ANALYZING THE ECONOMIC EFFECTS OF AQUACTIC ANIMAL DISEASE CONTROL REGIME IN KOREA

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ABSTRACT

The success or failure of aquaculture heavily depends on how effectively to manage aquatic animal diseases. In order to analyze the economic effects of aquatic animal diseases control, the specific factors and magnitudes of benefits and costs are identified with and without the proposed project for the disease control. These benefits can be derived from reduction of aquatic animals infected and died, consumption recovery, and so on. The benefit from reduction of aquatic animals infected and died is estimated under assumption that target death rate of aquaculture fishes should be reduced to half of current death rate without the project. The benefit from consumption recovery is based on the negative health information. elasticity of demand, estimated by almost ideal demand system including the negative health information. It is dealt with a dummy variable using monthly information data such as aquatic animal disease reported in main daily newspapers. The incremental costs with the proposed project can include monitoring costs for animal diseases, prevention quarantine costs, treatment costs of animals died, technology development costs for diseases remedy, and so on. As a result of the study, the annual economic effect is about 19.0 million US dollars, which scale is 35% of the annual net income in aquaculture industry of Korea. In addition, the total economic value (net present value) is 304.4 million US dollars under the assumption of 6% of social discount rate and 50 years of economic life, with 2.02 of benefit/cost ratio. It indicates how each disease control input affects the farmer's revenue, costs and profitability, and provides a directional policy for future extension work on application of disease control inputs.

Keywords: aquatic animal disease control, reduction effect of aquatic animals infected and died, consumption recovery effect, annual economic effect, total economic value

INTRODUCTION

Korea has the potential to drive growth in global economy. It has 433,000 km^2 of territorial waters under its jurisdiction, which covers five times its land area as well as shorelines spanning about 13,200 km. As a peninsula country, three sides are surrounded by seas, which have made a significant contribution to national industry. In 2003, Korea recorded the 12th largest production by capture and aquaculture fisheries with 2.492 million tons, the 20th biggest export of fishery products with 1.003 billion US dollars, and the 10th biggest import of fishery products with 1.935 billion US dollars in the world. In early developing stage from the 1950s to the 1970s, fisheries played a major role in the export industry. Since 2001 fishery imports have exceeded fishery exports, so Korea is now a net importer of fishery products. Fisheries, however, provided 39% of the public protein consumption in 2002 even though Korea's fishing industry has been steadily declining to less than 0.4 percent of the GDP.

In particular, aquaculture has played an important role in fisheries to complement declining coastal, offshore and deep sea fisheries in Korea. The aquaculture sector in Korea, however, results in losses due to inadequate controls and outdated or unsystematic rules on regulating diseases. In addition, disease outbreaks undermine consumers' confidence in the safety and wholesomeness of farmed fish and shellfish, and make them decrease fish consumption. Therefore, the success or failure of aquaculture fishery depends on how effectively to manage its diseases. Aquatic animal disease control is crucial to aquaculture, and thus, investment in disease control is vital to success and sustainability [1]. This paper is to identify and estimate the economic effects of disease control programs with understandings of status of Korean fisheries and aquaculture disease outbreaks.

STATUS OF FISHERIES IN KOREA

From 1985 annual total fishery production in Korea reached more than 3 million tons, but since 1996 it has been decreasing, as shown in Table I and Figure 1. That results from restrictions of fishing activities caused by the declaration of United Nation on the Law of the Sea (UNCLOS) and a serious degradation of fishery environment. Aquaculture production in 2003 amounted to 826,245 tons, which is 33.2 % of total fishery production of 2,486,617 tons. In particular, the policy "Development in nurturing fishery" has led to aquaculture being given much weight in fisheries. In the coastal and offshore fisheries the main target species are anchovy, squid, hair tail and horse mackerel, while in the deep-sea, squid, skipjack, and Alaska Pollack, in the aquaculture, fish species (flatfish and black rockfish), shell fishes (oyster, short neck clam and sea mussel), and seaweeds (laver and sea mustard).

