Estimating the Economic Impacts of Pollution in Estuaries[1)]

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Ⅰ. Introduction

Estuaries are important natural assets that support many economic benefits, including commercial fishing, recreation activities, transportation services, wildlife habitat and income from tourism, among others. However, many of the potential benefits from estuaries can be threatened by pollution. Addressing pollution problems in the most cost-effective manner poses many difficult challenges throughout the world and has been a major part of our research agenda for many years. Examples of this research include: (1)development of the official framework used throughout the United States to hold polluters of estuaries financially liable for oil and hazardous substance spills (the "Polluter Pays Principle") and (2)assisting estuary managers in developing affordable programs to preserve and restore important natural

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resources threatened by poor development and waste management practices.

Other examples of our research include (3) estimating the cost and benefits of proposed environmental regulations ("Regulatory Impact Analyses") and their potential impacts on businesses, and (4)environmental risk analyses done in order to understand better the potential impacts of government policies and of company operations.

Our research has addressed local and national issues within the United States, and increasingly we have been asked to study difficult international environmental issues in many parts of the world, including Korea and Southeast Asia. This work has given us the opportunity to learn much about these issues and to collaborate closely with government, industry and the public to help solve many practical yet challenging problems of great importance to those affected.

This brief article sketches how economists measure the impacts of estuary pollution, and indicates the important role economic analysis can play in estuary pollution management. Due to space limitations, we focus on the first two examples given above: Assessing monetary damages due to pollution incidents and working with estuary managers to develop cost-effective programs to protect and restore key natural resources. Our examples are primarily from the United States. Of course, specific estuary issues and approaches for dealing with issues differ from country to country, but the methods described in this article can be adapted for use elsewhere, as appropriate.

Ⅱ. Estuaries as Natural Assets: Importance and Conflicts

Estuaries (semi-enclosed bodies of saltwater with a substantial fresh water inflow) can be viewed as natural assets. Natural assets, like business assets,

can yield a sustainable flow of valuable services ("dividends"), provided they are properly maintained. Of course, the valuable natural services provided by estuaries are different than most services provided by businesses. Estuaries tend to be ecologically very productive areas for fisheries and often are popular sites for tourism and recreation, and for other activities that are sensitive to damages from pollution, such as mariculture.

At the same time, estuaries are geographic hubs that attract concentrations of people and commerce and are sinks for wastes from a multitude of activities in the surrounding watershed. These activities provides important benefits to society, but the concentration of human activities can threaten the environment and estuary-dependent economic activities that many people rely upon for their livelihood and enjoyment.

Major causes of estuary pollution include: Discharges of industrial contaminants and untreated domestic wastes; surface runoff of fertilizer, pesticides, and animal wastes from agriculture; and runoff of oil, grease and other substances from urban and road surfaces. Accidental oil and chemical spills from ships, barges and coastal industries are other important sources of contaminants.

In most cases, the sources of estuary pollution are known. The major challenges are (1) to understand the direct and indirect impacts of pollution on the environment and on people, and (2) to design sensible policies for its prevention and control, or to reverse pollution effects through restoration of lost resources. Sensible policies are those which are cost effective and for which the benefits to be realized reasonably justify the costs of these policies. These are simple but important rules that are sometimes overlooked. Most people generally support a healthy, attractive and productive environment. However, actions to control pollution or to restore the effects of pollution can be costly, budgets are limited, and environmental protection must compete with other worthwhile social objectives. Hence, difficult choices often must be

made. Policies that are not cost-effective or do not produce benefits reasonably in line with costs may not be adopted or implemented, or may waste scarce funds that could better be used in other beneficial programs.

Ⅲ. Assessing Money Damages Due to Pollution from Oil Spills: Examples

Oil spills are rare, but are very visible and controversial events when they occur. Oil spills are of great importance to Korea, because of the high risk of spills and the many important coastal resources and activities at risk from pollution. Highlighting the risk of spills, a recent study published by Etkin for Cutter Information Services shows that from 1960-1995 Korea had 31 large (greater 10,000 gallons) spills. Korea was tied with Singapore for number 9 among all countries in the number of large oil spills occurring in its coastal waters over this period. Mariculture, tourism and recreation are among the important coastal activities in Korea that are very vulnerable to oil spills.

