The Internal Structure And Development of Aquaculture in Taiwan

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Abstract

KEYWORDS: Internal Structure of Aquaculture, Aquaculture Development, Structural Adjustment.

This paper explores the economic implications concerning future aquaculture development in Taiwan. Also, historical development and internal structure of major species in terms of geographical distribution, operational structure, and income-cost structure are examined. It is suggested that structural adjustments concerning value-added, operational, and pricing are necessary for the future of Taiwan aquaculture.

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I. Introduction

Aquaculture development in Taiwan was motivated by strengthening fishery output and export during the 1950s and the 1960s. The "Five-Year Plan of Accelerating the Fishery Development in Taiwan" was implemented in September 1967 to further improve the fishery industry, including aquaculture (Shiung 1984) . The successful artificial breeding techniques for aquaculture purposes in the 1960s were an important milestone causing a significant increase in Taiwan's aquaculture output and income. The artificial fry procurement of grass, silver, and big head carps became reality in 1964. Experiments to artificially breed mud carp and mullet were successful in 1965 and 1970, respectively. In 1968, researchers created a method to artificially spawn six kinds of shrimp including kuruma, grass, and sand shrimps. The following developments added further support to a massive transition of aquaculture techniques and production in the 1960s and 1970s: improved eel cultivation, extended vertical and horizontal hang cultivation

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methods of oyster, and developed water reservoir, lake, and coastal cage or net fisheries. The output value of Taiwan's aquaculture had been the top one or two of the total fishery value since 1973. Those increasing include far-sea, offshore, coastal, and aquaculture output values between 1970 and 1991. Aquaculture had the largest growth rate (21.18 times) in terms of output value, followed by coastal fisheries (10.47 times), and far-sea fisheries (9.07 times). The output and value of inland water aquaculture has been dominating the marine culture and the inland fishing fisheries. The important causes of the successful improvement of Taiwan's aquaculture attributed not only to the fry procurement techniques in the 1960s but also the overall development of feeding, breeding, marketing, and production and processing techniques over time since 1953 (Chen and Lu 1970; Yuang and Che 1991).

For inland aquaculture, the market share of brackishwater aquaculture value had been decreasing when substituted by freshwater aquaculture. In 1971, the share of brackishwater aquaculture value in Taiwan decreased below 50%, and the share of freshwater aquaculture value increased significantly to 45.82% .After 1971, freshwater aquaculture value maintained a market share above 60%, except for the years 1986 and 1987. During the 1988-91 period, the average shares of brackishwater and freshwater aquaculture values were 34.04% and 64.07%, respectively. Other than the output value and market share, the problems of economic externalities for Taiwan's aquaculture development have recently caused attention and created a policy shift toward more restricted development of inland aquaculture. The externalities did not result from aquaculture production, they did however, greatly influence aquaculture including marine and freshwater pollution from industrial plants and inefficient development and plans for the domestic water resource system (Lai 1987). One major externality that resulted from aquaculture production was over-pumping underground water and the illegal cultivation of coastal land. Increased importance of inland freshwater aquaculture for domestic supply and foreign exports and the deteriorated externalities may require and internal change of production, operation, and income structures of the aquaculture industry in Taiwan.

Therefore, aquaculture structures need to be examined carefully to establish a new development strategy in association with more liberalized economy. This paper focuses on the analysis of the internal structure and development of Taiwan's aquaculture. The structure of aquaculture production is discussed in terms of aquaculture productivity and distribution. The operational structure is then analyzed by using data collected from samples of Taiwan's aquaculture farms. Finally, the income and cost strutures of Taiwan's aquaculture farms are analyzed. Several conclusions and suggestions are made in the final section.

II. Production Structure of Taiwan's Aquaculture

The production structure can be explained by the productivity and the regional production distribution by species. table 1 shows the productivity of Taiwan's fishery employment. Prior to 1970, the far-sea and offshore fisher-

Table 1 The Production and Labour Productivity of Taiwan's Aquaculture, selected year[a].

Year	Fishery Output			Fishery Value			Employment			Labour Productivity: Output			Labour Productivity: Value		
	Total Fishery (mt)	Aquaculture (mt)	Inland Aquaculture (mt)	Total Fishery (100NT)	Aquaculture (100NT)	Inland Aquaculture (100NT)	Total Fishery (persons)	Aquaculture (persons)	Inland Aquaculture[b] (persons)	Total Fishery mt/Person	Aquaculture[c] mt/Person	Inland Aquaculture[b] mt/person	Toatal Fishery 100NT/Person	Aquaculture[c] 100NT/Person	Inland Aquaculture[b] 100NT/Person
1965	381,690	54,160	43,478	3,276,549	708,734	647,294	276,155	- -	57,669	1.38	0.94	0.75	11.86	12.29	11.22
		(14.19)	(11.39)		(21.63)	(19.76)			(20.88)						
1970	613,152	72,725	54,833	7,156,553	1,367,994	1,057,568	259,470	- -	49,781	2.36	1.46	1.10	27.48	27.48	21.24
		(11.86)	(8.94)		(19.12)	(14.78)			(19.19)						
1975	779,951	127,577	96,263	17,378,424	6,612,510	5,464,204	293,792	- -	66,765	2.65	1.91	1.44	59.15	99.04	81.84
		(16.36)	(12.43)		(38.05)	(31.44)			(22.73)						
1980	936,334	175,008	145,020	46,085,630	15,070,740	12,201,198	308,981	- -	77,606	3.03	2.26	1.87	149.15	194.20	157.22
		(18.69)	(15.49)		(32.70)	(26.48)			(25.36)						
1985	1,037,721	253,144	214,668	66,892,997	25,418,005	22,001,409	363,733	100,173	86,531	2.85	2.93	2.48	183.91	293.74	254.26
		(24.39)	(20.69)		(38.00)	(32.89)			(23.79)						
1990	1,455,495	347,754	307,756	89,154,16	31,710,950	28,489,929	325,902		68,127	4.47	3.47	4.52	273.56	465.47	418.19
		(23.89)	(21.14)		(35.57)	(31.96)		(30.74)	(20.90)						