The number of fishermen including the crews of deep-sea fishing vessels having been decreasing sharply – 320,000 in the 1970s, 260,000 in the 1980s, 140,000 in 2000, 130,000 in 2002 – and the trend is expected to continue [2]. That is due to the development of advanced fishing gear and methods, improvement of fishing vessels and reduction of fishery resources.

Table I: Trend of Fishery Production in Korea

(Unit: 1,000 tons)

Year	1985	1990	1995	2000	2001	2002	2003
Total production	3,102	3,275	3,348	2,514	2,665	2,476	2,487
Coastal/Offshore	1,495	1,472	1,425	1,189	1,252	1,096	1,097
Aquaculture	788	773	996	653	656	782	826
Distant Waters	767	919	897	651	739	580	544
Inland Waters	53	34	29	21	18	19	20

From KMI (2005).

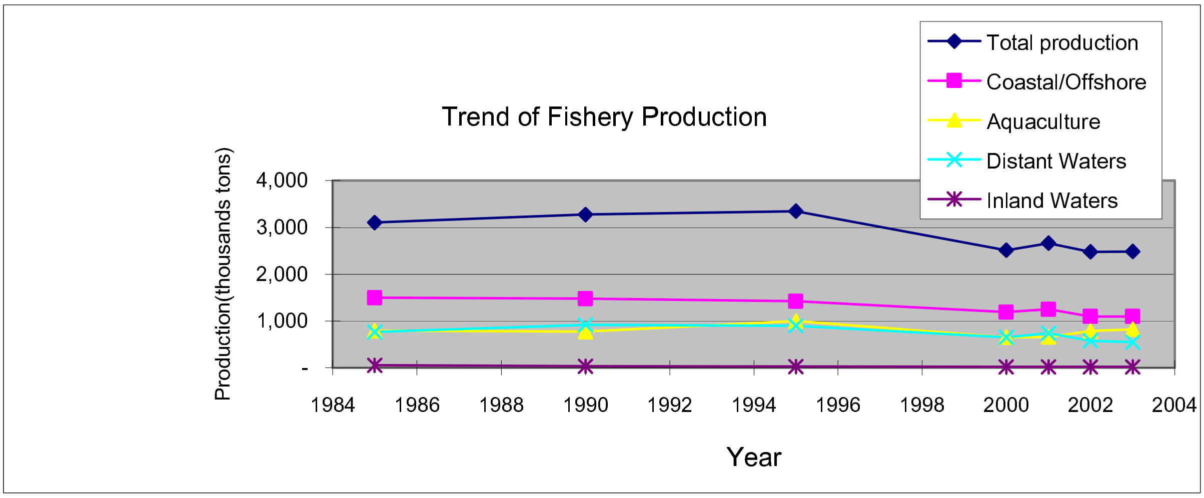

Figure 1. Trend of Fishery Production in Korea

STATUS OF AQUATIC ANIMAL DISEASE IN KOREA

Aquatic animal disease problems are serious in many areas where more intensive farms have been operating. Diseases are commonly caused by bacteria, protozoa, viruses, fungi and toxins. Bacterial, protozoan and viral infections are among the most common diseases encountered in fish aquaculture (Table II). Of main aquatic fish species, flatfish in Table III and Figure 2, was infected by bacteria (61.4%), protozoa (36.8%), and viruses (1.8%), while black rockfishes by bacteria (49%), protozoa (37%), viruses (2%), and others (12%), in 2002.

