systems rise, eel farmers would rather suspend their farming than invest in the facilities for intensive culture.

If the full costs of ground water are accounted, the real cost of traditional eel culture is high. In different regions, the social cost of ground water is different and here, it might be appropriate for the government to assist by setting up special areas to develop eel culture by reducing the social cost. This will be discussed in Chapter 6.

The quality of frozen roasted eel produced in Taiwan is as good as that produced in Japan (Yu, 2001). However, Table 4.21 and Table 4.22, show that Taiwan has lost the comparative advantage in roasted eel for the Japanese market. One reason is that the supply of raw material is unstable and this has caused some developers to transfer their investment to China or stop their business.

The import price of Chinese eels has a significant impact on the import price of Taiwanese eels in Japan. If Taiwanese eels are to improve their potential, it will be important to differentiate their quality of eels and to develop new products. To reduce risks of contamination, aquaculture products need careful processing and strict adherence to the safety guidelines. Unlike production processes based on raw material from capture fisheries, the manufacturing process of aquaculture products begins at the farms.

The mass import of eel from China and Taiwan has caused a crisis of eel farming industry in Japan. In 2001, the number of Japanese companies engaged in eel growing, around 500, is only one-eight the number of the industry's heyday in the mid-1970s (The Japanese Times, May 9, 2001). To protect this industry, Japanese eel growers have asked their government to impose an emergency "safeguard" import curb. Recently, Japanese eel growers negotiated with their Chinese counterparts, but there have been no substantive agreements to date (K. Katsuyama, Deputy Director, Administrative Division, Japan Fishery Agency, 2001, personal communication by e-mail).

If the situation of conditions in the Japanese eel industry getting worse, the Japanese government may restrict imports using the WTO rule that empowers member countries to impose import restrictions if the domestic industry can suffer serious damage (The Japanese Times, May 9, 2001). However, this might induce retaliation from the Chinese government.

Traditionally, Japanese consider the quality of domestic eel products to be better than that of imported products, and domestically grown eels are retailed at prices some 30 percent higher than those of imported eel (The Japanese Times, May 9, 2001). However, not all people can tell the differences between domestic and imported products and some Japanese importers had represented eels from China or Taiwan as domestic. To address this problem, the Japanese government has now required that all eels should be sold with the information provided on the place of origin and processing. Although this is not a discrimination measure (Katsuyama, 2001, personal communication by e-mail), it appears that the Japanese government hopes that the patriotism of Japanese citizens can help to reduce imports from other countries.

The mass production of eel from China may make a big impact on Taiwan's eel industry, because both areas depend on the Japanese market very strongly. In addition to improving products and extending product range, Taiwan should develop its domestic market and explore markets in other countries to alleviate the possible impact of the Japanese government in setting up trade curbs on eel import. However, there appear to be few immediate prospects for other countries to import such large quantities of eel. It may therefore be critical to negotiate with Japanese counterparts to obtain a good import quota. Although, the domestic market appears to be still difficult to develop because of the high price of eel, there is still some space to improve. To improve the quality or develop new products, which are more suitable for Taiwanese consumers might be useful for developing domestic markets.

Chapter 5

Cage culture

5.1 Introduction

The origins of cage culture are somewhat unclear, though it is probable that the first cage was the use of simple containment by fishermen as a convenient holding facility for fish until they could be accumulated and ready for sale (Beveridge 1996). Some documents show that the lower reaches of Mekong River was the place of origin of cage culture (Hickling 1962; Pantulu 1979). On the basis of recorded documents Hu (1994) proposed that cage culture had been practiced in ancient times in China. In Zhou Mi's work Bieji described how the fry were placed in cloth cages in open water with bamboo sticks supporting the four corners, allowing them to grow bigger for marketing after one and half months. From this document describing what in modern aquaculture could be called a 'hapa', the origin of cage culture might be traced back to at least 1243 in China.

Modern cages utilize synthetic mesh or netting materials and commonly have floating structural collars, usually fabricated from synthetic polymers and metals. Japan is considered an important source of inspiration for modern cage culture (Beveridge 1996). In Japan, the first experiment in cage culture was conducted in 1954, and the commercial culture of yellowtail (*Seriola quinqueradiata*) started in 1957 (Milne 1974). In Norway, cages were used to culture Atlantic salmon (*Salmo salar*) in the early 1960s and in Scotland the White Fish Authority commenced salmon cage culture trials around 1965 (Beveridge 1996).

In Taiwan, the first trial of cage culture started in Sun Moon Lake in 1970 and thereafter, investigations in the techniques of fresh water cage culture were conducted in the Shyr-Men Reservoir, the U-Shan-Tour Reservoir and the Der-Ji Reservoir. By 1987, there were 300 nets in the inland reservoirs in Taiwan producing some 1800 t annually. In inland cage culture, tilapia was the most important species by volume, while the average prices of perch and eel were higher (Annex D). In 1990, production from inland cages attained its highest level at 2,314 t (Table 5.1). However, the problem of eutrophication and deterioration of water quality forced the responsible agencies to prohibit the setting up of more cages in reservoirs, and because of the limited resources of water and land, the further development of this type of aquaculture was inevitably constrained (Fig 5.1). By 1990, production from inland cage was reducing, and by 1997, there has been no commercial inland cage production (Table 5.1). However, Taiwan is an island, surrounded by open sea, and therefore, has wide opportunities to develop sea cage culture. The advantage of sea cage culture would include availability of relatively unmodified natural environments, increased productivity in limited space; maintenance of good water quality because of water currents, and the reduction of dependence on fresh water and underground water.

Sea cage culture in Taiwan commenced in the Pen-Hu area in 1977, though before 1989, there were no records on quantity and value of production from this sector. By 1989, according to the Year Book of the Taiwan Fisheries Bureau, the total quantity, and value of production was 21 t, NT$ 3,218,000 respectively with an average value of about 153 NT$/kg. Production then increased dramatically, by 1998, reaching 884 t and a total value of 179,642,000 NT$ from a total area of sea cage culture of 1072,896 m^2 (Table 5.1). From 1989 to 1998, the average annual growth rates of production, value and area are 51.5%, 56.3% and 69.2% respectively (Table 5.2). Of the species from sea cage culture, red porgy (*Pagrus major*) was the most significant, with quantity and value of 261 t and NT$ 75,817,000 by 1997. Red porgy (*Pagrus major*), grouper (*Epinephelus spp.)* and cobia (*Rachycentron canadus*) had higher prices levels (about 300 NT$/ kg) among the species used, though the price of cobia dropped to 125 NT$/ kg in 1998 (Annex D). The average price of cobia dropped 350 NT$ in 1995 to 125 NT$ in1998, and the production increased from 3 t in 1995 to 17 t in 1998. It implied this fish is price elastic (i.e. elasticity of demand >1.0). The other species can be cultivated in land based systems, and so it is difficult to compare their elasticity.

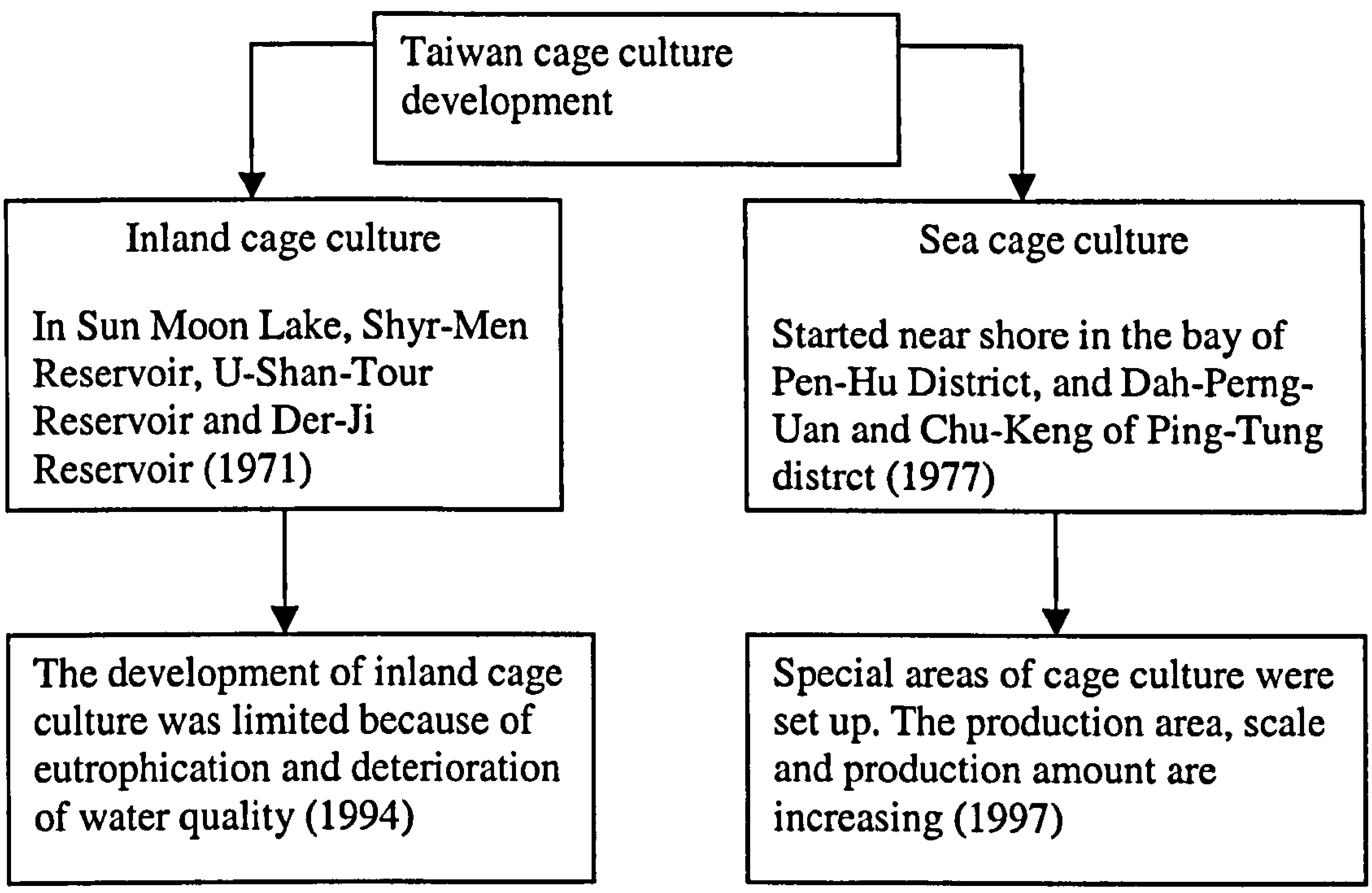


Fig.5.1 The development process of cage culture in Taiwan (modified from Chang, 2000).

The prices of products from sea cage culture are generally higher than those from inland culture. Since 1992, average prices from sea cage culture were over 200 NT$ compared with averages from inland cage culture which were usually lower than 100NT$. However, sea cage culture had lower productivity; at an average level of 1 kg m^{-2} in 1990 compared with levels as high as 177 kg m^{-2} from inland cage culture (Table 5.1).

Table5.1 Production, value and area of cage culture in Taiwan, 1989 - 1998.

Year		Quantity (metric ton)	Value (1000 NT$)	Price (NT$/Kg)	Area ($1000m^2$)	Productivity (kg m^{-2})
1989	Sea cage	21	3218	153	----	----
	Inland cage	633	27480	43	16	40
1990	Sea cage	103	13726	133	----	----
	Inland cage	2314	253946	110	13	177
1991	Sea cage	86	11541	134	76	1
	Inland cage	508	15043	29	14	36
1992	Sea cage	130	29327	225	113	1
	Inland cage	330	10898	33	4	84
1993	Sea cage	138	31529	228	181	1
	Inland cage	368	13955	38	4	93
1994	Sea cage	150	36278	241	181	1
	Inland cage	21	802	38	1	21
1995	Sea cage	357	94128	263	513	1
	Inland cage	----	----	----	----	----
1996	Sea cage	678	147500	218	534	1
	Inland cage	----	----	----	----	----
1997	Sea cage	837	186074	222	391	2
	Inland cage	0	0	----	0	----
1998	Sea cage	884	179642	203	1073	1
	Inland cage	0	0	----	0	----

Data source: Year Books of Taiwan Fisheries Bureau (1990-1999).

Table 5.2 The average annual growth rate of production, value and area of sea cage culture in Taiwan, 1989 - 1998.

	Quantity	Value	Area*
Annual growth rate	51.5%	56.3%	69.2%

* The average growth rate of area is from 1990-1998.

5.2 Development conditions

5.2.1 Culture area

The successful development of cage culture is very dependent on having access to suitable sites (Jensen 1996). Beveridge (1996) recommends to establish facilities for cage culture in areas where current speeds are normally less than 50 cm/sec. Currently, the major prefectures for cage culture are in Pen-Hu and Pintung. In Pen-Hu, there are about 900 single cages, 360 single cages in Pintung and 10 single cages in I-Lan. In Miaoli, Hwalian and Taitung, there are 4 single cages respectively.

In Pen-Hu Prefecture, cage culture has been carried out for more than 10 years. Initially, cages were set up by fishermen for keeping fish stock or as an appendix of a set net. Later, fishermen started feeding the stocked fish and, thus, commenced cage culture. Because of the strong monsoons during the winter period, most cages were set up in the inshore bays of Pen-Hu. However, although this can reduce monsoon damage, problems of self-pollution may quickly arise. Owing to the monsoon, water temperature decreases during the winter, thus reducing feeding and winter growth rate.

In Pintung Prefecture, cage culture started in Da-Pern-Wan. As Da-Pern-Wan is surrounded by land on three sides and is connected on one side to the open sea, water circulation is very restricted, and owing to this poor circulation, the cage farms in this area caused serious eutrophication. The local government therefore forced the farmers in this area to move elsewhere.

In 1997, Pingtung prefecture government started promoting cage culture and set up a specific area for cage culture in Fon-Kong and Shioa-Liu-Chou areas. In southern Taiwan, in the area from Tunkung to Fon-Liao, there is no monsoon and there is no typhoon from October to May of the following year. The typhoon period from June to September is the season for the propagation of several species of marine fish. After nursing, the fingerling can be transferred into cages, by which time they can avoid typhoon damage. These circumstances make Pintung prefecture a very suitable area for developing cage culture.

5.2.2 Legal rights for cage culture

Aquaculture is strongly affected by public law because it involves many social areas which concern modern governments (Rieser 1996). To avoid conflicts between cage farmers with navigation rights, the capture fisheries sector and other related functions, government must provide farmers a special legal right to develop cage culture. Among these, the establishment and protection of property rights of private culturists are paramount. Laws providing ownership of cage culture to the culturist have to be promulgated. Otherwise, investors would have little incentive to invest and to innovate. In Taiwan, cage culture is considered as a form of fisheries, and cage farmers must obtain fisheries rights to become legitimate, two types of which are suitable. These are the Zoning Fishery Right (ZFR) and the Specification Fishery Right (SFR). Both establish the right for fishermen to fish in a certain water area. However, applications for SFR are limited to the Fishermen's Association or Fisheries Production Cooperatives, while applications for ZFR can also include individuals or companies. The area allocations for ZFR are modest: for individual farmers less than 3 hectares and groups less than10 hectares. However, the SFR can be hundreds of hectares (Table 5.3). Applicants can obtain licenses from the local Fishermen Association, which has been delegated the authority, apart from in Pen-Hu, where fish farmers can only get the license directly from the local government.

Table 5.3 Features of Zoning Fishery Right (ZFR) and Specification Fishery Right (SFR).

Item	Zoning Fishery Right (ZFR)	Specification Fishery Right (SFR)
Qualification of applicant	Individual, partnership, company, institute of research, Fishermen Association and Fisheries Production Cooperation etc.	Fishermen Association and Fisheries Production Cooperation
Fishing		Fishermen Association and Fisheries Production Cooperation set up the rules for fishermen fishing in the area of SFR
Area for applicant	Less than 3 hectare for individual and less than 10 hectare for groups.	Hundreds of hectares
Duration of tenure	5 years	10 years
Current situation	Pen-Hu prefecture uses ZFR for cage culture	The other prefectures except Pen-Hu prefecture use SFR for cage culture
Coordination agency	The Fisheries Department of local government	Fishermen Association and Fisheries Production Cooperation

5.3 System features

5.3.1 Cage structure

Cages for fish culture have been constructed from a variety of materials and at a range of sizes. Basic requirements are that cage materials are strong, durable and non-toxic.

In 1970s, in the Pen-Hu Islands, the initial net cages were mounted on a 5m×5m×3m (m^3) or 6m×6m×4m (m^3) framework. After that, cages were gradually enlarged to 7m×7m×4m (m^3), 8m×8m×4m (m^3) and even to 10m×10m×5m (m^3). These are either in the form of a wooden square supported by floats made of a 1.0×0.6×0.5m^3 pieces of styrofoam wrapped in plastic sheet, or in the form of a series of five or six connected styrofoam pieces on each side (Fig 5.2). Detachable top nets are used to prevent fish from escaping. The bottom of the net cage is weighted with lead; four or five net cages are connected to become a group. Cages should not be too close together for avoiding the likelihood of low dissolved oxygen (Massser, 1997). Currently, a range of cages is used in Taiwan.

1. Flexible frameless cage: the framework is made of Styrofoam buoys and connected to the net. The shape is maintained by the buoys, sinkers and anchors. Usually, the sizes are from 7m×7m×4m deep (196 m^3) to 10m×10m×5m deep (500 m^3).
2. Rigid steel net cage: the framework is made of stainless steel. Nets are tied to the framework of the cages. The size are usually 5m×5m×3m deep (75 m^3). The major purpose of this kind of cage is rearing fingerlings.
3. Wooden semi-rigid cage: the framework is made of wood and connected to a flexible net cage, the size is usually 7m×7m×4m deep (196 m^3). When the weather worsens, for example, in a typhoon, the framework is disassembled and hauled to the shore. In normal conditions, farmers can stand and work from the framework for feeding, changing nets and other manipulations.
4. PVC rigid cage: the framework is made of PVC pipe and connected to the net cage with buoys made of Styrofoam. Similar to rigid steel frame cage, the size is about 5m×5m×3m deep (75 m^3), and it is usually used for rearing fingerling.

5. Submersible cage: the framework is made of circular flexible plastic PVC. During a period of wave attack, this kind of cage can be submerged under the surface of water to reduce damage. A hose is attached to the ring of the cage framework, which when submerged, allows water to fill the framework and sink the cage. Later the cage can be raised up by feeding compressed air down the hose to empty the water from the framework. Originally, the brand named Hvalpsund net cage was imported from Denmark, though now, some factories in Taiwan can produce systems of this type. The size is 16m∅×8m deep (1600 m^3), and it can accommodate 16t of stock at 19 kg m^{-3}.

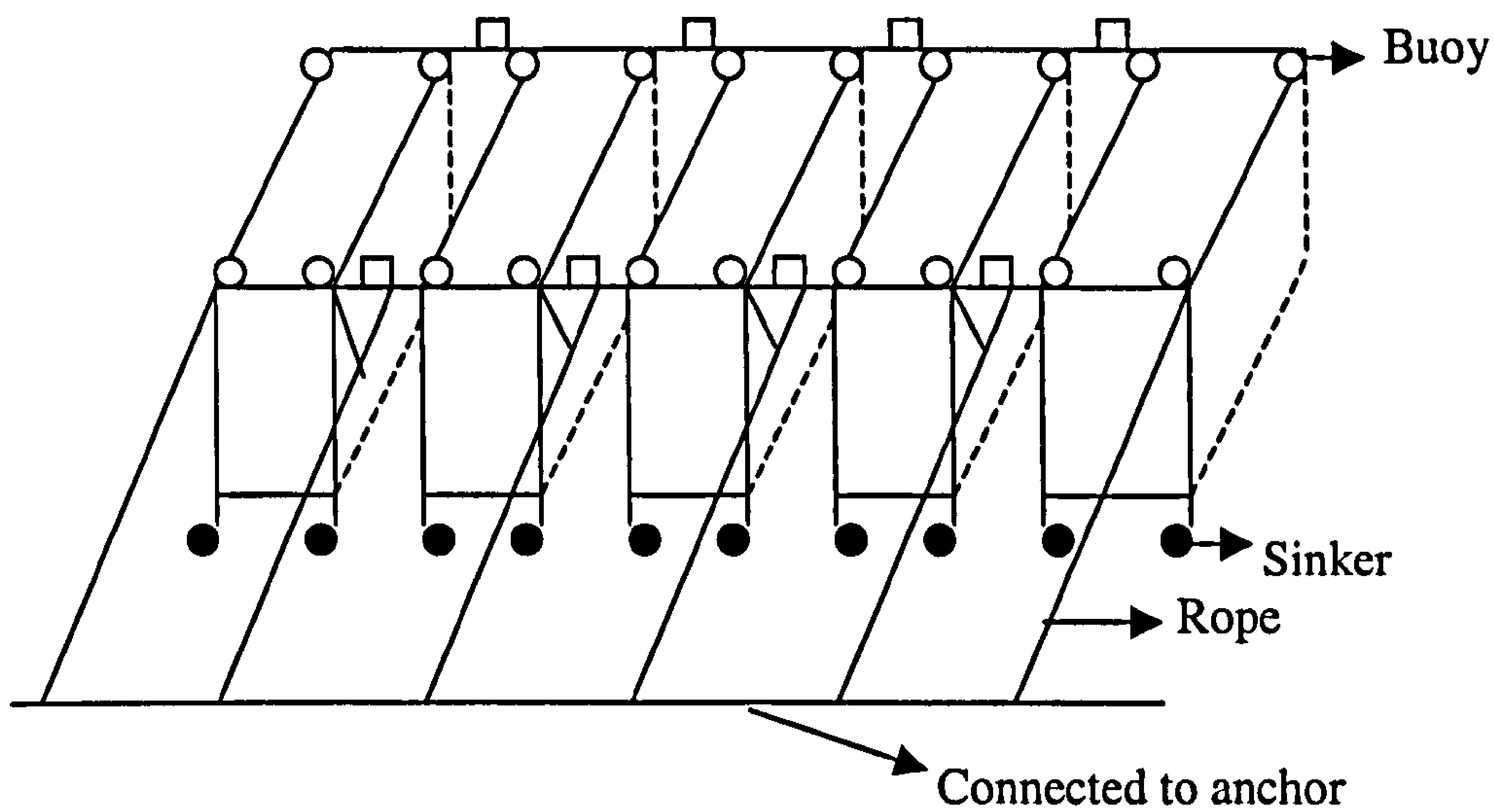


Fig 5.2 The traditional structure of cage in Taiwan.

