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**ECONOMIC ASPECTS OF EEL FARMING
IN TAIWAN**

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ECONOMIC ASPECTS OF EEL FARMING IN TAIWAN

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臺灣養鰻業之經濟研究

中文摘要 (Chinese Abstract)

臺灣養鰻業之前途端賴其投資利潤之大小。投資利潤在本報告中係以現值法求得。投資淨現值、還本(最低)鰻價以及投資還本率均分別根據養殖場面積、養成率、種鰻價格、餌料成本等不同情況分別計算。在臺灣，鰻可分為兩大類：本省鰻與進口歐洲鰻。養鰻場亦分為兩種類型：一為由鰻線養至成鰻，一為由鰻線養至鰻苗。各種鰻類與各種經營類型之投資利潤均分別計算之，其計算結果顯示(1)養成率與鰻線價格為影響養鰻業利潤之最重要因素，故提高養成率與降低生產成本實為增加養鰻利潤之必要條件；(2)歐洲鰻養殖業每年平均投資還本率高過同一養成率之本省鰻與鰻苗養殖業。因省產種鰻供不應求，故研究蓄養原產自他國之鰻線顯得格外重要；(3)成鰻價格愈高，投資淨現值與還本率亦愈高，當成鰻售價較計算所得之還本(最低)價格為高時，利潤率亦愈高。故養鰻業之前途亦需視成鰻之價格與市場需求而定之。據估計，臺灣近年來之成鰻生產約90%以上外銷至日本，故該國鰻魚市場之供需與本省養鰻事業有密切關係。日本之成鰻價格呈季節性變動，即自春季逐漸升高至夏季達最高峰，七月後又趨下降。本省業者可預估其放養及長成時間，俾於日本之供應量呈季節性減低或成鰻價格呈季節性升高時，及時增加外銷提高利潤。

由日本對鰻之總需要方程式求出其物價需要彈性為 -0.98 ，所得需要為 1.73 。因其國民所得增加甚速，故若成鰻價格無顯著增加時，其對鰻魚之總需要量亦必逐漸增加。

臺灣養鰻業者對於下列兩項事實應予重視。第一，日本與韓國正試驗室內養鰻。該養鰻法可使養殖時間由2年縮短至8個月，且養成率甚高。目前雖尚無成本資料可供比較，但室內魚池生產正在不斷擴展中，由此推測此種室內養鰻事業在技術方面似無困難，在經濟上亦有利可取。如試驗成功，將成為本省業者之競爭者。第二，由於日本養鰻專家之協助，中國大陸最近數年已積極研究養鰻，因此將來在日本市場上亦可能成為臺灣之主要競爭者。

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I. INTRODUCTION

Taiwan's climate is ideal for eel farming. However, the eel industry in Taiwan did not really grow until the latter part of the 1960's mainly due to a lack of demand for eel. As a result of increased demand for eel from Japan during the past few years, both the area of eel farming and the prices of seed eel and eel have increased rapidly. The total area of eel farms in Taiwan grew from about 60 hectares in 1966 to about 830 hectares in January 1972.¹⁾ It is now estimated to be in excess of 1,000 hectares. This rapid area expansion in Taiwan and the increasing demand for seed eel²⁾ from Japan have resulted in a phenomenal rise in the price of seed eel, from NT\$60 per kilogram in 1966 to about NT\$60,000³⁾ in March 1973 — an increase of 1,000 times the original price in seven years. In the same period, the price of eel increased only about threefold.

The economic aspects will play an important role in the development of this industry in the future. Past research has been primarily concerned with the biological and technical aspects of eel farming. This study is a modest attempt to analyze its economic aspects and examine items such as the cost-revenue situation and the market potentials of eel farming. It is hoped that the results of this study will facilitate evaluation of the probable future of the industry.

This study is divided into three parts. The cost-revenue analysis is presented in Section II. Section III discusses the price and demand for eel. A summary of the findings and conclusions is presented in Section IV.

-
- 1) Including 683.86 hectares of rearing ponds and 148.26 hectares of nursery ponds.
 - 2) The term seed eel in this study means the young eel that are used to stock the eel ponds. It includes the glass eel, which is seed eel in its earlier stage and is almost transparent, and the elver, which is larger and of dark color.
 - 3) US\$1=NT\$40 before 1973 and NT\$38 at present.

II. COST-REVENUE ANALYSIS

Profit is the goal of private investment. The future development of the eel industry in Taiwan is mainly dependent upon the profitability of the investment in this industry. There are several basic techniques for measuring the investment profitability.

1. A payback period is simply the ratio obtained by dividing the original investment in an asset by the gross annual profit expected before any allowance for depreciation. It measures the number of years required for the gross earnings on the project to pay back the original outlay. The most obvious defect of this technique is that it does not measure profitability and ignores what happens after a project has returned its investment.

2. The book return on book investment approach measures the profitability by taking the ratio of average annual profits expected from the project to book investment in the project. This method fails to take into account the timing of expected earnings or of expected outlays.

3. The present-value method measures the present value of the associated stream of net receipts discounted at the appropriate rate of interest, and subtracts the initial cost of the investment. This statement can be expressed mathematically as:

$$NPV = \sum_{i=1}^n \frac{Y}{(1+r)^i} - C_0 \quad (1)$$

where

NPV = the net present value

Y = the expected annual net profit

r = the discount rate

C_0 = the initial cost of the investment

$i = 1 \dots n$, the number of years in operation

In most investment processes, a large amount of capital outlay is necessary at the initial stage of investment with returns accruing to the investor over a period of time. A dollar in hand today is more valuable than a dollar to be gained sometime in the future. Therefore, the profitability of investment in the eel industry is measured by the present value method in this study.

The net profit (Y) can be expressed as $(R - C)$, where R is the annual gross revenue and C is the costs, exclusive of initial investment. The gross revenue R may in turn be expressed as $(P \times Q)$, where P represents the average price of eel and Q represents the average amount of annual production. If the initial investment has a salvage value (S), the formula (1) can be rewritten as:

$$NPV = \sum_{i=1}^n \frac{(P_i \cdot Q_i - C_i)}{(1+r)^i} - \left[C_0 - \frac{S}{(1+r)^n} \right] \quad (2)$$

By assuming annual revenue and operating costs to be constant, equation (2) can be again rewritten as:

$$NPV = Q \cdot P \left[\frac{1 - (1+r)^{-n}}{r} \right] - \left[C \left(\frac{1 - (1+r)^{-n}}{r} \right) + C_0 \right] + \frac{S}{(1+r)^n} \quad (3)$$

The criterion of this measurement is that:

If

$NPV > 0$ investment in this industry would be profitable

$NPV < 0$ investment in this industry would be undesirable

$NPV = 0$ break-even condition

Given the production costs, the level of production and the discount rate, it is possible to calculate the break-even price by using the present value formula. The break-even price is the minimum price resulting in a zero net present value. By assuming $NPV = 0$, equation (3) can be rewritten as:

$$Q \cdot P \frac{1 - (1+r)^{-n}}{r} = C \left[\frac{1 - (1+r)^{-n}}{r} \right] + C_0 - \frac{S}{(1+r)^n}$$

$$P = \left[C + \frac{C_0}{\frac{1 - (1+r)^{-n}}{r}} - \frac{\frac{S}{(1+r)^n}}{\frac{1 - (1+r)^{-n}}{r}} \right] \frac{1}{Q} \quad (4)$$

The criterion of this measurement is that if the expected farm price of eel is higher than the calculated minimum price, investment in this industry would be profitable. On the other hand, if the calculated minimum price is higher than the expected farm price, it would not be feasible, from an economic viewpoint, to invest in this industry.

The return per dollar of investment for the entire operating period can be calculated as:

$$\frac{NPV}{C_c} \quad (5)$$

where

$$C_c = C_0 - \frac{S}{(1+r)^n}$$

and the annual average rate of return on investment would be:

$$\frac{NPV}{C_c} \div N \quad (6)$$

where N = years of operation

There are two major species of eel in Taiwan: local eel, *Anguilla japonica*,

and imported European eel, *Anguilla anguilla*. There are also two types of eel farming: rearing elver to table size for final consumption and rearing the glass eel to seed eel for export or for stocking farms in the first type of operation. The cost-revenue analysis is done for each species and for each type of farming.

LOCAL EEL FARMING

Enumeration of costs and revenue

Both the initial capital costs and annual operating costs vary with the size of farm. In most cases, the larger the farm, the lower the unit cost. The cost items are estimated on three levels of farm size: under 3 ha., 3-5 ha, and over 5 ha., on a per ha. basis.⁴⁾

Initial capital cost. The initial capital cost here refers to the construction costs of eel ponds, buildings, wells, fences and the cost of equipment as shown in Table 1. Since the full amount of the expenses are treated as the initial cost as of time

Table 1. Estimated initial capital costs (NT\$/ha.) of Local Eel farming

Item	Under 3 ha.	3-5 ha.	Over 5 ha.	Remarks
Fish ponds	NT\$ 450,000	NT\$ 457,500	NT\$ 461,830	Concrete, 4 ft. in depth, the average size of a pond is 1/10 to 2/10 hectare.
Electric equipment	144,194	116,409	109,852	Including generator, cooling machine and electric wire and lighting.
Buildings	91,304	65,734	41,909	Including office, workshop, storage, etc.
Wells	46,804	43,498	43,557	1.5 wells per hectare on the average.
Water pump	27,200	20,200	15,400	10-15 H. P. per hectare.
Paddle wheel & electric motors	32,398	29,017	28,385	Acts aerators, 1-2 sets in a pond.
Fence	37,931	32,600	15,000	Concrete column, wire and bamboo.
Nets	8,333	7,500	6,000	
Truck and motorcycle	34,522	27,819	27,383	
Mis.	18,087	17,988	15,413	Including meat grinder, feed mixer, watch dog, furniture and other items.
Total	890,773	818,265	764,729	

4) This is estimated on total land area used, including land used for eel ponds as well as for other facilities. Eel ponds account for about 73, 75 and 77 percent of total land area of farm size under 3, 3-5 and over 5 ha. respectively.

0, there would be no allowance for annual depreciation and no charge for annual interest.

The construction cost of eel ponds varies mainly with the farm size and the type of construction: brick or concrete. The concrete type of construction is more popular and is, therefore, used in the cost estimation in this study.⁵⁾

Operating costs. Seed eel, feed and labor are the most important operating costs as shown in Table 2. The glass eel of *Anguilla japonica* are caught in estuarine water all along the coast of Taiwan. The catching season in Taiwan is from October to March, with the peak in December and January. Due to the high price of seed eel, people of various occupations, fishermen, farmers, civil servants, etc.,

Table 2. Estimated annual operating costs (NT\$/ha.) of Local Eel farming

Items	Under 3 ha.	3-5 ha.	Over 5 ha.	Remarks
Seed eel (1)	NT\$ 600,000	NT\$ 600,000	NT\$ 600,000	NT\$ 5/each, with stocking rate of 120,000 individuals
(2)	1,200,000	1,200,000	1,200,000	10/each, with stocking rate of 120,000 individuals
(3)	1,800,000	1,800,000	1,800,000	15/each, with stocking rate of 120,000 individuals
(4)	2,400,000	2,400,000	2,400,000	20/each, with stocking rate of 120,000 individuals
Feed (1)	510,000	510,000	510,000	NT\$ 8.5/each (low level), with harvesting rate of 50%
(2)	612,000	612,000	612,000	8.5/each (low level), with harvesting rate of 60%
(3)	714,000	714,000	714,000	8.5/each (low level), with harvesting rate of 70%
(4)	630,000	630,000	630,000	10.5/each (high level), with harvesting rate of 50%
(5)	756,000	756,000	756,000	10.5/each (high level), with harvesting rate of 60%
(6)	882,000	882,000	882,000	10.5/each (high level), with harvesting rate of 70%
Wages	116,026	87,676	85,203	
Maintenance and repair	103,623	94,164	75,412	
Electricity	35,346	34,798	32,173	
Chemicals	23,979	18,912	14,516	
Rent	23,459	23,459	23,459	
Mis.	50,000	48,857	45,059	

5) This includes the costs of access roads and drainage systems. The other items of initial cost are estimated on the basis of information obtained from a field survey of eel producers.

Table 2. (continued)

Harvesting rate (%)	Price of glass eel (NT\$/each)	Cost of feed (NT\$/each eel)	Total annual operating cost (NT\$ 1,000/ha.)		
			Under 3 ha.	3-5 ha.	Over 5 ha.
50	5	8.5	1,462	1,418	1,386
		10.5	1,582	1,538	1,506
	10	8.5	2,062	2,018	1,986
		10.5	2,182	2,138	2,106
	15	8.5	2,662	2,618	2,586
		10.5	2,782	2,738	2,706
20	8.5	3,262	3,218	3,186	
	10.5	3,382	3,338	3,306	
60	5	8.5	1,564	1,520	1,488
		10.5	1,708	1,664	1,632
	10	8.5	2,164	2,120	2,088
		10.5	2,308	2,264	2,232
	15	8.5	2,764	2,720	2,688
		10.5	2,908	2,864	2,832
20	8.5	3,364	3,320	3,288	
	10.5	3,508	3,464	3,432	
70	5	8.5	1,666	1,622	1,590
		10.5	1,834	1,790	1,758
	10	8.5	2,266	2,222	2,190
		10.5	2,434	2,390	2,358
	15	8.5	2,866	2,822	2,790
		10.5	3,034	2,990	2,958
20	8.5	3,466	3,422	3,390	
	10.5	3,634	3,590	3,558	

leave their work to catch seed eel during the fishing season. The seed eel caught are usually sold to collectors who in turn sell them either to eel farmers or middlemen.