Table II: Status of Aquatic Animal Disease Outbreaks

Types of Disease	Rate of Disease Outbreaks (%)			
	1996	1997	1998	1999
Bacteria	72.4	48.5	45.3	46.5
Protozoa	21.9	28.8	22.5	23.8
Viruses	4.6	7.8	7.8	12.8
Bacteria-mixed	1.0	10.5	8.2	9.0
Bacteria+protozoa	0.1	2.0	5.8	7.9

From MOMAF (Ministry of Maritime Affairs and Fisheries)'s internal data

Table III: The Rate of Diseases Outbreaks for Flatfishes

Types of Disease	The rate of diseases outbreaks for flatfishes (%)						
	1996	1997	1998	1999	2000	2001	2002
Bacteria	72.0	66.4	61.8	61.8	60.5	69.6	61.4
Protozoa	24.0	18.5	19.4	19.2	29.4	26.1	36.8
Viruses	0	8.1	12.4	10.7	6.9	3.7	1.8
Others	4	7	6.4	8.3	3.2	0.6	0

From MOMAF's internal data

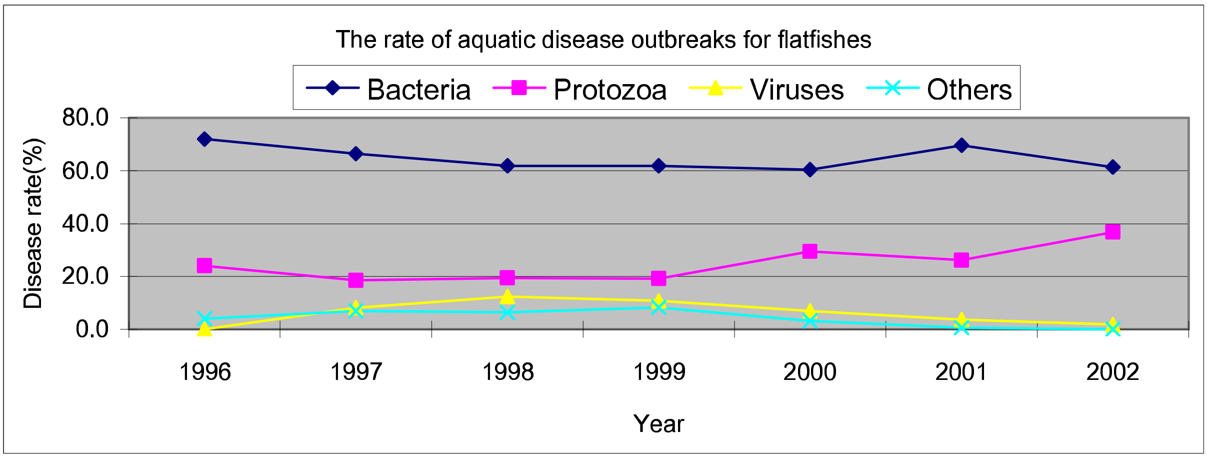

Figure 2. The Rate of Aquatic Diseases Outbreaks for Flatfishes

As shown in Table IV, annual death rate of aquatic animals has been steadily decreasing, representing about 10% in case of fish species and 52% in case of prawn, for average death rate from 2001 to 2005. According to Table V, the death rate of flatfishes in total aquatic animals is highest at 13.1%, next one is yellow tail (10.4%) and so on.

Table IV: Trends of Aquatic Animal Death Rate (unit: %)

Years	2001	2002	2003	2004	2005
Fish Species	13.5	11.9	8.4	7.8	7.1
Prawn	68.7	64.9	53.5	32.4	40.3

Table V: Status of Aquatic Animal Death in 2005

Fish Species	No. of Cultivation (thousand)	No. of Death (thousand)	Rate of Death (%)
Flatfish	182,511	23,932	13.1
Black rockfish	368,687	14,599	4.0
Sea bass	19,632	1,026	5.2
Sea bream	107,477	11,202	10.4
Mullets	39,977	350	0.9
Others	29,068	1,703	5.9
Total	747,352	52,812	7.1

