AN ECONOMIC PERSPECTIVE ON THE PROBLEM OF MARINE DEBRIS

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ABSTRACT

This paper examines the role of economic analysis in the development and implementation of an effective public policy to address the problem of marine debris. The economic theory of common property resources and other relevant aspects of natural resource and environmental economics are explained and used as a basis to critically review the economics literature on marine debris. Gaps in knowledge are identified and an economic data collection and research agenda is proposed.

INTRODUCTION

Many of the economic issues associated with the problem of marine debris are similar to those surrounding oil and hazardous substances pollution of the marine environment. The marine debris problem has not, however, received the same degree of attention by the research community as oil and hazardous substances pollution has. This is particularly true in the field of natural resource and environmental economics, as the review of the literature amply illustrates. Although a number of studies have shown that marine debris can have deleterious effects on marine life (Balazs 1985; Calkins 1985; Day et al. 1985; Bengston et al. 1988; Cooper et al. 1988), the current body of knowledge is insufficient to provide an assessment of the magnitude of the problem. And although research is continuing on the impacts of marine debris, neither does a coordinated effort exist to structure this research toward providing such an assessment, nor are efforts under way to ensure that research results are formulated in a way that will be useful for economic assessments.

This paper provides an overview of the economic aspects of the marine debris problem and suggests how economic analysis can play a role in finding effective and rational solutions. A research agenda is proposed to aid in quantifying the economic dimensions of the problem and assessing the effectiveness of economic incentives in achieving compliance with various laws and regulations.

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THE ECONOMIC PERSPECTIVE

Absent significant economic incentives, compliance with environmental laws and regulations is usually low. It is true that education, moral suasion, and fear of punishment will stimulate many to abide by laws and regulation, but past experience has shown that these efforts alone will not significantly reduce noncompliance with environmental regulations. Here we discuss how an economist would approach analytically the problem of marine debris, including the issue of compliance with prohibitions on debris disposal.

Background

In order to show how economics can be used in analyzing the problem caused by marine debris, it is necessary to provide a brief description of the economic theory of natural resource and environmental economics. This will help clarify some of the concepts behind such familiar terms as market failure, economic efficiency, benefit-cost analysis, economic damage assessment, the value of environmental improvement, and cost effectiveness. These terms are related to methods for analyzing policy alternatives designed to correct problems in the way individuals use scarce natural resources (including environmental goods and services).

The literature on the problem of marine debris highlights a wide range of detrimental impacts on living and nonliving resources. These detrimental impacts are known, generally, in economic terms as external diseconomies (or simply "externalities" for ease of exposition). Externalities arise when the marketplace fails to balance competing uses of a resource so that a particular resource's value to society is maximized. Under ideal circumstances, competitive markets will consider all the costs and benefits of an activity, balance competing uses, and produce the maximum net benefit to society. Thorough study of the market failures which result in marine debris would undoubtedly lead to more effective solutions.

Common Property Resources and Nonmarket Goods

Two sources of market failure predominate in the natural resource and environmental economics literature: common property resources and nonmarket goods. One type is discussed in a classic article by Hardin (1968) who wrote of the "tragedy of the commons." Common property is overexploited because everyone has the right to use it, but no one has personal responsibility for it. Rivers, estuaries, and oceans are examples of common property. It is not surprising then that these bodies of water are overutilized as waste repositories, since dumpers do not have to pay the full social cost for their use. Given the rising, high cost of land-based disposal, we can expect pressure on these resources to continue.

Even if private property rights for natural resources exist, the second type of market failure occurs because markets cannot be easily organized for many environmental goods and services. They form a general category called "nonmarket goods and services." An example of the existence of market failure where private property rights exist is in the

market for wetlands. Many wetlands are privately owned but may be used in a nonoptimal way by the private owner because he or she cannot capture the many social (public) benefits produced, such as water recharge, storm protection, water purification, wildlife habitat, and fishery production. The wetland owner is unable to identify the beneficiaries or measure the amount of individual benefit for each of these services, therefore these services go unpriced and undervalued in actual market transactions. From the owner's point of view, he or she may maximize the value of wetlands by developing them, but from society's point of view wetlands may be misallocated since the value of nonmarket services is ignored.