In the United States, the Oil Pollution Act of 1990 makes parties who spill oil strictly liable (meaning negligence need not be shown) for resulting losses. Following a spill, polluters are required by federal regulations to make the public and the environment "whole" in the most cost-effective manner. The categories of losses for which polluters are liable in the United States are truly sweeping. They include not only commercial fisheries, but also beaches, wildlife, and other natural resources. Polluters also are liable for other costs, including lost earnings by businesses and their employees, reduced public revenues, increased public costs, and damages to private property. And polluters must pay response and cleanup costs as well as reasonable costs of assessment. At the same time, solutions to restore injured natural resources must consider the cost of recommended restoration actions, and the costs of those actions cannot be disproportionate to the benefits that result from the

action.

In total the damages and costs from spills may be quite substantial: Claims often exceed many millions dollars, and frequently many tens of millions of dollars. In the exceptional case of the *Exxon Valdez* oil spill in Alaska, total costs were in the billions of dollars. In light of the potential for large damages, it is not surprising that liability for damages is an important approach for avoiding pollution. It serves to compensate those suffering losses; and, by making the polluter bear the cost of their actions, provides a built-in incentive for firms to exercise care to avoid spills. Liability also can be contentious, given the high economic stakes involved, and given the many challenges involved with estimating pollution damages. In some cases penalties added to damages reinforce these incentive effects.

Here is what happens in a typical case. Following a spill, government officials, acting as Trustees on behalf of the public, oversee studies to assess losses to the public. The Trustees then present a money claim for damages, response and cleanup, and assessment costs to the Responsible Party. Of course, private parties harmed by a spill, such as affected fisherman, tourism businesses, and coastal property owners, for example, also will carry out their own studies, as necessary, and file claims for losses.

Key issues in damage assessments from oil spills include: (1)estimating "injuries" to natural resources (e.g. fish and shellfish killed; mortality to marine birds and wildlife; oiling and disruption of ecosystems, such as wetlands or mangroves), and then (2)assigning a monetary value to the services lost due to these injuries. Estimating injuries is the responsibility of scientists who must document impacts on natural resources; estimating monetary losses--damages--is where economics is important.

Estimating damages can be very difficult, since many of the activities affected by oil spills, such as beach use, recreational fishing, pleasure boating, and loss of wildlife, are not valued in markets. Special studies often are

needed to assess these non-market values. Basically, four approaches can be used to estimate monetary damages from pollution:

Market Data. This approach is useful for goods and services, such as commercial fishing or tourism losses, that are bought and sold in the marketplace. Market data normally can be used to estimate lost profits, much as a business would assess the impact of an event (e.g., flood, plant closure) on its operations.

Revealed Values: Travel Cost. A second approach, useful for such recreational activities as beach use, swimming, boating, and fishing, employs information on individuals' recreational uses and the costs they incur to carry out these activities. Participants in effect reveal the value they attach to recreational activities by the amount they pay to travel to the site and how often they participate.

Revealed Values: Property Value. Environmental quality can be an important factor affecting the market price of property, along with more obvious attributes like the size and quality of a home, size of the land owned, and its distance from work, shopping and schools. A change in quality, like the discovery that an estuary is contaminated with hazardous materials, may reduce the market value of nearby property, all other factors being the same. The drop in the value of property is a measure of damages.

Stated Values. This approach uses carefully developed surveys in which people may be asked directly what they would be "willing to pay" for a specific activity rather than do without it. This approach, and its many variations, are similar to carefully developed surveys that

businesses use all the time in marketing to assess the feasibility and potential value of a product or service. Someone who would pay up to a given amount for a service rather than do without it is indicating the monetary value they attach to the service.

Productivity Approach. This important method can be very useful in cases where ecosystems are impacted by pollution. For example, wetlands and other coastal ecosystems provide many valuable ecological services that contribute to human uses. Among others, they serve as nursery areas and habitat, by that contributing to the "production" of fish, crabs and shellfish harvested by users.

