Analyzing the Recovery Effects of Marine Contaminated Sediment Cleanup Project on Wild Capture Fisheries in Korea

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Introduction

- Various contaminants in marine sediment cause biophysical harm and human health risks
- direct or indirect health threats to individuals result through contact with polluted materials or via the food chain
- ecological effects of polluted marine sediments can lead to a variety of losses to commercial and recreational fisheries and environmental services
- remediation and cleanup of that sediment should reduce or eliminate these harms even though its secondary pollution can have resulted in
- Though there are various types of predictable economic benefits from contaminated marine sediment cleanup, remedial actions such as dredging method and ocean disposal are typically very costly

- policy makers require information on priority to allocate the limited funds to use in marine sediment cleanup to any particular site and identification of the economic effects of the project which deduct costs of the cleanup from its relative values

- This paper identifies types of potential economic benefits that may result from marine sediment remediation, and focuses on estimating the net increase in value for producers and consumers from producing and consuming those fishes due to the marine contaminated cleanup project

- Almost Ideal Demand System (AIDS) is employed **to** estimate the demand for aquatic animals, and the production cost function **is** determined using market data, around in Yeosu Coastal District in Korea where the Government spent US$ 26.3 million on contaminated marine sediment cleanup for five years (2000-2005).

ECONOMIC BENEFITS FROM CONTAMINATED SEDIMENT CLEANUP

- can be divided into different categories: use and non-use benefits
- Use benefits are those derived from the direct physical use of a good such as eating fish from the sea or using recreational fishing and boating
- Non-use benefits are obtained without any direct physical use by the individual composed largely of three components: intra-generational altruistic (or vicarious) value; bequest values and existence values.
- Another classification of economic benefits is the distinction between market and non-market benefits.
- All market benefits are included in the use category, while non-market benefits can be found in both the use and non-use categories.

Table 1. Classifications of economic benefits of marine sediment remediation

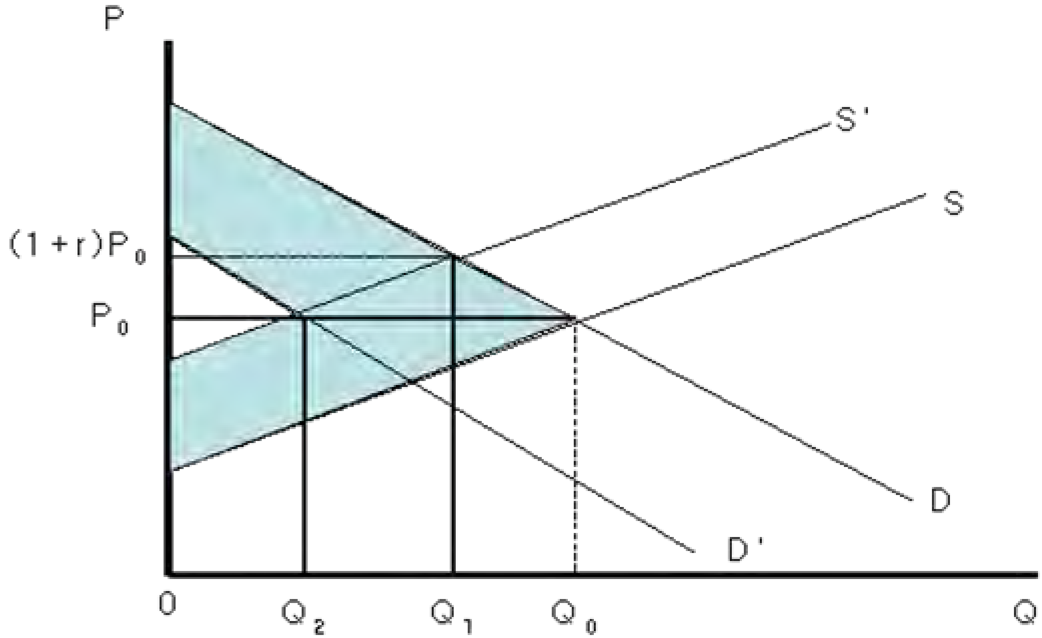
Economic Benefit Category	Biophysical or Economic Activity	Use/ Non-use	Market/ Non-market	Valuation Method
1. Capture Fisheries Recovery	- Reduction in fish death and infection - Increase in fish population	Use	Market	Production Function
2. Fish Consumption Recovery	- Increase in consumer preferences to fishes	Use	Market	AIDS model
3. Increase of Tourism	-Amenity improvement - Malodor reduction - Fishing, boating, swimming	Use	Non-market	TCM/CVM
4. Reduction of Human Health Risk	- Water quality improvement - Residential environment improvement	Use	Non-market	CVM/ABM/HPM
5. Ecosystem Integrity	- Ecosystem stability - Biodiversity increase	Non-use	Non-market	CVM
6. Others	- Navigation - Broader land use	Use	Market	CVM