The cost of seed eel varies with its price and the stocking rate. Seed eel in Taiwan are of the same species those cultured in Japan which in recent years experienced a shortage. With the rapid increase in the culture area of eel in Taiwan and the increasing demand from Japan, the price of seed eel has risen about 1,000 times during the past 7 years. No rise in price of any other commodity is comparable to this. The cost of seed eel accounts for about 41 and 73 percent of the total operating cost in price levels of NT\$5 and 20 (per individual), respectively.

The stocking rate varies with the farm size. According to the results of a field survey, the smaller the farm size, the higher is the rate stocked. Too high stocking rate frequently causes high mortality rate and low growth rate due to shortages

of oxygen and competition for food. In this study, the average stocking density of 120,000 seed eel per hectare is used in the calculations.

The cost of feed is the second most important operating expense. The estimation of the cost of feed (C_f) is based on the levels of production (Y), the conversion ratio of feed to eel (R), and the price of feed (P_f) as follows:

$$C_f = Y \cdot R \cdot P_f$$

Two types of feed are usually used: trash fish (small fish of poor quality and scraps from fish processing plants) and artificial feed. The conversion ratio of feed to eel is in the range of 10.0-15.0 : 1 in the case of trash fish and in the range of 2.0-2.5 : 1 in the case of artificial feed. The average conversion ratios are used in this study. The prices of both types of feed increased significantly during the past few months. Both high and low prices are used in the calculations. The conversion ratio and the price of feed are listed in the following table.

Table 3. Average conversion ratio and cost of feed

Type of feed	Average conversion ratio	Average price of feed/kg	Feed cost per kg of eel
Trash fish	12.5 : 1	NT\$ 4- 5	NT\$ 50.0-62.5
Artificial feed	2.3 : 1	22-27	50.6-62.1

The quality of feed given per day is about 5% to 15% of the total weight of the eel in the pond in the case of trash fish and about 1% to 3.5% in the case of artificial feed. The older the eel, the higher the percentage of feed to total weight of eel.

Labor costs vary with farm size as shown in the following table:

Table 4. Labor requirement per ha. by farm size

	Under 3 ha.	3-5 ha.	Over 5 ha.
Regular workers	2.20	2.10	2.30
Temporary workers	0.64	0.33	0.02
Total	2.84	2.43	2.32

The efficiency of labor increases with the increase in farm size. In large scale operations, most work is done by regular workers. The wage rate is about NT\$ 3,000 per month for male workers and about NT\$ 2,400 for female workers.

The land used for eel farming may be purchased. However, the price of land is increasing over time. It is likely that the land will be worth more, at present value, ten or twenty years later than it is now. Therefore, the purchase price of land is not treated as one of the initial costs. Instead, the cost of land is treated in the form of rent in this study.

The other cost items account for a small percentage of the total operating cost and are estimated on the basis of the information obtained from the field survey.

Annual production and revenue. Annual revenue is estimated as follows:

$$TR = (Q \cdot R) \cdot W \cdot P \quad (8)$$

where

TR = annual revenue per ha.

Q = number of seed eel stocked per ha.

R = harvesting rate (%)

W = average weight per eel at the time of harvesting

P = average unit price of eel

Based on the field survey, the average harvesting rate is in the range of 50-70 percent. The major factors affecting the harvesting rate of eels are: (1) disease, (2) stocking density, (3) water temperature, (4) water quality and (5) food supply. In this study harvesting rates of 50, 60 and 70 percent are used.

The price of eel is increasing over time due to increasing costs of production, mainly the cost of the seed eel. The current price of eel is in the range of NT\$180-220 per kg. In this study, price levels of NT\$180, 200 and 220 per kg are used in the calculations (Table 5).

Table 5. Estimated annual revenue (NT\$/ha) of Local Eel farming

Harvesting rate (%)	Production of eel (kg/ha)	Price of eel (NT\$/kg)	Annual revenue (NT\$ 1,000/ha.)
50	10,000	180	1,800
		200	2,000
		220	2,200
60	12,000	180	2,160
		200	2,400
		220	2,640
70	14,000	180	2,520
		200	2,800
		220	3,080

The length of the rearing period is in the range of 8-15 months due to differences in the rates of growth. The average rearing period of 12 months is used in this study.

Discount rate. The discount rate should reflect the rate of return that might reasonably be expected in an alternative investment. Decision makers use different discount rates for various classes of expenditures to reflect differences in the degree

of risk involved. If explicit allowance for risk and uncertainty is made in the estimates of costs and revenues, the rate of return in a riskless investment can be incorporated in the base discount rate. The risk and uncertainty of investment in eel production is assumed to be higher than other fish farming at the present. In this study, 10, 15, and 20 percent discount rates are used.

Salvage value. The normal physical life of fish ponds, buildings, and wells is estimated to be about 15 years. However, the loss of value of these facilities due to changes in farming technology or market demand is far less predictable than their physical life. In this study we consider only the end of the physical life. However, for those investors who are interested in knowing the cost-revenue situation for a short-term operation, calculations are also done for a 5-year term. In this case the salvage value is estimated by the fixed percentage method. It is assumed that the eel ponds and all other facilities can be shifted to other fish farming purposes after 5 years of eel production.

Results of calculations

The estimated costs and revenues are substituted in equations (3), (4), and (6). Calculations were done for four levels of price of seed eel, three levels of harvesting rate, two levels of cost of feed, three levels of price of eel, three levels of discount rate, two levels of length of operation, and three levels of farm size. The results are summarized in the following sections.

Net present value. The harvesting rate and the level of price of seed eel make a significant difference in the calculations as summarized in Tables 6-8. The present values are all positive in cases where the price per seed eel (or elver) is NT\$ 5 at all harvesting rates and are all negative when the price per seed eel is NT\$ 20. When price per seed eel is in the range of NT\$ 10-15, the net present values are

Table 6. Summary table of present value calculations for Local Eel farms under 3 ha., 15 years of operation

Harvesting rate	Price of seed eel (NT\$/each)	Cost of feed (NT\$/each eel)	Discount rate								
			10%			15%			20%		
			Price of eel (NT\$/kg)								
			180	200	220	180	200	220	180	200	220
50%	5	8.5	+	+	+	+	+	+	+	+	+
			10.5	+	+	+	+	+	+	+	+
	10	8.5		-	-	+	-	-	-	-	-
			10.5	-	-	-	-	-	-	-	-
	15	8.5		-	-	-	-	-	-	-	-
			10.5	-	-	-	-	-	-	-	-
	20	8.5		-	-	-	-	-	-	-	-
			10.5	-	-	-	-	-	-	-	-

60%	5	}	8.5	+	+	+	+	+	+	+	+	+
			10.5	+	+	+	+	+	+	+	+	+
	10	}	8.5	-	+	+	-	+	+	-	+	+
			10.5	-	+	+	-	-	+	-	-	+
	15	}	8.5	-	-	-	-	-	-	-	-	-
			10.5	-	-	-	-	-	-	-	-	-
20	}	8.5	-	-	-	-	-	-	-	-	-	
		10.5	-	-	-	-	-	-	-	-	-	
70%	5	}	8.5	+	+	+	+	+	+	+	+	+
			10.5	+	+	+	+	+	+	+	+	+
	10	}	8.5	+	+	+	+	+	+	+	+	+
			10.5	-	+	+	-	+	+	-	+	+
	15	}	8.5	-	-	+	-	-	+	-	-	+
			10.5	-	-	-	-	-	-	-	-	-
20	}	8.5	-	-	-	-	-	-	-	-	-	
		10.5	-	-	-	-	-	-	-	-	-	

Source: Appendix Table 1

Table 7. Summary table of present value calculations for Local Eel farms of 3-5 ha., 15 years of operation

Harvesting rate	Price of seed eel (NT\$/each)	Cost of feed (NT\$/each eel)	Discount rate									
			10%			15%			20%			
			Price of eel (NT\$/kg)									
			180	200	220	180	200	220	180	200	220	
50%	5	}	8.5	+	+	+	+	+	+	+	+	+
			10.5	+	+	+	+	+	+	+	+	+
	10	}	8.5	-	-	+	-	-	+	-	-	+
			10.5	-	-	-	-	-	-	-	-	-
	15	}	8.5	-	-	-	-	-	-	-	-	-
			10.5	-	-	-	-	-	-	-	-	-
20	}	8.5	-	-	-	-	-	-	-	-	-	
		10.5	-	-	-	-	-	-	-	-	-	
60%	5	}	8.5	+	+	+	+	+	+	+	+	+
			10.5	+	+	+	+	+	+	+	+	+
	10	}	8.5	-	+	+	-	+	+	-	+	+
			10.5	-	+	+	-	-	+	-	-	+
	15	}	8.5	-	-	-	-	-	-	-	-	-
			10.5	-	-	-	-	-	-	-	-	-
20	}	8.5	-	-	-	-	-	-	-	-	-	
		10.5	-	-	-	-	-	-	-	-	-	

70%	5	}	8.5	+	+	+	+	+	+	+	+	
			10.5	+	+	+	+	+	+	+	+	
	10	}	8.5	+	+	+	+	+	+	+	+	
			10.5	+	+	+	-	+	+	-	+	+
	15	}	8.5	-	-	+	-	-	+	-	-	+
			10.5	-	-	-	-	-	-	-	-	-
	20	}	8.5	-	-	-	-	-	-	-	-	-
			10.5	-	-	-	-	-	-	-	-	-

Source: Appendix Table 2

Table 8. Summary table of present value calculations for Local Eel farms over 5 ha., 15 years of operation

Harvesting rate	Price of seed eel (NT\$/each)	Cost of feed (NT\$/each eel)	Discount rate										
			10%			15%			20%				
			Price of eel (NT\$/kg)										
			180	200	220	180	200	220	180	200	220		
50%	5	}	8.5	+	+	+	+	+	+	+	+	+	
			10.5	+	+	+	+	+	+	+	+	+	
	10	}	8.5	-	-	+	-	-	+	-	-	+	
			10.5	-	-	-	-	-	-	-	-	-	
	15	}	8.5	-	-	-	-	-	-	-	-	-	
			10.5	-	-	-	-	-	-	-	-	-	
	20	}	8.5	-	-	-	-	-	-	-	-	-	
			10.5	-	-	-	-	-	-	-	-	-	
	60%	5	}	8.5	+	+	+	+	+	+	+	+	+
				10.5	+	+	+	+	+	+	+	+	+
		10	}	8.5	-	+	+	-	+	+	-	+	+
				10.5	-	+	+	-	+	+	-	+	+
15		}	8.5	-	-	-	-	-	-	-	-	-	
			10.5	-	-	-	-	-	-	-	-	-	
20		}	8.5	-	-	-	-	-	-	-	-	-	
			10.5	-	-	-	-	-	-	-	-	-	
70%		5	}	8.5	+	+	+	+	+	+	+	+	+
				10.5	+	+	+	+	+	+	+	+	+
		10	}	8.5	+	+	+	+	+	+	+	+	+
				10.5	+	+	+	+	+	+	-	+	+
	15	}	8.5	-	-	+	-	-	+	-	-	+	
			10.5	-	-	+	-	-	+	-	-	-	
	20	}	8.5	-	-	-	-	-	-	-	-	-	
			10.5	-	-	-	-	-	-	-	-	-	

Source: Appendix Table 3

positive only at the high levels of price of eel and harvesting rate. The higher the discount rate used, the lower is the net present value. The large scale operation is more profitable than small farms due to lower unit construction and operating costs.