If the above ecosystem productivity services per unit area have been estimated, then damages can be estimated. To do this, one would multiply the estimates of the economic value per unit of service per area (calculated using any of the economic methods described above) by the loss in the wetland or other coastal ecosystem area.

Of course, there are many different ways the above methods are applied in particular cases. Next we give some examples of two approaches for assessing the impact of pollution on estuaries, one a simplified approach and another where separate, incident-specific studies are needed.

A Simplified Approach. Most oil spills are small. In such cases, it is useful and cost-effective to have a simplified approach for assessing money damages, one that does not require extensive -- and expensive -- field observations.

In the mid-1980s we were asked by the United States Interior Department to develop, as part of a federal regulatory process, the first simplified approach

for assessing damages from oil and hazardous substance spills in estuaries and other marine areas throughout the United States. For this purpose, we worked with colleagues from the sciences to develop a user-friendly, interdisciplinary computer simulation model. The model, included in federal regulations, provides estimates of damages when public resources are affected, such as estuary waters and resources. Private claims are documented by the individuals suffering a loss and are not part of the model.

In a nutshell, the simplified approach works as follows. After a spill, a user of the model specifies the substance and amount spilled, where the spill occured, and other information, such as wind speed and direction and air temperature, that affect the movement of spilled oil. Then, the model simulates what happens to the spilled material over time in an estuary. For example, spilled oil may float on the water surface, evaporate, and degrade; some will be recovered in cleanup actions; and some will come ashore and eventually be removed.

As the oil spreads on and below the water's surface, the computer model simulates exposure of fish, shellfish, birds, and other organisms to the toxic parts of the oil. In some cases, beaches or shell fishing areas also may be closed due to concern with health threats to the public, or part of an estuary may be shut down to fishing due to placement of booms during cleanup actions.

Fish and shellfish exposed to high concentrations of oil for enough time may die, and birds contacted by oil slicks become very vulnerable to mortality. In the model, the number of fish, shellfish and bird killed due to contact with the oil is estimated, using relationships between exposure and death ("dose-response relationships") found in the literature. Then lost catch and other uses are estimated, and a monetary value is calculated. For example, if 2,000 pounds of fish worth $1 per pound are not harvested because of the spill, then this $2,000 loss becomes part of the damage claim. Similarly, if

fish worth $4,000 to recreational fishers is not caught due to the spill, then this also is included as a damage. Often public beaches are closed due to contamination by oil. If recreationists canceled, say, 1,000 beach trips because a beach was closed by oil pollution, and if each trip has a value of $7.50, estimated using one or more of the techniques mentioned above, then the responsible party is asked to pay $7,500 for this particular damage category.

Note that for the simplified model described here, dollar values are adopted from several sources. These include commercial fish prices, in the case of mortality to fish, and studies of the value of a beach day, adapted from the literature available on this subject.

The computer model outlined above was part of national regulations, as noted, and has been used many times throughout the United States to assess polluters for damages. For example, in the early summer of 1989, a large oil spill polluted sections of the Rhode Island coast. Many miles of popular beach and extensive shellfish grounds were closed. Mortality to lobsters and birds also occured. The model outlined above was used and resulted in estimates of damages of several million dollars, which was paid by the polluter. We also have adapted this model for use in Korea's Yellow Sea by using fisheries biological and market price data appropriate for that area and gathered by Korean researchers as part of a collaborative effort.

Site-Specific Studies. Not all spills fit the simplified approach used in the above model; in other estuary pollution incidents, we have had to use different approaches to assess the economic impacts of oil spills. For example, a large oil spill in New York Harbor caused a delay in vessel uses for a section of this major port. In this case, we obtained very detailed information about the number, size and types of vessels (tanker, container ship, cargo vessel, tug, etc.) affected and the length of the delay. We also obtained information about the cost of operating such vessels. With this data we were able to

estimate the substantial extra cost incurred from transportation delays due to this spill.

In another case, we were able to work with scientists' findings on the biological impacts of a spill to estimate damages. Here, a spill resulted in mortality to many millions of lobster, mostly very young lobster, far below legal size. This spill also caused government officials to close a large area to fishing for up to five months.