Source: Fishery Statistical Yearbook and Surver Report of Agriculture and Fishery, various years.

–: Not available

a: Figures in parentheses are share percentages. The aquaculture includes the marine culture, inland water fishing fishery, and inland water aquaculture.

b. The employment of the inland water fishing fishery is included in this category before 1988. The employment of the marine culture is included in the coastal Fishery between 1983-1988 and included in the far-sea fishery before 1983.

c: Divided by the employment of the inland aquaculture before 1988.

ies dominated the total fishery output and value. Taiwan's aquaculture output greatly increased in the mid-1970s, which was caused by the technical progress in culturing the major fish species. Between 1970 and 1990, aquaculture output, both in quantity and value, increased significantly. After the 1973 Conference of Ocean Law with the United Nations, it was announrked that most conuntries' ocean territory stretched to 200 miles; this announcement was considered detrimental to marine fishery sectors. Even though the announcement encouraged coastal fisheries and aquaculture output, the water pollution problem was not raised as a serious environmental or social problem until the early 1980s.

The aquaculture output rate decreased growth from 1985 to 1990, when the shortage of underground water and the polluted coastal and inland waters were serious. Over time, the aquaculture value increased and had more economic value than other fishery industries. It was clear that the high output value encouraged the movement of the domestic farm resources such as the farm land, fishpond, underground water, and farm labors toward inland aquaculture. In fact, the accompanied government control and management over aquaculture cultivation and competition from nearby countries became important factors restricting the aquaculture growth in Taiwan after 1985 (Jen 1990).

Dynamic structural changes of fishery and aquaculture production can be seen in their productivity. The unavailable total employment led to overestimated aquaculture productivities by using the inland aquaculture employment as the denominator before 1988. The decreased output of the total fishery in 1985 was mostly due to the depressed economic situation with a significant inflow of labors and other input resources. The high aquaculture productivities, found in the mid-1970s and the mid-1980s suggested major progress with aquaculture techniques. The techniques include increased cultural intensity,diversification, business orientation, cage or net cultivation, and monoculture (Yuang and Che 1991). In addition, the selection of high-value species combined with the limited growth of aquaculture employment had created superior aquaculture productivity, in terms of value, since the mid-1970s.

The production structure can be further explained by the farm scale and productivity in terms of the cultivation area (Table 2). The aquaculture area increased over time with a greater growth rate in the early 1970s and the late 1980s, after the successful development of many important artificial breeding and feeding techniques. Prior to 1980, the polyculture method was more extensively adopted than monoculture. However, monoculture had been more quickly and widely applied. This adoption created higher aquaculture value. The average family scale of Taiwan's aquaculture showed a decreasing, unstable trend over time, the smallest scale was in 1985. The increased family numbers of the marine culture and decreased family numbers of inland water aquaculture caused the increased average scale in 1990.

The productivity per hectare in terms of output and value showed an

Table 2 Taiwan's Aquacultural Area, Scale, and Productivity, selected years[a].

Year	Aquacultural Area			Total Output (mt)	Total value (100NT)	Total Aquacultural Family[b] (2) (units)	Average Aquacultural Scale (1)/(2) (ha/unit)	Average Aquacultural yield (mt/ha)	Average Unit Value (100NT/ha)
	Total (1) (ha)	Mono-Culture (ha)	Poly-Culture (acre)						
1965	38,148.3	24,693.7	13,454.6	54,160	708,734	14,713	2.59	1.42	18.58
	(100.0)	(64.7)	(35.3)						
1970	42,473.9	28,538.9	13,935.0	72,725	1,367,994	18,164	2.34	1.17	32.21
	(100.0)	(67.2)	(32.8)						
1975	53,606.5	31,771.5	21,835.0	127,577	6,612,510	22,536	2.38	2.38	123.35
	(100.0)	(59.3)	(40.7)						
1980	60,570.3	31,415.0	29,155.4	175,008	15,070,740	26,331	2.30	2.30	248.81
	(100.0)	(51.9)	(48.1)						
1985	65,979.7	36,835.3	29,144.4	253,144	25,418,005	30,407	2.17	2.17	385.24
	(100.0)	(55.8)	(44.2)						
1990	76,421.9	51,621.5	24,800.4	347,754	31,710,950	33,796	2.26	2.26	414.95
	(100.0)	(67.5)	(32.5)						

Source: Same as Table 1.

a: Figures in parentheses are share percentage.

b: Aquacultural family refers to the family of which members engage in aquacultural activities and receive the income of aquacultural production 50% on more than total income.

overall upward trend from 1970 to 1990. The increased growth rate of the average yield in the mid-1970s and after 1980 implies significant technical improvement over time. Moreover, the increased value had greater growth rates and smaller growth rates the increased output before and after 1985, respectively. Uncontrollable disease and deteriorated water quality killed large amounts of shrimp after the mid-1980s. This loss was the most important reason for a smaller increase of the average value per hectare in the late 1980s, and the early 1990s (Chen 1990).