Minimum (break-even) price of eel. The results of break-even price calculation are summarized in Figures 1-6. A higher rate of harvesting and a lower level of seed eel price result in a lower level of the minimum price of eel. The break-even price of eel is in the range of NT\$ 121-171 per kg between the harvesting rates of 70 and 50 percent when the price per seed eel is NT\$ 5, and is about doubled (NT\$ 249-357) when the price per seed eel is NT\$ 20. The discount rate, the size of farm and the period of operation also make a difference in the calculation. A higher discount rate, a smaller farm size and a shorter period of operation result

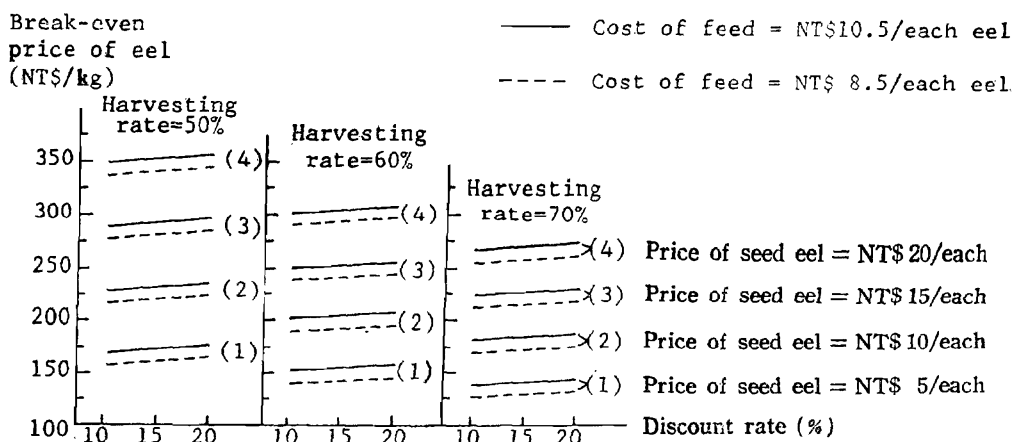


Fig. 1. Relationship among break-even price of Local Eel, price of seed eel, harvesting rate and discount rate for farm size under 3 hectares, 15 years of operation

Source: Appendix Table 4

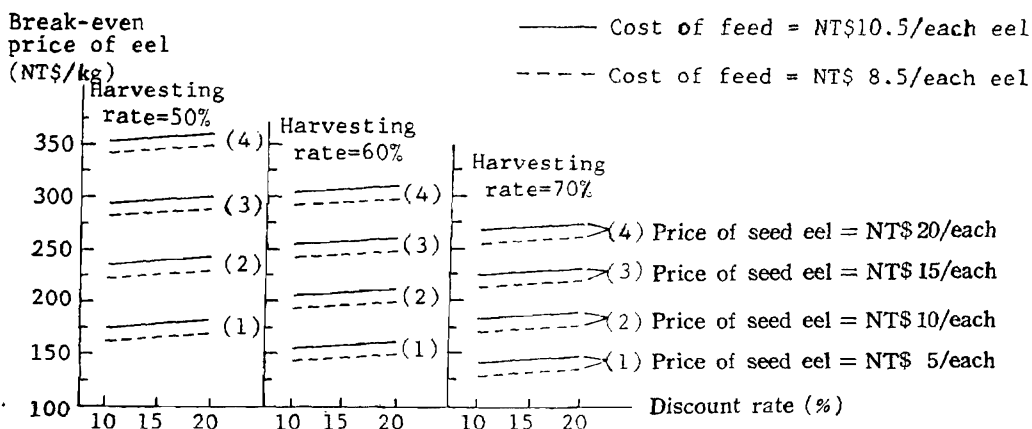


Fig. 2. Relationship among break-even price of Local Eel, price of seed eel, harvesting rate and discount rate for farm size under 3 hectares, 5 years of operation

Source: Appendix Table 5

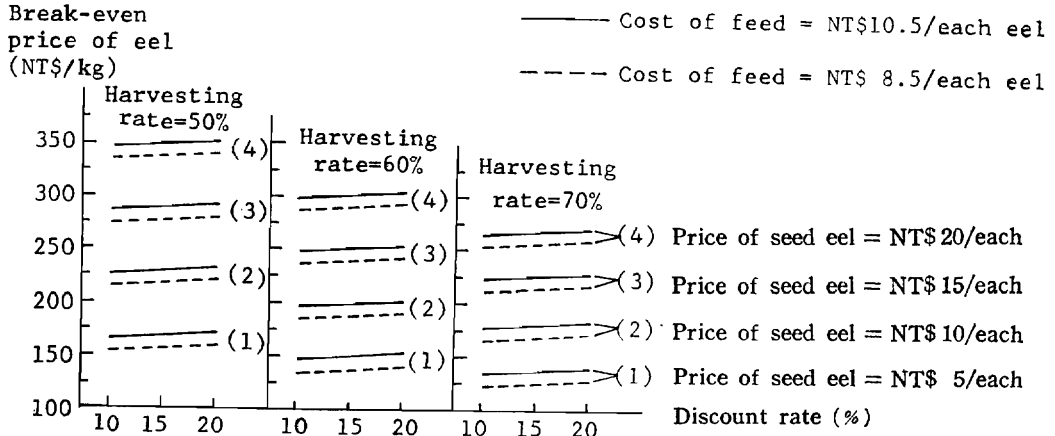


Fig. 3. Relationship among break-even price of Local Eel, price of seed eel, harvesting rate and discount rate for farm size 3-5 hectares, 15 years of operation

Source: Appendix Table 4

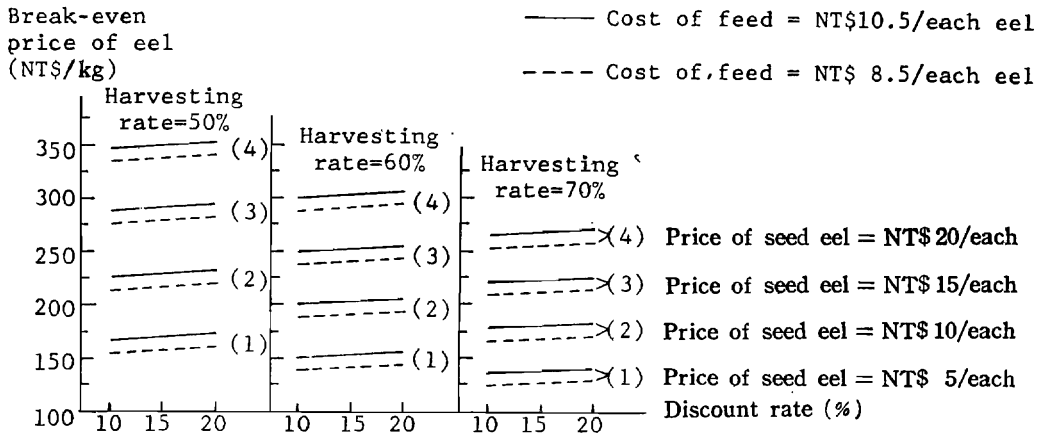


Fig. 4. Relationship among break-even price of Local Eel, price of seed eel, harvesting rate for farm size 3-5 hectares, 5 years of operation

Source: Appendix Table 5

in a higher level of break-even price of eel. The difference in the calculated break-even price is about NT\$ 6 between discount rates of 10 and 20 percent, about NT\$ 5 between large and small farms, and about NT\$ 3 between 5 and 15 years of operation. The current farm price level of eel is in the range of NT\$ 180-220 per kg. In order to make the operation just break-even, the highest price per seed eel should be in the range of NT\$ 6-8, NT\$ 8-10 and NT\$ 10-13 when the harvesting rate is 50, 60, and 70 percent respectively. Since the current price per seed eel is about NT\$ 12, the harvesting rate should be about 70 percent in order to make the operation just break-even. The results of the calculations suggest that in order to increase the net present value or to reduce the break-even price of eel, the harvesting rate should be increased by reduction of the mortality rate and the price of seed eel would then be reduced.

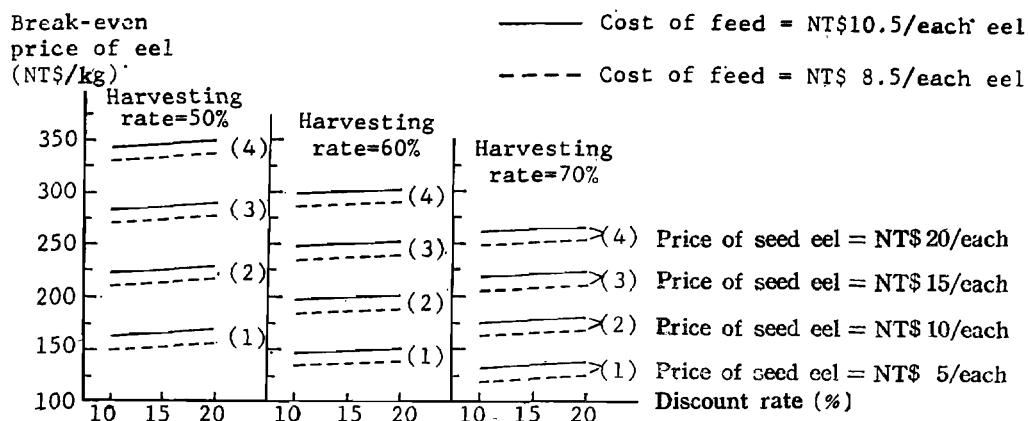


Fig. 5. Relationship among break-even price of Local Eel, price of seed eel, harvesting rate and discount rate for farm size over 5 hectares, 15 years of operation
Source: Appendix Table 4

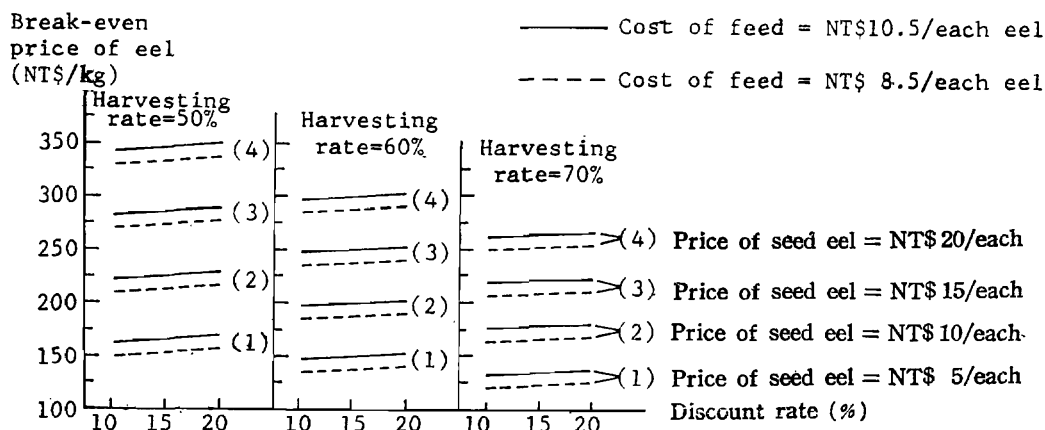


Fig. 6. Relationship among break-even price of Local Eel, price of seed eel, harvesting rate and discount rate for farm size over 5 hectares, 5 years of operation
Source: Appendix Table 5

Annual average rate of return on investment. The calculations are done only for those estimates with positive net present values and the results are summarized in Appendix Tables 6-8. The higher the harvesting rate and the price of eel, the higher is the annual average rate of return on investment. The low levels of price of seed eel and discount rate also resulted in a high level in the rate of return on investment. The annual average rate of return on investment is in the range of 17-48 percent between the harvesting rates of 50 and 70 percent when price per seed eel is NT\$ 5. When the price per seed eel is NT\$ 10, other things remaining equal, the rate of return on investment is positive only at the 70 percent harvesting rate, which is about 14 percent.

EUROPEAN EEL FARMING

With the rapid increase in the numbers of eel ponds, there has been a shortage of seed eel locally. Because the price of locally produced elver has gone up tremendously as mentioned earlier, some producers shift to the less costly imported European eel.

Enumeration of costs and revenues

Initial capital cost. Since European eel farming is still in the experimental stage, the farm size is usually less than one hectare. Therefore, the cost items are estimated by only one level of farm size — one hectare. The initial costs are all the same as those of local eel farms except the construction cost of eel ponds as shown in Table 9. Ponds for European eel are usually about 1.6 feet deeper than those ponds for local eel farming and thus cost more.

Table 9. Estimated initial capital costs (NT\$/ha.) of European Eel farming

Items	Cost	Remarks
Fish ponds	NT\$ 481,481	Concrete, 5 feet in depth, the average size of a pond is 1/10 to 2/10 hectare.
Electric equipments	144,194	Including generator, cooling equipment and electric wire and lighting.
Buildings	91,304	Including office, workshop, storage and living quarters, etc.
Wells	46,804	1.5 wells per hectare on the average.
Water pump	27,200	10-15 H. P. per hectare.
Paddle wheel and electric motors	32,398	Acts as aerators, 1-2 set in a pond.
Fence	37,931	Concrete column, wire and bamboo.
Nets	8,333	
Truck & motorcycle	34,522	
Mis.	18,087	Including meat grinder, feed mixer, watch dog, furniture and other items.
Total	922,254	

Operating cost. Seed eel, feed, labor, and maintenance are the most important cost items. The cost of seed eel is much cheaper than that of locally produced seed eel. Three price levels of seed eel are used in the calculations: NT\$ 1, 2, and 3 (per individual). The cost of feed is estimated by the same equation (7) and the same information is used as in the local eel farming. Since the growth rate of European eel is lower and the rearing period is longer (14 months instead of 12 months on the average) than local eel, the level of operating cost is higher

(Table 10). The cost of chemicals is also much higher than that in local eel farming because the European eel is more susceptible to disease and parasites.

Table 10. Estimated annual operating costs (NT\$/ha.) of European Eel farming

Item	Cost	Remarks
Seed eel (1)	NT\$ 120,000	NT\$ 1/each seed eel, with stocking rate of 120,000 individuals
(2)	240,000	2/each seed eel, with stocking rate of 120,000 individuals
(3)	360,000	3/each seed eel, with stocking rate of 120,000 individuals
Feed (1)	102,000	NT\$ 8.5/each eel (low level), with harvesting rate of 10%
(2)	306,000	8.5/each eel (low level), with harvesting rate of 30%
(3)	510,000	8.5/each eel (low level), with harvesting rate of 50%
(4)	714,000	8.5/each eel (low level), with harvesting rate of 70%
(5)	126,000	10.5/each eel (high level), with harvesting rate of 10%
(6)	378,000	10.5/each eel (high level), with harvesting rate of 30%
(7)	630,000	10.5/each eel (high level), with harvesting rate of 50%
(8)	882,000	10.5/each eel (high level), with harvesting rate of 70%
Wages	135,367	
Maintenance and repair	120,897	
Electricity	41,238	
Chemicals	50,365	
Rent	27,370	
Mis.	58,335	

Table 10. (continued)

Harvesting rate (%)	Price of seed eel (NT\$/each)	Cost of feed (NT\$/each eel)	Total annual operating cost (NT\$1,000/ha)
10	1	8.5	656
		10.5	680
	2	8.5	776
		10.5	800
	3	8.5	896
		10.5	920
30	1	8.5	860
		10.5	932
	2	8.5	980
		10.5	1,052
	3	8.5	1,100
		10.5	1,172

50	1	}	8.5	1,064
			10.5	1,184
	2	}	8.5	1,184
			10.5	1,304
	3	}	8.5	1,304
			10.5	1,424
70	1	}	8.5	1,268
			10.5	1,436
	2	}	8.5	1,388
			10.5	1,556
	3	}	8.5	1,508
			10.5	1,676

Annual production and revenue. European eel cannot tolerate high temperatures and are vulnerable to many diseases and parasites. The mortality rate is relatively high. Total annual revenue varies with the harvesting rate (Table 11). In this study the harvesting rates of 10, 30, 50, and 70 percent are used.