THE EECONOMIC EFFECTS OF AQUATIC ANIMAL DISEASE MANAGEMENT

The structure of a benefit-cost analysis

One of economic tools for comparing the desirable and undesirable impacts of proposed policies is benefit-cost analysis (BCA). BCA systematically identifies and organizes economic cash inflows and outflow that are expected to result from a proposed public policy or program. Much confusion, however, surrounds this analysis in practice versus in principle. There is no doubt that BCA has been misused and abused. Therefore, only its appropriate usage can revive its merits. Cash flows can be formally expressed as incremental definition: Incremental cash flows = cash flows with the project – cash flows without the project. It is important not to fall in to the trap of thinking that a direct comparison of before and after project scenarios is equivalent to incremental cash flows.[1]

There are several capital budgeting models which represent discounting techniques: net present value (NPV); internal rate of return (IRR); and benefit/cost ratio (B/C ratio). NPV takes net incremental cash flows and discounts them at the social rate of discount:

$$NPV = \sum_{t=1}^{t=n} \frac{NB_t}{(1+r)^t} - I_0$$

where NB_t is the net incremental cash flow in year *t*; *r* is the opportunity cost of capital, and I_0 is the initial investment. The decision criterion is that the project should be rejected if NPV<0, otherwise it should be accepted. On the other hand, the IRR is the rate of discount that lets NPV=0:

$$0 = -I_0 + \sum_{t=1}^{t=n} \frac{NB_t}{(1+IRR)^t}$$

Projects are selected if the IRR is greater than the opportunity cost of capital. Another way to calculate the economic decision criteria is B/C ratio by taking the present value of the benefit stream and dividing by the present worth of the cost stream.

$$\sum_{t=1}^{t=n} \frac{TB_t}{(1+r)^t} / (\sum_{t=1}^{t=n} \frac{TC_t}{(1+IRR)^t} + I_0)$$

If the ratio is greater than 1 then the project should be undertaken.

Identification of benefits and costs

The basis for the establishment of economic benefits and costs is the "with and without" principle. Measuring the economic benefits and costs resulting from aquatic animal disease control programs is not easy. With the project total revenues increase due to reduction in death, reduction in consumption substitution effect, and reduction in infection, involving the economic welfare on the part of both consumer and producer surplus, and disease control costs such as monitoring cost, prevention cost, treatment cost and R&D cost are also added to the economic costs. Figure 3 stands for an overall framework of BCA for aquatic animal disease control project.