The production structure can be further explained by the regional distribution and concentration of aquaculture by major category and species (Table 3). More than 98％ of the aquaculture area was cultivated for live fishes, shell fishes, lobster, and shrimps in 1990. Milkfish, tilapia, common carp, and eel are major species of live fishes under both monoculture and polyculture with concentration ratios over 75％ .However, the average unit prices were only high for eel as a major exporting product. Eel exports were in frozen and preserved forms creating nearly 500 thousand U.S. dollars of gross return in 1990. Moreover, the value of eel was 39％ of the aquaculture value and 13.87％ of the fishery value in 1990, respectively. High production cost, deteriorated environment, outflow investment trend, and competition from mainland China during recent years have restricted development of the eel industry in Taiwan (Chou 1991).

Among major aquaculture species, the milkfish development had not

Table 3 Taiwan's Aquacultural Area, Output, and Value by Product Category and Species, 1990[a].

Fish Category & Species			Total (ha)	Mono-re culture (ha)	Poly-Culture (ha)	Output (m.t.)	Value (1000NT)	Average Unit Price (1000NT/m.t.)	Major Four Production regions and concentration ratio[e]
Live Fishes	Subtotal		36,739 (48.1)	18,264 (35.4)	18,475 (74.5)	—	—	—	—
	Major Species	Milkfish[b]	12,850	9,246	3,604	90,716	2,815,829	31.04	Kaohsiung Pref., Chiayi Pref., Tainan Pref., Tainan city. (0.93)
		Tilapia	9,214	1,445	7,769	53,103	1,659,475	31.25	Tainan Pref., Chiayi Pref., Kaohsiung Pref., Yunlin Pref. (0.76)
		Common Carp	5,560	218	5,342	3,572	122,074	34.18	—
		Eel	3,966	3,948	18	55,837	12,368,099	221.50	Yunlin Pref., Changhwa Pref., Chiayi Pref., Kaohsiung Pref. (0.78)
		Others	5,149	3,407	1,742	—	—	—	—
Shell Fishes	Subtotal		24,478 (32.0)	20,625 (40.0)	3,853 (15.5)	—	—	—	—
	Major Species	Oyster	16,235	16,235	0	28,167	2,290,125	81.31	Chiayi Pref., Yunlin Pref., Tainan city, Changhwa Pref., (0.82)
		Hard Clam	5,119	2,416	2,703	18,630	1,124,143	60.34	Yunlin Pref., Changhwa Pref., Chiayi Pref., Tainan Pref., (0.99)
		Fresh-Water Clam[c]	2,636	1,526	1,110	16,211	743,831	45.88	Yunlin Pref., Changhwa Pref., Taoyuan Pref., Hwalien Pref. (0.99)
		Others	488	448	40	217,719	—	—	—

Table 3 Continue

Fish Category & Species			Total (ha)	Mono Culture (ha)	Poly-Culture (ha)	Output (mt)	Value (1000NT)	Average Unit Price (1000NT/mt)	Major Four Production Regions and Concentration Ratio[e]
	Subtotal		14,138 (18.5)	12,299 (23.8)	1,839 (7.4)	—	—	—	—
Lobster and Shrimps	Major Species	Grass Shrimp[d]	8,117	6,409	1,708	9,215	1,992,406	216.21	Tainan Pref., Chiayi Pref., Yunlin Pref., Pingtung Pref., (0.76)
		Kuruma shrimp	2,907	2,882	25	10,707	3,125,042	291.87	Yilan Pref., Pingtung Pref., Changhwa Pref., Yunlin Pref., (0.93)
		Giant Fresh Water Prawn	2,171	2,170	1	11,607	1,856,150	159.92	Pingtung Pref., Yunlin Pref., Kaohsiung Pref., Taitung Pref.(0.99)
		Others	943	838	105	—	—	—	—
Others			1,066 (1.4)	434 (0.8)	633 (2.6)	—	—	—	—
Total			76,421 (100.0)	51,621 (100.0)	24,801 (100.0)	347,757 (100.0)	31,710,950 (100.0)	91.19	Chiayi Pref., Tainan Pref., Yunlin Pref., Changhwa Pref., (0.61)

Source: Same as Table 1.

—: Not available.

a: Figures in parentheses are shares of grand total.

b: The output and value of milkfish in 1990 were specially high, the average 1991-1992 output and value were 33,222 mt. and 1,438,348.5 thousand NT dollars.

c: The output and value of the fresh-water clam were high, the average 1991-1992 output and value were 11,925 m.t. and 567,606.5 thousand NT dollars.

d: The output and value of the grass shrimp in 1990 were significantly lower than previous years, the average 1991-1992 output and value were 10,547 mt. and 2,521,098 thousand NT dollars.

e: The concentration ratios of total output are in parenthses.

been optimistic because of decreasing market demand and increasing resource competition from other high-value species since the early 1980s (Lee 1983). However, development of deepwater and freshwater instead of brackishwater cultivation and manufacturing techniques supported the increased aquaculture output and value since 1986 (Yuang and Che 1991). Development of marketing and manufacturing techniques for milkfish were suggested as recent important agribusiness issues to be resolved.