Table 11. Estimated annual revenue (NT\$/ha.) of European Eel farming

Harvesting rate (%)	Production of eel (kg/ha)	Price of eel (NT\$/kg)	Annual revenue (NT\$/kg)
10	2,000	180	360
		200	400
		220	440
30	6,000	180	1,080
		200	1,200
		220	1,320
50	10,000	180	1,800
		200	2,000
		220	2,200
70	14,000	180	2,520
		200	2,800
		220	3,080

The market prices of European and local eel are the same. The price level of NT\$ 180, 200 and 220 per kg are used in the calculations.

Results of calculations

The estimated costs and revenues are also substituted into equations (3), (4), and (6). The calculations were done for three price levels of seed eel, four levels of harvesting rates, two levels of price of feed, and three levels of discount rates.

Net present value. The results of the calculations are summarized in Table 12. Again, the harvesting rate, the price level of seed eel, and the price of eel make a significant difference in the calculations. The net present values are all negative when the harvesting rate is 10 percent and are all positive when the harvesting rate is over 50 percent. At the harvesting rate of 30 percent, the net present value is positive only at the lower price level of seed eel and higher price level of eel.

Table 12. Summary table of present value calculations for European Eel farms, 15 years of operation

Harvesting rate	Price of seed eel (NT\$/each)	Cost of feed (NT\$/each eel)	Discount rate								
			10%			15%			20%		
			Price of eel (NT\$/kg)								
			180	200	220	180	200	220	180	200	220
10%	1	8.5	-	-	-	-	-	-	-	-	-
		10.5	-	-	-	-	-	-	-	-	-
	2	8.5	-	-	-	-	-	-	-	-	-
		10.5	-	-	-	-	-	-	-	-	-
	3	8.5	-	-	-	-	-	-	-	-	-
		10.5	-	-	-	-	-	-	-	-	-
30%	1	8.5	+	+	+	+	+	+	+	+	+
		10.5	+	+	+	-	+	+	-	+	+
	2	8.5	-	+	+	-	+	+	-	+	+
		10.5	-	+	+	-	-	+	-	-	+
	3	8.5	-	-	+	-	-	+	-	-	+
		10.5	-	-	+	-	-	-	-	-	-
50%	1	8.5	+	+	+	+	+	+	+	+	+
		10.5	+	+	+	+	+	+	+	+	+
	2	8.5	+	+	+	+	+	+	+	+	+
		10.5	+	+	+	+	+	+	+	+	+
	3	8.5	+	+	+	+	+	+	+	+	+
		10.5	+	+	+	+	+	+	+	+	+
70%	1	8.5	+	+	+	+	+	+	+	+	+
		10.5	+	+	+	+	+	+	+	+	+
	2	8.5	+	+	+	+	+	+	+	+	+
		10.5	+	+	+	+	+	+	+	+	+
	3	8.5	+	+	+	+	+	+	+	+	+
		10.5	+	+	+	+	+	+	+	+	+

Source: Appendix Table 12

Minimum (break-even) price of eel. The results of the calculations are summarized in Figures 7 and 8. A lower harvesting rate and higher price of seed eel

increase the minimum price of eel. The break-even price of eel is in the range of NT\$ 99-438 per kg between the harvesting rates of 70 and 10 percent when the price per seed eel is NT\$ 1, and in the range of NT\$ 120-558 when the price per seed eel is NT\$ 3. The difference in the calculated break-even prices is about NT\$ 20 higher per kg for a 5-year operation than that of 15 years. Since the current price per European elver is about NT\$ 1 and the current price of eel is about NT\$ 200 per kg, the lowest harvesting rate is about 25 percent, compared with 70 percent in the case of local eel production in order to make the operation just break-even.

The results of the calculations suggest that in order to increase the net present value or to reduce the break-even price of eel, the harvesting rate should be increased.

Annual average rate of return on investment. The calculations are done only for those estimates with positive net present values and the results are summarized in Appendix Table 14. The higher the harvesting rate and the lower the price of elver, the higher is the rate of return on investment. The high levels of eel price also resulted in a high rate of return. The annual average rate of return on in-

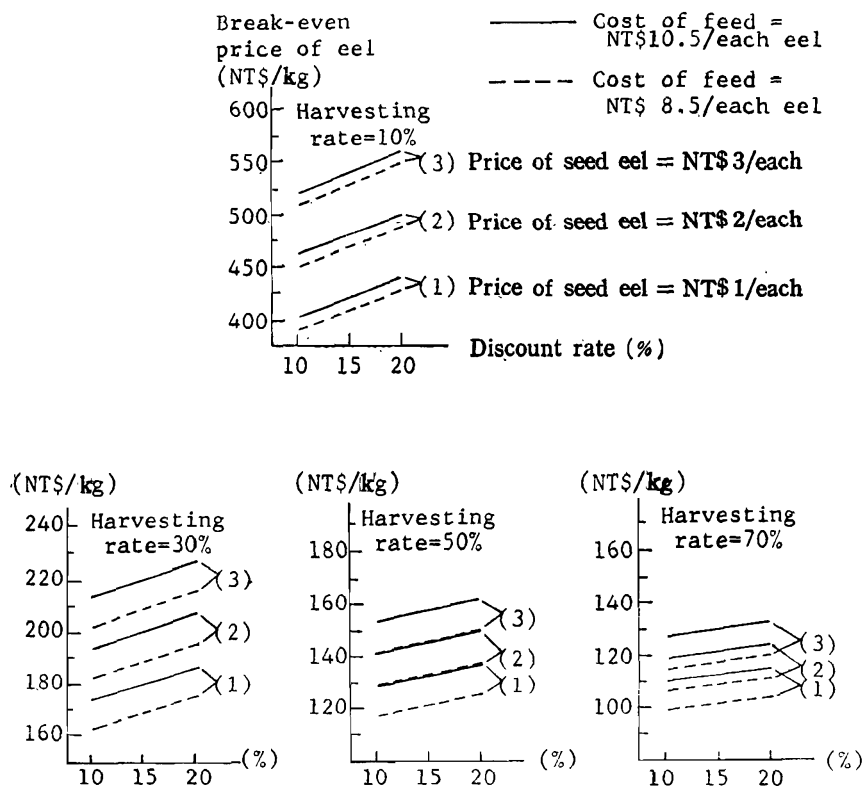


Fig. 7. Relationship among break-even price of European Eel, price of seed eel, harvesting rate and discount rate for 15 years of operation

Source: Appendix Table 13

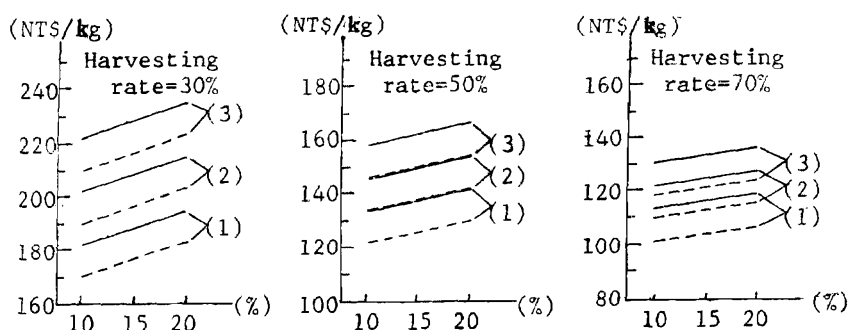
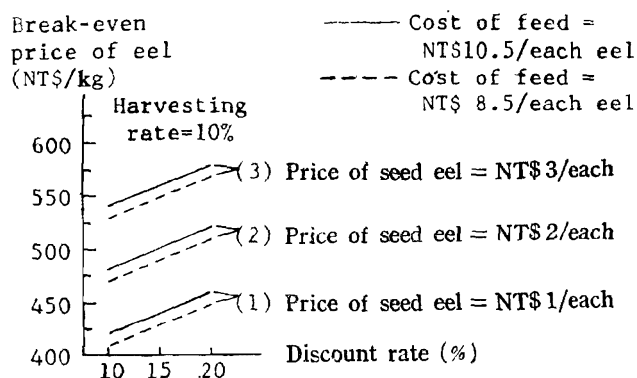


Fig. 8. Relationship among break-even price of European Eel, price of seed eel, harvesting rate and discount rate for 5 years of operation
Source: Appendix Table 13

vestment is in the range of 8-78 percent between the harvesting rates of 30 and 70 percent when the price per elver is NT\$ 1 and the price of eel is NT\$ 200 per kg. When the price per elver is increased to NT\$ 2 and other things remain equal, the annual average return on investment would drop to the level of 1-62 percent. The annual average rate of return on investment in European eel farming is higher than that in local eel farming at the same level of harvesting rate.

Seed eel (elver) farming. When seed eel are first caught, about 5,000-6,000 individuals (glass eel) weigh one kg. After 4-6 months, the weight increases to about

Table 13. Seed eel imports in Japan, 1969-1972
(in tons)

	1969	1970	1971	1972
Taiwan	39	101	265	67
France	20	10	24	64
Korea	1	11	9	—
Italy	—	6	7	2
England	—	4	—	8

Source: *Japanese Fish Culture News*

100 individuals (elvers) per kg. A large proportion of the seed eel were exported to Japan before 1971 (as shown in Table 13). To conserve sufficient seed eel for stocking the expanding local eel ponds, the Taiwan Fisheries Bureau now limits the export of seed eel to the period of April 1st to September 31st. Taiwan's export of seed eel has dropped significantly since 1972. It is estimated that more than 100 tons of European eel have been imported by Japan this year.

Enumeration of costs and revenues

The farm size for seed eel production is relatively small. The cost items are estimated on a one-tenth hectare basis. Both initial and operating costs are estimated on the basis of the information obtained from the field survey of seed eel farmers as shown in Tables 14 and 15. Annual revenues are estimated by using equation (8) as shown Table 16. Three harvesting rates 70, 80 and 90 percent are used in the Calculations along with two price levels of seed eel (NT\$ 1,100 and 1,300 per kg).

Table 14. Estimated initial capital costs (NT\$/0.1 ha) of seed eel farming

Item	Cost	Remarks
Fish ponds	NT\$ 52,500	Concrete, 4 feet in depth, the average size of a pond is 1 to 2.5 ares.
Electric Equipment	7,188	Including diesel engine, electric wire and lighting
Buildings	5,469	Including office, workshop, storage and living quarters, etc.
Wells	2,038	0.4-1 wells per 10 ares.
Water pump	2,400	1.5-3 H. P. per 10 ares.
Paddle Wheel and electric motors	4,891	Acts as aerators, 0.5 set per 10 ares.
Fence	841	Concrete column and wire.
Net	859	
Truck & motorcycle	11,094	
Mis.	3,125	Including feed mixer, furniture watch dog, etc.
Total	90,405	

Results of calculations

The estimated costs and revenues are substituted into equations (3), (4), and (5). The calculations were performed for four levels of price of glass eel three levels of harvesting rates, two levels of cost of feed, two levels of price of seed eel and three levels of discount rates.