The marine debris problem combines both types of market failure. Most of the resources affected, living and nonliving, are common property and have nonmarket values. Effective solutions to the marine debris problem must focus on resolving these two market failures. Implementing systems of private property rights in the rivers, estuaries, and oceans does not seem feasible. The solution to the common property resource problem has largely been government ownership and management. The government, it is often assumed, could represent and balance competing uses of resources if all the costs and benefits of the various activities were known. The government, acting as the private sole owner, could presumably maximize the value of its resources. However, experience has shown that such an outcome is not likely for a variety of reasons: lack of information, overlapping jurisdictions, conflicts of interests across jurisdictions, and the co-opting of politicians and managers by a particular interest group, to name a few.

Markets are vitally important sources of information on the value of goods and services. It is this aspect more than any other that leads to efficient outcomes from smoothly functioning markets. The costs and benefits of various courses of action are discovered through billions of private transactions. The major problem for nonmarket goods and services is the absence of quantifiable information about the costs and benefits of actions which affect them. Two broadly defined categories of nonmarket goods and services are expected to account for a major portion of the social costs of marine debris: recreational use value and intrinsic value of natural resources and the environment.

Recreational Use Value

Recreational use is generally recognized as second in importance only to human health as a beneficiary of water pollution control. Over the past 20 years, economists have been developing information collection and analytical techniques to estimate the recreational use value of natural resources. Survey sampling techniques and the use of questionnaires are the primary methods of information collection. Analytical techniques fall into two general categories; demand modeling and the use of direct valuation questions, e.g., contingent valuation approach. In demand modeling, individual expenditures on goods and services used in producing a recreational experience serve as proxies for actual market prices. In the contingent valuation approach, individuals are given a hypothetical situation defining the quantity and quality of the recreation experience. They are then asked how they would value in dollar terms a particular change in the quantity or

quality of a recreation resource. Some economists prefer the demand modeling approach because it is based on actual behavior; others prefer the contingent valuation method because of the flexibility it provides for addressing incremental environmental changes. Both have imperfections, and research on improved methods for estimating recreational use values continues.

Intrinsic Value

One of the value categories that is often excluded from estimates of the total economic value of nonmarket goods is referred to as intrinsic value. This term is used to define values that people place on natural resources that are independent of their present use. These values can be reduced by human activities that lower the quantity and quality of the resources in question. Such values appear to derive from a variety of motives including the desire to bequeath a legacy of natural resources such as clean oceans to future generations, or the sense of well-being that results from simply knowing that certain natural resources exist.

In the few empirical studies that have been completed to date, aggregate intrinsic values for unique natural resources have been shown to be quite large. As to the likely ratio of intrinsic values to use values, it is still too early to draw any firm conclusions. Most who have studied this issue agree that intrinsic values exist, but continue to debate how they can be measured accurately. The methods of collecting and analyzing data on intrinsic values closely follow the contingent valuation method used for recreational use values. Research on this important area of valuation is likely to intensify in the near future.

Efficient and Equitable Allocation of a Pollutant

Economic efficiency is one normative criterion for judging various policy outcomes. It is based on the maximization of the net social benefits to society from any activity (net benefits being equal to total social benefits minus total social costs). It is a normative criterion because there are an infinite number of economically efficient outcomes, each associated with a different distribution of wealth and income. A change in the distribution of wealth and income could change the benefits and costs of any activity and therefore the amount of the activity that is economically efficient. The distribution of wealth and income is another normative criterion used for judging policy outcomes and is commonly referred to as the equity or fairness criterion. Economists artificially separate the two criteria of economic efficiency and equity in order to make analysis tractable. Below, the concepts of economic costs and benefits and the economically efficient allocation of a pollutant are discussed. Following that, equity and another criterion related to efficiency, cost effectiveness, are presented.