Netting of different mesh size is used in the cages during the production phase, using a larger mesh as the fish get larger. Nets may also be replaced whenever there is extensive growth of algae. To do this, about two-thirds of the old net is disassembled from the framework, on to which is then mounted the new net. The remaining part of the new net is made to envelope the old one and the fish in the old net are emptied into the new one. After that the old net is removed and the new one is mounted completely. When the old nets have been removed, fish farmers use high pressure water jets to clean them.

Most fish farmers use flexible instead of rigid frames, which only use styrofoam buoys instead of a rigid framework, while the framework of cages is usually mounted when changing nets. During the typhoon period some fish farmers pound steel bars to the sea bottom to serve as a heavier sinker to which the net cage is mounted, with its top submerged to about 2m below the sea surface. It is said that the flexible and submerged net cages are more weather resistant.

5.3.2 Anchoring

Cages must be fixed in designated places by anchoring. Initially, 4 or 5 cages were connected together and the two ends of each group were each attached to a 70 kg steel anchor in 5-8m of water (Chen 1992). Some fish farmers used cement blocks or bags of gravel to replace the steel anchors. More recently, cement blocks of about 5-15 t have become the most widely used material for anchoring. After the blocks are placed into the water, the cages are connected using ropes or steel chains. If the water bottom type is sand, the anchor becomes embedded owing to the current flow. If the bottom type is rock, some farmers will use pins to anchor this system directly to the rock.

5.3.3 Net management

Biofouling, the growth of algae and other animals on the sides of the cage, is a common problem. In tropical inshore areas, nutrient-rich water accelerates marine biofouling, which will reduce mesh size and restrict the flow of water through cages, thus reducing the rate of DO supply and waste metabolite removal. Biofouling will also increase resistance to water flow and increase the force of the current on the cage structure and netting, thereby causing deformation of the bag; decreasing the cage volume for fish; reducing the useful life of the nets and potentially causing damage to the cage structure. Although there are other methods for coping with biofouling, for example, chemical or biological control agents, fouling resistant or rotating designs, fish farmers in Taiwan have used the most basic approach, exchanging nets and cleaning them with high pressure water jets. The frequency for exchanging nets depends on the weather and the species being reared. In the summer season the frequency of exchanging nets is higher than in the winter as biofouling is more rapid and as fish grew faster in higher temperatures and the feeding ratio is higher. The species which grow most rapidly, require more frequent net exchange. For example, in the summer season cages for rearing cobia (*Rachycentron canadus*) usually required a net exchange every 25 days where those for silver bream (*Sparus sarba*) need to be exchanged every 90 days (Chen, personal communication, 1999).

5.3.4 Feeding

Caged fish in most cases will receive no natural food and, therefore, must have nutritionally complete feeds. These feeds should have adequate protein and energy levels, balanced in amino acids and in essential fatty acids, and be supplemented with a complete array of vitamins and minerals. In Taiwan, feeds for cage aquaculture include trash fish and moist or dry formulated feed. Their use varies with species. Thus, groupers (*Epinephelus spp.*) are usually fed with trash fish and cobia with formulated feeds. During the winter season, with reduced feeding activity, feeding frequency and ration is also reduced. In the summer season, the typical feeding frequency for fingerling is 5-6 times per day and for harvestable fish is once per day. Hand feeding are also important, as from the behavior of fish in feeding, farmers can observe and understand their state of health.

5.4 Cultured species

Many species of fish are suitable for cage culture. Because capital and operating costs of cage culture are high in Taiwan, priority is given to farming of high value species to offset the high investment, particularly in the case of carnivorous fish which require high cost diet based on fishmeal. The major cage cultured species are extremely diversified and include cobia (*Rachycentron canadus*), red porgy (*Pagrus major*), silver bream (*Sparus sarba*), Spangled emperor (*Lethrinus nebulosus*), Dumerils's Amberjack (*Seriola dumerili*), Brown croaker (*Atrobucca nibe*), snappers (*Lutjanus spp.*), grouper (*Epinephelus spp.*) red drum (*Sciaenops ocellatus*) and others. The fingerling size of most of the species is about 3 cm except for cobia, which is about 9-10cm (Table 5.4). Among those species, cobia is the fastest growing and provides the best output per fry supply, growing up to 10 kg after 18 months.

In many areas of the world, fry and fingerling production is the main technical problem yet to be overcome. However, in Taiwan this issue is not serious, as almost all species for cage aquaculture can be artificially propagated. Taiwan's aquaculturists have sophisticated skills in propagation and most fry and seed for sea cage culture can be obtained from hatcheries (Liao 1995). According to the numbers and facilities of hatchery farms, the Taiwanese Fish Breeding Association estimated that the potential production of fingerling in Taiwan was far more than the current demand (Table 5.4).

Hatchery production seasons are shown in Table 5.5. The size at harvest, stocking density, and the culture period are shown in Table 5.6. The harvest sizes of most species are between 0.3-1 kg except for cobia and amberjack, which are 6-10 kg and 1.5-2 kg respectively. The stocking densities before harvest of most species are between 6-12 fish/m^3 except for cobia and amberjack, which are 2-5 (about and 3-4 fish/ m^3 respectively. The culture period of most species is about 1 to 1.5 years. Currently, cobia is the most widely produced fish in Pen-Hu and accounts for 38% of its total production, followed by red porgy, which accounts for 28% (Table 5.7). Amongst the species grown, cobia is considered as having the greatest potential in Taiwan, attaining a weight of 6-8 kg in one year with food conversion ratios ranging from 1.6 to 2 using dry pelleted food (Chang 2000). The survival rate of cobia can be as high as 90% and about 150 t of whole fish, at an average 6 kg, was exported to Japan in 1999 at a wholesale price of around US$ 4.48 to $ 5.70 kg^{-1} (Chen 2000).

Table 5.4 The size of fingerling, domestic demand, estimated production potential and average price of different species for cage culture in Taiwan.

Species	Size	Demand	Estimated potential	Average price (NT$)
Cobia (*Rachycentron canadus*)	9-10 cm	1,390,000	1,500,000	22
Red porgy (*Pagrus major*)	3 cm	200,000	1,500,000	6.5
Silver bream (*Sparus sarba*)	3 cm	4,400,000	10,000,000	3
Snapper (*Lutjanus spp.*)	3 cm	6,650,000	30,000,000	4.5
Grouper (*Epinephelus spp.*)	3 cm	4,450,000	18,000,000	18
Red drum (*Sciaenops ocellatus*)	3 cm	1,000,000	30,000,000	2.5

Data source: Fish Breeding Association*, 1999.

Table 5.5 The propagation season of different species for cage culture in Taiwan.

Species	Month											
	Jan.	Feb	Mar	Apr	May	Jun.	Jul.	Aug	Sep	Oct	Nov	Dec
Cobia (*Rachycentron canadus*)					----	----	----					
Red porgy (*Pagrus major*)	----	----									----	----
Silver bream (*Sparus sarba*)	----	----								----	----	----
Brown croaker (*Atrobucca nibe*)	----	----	----									
Grouper (*Epinephelus spp.*)			----	----	----	----	----	----	----	----	----	
Red drum (*Sciaenops ocellatus*)	----	----	----	----								
Spangled emperor (*Lethrinus nebulosus*)					----							

Data source: Fish Breeding Association, 1999.

Table 5.6 Size at harvest, stocking density and culture period of main fishes cultured in offshore cages in Taiwan.

Species	Size at harvest (kg)	stocking density before harvest (fish/m^3)	culture period (months)
Cobia (*Rachycentron canadus*)	6-10	2-5	12-18
Dumerils's Amberjack (*Seriola dumerili*)	1.5-2	3-4	12-14
Pink snapper (*Lutjanus erythropterus*)	0.6-1	6-12	10-12
Grey snapper (*L. argentimaculatus*)	0.4-0.6	6-10	10-12
White-spotted snapper (*L. stellatus*)	0.6-1	6-10	10-12
Grouper (*Epinephelus coioides*)	0.6	6-10	10-12
Pompano (*Trachinotus blochii*)	0.3-0.6	6-10	10-12
Red porgy (*Pagrus major*)	0.3-0.6	8-12	12-14

Source: Su et al., 1999.

* Fish Breeding Association did not mention how the demands and potentials were estimated.

Table 5.7 The production amount and percentage of cage aquaculture fish in Pen-Hu, 1997.

Fish species	amount Produced (tonnes/year)	Percentage (%)
Cobia (*Rachycentron canadus*)	660	38.0
Red porgy (*Pagrus major*)	483	28.0
Silver bream (*Sparus sarba*)	255	14.7
Spangled emperor (*Lethrinus nebulosus*)	118	6.8
Dumerils's Amberjack (*Seriola dumerili*)	97	5.6
Brown croaker (*Atrobucca nibe*)	44	2.5
Others	78	4.5
Total	1735	100

Data resource: statistical data of Peu-Hu government (1998).

5.5 Markets

5.5.1 Marketing channels

In the Pen-Hu area, most cage farmers sell their fishes through dual distribution channels, selling directly to consumers as well as through independent marketing intermediaries. Usually, farmers' wives or relatives will sell some fish directly to consumers at the retail market in Pen-Hu (aout 20%). The other fishes are sold to Taiwan Island by wholesalers. By contrast, cage farmers in Taiwan usually sell all their fishes to wholesalers, who also collect products from fish farmers and deliver them to auction markets. In auction markets, products were sold to retailers, who then sell to consumers in retail markets.

Some cage culture farmers (such as Fuw –Cheng Marine Biotec. Co. Ltd. in Pen-Hu) also try to sell their fishes to Japanese markets as materials for raw fish (sashimi). Farmers consider cobia is a good candidate species for the sashimi market in Japan and have tried to develop this. According to Tsai's (1999, personal communication) estimation, the marketing channel of cage culture could be summarized as shown in Fig. 5.3.

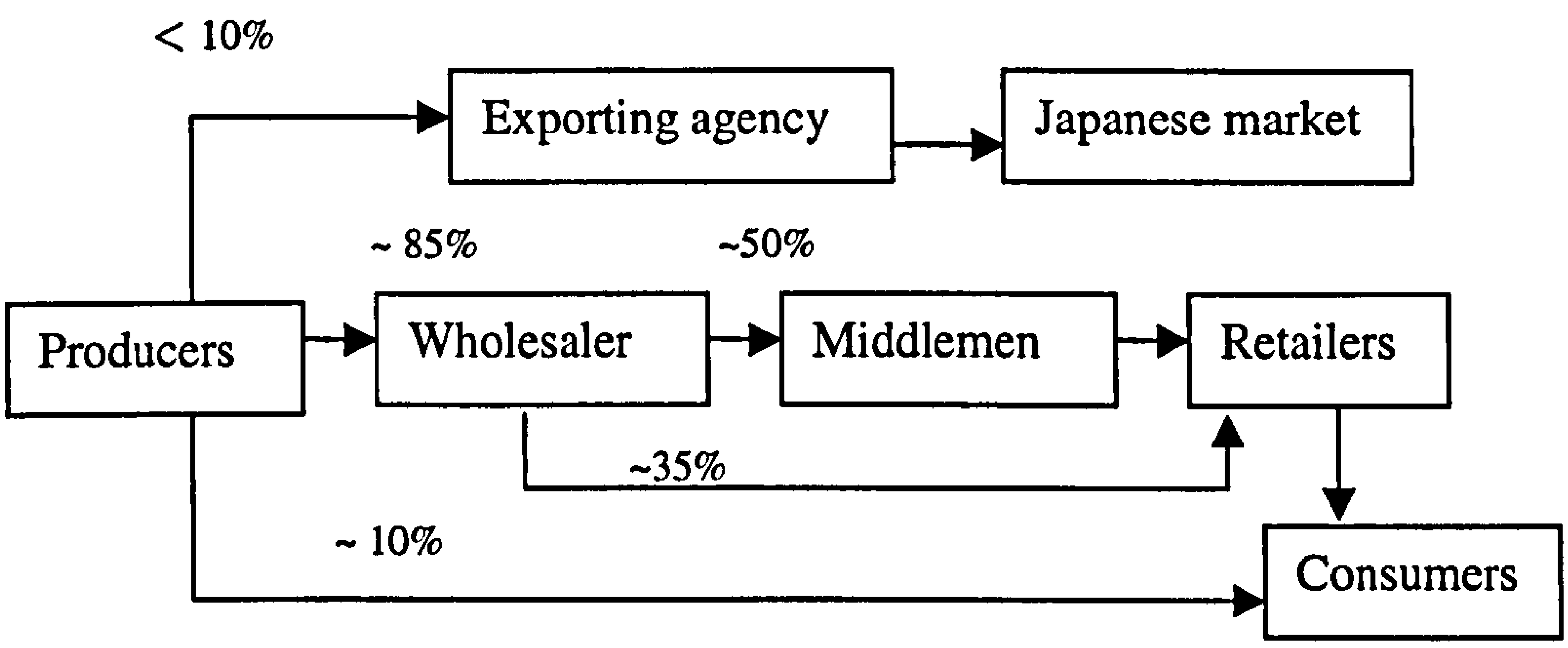


Fig 5.3 The marketing channels of products from cage aquaculture.

5.5.2 Market characteristics

In Taiwan, there is a market preference for live fish, which are transported in live-haul trucks. Usually, the weaker fish are separated and sold locally, or slaughtered for further markets, as they are not likely to survive long distance transportation, which may be more than 300 Km and take more than 3 hours.

Prior to transport, fish are starved for a day, or longer for larger fish, to reduce the contamination of water by excrement and to sedate the animal to make it less active. Often, fish are also sedated by gradually lowering the water temperature during transport, gradually raising it again to ambient when arriving at the destination.

Lowering the temperature has also been shown to improve the texture of the fish flesh (Subasinghe 1996).

5.6 Economic evaluation

5.6.1 Introduction

Because of the breakthrough of the technology in rearing larvae and the diversified demand of consumers, several fish species may be considered as candidates for marine cage aquaculture. Most of the candidates are high priced species, typically those sold to restaurants or retail markets directly and fetching premium prices. Among those candidates, the dominant species include red porgy (*Pagrus major*), silver bream (*Sparus sarba*), grouper (*Epinephelus fario*), Dumeril's amberjack (*Seriola dumerili*), the spangled emperor (*Lethrinus nebulosus*), and cobia (*Rachycentron canadus*) etc.

However, it must be recognized that the development of a commercially viable aquatic farming system requires much more research and development effort than the experimental raising of a few animals under controlled conditions. It was therefore considered logical to concentrate efforts on a smaller number of species and farming systems in order to have an adequate number of properly tested technologies for commercial application (Pillay, 1994).

In 1998, Wang and Huang analysed the cost structure of cage aquaculture in Taiwan. However, they did not compare profitability between these candidate species. The aim of this section is therefore to compare the costs and benefits of different cage aquaculture candidates.

For this purpose, 22 cage farmers were surveyed by questionnaire in 1999, 10 in Pen-Hu and 12 in Ping-Tong county. The average farm size is about 32.14 cages. The selection of samples is described in Chapter 2.

5.6.2 Cost analysis

The average cost of cage aquaculture can be categorised into two components: capital and operating cost. The capital costs comprise the costs of net, rope, buoys, anchoring, installation, raft, building, and outboard motor. The operating costs consist of variable costs (costs of fingerlings, feeds, labour, fuel and miscellaneous) and overheads (interest and depreciation).

In carrying out this exercise, three important assumptions have been made:

1) investment costs are covered by a loan at an annual interest rate of 8%;
2) facilities and equipment are subjected to straight line depreciation over their useful lifetime;
3) the useful lifetime of the net, ropes, buoys and anchoring is 10 years, while those of the building, boat and outboard motor are 30, 20 and 5years respectively.

Because spending on variable costs is spread throughout the culture period the interest is assumed to be charged on an average of 50%, as total expenditure on variable cost is not paid out at the beginning. However, interest is charged on 100% of the fixed cost (Christensen. 1993), as this is incurred at the outset of each period in operation.

To simplify the comparative analysis, cost were separated into those which were similar regardless of the species grown, and those, such as fingerlings and feeds, which differed with species. The average common costs of cage aquaculture across different species are shown in Table 5.8. The differential costs of fingerlings and feeds are separately specified in Table 5.10 and Table 5.11. Among the cage aquaculture species, the price of grouper fingerling is the highest, at 34.7 NT$ each, the average cost of fingerlings per farm is 3.40 million NT$ and the average cost per kg produced is 46.7 NT$ (Table 5.9). Next to grouper is Dumerils's Amberjack, whose fingerling price is 34.6 NT$, average cost of fingerlings per farm is 2.88 million NT$ and the average cost per kg produced is 29.6 NT$. The average costs of feeds for different species are listed in Table 5.11.The highest is cobia, at 5.2 million NT$ per farm, followed by silver bream, at 5.03 million NT$. The highest average cost of feeds for producing 1kg fish is silver bream, at 57.9 NT$, followed by grouper, at 56.0 NT$. The average survival rate and feed conversion ratios of different species are shown on Table 5.9.

Operating costs are shown in the Table 5.12, which shows that the major costs are feed, fingerling and labour. Apart from grouper and Dumerils's Amberjack, which have higher fingerling costs, ratios of feed to total operating cost are more than 50%. Next to feed, fingerling is the second highest cost, for grouper and Dumerils's Amberjack at 33.0 and 26.8% of total, respectively. Ratios for others range from 12.43 to 14.49%. The third highest cost is labour, at 12.2 to 16.1% of total operating cost.

Table 5.8 Fixed and variable cost structure (exclude feed and fingering) per farm for cage aquaculture in Taiwan. Unit: thousand NT$

Items	Total cost	Annual depreciation
Capital cost		
Net	2016.6	201.7
Rope	390.1	39.0
Buoy	317.6	31.8
Anchoring	250.0	25.0
Install	387.9	38.8
Building (including feed storage, office fridge etc.)	564.6	18.8
Boat	295.2	14.8
Engine of outside boat	124.5	24.9
Total capital cost	4346.5	
Operating cost		
Labour	1316.1	
Fuel	202.2	
Interest of fixed cost	347.7	
Subtotal of variable cost	1866	
Depreciation	394.8	
Miscellaneous	197.6	
Subtotal of overhead	592.4	
Total operating cost	2458.4	

Table 5.9 The average survival rate and feed conversion ratio (FCR) of different species.

Fish species	Survival rate	FCR
Cobia	48.9	2.0
Red porgy	41.7	1.7
Silver bream	57.5	1.9
Spangled emperor	48.6	2.0
Dumerils's Amberjack	51.2	2.1
Grouper	55.7	2.3

Data source: Wang and Huang (1998).

Table 5.10 The average cost of different species of fingerlings for cage aquaculture per year.

Fish species	Average price of fingerlings (NT$)	Average density (fingerlings/ cage)	Average cost/cage (NT$)	Average cost/farm (Million NT$)	Average cost/kg produced (NT$)
Cobia	18.9	2,083	39,446	1.27	11.9
Red porgy	6.4	5,274	33,640	1.08	9.4
Silver bream	3.6	10,018	35,779	1.15	13.2
Spangled emperor	8.1	4,533	36,805	1.18	13.7
Dumerils's Amberjack	34.6	2,588	89,598	2.88	29.6
Grouper	34.7	3,047	105,744	3.40	46.7

Table5.11 The average cost of feed for different species of cage aquaculture per year.

Fish species	Average price of feed (NT$/kg)	Average amount of feed (kg/cage)	Average cost of feed (NT$/cage)	Average cost of feed (Million NT$/farm	Average cost /kg produced (NT$)
Cobia	24. 7	6614.9	162,775	5.23	49.2
Red porgy	24.1	6254.0	150,602	4.84	41.9
Silver bream	30.2	5198.1	156,639	5.03	57.9
Spangled emperor	25.1	5235.0	131,287	4.22	48.9
Dumerils's Amberjack	25.1	6243.5	156,236	5.02	51.5
Grouper	24.5	5182.1	126,760	4.07	56.0

Table 5.12 The cost structure of the average operating cost of production of cage aquaculture in Taiwan. Unit: thousand NT$

	Cobia	Red porgy	Silver bream	Spangled emperor	Dumerils's Amberjack	Grouper
Variable cost						
Fingerling	1267.9 (13.6)	1081.3 (12.4)	1150.0 (12.8)	1183.0 (14.5)	2879.9 (26.8)	3398.9 (33.0)
Feed	5232.1 (56.2)	4840.8 (55.6)	5034.8 (56.1)	4219.9 (51.7)	5021.9 (46.7)	4074.4 (39.5)
Labour	1316.1 (14.2)	1316.1 (15.1)	1316.1 (14.7)	1316.1 (16.1)	1316.1 (12.2)	1316.1 (12.8)
Fuel	202.2 (2.2)	202.2 (2.3)	202.2 (2.3)	202.2 (2.3)	202.2 (1.9)	202.2 (2.0)
Miscellaneous	197.6 (2.1)	197.6 (2.3)	197.6 (2.2)	197.6 (2.4)	197.6 (1.8)	197.6 (1.9)
Subtotal	8,215.9 (88.3)	7,638 (87.7)	7,900.7 (88.1)	7,118.8 (87.0)	9,617.7 (89.4)	9,189.2 (89.2)
Overhead costs						
Depreciation	394.8 (4.2)	394.8 (4.5)	394.8 (4.4)	394.8 (4.8)	394.8 (3.7)	394.8 (3.8)
Interest on fixed costs	347.7 (3.7)	347.7 (4.0)	347.7 (3.9)	347.7 (4.3)	347.7 (3.2)	347.7 (3.4)
Interest on variable costs	344.4 (3.7)	321.3 (3.7)	331.8 (3.7)	300.5 (3.7)	400.5 (3.7)	383.4 (3.7)
Subtotal	1086.9 (11.6)	1063.8 (12.2)	1074.3 (12.0)	1043 (12.8)	1143 (10.6)	1125.9 (10.9)
Total	9,302.8	8,701.8	8,975	8,161.8	10,760.7	10,315.1

Figures in brackets are percentages of total.