The harvesting rate and the level of glass eel prices make a significant difference in the calculation again. The net present values are positive only when the price per glass eel is NT\$5 at all the harvesting rates (Table 17). The break-even price is in the range of NT\$ 855-1,101 per kg between the harvesting rates of 90 and 70 percent when the price of glass eel is about NT\$5. If the price per glass eel is increased to NT\$20, other things remaining equal, the break-even price would

be about NT\$2,520-3,243 per kg. The calculated break-even prices for a 5-year operation are about NT\$35 per kg higher than those of a 15 year operation (Figures 9 and 10). The annual average rate of return on investment is in the range of 2-18

Table 15. Estimated annual operating costs (NT\$/0.1 ha) of seed eel farming

Item	Cost	Remarks
Glass eel	(1) NT\$ 100,000	NT\$ 5/each glass eel, with stocking rate of 120,000 individuals.
	(2) 200,000	NT\$ 10/each glass eel, with stocking rate of 120,000 individuals.
	(3) 300,000	NT\$ 15/each glass eel, with stocking rate of 120,000 individuals.
	(4) 400,000	NT\$ 20/each glass eel, with stocking rate of 120,000 individuals.
Feed	(1) 14,000	NT\$1/each seed eel (low level), with harvesting rate of 70%.
	(2) 16,000	NT\$1/each seed eel (low level), with harvesting rate of 80%.
	(3) 18,000	NT\$1/each seed eel (low level), with harvesting rate of 90%.
	(4) 18,200	NT\$1.3/each seed eel (high level), with harvesting rate of 70%.
	(5) 20,800	NT\$1.3/each seed eel (high level), with harvesting rate of 80%.
	(6) 23,400	NT\$1.3/each seed eel (high level), with harvesting rate of 90%.
Wages	9,000	
Maintenance and repair	5,209	
Electricity	2,800	
Chemicals	3,000	
Rent	3,018	
Mis.	1,000	

Table 15. (continued)

Harvesting rate (%)	Price of glass eel (NT\$/each)	Cost of feed (NT\$/each eel)	Total annual operating cost (NT\$1,000/0.1 ha)
70	5	1.0	138
		1.3	142
	10	1.0	238
		1.3	242
	15	1.0	338
		1.3	342
20	1.0	438	
	1.3	442	
80	5	1.0	140
		1.3	145
	10	1.0	240
		1.3	245
	15	1.0	340
		1.3	345
20	1.0	440	
	1.3	445	

90	5	}	1.0	142
			1.3	147
	10	}	1.0	242
			1.3	247
	15	}	1.0	342
			1.3	347
20	}	1.0	442	
		1.3	447	

Table 16. Estimated annual revenue (NT\$/0.1 ha) of seed eel farming

Harvesting rate (%)	Production of eel (kg/0.1 ha)	Price of seed eel (NT\$/kg)	Annual revenue (NT\$1,000/0.1 ha)	
70	140	}	1,100	154
			1,300	182
80	160	}	1,100	176
			1,300	208
90	180	}	1,100	198
			1,300	234

Table 17. Summary table of NPV of seed eel farming, 15 Years of operation

Harvesting rate	Price of glass eel (NT\$/each)	Cost of feed (NT\$/each)	Discount rate						
			10%		15%		20%		
			Price of eel (NT\$/kg)						
			1,100	1,300	1,100	1,300	1,100	1,300	
70	5	}	1.0	+	+	+	+	-	+
			1.3	-	+	-	+	-	+
	10	}	1.0	-	-	-	-	-	-
			1.3	-	-	-	-	-	-
	15	}	1.0	-	-	-	-	-	-
			1.3	-	-	-	-	-	-
20	}	1.0	-	-	-	-	-	-	
		1.3	-	-	-	-	-	-	
80	5	}	1.0	+	+	+	+	+	+
			1.3	+	+	+	+	+	+
	10	}	1.0	-	-	-	-	-	-
			1.3	-	-	-	-	-	-
	15	}	1.0	-	-	-	-	-	-
			1.3	-	-	-	-	-	-
20	}	1.0	-	-	-	-	-	-	
		1.3	-	-	-	-	-	-	

90	5	}	1.0	+	+	+	+	+	+
			1.3	+	+	+	+	+	+
	10	}	1.0	-	-	-	-	-	-
			1.3	-	-	-	-	-	-
	15	}	1.0	-	-	-	-	-	-
			1.3	-	-	-	-	-	-
20	}	1.0	-	-	-	-	-	-	
		1.3	-	-	-	-	-	-	

Source: Appendix Table 16

percent at the 70 percent harvesting rate, and in the range of 22-45 percent at the 90 percent harvesting rate (Appendix Table 18). Investment in seed eel farming yields less returns than investment in local and European eel farming.

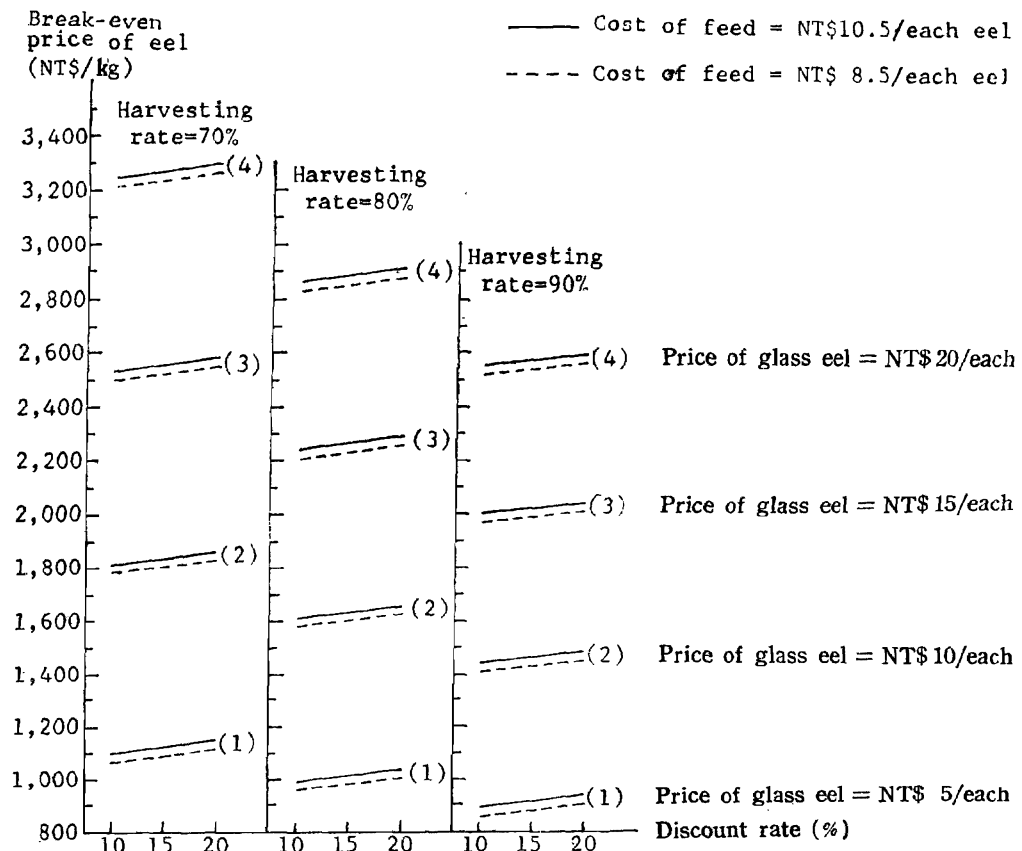


Fig. 9. Relationship among break-even price of seed eel (elver), price of glass eel, harvesting rate and discount rate for 15 years of operation

Source: Appendix Table 17

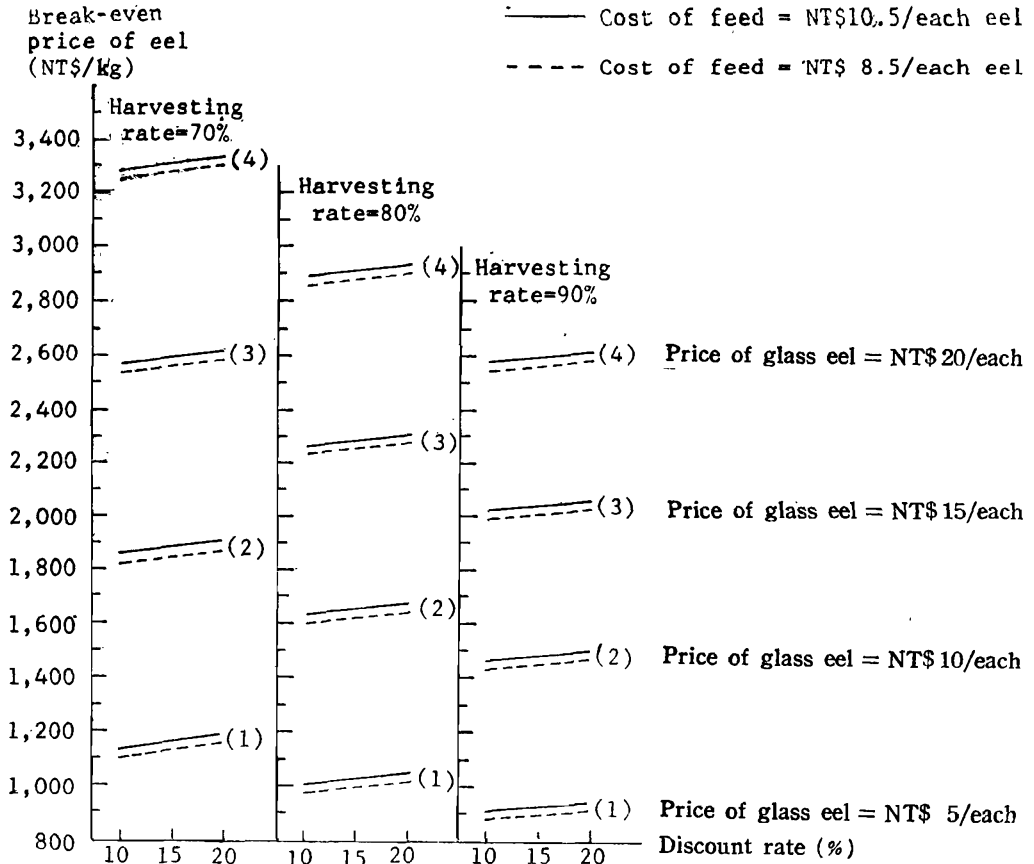


Fig. 10. Relationship among break-even price of seed eel (elver), price of glass eel, harvesting rate and discount rate and discount rate for 5 years of operation

Source: Appendix: Tabl 17

III. PRICES AND DEMAND FOR EEL

The calculations in the previous section indicate that the profit from eel farming can only be increased by reduction in the cost of production and by increase in the harvesting rate from a production point of view. However, the previous calculations also indicate that the higher the price level of eel, the higher are the net present value and the rate of return on investment; the higher the market price of eel than the calculated break-even price, the higher is the profit rate. Therefore, the prospective future of this industry depends also on the price and market demand for eel.

Japan is the most important eel producing and consuming country in the world. It is estimated that over 90 percent of the eel production in Taiwan has been exported to Japan during the past few years. Taiwan's exports of eel accounted for about 0.4 percent of the total eel supply in Japan in 1969 and about 16 percent in 1972 as shown in Table 18. It also accounted for about 96 percent of the total eel imports in Japan. Therefore, the prospective growth of the eel industry in Taiwan is dependent mainly on the Japanese markets.

The prices of eel in Japan vary seasonally. Prices begin to rise in the spring and increase until it reaches its peak in July which is traditionally a month for eel consumption. The prices for eel decline after July because of the declining demand. During the past few years, the price level of eel has been increasing because the production from domestic sources has been decreasing and this decrease is due to poor catches of seed eel and disease.

Table 18. Eel imports from Taiwan as a percentage of total eel supply in Japan

Years	Total eel supply ¹⁾	Imports from Taiwan	Percentage of total supply
	(tons)	(tons)	(%)
1969	26,581	98	0.4
1970	20,082	605	3.0
1971	18,502 ²⁾	1,491	8.1
1972	20,368 ²⁾	3,298	16.2

¹⁾ Including production from eel farms and natural waters and imports.

²⁾ Estimated.

Sources: Japanese Yearbook of Marine Products and Bureau of Foreign Exchange, Central Bank of China.

In order to understand the market aspects of eel sales in Japan, we should know the functional relationships between demand for eel and the possible determinants of demand such as prices and income. The following aggregated demand function for eel in Japan is postulated.

$$Q = f\left(\frac{P_e}{WPI}, -\frac{I}{CPI}\right)$$

Where

Q = total aggregate consumption of eel (tons)

P_e = wholesale price of eel (1,000 Yen/ton)

I = current aggregate income (1,000 million Yen)

WPI = wholesale price index

CPI = consumer price index (all commodities)

The function states that aggregate eel consumption is related to the ratio of eel price to other prices in the economy and real aggregate income. We hypothesize an inverse relationship between eel consumption and eel price and a positive relationship between aggregate eel consumption and aggregate income.

The demand equation at the producer's level based on annual average data for 1961-1970 is computed by the Least Squares Method. The results are as follows:

$$Q = 3,839 - 19.97 \frac{P_e}{WPI} + 1.03 \frac{I}{CPI} \quad R^2 = 0.96 \quad (9)$$

(2.31)* (0.07)*

* Figures in parentheses are standard errors.

The results reveal a significant negative effect of increase in price of eel on eel consumption and positive effect of increase in standard of living on consumption. Both regression coefficients are statistically significant at the one percent level. The coefficient of determination is 0.96. This means that 96 percent of the variance of the quantity demanded (Q) can be explained by the independent variables such as price and income.

Once the demand equation has been estimated, the price elasticity of demand (E_p) for eel at the mean price and quantity can be calculated as:

$$E_p = \frac{\partial Q}{\partial P} \cdot \frac{\bar{P}}{Q} = -0.98 \quad (10)$$

This result tells us that a one percent change in price, income remaining equal, causes a -0.98 percent change in demand for eel.

The income elasticity of demand (E_i) for eel at the producers level can be calculated as:

$$E_i = \frac{\partial Q}{\partial I} \cdot \frac{\bar{I}}{Q} = 1.73 \quad (11)$$

This equation suggests that a one percent change in aggregate national income causes a 1.73 percent change in demand for eel, if there is not significant rise in the price of eel. Since the aggregate national income is increasing rapidly, we can assume, based on the above results, that the aggregate demand for eel is increasing and will continue to do so if there is no significant increase in the price of eel.