Economic Costs

The fundamental economic measure of the cost of any action is its opportunity cost. This basic concept has an analogy in physics: two objects

cannot occupy the same space at the same time. In other words, one cannot undertake one activity without giving up something else. Opportunity cost, therefore, measures the value of the next best thing forgone in order to have the preferred choice. Social cost is simply measured by how much of some other thing is given up in order to have the preferred choice. For example, to estimate the full social cost of cleaning a marsh after an oil spill, one should count the opportunity costs of all the equipment, supplies, and wages paid to employees (using market prices), plus the nonmarket opportunity costs of any physical damage done (including those caused by the cleanup itself). Of course measuring the value of the aesthetic and biomass damage inflicted, since there is no market price established for them, is difficult.

Opportunity costs are incurred regardless of whether monetary transactions, or exchanges, take place. Both explicit costs, which show up in an accounts ledger, and implicit costs should be included in any full social cost accounting of a change in the quality or quantity of a natural resource. For example, the social cost of a beach littered with debris includes the cost of cleanup plus the lost enjoyment of the beach caused by the nonmarket aesthetic insult of the debris' presence until the cleanup is accomplished. Thus the social costs of any activity (beach litter) include the lost benefits from other activities impaired by that activity (beach use).

Economic Benefits

A benefit is the economic value of any good or service that provides utility or satisfaction to one or more individuals. Benefits enhance a person or group's well-being. They can be derived from the consumption of commodities such as offshore oil and gas, or fish, or from nonconsumptive enjoyment of a sunset or body surfing. Commodities, especially those valued in the competitive marketplace, where externalities do not exist, are much easier to measure because their prices are determined in arm's length exchanges which reflect the consumer's willingness to pay and the cost of all inputs used in their production.

Economic Efficiency

Economically efficient outcomes in the choice between competing activities are ones where net benefits (total benefits minus total costs) to society are maximized. When dealing with pollution, this concept is more easily understood by an equivalent formulation involving the minimization of two rather different types of costs: damage costs and control (or avoidance) costs. In the case of marine debris, damage costs would include such social costs as lost recreational use, intrinsic damage such as harm to pristine environments or marine mammals, and damages to ships from entanglement of propellers and steering gear. Control or avoidance costs include the cost of avoiding the pollution as well as the cost of removing or recycling the marine debris causing the harm.

The economically efficient outcome will occur at the quantity of marine debris corresponding to the point where the marginal control cost is equal to the marginal damage cost. This is shown in Figure 1 as point Q*.