The major aquaculture shellfishes were oyster, clams, and shrimps concentrated on the Southeast and Northeast coastal regions. The 1990 unit prices of these shellfish products were higher than the live fishes, except eel. The major problems for future development will be the high production cost, water pollution, and diseases. Thus, improving cultivation techniques, environmental engineering, sanitary conditions, and product quality are future policy directions (Jen 1990).

For regional dispersion of aquaculture cultivation, Tainan Prefecture and Chiayi Prefecture, had the largest areas in 1985 and 1990, respectively (Table 4). However, Tainan prefecture had significant expansion in the late 1980s, while Chiayi Prefecture decreased both monoculture and polyculture areas. In 1990, the cultivated monoculture area in Tainan Prefecture increased. This increase implies changing cultivated species and improving cultivation techniques. The underlying reason for the shift of culivation areas from Chiayi to Tainan or elsewhere, was the serious shortage of underground water in Chiayi. The water shortage resulted from the over-

Table 4 Regional Distribution of Aquacultural Area in Taiwan, 1985 & 1990.

City & Prefectures	Aquacultural Area							
	Total		Share of Grand Total		Monoculture		Polyculture	
	1985 (ha)	1990 (ha)	1985 (%)	1990 (%)	1985 (ha)	1990 (ha)	1985 (ha)	1990 (ha)
Kaohsiung City	382	354	0.58	0.46	259	294	123	60
Taiwan Province	65,598	76,067	99.42	99.51	26,577	51,326	29,021	24,741
Taipei Pref.	119	84	0.18	0.11	55	67	64	17
Yilan Pref.	715	1,917	1.08	2.51	511	1,785	204	132
Taoyuan Pref.	3,620	3,393	5.49	4.44	91	168	3,529	3,225
Hsinchu Pref.	432	465	0.65	0.61	33	38	399	427
Miaoli Pref.	586	531	0.89	0.69	16	95	570	436
Taichung Pref.	555	119	0.84	0.16	25	73	530	46
Changhwa Pref.	5,444	6,495	8.25	8.50	4,642	5,250	802	1,245
Nantou Pref.	135	1,197	0.20	1.57	37	30	99	1,167
Yunlin Pref.	9,714	11,817	14.72	15.46	4,688	8,148	5,026	3,669
Chiayi Pref.	13,866	11,687	21.02	15.29	7,117	6,647	6,750	5,040
Tainan Pref.	13,456	17,828	20.41	23.33	8,043	11,751	5,422	6,077
Kaohsiung Pref.	5,263	5,826	7.98	7.62	2,908	4,549	2,355	1,277
Pingtung Pref.	3,212	5,497	4.87	7.19	2,839	5,007	373	490
Taitung Pref.	221	364	0.33	0.48	63	232	158	132
Hwalien Pref.	760	695	1.15	0.91	450	253	311	442
Penghu Pref.	638	559	0.97	0.73	638	559	0	0
Hsinchu City	1,109	238	1.68	0.31	902	155	207	83
Taichung City	16	6	0.02	0.00	5	1	11	5
Chiayi City	39	12	0.06	0.02	0	0	39	12
Taiwan City	5,688	7,337	8.62	9.60	3,515	6,518	2,173	819
Grand Total	65,980	76,421	100.0	100.0	36,835	51,621	29,144	24,801

Source: Taiwan Agricultural Yearbook 1986 and 1991.

extracted water for the freshwater cultivation (Jeng 1991). The increased monoculture area and decrased polyculture area from 1985 to 1990 showed similar development in cultivation species, methods, and techniques.

From 1985 to 1990, a more concentrated aquaculture production was planned; more cultivation areas were found south of Taichung Prefecture and on the east coast region, except for Chiayi Prefecture. The most significant growth during that time was in Nantou Prefecture, which focused on inland polyculture.

Considering the deteriorated cultivation environment and increased foreign competition under economic liberalization, a continuous expansion of the domestic aquaculture industry is doubtful. Shaw (1990), Chu (1990), Chen and Chiuan (1990), Jen (1990), and Yuang and Che (1991) suggest that future development strategies will improve fishery processing techniques, develop leisure aquaculture and coastal fishery industries, establish managed and specialized cultivation areas, and select valuable species with improved cultivation techniques.

III.Operational Structure of Taiwan's Aquaculture

To understand the operational structure of Taiwan's aquaculture, 180 sample farms were randomly selected for nine major species in July 1992. Basic operational information on scale, employment, skills, demographic, social, and economic contents were exmined. Data collected from the survey are shown in Tables 5 and 6. In Table 5, milkfish farms had the largest average scale while the tilapia, eel, and freshwater clam farms had scales less than 2 ha (among the sample farms). The olw milkfish unit price, which resulted from excess production, provided special attention to the improved economies of scale. The eel production existing in many relatively small-scale farms was interesting. According to Chou (1991), the average scale of eel ponds was below 0.8 hectare. The selected samples had greater scale than the overall average scale in Taiwan.

Moreover, certain levels of correspondence existed between the cultivating water type and the average scale. Most brackishwater species are cultivated in cheaper and larger land around the coastal area. However, the freshwater milkfish and giant freshwater prawn had large scales, which may be explained by cheaper land for milkfish and the high price of prawn.