In order to share the Japanese market, the following necessary conditions must be met by the eel industry in Taiwan.

$$P_b + C_m < P_j$$

or

$$P_b < P_j - C_m \quad (12)$$

Where

P_b = calculated break-even (minimum) price of eel

P_j = the selling price in Japan under competitive conditions

C_m = marketing and transportation costs from Taiwan to Japan

Three marketing channels exist: (1) local eel producers→middlemen→Japanese importers; (2) local eel producers→eel producers' cooperative→Japanese importers; and (3) local eel producer→Japanese importers. In all three cases, the marketing cost can be calculated as:

$$C_m = C_a + C_b + C_d \quad (13)$$

Where

C_a = packing cost, air fare and commissions.

In the first case it presently costs about NT\$40 per kg of eel. In the second case, the eel producers' cooperative ships the product of its members to Japan by chartered airplane which costs about NT\$20.50 per kg of eel. It costs about the same amount (NT\$20.50) for the third case.

C_a = Japanese import duty which is about 5 percent of the selling price in Japan

C_d = Importers's commission which is also about 5 percent of the selling price in Japan.

The break-even (minimum) price (P_b) of eel under various conditions were calculated in the previous section. The marketing costs are relatively stable and can be predicted. With the information provided in this study, eel producers in Taiwan should be able to figure out whether it is possible to ship their products to Japan without losing money. Since the prices of eel in Japan fluctuate seasonally, local producers control their production and market their stock at times when supplies are seasonally low, or when the prices are seasonally high in Japan. The aggregate demand equation in Japan suggests an approximately unitary price elasticity. If the rate of increase in supply from domestic and foreign sources, such as Taiwan, mainland China, Korea, etc., are faster than that of demand in the future, the price level of eel in the Japanese market is likely to fall.

There is presently no information available on the price and demand for eel in the local markets. Eel is regarded as a luxury food item and is consumed mainly

in restaurants. Since eel is rich in protein and vitamins, especially vitamin A, as shown in Table 19, it would become a popular food item if its price could be reduced significantly.

Table 19. Comparison of nutrition value of selected fish species and poultry products (unit/100 g)

Items	Calories (Cal.)	Protein (g.)	Fat (g.)	Vitamin A (I. U.)
Eel	249	20	18	3,000
Common Carp	178	22	9	20
Crucian Carp	103	17	3	50
Milkfish	136	21	5	292
Mackerel	114	18	4	50
Sea Bream	111	19	3	90
Marlin	128	23	3	10
Tuna	113	26	0.3	20
Shrimp	84	16	1.1	100
Oyster	96	10	4	100
Poultry	129	21	5	40
Egg	152	13	11	800

IV. SUMMARY AND CONCLUSIONS

Profit is the goal of private investment. The future development of the eel industry in Taiwan depends mainly on the profitability of the investment in the industry. The profitability of the investment is measured by using the present value method in this study. The net present value of the investment, the minimum (break-even) price of eel and the rate of return on investment are calculated under various conditions, such as farm sizes, harvesting rates, prices of seed eel, prices of eel, cost of feed and rates of discount. There are two major species of eel in Taiwan: Local eel and imported European eel, and two types of eel farming: rearing the glass eel to table size for final consumption and rearing the glass eel to larger size seed eel. The calculations are done for each species and for each type of operation. The results of the calculations indicate that the harvesting rate and the price of seed eel (glass eel and elver) are the most important factors affecting the profitability of eel farming. Further efforts for increasing the harvesting rate and reducing the costs of production seem necessary. The results of the calculations also suggest that the annual average rate of return on investment in European eel farming is higher than investment in local eel and seed eel farming at the same rates of harvesting. Since there is a shortage of supply of locally produced seed eel, research on the rearing of eel from other countries of origin also seems necessary.

The calculations also indicate that the higher the price level of eel, the higher are the net present value and the rate of return on investment; the higher the market price of eel than the calculated break-even price, the higher is the profit rate. Therefore, the prospects of this industry depend also on price and market-demand for eel.

It is estimated that over 90 percent of the eel production in Taiwan has been exported to Japan in recent years. The prices of eel in Japan fluctuate seasonally: they increase from spring and reach their highest level in the summer and decline after July. Local producers could control their production and market their stock at times when supplies are seasonally low or when the prices are seasonally high in Japan in order to increase their profits.

The aggregate demand equation for eel in Japan suggests an approximately unitary price elasticity (-0.98) and high income elasticity of demand (1.73). Since the income is increasing rapidly, we can assume that the aggregate demand for eel is also increasing in Japan, if there is no significant increase in the price of eel.

There are two events which may be important to the development of the eel industry in Taiwan. First, both Japan and Korea are experimenting in indoor eel farming. The rearing period of eel can be reduced from 2 years to 8 months

with a high harvesting rate under indoor farming conditions. There is no cost data available for comparison. Yet since the production from indoor farms is expanding, it indicates that indoor eel farming is technologically and economically feasible. Second, mainland China has been doing research on eel culture in recent years with the help of Japanese eel specialists and may become Taiwan's major competitor in the Japanese eel market in the future.

The data used in the cost-revenue analysis are based mainly on the information obtained from the field survey of 30 eel producers. They are considered reliable. The marketing analysis is primarily based on Japanese data which are the best data available for this study.

Appendix Table 1. Estimated NPV (NT\$1,000/ha) of Local Eel farming, for farm size under 3 hectares, 15 years of operation

Harvesting rate	Price of seed lee (NT\$/each)	Cost of feed (NT\$/each eel)	Discount rate																	
			10%			15%			20%											
			180	200	220	180	200	220	180	200	220	180	200	220						
50%	5	{	1,677	3,198	4,719	1,083	2,253	3,422	688	1,623	2,558	764	2,285	3,807	381	1,551	2,720	126	1,062	1,997
	10	{	-2,387	-1,366	156	-2,425	-1,256	-86	-2,118	-1,183	-248	-3,800	-2,278	-757	-3,127	-1,958	-788	-2,679	-1,744	-809
	15	{	-7,451	-5,929	-4,408	-5,934	-4,764	-3,595	-4,923	-3,988	-3,053	-8,363	-6,842	-5,321	-6,635	-5,466	-4,296	-5,484	-4,549	-3,614
	20	{	-12,014	-10,493	-8,972	-9,442	-8,273	-7,103	-7,728	-6,793	-5,858	-12,927	-11,406	-9,884	-10,144	-8,974	-7,805	-8,289	-7,354	-6,419
60%	5	{	3,639	5,465	7,290	2,592	3,995	5,398	1,894	3,016	4,138	2,544	4,369	6,195	1,750	3,153	4,556	1,221	2,343	3,465
	10	{	-924	901	2,726	-917	487	1,890	-911	211	1,333	-2,020	-194	1,631	-1,759	-355	1,048	-1,585	-463	659
	15	{	-5,488	-3,663	-1,837	-4,425	-3,022	-1,618	-3,717	-2,595	-1,473	-6,583	-4,758	-2,933	-5,267	-3,864	-2,460	-4,390	-3,268	-2,146
	20	{	-10,052	-8,226	-6,401	-7,934	-6,530	-5,127	-6,522	-5,400	-4,278	-11,147	-9,322	-7,496	-8,776	-7,372	-5,969	-7,195	-6,073	-4,951
70%	5	{	5,602	7,731	9,861	4,100	5,738	7,375	3,100	4,409	5,718	4,324	6,453	8,583	3,118	4,755	6,393	2,315	3,624	4,933
	10	{	1,038	3,168	5,297	592	2,229	3,866	295	1,604	2,913	-240	1,890	4,019	-390	1,247	2,884	-491	818	2,128
	15	{	-3,526	-1,369	734	-2,917	-1,279	358	-2,511	-1,201	108	-4,804	-2,674	-544	-3,899	-2,262	-624	-3,296	-1,987	-678
	20	{	-8,089	-5,960	-3,830	-6,425	-4,788	-3,150	-5,316	-4,007	-2,698	-9,367	-7,238	-5,108	-7,407	-5,770	-4,133	-6,101	-4,792	-3,483

Appendix Table 2. Estimated NPV (NT\$1,000/ha) of Local Eel farming, for farm size 3-5 hectares, 15 years of operation

Harvesting rate	Price of seed eel (NT\$/each)	Cost of feed (NT\$/each eel)	Discount rate											
			10%				15%				20%			
			180	200	220	180	200	220	180	200	220	180	200	220
			Price of eel (NT\$/kg)											
50%	5	{ 8.5 10.5	2,088 1,176	3,610 2,697	5,131 4,218	1,416 715	2,586 1,884	3,755 3,053	968 407	1,904 1,342	2,839 2,278			
	10	{ 8.5 10.5	-2,475 -3,388	-954 -1,868	567 -346	-2,092 -2,794	-933 -1,624	247 -455	-1,837 -2,398	-902 -1,463	33 -528			
	15	{ 8.5 10.5	-7,039 -7,952	-5,518 -6,431	-3,997 -4,909	-5,601 -6,302	-4,431 -5,133	-3,262 -3,963	-4,642 -5,203	-3,707 -4,268	-2,772 -3,333			
	20	{ 8.5 10.5	-11,603 -12,515	-10,081 -10,994	-8,560 -9,473	-9,109 -9,811	-7,940 -8,641	-6,770 -7,472	-7,447 -8,009	-6,512 -7,073	-5,577 -6,138			
				4,051 2,955	5,876 4,781	7,702 6,606	2,925 2,083	4,328 3,486	5,732 4,890	2,175 1,501	3,297 2,624	4,419 3,746		
60%	5	{ 8.5 10.5	-513 -1,608	1,312 217	3,138 2,043	-584 -1,426	820 -22	2,223 1,381	-631 -1,304	492 -182	1,614 940			
	10	{ 8.5 10.5	-5,077 -6,172	-3,251 -4,346	-1,462 -2,521	-3,092 -4,934	-2,689 -3,531	-1,285 -2,127	-3,436 -4,109	-2,314 -2,987	-1,192 -1,865			
	15	{ 8.5 10.5	-9,640 -10,736	-7,815 -8,910	-5,989 -7,085	-7,600 -8,442	-6,197 -7,039	-4,794 -5,636	-6,241 -6,914	-5,119 -5,792	-3,997 -4,670			
	20	{ 8.5 10.5	6,013 4,735	8,143 6,865	10,272 8,995	4,433 3,451	6,071 5,088	7,708 6,726	3,381 2,595	4,690 3,905	5,999 5,214			
70%	5	{ 8.5 10.5	1,449 172	3,579 2,301	5,790 4,431	925 -57	2,562 1,580	4,200 3,217	576 -210	1,885 1,099	3,194 2,408			
	10	{ 8.5 10.5	-3,114 -4,392	-985 -2,266	1,145 -133	-2,583 -3,566	-946 -1,928	691 -291	-2,230 -3,015	-920 -1,706	389 -397			
	15	{ 8.5 10.5	-7,678 -3,956	-5,548 -6,826	-3,419 -4,696	-6,092 -7,074	-4,455 -5,437	-2,817 -3,800	-5,035 -5,820	-3,726 -4,511	-2,417 -3,202			
	20	{ 8.5 10.5												

Appendix Table 3. Estimated NPV (NT\$1,000/ha) of Local Eel farming, for farm size over 5 hectares, 15 years of operation

Harvesting rate	Price of seed eel (NT\$/each)	Cost of Feed (NT\$/each eel)	Discount rate												
			10%			15%			20%						
			180	200	220	180	200	220	180	200	220	180	200	220	
50%	5	{	2,386	3,907	5,428	1,657	2,827	3,996	1,172	2,107	3,042	1,634	-698	237	3,042
		{	1,473	2,994	4,515	955	2,125	3,294	611	1,546	2,481	-2,195	-1,260	-324	2,481
	10	{	-2,178	-657	864	-1,851	-682	488	-1,634	-698	237	-2,195	-1,260	-324	237
		{	-3,091	-1,570	-48	-2,553	-1,384	-214	-2,195	-1,260	-324	-2,195	-1,260	-324	-324
	15	{	-6,742	-5,221	-3,699	-5,360	-4,190	-3,021	-4,439	-3,504	-2,569	-5,000	-4,065	-3,130	-2,569
		{	-7,655	-6,133	-4,612	-6,061	-4,892	-3,722	-5,000	-4,065	-3,130	-5,000	-4,065	-3,130	-3,130
	20	{	-11,305	-9,784	-8,263	-8,868	-7,699	-6,529	-7,244	-6,309	-5,374	-7,805	-6,870	-5,935	-5,374
		{	-12,218	-10,697	-9,176	-9,570	-8,400	-7,231	-7,805	-6,870	-5,935	-7,805	-6,870	-5,935	-5,935
60%	5	{	4,348	6,173	7,999	3,166	4,569	5,973	2,378	3,500	4,622	-427	695	1,817	4,622
		{	3,253	5,078	6,904	2,324	3,727	5,130	1,705	2,827	3,949	-1,101	22	1,144	3,949
	10	{	-216	1,610	3,435	-343	1,061	2,464	-427	695	1,817	-1,101	22	1,144	1,817
		{	-1,311	514	2,340	-1,185	219	1,622	-1,101	22	1,144	-1,101	22	1,144	1,144
	15	{	-4,779	-2,954	-1,128	-3,851	-2,448	-1,044	-3,233	-2,110	-988	-3,233	-2,110	-988	-988
		{	-5,875	-4,049	-2,224	-4,693	-3,290	-1,886	-3,906	-2,784	-1,662	-3,906	-2,784	-1,662	-1,662
	20	{	-9,343	-7,518	-5,692	-7,360	-5,956	-4,553	-6,038	-4,916	-3,794	-6,038	-4,916	-3,794	-3,794
		{	-10,438	-8,613	-6,787	-8,202	-6,798	-5,395	-6,711	-5,589	-4,467	-6,711	-5,589	-4,467	-4,467
70%	5	{	6,310	8,440	10,570	4,674	6,312	7,949	3,584	4,893	6,203	-2,799	4,108	5,417	6,203
		{	5,032	7,162	9,292	3,692	5,329	6,967	2,799	4,108	5,417	-2,799	4,108	5,417	5,417
	10	{	1,747	3,876	6,006	1,166	2,803	4,440	779	2,088	3,397	-2,799	4,108	5,417	3,397
		{	469	2,599	4,728	184	1,821	3,458	6	1,303	2,612	-2,799	4,108	5,417	2,612
	15	{	-2,817	-687	1,442	-2,343	-705	932	-2,026	-717	592	-2,026	-717	592	592
		{	-4,095	-1,965	165	-3,325	-1,688	-50	-2,812	-1,503	-193	-2,812	-1,503	-193	-193
	20	{	-7,381	-5,251	-3,121	-5,851	-4,214	-2,576	-4,832	-3,522	-2,213	-4,832	-3,522	-2,213	-2,213
		{	-8,659	-6,529	-4,399	-6,833	-5,196	-3,559	-5,617	-4,308	-2,999	-5,617	-4,308	-2,999	-2,999