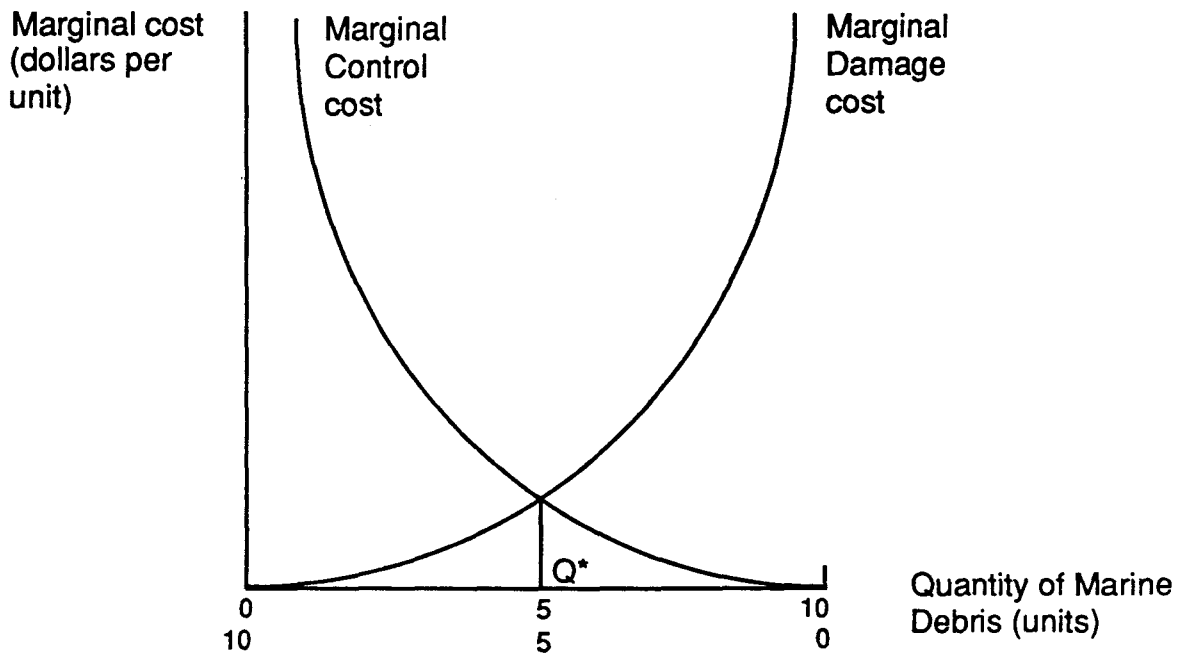

Figure 1.--Efficient allocation of a pollutant--static case.

A nonzero optimum quantity of marine debris at point Q* implies that there is some benefit from the use of products that end up as marine debris. Reducing the quantity of marine debris below Q* would be inefficient from society's point of view because the social cost of reducing it by an additional unit would exceed the value of an additional unit of other goods and services otherwise damaged. The zero level of marine debris is not a socially desirable outcome in this case.

The above static analysis assumes that marine debris items are not persistent pollutants, that is, the pollutant does not have detrimental impacts over many time periods. Some forms of marine debris, however, are persistent pollutants. Even if all marine debris were controlled today, the amount accumulated in the environment would still have detrimental impacts for years to come. Because of the persistent nature of this type of pollutant, the analysis of the efficient pollutant level must take into account the intergenerational transfer of costs and benefits. In economics, we call this the dynamic efficiency criterion. Dynamic efficiency would be achieved at the pollutant level that maximizes the present value of net benefits over time. The mathematical formulation would be:

$$PV[B_1 \ldots B_n] = \sum_{i=0}^{n} \frac{(B-C)_i}{(1+r)^i}$$

where B equals the total benefits of the goods that are produced jointly with the pollutant, i.e., marine debris; C the total cost of producing these goods plus the cost imposed on other goods and services impacted by the marine debris; i the time period; and r the social discount rate used

to make net benefits comparable across different time periods. The dynamically efficient allocation of a pollutant in this case has to satisfy the condition that the present value of the marginal net benefit from the last unit in period one equals the present value of the marginal benefit in each following period (Tietenberg 1988).

There is one interesting difference between the first efficiency outcome presented in Figure 1 (the static efficiency criteria) and the dynamically efficient outcome. In the dynamically efficient outcome, new marine debris after a certain amount of time must be eliminated. In the static outcome of Figure 1, Q*, marine debris enters the environment each new time period. However, the dynamically efficient outcome recognizes that marine debris such as plastics causes damage over many periods. Thus, as marine debris continues to accumulate in the environment, not only the new but also the old marine debris is causing damage resulting in social costs. At some future time the old marine debris will have accumulated to a point where the costs are so high that economic efficiency requires the elimination of all new marine debris. That is, the point is reached where it is less costly to recycle all new marine debris or switch to cheaper substitutes.