Note: AIDS - Almost Ideal Demand System; CVM – Contingent Valuation Method;
TCM – Travel Cost Method; ABM – Averting Behavior Model; HPM – Hedonic Pricing Method

ECONOMIC BENEFITS TO RESTORING COMMERCIAL FISHERIES

Theoretical backgrounds for the economic benefits

- If contaminated sediment has contributed to the degradation of fish and wildlife populations, remediation may help to restore those populations which may reduce the death rate and infection rate from fish diseases



- In economic terms, the death and infection rate shifts the supply curve from S to S' in Figure 1, indicating a change of a sort of technology and/or factor price which is the non-price variable in the product supply function

- If the death and infection rate can be reduced by a remediation project, the quantity supplied would recover from Q_1 to Q_0
- , the fish and wildlife have concentrations of PTS in their flesh that may cause harm to humans who consume them in substantial quantities leading to a decrease in the consumption of these species
- Such fish diseases make consumers substitute their fish consumption for other pro duct consumption such as beef, shifting the demand curve from D to D' in Figure 1. In the same way, if the death and infection rate can be reduced, the quantity dema nded would recover from Q_2 to Q_1 The shift in demand is due to a change of consu mer's preference rather than a change of its own price.
- the shaded area in Figure 1 represents the recovery effects of social welfare occurr ed from marine contaminated sediments clean-up and can be derived from the foll owing equation:

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

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

- Using market price and landing data,

the increase in social welfare for wild capture fisheries can be measured by a net benefit approach as an alternative:

$$
\begin{aligned}
NB = NB_s - NB_c &= (P_0 - v)(Q_0 - Q_1) - rP_0Q_1 + (P_0 - v)(Q_1 - Q_2) + rP_0Q_1 \\
&= (P_0 - v)(Q_0 - Q_2)
\end{aligned}
$$

- Where NB = Net Benefits
- NB_s = Net Benefits with the project
- NB_c = Net Benefits without the project
- v = Variable cost
- r = increasing rate of price
- P_0 = current market price

Estimating demand function of wild capture fisheries

- Deaton and Meulbauer(1980) developed AIDS model as a demand model :
- $$w_i = \alpha_i + \sum_{j=1}^{n} \gamma_{ij} \ln P_j + \beta_i (\ln E - \ln P^*)$$
- where, in observation t;
- w_i is the budget or expenditure share of the good;
- p_j is the nominal price of the good;
- E is total expenditure;
- P*is the Stone's price index.

- For estimating the effect of fish disease information, the model includes a dummy variable for fish disease information as follow:

$$w_i = \alpha_i + \varphi_i \ln H_i + \sum_{j=1}^{n} \gamma_{ij} \ln P_j + \beta_i (\ln E - \ln P^*)$$

- Where Hi is a dummy variable for health information.
- Brown and Schrader(1990) employed a dummy variable for cholest erol information which affects U.S. demand for shell eggs.

- The negative health information is dealt with a dummy variable whi ch indicates whether or not aquatic animal disease outbreak such a s outbreaks of cholera and vibrio was reported in main daily newsp apers in Korea.