The average costs for producing 1 kg of products are shown in Table 5.13. This table shows that grouper has the highest cost per kg at 141.8 NT$ (4.4 US$), followed by Dumerils's Amberjack and silver bream at 110.5 and 103.1 NT$, respectively. The lowest is red porgy, at 75.3 NT$. The costs for producing 1kg of product were 87.5, 75.3, 103.1, 94.6, 110.5 and 141.8 NT$/kg, the highest and lowest cost ranged from 78.2-95.1, 65.6-83.5, 93.2-110.8, 86.4-109.7, 98.6-119.3 and 129-149.2 NT$/kg in the species of cobia, red porgy, silver bream, spangled emperor, Dumerils's Amberjack and grouper, respectively. The key contributory factors in the cost for producing 1 kg of products were feed, fingerling and labour.

The cost of feed for producing 1kg of product were 49.2, 41.9, 57.9, 48.9, 51.5 and 52.0 NT$/kg, the highest and lowest cost of feed ranged from 46.7-53.1, 37.1-43.6, 54.2-60.8, 46.9-49.7, 48.9-53.7 and 54.8-57.4 NT$/kg in the species of cobia, red porgy, silver bream, spangled emperor, Dumerils's Amberjack and grouper, respectively.

The cost of fingerling for producing 1kg of product were 11.9, 9.4, 13.2, 13.7, 29.6 and 46.7 NT$/kg, the highest and lowest cost of fingerling ranged from 7.8-14.2, 7.9-13.2, 9.7-15.1, 10.2-15.6, 23.1-34.5 and 42.3-49.2 NT$/kg in the species of cobia, red porgy, silver bream, spangled emperor, Dumerils's Amberjack and grouper, respectively.

The cost of labour for producing 1kg of product were 12.4, 11.4, 15.1, 15.3, 13.5 and 18.1 NT$/kg, the highest and lowest cost of labour ranged from 9.7-14.5, 8.6-13.6, 12.1-18.3, 12.1-18.4, 11.8-15.8 and 15.8-21.3 NT$/kg in the species of cobia, red porgy, silver bream, spangled emperor, Dumerils's Amberjack and grouper, respectively.

Better FCR, higher survival rate and lower cost of labour are important in reducing cost. Therefore, better management, bigger farm to reduce the labour cost by economies of scale might be important in reducing production cost.

Table 5.13 The cost structure of the average operating cost for producing 1 kg of cage aquaculture products in Taiwan. Unit: NT$

	Cobia	Red porgy	Silver bream	Spangled emperor	Dumerils's Amberjack	Grouper
Variable cost						
Fingerling	11.9 (7.8-14.2)	9.4 (7.9-13.2)	13.2 (9.7-15.1)	13.7 (10.2-15.6)	29.6 (23.1-34.5)	46.7 (42.3-49.2)
Feed	49.2 (46.7-53.1)	41.9 (37.1-43.6)	57.9 (54.2-60.8)	48.9 (46.9-49.7)	51.5 (48.9-53.7)	56.0 (54.8-57.4)
Labour	12.4 (9.7-14.5)	11.4 (8.6-13.6)	15.1 (12.1-18.3)	15.3 (12.1-18.4)	13.5 (11.8-15.8)	18. 1 (15.8-21.3)
Fuel	1.9 (1.5-2.3)	1.8 (1.5-2.2)	2.3 (1.9-2.6)	2.3 (2.0-2.6)	2.1 (1.6-2.4)	2.8 (2.4-3.2)
Miscellaneous	1.9 (1.6-2.3)	1.7 (1.4-2.1)	2.3 (2.1-2.6)	2.3 (2.0-2.6)	2.0 (1.8-2.2)	2.7 (2.4-3.0)
Subtotal	77.3	66.2	90.8	82.5	98.7	108.2
Overhead costs						
Depreciation	3.7 (3.2-4.6)	3.4 (3.1-3.8)	4.5 (4.1-4.9)	4.6 (4.3-4.9)	4.1 (3.7-4.4)	5.4 (5.1-5.7)
Interest on fixed cost	3.3 (3.0-3.5)	3.0 (2.8-3.3)	4.0 (3.6-4.3)	4.0 (3.7-4.2)	3.6 (3.3-3.9)	4.8 (4.4-5.1)
Interest on variable cost	3.2 (2.9-3.6)	2.8 (2.4-3.2)	3.8 (3.4-4.1)	3.5 (3.2-3.8)	4.1 (3.7-4.4)	5.3 (4.8-5.6)
Subtotal	10.2	9.2	12.3	12.1	11.8	15.5
Total	87.5 (78.2-95.1)	75.3 (65.6-83.5)	103.1 (93.2-110.8)	94.6 (86.4-109.7)	110.5 (98.6-119.3)	141.8 (129-149.2)

Figures in parentheses are the range of highest and lowest cost.

5.6.3 Benefit analysis

The profit (P) is equal to the revenue (MI) minus production cost (C). Profitability can be estimated by the benefit-cost ratio (BCR) and the income ratio (IR)(Chen 1994).

The respective formulas are as follows:

$$BCR=P/C$$

$$IR=P/MI$$

Where P = Profit

C = Production cost

MI = Revenue

If the values of BCR and IR are specifically high compared with other options, it indicates the operation is economically sound and further development is feasible.

Revenues depend on market prices, which may differ widely from place to place. Usually, the same species can fetch higher price in Pen-Hu than elsewhere in Taiwan, as people in Pen-Hu traditionally like to eat fish and are willing to pay higher prices. As Table5.14 shows, the highest revenue per farm unit of 97.42 tonnes annual production is attained from Dumerils's Amberjack, with an average annual revenue of 29.23 million NT$ (820,000 US$) after which is red porgy, with an average profit of 23.11 million NT$ (722,000 US$). The lowest revenue is seen with grouper, at only 16.73million NT$ (523,000 US$). Regarding average profit, benefit-cost ratio and income ratio, Dumerils's Amberjack also offers the best performance, at 18.47 million NT$, 1.72 and 0.63 respectively, following which is red porgy, with an average profit, benefit-cost ratio and income ratio of 14.40 million NT$, 1.66 and 0.62 (Table 5.15).

Table 5.14 The average cost of production, amount of production, price, revenue and benefit for different cage aquaculture species.

Fish species	Average cost of production (Million NT$/farm)	Average amount of production (tonnes /farm)	Product-ion cost (NT$/kg)	Average price of fish (NT$/kg)	Average revenue (Million NT$/farm)
Cobia	9.30	106.31	87.5	160	17.01
Red porgy	8.70	115.53	75.3	200	23.11
Silver bream	8.98	87.02	103.1	220	19.14
Spangled emperor	8.16	86.29	94.6	200	17.26
Dumerils's Amberjack	10.76	97.42	110.5	300	29.22
Grouper	10.32	72.74	141.8	230	16.73

Table 5.15 The average profit, benefit cost ratio and income ratio of different cage aquaculture species. Unit: Million NT$

Fish species	Average profit/ farm	BCR	IR
Cobia	7.71	0.83	0.45
Red porgy	14.40	1.66	0.62
Silver bream	10.17	1.1	0.53
Spangled emperor	9.10	1.1	0.53
Dumerils's Amberjack	18.47	1.72	0.63
Grouper	6.41	0.62	0.38

The ranges of highest and lowest profit shows that Dumerils's Amberjack had the highest profit at 19.6-17.6. million NT$ (Table 5.16). However, cobia might have higher profit than Spangled emperor and grouper might have higher profit than cobia when there is a better performance. Better FCR, higher survival rate and lower cost of labour are the important factors to increase profit.

Table 5.16 The range of profit, benefit cost ratio and income ratio of different cage aquaculture species. Unit: Million NT$

Fish species	Profit		BCR		IR	
	Highest	Lowest	Highest	Lowest	Highest	Lowest
Cobia	8.70	6.90	1.05	0.68	0.51	0.41
Red porgy	15.53	13.46	2.05	1.40	0.67	0.58
Silver bream	11.03	9.50	1.36	0.99	0.58	0.50
Spangled emperor	9.80	7.79	1.32	0.82	0.57	0.45
Dumerils's Amberjack	19.61	17.60	2.04	1.51	0.67	0.60
Grouper	7.35	5.88	0.78	0.54	0.44	0.35

5.6.4 Cash-flow and discounted financial indicators

The pattern of cash flow includes capital cost, operating cost (excluding interest and depreciation) and revenue. A 5-year nominal and a discounted cash flow analysis (at 10% discount rate) of cage culture farm reveal that investment in Dumerils's Amberjack can obtain the highest NPV at 67921.6 thousand NT$, followed by red porgy at 52662.2 thousand NT$ (Table 5.17 and Table 5.18). The lowest NPV is seen with grouper at 23446.6 thousand NT$.

Table 5.17 Nominal cash-flow projection for cage culture.

Unit: Thousand NT$

	Year0	Year1	Year2	Year3	Year4	Year5
Cash flow						
Capital cost						
Cobia	4346.5	0	0	0	0	0
Red porgy	4346.5	0	0	0	0	0
Silver bream	4346.5	0	0	0	0	0
Spangled emperor	4346.5	0	0	0	0	0
Dumerils's Amberjack	4346.5	0	0	0	0	0
Grouper	4346.5	0	0	0	0	0
Operating cost						
Cobia		8215.9	8215.9	8215.9	8215.9	8215.9
Red porgy		7638.0	7638.0	7638.0	7638.0	7638.0
Silver bream		7900.7	7900.7	7900.7	7900.7	7900.7
Spangled emperor		7118.8	7118.8	7118.8	7118.8	7118.8
Dumerils's Amberjack		9617.7	9617.7	9617.7	9617.7	9617.7
Grouper		9189.2	9189.2	9189.2	9189.2	9189.2
Revenue						
Cobia		17009.6	17009.6	17009.6	17009.6	17009.6
Red porgy		23106.0	23106.0	23106.0	23106.0	23106.0
Silver bream		19144.4	19144.4	19144.4	19144.4	19144.4
Spangled emperor		17258.0	17258.0	17258.0	17258.0	17258.0
Dumerils's Amberjack		29226.0	29226.0	29226.0	29226.0	29226.0
Grouper		16730.2	16730.2	16730.2	16730.2	16730.2
Net cash flow						
Cobia	-4346.5	8793.7	8793.7	8793.7	8793.7	8793.7
Red porgy	-4346.5	15468.0	15468.0	15468.0	15468.0	15468.0
Silver bream	-4346.5	11243.7	11243.7	11243.7	11243.7	11243.7
Spangled emperor	-4346.5	10139.2	10139.2	10139.2	10139.2	10139.2
Dumerils's Amberjack	-4346.5	19608.3	19608.3	19608.3	19608.3	19608.3
Grouper	-4346.5	7541.0	7541.0	7541.0	7541.0	7541.0

Table 5.18 Discounted cash-flow projection for cage culture.
The discount rate for NPV is 10%. Unit: Thousand NT$

	Year0	Year1	Year2	Year3	Year4	Year5
Cash outflow						
Cobia	4346.5	7394.3	6654.9	5989.4	5390.5	4851.4
Red porgy	4346.5	6874.2	6186.8	5568.1	5011.3	4510.2
Silver bream	4346.5	7110.6	6399.6	5759.6	5183.6	4665.3
Spangled emperor	4346.5	6406.9	5766.2	5189.6	4670.6	4203.6
Dumerils's Amberjack	4346.5	8655.9	7790.3	7011.3	6310.2	5679.2
Grouper	4346.5	8270.3	7443.3	6698.9	6029.0	5426.1
Revenue						
Cobia	0	15308.6	13777.8	12400.0	11160.0	10044.0
Red porgy	0	20795.4	18715.9	16844.3	15159.9	13643.9
Silver bream	0	17230.0	15507.0	13956.3	12560.6	11304.6
Spangled emperor	0	15532.2	13979.0	12581.1	11323.0	10190.7
Dumerils's Amberjack	0	26303.4	23673.1	21305.8	19175.2	17257.7
Grouper	0	15057.2	13551.5	12196.3	10976.7	9879.0
Net cash flow						
Cobia	-4346.5	7914.3	7122.9	6410.6	5769.5	5192.6
Red porgy	-4346.5	13921.2	12529.1	11276.2	10148.6	9133.7
Silver bream	-4346.5	10119.3	9107.4	8196.7	7377.0	6639.3
Spangled emperor	-4346.5	9125.3	8212.8	7391.5	6652.3	5987.1
Dumerils's Amberjack	-4346.5	17647.5	15882.7	14294.5	12865.0	11578.5
Grouper	-4346.5	6786.9	6108.2	5497.4	4947.7	4452.9
NPV						
Cobia	28063.4					
Red porgy	52662.2					
Silver bream	37093.2					
Spangled emperor	33022.5					
Dumerils's Amberjack	67921.6					
Grouper	23446.6					

5.6.5 Sensitivity

Overall profitability is clearly sensitive to relatively small changes in values of certain costs and selling price. Here, market prices of fishes, feed and fingerling prices, and survival rates were used to test the sensitivity of profit.

The break even price of cobia, red porgy, silver bream, spangled emperor, Dumerils's Amberjack and grouper were 87.5, 75.3, 103.1, 94.6, 110.5 and 141.8 NT$/kg, accounting for 54.7, 37.7, 46.9, 47.3, 36.8 and 61.7% of the current market prices, respectively. The species with the highest profit sensitivity to market prices is grouper, where profit increased 131% when market price increased 50%. This was followed by cobia, profit from which increased by 110% when market price increased 50%. The lowest candidate is Dumerils's Amberjack, where profit increased 79% when market price increased 50%. When prices decreased 50%, the profits of grouper and cobia became negative (Table 5.19).

Table 5.19 Sensitivity of profitability in changing market price of products.

Unit: Million NT$

	Increase 50%		Increase 25%		Decrease 25%		Decrease 50%	
	Profit	BCR	Profit	BCR	Profit	BCR	Profit	BCR
Cobia	16.21 (110)	1.74	11.96 (55)	1.29	3.45 (-55)	0.37	-0.80 (-110)	-0.09
Red porgy	25.96 (80)	2.98	20.18 (40)	2.32	8.63 (-40)	0.99	2.85 (-80)	0.33
Silver bream	19.74 (94)	2.20	14.96 (47)	1.67	5.38 (-47)	0.60	0.60 (-94)	0.07
Spangled emperor	17.73 (95)	2.17	13.41 (47)	1.64	4.78 (-47)	0.59	0.47 (-95)	0.06
Dumerils's Amberjack	33.08 (79)	3.07	25.77 (40)	2.39	11.16 (-40)	1.04	3.85 (-79)	0.36
Grouper	14.78 (131)	1.43	10.60 (63)	1.03	2.23 (-63)	0.22	-1.95 (-131)	-0.19

The figures in parentheses are the percentages of increased profit.

The highest sensitivity of profits to feed prices is shown with cobia, where profit increased by 33.9% when feeds prices decreased by 50%, followed by grouper, where profit increased by 31.8% when feed prices decreased by 50%. The lowest is Dumerils's Amberjack, where profit increased by 13.5% when feed prices decreased by 50% (Table 5.20).

Table 5.20 Sensitivity of profitability in changing feed prices.

Unit: Million NT$

	Increase 50%		Increase 25%		Decrease 25%		Decrease 50%	
	Profit	BCR	Profit	BCR	Profit	BCR	Profit	BCR
Cobia	5.07 (-32.2)	0.42	6.38 (-17.3)	0.60	9.00 (16.7)	1.12	10.32 (33.9)	1.54
Red porgy	11.96 (-16.9)	1.07	13.18 (-8.5)	1.33	15.60 (8.3)	2.08	16.82 (16.8)	2.67
Silver bream	7.63 (-25.0)	0.66	8.89 (-12.6)	0.87	11.42 (12.3)	1.48	12.68 (24.7)	1.96
Spangled emperor	6.97 (-23.4)	0.68	8.03 (-11.8)	0.87	10.14 (11.4)	1.43	11.20 (23.1)	1.85
Dumerils's Amberjack	15.93 (-13.8)	1.20	17.19 (-6.9)	1.43	19.71 (6.7)	2.07	20.97 (13.5)	2.54
Grouper	4.36 (-32.0)	0.35	5.38 (-16.1)	0.47	7.43 (15.9)	0.80	8.45 (31.8)	1.02

The figures in parentheses are the percentages of increased profit.

The highest sensitivity of profits to fingerling prices occurs with grouper, where profit increased 26.5% when fingerling prices decreased 50%, followed by cobia, where profit increased 8.3% when fingerling prices decreased 50%. The lowest is red porgy, where profit increased 3.8% when feed prices decreased 50% (Table 5.21).

Table 5.21 Sensitivity of profitability to changing price of fingerling.

Unit: Million NT$

	Increase 50%		Increase 25%		Decrease 25%		Decrease 50%	
	Profit	BCR	Profit	BCR	Profit	BCR	Profit	BCR
Cobia	7.07 (-8.3)	0.71	7.39 (-4.2)	0.77	8.02 (4.2)	0.89	8.34 (8.3)	0.96
Red porgy	13.86 (-3.8)	1.50	14.13 (-1.9)	1.58	14.67 (1.9)	1.74	14.94 (3.8)	1.83
Silver bream	9.59 (-5.7)	1.00	9.88 (-2.9)	1.07	10.46 (2.9)	1.20	10.74 (5.7)	1.285
Spangled emperor	8.50 (-6.6)	0.97	8.80 (-3.3)	1.04	9.39 (3.3)	1.19	9.69 (6.6)	1.28
Dumerils's Amberjack	17.03 (-7.8)	1.40	17.75 (-3.9)	1.55	19.19 (3.9)	1.91	19.91 (7.8)	2.14
Grouper	4.72 (-26.4)	0.39	5.56 (-13.3)	0.50	7.26 (13.3)	0.77	8.11 (26.5)	0.94

The figures in parentheses are the percentages of increased profit.

Different species have different average survival rate (Table 5.9). The highest sensitivity of profits to increasing survival rates is grouper, where profit increased 98.6% when survival rate increased 50 %, followed by cobia, where profit increased 76.4% when survival rate increased 50%. The lowest is red porgy, where profit increased 63.4% when survival rate increased 50%. (Table 5.22).

Table 5.22 Sensitivity of profitability in different survival rates.

Unit: Million NT$

	Increase 50%		Increase 25%		Decrease 25%		Decrease 50%	
	Profit	BCR	Profit	BCR	Profit	BCR	Profit	BCR
Cobia	13.60 (76.4)	1.14	10.65 (38.2)	1.00	4.76 (-38.2)	0.60	1.82 (-76.4)	0.27
Red porgy	23.54 (63.4)	2.12	18.97 (31.7)	1.91	9.84 (-31.7)	1.31	5.27 (-63.4)	0.84
Silver bream	17.22 (69.4)	1.50	13.70 (34.7)	1.34	6.64 (-34.7)	0.86	3.11 (-69.4)	0.48
Spangled emperor	15.62 (71.7)	1.52	12.36 (35.8)	1.34	5.84 (-35.8)	0.82	2.58 (-71.7)	0.43
Dumerils's Amberjack	30.57 (65.5)	2.30	24.52 (32.8)	2.04	12.41 (-32.8)	1.30	6.36 (-65.5)	0.77
Grouper	12.74 (98.6)	1.03	9.58 (49.3)	0.85	3.25 (-49.3)	0.35	0.87 (-98.6)	0.01

The figures in parentheses are the percentages of increased profit.

5.7 Constraints

5.7.1 Environment

Because there are strong currents, such as the Kuroshio, and typhoons on the eastern coast of Taiwan, major sites for cage aquaculture have been limited to the western coast. However, this coast still suffers serious damage from typhoons and monsoons and this has hampered development (Beveridge 1996). Apart from the southern coast, every coast of Taiwan suffers from monsoon waves continuously during the winter (Twu et al 1986), during which season, significant wave heights are estimated to be

3m on average, with periods of around 10 seconds. Taiwan is also prone to large storms during the annual typhoon season, which are particularly acute on the coastal fringe. In summer and autumn, almost all coasts are subject to the threat of typhoon-generated waves, and immense waves exceeding 10 m have occurred quite often. In 1998, typhoon Zeb damaged a number of cage units in Taiwan, including breakage of anchor ropes, broken nets, deformed and destroyed cage frames, fish escaping from nets, and mortality due to overcrowding and friction induced by deformation of the nets. Usually, the typical losses from typhoon are the damage of cage and fish die because of friction. Whole cages were broken and all the fish escaped are not common. Almost every year typhoon will attack Taiwan. However, the level of damage from typhoon depends on the frequency and strength of typhoon, and the prevention that farmers did.