Equity

As mentioned above, there are an infinite number of economically efficient allocations of marine debris depending upon the distribution of wealth and income. Wealth, broadly speaking, would include the amounts of both human and nonhuman capital a person owns. Human capital is a person's skills and abilities. Income is a flow from the stock of human and nonhuman capital. An increase in marine debris may result in an increase in the cost of beach visitation, since a person may have to travel further to get to a clean beach. This increase in cost can be thought of as a decrease in income available to the person to purchase other goods and services--an opportunity cost. Equity addresses the question of fairness in the distribution of net benefits from any activity. No generally accepted standards of fairness exist. Resolution of disputes over fairness are generally resolved in political or judicial processes. Implementation of policies that have high net benefits can fail because the benefits of the activity are concentrated in one region of the country and the costs in another. Unless the region that is disadvantaged is compensated for the added costs imposed by the policy, the policy may be defeated. There are several criteria that are generally used in evaluating the issue of equity. They are horizontal equity, vertical equity, and sustainability.

Horizontal equity occurs when people with equal incomes are treated equally. This can be used in judging the geographic fairness of a given policy. If people with comparable income levels in different parts of the country receive different net benefits, the horizontal equity criterion is violated.

Vertical equity deals with the treatment of unequals or those with different incomes. In assessing vertical equity, net benefits are distributed among income groups either progressively, regressively, or

proportionally. Distribution is said to be proportional if the net benefit received is proportional to income. It is said to be regressive if the net benefit represents a larger proportion of the income of the rich than of the poor, and is progressive if, as a proportion of their income, the poor receive a larger share than the rich. Since many of our societal programs are designed to aid the poor, it is usually assumed that regressive policies are bad. Some economic efficiency may be sacrificed to achieve greater equity.

The last criterion is sustainability. This involves intergenerational transfers of net benefits. As we have seen in the discussion of efficiency above, the marine debris problem can be characterized by intergenerational transfers because of the persistent nature of the pollutant. The sustainability criterion suggests that, at a minimum, future generations should be left no worse off than present generations.

Cost Effectiveness

A concept more closely related to the efficiency criterion of policy is the cost effectiveness approach. Under this approach it is recognized that, due to the lack of full and accurate information, determination of the optimal efficiency point is impossible. The cost effectiveness approach evaluates policies and management strategies as to the least costly way in which a given level of environmental quality can be achieved. In the case of persistent marine debris, the economically efficient solution may be an eventual ban on its use and disposal in the oceans altogether. However, compliance with such a ban would likely result in economic hardship for certain sectors of the economy and would be costly to enforce.

Laws and regulations that contain market-based incentive systems are, in theory, less costly than traditional regulatory approaches. Incentive systems use market forces to reduce pollution by requiring polluters to pay all or part of the social cost of their activity. They are penalized economically for high levels of pollution and are rewarded with lower fees for reduced levels of pollution. The laws and regulations that currently exist on marine debris do not contain market-based incentive systems to achieve compliance. This is an area where future research could pay big dividends.

Economic Impact

Many government officials appear more persuaded by the effects of their decisions and policies on sales, employment, and income, i.e., economic impact, than by efficiency, equity, sustainability, or cost effectiveness. Much of the time, concern about sales, employment, and income is expressed in terms of equity or fairness and reflects genuine concern for the health and welfare of people in the communities affected by various decisions and policies. However, economists would generally agree that maximization of sales, employment, and income are not preferable to economic efficiency as objectives of social policy, since irrational conclusions are often derived from analyses based upon maximization of economic impact. An example should help clarify this point.

Consider Figure 2, showing the demand and supply of commercially caught fish. The demand for commercially caught fish is shown in D_1; S_1 and S_2 are the supply of fish before and after pollution, respectively. Before pollution, consumers purchase Q_1 pounds of fish per time period at price P_1 per pound. Total sales revenue is equal to the area OP_1AQ_1.