- The parameters for the AIDS model are estimated by monthly time series data, which periods are 144 months from January 1994 to De cember 2005

- Table 2 indicates basic statistic for expenditure share during 144 months (from January 1994 to December 2005)

Table 2. Statistic for expenditure shares

Types	Mean	Standard deviation	Minimum	Maximum
Fish	0.27178	5.24E-02	0.15648	0.40475
Crustaceans	4.39E-02	2.49E-02	8.81E-03	0.12307
Shellfish	5.92E-02	1.99E-02	2.09E-02	0.13032
Mollusk	7.31E-02	3.64E-02	2.18E-02	0.2
Beef	0.50435	9.01E-02	0.22815	0.69461

Table 3. The results of demand elasticities

Types	Fish	Crustaceans	Shellfis	Mollusks	Beef
Fish	-0.978837	-0.027253	-0.001331	0.011202	-0.008568
Crustaceans	-0.170578	-0.555565	0.022961	0.355143	0.023054
Shellfish	-0.019073	-0.012050	-1.046091	0.111377	0.440718
Mollusk	0.023775	0.034912	0.034167	-1.451547	0.132956
Beef	-0.009025	-0.009172	-0.009162	-0.009153	-1.036520
Expenditure	0.983134	0.990287	1.030822	1.048876	0.999354
Disease information	**-0.060769**	**-0.197025**	**-0.052566**	**-0.142073**	**0.070912**

- In Table 3, price elasticity(red number) for each aquatic animal keeps internal consistency (theoretical validity), presenting a negative(-) sign.

- All expenditure elasticities(purple number) represent close to unit elasticity, and cross elasticities between beef and aquatic animals except fish imply their substitutes

- It is confirmed that the negative health information variable negatively affects the consumption of aquatic animals and positively affects the beef consumption, showing the theoretical validity

- Among aquatic animals, crustaceans are the most sensitive to disease information
- Ex) A 1 % decrease in the death rate results in about 0.2 % increase in the quantity demanded of crustaceans

Results

Estimating the recovery effects of capture fisheries

- 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

  Q_1 represents the quantity produced after outbreaks of fish diseases and

  Q_2 is the current quantity produced without the project which reflects current death rate and consumption substitute rate

  'd' is the target death rate to reach with the project, and 'c' is the consumption recovery rate

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

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

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

- Using the reduction rate of aquatic animal diseases (d=5%) and the consumption recovery rate(c), the quantity recovered rises by average 5.6% in Table 4

- **Table 4. The estimation of the quantities recovered** (Unit: M/T)

Items	Fish	Crustaceans	Shellfish	Mollusk
D	5%	5%	5%	5%
C	0.304%	0.985%	0.263%	0.7104%
Q_2	84,502	1,930	1,500	8,200
Q_1	84,760	1,949	1,504	8,259
Q_0	89,221	2,052	1,583	8,693

1. Q_2 is annual catch of each aquatic animal around the cleanup sites based on 200[illegible], without the cleanup project.
2. Q_1 adds the quantity recovered from the reduction rate of aquatic animal death or infection to Q2.
3. Q_0 is the quantity yielded with the cleanup project, which adds the quantity recovered from the reduction rate of aquatic animal death or infection and the consumption recovery rate to Q2.

- Total annual recovery effects of the cleanup project on wild capture fisheries are estimated to be 10.778 million dollars of which 84% is from fish in Table 5 below:

- **Table 5. Annual recovery effects (target reduction rate of the diseases, d=5%)**

(Unit: US$ 1,000, M/T)

Items	Fish	Crustacean	Shellfish	Mollusk
Selling prices per unit	2.909	4.686	4.264	3.404
Q_0	89,221	2,052	1,583	8,693
Q_2	84,502	1,930	1,500	8,200
Annual recovery effects	9,059	377	234	1,108

1. Selling prices per unit represent the weighted average value of each aquatic species in Korea, based on national data of 2005.
2. Annual recovery effects on wild capture fisheries = (selling price – variable cost) × (Q_0 - Q_2)
3. Variable costs per unit are assumed to be 34% of selling prices per unit, which is calculated by national data for cost share.

Sensitivity analyses

- To reflect the uncertainties for the reduction rate of species diseases, sensitivity analysis are used to assess what if the reduction rate of aquatic animal disease is changed to be 7.5% and 2.5% which indicate the change of ±50% against the original target reduction rate of species disease (d=5%), holding all other base-case data constant

- **Table 6. Annual recovery effects (when target reduction rate of the diseases, d=7.5%) :**(Unit: US$ 1,000, M/T)

Items	Fish	Crustacean	Shellfish	Mollusk
Q2	84,502	1,930	1,500	8,200
Q1	84,760	1,949	1,504	8,259
Q0	91,632	2,107	1,626	8,928
Annual recovery effects	13,689	548	354	1,636