5.7.2 Diseases

Cage culture is one of the most intensive forms of aquaculture, and as a consequence fish diseases can be problematic. Most diseases affecting cage aquaculture a are epizootics, including Benedeniasis (*Benedenia spp.*), sea lice (*Caligus spp.*), Dactylogyrus (*Dactylogyrus spp*), Ichthyophthirius (*Ichthyophthirius spp.*), Trichodina (*Tricodina spp.*), Myxospora (*Myxosporidia spp.*) and Epistylis (*Vorticella spp*) and ulcer on the skin of groupers. Among these, Benedeniasis, the ulcer on the skin of groupers and sea lice are the most serious, potentially causing serious mortality to the extent of only 20% survival rate and increasing the cost in feed, fry and labour.

Although Benedenia and sea lice can be cured by freshwater baths, they are not particularly effective for sea lice, and this also depends on the tolerance of stock to fresh water. Cage fish farmers usually dip fishes in freshwater for less than 10 minutes every 10-12 days. The fish can tolerate a fresh water bath for 10minute but *Benedenia spp* can only tolerate this for 3 minutes (Chen, personal communication, 1999). However, this work is tedious and laborious. Benedeniasis infections usually occur in the spring and autumn season, during the months of October, November, February, March and April. Skin ulcer of groupers happens throughout the whole year, though autumn and winter are the most serious seasons. It is postulated that this disease is caused by bacteria and occurs most often after the transportation of small fish or after infection by parasites. Small fish that cannot stand strong currents will rub against cage nets and induce secondary bacterial infection. Sea lice infections happen the whole year round though the most serious period is summer. During the rainy period when the salinity is lower and turbidity is higher, sea lice infections become less serious.

5.7.3 Management

According to Wang et al (1998) and this investigation, the major costs of production are feeds (about 50%), fingerlings (about 20%) and labour (about 15%). Because of high feed cost, it is difficult to lower the price of cage aquaculture products, and therefore, the market size may be limited. If cheaper formulated feeds can be developed, this may greatly increase the potential for development. Having personnel on hand to make frequent inspections for sign of the fatigue of structures and nets to ensure that the cultivars are performing properly will help operators to avoid catastrophic loss. However, this requires higher expenditure in the cost of labour. For example, to prevent the mortality from Benedeniasis, farmers need to spend plenty of time in fresh water bath, which is crucial in management. In Taiwan, most farms are run by families with limited additional staffing, and they did not spend so much money in labour. As a result a number of serious losses have occurred. A better management can improve the survival rate to 70%.

5.8 Discussion

The success of a cage aquaculture farming facility depends on the combination and fine tuning of cages, nets, and moorings utilized in response to the local site-conditions (Lisac .1996). Masser (2000) points out that the superior characteristics of candidates for aquaculture include marketability, ease of breeding, rapid growth, tolerance of poor water quality, disease resistance, tolerance of crowding and handling, ease of harvest, easy to feeding formulated diets and omnivore. A number of specific changes may be considered to improve opportunities for development:

(a) Improvement of the cage structure for poor weather conditions

The expansion of cage aquaculture is restricted by the specific environmental conditions. Constant stress from waves and currents, with intermittent exposure to storms that greatly increase stress levels and result in rapid fatigue of structures and nets, requiring the use of stronger materials and advanced engineering. In addition, currents can cause deformation of net pens, which may reduce productive capacity For example, submersible cages could be less impacted by waves, permit avoidance of surface storms without relocating the system, and be less susceptible to biofouling and corrosion than their floating counterparts.

(b) Feed improvement

Feed is the main cost of cage culture, and technical problems in feed manufacture are critical in its development. Currently, fish farmers use trash fish or formulated diets to feed fish and the protein content of the formulated diets is as high as 40%. Reduction of the protein content would lower the cost of feed and potentially widen the range of raw materials but there is still insufficient research.

(c) Industrialise production system

In Norway, the average annual production of cage aquaculture salmon reached 350 t per FTE* person employed (Taiwan Fisheries Bureau, 1997). In contrast, the average annual production in cage aquaculture in Taiwan is only about 30 t per FTE person employed. Thus, while this is partly a function of high labor cost in Norway, modernisation of the production system could increase competitive ability and reduce production cost. For example, feeding is still manual from a raft, when it is now possible to use an automatic feed delivery system which also improves feeding efficiency. The development of innovative technology to allow appropriate levels of feeding, long distance monitoring and communication, and carefully planned responses to emergency situations are important. Craft or barges designed for efficient servicing of the cages, harvesting fish and dealing with routine tasks associated with the operation of cage farming should also be investigated. However, all of these must demonstrate their potential for cost effective performance with the wider range of species involved in this sector.

* Full time equivalent

(d) Marketing promotion

Marketing is one of the main problems in developing cage aquaculture, and the development and promotion of markets in Taiwan, Japan, China and other countries is a critical issue. If the target market is for restaurants, the preferred size is usually 1-2 kg. Grouper is suitable to promote for this market because of its harvesting size. Bigger fish, such as cobia, which is harvested at 7-8 kg, may be promoted for the raw fish and fillet market. To profit from aquaculture, adequate information about potential markets is required, including domestic and foreign production, exports and imports, product forms (such as live, fresh, frozen, fillet etc.), and processing and distribution cost.

Cage culture may release some pressure on the demand for land and water. Sea cage culture could also avoid impacting the more environmentally sensitive coastal zone and there might be some benefit in term of improved product quality (Stickney 1997). In Taiwan, the development of sea cage aquaculture has some potential, as it is surrounded by open ocean, there are many candidate species for sea cage culture, and farmers have experience in other sectors of aquaculture. Technology from Norway is being imported, and government considers cage culture to be an important step in the future development of aquaculture.

It is common that the cage farmers in Taiwan rear two, three, or even more, species to reduce the risks in monoculture, aiming for both more species and more markets. Diversified farms can cope better with market and climate fluctuation as they can contribute to a smoother harvesting pattern, and consequently cash flow, throughout the year. Capacity can also be utilized more evenly. As overhead costs would be higher for sea cage aquaculture and there would be a limited coastal environment of suitable quality (depth, current, and water quality etc.,) the production of luxury species, rather than high volume, low value ones, would undoubtedly be given highest priority.

The establishment of a licensing or permit process could provide orderly development of the industry, and a sound legislative and leasing program is imperative. The legal rights for cage culture were described in 5.22. However, the following features are likely to be important.

1. Both the seabed and the water column should be included in the lease. It can avoid the conflicts between farmers and other activities, such as diving and fishing.
2. The period of leasing should be long enough for farmers (e.g. longer than pay back period, it needs at least 2 years in this study) to start and establish a viable culture operation. Within this period, farmers can make profits and would be prepared to invest on system.
3. The leased areas should have adequate legal protection against degraded water quality, theft of culture organism and facilities, and trespassing (DeVoe and Mount 1989), as it is essential to reduce overall risks in the production system. In Taiwan, although the legal protections exist, sometimes it is difficult to find the criminals.

Some coastal regions in Taiwan are increasingly polluted (Hsiao, 1994a). Cage culture located in those nearshore waters can be subjected to such pollutants. The capacity of a farming site to accept the waste from fish farm can also be exceeded if the intensity of culture becomes excessive, though compared with municipal, industrial, agricultural and nonagricultural river inputs, the inputs of phosphorus and nitrogen from aquaculture is commonly very small (Stickney 1997).

Establishing systems of a large size with a relatively low biomass per unit area can also help ensure the proper dispersal of released nutrient. To prevent excessive growth of cage culture within a given location, careful attention to the sites and density of cage culture within a given locale will ensure that the sustainability of the activity is maintained. If the structure of cages can be improved to resist moderate currents, cages can be set up in areas with some currents which will be useful to prevent sedimentation, as they may assist in cleaning the seabed. Nutrient released from fish farms could also be converted to biomass in polyculture facilities. Thus, developing seaweed culture in association with cage culture may be an option for recycling nutrients released from cages and incorporated into seaweed (Stickney 1997).

The dispersion of nutrients released and the uneaten feeds from cage farms might increase local floral and faunal productions and attract wild fish in offshore areas. Sport and commercial fishing could be enhanced because the structure associated with offshore mariculture facilities can serve as fish attracting devices and increased nutrients levels can promote overall local productivity. Modest increase in offshore nutrient levels might be actually a benefit (Stickney 1997). It may consequently be appropriate for government to assist fish farmers to set up some facilities for recreational fisheries.

According to ADCP (1983), feed represents 40-60% of the total operating costs in intensive aquaculture and is very similar to the results of this research (Table 5.12 and

Table 5.13). It is therefore, only feasible if the fish being cultured can fetch a sufficiently high price to generate a profit when harvested (Beveridge, 1996), as is the case in Taiwan. The sensitivity of profit to market prices and feed prices were particular notable for grouper and cobia (Table 5.19 and Table 5.20). However, for an ideal profitability target, it was suggested (ADCP 1985) that feed costs should not exceed 20% of farm gate value of the fish. In this survey, most species had feed costs of more than 50%, suggesting that reducing feed costs relative to market price is an important issue. This investigation found that although Dumerils's Amberjack (*Seriola dumerili*) and red porgy (*Pagrus major*) can make higher profits than other species, fish farmers still have great expectation for cobia (*Rachycentron canadus*). Because Taiwan's market is not big enough, this is based primarily on the hope that the Japanese market can be developed, and cobia can become a candidate for sashimi (raw fish).

The survey revealed that mortality rates in cage culture was very high (Table 5.10). Whether this is because of the quality of feed, fingerlings or other factors is still not clear. The survival rates definitely will influence the profit of cage culture. The sensitivity of profits to survival rates was higher in grouper and cobia (Table 5.22).

Marketing channels for sea cage species are quite similar to those for other fisheries products in Taiwan. Most products are sold to wholesalers and re-sold in auction markets to retailers. As wholesalers collect the products and commonly control prices, the establishment of production and marketing groups might help farmers to get higher profits. This will be discussed further in Chapter 6. Some farmers have attempted to open up Japanese markets, but have still confronted difficulties. Another threat is fisheries products from China, which compete at a number of levels. Some fishermen do not catch fish, but trade fish, bought from Chinese fishermen in the open ocean and re-sold to Taiwan. This has lowered prices of some marine fish products, and threatened the profitability and development of sea cage culture.

Apart from efficiency and market issues, cage culture faces objections concerning issues such as visual pollution; potential impact on non-target bacteria from the use of antibiotics in fish feed; infection of wild fish with diseases carried by cultured fish; pollution of the water column and destruction of the benthic community from waste feed and fecal deposition. There are also concerns for interference with navigation and removal of access to traditional commercial fishing. Successful cage culture should emphasize the development of appropriate site-specific systems and public policy strategies that integrate the various disciplines, including social, physical and biological sciences. With improvements in structure design, materials and farm operation, cage culture is expected to expand in the future. However, this will require a critical coalition or team building approach (Jensen 1996), and the important lessons for investment can be learned from other countries such as Norway, Scotland, Canada or Chile.

Chapter 6

Sustainability

6.1 Introduction

Although the final goals of environmental protection and development of aquaculture are not necessarily in conflict but may indeed be the same, namely to improve the human quality of life or welfare for present and future generations, aquaculture, like all farmed food production may have a large effect on the environment. Those effects can be negative, such as reduction of the abundance and diversity of wildlife; change in soil, water and landscape quality and occupation and fragmentation of former natural habitats (Pullin 1993).

The viability of aquaculture can be viewed from two levels: farm and society. At the level of the farm, sustainability depends on its productivity and on market factors reflected in costs for production and revenues from its products. However, the social costs from aquaculture cannot be assessed in isolation from the rest of the economy (Shang and Tisdell 1997). In Taiwan, the profits from aquaculture in the past two decades have attracted numbers of new entrants. However, a range of potentially negative environmental, economic and social factors may pose increasing challenges in the future. It is important, therefore, to consider the issues which may allow the aquaculture sector to remain viable and effective, i.e. sustainable, in delivering a range of economic and social benefits, and also to consider those factors which may threaten its future potential and would need to be effectively addressed to enable the sector to prosper.

Sustainable development is an increasingly widely used concept in planning, thought subject to different definitions. The UN World Commission on Environment and Development defined sustainable development as:

> "Meeting current needs without compromising the ability of future generations to meet theirs" (Anon 2000).

The FAO (1991) has defined sustainable development in a similar manner, extending it more specifically to be:

> "The management and conservation of the natural resource base, and the orientation of technological and institutional change in such a manner as to ensure the attainment and continued satisfaction of human needs for present and future generations. Such sustainable development conserves land, water, plant and animal genetic resources, is environmentally non-degrading, technically appropriate, economically viable and socially acceptable".

Aquaculture is sustainable only when it can cope with and recover from stress and maintain or enhance its capability and assets both now and in the future, while not undermining the natural resource base. Unsustainable systems will deplete or run down capital (financial or natural resource), leaving less for future generations. The sustainable development of aquaculture can be judged in economic, environmental and social systems, but invariably, the result is a series of trade-offs between all three of these components, as summarized in Fig.6.1.

This implies that a sustainable aquatic farm must be economically viable, ecologically sound and socially acceptable. It would not specifically strive to maximize any single result, but rather to achieve a long-term balance among outcomes. The process of trade-offs among goals must also be adaptive, and the priority among goals should be weighted by the three systems (Barbier 1987). The trade-off includes the tension between obtaining better income and environmental sustainability, the tension between maximizing production in the short term and guarding against vulnerability to external shocks in the long term and the tension of conflict between fish farmers and others.

The sustainability of aquaculture can be described as depending on two sets of factors: intrinsic and extrinsic. Intrinsic factors are related to adequate on-farm planning and management, such as water quality, culture techniques, location and operation of facilities, seed supply, species characteristics and availability of artificial and natural feed, etc. Extrinsic factors refer to off-farm factors, such as national policy, natural hazard, pollution, the market, sociocultural conditions and legislative control (Chua 1997). The following sections attempt to examine these issues as they affect the aquaculture sector in Taiwan, and in particular, the focus areas defined in previous chapters.

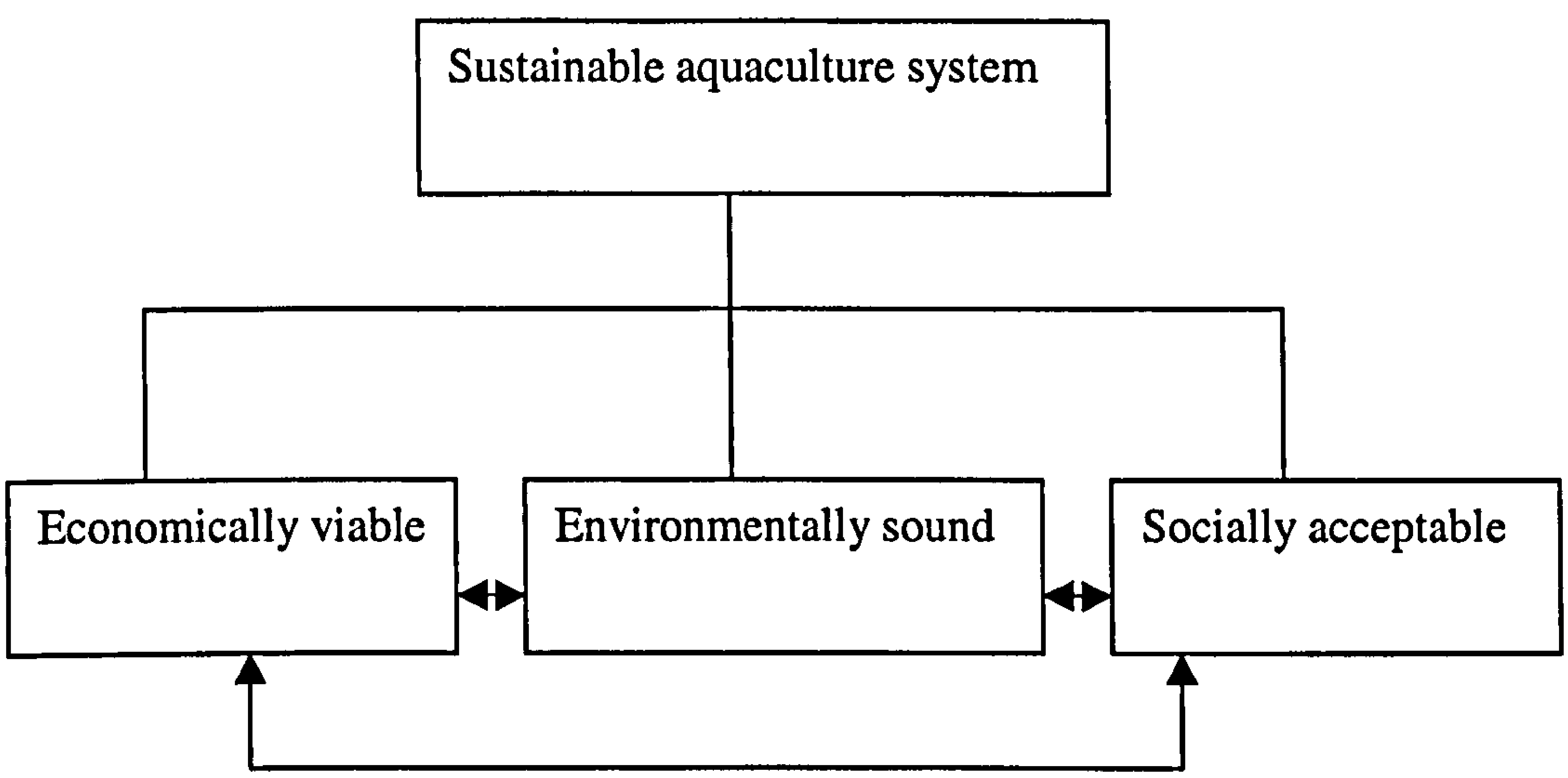


Fig.6.1 Sustainable aquaculture system (modified from Shang and Tisdell 1997).

6.2 Social and economic issues

6.2.1 Introduction

Most aquaculture in Taiwan is carried out intensively. Usually, intensive aquaculture is not previously driven by food shortage objectives, but by market price (Folke 1997). Intensive fish farming relies on high stocking rates and formulated diets to achieve high yields of marketable fish within purpose-built rearing facilities by means of close supervision over the entire production cycle (Shepherd and Bromage 1992). The logic of intensification is not related to a biological concept of efficiency, but to resulting net gain of commercial benefits that can be attained in certain economic conditions. If the revenue is lower than the cost, the industry will not be feasible. The economic factors of aquaculture as outlined in earlier chapters are shown in Fig 6.2. Clearly, feasibility depends on the difference between cost and revenue and hence the potential to decrease cost and increase revenue i.e. improve financial performance is critical. These issues are discussed in the following sections.

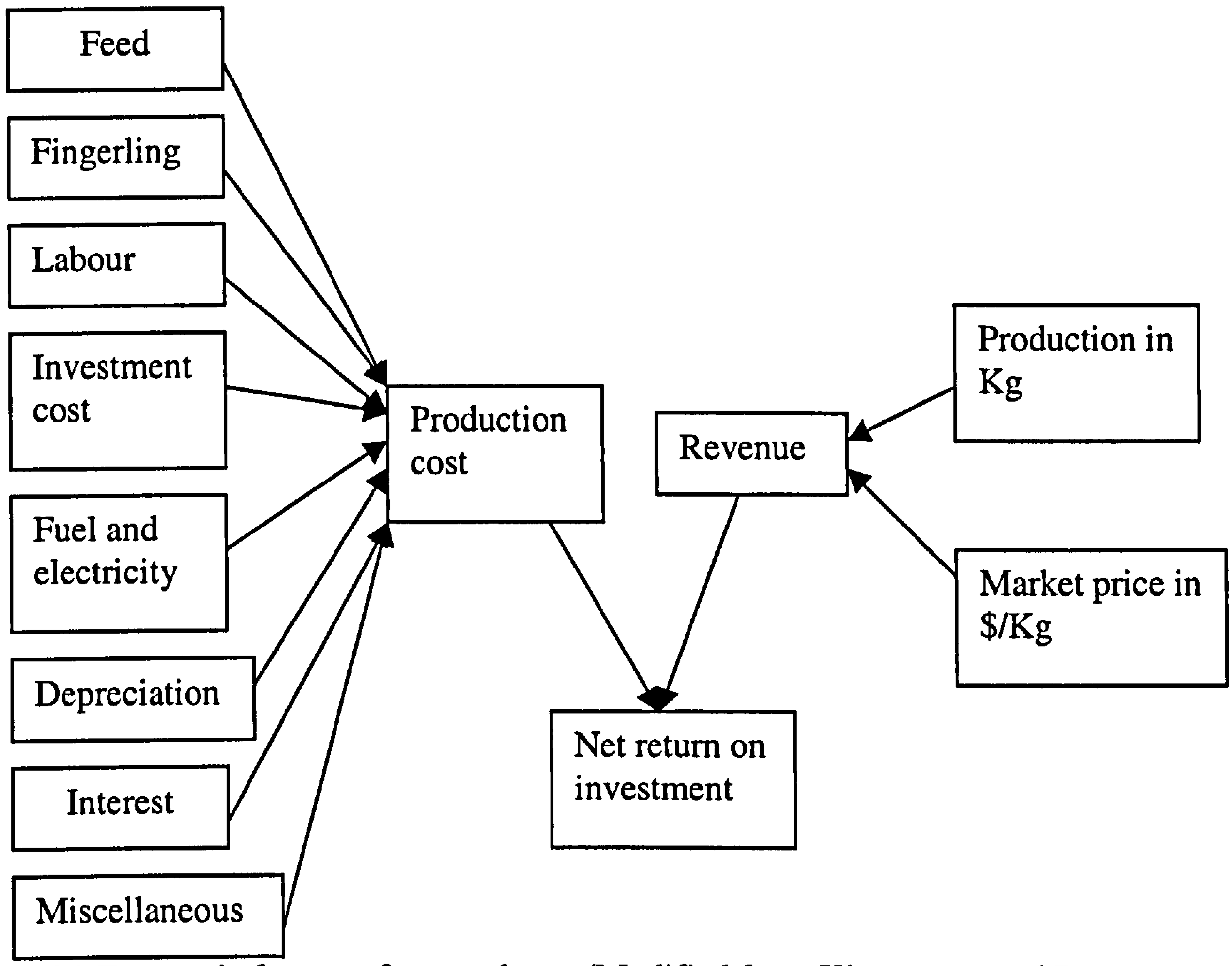


Fig 6.2 Economic factors of aquaculture. (Modified from Klemetson, and Rogers 1985).