If pollution reduces the stock of fish, the supply curve shifts back to S_2 and consumers now purchase only Q_2 pounds per time period at the higher price, P_2. Total revenue is now equal to the area OP_2BQ_2. The problem with this analysis is that total revenue may have increased, decreased, or remained the same depending upon the price elasticity of demand. If demand is inelastic (a 10% increase in price will result in a <10% decrease in quantity demanded), then total revenue will increase. Thus, when demand is inelastic, if pollution reduces fish stocks it results in increases in total sales revenue.

Now consider the efficiency approach. Area $P_1P_1{*}A$ measures the net value (consumer's surplus) associated with commercial fishing before the pollution. This would be a measure of the net benefits of commercial fishing to society. Now when pollution reduces the stocks, supply shifts to S_2 and the new consumer's surplus is equal to the area $P_2P_1{*}B$, which is less than the area $P_1P_1{*}A$ by the amount equal to the area P_1P_2BA. Thus, using the efficiency criterion, there is a net loss to society from the pollution injury to this commercial fishery. This loss would then be compared to the gains in consumer's surplus from the products that result in the pollution to determine if society gains or loses from their production.

Such comparisons are commonly known as benefit-cost analyses. They provide more comprehensive information to decisionmakers about the overall result of a given project or policy change than the rather incomplete picture conveyed by economic impact analyses. A benefit-cost analysis can help determine whether, for example, the social benefits of a specific set of policies to reduce marine debris outweigh their costs.

Categories of Social Cost

The following categories can be delineated as the major areas of known economic costs or externalities associated with marine debris:

- Commercial fisheries. Through what is called "ghost fishing," discarded or lost nets and other types of debris can entangle fish and reduce the quantity of various species and thereby impose costs on fishermen and consumers. Debris can also become entangled in fishermen's nets and either damage them or cause them to operate inefficiently.

- Ships. Debris can become entangled in the propellers and steering gear and can clog the water intake of vessels, thereby causing physical damage to ships of all types, including recreational fishing, cargo, military, and research vessels, and imposing repair and delay costs on their owners.

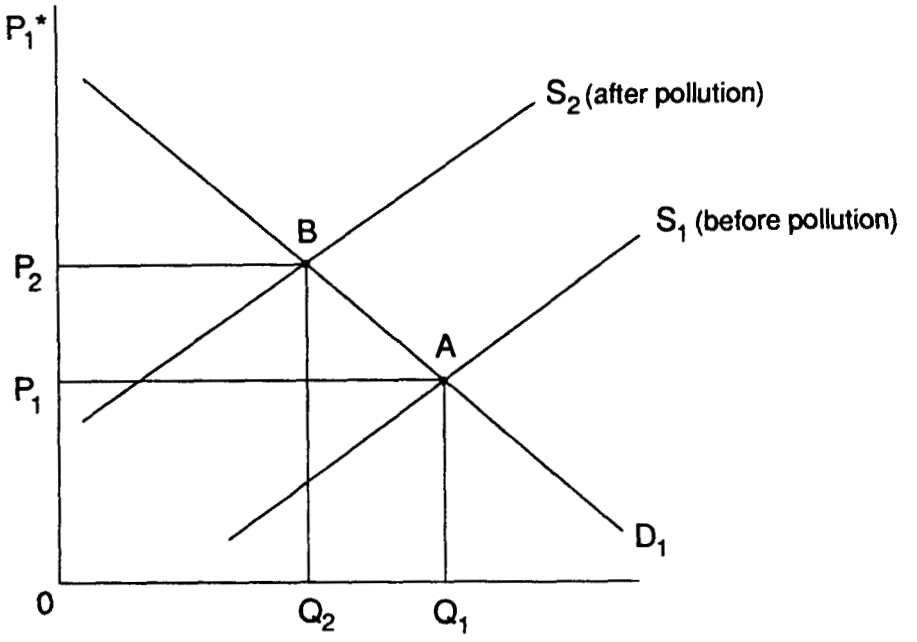

Figure 2.--Impact of pollution on the supply of commercially caught fish.