- Increasing the reduction rate of species disease by 7.5% from base-case, annual recovery effects are increased from US$10.778 million to US$16.228 million, indicating an increasing rate of 51.4%

- In contrast, annual recovery effects decrease to US$5.609 million, which indicates a decreasing rate of 65.4%, in case of decreasing the reduction rate of aquatic animal diseases by 2.5% from base-case as seen below in Table 7:

Table 7. Annual recovery effects (when target reduction rate of the diseases, d=2.5%) (Unit: US$ 1,000, M/T)

Items	Fishes	Crustaceans	Shellfishes	Mollusks
Q2	84,502	1,930	1,500	8,200
Q1	84,760	1,949	1,504	8,259
Q0	86,933	1,999	1,543	8,470
Annual recovery effects	4,667	214	120	608

Conclusion

- Contaminated sediment cleanup can result in an array of benefits: reduction in aquatic animal death and infection, increase in consumption recovery.
- Economic benefits include: an increase in tourism including recreational fishing, reduction in human health risk, increase in amenity and aesthetics, increase in ecosystem integrity and others
- Paper applies AIDS model to estimate consumption recovery rate, and calculate quantity recovered by using reduction rate of aquatic animal diseases and the consumption recovery rate at cleanup site, Yeosu Coastal District in Korea
- In cases of 5% of target reduction rate of aquatic animal diseases-total annual effect of the cleanup project on wild capture fisheries is estimated to be US$ 10.8 million of which 84% is from fish

- To reflect uncertainties for the reduction rate of aquatic animal diseases, sensitivity analyses are used to assess “what if” scenarios where the reduction rate of aquatic animal disease is changed to be 7.5% and 2.5%.

- For a 7.5% change - annual recovery effect increases by 51.4%

- Recovery rate decreases by 65.4% in reduction rate at 2.5%

- **Results** show positive insights for public policy:

  - are useful starting points in understanding the economic implications of cleaning up marine contaminated sediments

  - provides a preliminary indication of the main economic benefits from the cleanup projects and gives the justification of cleanup projects to public policy makers

  - method for extended economic appraisal needs to be developed together with a useful means to assess the economic feasibility for cleanup projects In order to sufficiently take into account the potential costs and benefits.

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Abstract

There are various types of predictable economic benefits from contaminated marine sediment cleanup. These benefits can be derived from reduction in the number of aquatic animals dead or infected, increase in their consumption recovery, increase in tourism including recreational fishing, reduction in human health risk, increase in amenity and aesthetics, increase in ecosystem integrity, and so on. The paper focuses on estimating the net increase in value for producers and consumers from producing and consuming aquatic animals due to marine contaminated cleanup project. Almost Ideal Demand System (AIDS) is employed for estimating the demand for aquatic animals, and their production cost functions are determined using market data. The result shows surplus of US$ 10.8 million per year to the net increase for producers and consumers.

1. INTRODUCTION

Marine sediments are contaminated from discharges of many pollution sources including releases from industries, sewage treatment plants, runoff, rivers, shoreline erosion and coastal facilities (Grigalunas and Opaluch, 1989). Various contaminants in marine sediment cause biophysical harm and human health risks. There are direct or indirect health threats to individuals through contact with polluted materials or via the food chain. The ecological effects of polluted marine sediments can also lead to a variety of losses to commercial and recreational fisheries, environmental services, and so on. The remediation and cleanup of that sediment should reduce or eliminate these harms even though its secondary pollution can have resulted in. Though there are various types of predictable economic benefits from contaminated marine sediment cleanup, remedial actions such as dredging method and ocean disposal are typically very costly. Therefore, policy makers require information on priority to allocate the limited funds to use in marine sediment cleanup to any particular site and identification of the economic effects of the project which deduct costs of the cleanup from its relative values.