6.2.2 Improving financial performance

Strategies for improving financial performance of the aquaculture industry have been discussed in specific cases in earlier chapters and cover both supply and demand issues. The attributes or variables that influence financial and economic performance, and the nature of the links between those attributes and end performance is illustrated schematically in Fig.6.3. (Sherer 1982). From Figure 6.3, it can be seen that the situation of supply, demand and market structure will affect the conduct and performance of the sector as a whole. In attaining economies of scale, increased supplies from large-scale aquaculture enterprises may lower prices and in turn further increase the pressures for efficiency.

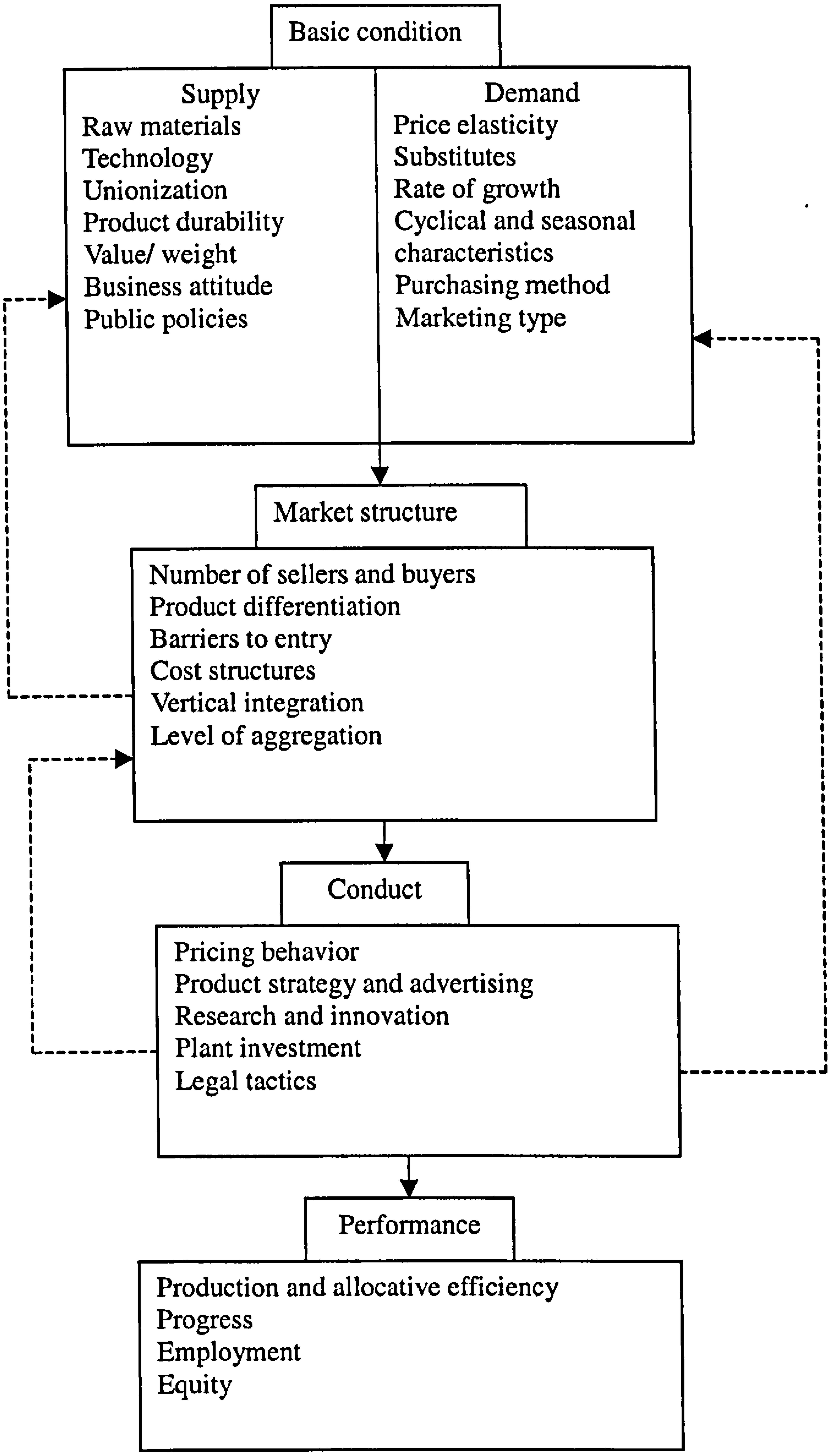


Fig 6.3A model of industrial organization analysis (the dotted lines indicate feedback effects) (adapted from Sherer 1982).

However, limited land resources and expensive labour costs may favour family labor, and without substantial investment in mechanisation, it may be difficult to develop large-scale aquaculture enterprises in Taiwan. Limited land resources force producers to apply intensive aquaculture, though, this increases risks (such as D.O. depletion or water quality deterioration), and needs high levels of experience and close supervision. Investment may also be constrained by the conditions in which wealthy investors do not want to take the risk to invest while experienced farmers did not have enough capital to expand their farm, nor does the risk allows them to obtain adequate loans or insurance. This makes the condition of aquaculture in Taiwan different from that in Norway, where good access to capital and high labour costs have resulted in a highly mechanised industry.

National tradition has also restricted the development of larger-scale enterprise: in many sectors, there is a joke that if you throw a stone in the street of Taipei, you are likely to hit a chairman of a board. There is one company for every 18 people in Taiwan (the highest density in the world) (Anon 1998), people preferring not to work for others "better the head of a chicken than the tail of an ox", according to an old Chinese saying, and most Taiwanese feel most comfortable in a company financed and run by their own family.

Small to medium-sized enterprises therefore make up 98.5% of Taiwan's companies, 75-80% of all employment and 47% of the total economy (Anon 1998) and about 60% of aquatic farms in Taiwan are less than a hectare in area (Liao *et al* 1995b). Government economists refer to corporate Taiwan as an "army of ants". There is, therefore, a bias against large-scale aquaculture enterprise.

Industry structure

In early years, the aquaculture sector was often characterized by disorganized marketing, with seasonal gaps of supply. Since most aquatic farms are small and independent, they have a disadvantage in selling their products, where prices are decided by market condition and not by farmers. As with agriculture, markets are completely competitive, and small producers were easily open to major price falls during period of high availability. To obtain higher profits, farmers can organize production and marketing groups, combining together to negotiate prices in purchasing inputs and selling their product, taking the advantage of larger scale. An equally important function of these bodies would be to establish and maintain appropriate product quality standards to which members must adhere. This would make it easier to undertake sales promotion for the industries as a whole.

By "collusion", small farmers can unite and set up groups and agreements to control production to optimize profits, in effect developing cartels, of which 3 kinds can be defined (Wu 1998).

-. Price cartels: most companies agree in price levels, or define the lowest price to avoid price competition.

-. Production cartels: companies agree to limit production levels to control the price in the market.

-. Territory cartels: the goal is to separate different areas for different companies to avoid competition.

In general, a production cartel might be a more suitable approach as, price cartels are illegal in Taiwan, and Taiwan is not big enough to use a territory cartel. Moreover, although some species have relatively high price elasticity of demand, the E.O.D. of most fishery products is less than 1 in Taiwan (Wu, 1998), producers can obtain larger profits by using production levels to control the price rather than using price to control demand. However, if the production and marketing groups combine to control production levels, they must confront the problem of quota; as each member would compete for as high a quota as possible, and it may therefore be difficult to attain agreement. Even if a quota is agreed, it is difficult to guarantee that some farmers, 'free-riders'- will not produce extra fish above quota. If a lot of farmers "cheat" and produce more than their quotas, the agreement will collapse. Therefore, sound rules with severe penalties for infringement, a good marketing system and reasonable production levels are imperative. To assess the potential for such action, in 1997, Wu (1998) sent 636 questionnaires to fish farmers with 168 responses (26.3%). The major difficulties of production and marketing groups for aquaculture in Taiwan were summarized in Table 6.1, which suggests that considerable issues are to be overcome. The potential organization of a production and marketing group is illustrated in Fig.6.4, in which the cooperation of government, research institutes and private sectors might all be important in development.

Table.6.1 The major difficulties of production and marketing groups for aquaculture in Taiwan.

Major difficulties	Percentage
1. Lack of financial support	25%
2. Members are not strongly combined together	17%
3. The knowledge of aquaculture technology is insufficient	15%
4. Difficult to control production amount	13%
5. Difficult to predict natural disaster	11%
6. Have not sound system of production and marketing	9%
7. Deteriorated water quality causes fish disease	6%
8. Lack of instruments for aquaculture	4%
Total	100%

Source: Wu, 1998.

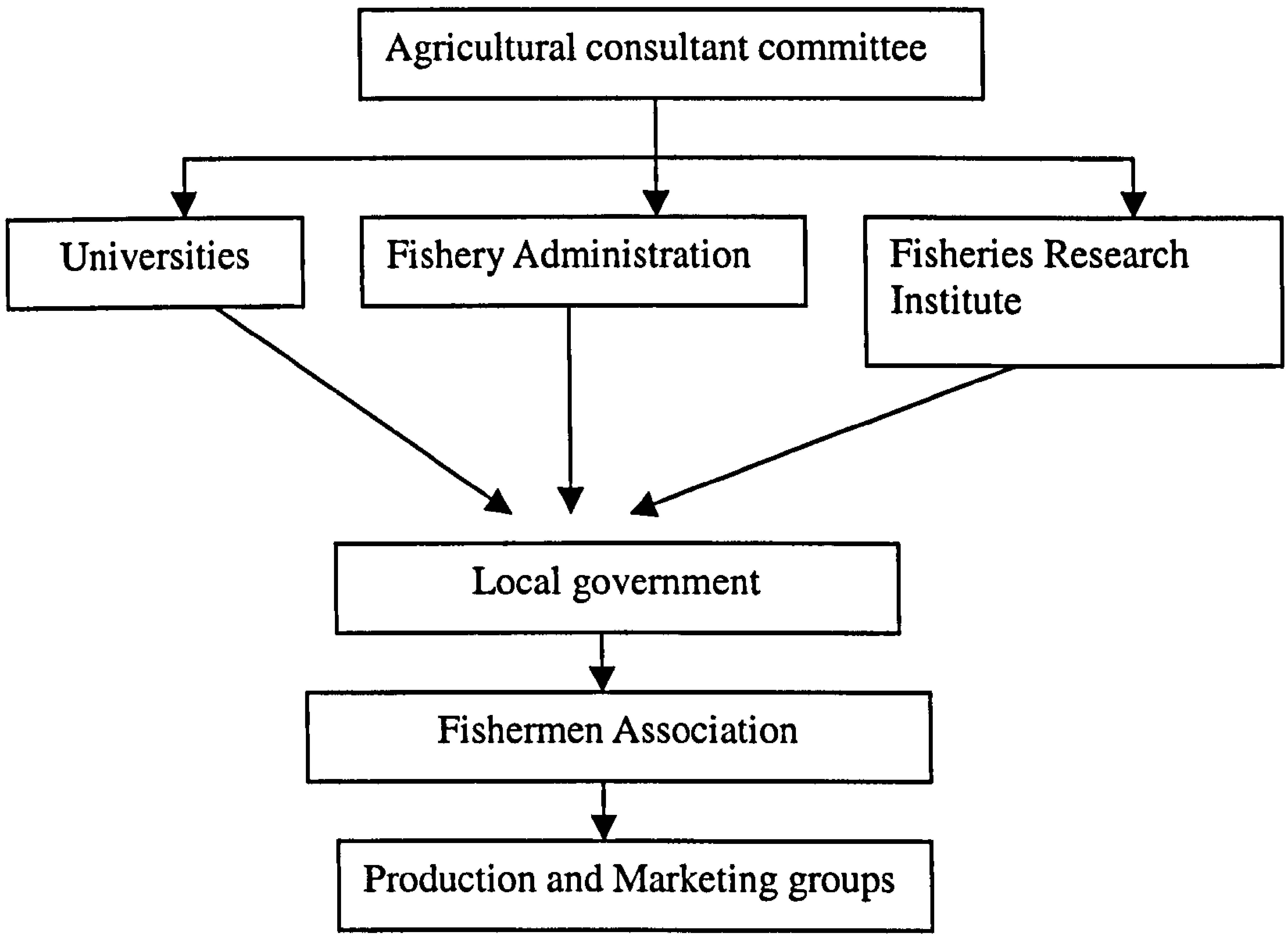


Fig. 6.4 The organization of aquaculture production and marketing groups in Taiwan.

Marketing development

According to Porter (1980), the state of competition depends on five basic forces; rivalry among existing firms, threat of new entrants, suppliers, buyers and substitutes. In coping with the five competitive forces, Porter categories successful strategies as involving one or more of three elements:

- Cost leadership
- Product differentiation
- Focusing on a particular market segment

In cost leadership, the aim is to reduce costs. Here, production efficiency and economies of scale are required. Economies of scale refer to reductions in unit costs of a product as the absolute volume per period increases. Such economies of scale can also deter entry by forcing the entrant to come in at large scale and risk strong reaction from existing firms or come in at a small scale and accept a cost disadvantage. If a large portion of the total supply is purchased by a few given buyers, this will raise the buyers' power, enabling them to force down prices and/or bargaining for higher quality or more service. In contrast, when dealing with buyers, greater power is associated with a large market share, and large volume makes it possible to supply a greater number of market outlets on a cost- effective basis. In aquaculture, economies of scale can be created by integration. This can be implemented through a farm being bought out or merged, or by setting up the production and marketing groups.

However, if production economies of scale are not large enough, or if the factors of site capacity and legal constraints restrict the scale to expand, the industry might be fragmented. In Taiwan, e.g. traditional cage culture is a fragmented industry and therefore faces a marketing disadvantage. As a consequence, the development of small grower groups to market products collectively may be a practical option to deal with this problem. Thus, if large modern cage farmers or grouped farmer associations can control the production levels and hence influence price, they would have a potential marketing advantage, and so the structure of business sector may increasingly be dominated by them.

The second generic strategy is to differentiate the products. In aquaculture, product differentiation can be carried out by differing the culture species, harvesting season, fish size, offering a variety of products and/or by setting up brand names. In a fragmented industry, producers can join together to become an association and set up their own brand names. Differentiation can reduce shorter-term competitive rivalry because of brand loyalty by customers and their resulting lower sensitivity to price. Differentiation can yield higher margins, and can mitigate buyer power, since buyers lack comparable alternatives, and are thereby less price sensitive. However, achieving differentiation may reduce the market share, and is often incompatible with high market share.

The final generic strategy is to focus on a particular buyer group. Unlike the low cost and differentiation strategies, aimed at achieving objectives for the whole industry, this strategy builds around serving a particular target based clearly on the premise that firms are able to identify and service their narrow target most effectively. As a result, the firm achieves benefits of differentiation either by better meeting the needs of the particular target, or by lower costs in serving this target, or both. In aquaculture, applying this strategy requires a clear demographic investigation and also implies some limitations on the overall market share achievable. As such, this strategy it may not be very suitable for aquaculture.

Potential international competition

The factors influencing the potential for international competition may include those of resource, technology and administration. The resources can be classified as natural and non-natural. Natural resources factors include water, land and their qualitative features. Such factors are crucial in the growth and survival of aquatic animals and will influence the carrying capacity. One of the reasons that the tiger prawn (*Penaeus monodon*) industry collapsed in Taiwan was because of the lack of quantity and quality of water. Non-natural resources refer to factors such as capital and marketing organisation. A farm needs a loan to cover not only construction costs but also operating costs for the first few years until the first or second harvest generates a positive cash flow. Therefore, capital is usually a problem during the start-up phase of a new company. In the competition of commercial sales, it is difficult to distribute products far from the point of production without a strong sales organisation.

Another important factor for international competition is technology. This is the basis of any industry, and new technology must be developed as conditions change if any industry is to remain competitive (Ackefors, 1994). Supply of better seeds, feeds, feeders, cages, therapeutic and prophylactic drugs, aeration devices and other equipment is important for the success of aquaculture. Competent management is also critical to the operation of an aquaculture farm. A successful farm manager must be able to recognise and correct biological and water chemical problems, and make effective emergency field repairs to complex equipment

The third important factor is administration. Legislation must be favourable to farmers. If the political will is very strong in opposing aquaculture, little significant development can be expected Aquaculture is dependent on institutional support, including universities. The transfer of new technologies from governmental research to the private industry and diagnosis of diseases are also important.

Compared to other Asia countries (such as China, the Philippines, Thailand and Malysia etc.) Taiwan has a disadvantage of limited natural resources and higher wages. In the longer term, if those countries develop better technology and obtain governmental support, they may be able to start supplying the market at lower prices and Taiwan may lose long-term competitive advantage. For example, China has replaced Taiwan as the biggest eel exporting country in the Japanese market, and Thailand has overtaken Taiwan to become the biggest producer of tiger prawn (*Penaeus monodon*) in Asia, and even the biggest producer in the world (FAO. 2001). In the longer term, if Taiwan loses the advantage of cost leadership, focusing on product differentiation might be another way forward in international competition.

Developing market demand

Though traditionally thought of as a simple post production issue, marketing is a much broader concept underlying the entire basis in which production is established and developed. The link between producers and consumers, it consists of individual and organizational activities that facilitate and expedite satisfying exchange relationships in a dynamic environment through the creation, distribution, promotion and pricing of goods (Dibb *et al.* 1997). In the process of getting the products from producers to consumers, the product passes from one owner to another through a network of marketing channels, from the place of production to the point of final consumption.

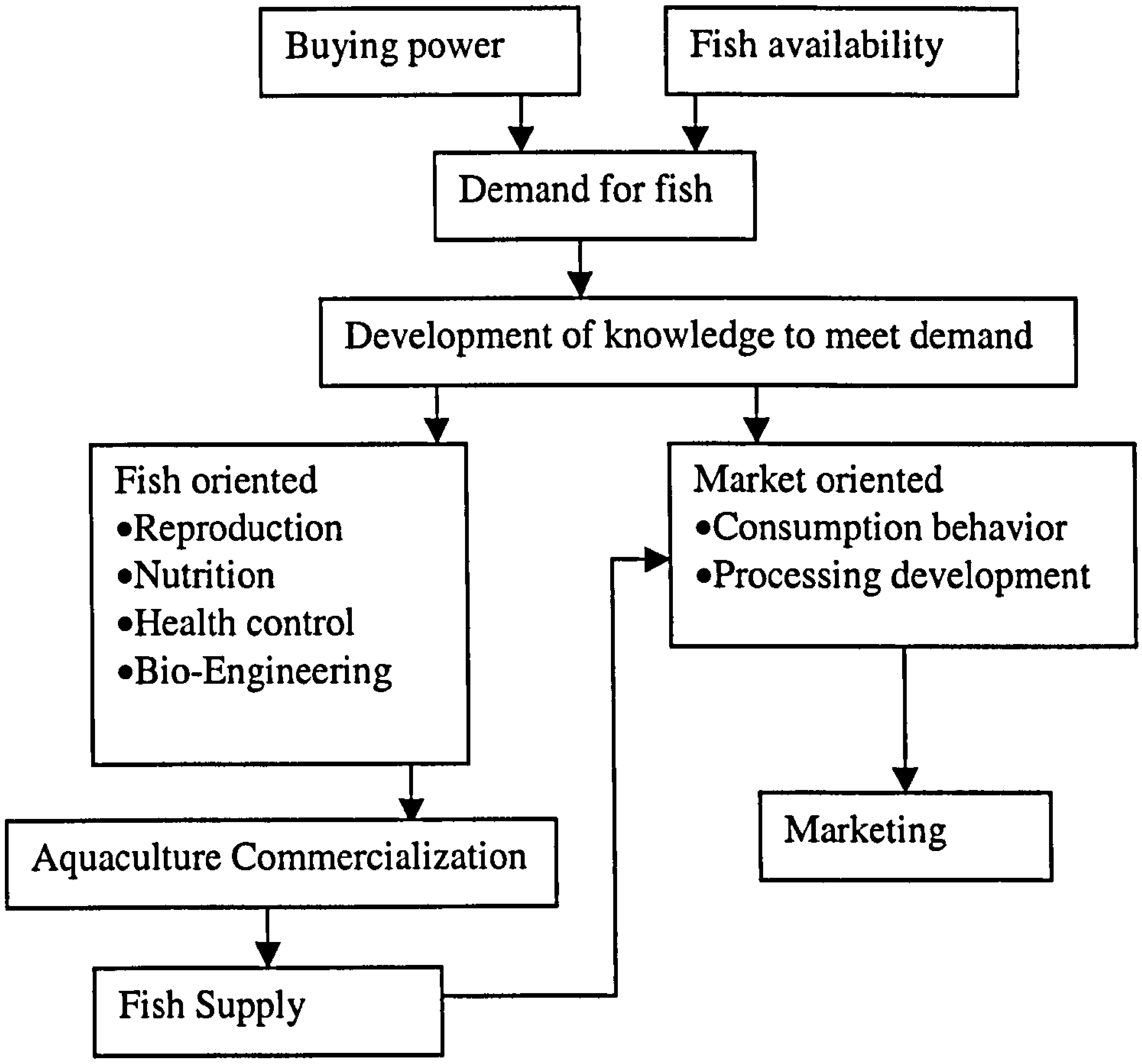


Fig 6.5 Features of a demand pull aquaculture market (Modified from Huisman, 1986).