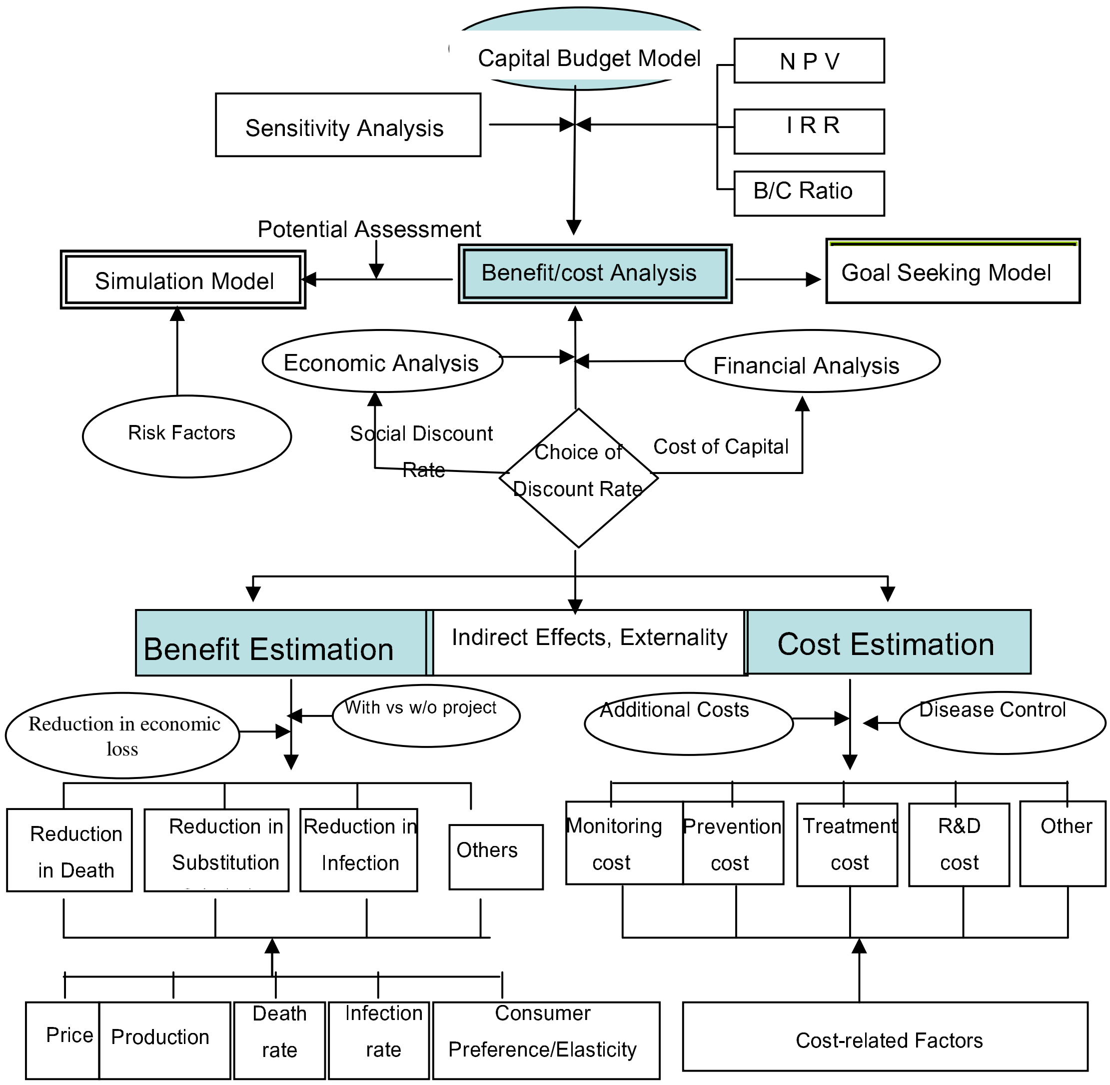

Figure 3. An overall framework of BCA for aquatic animal disease control project

The economic benefits determination

The economic benefits occurred from introducing the new aquaculture disease control regime[2] can be largely classified into the reduction effect of death rate and infection rate and the consumption recovery effect. The death and infection rate due to disease shifts the supply curve from S to S' in Figure 4, indicating a change of a sort of technology and factor price which is the non-price variable in the product supply function. If the death and infection rate can be reduced by the new disease control regime, the quantity supplied would recover from Q_1 to Q_0. Meanwhile, aquaculture disease makes consumers substitute their fish consumption for other product consumption such as beef, shifting the demand curve from D to D' in Figure 4.[3] In the same way, if the death and infection rate can be reduced, the quantity demanded would recover from Q_2 to Q_1.