Quantitative economic analysis approaches for managing contaminated marine sediments include cost-effectiveness analysis (CEA), cost-benefit analysis(CBA) and multiple criteria analysis(MCA). They can provide valuable implications and remedial action decisions at a site and efficient allocations among multiple sites. Grigalunas and Opaluch(1989) introduced CEA and CBA as the application of economic analysis for managing contaminated marine sediments. Navrud and Barton(2006) conducted a CBA of remediation in the Grenland fjords including valuation of the benefits to commercial fisheries, coastal real estate values and household uses of the fjords from removal of dietary health advisories(Barton et al., 2010). Linkov et al.(2004; 2006) and Yatsalo et al.(2007) used MCA to combine mixed qualitative and quantitative information on the benefits of remediation for managing contaminated sediments. In CBA of public projects, economic valuation methods are often employed to assess the economic benefits for non-marketed resources. Krieger and Hoehn(1999) used contingent valuation method for estimating willingness-to-pay (WTP) for information about health risks reduction associated with environmental contamination in the Great Lakes. Bishop et al.(2000) conducted a choice experiment survey of households in Green Bay, Lake Michigan, for different PCB remediation scenarios. Barden et al.(2004) used hedonic pricing method and conjoint analysis method for estimating homeowners' WTP for full harbor contaminant cleanup in the Waukegan Harbor area, Illinois, USA. Barton et al.(2010) conducted contingent valuation survey for valuing economic benefits of large-scale remediation of contaminated marine sediments in the Greenland fjords, Norway. In a different view of the economic benefits for marine contaminant cleanup, Grigalunas et al.(2001) estimated the economic costs to fisheries from disposal of clean dredged sediments from in and around Providence Harbor, RI, USA, using a bio-economic framework.

Economic benefits to restoring beneficial uses from contaminated marine sediment cleanup can be derived from reduction in the amount of aquatic animals dead or infected, increase in their consumption recovery, increase in tourism including recreational fishing, reduction in human health risk, increase in amenity and aesthetics, increase in ecosystem integrity, and so on. This paper identifies the types of potential economic benefits that may result from marine sediment remediation, and focuses on estimating the net increase in value for producers and consumers from producing and consuming those fishes due to the marine contaminated cleanup project. The Almost Ideal Demand System (AIDS) is employed **to** estimate the demand for fish, and the production cost function for fish is determined using market data, around in Yeosu Coastal District in Korea where the Government spent US$ 26.3 million on contaminated marine sediment cleanup for five years (2000-2005).

2. ECONOMIC BENEFITS OF CONTAMINATED SEDIMENT CLEANUP

Economic benefits of marine contaminated sediment remediation project can be divided into different categories. One classification of economic benefits is the distinction between use and non-use benefits. Use benefits are those derived from the direct physical use of a good such as eating fish from the sea or using recreational fishing and boating. Direct use benefits include both its consumptive uses such as fish, shellfish and fuel wood, as well as non-consumptive uses such as recreation, ecotourism, bird-watching, *in-situ* research and education, and navigation. Various functional values of coastal ecosystems are one of important indirect use benefits. Their benefits derive from supporting or protecting economic activities such as fisheries via nursery/habitat functions, waste treatment, flood control, storm protection, and so on. Non-use benefits are obtained without any direct physical use by the individual. Non-use values are composed largely of three components: (1) intra-generational altruistic (or vicarious) value – the value that individuals place on others having good resource today; (2) bequest values (intergenerational altruistic value) – the value that the current generation places on the availability of the benefit for future generations; and (3) existence values – the value that monetises individuals' satisfaction from simply knowing that a resource exists even if they never used it.

In the economic literature, option value is a difference between *ex ante* and *ex post* valuation due to the uncertainty about his or her future use for a resource and/or its availability as a risk premium to compensate for uncertainty about a resource in the future. Quasi-option value is potential benefit occurred from delaying exploitation and conversion of the resource today.

The second classification of economic benefits is the distinction between market benefits and non-market benefits. Market benefits arise from the resource traded in the markets. Eventually all market benefits are also included in the use category. Non-market benefits have no market-determined value and not generally bought or sold in the markets, but may possess significant value to individuals. Non-market benefits can be found in both the use and non-use categories (Sediment Priority Action Committee, 2000). Table 1 shows the classification of the economic benefit categories according to whether they represent use or non-use benefits and market or non-market benefits.