A greater impetus for the development of aquaculture will be market demand for fish and local pressures for new forms of livelihood and enterprise. There are two kinds of market of aquaculture in Taiwan, described as demand-pull and supply-push respectively. The development of a demand-pull market (Fig 6.5) arises from demand from consumers (such as milkfish and eel etc.). By contrast, the development of a supply push market (such as cage aquaculture) is not specifically because of demand from customers, but because of increasing supply from producers (e.g. through a new species and/or technology) (Fig 6.6). Thus in cage aquaculture product (fish) expansion as a result of the collective consequences of decisions to expand by individual businesses must create the market for development.

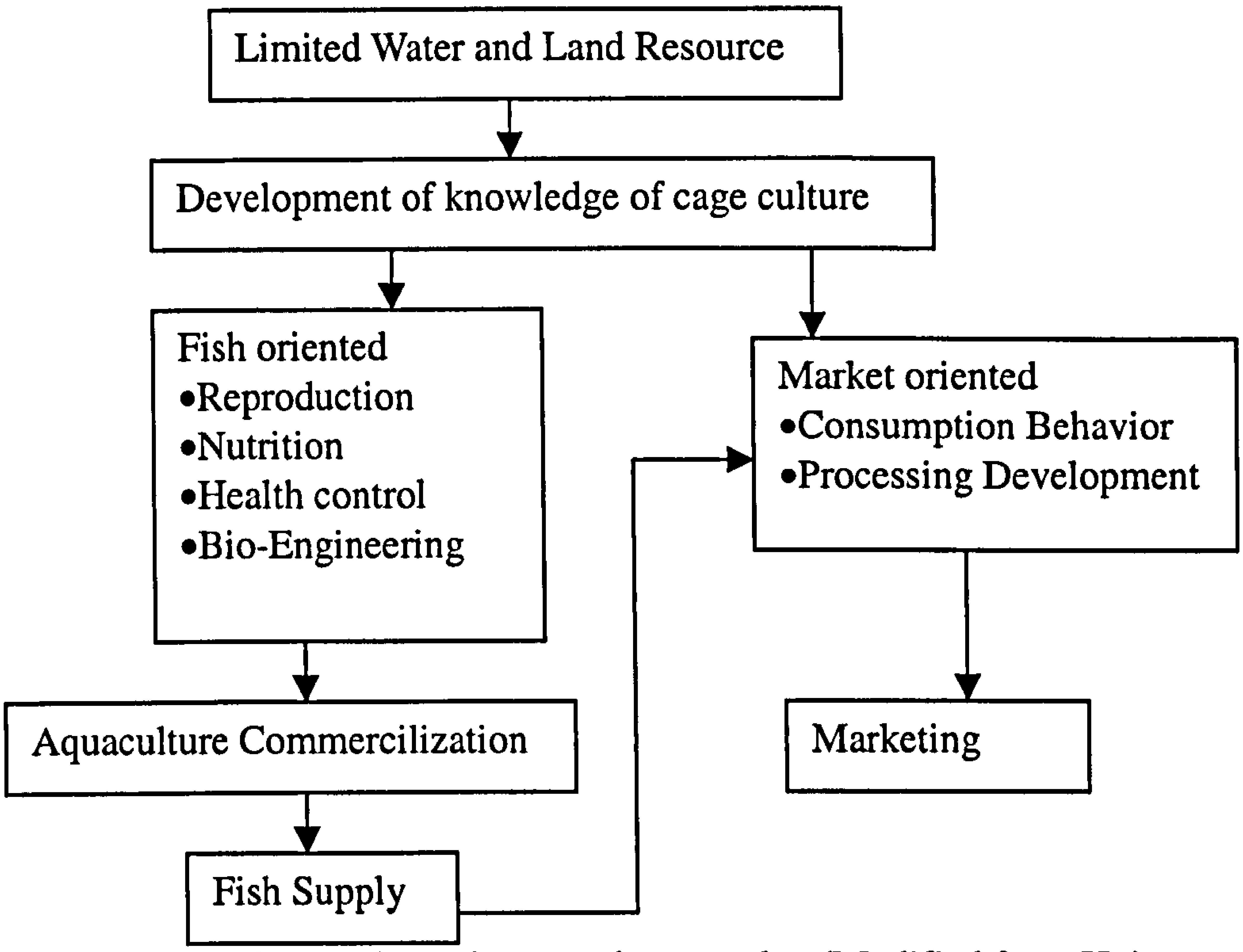


Fig. 6.6 Features of a supply push aquaculture market (Modified from Huisman, 1986).

Potential marketing strategy for aquaculture

With regard to the main marketing strategies in salmon farming, Shaw (1997) categorized five major elements. They are market targets, products, pricing, market channels and promotion.

Firstly, the market targets of production must be set up. Depending on whether they are international (such as shrimp or eel) or domestic (such as milkfish) or both, it must be known which market sectors and which countries are emphasized.

Secondly, product strategies must be set up. This would include harvest timing, harvest sizes and quality control. In principle, it would be desirable to be able to plan supplies in line with forecast demand, although this has not always been achieved in practice. When considering harvest sizes, preferred market sizes should be known. Farmers with little experience of marketing can also underestimate the importance of quality to consumers, being usually more concerned with finding a sale for the fish rather than with how consumption ultimately occurs. However, a farmer who produces good quality fish will be interested in consumers being satisfied with the products. Quality factors of particular importance are accurate size, grading, appearance, lack of any off-flavours, professional packing and freshness. Service issues are also increasingly critical – physical quality alone may be insufficient. If processors can develop new popular products, it can also help the development of the industry significantly. The attractiveness and convenience of the packaging materials are influential in selling the dressed fish, especially in supermarkets. Neat and appealing containers increase the sale of fish in retail markets. If farmers can join together and set up trade associations, education programmes on quality for members can be incorporated into the activities of trade association (such as the eel production and marketing association in Taiwan).

The third element is pricing. In Taiwan, traditional aquaculture is fragmented and prices are usually decided by the market, i.e. producers are price takers. However, if the fish farmers can join together and regulate the amount and quality of product (i.e. under oligopoly condition), they might enjoy some degree of market power and be able to influence the price of their products. This can be further extended where consumers needs are better targeted.

Mudie (1994) describes a typical pricing approach as:

$$P=UVC+(F/X)+(rK/X)$$

Where P is selling price,

UVC is unit variable cost,

F is fixed cost,

X is standard unit volume,

r is profit rate desired and

K is the capital employed.

But when targeting a price, demand elasticity must also be considered. It may be that demand for a certain type of fish or its product is highly sensitive to relatively small changes in price. This price elasticity of demand i.e. the units of demand change as a result of the units of price change, can be an important consideration for fish farmers in developed markets who may be tempted to produce for premium prices before trying to establish the new potential market. Intensive farming is characterized by low fixed costs because of high productivity per area, but high variable cost mainly for feeds and water quality maintenance. If market prices are favorable, intensive farming remains profitable. Once prices drop, so does profitability because of the high production or variable cost (Primavera 1991). It may therefore, be more suitable to choose high price species to cultivate in Taiwan due to that high variable cost associated with the intensive forms of aquaculture which may be required due to other factors.

The fourth strategy is to shorten the marketing channel. This can reduce the margins of the channel, maintain sufficient first-sale price, reduce the retail price, increase consumer demand and benefit the producers and consumers. Usually, the highest profit margins achieved by fish-farmers result from supplying live fish, though this does not guarantee a high profit in absolute terms as the quantity sold, and the cost of selling must be considered. Although some supermarkets (such as Welcome, Carrefour and Macro etc.) can apply economies of scale to fish purchasing and handling, selling fish to supermarkets is relatively unpopular among fish farmers in Taiwan, as payment terms are usually delayed, with buyers routinely paying by check or asking for credit of 1-2 months. Small farm owners need cash for operating costs and may find it difficult to work with the credit terms. There is no simple solution for this, but good local representation and contracts are essential for mitigating this problem. This can be achieved e.g. by fish farming trade association setting up an extensive network and selling products directly to retailers or supermarkets, or by fish farmers making contracts directly with retailers or supermarkets.

The final strategy is product promotion. Because fish are common commodities, the role played by product differentiation may be small and there will be a lot of free riders who take the advantage from advertising by others. To solve this problem, large farmers can set up their own brands and small farmers can set up brands in the names of trade associations. Not only do the trade associations promote the products, they can control its quality as for generic advertising to be successful the actual quality of the products must match the image and expectation created.

6.3 Environmental factors

6.3.1 Introduction

Sustaining food supply requires protecting the environment as the basis for production. Environmental sustainability is achieved when the productivity of a natural resource is conserved or enhanced for use by future generations (Chua 1997). Increasing production through intensifying culture creates the risk of taxing the carrying capacity of the environment. Concentrating many animals in a small space creates high oxygen demands, increases the concentration of waste products (such as nitrate and phosphate etc.) and increases the transmission of diseases. The application of various forms of chemical or antibiotic treatment against diseases can also pose public health problems. As aquaculture develops, it is possible that some external effects will happen. When evaluating the feasibility of aquaculture, the social costs of waste treatment, pollution prevention and taxes on discharging effluents are usually neglected. However, environmental impact should be considered and should be fully integrated into development discussion.

6.3.2 Key issues

Eutrophication or hypernutrification

Because land is limited in Taiwan, almost all its aquaculture is intensive, in which the aquatic animals gain energy from allochthonous (external) rather than autochthonous (internal) sources. That means that extra feed is imperative. However, feed losses are inevitable. Intensive farms, including cage systems have a high production per unit area and a correspondingly large amount of particulate organic waste, as well as soluble-inorganic excretory waste. Fish farms/cages produce orthophosphate and nitrogenous nutrients, and high concentrations have been observed in adjacent surface waters (Hansen *et al.*, 2001). Since the raw material for fabricating the feed pellets often originates from other water bodies, the result is also a net addition of nutrients to the receiving environments (Folke 1992). Depending on the quantity and composition of the effluents and the susceptibility of receiving environment, these emissions may have varying and sometimes severe, ecological impacts. Nutrient releases from intensive farms represent a net addition to environmental loading. Excessive nutrient enrichment or eutrophication can cause impact in coastal areas and may affect socioeconomic activities that are dependent on the quality of these areas (Folke and Kautsky, 1989), including negative feedback on the aquaculture activity itself. However farmers might argue that the severity of pollution caused by aquaculture is far less serious than caused by other industries and domestic sewage wastes. Further research is needed to clarify who is the most serious source of pollution.

Chemical waste

A wide range of chemicals is used by the aquaculture industry. Most of these are biocides, used to control bacterial, fungal, protozoan and other diseases (Beveridge *et al.*, 1994). If these chemicals and materials such as those used for anti-fouling treatment of cages are released outside their targeted purpose, there may be adverse effect on the local environment. The high incidence of infections followed by medication through feeds and water baths has been a burden to the aquaculture industry. Feed based treatments are used in land-based fish farms and sea cages. However, chemical treatments using water baths are usually used in land-based farm rather than in sea cages because of the effect of dilution in the open area and because the technique has not been well developed in sea cages yet. In Taiwan, currently, there is a lack of transparency in the industry regarding the use of chemical inputs and there has been little public debate on these regards. The absence of a monitoring mechanism complicates the introduction of industry standards. This has lead to the feeling that fish from aquaculture are not as clean and healthy as their wild counterpart, and to adverse effects for aquaculture in attempting to develop and/or improve markets. However, some fish farmers may argue that the pollution from industry and domestic sewage might be more serious than from aquaculture (Stickney 1997). Therefore, the severity of the pollution from aquaculture and other industry need further investigation.

6.3.3 Key biological impacts

Changes in aquatic fauna and flora

The establishment of aquaculture usually increases human activity in the immediate vicinity, which in turn can have impact on wildlife, especially in remote areas, through disturbance of breeding or feeding. Increased conflicts between man and wildlife, especially with piscivorous (fish-eating) animals are occurring in Taiwan. The end result may be the death of animals, either deliberately (shooting, trapping) or accidentally (entanglement), or the loss of stock for fish farmers. For example, a number of aquaculture developments had occupied the habitat of the spoonbill (*Platalea minor*) - an endangered species, resulting in conflicts between fish farmers and animal protection groups. Finally, the government had to negotiate between these interests to set up special protection areas to solve the conflicts.

High densities of farmed fish and food also attract predators and scavengers, which may in turn displace local species (Beveridge *et al.*, 1993). Released nutrient from fish farms can also change the composition of species flora. In 1998, there was a serious 'red tide crisis' in Hongkong, which was caused by aquaculture and nearly decimated all investments of the fish farmers in a short period of 2 days (Lai and Lam, 1999). The precipitation of uneaten feed and faecal materials can also cause severe disturbance of the macrobenthic community (Brown *et al.*, 1987). Some benthic fauna and flora may be replaced by bacteria because of environmental deterioration. The ecological change might interfere the sustainable development of aquaculture.

Hybridization between wild and farmed strains

Whether deliberate or not, it is inevitable that some fish will escape from aquaculture facilities, and cages can be particularly risky. During storms and through other incidents, large numbers of fish can escape. As an aquaculture industry develops, the advantage offered by strains that are superior to those from the wild in terms of growth, disease resistance, color, shape etc. will become increasingly apparent and selected for. The selected organisms are increasingly domesticated and would potentially exhibit lower fitness in the wild (Donaldson 1997). When those selected strains escape, they may possibly interbreed with wild strains and thus reduce the variability of the wild population. There are fears that such interactions will adversely affect the gene pool through the introduction of nonadaptive genes, though this depends on the potential of aquaculture stock to breed in the wild (Beveridge et al., 1994). Except for eel, whose fingerlings are collected from wild, most aquaculture species in Taiwan are artificially selected and hatchery produced. However there have been no investigations on genetic interactions carried out in Taiwan. According to Primavera (1991), such impacts on aquatic biodiversity are rarely positive, occasionally neutral but usually negative. However according to observation of cage farmers in Pen-Hu, most feral fish will stay near the original cages (Chen personal communication 1999), so the development of recreational fishing near the cage may perhaps reduce the genetic interaction between wild and feral stock.

Spread of diseases from farmed to wild fish

Although diseases in wild fish appear to be uncommon, these may be a serious threat in intensive culture, due to behavioral stress and limited environmental conditions. The development of the fish culture industry had led to an associated increase in the number and severity of diseases of farmed fish and it is understandable that concern has been expressed about the possible transfer of these diseases to the wild (Saunders, 1991). Such transfers may occur through the discharge of infectious waste water to the wild, through contact of wild fish and farmed fish on each side of the cages, through feral farmed fish and through contact with contaminated gear etc (Hastein and Lindstad 1991). However, potential negative interactions are not just one-way, since wild fish may in some cases be an important reservoir for pathogens, which can create problems of disease eradication at culture sites. Although it is difficult to demonstrate transmission from farmed to wild fish, the high frequency of diseases and on farms and the concentration of pathogens may have the potential to cause outbreaks of diseases in wild fish population.

Development of antibacterial resistant bacteria

In Taiwan, different kinds of antibacterials are used in aquaculture, with application typically by addition to the water or by incorporation into the feed. Long-term antibacterial treatment of cultured fish may result in increased levels of resistance in bacteria in the surrounding environment. Antibacterial resistance may also be genetically transferred from harmless and normal sedimentary bacteria to bacterial fish pathogens (Herwig *et al.*, 1997). The three well established mechanisms of gene transfer, transduction, transformation, and conjugation, are all believed to occur in the aquatic environment (Saye and Millers !989). Genetic transfer of antibacterial resistance was demonstrated with bacterial isolates obtained from sediment samples collected beneath Norwegian fish farms. Such antibacterial resistant strains of fish pathogen may make it more difficult to treat fish (Sandaa et al., 1992). Heavy usage of antibacterials, such as OTC (Oxytetracycline) may also result in their persistence in the environment for months to years (Coyne *et al.*, 1994). These increased residues may represent a significant threat in maintaining the health of the cultured fish and the continued viability of the farm itself, and the product might even threaten human health.

6.3.4 Physicochemical impacts

Sedimentation

Wastes from fish farms include organic solids and dissolved organic and inorganic nutrients. Most organic solids are from uneaten feed and faecal materials. Even the high-energy or low-pollution commercial fish feeds were introduced, there are still 10-25% of the dry weight of the feed consumed, or 100-250 kg dry weight per tonne fish production, is voided as faeces (Cho et al. 1994, Chen et al. 1999). Increased loads of organic materials to the sediment shift decomposition processes from aerobic to anaerobic. The features of such sediments are substantially lowered redox potentials and the presence of hydrogen sulphide in the pore water, mats of sulphide-oxidizing bacteria and severe disturbance of the macrobenthic community (Brown *et al.*, 1987). The azoic (devoid of oxygen) zone is enriched with carbon, nitrogen and phosphorus, and may be completely devoid of macrobenthos (Beveridge, 1994). In sediments with severe organic enrichment, methanogenic bacteria will produce gas and lower pH value. The released gas has been shown to consist of methane with up to 1800 mgl^{-1} of hydrogen sulphide (Samuelsen *et al.*, 1988). The impact of sedimentation is more serious in sea cage culture because the rearing area in land-based area will be cleared after harvest and is easier to be ignored by fish farmers in the open sea. However, in Taiwan investigations of sedimentation beneath sea cages have still not been reported.

Land subsidence and salinisation

In Taiwan, the fresh water used for aquaculture is usually groundwater pumped from aquifers, rather than river water, which may be contaminated with domestic, agricultural and industrial pollutants. Where this is acceptable at a modest level, massive extraction of freshwater from underground aquifers poses a serious threat to the environment, with depleted aquifers are subjected to physical destabilisation and/or salt-water intrusion. The uncontrolled enthusiasm for intensive prawn cultivation required very large amounts of pumped ground water that caused water level decline and attendant compaction of aquifers, which eventually led to land subsidence and vulnerability to floods. In addition to land surface depression, salinisation of surrounding areas may decrease agricultural production and affect the soil, to preclude conversion to agriculture or even other aquatic crops. According to Primavera (1991), roughly 6600 m^3 of fresh water are needed to dilute full seawater in a one-hectare pond at one-meter water depth over a cropping period of 4 months. In Taiwan, land subsidence due to excessive pumping of underground freshwater by prawn farmers has caused two-story houses to become one-story bungalows.

6.3.5 Management approaches

Zoning of production area

For reasonable use of limited water and land resources, zoning of aquaculture production area is one approach suggested to address issues of environmental deterioration. Zoning means dividing an area into definable parts, and regulating the use of land or waters within these (Corbin and Young 1997). In areas zoned for production, fish farmers can obtain the right of tenure and water use- legitimately, also providing protection against other users etc. Well-controlled zoning of aquaculture production can avoid conflict between fish farmers and other interested users and can avoid the use of unsuitable types of aquaculture. It can also provide opportunities for the government and private sectors to systematically plan and develop the allocated areas, such as grouping together to construct proper engineering systems. In such areas, aquaculture and aquaculture-friendly activities may be allowed, protecting them from adverse effects of other activities, and allowing a more focused approach to environmental management.

Managing aquacultural zones needs the cooperation of the fish farmers, other related industries, non-governmental organizations (such as fishermen associations; and production and marketing groups), and agencies of local governments. When designing an aquacultural zone, expert advice and cautious evaluation are imperative e.g. knowledge of the carrying capacity is essential to determine the type and size of an aquacultural zone. The planning process needs to consider the possible environmental impacts, and the preventive and mitigating measures against possible adverse effects of other activities within or outside the zones on its potential development.

In aquacultural zones, government can also offer supporting infrastructure. By 1993, 42 aquaculture production areas with a total area of 12,713 ha had been set up in Taiwan. These were in the counties of I-Lan (7), Chung-Hwa (3), Yu-Lin (6), Chia-I County (8), Tainan (6), Koashung (4), Ping-Tung (7) and Hwa-Lian (2). In each of production areas, 10 km of. road, 7 km of inflow and effluent canals, 7 km of dikes and 40 water gates have been constructed. Of the 42 production areas, 6 areas in Hwa-Lian, Ping-tung and Chia-I are for fresh water species and the other 36 areas for brackish water species. There are 7 fresh water species cultivated in the 6 fresh water areas and 19 species cultivated in the 36 brackish water areas (Table 6.2). The production quantity of the 42 areas is about 98,000 t, about 38% of total aquaculture output in Taiwan. The value of production from these areas is about 10 billion NT$, (~300 million US$) about 36% of national value in Taiwan.

Table 6.2 Species cultivated in aquaculture production areas.