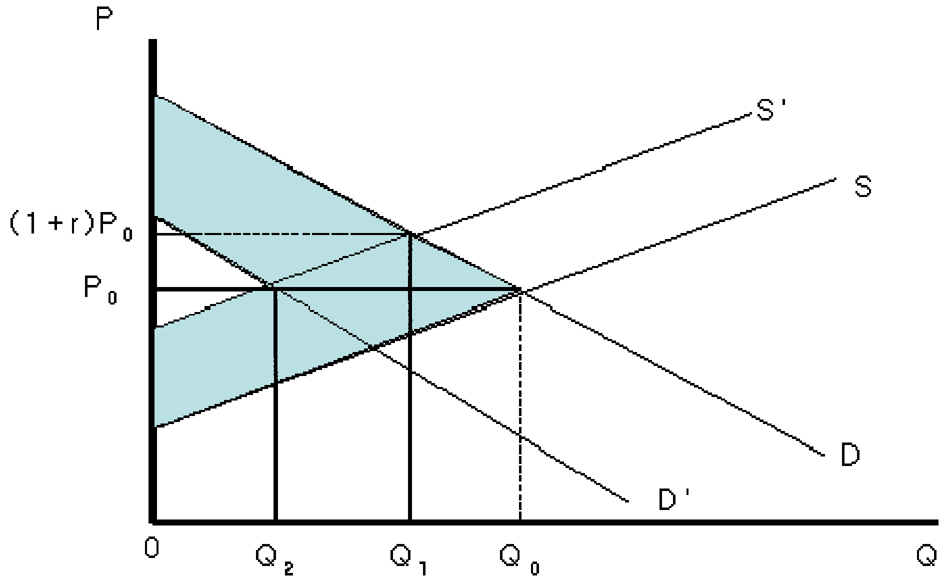

Figure 4. The recovery effects of social welfare from the new schemes

Likewise, the shaded area in Figure 4 represents the recovery effects of social welfare occurred from the new aquaculture disease control schemes and can be derived from the following equation.

$$\int_0^{Q_1} f^{-1}(d)dQ + \int_{Q_1}^{Q_0} f^{-1}(d)dQ - \int_0^{Q_1} f^{-1}(d')dQ - \left(\int_0^{Q_1} f^{-1}(s)dQ + \int_{Q_1}^{Q_0} f^{-1}(s)dQ\right) + \int_0^{Q_1} f^{-1}(s')dQ$$

$$= \int_0^{Q_0} f^{-1}(d)dQ - \int_0^{q_1} f^{-1}(d')dQ - \int_0^{Q_0} f^{-1}(s)dQ + \int_0^{Q_1} f^{-1}(s')dQ$$

The estimation of the production recovered

It is not simple to estimate the supply quantity (Q_1Q_0) and the demand quantity (Q_2Q_1) recovered from the reduction of the death and infection rate. Q_0 indicates the desirable target quantity recovered from the reduction of the death rate with the project of the new disease control scheme, while Q_2 is the current quantity produced without the project which reflects current death rate and consumption substitute rate, and Q_1 represents the quantity produced after outbreaks of aquaculture diseases. Hereafter 'd' is the target death rate to reach with the project, and 'c' is the consumption recovery rate. The quantities recovered from the reduction of the death rate can be calculated as the following equations:

$$Q_2 = Q_0(1-d)(1-c)$$

$$Q_1 = \frac{Q_2}{(1-c)} = Q_0 \times (1-d)$$

$$Q_0 = \frac{Q_2}{(1-d)(1-c)} = \frac{Q_1}{(1-d)}$$

It is noted that 'd' is an exogenous variable derived from pathological analysis[4], while 'c' can be derived from the impacts of negative health information on the raw fish demand. Using the Almost Ideal Demand System [3] including negative health information [4, 5, 6], this study derived the negative health information elasticity of demand.[5] The negative health information is dealt with a dummy variable which indicates whether or not aquatic animal disease outbreak was reported in main daily newspapers.[6] The results of the negative health information elasticity of demands for flatfish, black rockfish, yellow tail, sea bass, sea bream and beef are -0.2681, -0.0823, -0.0392, -0.0618, -0.0391 and 0.004307, respectively. It is confirmed that the negative health information variable negatively affects the raw fish consumption and positively affects the beef consumption, showing the theoretical validity. For example, a 1 % decrease in the death rate for flatfish results in 0.268 % increase in the quantity demanded which means the consumption recovery rate (c).[7] The estimation of the quantities recovered from the death and infection rate is specifically shown in Table VI.