Table 1. Classifications of economic benefits of marine sediment remediation

Economic Benefit Category	Biophysical or Economic Activity	Use/ Non-use	Market/ Non-market	Valuation Method
1. Capture fisheries Recovery	- Reduction in fish death and infection - Increase in fish population	Use	Market	Production Function
2. Fish consumption recovery	- Increase in consumer preferences to fishes	Use	Market	AIDS model
3. Increase of Tourism	-Amenity improvement - Malodor reduction - Fishing, boating, swimming	Use	Non-market	TCM/CVM
4. Reduction of human health risk	- Water quality improvement - Residential environment improvement	Use	Non-market	CVM/ABM /HPM
5. Ecosystem Integrity	- Ecosystem stability - Biodiversity increase	Non-use	Non-market	CVM
6. Others	- Navigation - Broader land use	Use	Market	CVM

Note: AIDS - Almost Ideal Demand System; CVM – Contingent Valuation Method; TCM – Travel Cost Method; ABM – Averting Behavior Model; HPM – Hedonic Pricing Method

3. ECONOMIC BENEFITS TO RESTORING COMMERCIAL FISHERIES

3.1 Theoretical backgrounds for the economic benefits

If the contaminated sediment has contributed to the degradation of fish and wildlife populations, remediation may help to restore those populations. This may reduce the death rate and infection rate from fish diseases. In economic terms, the death and infection rate shifts the supply curve from S to S' in Figure 1, indicating a change of a sort of technology and/or factor price which is the non-price variable in the product supply function. If the death and infection rate can be reduced by a remediation project, the quantity supplied would recover from Q_1 to Q_0. Meanwhile, the fish and wildlife have concentrations of PTS in their flesh that may cause harm to humans who consume them in substantial quantities. This leads to decrease their consumption of these species. Such fish diseases make consumers substitute their fish consumption for other product consumption such as beef, shifting the demand curve from D to D' in Figure 1.[1] In the same way, if the death and infection rate can be reduced, the quantity demanded would recover from Q_2 to Q_1.

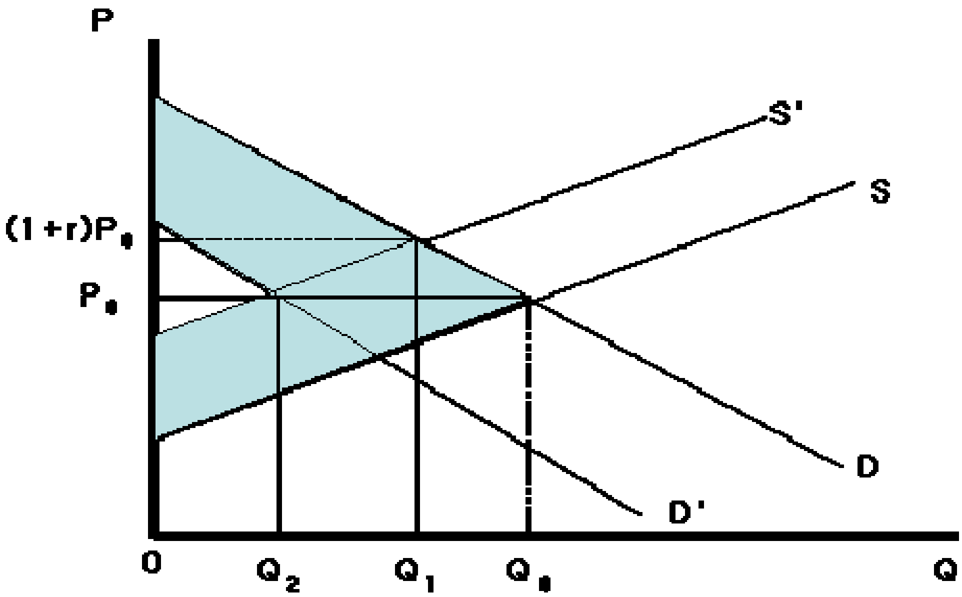

Figure 1. The recovery effects of social welfare from cleanup project

Likewise, the shaded area in Figure 1 represents the recovery effects of social welfare occurred from marine contaminated sediments cleanup and can be derived from the following equation.

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

Using market price and landing data, the increase in social welfare for wild capture fisheries can be measured by a net benefit approach as an alternative as follow:

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

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

Where NB=Net Benefits

NB_s =Net Benefits with the project

NB_c = Net Benefits without the project

v = Variable cost

r = increasing rate of price

P_0 =current market price

3.2 Estimating demand function of wild capture fisheries

During the last two decades, the AIDS model, which was developed by Deaton and Meulbauer(1980), has been gained prominence in demand analysis. The AIDS model can be defined as:

$$w_i = \alpha_i + \sum_{j=1}^{n} \gamma_{ij} \ln P_j + \beta_i (\ln E - \ln P^*)$$

$$\ln P^* = \sum_{i=1}^{n} w_{i,t-1} \ln P_t$$

And where, in observation t;

w_i is the budget or expenditure share of the i^{th} good;

P_j is the nominal price of the j^{th} good;

$\ln E$ is total expenditure;

$\ln P^*$ is the Stone's price index.