	Number of areas	Species	
		Common name	Scientific name
Fresh water	6	Tilapia	*Oreochromis spp.*
		Japanese eel	*Anguilla japonica*
		Japanese sea perch	*Lateolabrax japonicus*
		Barramundi	*Lates calcarifer*
		Large mouth bass	*Micropterus salmoides*
		Corbiculas	*Corbiculas formosana*
		Giant river prawn	*Macrobrachium rosenbergii*
Brackish water	36	Milkfish	*Chanos chanos*
		Orange dotted grouper	*Epinephelus coioides*
		Garrupa	*Epinephelus fario*
		Yellow fin sea bream	*Acanthopagrus latus*
		Black porgy	*Acanthopagrus schlegeli*
		Gray snapper	*Lutjanus nebulosus*
		Striped threadfin	*Polynemus plebelus*
		Silver bream	*Sparus sarba*
		Red porgy	*Pagrus major*
		Flathead mullet	*Mugil cephalus*
		Jacks	*Caranx spp.*
		Three striped tigerfish	*Therapon jarbua*
		Dusky spinefoot	*Siganus fuscescens*
		Grass prawn	*Penaeus monodon*
		Kuruma prawn	*Penaeus japonicus*
		Sand shrimp	*Metapenaeus ensis*
		Mud crab	*Scylla serrata*
		Poker chip venus	*Meretrix lusoria*
		Gracilaria	*Gracilaria spp.*

Improving feed efficiency

Intensive aquaculture of carnivores requires concentrated protein and fish oil and has led to increasing dependency on wild fish. In 1999, almost one quarter of the total fishery production was utilised as raw material for the production of animal feed, reaching 29 million tonnes (FAO, 2001). It was estimated that about 17% of fishmeal was used in aquaculture in 1994 and it that this would reach 23% in 2010 (Pike, 1997). Moves to wider the resource base for feeds, with a range of ingredient options are important for the future. The determination of nutritional requirements at different life-history stages is of key importance in maximizing the efficiency of nutrition and in the development of diets for potential aquaculture species (Donaldson 1997). Three aspects are important. Firstly, alternative protein resources for fish feeds need to be developed. Secondly, the development of low-pollution diets, improving feed conversion efficiency and reducing phosphorus and nitrogen excretion is important in environmental protection. Thirdly, using least-cost formulation that integrates the knowledge of nutritional requirements with ingredient cost can be valuable in reducing production cost. When extraneous feeding of fish cultivars is necessary, it will be better, if this can be achieved in an ecologically sustainable manner.

Reducing genetic impacts from feral stock

Even if great care is taken to prevent the escape of fish from aquaculture, it might occur, and become detrimental to one or more native species. To avoid genetic impacts on wild stocks, techniques, such as chemical sterilization and polyploidy, could be used to produce cultivars for stocking that are unable to reproduce (Rogne, 1995, Stickney 1997). Also, it should be prudent to avoid the culture of exotic species except for making sure that the escapees will not be able to establish reproducing populations.

Reducing use of chemicals

To control diseases and reduce fouling of cages, a wide range of chemicals is used by the aquaculture industry. As mentioned in the previous section, those chemicals may have adverse effects on the local environment. For sustainable development, effective regulation is important to control the use of chemicals, with proper standards for monitoring and administrating their use. However, it is costly to implement these works. If possible, national agencies should establish dialog and collaborate with the private sector (particularly local farmers), non-governmental organizations and international institutions (Corbin and Young 1997).

6.4 Other issues of sustainability

6.4.1 Risk

Aquaculture is a relatively new technology and hence risky for new entrants. Producers face a variety of production related risks, and risks such as the fluctuation of market demand are also particularly important. Price volatility can be an important constraint and if prices paid to producers are subject to wide fluctuations, the viability of aquaculture could be threatened. Natural disasters may also be important; Taiwan is a typhoon and monsoon-prone country, with typhoons typically occurring almost 3-4 times each year. The development of some forms of aquaculture (such as cage culture) might be an impediment to some types of fishing activities, and therefore, vandalism or poaching may occur. Farms located in accessible public water bodies may be especially vulnerable. Aquaculture is in turn often impacted by other activities. Water pollutants (e.g. heavy metals, chemical wastes, and pesticides from industries, agriculture and domestic sewage) can threaten its environments. The contamination of products that are harmful to the health of customers might also threaten development. In Taiwan, oyster had been found to be contaminated by the discharge of copper compound from recycling factories (Han and Huang 1990), and although the incidence was just local, the oyster farmers of whole island suffered.

6.4.2 Role of the government and other institutions

The sustainability of aquaculture in Taiwan could be considered to have reached a crossroads. Further development needs a reorientation not only in operation and management at the farm level but also greater control, integrated planning, and management of the industry by the state (Chua 1997). National policies are important to the development of aquaculture and can have major impact on the distribution of benefits. A national policy not only contributes to the avoidance of use conflicts but also creates investment opportunities for the new economic activities, such as cage culture. The development of aquaculture requires certain interventions from government, including appropriate policies and planning, and the development and adoption of new technologies. The appropriate roles of government would include national planning and legislation, infrastructure support, research, extension and information service.

Government can also promote the establishment of cooperatives for fish farmers, though which would be easier and more effective for extension workers to disseminate information and training. Currently, the lack of appropriate extension services has resulted in farmers engaged in aquaculture relying heavily on their own perception and their neighbors' or friends' experience. Extension services should be geared toward promotion of technologies for and adoption of aquaculture and economic analysis. These advisory efforts may include site selection and construction, feed composition and management, water quality control, disease management and marketing. Encouraging research institutes to link to industry needs and participation can also help the development of extension work. Interventions should be targeted to promote the long-term environmental and economic sustainability.

When planning an aquaculture development project, both positive and negative aspects have to be identified and valued, and compared with alternative opportunities in using limited resources. For developing aquaculture, government needs to set up the agenda, which includes the necessary administrative, promotional, regulatory and enforcement frameworks. The process of policy formation includes problem definition, criteria for evaluation, generation of alternatives, procedures for implementation, and identification for next steps, which include procedures for monitoring, evaluation and reassessment (Corbin and Young 1997).

Government could take the lead in cooperation with the industry, providing the guidelines and management measures to prevent, control and mitigate adverse impacts. To guide sustainable development for aquaculture as for other sectors, externalities and socioeconomic feasibility should be assessed more comprehensively. The misuse of scarce resources often results in real social losses in the long term and will undermine the basic requirements for sustainable development. If the farms aim to maximize the profits rather than cover the social costs, selective economic intervention from government may be required providing good practice, but to bringing private costs of farms into line with their social costs, thereby, internalizing the environmental externality (Shang and Tisdell 1997). To encourage internalization, incentives, such as tax reductions, or controls such as heavy penalties can be used. Information for timely policy and management intervention, such as farming systems, financial investment, operators, products market, socioeconomic benefits and constrains must be gathered, updated, and analyzed by government.

When performing the plan, the cooperation of line agencies, non-governmental organizations and other stakeholders together with government should be sought to utilize power, influence, and resources to assure that industry embraces the desired characteristic through direct and indirect intervention (Corbin and Young 1997). The local administrative structure (in Taiwan, such as fishery agencies in local government) has the greater ability to discern potential problems and can be more promptly and effectively engaged in preventive, rather than reactive management (Chua 1997). For the long-term development of aquaculture, local government must understand the economic values and social benefits and commit to development. However, potential issues of the costs and effectiveness of enforcement activities need to be realized, and self-regulation or voluntary compliance could be encouraged where feasible to reduce the necessity and costs of governmental oversight

6.5 Discussion

No matter how ecologically sound, the industry of aquaculture cannot attain sustainability if it is not profitable. Neither will it be sustainable, if it is not ecologically sound, no matter how productive or profitable it may be in the short run. Improvements in aquaculture will not be sustainable unless they are met by adequate policies, socio-economic criteria and an environmentally sound regulatory framework (Anon 2000). Successful sustainable aquaculture has to maintain an aim of meeting requirements for production at socially acceptable economic and environmental costs. The most sustainable development will be one that attains the best possible relationship of the forces active in the local and regional dynamic of cultural and economic systems as well as in larger dynamic, but normally slower-changing, ecological system (Bardach 1997).

In the Philippines and other developing countries, the development of intensive aquaculture had confronted a range of social impacts. These include the displacement of labour, credit monopoly by big businessmen and the transfer of natural resources into privately-owned single purpose resource. Intensive aquaculture with its high capital cost has a poor employment-to-investment ratio, and the benefits have remained with farm owners, entrepreneurs and traders without trickling down to community residents (Primavera 1991). The development of aquaculture has not improved living standards nor village welfare, but instead, brought about social displacement and marginalization of fishermen on the top of ecological cost. In contrast, the situation of aquaculture in Taiwan is different. High risk, lack of capital and the characteristics of the Taiwanese people and society have caused most aquatic farms to be small to medium sized, instead of being monopolized by corporate interests. However, they then could not get the advantage of economies of scale. To commercialize, producers require high capital input. Well-organized production and marketing groups, fishermen associations or big businessmen in joint ventures with their own collateral, together with the credit offered by banks and financial institutes, might help to overcome this problem.

To develop aquaculture, the first question is whether a suitable market exists, expressed as potential sales volume, price and harvest pattern. For example, cage aquaculture is a new industry in Taiwan and the commercial distribution of its production is problematic. Aquaculture products can enjoy distinct advantages over those from capture fisheries, offering to remove the uncertainty of supply associated with traditional fishing, enabling food retailers to place contracts and plan forward sales, as is customary for conventional livestock products. Harvest can be timed to get maximum price benefit. Contract growing also offers advantage to the processor, with uniform supply and higher levels of plant utilization (Lee 1981).

The demand for fish will be influenced not only by its price, but also by the price of potential substitutes (such as white and red meat), as well as by habits, health consciousness and income levels of consumers (Shepherd and Bromage 1992). An important factor for Asia's dominance in aquaculture is that demand for fish is higher than that for poultry and red meat when compared with Europe or North America, due in part to traditional eating habits (Shepherd and Bromage 1992). To compete with other meat product, uniform, palatable products are essential and products with off-flavor or undesirable sizes should be rejected.

Often, quality and uniformity of the product can improve the marketability of aquaculture products, as compared to those from capture fisheries. In order to achieve maximum profits, it is clearly important to organize harvesting, packing, processing and distribution of the products. The increasing awareness of quality among consumer and the high quality standards of many importing countries has necessitated the processor of aquaculture products to adopt guaranteed methods of assuring product quality and safety. The implementation of quality management systems, fulfilling the requirements of internationally accepted standard, for example, the Hazard Analysis Critical Control Point (HACCP) (Subasinghe 1996) and the ISO 9000 series (Jakobsen 1993), is an effective way to meet and even profit from the increasing demands raised by customers.

The past emphasis on maximizing the efficiency of producing a single food commodity has led to very high harvest levels per unit surface area. However, the environmental cost of such monocultures is also very high. When compared to low-density culture, intensive farms are more vulnerable to diseases because the crowding and build-up of wastes favors the growth and transmission of pathogens (Primavera, 1991). As a consequence chemicals or antibiotics may be overused. The release of byproducts (such as excess lime, organic wastes, pesticide, and disease micro-organisms) may directly or indirectly affect estuarine and marine organisms and produce resistant strains of pathogens. Withdrawal of groundwater and pumping of harmful byproducts into coastal waters may produce largely negative results. The dilution of pollution by and of aquaculture is being less and less accepted publicly. Good farm management practices, such as using good site selection and design; adding effluent treatment ponds; using various modes of water recycling and aeration; controlling stock rates; using biofilter and sediment management; maintaining adequate distances between groups of cages might all reduce the pollution and internalize the externalities (Shang and Tisdell 1997). However, these are big challenges for engineers and biologists. To further simplify the control and regulation of environmental impacts related with aquaculture, the development of aquacultural zones and a sound licensing system might be useful. In Taiwan, the monitoring of environmental quality and the enforcement of regulations on licensing are still not well grounded.

For reducing the overuse of limited resource, aquaculture in Taiwan can try to change towards greater specialization in particular aspects, such as fry or fingerling production for export to other countries. Ancillary products, such as feeds, chemicals, aerator, pumps and the technology can also be exported to other countries. However, this requires particular skills, which will need to be provided.

The health and potential of a national aquaculture industry depends on economic factors, legal policies (legislative, judicial and enforcement), government/ private-sector cooperation, import-export policy, and customers' practice (Bardach 1997). The role of government in guiding, directing, and monitoring the development of aquaculture is important to achieve expansion in a way most beneficial for society (Corbin and Young 1997). It is important to realize that natural resources should be shared with all potential users in a way that will benefit the society while not harming the ecosystem. The problems of aquaculture can be solved by learning from experience and finding ways to tackle them as they arise, not only in theory but by combining this with practical application. Even though Taiwan has experienced a prosperous period in aquaculture, a growing industry in itself is not a measure of success. It is the content of growth that matters (Arrow *et al.*, 1995). The success of aquaculture should be measured not by fish production alone but by a range of fish and other crop products, and environmental and cultural benefits.

Chapter 7

Conclusions

7.1 Introduction

In Taiwan, the history of aquaculture spans over 300 hundred years. However the problems of environmental deterioration, diseases, and export market competition with other countries have caused Taiwan to readjust the direction of its aquaculture development. Here, three main strategies for readjustment - adjusting existing production (e.g. diversifying productive and marketing strategies), improving existing systems (e.g. intensification of eel culture to reduce use of ground water) and developing new systems (e.g. cage culture) were examined, with pond based milkfish culture, pond and tank culture of eel and cage culture of higher value marine fish the focus of study.

7.2 Milkfish culture

The success of artificial propagation of milkfish caused traditional fry collection from the wild to decline, with the potential supply of hatchery fry being more than enough for domestic demand. However, the seasonal shortage of fry required some farmers to import fry to stock before May. The development of deep water culture has increased the density and productivity of milkfish culture. However, cold weather is a significant problem, as mass motalities arise as water temperature drops below 10 °C, it cause.

This survey suggested that milkfish culture is not economically sound and showed that more than 75% of milkfish farmers had other source of family income. A number of farmers used polyculture with other species to spread risk and increase revenue. However only farm sizes in the 4-< 5 ha category showed higher profit levels than monoculture. When farm size exceeded 5 ha, it might be difficult for a family to manage. In the future, milkfish farm could be adjusted to 4-<5 ha, or replaced by better managed, industrialised, larger farms.

The marketing channel for milkfish is very complex. It might be possible to shorten this by strengthening the functions of production and marketing groups. The price of milkfish is easily influenced by production quantity and seasonal variation, and therefore, better information on expected production levels and better harvesting strategies could be important in improving the market power. Although the low price of milkfish can be considered as an advantage in competing in wider food markets, however, their boniness is a disadvantage for consumer preference. Here, new techniques such as those of boneless preparation may offer future advantages. Proper management in fish farms and appropriate quality control through Fishermen Association, and production and marketing groups might improve the image of milkfish to fetch a higher price.

7.3 Eel culture

Eel culture is one of the most important aquaculture sectors in Taiwan with total value the highest among all aquaculture sectors, and almost 90% of production exported to Japan. However, the limited land and water resource, a shortage of eel seed, and the competition with China for Japanese market has caused this sector to decline. To overcome these problems, super-intensive systems based on the culture of European glass eel have been introduced.

Although super-intensive system show higher average profit, the distribution of profitability shows that it is still possible for traditional eel culture to have a higher profit than super-intensive culture. Most farmers still do not want to try more intensive eel culture as it is difficult for many to invest amount of 7,000,000 NT$ (218,750 US$) or more in the necessary facilities. Farmers also consider that the growth rate of eel in super-intensive system is slower than in traditional system. However, when the effect of social cost, such as the cost of ground water extraction, was considered, super intensive eel culture was more economically sound than traditional eel culture.

The mass production of eel from China may make a big impact on Taiwan's eel industry, as both areas depend on the Japanese market very strongly. It might be important to differentiate the quality of eel and to develop new products. In addition to improving products and extending product range, it might also be useful to develop domestic market. To develop a domestic market, it is important to create new products which are more suitable for Taiwanese consumers, and reduce the production cost, such as increasing survival rate and reducing feed cost.

In the future, Taiwan might lose the advantage of cost if environmental costs are brought into consideration, and lose competitive advantage to China to the Japanese market. To negotiate with Japanese counterparts to obtain a better import quota might be critical in the near future.

7.4 Cage culture

Cage culture is a new sector of aquaculture in Taiwan, with typical unit being25-75 cages run by family from hatchery fry. This sector was found to be broadly profitable as most species grown can fetch a sufficiently high price to generate profit. Feed is the highest operating cost and represent 40-56% of the total operating cost, suggesting that reducing feed cost is an important issue.

Although this survey found Dumerils's Amberjack (*Seriola dumerili*) and red porgy (*Pagrus major*) can make higher profit than other species, producers have great expectation for cobia (*Rachycentron canadus*). A notable variation in profitability was observed for the species currently farmed, with 18.47 million NT$ profit in Dumerils's Amberjack and 6.42 million NT$ in grouper (*Epinephelus spp.*). Market sizes in all cases were relatively small, though there is a potential market for cobia in the Japanese market as raw fish (sashimi). The likely impacts of expanded production might be an environmental impact and a limited market. However, increasing farm size might result in economies of scale, and so reduce the production cost and selling price. This should increase market size.

The sector is restricted by specific environmental condition with strong currents and typhoon exposure as serious potential constraints. The improvement of cage structures and systems to enable them to reliably withstand poor weather conditions is therefore crucial for development, as though theoretical returns currently appear to be acceptable, the risks may be perceived to be too high for significant investment. A survey of current farm units revealed that mortality rates were very high, either because of diseases poor nutrition or unhealthy fry. Further research in diseases, nutrition, hatchery production and fry quality would be helpful.

As Taiwan's market is not big enough, this is primarily on the hope that cobia can become a candidate for sashimi in Japanese market. For the further development of cage culture, marketing promotion is required.

7.5 Sustainability

A sustainable aquacuture industry must be economically viable, ecologically sound and socially acceptable. To improve financial performance, it is suggested to set up a production and marketing group through which producers might be able to control production level, enlarge economies of scale, shorten marketing channel, control the quality of products, and promote products.

To protecting the environment, zoning of production areas is suggested. Well-controlled zoning of aquaculture production can avoid conflict between fish farmers and other interested user, provide opportunities for the government and private sector to systematically plan and develop the allocated areas, and protect environment from adverse effects of aquaculture or other activities.

The development of aquaculture requires appropriate policy approaches and certain interventions from government, including appropriate national planning and legislation, infrastructure support, research, extension and information service. In carrying out such initiatives, government agents should use power, influence and resources to assure that industry embraces the desired characteristic through direct or indirect intervention. However, self -regulation or voluntary compliance should be encouraged to reduce the necessity and costs of governmental oversight.

7.6 Further research

7.6.1 Economies of scale and industry aggregation

In this research, although there were apparent relationship in specific cases, the evidence of economies of scale was ambiguous, and it is not really clear what effect increasing the scale of production has on efficiency and unit cost. The lack of evidence of economies of scale was in part due to the limited sample sizes, as there were only 64, 5 and 22 samples in traditional eel culture, super intensive eel culture and cage culture, respectively. Although there were larger sample sizes in milkfish culture and farm sizes in the categories of 4-<5 ha appeared to be more profitable than other categories, the economies of scale were not still very clear. This may have been due to the relatively poor financial returns in the sector, or deficiencies in data quality. In all cases there may have been to high level of site or operator-specific variability in performance to identify clear scalar relationships. Related to this is the question of whether such economies were leading to changes in farm size and possible concentration of production into smaller number of larger, more efficient units.

7.6.2 Market research

This is very important for new product development, since the success of product innovation depends on being able to identify and measure demand characteristics of potential purchasers. In this research some market features and consumer attitudes can be further investigated, e.g. most eel were exported to the Japanese market, wherein, the attitude of Japanese consumers towards different eel products and products from different countries would be very valuable in understanding potential competitiveness.

Another area of research concerns the attitude of consumers towards new products, such as boneless preparation in milkfish, as the cost of this preparation and the prices that consumers would be willing to pay would be crucial for the wider adoption and development of this technique. More broadly, consider future potential for expansion, demand elasticity must also be considered in pricing, and further research in measuring the (expand) E.O.D. for aquaculture products and species wouls be important.

7.6.3 External costs of aquaculture

Intensification of aquaculture in Taiwan has stimulated the use of more chemicals, and with great nutrient input, created more serious eutrophication. The overuse of ground water had also caused serious land subsidence. Although the social cost of ground water was estimated in this research, the costs of pollution and other impacts of aquaculture is as yet relatively unexplored, and the methods used to estimate social costs of ground water are themselves controversial. Further researches is required across all the issues of externalities.