Table VI: The estimation of the quantities recovered from the death and infection rate

(Unit: M/T)

	Flatfish	Black rockfish	Yellow tail	Sea bass	Sea bream	Other fishes	Crustaceans	Shellfish	Others
d	5%	5%	5%	5%	5%	5%	20%	5%	5%
c	1.341%	0.412%	0.196%	0.309%	0.196%	0.877%	5.362%	1.341%	1.341%
Q_2	32,141	19,708	45	1,850	6,833	3,899	2,426	304,889	9,176
Q_1	**32,578**	**19,790**	**45**	**1,856**	**6,846**	**3,933**	**2,526**	**309,049**	**9,301**
Q_0	**34,292**	**20,918**	**47**	**1,953**	**7,207**	**4,141**	**3,204**	**325,298**	**9,790**

Note. 1. Consumption recovery rate of other fishes is assumed from the weighted average consumption recovery rate of flatfish, black rockfish, yellow tail, sea bass and sea bream.
2. The negative health information elasticity of crustaceans, shellfish and others are assumed to be equal to that of flatfish

The estimation of variable costs

Holding marginal costs constant assumption in the study, average variable costs can be substituted for the marginal costs. The data for variable costs standardized by sampling survey include seed cost, fuel cost, feed cost, medicine cost and others. As shown in Table VII and Table VIII, the weighted average variable costs per ton are calculated into 3,983 dollars and 3,535 dollars, for flat fish and black rockfish respectively.[8]

The estimation of incremental cost for the project

The cost of disease control project includes monitoring costs for animal diseases, prevention quarantine costs, treatment costs of animals died, technology development costs for diseases remedy, and so on. This paper introduces disease control cost estimated from MOMAF for benefit-cost analysis, which scale is totally 19,018 thousand US dollars.

Table VII: The estimation of standard variable cost for flatfish

(Unit: $1)

Size(ha)	0.2	0.33	0.46	0.46	Average
Quantity(tons)	44	52.4	92.2	118.3	306.9
Seed cost	55700	57944	71572	106650	291866
Fuel cost	8524	9347	19869	4443	42183
Feed cost	75805	96075	199222	271202	642304
Medicine cost	19780	26018	45151	43931	134880
Others	15981	18938	33581	42623	111123
Total variable cost	175790	208322	369395	468849	1222356
Variable cost/ton	**3995.2**	**3975.6**	**4006.5**	**3963.2**	**3982.9**

Table VIII: The estimation of standard variable cost for rockfish

(Unit: $1)

Size(ha)	0.2	0.25	0.4	0.5	0.7	1	1.5	Average
Quantity(tons)	25.5	19.6	26.6	42.26	43.8	128.5	125.05	411.3
Seed cost	17500	11366	17000	31110	21000	80000	88000	265976
Fuel cost	1000	2040	4800	6000	7200	12240	7440	40720
Feed cost	71600	29300	82040	117810	98554	284800	263074	947178
Medicine cost	6000	2208	10500	8760	6480	24480	9600	68028
Others	9610	4491	11434	16368	13323	40152	36811	132190
Total variable costs	105710	49405	125774	180048	146557	441672	404925	1454092
Variable cost/ton	**4146**	**2521**	**4728**	**4261**	**3346**	**3437**	**3238**	**3535**

Results of the economic effects

Due to the restriction of data, this paper attempts to analyse a simplified preliminary feasibility in Table IX. As shown in Table IX, if the death rates with the project are changed into half of the average death rate without the project, the annual economic effect and the total economic value (net present value) of the new aquatic animal disease control system is estimated as **19,315 thousand dollars** and **304,444 thousand dollars** in which benefit/cost ratio is 2.016 under 6% of social discount rate and 50 years of the economic life for the project, respectively.[9] The estimated annual economic effects account for 35% of annual net profits under the assumption of the rate of return of 10% which is relatively considerable.