Appendix Table 4. Estimated break-even price (NT\$/kg) of Local Eel, 15 years of operation

Harvesting rate	Price of seed eel (NT\$/each)	Cost of feed (NT\$/each eel)	Size of farm																	
			Under 3 ha.						Between 3-5 ha.						Over 5 ha.					
									Discount rate											
			10%	15%	20%	10%	15%	20%	10%	15%	20%	10%	15%	20%						
50%	5	{	158	162	166	153	156	160	149	152	155	170	174	177	165	168	171	161	164	167
	10	{	218	222	225	213	216	219	209	212	215	230	234	237	225	228	231	221	224	227
	15	{	278	282	285	273	276	279	269	272	275	290	294	297	285	288	291	281	284	287
	20	{	338	342	345	333	336	339	329	332	335	350	354	357	345	348	351	341	344	347
60%	5	{	140	143	146	136	138	141	132	135	138	152	155	158	148	150	153	144	147	150
	10	{	190	193	196	186	188	191	182	185	188	202	205	208	198	200	203	194	197	200
	15	{	240	243	246	236	238	241	232	235	238	252	255	258	248	250	253	244	247	250
	20	{	290	293	296	286	288	291	282	285	288	302	305	308	298	300	303	294	297	300
70%	5	{	127	130	133	124	126	128	121	123	125	139	142	145	136	138	140	133	135	137
	10	{	170	173	176	166	169	171	164	166	168	182	185	188	178	181	183	176	178	180
	15	{	213	216	218	209	212	214	206	209	211	225	228	230	221	224	226	218	221	223
	20	{	256	259	261	252	254	257	249	252	254	268	271	273	264	266	269	261	264	266

Appendix Table 5. Estimated break-even price (NT\$/kg) of Local Eel, 5 years of operation

Harvesting rate	Price of seed eel (NT\$/each)	Cost of feed (NT\$/each eel)	Size of farm																	
			Under 3 ha.				Between 3-5 ha.				Over 5 ha.									
			10%	15%	20%	10%	15%	20%	10%	15%	20%	10%	15%	20%						
50%	5	{ 8.5 10.5	162	166	170	156	160	163	152	155	158	174	178	182	168	171	175	164	167	170
	10	{ 8.5 10.5	222	226	230	216	219	223	212	215	218	234	238	242	228	231	235	224	227	230
	15	{ 8.5 10.5	282	286	290	276	279	283	272	275	278	294	298	302	288	291	295	284	287	290
	20	{ 8.5 10.5	342	346	350	336	339	343	332	335	338	354	358	362	348	351	355	344	347	350
60%	5	{ 8.5 10.5	143	147	150	138	141	144	135	138	140	155	159	162	150	153	156	147	150	152
	10	{ 8.5 10.5	193	197	200	188	191	194	185	188	190	205	209	212	200	203	206	197	200	202
	15	{ 8.5 10.5	243	247	250	238	241	244	235	238	240	255	259	262	250	253	256	247	250	252
	20	{ 8.5 10.5	293	297	300	288	291	294	285	288	290	305	309	312	300	303	306	297	300	302
70%	5	{ 8.5 10.5	130	133	136	126	129	131	123	125	128	142	145	148	138	141	143	135	137	140
	10	{ 8.5 10.5	173	176	179	169	171	174	166	168	171	185	188	191	181	183	186	178	180	183
	15	{ 8.5 10.5	216	219	221	212	214	217	209	211	213	228	231	233	224	226	229	221	223	225
	20	{ 8.5 10.5	259	261	264	255	257	260	251	254	256	271	273	276	267	269	272	263	266	268

Appendix Table 6. Estimated average annual rate of return on investment*(%) of Local Eel farming, for farm size under 3 hectares

Harvesting rate	Price of seed eel (NT\$/each)	Cost of feed (NT\$/each eel)	Discount rate											
			10%			15%			20%					
			Price of eel (NT\$/kg)											
			180	200	220	180	200	220	180	200	220	180	200	220
50%	{ 5	{ 8.5	13	24	35	8	17	26	5	12	19	1	8	15
	{ 10	{ 10.5	6	17	28	3	12	20	1	8	15			
	{ 15	{ 8.5			1									
	{ 20	{ 10.5												
60%	{ 5	{ 8.5	27	41	55	19	30	40	14	23	31	9	18	26
	{ 10	{ 10.5		33	46	13	24	34		2	10		5	5
	{ 15	{ 8.5		7	20		4	14						
	{ 20	{ 10.5			12			8						
70%	{ 5	{ 8.5	42	85	74	31	43	55	23	33	43	17	27	37
	{ 10	{ 10.5	32	48	64	23	36	48	2	12	22		6	16
	{ 15	{ 8.5	8	24	40	4	17	29						
	{ 20	{ 10.5		14	30		9	22						

* $\frac{NPV}{C_0} / N \times 100\%$

Appendix Table 7. Estimated average annual rate of return on investment*(%) of Local Eel farming, for farm size 3-5 hectares

Harvesting rate	Price of seed eel (NT\$/each)	Cost of feed (NT\$/each eel)	Discount rate											
			10%				15%				20%			
			180	200	220	240	180	200	220	240	180	200	220	240
50%	{ 5	{ 8.5	17	29	41	12	21	31	8	16	23			
	{ 10	{ 10.5	10	22	34	6	15	25	3	11	19			
	{ 15	{ 10.5	—	—	5	—	—	2	—	—	0			
	{ 20	{ 10.5	—	—	—	—	—	—	—	—	—			
60%	{ 5	{ 8.5	33	48	63	24	35	47	18	27	36			
	{ 10	{ 10.5	24	39	54	17	28	40	12	21	31			
	{ 15	{ 10.5	—	11	26	—	7	18	—	4	13			
	{ 20	{ 10.5	—	2	17	—	—	11	—	—	8			
70%	{ 5	{ 8.5	49	66	84	36	49	63	28	38	49			
	{ 10	{ 10.5	39	56	73	28	41	55	21	32	42			
	{ 15	{ 10.5	12	29	47	8	21	34	5	15	26			
	{ 20	{ 10.5	1	19	36	—	13	26	—	9	20			
			—	—	9	—	—	6	—	—	3			
			—	—	—	—	—	—	—	—	—			
			—	—	—	—	—	—	—	—	—			

* $\frac{NPV}{C_0} / N \times 100\%$

Appendix Table 8. Estimated average annual rate of return on investment*(%) of Local Eel farming, for farm size over 5 hectares

Harvesting rate	Price of seed eel (NT\$/each)	Cost of feed (NT\$/each eel)	Discount rate											
			10%				15%				20%			
			180	200	220	180	200	220	180	200	220	180	200	220
50%	5	{ 8.5 10.5	21 13	34 29	47 36	14 8	25 19	35 29	10 5	18 13	27 22			
	10	{ 8.5 10.5	—	—	8	—	—	4	—	—	2			
	15	{ 8.5 10.5	—	—	—	—	—	—	—	—	—			
	20	{ 8.5 10.5	—	—	—	—	—	—	—	—	—			
60%	5	{ 8.5 10.5	38 28	54 44	70 60	28 20	40 32	52 45	21 15	31 25	40 34			
	10	{ 8.5 10.5	—	14 4	30 20	—	9 2	21 14	—	6 0	16 10			
	15	{ 8.5 10.5	—	—	—	—	—	—	—	—	—			
	20	{ 8.5 10.5	—	—	—	—	—	—	—	—	—			
70%	5	{ 8.5 10.5	55 44	74 62	92 81	41 32	55 46	69 61	31 24	43 36	54 47			
	10	{ 8.5 10.5	15 4	34 23	52 41	10 2	24 16	39 30	7	18 11	30 23			
	15	{ 8.5 10.5	—	—	13 1	—	—	8	—	—	5			
	20	{ 8.5 10.5	—	—	—	—	—	—	—	—	—			

* $\frac{NPV}{C_0} / N \times 100\%$

Appendix Table 9. Estimated profit ratio*(%) of Local Eel farming, for farm size under 3 hectares

Harvesting rate	Price of seed eel (NT\$/each)	Cost of feed (NT\$/each eel)	Discount rate											
			10%				15%				20%			
			Price of eel (NT\$/kg)											
50%	5	{	180	200	220	180	200	220	180	200	220	180	200	220
			188	359	530	1,216	253	384	77	182	287			
	10	{	86	257	427	43	174	305	14	119	224			
			8.5	10.5	17	—	—	—	—	—	—			
	15	{	—	—	—	—	—	—	—	—	—	—	—	
			8.5	10.5	—	—	—	—	—	—	—			
	20	{	—	—	—	—	—	—	—	—	—	—	—	
			8.5	10.5	—	—	—	—	—	—	—			
60%	5	{	409	613	818	291	449	606	213	339	465			
			286	491	695	196	354	512	137	263	389			
	10	{	—	101	306	—	55	212	—	24	150			
			8.5	10.5	183	—	—	118	—	—	74			
	51	{	—	—	—	—	—	—	—	—	—			
			8.5	10.5	—	—	—	—	—	—	—			
	20	{	—	—	—	—	—	—	—	—	—			
			8.5	10.5	—	—	—	—	—	—	—			
70%	5	{	629	868	1,107	460	644	828	348	495	642			
			486	724	964	350	534	718	260	407	554			
	10	{	117	336	595	66	250	434	33	180	327			
			8.5	10.5	451	—	140	324	—	92	239			
	15	{	—	—	82	—	—	40	—	—	12			
			8.5	10.5	—	—	—	—	—	—	—			
	20	{	—	—	—	—	—	—	—	—	—			
			8.5	10.5	—	—	—	—	—	—	—			

* $\frac{NPV}{C_0} \times 100\%$

Appendix Table 10. Estimated profit ratio*(%) of Local Eel farming, for farm size 3-5 hectares

Harvesting rate	Price of seed eel (NT\$/each)	Cost of feed (NT\$/each. eel)	Discount rate								
			10%			15%			0%		
			180	200	220	180	200	220	180	200	220
50%	5	{ 8.5 10.5	255 144	441 330	627 515	173 87	316 230	459 373	118 50	233 164	347 278
	10	{ 8.5 10.5	—	—	69	—	—	30	—	—	4
	15	{ 8.5 10.5	—	—	—	—	—	—	—	—	—
	20	{ 8.5 10.5	—	—	—	—	—	—	—	—	—
60%	5	{ 8.5 10.5	495 361	718 584	941 807	357 255	529 426	700 598	266 183	403 321	540 458
	10	{ 8.5 10.5	—	160 27	383 250	—	100	272 169	—	60	197 115
	15	{ 8.5 10.5	—	—	—	—	—	—	—	—	—
	20	{ 8.5 10.5	—	—	—	—	—	—	—	—	—
70%	5	{ 8.5 10.5	735 579	995 839	1,255 1,099	542 422	742 622	942 822	413 317	573 477	733 637
	10	{ 8.5 10.5	177 21	437 281	698 542	113	313 193	513 393	70	230 134	390 294
	15	{ 8.5 10.5	—	—	140	—	—	84	—	—	47
	20	{ 8.5 10.5	—	—	—	—	—	—	—	—	—

* $\frac{NPV}{C_0} \times 100\%$

Appendix Table II. Estimated profit ratio*(%) of Local Eel farming, for farm size over 5 hectares

Harvesting rate	Price of seed eel (NT\$/each)	Cost of feed (NT\$/each eel)	Discount rate																	
			10%				15%				20%									
			180	200	220	180	200	220	180	200	220	180	200	220						
50%	5	{	312	511	710	217	370	523	153	276	398	193	392	560	125	278	431	80	202	324
	10	{	—	—	113	—	—	64	—	—	—	—	—	—	—	—	—	—	—	31
	15	{	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	20	{	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
60%	5	{	569	807	1,046	414	597	781	311	458	604	425	664	903	304	487	671	223	370	516
	10	{	—	210	449	—	139	322	—	91	238	—	67	306	—	29	212	—	3	150
	15	{	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	20	{	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
70%	5	{	825	1,104	1,382	611	825	1,039	469	640	811	658	937	1,215	483	697	911	366	537	708
	10	{	228	507	785	152	367	581	102	273	444	61	340	618	24	238	452	—	170	342
	15	{	—	—	189	—	—	122	—	—	77	—	—	22	—	—	—	—	—	—
	20	{	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—