The challenge in this case was to account for short-tem lost (really, delayed) catch due to closure of large fishing grounds and for lost catch, years in the future, when the young lobsters killed by the spill would have been of legal size for harvesting. We used a model of the lobster fishery that tracks lobsters through time. The model estimates how many lobsters would have survived, but for the spill, how they would have grown over time, and when they would have been caught, if the spill had not occured. This allowed us to estimate both the lost catch in the short-run due to closure and also the longer run drop in catch due to mortality to young lobsters. Again, key input to our work in this case was scientists' estimates of morality to lobster due to the spill.

In sum, increasing concern with environmental issues on the part of the public, and concern with potential liability on the part of companies, has created much interest in estimating money damages from oil spill (and other pollution incidents). Improved methods are needed, and in our research we have sought to contribute improved approaches to address these difficult problems.

Ⅳ. Impacts of Pollution and Estuary Management

In the United States, some 28 estuaries of national significance have been included in the National Estuary Program, supported by the Environmental

Protection Agency. The purpose of this program is to protect and restore critical natural resources in the selected estuaries. Much of the value of these estuaries stems from the generally high quality of the environment and activities they support. In most cases, however, little specific information is known about many uses of these areas. Even less is known about the public's view on management programs to preserve and restore key natural resources in the estuary that have been lost or degraded over time.

To contribute to improved management, we have undertaken a series of economic studies in the Peconic Estuary on East End of Long Island, New York. An important part of this work involved focus groups and meeting with businesses and scientists to carefully develop surveys of the public. The surveys were needed to identify citizens concerns, and their preferences and willingness to pay for possible public programs to protect and restore key estuarine resources. This information was used to identify resource priorities and the value of resource programs to respondents, to be compared later with the cost of programs.

We also asked the public about their recreational uses (e.g. swimming, boating, fishing) in the estuary and about their perceptions of water and beach quality. We did this to learn how quality affects decisions to engage in recreation and the benefits the public receives from these activities. We learned, for example, that swimmers respond to changes in water quality, such as clarity and pollution, and recreational anglers also care about quality--how much they can catch. Given these results, we can estimate the benefits from improved water and fishing quality due to management decisons.

In addition to surveys, we are doing a property value study. The purpose of this work is to see how environmental attributes of interest to managers, such as open space (undeveloped lands), wetlands, water quality, and preserving farmlands, might affect the value of property in the area.

Our economic studies were designed in collaboration with managers to help

them assess: (1) the priorities the public has for restoring and preserving estuary resources, and (2) estuary uses and the benefits they provide. Ongoing work will examine the cost of programs to protect and restore resources, which then can be compared with estimated benefits. Finally, we will examine how resource protection and preservation programs might be funded to ensure that the programs selected by estuary managers can be implemented.

Ⅴ. Summary and Conclusions

Estuaries are natural assets that can provide many valuable natural services, if they are maintained. However, estuaries are under severe stress from pollution in many parts of the world. The public has become much more aware of, and concerned with, pollution and its consequences. At the same time, businesses have good reason to be more concerned with pollution and its control due to the high costs of pollution controls, and potential major liability for damages and payment of penalties they face in the event of a serious pollution incident. While it is important to protect the environment and the many benefits it provides, it is also critical that costs of controlling pollution are carefully managed through (1) identifying cost-effective methods for pollution control and (2) identifying cases where potential benefits justify control expenditures.

Our research at URI in Environmental Economics, and in our new Korea-America Center for Joint Research on Marine Policy, examines many issues dealing with estuarine pollution, as noted: Assessing damages from pollution incidents; evaluating the benefits and costs of different policies; identifying cost-effective means of controlling pollution; regulatory impact analyses; and risk analyses, to name a few. Of course, specific issues and approaches for dealing with these issue vary from country--the

same polices may not apply everywhere.

Nevertheless, estuary pollution is an important issue internationally and will become even more significant in the future as the populations of coastal areas grow and conflicts multiply. The methods that we are developing can be used to contribute to environmental policy, taking into account different issues and approaches to these issues in different countries.