The different cultivation skill levels are set upas partitioned groups to create a hierarchal structure in aquaculture employment. Shrimp and prawn production require a high level of cultivation skill. Only the giant freshwater prawn samples exhibited a low skill requirement for full-time employment in 1992. Moreover, the oyster and milkfish farm operators had high skill level for full-time employment, while other species in the same category were the opposite. The underlying reason for the low skill levle of full-time employment may be lack of demand for certain labors during the year. Also, aquaculture is risky in terms of deteriorated water quality and disease control. Nevertheless, the low-skill tilapia farms are an exception to the above reasoning because tilapia farms do not have serious labor shortages or water problems in polyculture ponds.

The current labor shortage may arise in future stages of aquaculture development. In fact, the labor shortage prevailed the year of 1992 for Taiwan's major aquaculture species. Feeding and harvesting worker shortages were common in the listed species of Table 5. Industrialized eel production used contract workers without a significant labor shortage. The species, especially sensitive to disease and a particular living environment (such as shrimps under intensive care) exhibited a high degree of continuous labor shortages, while other species had only seasonal shortages. If aquaculture development moves toward higher levels of specialization, the labor shortage problem will increase. As a result, labor-saving cultivation techniques, instead of feed-cost saving techniques, will be highly encouraged.

Table 6 shows demographic, social, and economic characteristics of the sample farms by scale, skill level, and water type in 1992. The following characteristics typified older operators' farms: freshwater cultivation, lower skill level, and small scale. These findings imply that older operators are not willing to risk adverse behavior and that younger people are not willing to participate in aquaculture .

Other demographic and social variables, such as low education level, part-time operation, limited training, less than 3 years experience, inherited farms, and participating in certain organizations, are common phenomena of the sample farms. The farmers' prevailing low level education makes learning and developing their own skills extremely difficult. Future exten-

Table 5 The Operational Scale, Employment, and Skills of Sample Farms by Major Aquacultural Species in Taiwan, July 1992.

Species	Number of Sample Farms (Units)	Average Scale (ha)	Full Time[a] (Units)	Month of Labour Shortage[b]	Type of Labour Shortage	Cultivation Skill Level[c]	Water Type[d]
Oyster	25	2.95	20 (0.80)	2-12	B,F	0	3
Milkfish	12	5.78	11 (0.92)	8-9 12-1	A,E	0	1,2,3
Tilapia[e]	23	1.95	8 (0.35)	5-6 12	D	0	1,2
Grass Shrimp	18	2.70	13 (0.72)	7-1	A,D	1	1,2,3
Hard Clam	25	2.75	10 (0.40)	3-9 11	E	0	2,3
Eel	20	1.59	16 (0.80)	--	--	0	1
Kuruma shrimp	20	2.01	20 (1.00)	1-12	E	1	3
Fresh-Water Clam	17	1.13	8	1-3	B,C	0	1
Giant Fresh-Water Prawn	20	2.09	6 (0.30)	1-12	E	1	1
Grand Total	180	2.44	112 (0.62)	—	—	—	—

–: Not available.
a: Figures in parentheses share of total sample.
b: A: Pond integration; B: Breeding; C: Management; D: Feeding; E: Harvesting; F: Shell peeling.
c: High skill leve=1, low skill level=0.
d: Fresh water=1; Mixed water=2; Brackish=3.
e: Most carps and tilapia are poly-culture together and is defined as tilapia pond.

Table 6 Demographic, Social, and Economic Characteristics of Sample Farms in Taiwan by Scale, Skill Level, and Type, July 1992[a].

Category & Classifications		Number of Sample Farms (Units)	Averge Age of Operator (Years)	Farm Operator with High Education Level[b] (%)	Farms of Part-Time Operation (%)	Farms Participating Training Class (%)	Farms' Experience of More Than 3 Years (%)	Farms were Inherited (%)	Farm Operator Not Participating Organization	Farms with Short-term Loans (%)	Farms with Long-term Loans (%)	Farm Products Sold to Wholesalers or Dealers (%)	Farms will Maintain Operation (%)	Farms to be Inherited (%)	Farms Affected by Water Pllution and Shortage (%)
Scale	Large	54	46.78	14.8	37.04	27.78	46.30	53.70	31.48	18.52	42.59	75.93	77.78	40.74	35.19
	Middle	67	46.99	2.99	38.81	10.45	40.30	40.30	37.31	19.40	29.85	92.54	83.58	47.76	44.78
	Small	59	50.75	6.78	37.29	10.17	38.98	38.98	32.20	18.64	25.42	91.53	79.66	59.32	55.93
Skill Level	High	78	46.88	12.82	29.49	25.64	24.64	24.36	28.21	33.33	47.44	100.00	80.77	38.46	412.03
	Low	102	50.88	3.92	34.31	7.84	7.84	54.90	38.24	7.84	20.59	77.45	80.39	38.24	49.02
Water Type	Fresh-Water	92	50.86	8.70	44.57	6.52	6.52	30.43	35.87	26.09	39.13	86.96	89.13	53.26	30.43
	Mixed Water	28	46.07	10.71	57.14	3.57	3.57	39.29	82.14	7.14	35.71	82.14	67.86	53.57	67.86
	Brackish	60	47.93	5.00	18.33	35.00	35.00	60.00	8.33	13.33	20.00	90.00	73.33	41.67	58.33

Source: Survey of this research.

a: Percentages ard calculated throughout the division of the farm numbers of each characteristic to the total farm numbers of each classification.

b: Bachelor degree and above mean high education level while high school graduation and below mean low education level.

sion services may further be depressed in terms of the high percentage of part-time sample farms. In 1991, 52.85% of Taiwan's aquaculture operators were part-time operators. This number was higher than the part-time percentages among listed categories except for the mixed-water farms. For technology transfer, a high percentage of operators in large scale, high-skill, and brackishwater farms were participating in training classes. It seems that aquaculture production will demand new and effective skills and training in the future. Moreover, the low percentage of inherited farms accompanies the low percentage of experienced farm operators. The core fishermen program may be the place to consider inheritance. Future extension services must include more financial convenience and training as Chu (1989) suggested.