* $\frac{NPV}{C_0} \times 100\%$

Appendix Table 12. Estimated NPV (NT\$ 1,000/ha) of European Eel farming, 15 years of operation

Harvesting rate	Price of seed eel (NT\$/each)	Cost of feed (NT\$/each eel)	Discount rate												
			10%			15%			20%						
			Price of eel (NT\$/kg)												
			180	200	220	180	200	220	180	200	220	180	200	220	
10%	1	{ 8.5 10.5	-3,170 -3,353	-2,866 -3,049	-2,562 -2,744	-2,651 -2,791	-2,417 -2,557	-2,183 -2,323	-2,304 -2,416	-2,117 -2,229	-1,930 -2,042				
	2	{ 8.5 10.5	-4,083 -4,266	-3,779 -3,961	-3,475 -3,675	-3,352 -3,493	-3,118 -3,259	-2,884 -3,025	-2,865 -2,977	-2,678 -2,790	-2,491 -2,603				
	3	{ 8.5 10.5	-4,996 -5,178	-4,692 -4,875	-4,387 -4,570	-4,054 -4,194	-3,820 -3,960	-3,586 -3,727	-3,426 -3,539	-3,239 -3,352	-3,052 -3,164				
				754 207	1,667 1,119	2,580 2,032	367 -54	1,068 647	1,770 1,439	108 -228	669 333	1,230 894			
30%	1	{ 8.5 10.5	-188 -706	754 207	1,667 1,119	-335 -756	367 -54	1,089 647	-453 -789	108 -228	669 333				
	2	{ 8.5 10.5	-1,071 -1,619	-158 -706	754 207	-1,037 -1,458	-335 -756	367 -54	-1,014 -1,350	-453 -789	108 -228				
	3	{ 8.5 10.5	4,679 3,766	6,200 5,288	7,722 6,809	3,384 2,682	4,553 3,852	5,723 5,021	2,521 1,960	3,456 2,895	4,391 3,830				
50%	1	{ 8.5 10.5	3,766 2,854	5,288 4,373	6,809 5,896	2,682 1,981	3,852 3,150	5,021 4,320	1,960 1,399	2,895 2,334	3,830 3,269				
	2	{ 8.5 10.5	2,854 1,941	4,373 3,462	5,896 4,983	1,981 1,279	3,150 2,448	4,320 3,618	1,399 838	2,334 1,773	3,269 2,708				
	3	{ 8.5 10.5	8,604 7,326	10,734 9,456	12,863 11,585	6,401 5,419	8,038 7,056	9,676 8,693	4,933 4,148	6,243 5,457	7,552 6,766				
70%	1	{ 8.5 10.5	7,691 6,413	9,821 8,543	11,951 10,673	5,700 4,717	7,337 6,354	8,974 7,992	4,372 3,587	5,682 4,896	6,991 6,205				
	2	{ 8.5 10.5	6,778 5,501	8,908 7,630	11,038 9,760	4,998 4,015	6,635 5,653	8,272 7,290	3,811 3,026	5,120 4,335	6,430 5,644				
	3	{ 8.5 10.5													

Appendix Table 13. Estimated break-even price (NT\$/kg) of European Eel

Harvesting rate	Price of seed eel (NT\$/each)	Cost of feed (NT\$/each eel)	Period of operation					
			15 years			5 years		
			10%	15%	20%	10%	15%	20%
10%	1	8.5 10.5	388 400	407 419	426 438	408 420	428 440	448 460
	2	8.5 10.5	448 460	467 479	486 498	468 480	488 500	508 520
	3	8.5 10.5	508 520	527 539	546 558	528 540	548 560	568 580
30%	1	8.5 10.5	164 176	170 182	176 188	170 182	177 189	183 195
	2	8.5 10.5	184 196	190 202	196 208	190 202	197 209	203 215
	3	8.5 10.5	204 216	210 222	216 228	210 222	217 229	223 235
50%	1	8.5 10.5	118 131	122 134	126 138	122 134	126 138	130 142
	2	8.5 10.5	131 143	134 146	138 150	134 146	138 150	142 154
	3	8.5 10.5	143 155	146 158	150 162	146 158	150 162	154 166
70%	1	8.5 10.5	99 111	102 114	105 117	102 114	105 117	108 120
	2	8.5 10.5	108 120	110 122	113 125	111 123	113 125	116 128
	3	8.5 10.5	116 128	119 131	122 134	119 131	122 134	125 137

Appendix Table 15. Estimated profit ratio*(%) of European Eel farming

Harvesting rate	Price of seed eel (NT\$/each)	Cost of feed (NT\$/each eel)	Discount rate																	
			10%				15%				20%									
			180	200	220	180	200	220	180	200	220	180	200	220						
10%	1	{ 8.5 10.5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	2	{ 8.5 10.5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	3	{ 8.5 10.5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
30%	1	{ 8.5 10.5	82	181	280	40	116	192	12	73	133	22	121	220	146	—	—	—	—	—
	2	{ 8.5 10.5	—	82	181	—	40	116	—	—	73	—	22	121	70	—	—	—	—	—
	3	{ 8.5 10.5	—	—	82	—	—	40	—	—	—	—	—	—	40	—	—	—	—	—
50%	1	{ 8.5 10.5	507	672	837	367	494	621	273	375	476	408	573	738	544	213	213	213	213	213
	2	{ 8.5 10.5	408	573	739	291	418	544	213	314	415	309	474	639	498	152	152	152	152	152
	3	{ 8.5 10.5	309	474	639	215	342	468	152	253	354	210	375	540	392	91	91	91	91	91
70%	1	{ 8.5 10.5	933	1,164	1,395	694	872	1,049	535	677	819	794	1,025	1,256	943	450	450	450	450	450
	2	{ 8.5 10.5	834	1,065	1,296	618	796	973	474	616	758	695	926	1,157	867	389	389	389	389	389
	3	{ 8.5 10.5	735	966	1,197	542	719	897	413	555	697	596	827	1,058	790	328	328	328	328	328

* $\frac{NPV}{C_0} \times 100\%$

Appendix Table 16. Estimated NPV (NT\$1,000/0.1 ha) of seed eel farming, 15 years of operation

Harvesting rate	Price of glass eel (NT\$/each)	Cost of feed (NT\$/each eel)	Discount rate					
			10%		15%		20%	
			Price of eel (NT\$/kg)					
			1,000	1,300	1,100	1,300	1,100	1,300
70%	{ 5	{ 1.0 1.3	31 -1	244 212	3 -22	167 142	-16 -35	115 96
	{ 10	{ 1.0 1.3	-730 -761	-517 -548	-582 -606	-418 -443	-438 -503	-352 -372
	{ 15	{ 1.0 1.3	-1,490 -1,522	-1,277 -1,309	-1,166 -1,191	-1,003 -1,027	-951 -970	-820 -840
	{ 20	{ 1.0 1.3	-2,251 -2,283	-2,038 -2,070	-1,751 -1,776	-1,587 -1,612	-1,418 -1,438	-1,287 -1,307
80%	{ 5	{ 1.0 1.3	183 147	427 390	120 92	307 279	78 55	227 205
	{ 10	{ 1.0 1.3	-577 -614	-334 -371	-465 -493	-278 -306	-390 -412	-240 -263
	{ 15	{ 1.0 1.3	-1,338 -1,375	-1,095 -1,131	-1,050 -1,078	-862 -890	-857 -880	-708 -730
	{ 20	{ 1.0 1.3	-2,099 -2,135	-1,855 -1,892	-1,634 -1,662	-1,447 -1,475	-1,325 -1,347	-1,175 -1,198
90%	{ 5	{ 1.0 1.3	335 294	609 568	237 205	447 416	171 146	340 314
	{ 10	{ 1.0 1.3	-425 -466	-151 -193	-348 -379	-137 -169	-296 -322	-128 -153
	{ 15	{ 1.0 1.3	-1,186 -1,227	-912 -953	-933 -964	-722 -754	-764 -789	-595 -621
	{ 20	{ 1.0 1.3	-1,946 -1,688	-1,673 -1,714	-1,517 -1,546	-1,307 -1,338	-1,231 -1,257	-1,063 -1,088

Appendix Table 17. Estimated break-even price (NT\$/kg) of seed eel

Harvesting rate	Price of glass eel (NT\$/each)	Cost of feed (NT\$/each eel)	Period of operation					
			15 years			5 years		
			Discount rate					
			10%	15%	20%	10%	15%	20%
70%	5	1.0	1,071	1,096	1,124	1,104	1,131	1,159
		1.3	1,101	1,126	1,154	1,134	1,161	1,189
	10	1.0	1,785	1,810	1,838	1,818	1,845	1,873
		1.3	1,815	1,840	1,868	1,848	1,875	1,903
	15	1.0	2,449	2,524	2,552	2,532	2,559	2,587
		1.3	2,529	2,554	2,582	2,562	2,589	2,617
	20	1.0	3,213	3,238	3,266	3,246	3,273	3,301
		1.3	3,243	3,268	3,296	3,276	3,303	3,331
80%	5	1.0	950	972	996	678	1,002	1,026
		1.3	980	1,002	1,026	1,008	2,032	1,056
	10	1.0	1,575	1,597	1,621	1,603	1,627	1,651
		1.3	1,605	1,627	1,651	1,633	1,657	1,681
	15	1.0	2,200	2,222	2,246	2,228	2,252	2,276
		1.3	2,230	2,252	2,276	2,258	2,282	2,306
	20	1.0	2,825	2,847	2,871	2,853	2,877	2,901
		1.3	2,855	2,877	2,901	2,883	2,907	2,931
90%	5	1.0	855	875	896	881	902	924
		1.3	885	905	926	911	932	954
	10	1.0	1,410	1,430	1,451	1,436	1,457	1,479
		1.3	1,440	1,460	1,481	1,466	1,487	1,509
	15	1.0	1,965	1,985	2,006	1,991	2,012	2,034
		1.3	1,995	2,015	2,036	2,021	2,042	2,064
	20	1.0	2,520	2,540	2,561	2,546	2,567	2,589
		1.3	2,550	2,570	2,591	2,576	2,597	2,619

Appendix Table 18. Estimated average annual rate of return on investment*(%) of seed eel farming

Harvesting rate	Price of elver (NT\$/each)	Cost of feed (NT\$/each eel)	Discount rate					
			10%		15%		20%	
			1,100	1,300	1,100	1,300	1,100	1,300
70%	5	{	1.0	18	0	12	8	17
			1.3	16	-	10	7	15
	10	{	1.0	-	-	-	-	-
			1.3	-	-	-	-	-
	15	{	1.0	-	-	-	-	-
			1.3	-	-	-	-	-
	20	{	1.0	-	-	-	-	-
			1.3	-	-	-	-	-
80%	5	{	1.0	31	9	23	6	25
			1.3	29	7	21	4	23
	10	{	1.0	-	-	-	-	-
			1.3	-	-	-	-	-
	15	{	1.0	-	-	-	-	-
			1.3	-	-	-	-	-
	20	{	1.0	-	-	-	-	-
			1.3	-	-	-	-	-
90%	5	{	1.0	45	17	33	13	33
			1.3	42	15	37	11	37
	10	{	1.0	-	-	-	-	-
			1.3	-	-	-	-	-
	15	{	1.0	-	-	-	-	-
			1.3	-	-	-	-	-
	20	{	1.0	-	-	-	-	-
			1.3	-	-	-	-	-

* $\frac{NPV}{C_0} / N \times 100\%$

Appendix Table 19. Estimated profit ratio*(%) of seed eel farming

Harvesting rate	Price of elver (NT\$/each)	Cost of feed (NT\$/each eel)	Discount rate							
			10%		15%		20%			
			Price of eel (NT\$/kg)							
70%	5	{	1.0	1,100	1,300	1,100	1,300	1,100	1,300	
			1.3	34	270	3	184	127	106	
	10	{	1.0	—	—	—	—	—	—	
			1.3	—	—	—	—	—	—	
	15	{	1.0	—	—	—	—	—	—	
			1.3	—	—	—	—	—	—	
	20	{	1.0	—	—	—	—	—	—	
			1.3	—	—	—	—	—	—	
	80%	5	{	1.0	203	472	133	340	86	252
				1.3	162	431	102	310	61	227
		10	{	1.0	—	—	—	—	—	—
				1.3	—	—	—	—	—	—
15		{	1.0	—	—	—	—	—	—	
			1.3	—	—	—	—	—	—	
20		{	1.0	—	—	—	—	—	—	
			1.3	—	—	—	—	—	—	
90%		5	{	1.0	371	674	262	495	189	376
				1.3	325	628	227	460	162	348
		10	{	1.0	—	—	—	—	—	—
				1.3	—	—	—	—	—	—
	15	{	1.0	—	—	—	—	—	—	
			1.3	—	—	—	—	—	—	
	20	{	1.0	—	—	—	—	—	—	
			1.3	—	—	—	—	—	—	

* $\frac{NPV}{C_0} \times 100\%$

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