Table IX: Results of benefit-cost analysis for the economic effectiveness

(Unit: thousand dollars, MT)

Items	Flatfish	Rockfish	Other fishes	Crustacean	Shellfish	Other aquatic animals	Total
Market price/ton	9.430	8.262	10.612	16.308	0.951	1.949	
Variable cost/ton	3.983	3.535	4.541	8.154	0. 476	0. 975	
Quantity (with project) Q_0	34,292	20,918	14,624	3,204	325,298	9,790	
Quantity (without project) Q_2	32,141	19,790	13,860	2,426	304,889	9,176	
Death rate (with project)	0.05	0.05	0.05	0.20	0.05	0.05	
Consumption recovery rate	0.01341	0.00412	0.00234	0.05362	0.01341	0.01341	
Total revenues	303,090	163,505	147,082	39,563	289,949	17,884,	**961,074**
Incremental benefits	11,717	5,330	4,636	6,346	9,704	599	**38,333**
Incremental costs							**19,018**
Annual economic effect							**19,315**
Total economic value (NPV)							**304,444**
b/c ratio							**2.016**

CONCLUSION

Aquaculture fishery in Korea has led other declining fisheries such as coastal, offshore, deep sea, and inland fisheries. Therefore, an effective aquatic animal disease control is critical to sustain the fisheries in Korea. Firstly, the paper reviewed status of fisheries and aquatic animal disease in Korea. Aquaculture production in 2003 accounts for 826,245 tons, which is 33.2% of total fishery production. Flatfish production forms about 60%, and black rockfish production, about 30%, in fish aquaculture. The death rate of flatfishes in total aquatic animals is the highest at 13.1%, that of black rockfish, 4.0%. Secondly, the paper analysed the annual economic effects and the total economic value (net present value under the assumption of 6% of social discount rate and 50 years of the economic life) of aquatic animal disease control programs. Under the limited data the annual economic effect and the total economic value were estimated as **19,315 thousand dollars** and **304,444 thousand dollars,** in which benefit/cost ratio is 2.016, respectively. The estimated annual economic effects account for 35% of annual net profits under the assumption of the rate of return of 10% which is relatively considerable.

It indicates how each disease control input affects the farmer's revenue, costs and profitability, and provides a directional policy for future extension work on application of disease control inputs. A more refined method, however, needs to be introduced for determining optimal investment in aquatic animal disease control.

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ENDNOTES

[1] Consider the following example. An investment project has been proposed to increase the productivity of flatfish farms by controlling its diseases. Without the project it has been estimated that the flatfish stock will grow at approximately 1.3%. With the project its stock is estimated to increase by 3.4%. Correspondingly its production is expected to increase over the economic life of the project at a similar rate. If the project analyst compared the output before and after the project he would erroneously attributed the total increase in its production, approximately 3.4%, to the project investment. Actually what can be attributed to the project investment is only 2.1% (=3.4%-1.3%) increase in production since 1.3% would have occurred anyway.

[2] The new proposals are aimed at improving the health of fish, crustaceans and mollusks and reducing the mortality rate due to disease. In contrast with existing legislations, the main emphasis of the new one will focus on preventing the outbreak of disease rather than dealing with the consequences of an outbreak. The new scheme will replace several existing directives with just one, offering more flexibility for decisions to be taken at national, local or farm levels.

[3] The shift in demand is due to a change of consumer's preference rather than a change of its own price.

[4] In this paper the target death rates are assumed to reduce to half of average death rate for five years from 2001 to 2005 as shown in Table 4.

[5] The negative health information elasticity of demands measures the responsiveness of the quantity demanded to a change in the negative health information of the product, holding constant the value of all other variables in the demand function. More detailed explanation is beyond the objective of the paper.

[6] The negative information data used include data from January 1994 to December 2002.

[7] c= - (negative information elasticity for each aquatic animals x reduction rate of death rate). For example, consumption recovery rate for flatfish=0.2681 x (10%-5%) = 1.341%

[8] For simplified analysis, variable costs for other aquatic animals excluding flatfish and rockfish are supposed to be approximately 50 % of their market prices.

[9] Annual incremental benefits can be calculated as follows:

$$NB = NB_s + NB_c = (P_0 - v)(Q_0 - Q_1) - rP_0Q_1 + (P_0 - v)(Q_1 - Q_2) + rP_0Q_1$$
$$= (P_0 - v)(Q_0 - Q_1 + Q_1 - Q_2)$$
$$= (P_0 - v)(Q_0 - Q_2)$$