Most operators join nearby farmers' and fishery associations. Both high-skill and freshwater cultivation, such as shrimp and eel farms, need more cooperative services, in addition to the services from the Fishery Association. The Fishery Association will strengthen future marketing services to receive definite recognition of more fishery operators. Many other development services and cooperations from the Fishery Association were recommended by Chu (1989), such as financial support for extension, vertical and horizontal coordination, product promotion, information transfer, education, etc.

Economic characteristics of the sample aquaculture farms are explained by farm loans and marketing channels, with the assumption that price-taking behavior prevails. Price-taking behavior is the position farm loans and stable marketing channels choose to rdflect the existence of possible price risks. This is because existing numbers of farms and their geographic distribution show farmers are more like price takers than price offerers. Most of the short-term loans were obtained from the Farmers' Association and hueys, which are local financial assistance groups organized by reliable or related individuals. Among all categories, farms of high-skill level and freshwater species showed greater demand for short-term loans. The underlying implication may be that the above two classifications are more business oriented operations than the others.

Farms of large scale, high-skill level, and freshwater as well as mixed-water cultivation showed the greatest requirements of long-term loans, especially those from the Farmers' Association, Fishery Association, and banks. The largest frequencies of both the short-term and long-term loans existed in the large scale, high-skill, and freshwater farms. It becomes clear that those who demand more loans will have a closer relationship with local financial and marketing organizations despite their membership. Thus, improved capital intermediation of the farmers' and fishery Associations and local banks will play a critical role in future market-oriented development in Taiwan's aquaculture.

Further, most aquaculture farm operators choose the most convenient at-farm channel to sell their products. Dealers prefer aquaculture products raised in the middle and small scale, high-skill, and brackishwater farms. It seems that operators with a higher education, lower age, larger scale, and lower skill may pay more attention to alternative marketing channels for their products. Unfortunately, searches for the underlying reasons of such stable marketing channels failed. The most popular alternative channel was selling products to processing plants. For other channels, cooperative and direct marketing had not been well developed. The combination of multi-channel marketing may help the efficiency of product quality and prices in various markets. However, developing alternative marketing channels and combining them may require teaching the farm operators and promoting business oriented enterprises.

Concerning sustainable aquaculture cultivation, three areas were under question. For continuity of operation, less than 80% of the small scale, mixed-water, and brackishwater sample farms were willing to maintain operation; the other classifications were more willing to maintain. For farm inheritance, less than 60% of sample farms under each classification will be left to the next generation; the small-scale, freshwater, and mixed-water farms had a greater percentage to be inherited. The increased number of small-scale, freshwater, and mixed-water farms will be problematic for Taiwan's aquaculture because of the unhealthy economy and water shortage. In view of water pollution and water shortage, nearly half of each kind of farm was affected. For future development, mixed-water and brackishwater cultivation may deserve more attention to improvement of their existing environment.

IV.Income and Cost Structure of Taiwan's Aquaculture

The income of aquaculture farms can be divided into farm and off-farm sources; farm income sources include aquaculture output, fry, byproducts, etc. The off-farm income sources are from other farms, non-fishery works, and others such as subsidies. Costs of aquaculture can be classified into direct and indirect costs. Unfortunately, the detailed income and cost structure of the overall aquaculture farms are not available. Our survey will explain the income and cost structure of Taiwan's aquaculture farms by major species. Many income and cost variables used as structural information are listed in Tables 7 and 8.

Table 7 explains the family dependence on aquaculture income, average income, and important income sources of major species. In 1992, more than 89% of the sample farm families exhibited a level of income dependence over 0.75, excluding some farms of milkfish, hard clam, freshwater clam, and freshwater giant prawn. The high income dependence levels might relate closely to the high rate of full-time farms shown in Table 6; over 62% of sample farms were under full-time operation.

Among the average total income of sample farms in terms of the cultivation area, eel farms had the highest average income, NT$9,172,040 per ha, while the kuruma shrimp farms had the second highest average income, NT$2,445,124 per ha in 1992.The lowest average annual income below the

Table 7 Aquacultural Income Dependence, Level,Sources of Sample Farms by Major Species, 1992.