For estimating the effect of fish disease information[2], the model includes a dummy variable for fish disease information as follow:

$$w_i = \alpha_i + \varphi_i \ln H_i + \sum_{j=1}^{n} \gamma_{ij} \ln P_j + \beta_i (\ln E - \ln P^*)$$

Where H_i is a dummy variable for health information[3].

The parameters for the AIDS model are estimated by monthly time series data, which periods are 144 months from January 1994 to December 2005, for fish, crustaceans, shellfish, mollusks, and beef as a substitute of aquatic products. Table 2 indicates basic statistic for

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[2] Brown and Schrader(1990) employed a dummy variable for cholesterol information which affects U.S. demand for shell eggs.

[3]The negative health information is dealt with a dummy variable which indicates whether or not aquatic animal disease outbreak such as outbreaks of cholera and vibrio was reported in main daily newspapers in Korea. The negative information data used include monthly data from January 1994 to December 2005.

expenditure share during 144 months (from January 1994 to December 2005).

Table 2.Statistic for expenditure shares

Types	Mean	Standard deviation	Minimum	Maximum
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Beef	0.50435	9.01E-02	0.22815	0.69461

Table 3 shows the results of price elasticity, cross elasticity, expenditure elasticity, and disease information elasticity.[4] In Table 3, price elasticity for each aquatic animal keeps internal consistency (theoretical validity), presenting a negative (-) sign. Price elasticity for crustaceans is -0.555565 which is the most inelastic, while its elasticity for mollusks is -1.451547 which is the most elastic, and price elasticities for fish, shellfish and beef are approximately unit elastic. All expenditure elasticities represent close to unit elasticity, and cross elasticities between beef and aquatic animals except fish imply their substitutes. Fish and beef have quite a low complementary relationship in which cross elasticity is -0.008568 because fish include raw fish as well as fresh fish which should have a complementary relationship with beef.

Table 3.The results of demand elasticities

Types	Fish	Crustaceans	Shellfish	Mollusks	Beef
Fish	-0.978837	-0.027253	-0.001331	0.011202	-0.008568
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Disease information	-0.060769	-0.197025	-0.052566	-0.142073	0.070912

In particular, disease information elasticities have negative signs which indicate reduction of

[4] Green and Alston(1990) derived these elasticities which formulas can be referred.

their consumptions if disease information is occurred. It is confirmed that the negative health information variable negatively affects the consumption of aquatic animals and positively affects the beef consumption, showing the theoretical validity. Among aquatic animals, crustaceans are the most sensitive to disease information. For example, a 1 % decrease in the death rate results in about 0.2 % increase in the quantity demanded of crustaceans because disease information elasticity of crustaceans is -0.197.

4. RESULTS

4.1 Estimating the recovery effects on capture fisheries

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, 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 fish 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:

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

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

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

Table 4. The estimation ofthe quantities recovered

(Unit: M/T)

Items	Fish	Crustaceans	Shellfish	Mollusk
d	5%	5%	5%	5%
c	0.304%	0.985%	0.263%	0.7104%
Q_2	84,502	1,930	1,500	8,200
Q_1	84,760	1,949	1,504	8,259
Q_0	89,221	2,052	1,583	8,693

Note: 1. Q_2 is annual catch of each aquatic animal around the cleanup sites based on 2004, without the cleanup project.
2. Q_1adds the quantity recovered from the reduction rate of aquatic animal death or infection to Q2.
3. Q_0 is the quantity yielded with the cleanup project, which adds the quantity recovered from the reduction rate of aquatic animal death or infection and the consumption recovery rate to Q2.

It is noted that 'd' is an exogenous variable derived from pathological analysis[5], while 'c' can be derived from disease information elasticities which indicate the impacts of negative health information on the quantities demanded of aquatic animals.[6]Using the reduction rate of aquatic animal diseases (d=5%) and the consumption recovery rate(c), the quantity recovered rises by average 5.6% in Table 4.