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Annex A.1 The questionnaire for milkfish farmers

1. Farm environment

1.1 The ownership of the land for fish farm

☐ Owned by yourself ☐ Rent from government ☐ Rent from private

☐ Others ____________________

1.2 Farm size

Pond size	Number

1.3 Water source

☐ Underground water ☐ Stream or rive ☐ Reservoir ☐ Sea water

☐ Others

1.4 Type of culture ☐ Monoculture ☐ Polyculture

1.5 If polyculture, what kind of fishes are cultivated with milkfish?____________

____

2. Production costs and revenues

2.1 Capital cost

Items	Number	Price	Useful life	Cost of maintenance
Land Cost				
Workshed and storage house				
Pond construction				
Power generator				
Paddle wheel				
Feeder				
Pump				

2.2 Cost of fingerlings

Amount	Price

2.3 Cost of labor

	Number	Wage
Full time labors		
Part time labor		

2.4 Cost of feed

	Amount	Price
Fingerling		
Juvenile		
Marketing size		

2.5 Other costs

Items	Amount	Price
Chemicals		
Electricity		
Miscellaneous		

2.6 Revenues

Harvest amout	Size	Price

3. Personal information

3.1 Age: ________________

3.2 Education attainment

☐ None ☐ Elementary ☐ Junior high school ☐ Senior high school
☐ College or above

3.3 Experience in milkfish culture

☐ 1-10 years ☐ 11-20 years ☐ 21-30 years ☐ 31-40 years
☐ 40 years and above

3.4 Is milkfish culture your only source of family income

☐ Yes ☐ No

Annex A.2 The questionnaire for traditional eel farmers

1. Farm environment

1.1The ownership of the land for fish farm

☐ Owned by yourself ☐ Rent from government ☐ Rent from private

☐ Others ______________________________

1.2 Farm size

Pond size	Number

1.1 Water source

☐ Underground water ☐ Stream or rive ☐ Reservoir ☐ Others

1.2 Type of culture ☐ Monoculture ☐ Polyculture

1.3 If polyculture, what kind of fishes are cultivated with eel?______________

2. Production costs and revenues

2.1 Capital cost

Items	Number	Price	Useful life	Cost of maintenance
Land Cost				
Workshed and storage house				
Pond construction				
Power generator				
Paddle wheel				
Pump				

2.2 Cost of eel seed

Amount	Price

2.3 Cost of labor

	Number	Wage
Full time labors		
Part time labor		

2.4 Cost of feed

	Amount	Price
Eel seed		
Juvenile		
Marketing size		

2.5 Other costs

Items	Amount	Price
Chemicals		
Electricity		
Miscellaneous		

2.6 Revenues

Harvest amout	Size	Price

3. Personal information

3.1 Age: ________________

3.2 Education attainment

☐ None ☐ Elementary ☐ Junior high school ☐ Senior high school
☐ College or above

3.3 Experience in eel culture

☐ 1-10 years ☐ 11-20 years ☐ 21-30 years ☐ 31-40 years
☐ 40 years and above

3.4 Is eel culture your only source of family income

☐ Yes ☐ No

Annex A.3 The questionnaire for super-intensive eel farmers

1. Farm environment

1.1 The ownership of the land for fish farm

☐ Owned by yourself ☐ Rent from government ☐ Rent from private
☐ Others ________________________________

1.2 How many intensive systems in your farm.____________

1.3 Farm size

Tank size	Number

1.4 Water source

☐ Underground water ☐ Stream or rive ☐ Reservoir ☐ Others

2. Production costs and revenues

2.1 Capital cost

Items	Number	Price	Useful life	Cost of maintenance
Land Cost				
Workshed and storage house				
Cost of systems				

2.2 Cost of eel seed

Amount	Price

2.3 Cost of labor

	Number	Wage
Full time labors		
Part time labor		

2.4 Cost of feed

	Amount	Price
Eel seed		
Juvenile		
Marketing size		

2.5 Other costs

Items	Amount	Price
Chemicals		
Electricity		
Oxygen		
Miscellaneous		

2.6 Revenues

Harvest amount	Size	Price

3. Personal information

3.1 Age: ________________

3.2 Education attainment

☐ None ☐ Elementary ☐ Junior high school ☐ Senior high school
☐College or above

3.3 Experience in eel culture

☐ 1-10 years ☐ 11-20 years ☐ 21-30 years ☐ 31-40 years
☐ 40 years and above

3.4 Is eel culture your only source of income

☐ Yes ☐ No

Annex A.4 The questionnaire for cage farmers

1. Farm environment

1.1 Farm size

Kinds of cages	Number	Size

1.2 Culture species ____

2. Production costs and revenues

2.1 Capital cost

Items	Number	Price	Useful life	Cost of maintenance
Cage (include net)				
Rope				
Buoy				
Anchoring				
Install				
Workshed and storage house				
Boat				
Engine of outside boat				

2.2 Cost of fingerling

species	Amount	Price

2.3 Cost of labor

	Number	Wage
Full time labors		
Part time labor		

2.4 Cost of feed

Species	Amount	Price

2.5 Other costs

Items	Amount	Price
Fuel		
Miscellaneous		

2.6 Revenues

Species	Harvest amout	Size	Price

3. Personal information

3.1 Age: ________________

3.2 Education attainment

☐ None ☐ Elementary ☐ Junior high school ☐ Senior high school
☐College or above

3.3 Experience in cage culture

☐ 1-10 years ☐ 11-20 years ☐ 21-30 years ☐ 30 years and above

3.4 Is cage culture your only source of family income

☐ Yes ☐ No

Annex A.5 The questionnaire for consumers of milkfish

1. What kind of products of mikfish do you prefer?

☐ Fresh fish ☐ Canned fish ☐ Fish meat ball ☐ Others ____________

2. What kinds of fresh part of milkfish do you prefer?

☐ Whole fish ☐ Scaled and gutted whole fish ☐ Head ☐ Belly part

☐ Others________________

3. Which season do you prefer for purchasing milfish?

☐ Spring ☐ Summer ☐ Autumn ☐ Winter ☐ Uncertain

4. What are your preferred purchasing sizes of milkfish?

☐ 300g ☐ 600g ☐ 900g ☐ 1200g

5. What are the frequencies of buying milkfish?

☐ Every week ☐ Every two weeks ☐ Every three weeks ☐ One month

☐ Uncertain

6. What are the amounts of buying milkfish every time?

☐ About 600g ☐ About 1200g ☐ About 1800g ☐ Uncertain

7. What are the reasons that you do not buy milkfish?

☐ Bony ☐ Too expensive ☐ Others______________________

8. What is your opinion concerning the price of milkfish?

☐ Very expensive ☐ Expensive ☐ Acceptable ☐ Cheap ☐ Very cheap

9. What is your opinion concerning the quality of milkfish?

☐ Excellent ☐ Good ☐ Acceptable ☐ Bad ☐ Very bad

10. What is your evaluation concerning the price and quality of milkfish?

☐ Excellent ☐ Good ☐ Acceptable ☐ Bad ☐ Very bad

11. What kinds of situations will you buy more milkfish?

☐ Price is cheaper ☐ Quality is better ☐ Others

Annex A.6 The questionnaire for consumers of eel

1. What kind of products of eel do you prefer?

☐ Fresh fish ☐ Frozen roasted ☐ Others ____________________

4. Which season do you prefer for purchasing eel?

☐ Spring ☐ Summer ☐ Autumn ☐ Winter ☐ Uncertain

5. What are your preferred purchasing sizes of eel?

☐ 200g ☐ 300g ☐ 600g

6. What are the ways that you cook eel?

☐ Stewed with Chinese herbs ☐ Roasted ☐ Others

7. What are the frequencies of buying eel?

☐ Every week ☐ Every two weeks ☐ Every three weeks ☐ One month

☐ Uncertain

8. What are the amounts of buying eel every time?

☐ About 600g ☐ About 1200g ☐ Uncertain

9. What are the reasons that you do not buy eel?

☐ Bony ☐ Too expensive ☐ Difficult to cook ☐ Others___________

10. What is your opinion concerning the price of eel?

☐ Very expensive ☐ Expensive ☐ Acceptable ☐ Cheap ☐ Very cheap

11. What is your opinion concerning the quality of eel?

☐ Excellent ☐ Good ☐ Acceptable ☐ Bad ☐ Very bad

12. What is your evaluation concerning the price and quality of eel?

☐ Excellent ☐ Good ☐ Acceptable ☐ Bad ☐ Very bad

13. What kinds of situations will you buy more eel?

☐ Price is cheaper ☐ Quality is better ☐ Others

Annex B.1 The culture area for milkfish in Taiwan from 1987 to 1997.

Unit: ha

Year	Total aquaculture area		Area			R1*	R2**
			Brackish pond	Fresh water pond	**Subtotal**		
1987	**66,302.12**	monoculture	6117.00	763.20	6,880.20	**12.53**	**12.53**
		polyculture	841.84	588.40	1,430.24		
		Subtotal	**6,958.84**	**1,351.60**	**8,310.44**		
1988	**67,406.10**	monoculture	4659.60	1092.11	5,751.71	**11.19**	**11.19**
		polyculture	1068.24	720.57	1,788.81		
		Subtotal	**5,727.84**	**1,812.68**	**7,540.52**		
1989	**71,082.53**	monoculture	4986.62	1204.30	6,190.92	**13.23**	**13.23**
		polyculture	1663.53	1552.47	3,216.00		
		Subtotal	**6,650.15**	**2,756.77**	**9,406.92**		
1990	**76,421.90**	monoculture	6781.23	2460.12	9,241.35	**16.81**	**16.81**
		polyculture	2207.92	1395.73	3,603.65		
		Subtotal	**8,989.15**	**3,855.85**	**12,845.00**		
1991	**74,078.76**	monoculture	6546.21	1802.63	8,348.84	**16.97**	**16.97**
		polyculture	2225.84	1993.67	4,219.51		
		Subtotal	**8,772.05**	**3,796.30**	**12,568.35**		
1992	**72,293.00**	monoculture	6508.13	1685.93	8,194.06	**17.30**	**17.30**
		polyculture	2833.05	1476.61	4,309.66		
		Subtotal	**9,341.18**	**3,162.54**	**12,503.72**		
1993	**70,965.01**	monoculture	5403.14	1624.11	7,027.25	**15.05**	**14.38**
		polyculture	1801.31	1375.74	3,177.05		
		suspended	363.62	113.12	476.74		
		Subtotal	**7,568.07**	**3,112.97**	**10,681.04**		
1994	**69,602.78**	monoculture	5655.66	1533.29	7,188.95	**16.17**	**14.97**
		polyculture	1834.48	1398.01	3,232.49		
		suspended	702.97	130.53	833.50		
		Subtotal	**8,193.11**	**3,061.83**	**11,254.94**		
1995	**70,075.31**	monoculture	6166.61	1436.86	7,603.47	**17.33**	**16.13**
		polyculture	1887.45	1872.29	3,759.74		
		suspended	713.43	70.50	783.93		
		Subtotal	**8,767.49**	**3,379.65**	**12,147.14**		
1996	**67,613.37**	monoculture	4062.60	1667.28	5,729.88	**17.43**	**14.30**
		polyculture	2408.22	1529.08	3,937.30		
		suspended	2071.89	44.60	2,116.49		
		Subtotal	**8,542.71**	**3,240.96**	**11,783.67**		
1997	**63,155.51**	monoculture	3247.87	1291.54	4,539.41	**17.16**	**14.75**
		polyculture	2719.01	2059.85	4,778.86		
		suspended	1420.82	97.90	1,518.72		
		Subtotal	**7,387.70**	**3,449.29**	**10,836.99**		

1998	**63,188.84**	monoculture	5278.57	1609.95	6888.52	**19.24**	**17.47**
		polyculture	1932.83	2219.50	4152.33		
		suspended	814.59	300.87	1115.46		
		Subtotal	**8,025.99**	**4,130.32**	**12,156.31**		
1999	**63,214.74**	monoculture	6146.93	1158.38	7305.31	**19.19**	**17.95**
		polyculture	1758.32	2281.66	4039.98		
		suspended	451.24	334.79	786.03		
		Subtotal	**8,456.49**	**3,774.83**	**12,131.32**		
2000	**62,567.10**	monoculture	6464.61	1363.42	7828.03	**22.61**	**21.35**
		polyculture	3337.22	2193.53	5530.75		
		suspended	602.29	184.23	786.52		
		Subtotal	**10,404.12**	**3,741.18**	**14,145.30**		

Data source: Year Book of Taiwan Fisheries Bureau

* R1 is the ratio of milkfish culture area to total aquaculture area in Taiwan.

** R2 is the the ratio of real milkfish culture area to total aquaculture area in Taiwan. The real milkfish culture area is referred to that the milkfish culture area deducts the suspended milkfish culture area.

Annex B.2 The production quantity and value of milkfish in Taiwan from 1987 to 1997.

Unit: mt/1000NT$

Year	Production quantity					Production value				
	Total Aqua-culture	Brack-ish water pond	Fresh water pond	**Total milk-fish**	**R1***	Total Aquaculture	Brackish water pond	Fresh water pond	**Total milk-fish**	**R2****
1987	305,428	**19476**	**9351**	**28,827**	**9.44**	35,232,460	**1058348**	**509924**	**1,568,272**	**4.45**
1988	300,974	**23161**	**16511**	**39,672**	**13.18**	34,478,389	**1168196**	**776820**	**1,945,016**	**5.64**
1989	249,755	**12601**	**8481**	**21,082**	**8.44**	26,524,516	**577103**	**417722**	**994,825**	**3.75**
1990	344,263	**75244**	**15429**	**90,673**	**26.34**	31,530,574	**2331927**	**481759**	**2,813,686**	**8.92**
1991	291,885	**27106**	**14126**	**41,232**	**14.13**	30,256,203	**980181**	**427909**	**1,408,090**	**4.65**
1992	261,648	**15580**	**9534**	**25,114**	**9.60**	29,292,039	**946343**	**517888**	**1,464,231**	**5.00**
1993	285,275	**16844**	**28669**	**45,513**	**15.95**	29,815,944	**760266**	**1157966**	**1,918,232**	**6.43**
1994	287,965	**26188**	**40590**	**66,778**	**23.19**	33,566,439	**1148663**	**1778478**	**2,927,141**	**8.72**
1995	286,634	**28058**	**35196**	**63,254**	**22.07**	36,514,231	**1455262**	**1900564**	**3,355,826**	**9.19**
1996	272,525	**27806**	**30647**	**58,453**	**21.45**	32,727,444	**1437008**	**2133046**	**3,570,054**	**10.91**
1997	270,139	**31259**	**31490**	**62,749**	**23.23**	27,100,002	**1321106**	**1335728**	**2,656,834**	**9.80**
1998	253,339	**28359**	**29990**	**58,349**	**23.03**	27,043,476	**1287480**	**1214694**	**2,502,174**	**9.25**
1999	263,069	**22649**	**28175**	**50,824**	**19.32**	23,780,415	**1104451**	**1320822**	**2,425,273**	**10.20**
2000	256,399	**16267**	**23463**	**39,731**	**15.50**	25,912,938	**880497**	**1138709**	**2,019,207**	**7.79**

Data source: Year Book of Taiwan Fisheries Bureau

* R1 is the ratio of total milkfish production quantity to total aquaculture production quantity.

** R2 is the ratio of total milkfish production value to total aquaculture production value.

Annex C.1 The seasonal variation of fresh eels imported from Taiwan for the Japanese market from 1994 to 1998. Unit: mt

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug	Sep.	Oct.	Nov.	Dec.	Ave
1994	592.73	348.69	555.02	557.84	731.91	1060.42	3087.21	1180.37	347.32	179.66	181.84	495.85	776.57
1995	667.59	490.60	732.82	801.41	781.01	820.84	2063.50	1061.02	142.30	154.20	228.42	519.82	705.29
1996	463.13	481.50	562.11	557.29	545.50	783.01	1869.81	1189.13	485.20	316.39	287.01	527.07	672.26
1997	453.29	488.61	503.24	515.07	601.49	978.08	2463.32	1123.66	644.01	472.71	482.04	720.07	787.13
1998	806.64	757.08	663.65	646.79	602.01	763.82	1565.90	636.78	337.41	294.03	401.20	646.56	676.82
Ave.	596.67	513.30	603.37	615.68	652.38	881.23	2209.95	1038.19	391.25	283.40	316.10	581.87	723.62
Index	82.46	70.93	83.38	85.08	90.16	121.78	305.40	143.47	54.07	39.16	43.68	80.41	100.00

Data source: Customs Bureau, Ministry of Finance, Japan.

Annex C.2 The seasonal variation of fresh eels imported from China for the Japanese market from 1994 to 1998. Unit: mt

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug	Sep.	Oct.	Nov.	Dec.	Ave
1994	586.94	589.25	432.80	403.96	419.55	334.31	739.53	542.18	488.11	350.45	411.25	400.41	474.90
1995	286.49	172.37	174.93	172.16	150.26	439.45	661.45	537.40	203.63	131.17	118.77	107.96	263.00
1996	155.92	118.83	110.85	155.38	237.42	458.19	778.41	157.06	138.49	123.51	248.60	413.49	258.01
1997	383.74	279.12	256.24	296.16	323.40	520.58	728.73	146.42	112.78	167.00	247.14	280.24	311. 80
1998	166.69	157.36	319.18	400.05	431.05	509.24	948.48	204.35	123.99	152.46	394.46	521.20	360.71
Ave.	315.96	263.39	258.80	285.54	312.34	452.35	771.32	317.48	213.40	184.92	284.04	344.66	333.68
Index	94.69	78.93	77.56	85.57	93.60	135.56	231.15	95.14	63.95	55.42	85.12	103.30	100.00

Data source: Customs Bureau, Ministry of Finance, Japan.

Annex C.3 The seasonal variation of processed eels imported from Taiwan for the Japanese market from 1994 to 1998. Unit: mt

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug	Sep.	Oct.	Nov.	Dec.	Ave
1994	996.44	1039.20	1270.78	1567.14	1435.97	1244.64	1974.09	878.66	1096.62	583.96	707.38	495.15	1107.50
1995	265.88	431.54	787.16	1308.97	1192.38	1069.87	636.50	240.60	274.86	296.86	248.76	359.98	592.78
1996	295.01	279.36	448.33	942.94	970.88	1084.30	694.04	279.65	503.72	323.86	327.35	300.38	537.49
1997	332.56	357.67	644.82	510.37	548.59	513.76	407.72	336.24	463.44	240.51	169.34	206.46	394.29
1998	258.98	199.35	428.57	426.49	470.83	477.99	261.17	31.77	53.42	53.76	125.44	148.85	244.72
Ave.	429.77	461.42	715.93	951.18	923.73	878.11	794.71	353.38	478.41	299.80	315.65	302.16	575.35
Index	74.70	80.20	124.43	165.32	160.55	152.62	138.12	61.42	83.15	52.11	54.86	52.52	100..00

Data source: Customs Bureau, Ministry of Finance, Japan.

Annex C.4 The seasonal variation of processed eels imported from China for the Japanese market from 1994 to 1998. Unit: mt

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug	Sep.	Oct.	Nov.	Dec.	Ave
1994	2023.65	1332.29	1601.87	2700.15	2737.76	2325.88	2130.83	1186.54	854.38	2170.42	2144.22	2416.60	1968.72
1995	1885.78	1250.62	2000.37	2595.63	3410.50	3780.80	3044.15	1138.45	823.70	2169.09	2996.18	2434.88	2294.18
1996	2870.11	1913.24	1461.38	3919.93	5883.35	5747.87	3632.94	1701.51	1767.18	2564.78	2801.07	3541.58	3150.41
1997	4922.67	3117.71	4439.24	5181.08	6679.40	5403.38	4864.33	2657.37	3014.66	3297.17	3086.33	2801.67	4122.08
1998	2722.66	2463.45	4353.19	6268.52	5969.87	4736.54	5851.05	3190.35	1586.44	2487.96	4176.04	3656.49	3955.21
Ave.	2884.97	2015.46	2771.21	4133.06	4936.18	4398.89	3904.66	1974.84	1609.27	2537.89	3040.77	2970.25	3098.12
Index	93.12	65.05	89.45	133.41	159.33	141.99	126.03	63.74	51.94	81.92	98.15	95.87	100.00

Data source: Customs Bureau, Ministry of Finance, Japan.

Annex D.1 Production and value of different species used in cage culture in Taiwan.

Unit: ton, thousand NT$

	Offshore cage culture				Inland cage culture			
Year	Species	Quantity	Value	V/Q	Species	Quantity	Value	V/Q
1989	Black sea bream	5	1000	200	Tilapia	475	17527	37
	Misc. sea bream	16	2218	139	Common carp	118	5310	45
					Crucian carp	8	416	52
					Big head carp	1	47	47
					Perch	26	3930	151
					Milk fish	5	250	50
1990	Red porgy	1	200	200	Tilapia	534	17070	32
	Black sea bream	3	518	173	Common carp	110	4730	43
	Misc. sea bream	99	13009	131	Crucian carp	19	969	51
					Eel	1651	231177	140
1991	Misc. sea bream	86	11541	134	Tilapia	366	9742	27
					Common carp	121	4356	36
					Crucian carp	21	945	45
1992	Red porgy	69	20859	302	Tilapia	218	6322	29
	Misc. sea bream	53	8289	156	Common carp	96	3840	40
	Malabar cavalla	8	179	22	Crucian carp	16	736	46
1993	Red porgy	58	18241	315	Tilapia	209	6509	31
	Misc. sea bream	80	13288	166	Common carp	120	5400	45
					Crucian carp	36	1872	52
					Other fishes	3	174	58
1994	Red porgy	59	20644	350	Tilapia	11	281	26
	Misc. sea bream	91	15634	172	Common carp	3	99	33
					Crucian carp	5	350	70
					Other fishes	2	72	36
1995	Red porgy	137	47692	348				
	Misc. sea bream	108	18686	173				
	Brown croakeer	31	3320	107				
	Groupers	68	22130	325				
	Cobia	3	1050	350				
	Other scads	2	350	175				
	Other fishes	8	858	107				
1996	Sea perch	16	1034	65				
	Red porgy	200	56913	285				
	Black sea bream	18	4186	233				
	Misc. sea bream	141	24870	176				
	Brown croakeer	27	2949	109				
	Groupers	141	38253	271				
	Cobia	13	4680	360				
	Other scads	20	1463	73				
	Other fishes	101	13154	130				
1997	Sea perch	10	756	76				
	Red porgy	261	75817	290				
	Black sea bream	16	3586	224				
	Misc. sea bream	137	24126	176				

	Brown croakeer	28	3027	108				
	Groupers	150	44559	297				
	Cobia	9	3330	370				
	Other scads	69	12471	181				
	Other fishes	156	18402	118				
1998	Sea perch	12	856	71				
	Red porgy	201	62133	309				
	Black sea bream	13	1820	140				
	Misc. sea bream	156	28698	184				
	Brown croakeer	29	3120	108				
	Groupers	151	38579	255				
	Cobia	17	2133	125				
	Other scads	98	16528	169				
	Other fishes	209	25775	123				

Data source: Year Book of Taiwan Fisheries Bureau