Species	Number of Sample Farms (Units)	Farms of Income Dependece Greater than 0.75[a] (Units)	Average Total Income by Area[b] (NT/ha)	Average Total Income by Family[c] (NT/unit)	Average Income from Aquaculture Products[d] (NT/ha)	Average Income from Aquacultural By-products[d] (NT/ha)
Oyster	25	25	236,680	698,206	209,797 (88.64%)	0 (0.00%)
Milkfish	12	10	410,887	2,374,927	256,178 (62.35%)	132,571 (32.26%)
Tilapia[e]	23	23	382,826	746,511	276,850 (72.32%)	71,857 (18.77%)
Grass Shrimp	18	17	418,556	1,130,101	250,043 (59.74%)	14,817 (3.54%)
Hard Clam	25	20	462,543	1,271,993	339,151 (73.32%)	37,943 (8.20%)
Eel	20	20	9,172,040	14,583,543	8,803,306 (95.98%)	0 (0.00%)
Kuruma shrimp	20	20	2,445,124	4,914,699	2,433,933 (99.54%)	9,524 (0.39%)
Fresh-Water Clam	17	10	280,463	316,923	157,249 (56.07%)	0 (0.00%)
Fresh-Water Giant Prawn	20	16	883,85	1,847,257	773,758 (87.54%)	0 (0.00%)
Grand Total	180	161	(1,632,553)	(3,983,429)	(1,500,029) (91.88%)	–

Source: Survery of this research.
a: Income dependence is defined as the aquacultural income divided by the total family income.
b: The total family income divided by the average farm scale.
c: Average total income by area times the average scale.
d: Percentage in parentheses are shares of total average income.
e: For the average income of the sample farms and aquacultural products, figures in the parentheses are average income.

Table 8 Aquacultural Cost Structure of Sample Farms by Major Species, 1992.

Unit：NT$/ha

Cost Items / species	Direct Costs					Indirect Costs							
	Own and Hired Labour Expenses	Fry Expenses	Feed, Fertilizer, Medicine Expenses	Water and Electricity Expenses	Maintenance and Other Expenses	Discount Value	Rents and Interest Expenses	Transportation, Packaging, Storage Expenses	Insurance and Business Expenses	Grand Total Cost by Area[a]	Grand Total Cost by Family[a]	Net Income by Area[b]	Net Income by Family[b]
Oyster	39,570	0	0	3,215	49,992	4,141	—	—	12,760	109,678	323,391	127,002	374,715
Milkfish	42,509	49,265	200,027	29,613	4,439	—	1,067	—	0	326,920	1,889,598	83,967	485,329
Tilapia	44,347	82,142	139,601	14,026	3,619	—	—	13,174	0	266,908	520,471	115,918	226,040
Grass Shrimp	70,898	103,400	178,576	36,644	31,361	24,652	53,073	—	10,211	508,816	1,373,803	-90,250	-243,702
Hard Clam	100,728	75,243	69,996	25,278	6,432	22,315	4,650	427	489	305,558	840,285	156,987	431,708
Eel	344,118	2,190,706	2,163,127	203,630	73,776	—	—	—	0	4,975,357	7,910,818	4,196,683	6,672,725
Kuruma shrimp	454,890	88,253	929,458	255,976	255,253	36,756	32,030	3,571	10,629	2,066,817	4,154,302	378,307	760,397
Freshwater Clam	196,696	41,155	6,225	55,665	17,020	5,507	7,627	373	11,050	341,317	385,688	-60,854	-68,765
Giant Fresh-Water Prawn	246,416	102,337	465,807	97,005	170,091	58,412	960	—	0	1,141,027	2,384,746	-257,172	-538,489

Source: Survey of this research.
a: Total cost by area times the average scale.
b: total income minus total cost.
—: not anailable or mininal.

subsistence level appeared in the oyster and freshwater clam farms. The average total income per family in 1992 represented a seriously low family income problem for the freshwater clam farms. These results explain why freshwater clam farms had a smaller farm income dependence than the other farms.

For the most important income source, only farms of oyster, eel, kuruma shrimp, and giant freshwater prawn received more than 80% of the average total income from aquaculture output. Grass shrimp and freshwater clam farms exhibited very low percentages of average total income from farm output. The other major income sources of the freshwater clam farms were from the temporary off-farm salary and the fry sale. The grass shrimp farms' different income structure could be explained by the uncontrollable spread of shrimp disease. Thus, the culturists turn to other major income sources such as fishing. Aquaculture byproducts, such as grass carp, crucian carp, and big head carp, are also important income sources.

The aquaculture cost structure of the sample farms are listed in Table 8, the highest average production costs appeared in the high-income eel and kuruma shrimp farms. The labor inputs for milkfish, tilapia, grass shrimp, and eel production were not as important as for the oyster, hard clam, kuruma shrimp, freshwater clam, and giant freshwater prawn production. Feed, fertilizer, and medicine expenses were highest in milkfish, tilapia, grass shrimp, eel, kuruma shrimp, and giant freshwater prawn farms. Fry was most expensive for milkfish, tilapia, grass shrimp, hard clam, and eel farms.

For indirect costs, the high discount values of the grass shrimp, hard clam, kuruma shrimp, and giant freshwater prawn farms implied the demand for large capital or equipment investments. The very expensive rent and interest for the grass shrimp and kuruma shrimp farms at least partly explain their short-run potential profit capabilities. However, the negative net average incomes of the grass shrimp and giant freshwater prawn farms further implied that the riskier the business is, the potentially higher profits will be. The prevailing diseases caused by abusing the medicine for shrimps and freshwater clam were the most important factors leading to a negative net average income for some aquaculture farms in 1992 (Yuang and Che 1991).