Total annual recovery effects of the cleanup project on wild capture fisheries are estimated to be 10.778 million dollars of which 84% is from fish in Table 5.

Table 5. Annual recovery effects (target reduction rate of the diseases, d=5%)

(Unit: US$ 1,000, M/T)

Items	Fish	Crustaceans	Shellfish	Mollusk
Selling prices per unit	2.909	4.686	4.264	3.404
Q_0	89,221	2,052	1,583	8,693
Q_2	84,502	1,930	1,500	8,200
Annual recovery effects	9,059	377	234	1,108

Note: 1. Selling prices per unit represent the weighted average value of each aquatic species in Korea, based on national data of 2005.
2. Annual recovery effects on wild capture fisheries = (selling price – variable cost) × (Q_0 - Q_2)
3. Variable costs per unit are assumed to be 34% of selling prices per unit, which is calculated by national data for cost share.

4.2 Sensitivity analyses

To reflect the uncertainties for the reduction rate of species diseases, sensitivity analysis are used to assess what if the reduction rate of aquatic animal disease is changed to be 7.5% and 2.5%, which indicate the change of ± 50% against the original target reduction rate of species disease (d=5%), holding all other base-case data constant.

In case of increasing the reduction rate of species disease by 7.5% from base-case, annual recovery effects are increase from US$10.778 million to US$16.228 million, which indicates an increasing rate of 51.4%. In contrast, annual recovery effects decrease to US$5.609 million, which indicates a decreasing rate of 65.4%, in case of decreasing the reduction rate of aquatic animal diseases by 2.5% from base-case.

[5]KORDI(2006) predicted that 'd' can be 5% when marine contaminated sediment cleanup project will be conducted.

[6] c= - (negative information elasticity for each aquatic animal x d). For example, consumption recovery rate for fish=0.060769 x 5% = 0.3038%

Table 6. Annual recovery effects (when target reduction rate of the diseases, d=7.5%)

(Unit: US$ 1,000, M/T)

Items	Fish	Crustaceans	Shellfish	Mollusk
Q_2	84,502	1,930	1,500	8,200
Q_1	84,760	1,949	1,504	8,259
Q_0	91,632	2,107	1,626	8,928
Annual recovery effects	13,689	548	354	1,636

Table 7. Annual recovery effects (when target reduction rate of the diseases, d=2.5%)

(Unit: US$ 1,000, M/T)

Items	Fish	Crustaceans	Shellfish	Mollusk
Q_2	84,502	1,930	1,500	8,200
Q_1	84,760	1,949	1,504	8,259
Q_0	86,933	1,999	1,543	8,470
Annual recovery effects	4,667	214	120	608

5. CONCLUSION

The paper aims to estimate the recovery effects of marine contaminated sediments cleanup on wild capture fisheries. A central concern is often related to wild capture fisheries from which benefits can be derived from reduction in aquatic animal deaths or infection and increases in their consumption recovery. In addition to the recovery effects on fisheries, predictable economic benefits from contaminated sediment cleanup include an increase in tourism including recreational fishing, reduction in human health risk, increase in amenity and aesthetics, increase in ecosystem integrity and others. This paper applies AIDS model to estimate the consumption recovery rate, and calculate the quantity recovered by using the reduction rate of aquatic animal diseases and the consumption recovery rate at the cleanup site, Yeosu Coastal District in Korea.

The results show that the total annual effect of the cleanup project on wild capture fisheries is estimated to be US$ 10.8 million of which 84% is from fish in a case 5% of target reduction rate of aquatic animal diseases. To reflect the uncertainties for the reduction rate of aquatic animal diseases, sensitivity analyses are used to assess “what if” scenarios where the reduction rate of aquatic animal disease is changed to be 7.5% and 2.5%. In the former case, the annual recovery effect increases by 51.4%, whilst it decreases by 65.4% in the latter case. This indicates that economic benefits from fisheries can be seriously reduced without the cleanup project.

The results of this paper provide important insights for public policy. For policy purposes, the results are useful starting points in understanding the economic implications of cleaning up marine contaminated sediments. This analysis provides a preliminary indication of the main economic benefits from the cleanup projects and gives the justification of cleanup projects to public policy makers. In order to sufficiently take into account the potential costs and benefits, a method for extended economic appraisal needs to be developed together with a useful means to assess the economic feasibility for cleanup projects.

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