Considering the farm income structure improvement, the grass shrimp farms were the most difficult to be subsidized or concerned with huge income deficits in 1992. The low productivity must be corrected by ceasing medicine abuse and improving the environment. Although the average giant freshwater prawn production showed the largest deficit in the sample group, only those farms with high levels of income dependence had major problems needing urgent treatment. A similar situation happened with freshwater clam production. The high off-farm income may not shrink the industry. Disaster subsidies and financial assistance may help these farms.

Among the important aquaculture species, eel production showed the highest net income both in terms of area and family, while the kuruma shrimp production was the second highest. For kuruma shrimp and eel, future development and market competitiveness depends on keeping production expenses down. An effective disease control method for grass shrimp and giant freshwater prawn will help decrease production cost, lower mortality rates, and raise profits. The cost and the availability of fry for milkfish, tilapia, grass shrimp, hard clam, eel, freshwater clam, giant freshwater prawn, etc., must improve effectively and efficiently to continue competitiveness (Day 1987; Lee 1983; Chen 1989; Yuang and Che 1991; Chou 1991). To improve the aquaculture competitiveness in Taiwan, we need to carefully identify specific problems for each species. The income and cost structure provides useful information to specify urgent demands for aquaculture development.

V. Conclusion

This paper examines the internal structure and development of Taiwan's aquaculture. The technical and economic development changed the internal structure of aquaculture, which may imply important future strategies and policies for aquaculture development.

The production structure of Taiwan's aquaculture presented an accelerating productivity and regional concentration among nine major species. The aggressive technical progress of inland aquaculture in Taiwan created the profitability and market competitiveness for most selected species to have high unit value. However, the input resource movements, foreign competition, and deteriorated cultivation environment, such as polluted and over-pumped water, have hindered the expansion of domestic aquaculture. As a result, Taiwan's aquaculture development turned toward more fresh-water and monoculture cultivation and more regional concentration on the west coast. Further technical progress or regional dispersion may not maintain the profitability or competitiveness under more restrictive government regulation and liberalized markets. Development strategies then included improving fishery processing techniques, establishing specialized cultivation areas, developing leisure aquaculture, and selecting species with potential to improve with technology.

The operational structure of Taiwan's aquaculture is explained by examining 180 randomly selected sample farms in terms of the economic, demographic, and social factors collected in July 1992. No definite relationships exist among species in terms of the operational scale, full-time operation, labor shortage, skill level, and water type. However, the industrialized eel production does not have a labor shortage or a very large scale. Farms of high-skill level species have moderate scales and only minor labor shortages. Future development of labor-saving cultivation techniques for all species deserve great encouragement.

The other economic factors, such as financial demand and marketing alternatives, are also analyzed. Species of higher market prices and riskier cultivation exhibit a greater demand for loans from the Associations, local banks, and private Huis than do the other species. If aquaculture's future development becomes more specialized and capital intensive, the financial intermediation in the aquaculture sector will be more important than ever.

The demographic factors suggest aging problems and risk adverse behavior: Older operators, with little education, training, or experience, are a common phenomena in the aquaculture sector. Social factors, such as farm inheritance, part-time operation, and local organization participation, must be considered together with demographic issues. For example, strengthening the functions of the Fishery Association will help information and technique transfer as well as marketing effectiveness. Establishing a core of fishermen will encourage farm inheritance to lower the average turnover age and increase the experience requirements.

The income and cost structure of Taiwan's aquaculture is also explained by the sample farms; nearly 90% of the sample farms have an income dependence level above 0.75, except for some clam and prawn farms. Full-time farms may possess a higher level of income dependence than the part-time farms, which is especially true for the freshwater clam. Among the major species, only eel, kuruma shrimp, and giant freshwater prawn production had a very large gross income per hectare. While the eel and kuruma shrimp farms received positive and large net incomes, the prawn farms had huge negative net incomes. The farms of grass shrimp and freshwater clam having negative net income possess different income structure than the prawn farms. The grass shrimp also becomes a major income source from leisure fishing activities, which are open to the public.

Freshwater clam provides income as off-farm temporary works. Thus, prawn farms with high income dependence are under a very serious survival condition.

The cost structure suggests that future competitiveness may depend on different cost-saving focuses of different species. The development of fry procurement for eel, milkfish, tilapia, grass shrimp, hard clam, freshwater clam, and giant freshwater prawn production will be crucial for their income improvements. The effective control over medicine use may be helpful to lower average cost per unit of output from decreased death rate. The maintenance expenses reduction of the kuruma shrimp farm will increase its net income. Thus, different species need specific cost reducing methods and techniques to improve the net income structure. Several suggestions can be made from the above analysis:

A. Consider value-added leisure activities to be expanding aquaculture cultivation.

B. Set up the specialized cultivation region to accompany the development of the proper species, financial availability, marketing services, economies of scale, technology transfer, and inheritance to improve the internal structure of aquaculture in Taiwan.

C. Establish a price stabilization fund to lower the income risk and the short-term financial difficulties of aquaculture cultivation.

D. Establish and evaluate a time-phase development plan to coordinate with the possible market liberalization in the future.

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摘　要

關鍵字：養殖漁業內部結構、養殖漁業發展、結構調整。

本文剖析未來在台灣發展養殖漁業的經濟涵義。同時，台灣養殖漁業的發展歷史以及主要養殖產品項目的內部結構，即依地理區域分佈、經營結構、所得與成本結構，均被加以披露。分析結果認為，未來台灣的養殖漁業必須重視與附加價值、經營技術與決價相關的結構調整。

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