- Marine mammals, birds, and turtles. Through entanglement in and ingestion of plastics, we know that large numbers of birds and animals become injured and die, imposing costs on those members of society who obtain use value from these animals through viewing, hunting, and scientific research, or intrinsic values from the mere fact that these organisms exist.

- Recreation, such as beach use, hiking, camping, and picnicking. Debris causes aesthetic losses, as demonstrated by users who are willing to go to considerable expense to avoid it, such as through cleanup of beaches or extra travel to recreate in areas with less debris. Property owners in coastal areas may also suffer reductions in the value of their property if debris renders it less desirable from an aesthetic or recreational standpoint.

- Long-term impact. There could be other, as yet unknown, long-term impacts of marine debris on the health of humans and the biota which now, or may at some time in the future, impose unexpected costs on society.

The State of Economic Knowledge on Marine Debris

To date there have been only a handful of economic studies directed at the problem of marine debris. The present state of knowledge is reminiscent of what was known about the economics of oil spills and their prevention

some 20 years ago. A small number of studies have been conducted by state or local governments on the out-of-pocket costs but not necessarily the full opportunity costs of cleaning up small sections of beaches. There has been one detailed study on the effects of debris on individuals' willingness to pay for tourist accommodations in a small area of coastal Massachusetts several years ago (Wilman 1984). It revealed that overnight tourists did place a premium on reduced quantities of beach debris. However, the study ironically did not set out to measure the benefits of debris reduction, but rather the economic costs of oil spills on Cape Cod beaches. Since there were no actual oil spills there to study, the author used debris as a surrogate for the effect of oil on the value of beach recreation. There has also been one study on the costs of recycling shipboard plastic waste in the Port of Newport, Oregon (Recht 1988). It provides some useful information and anecdotes of what such a program entails from both a management and a cost standpoint. And finally, there has been one paper written on the types of economic incentives that might be applied to the problem of debris and what general types would likely be effective (Sutinen 1988). At present there are economic studies under way on some aspects of the debris problem that plagued the New England and mid-Atlantic coasts of the United States during the summers of 1987 and 1988.

In addition to the modest amount of economic research directed at the debris problem, there is some important complementary research being conducted on the value of various types of beach use, intrinsic values of natural resources, the costs and benefits of waste recycling programs, and the costs and marketability of degradable plastics. Results of such governmental and academic research programs can be found in the natural resource and environmental economics literature.

RESEARCH AGENDA

A review of the literature reveals that there is little known about the magnitude of the marine debris problem or of its social costs (or conversely, the benefits of a reduction in the quantity of debris). Justification of public programs to mitigate or eliminate these costs will require such estimates. But knowledge of these costs is only a first step. Laws and regulations require changing people's behavior to bring them into compliance. Market-based incentives will likely be the most cost-effective means of achieving compliance. Research is therefore needed on the relative effectiveness of various market based incentive programs in achieving compliance with various laws and regulations. Below is a list of suggested research projects that partially address both the issue of identifying the magnitude of the social costs of marine debris and various market-based incentive programs.

Social Costs

Aesthetics

Debris makes beaches and other recreational areas less attractive. Shorefront properties are also made less attractive, but whereas the loss in value of shorefront properties may show up in market transactions, the recreational values are nonmarket. Two studies are recommended to help understand the magnitude of this type of economic loss.

1. A study of the economic costs of debris on a specific set of beaches. This study would pick a set of beaches and investigate the economic value of lost services that would result from different levels of debris on the beach. The beaches chosen would ideally have wide regional representation. The study should be designed so that the methodology and the loss estimates could be expanded to other regions of the country.

2. A study of property value losses due to marine debris. Property value studies have been used by economists in estimating the economic damages from various environmental pollution problems. These techniques could easily be extended to the marine debris problem. Several regional studies should be conducted to show the effects throughout the nation.

Intrinsic Value

Debris traps and entangles fish and wildlife. Fish and wildlife also ingest various types of debris resulting in morbidity and mortality. This type of physical injury to the environment results in economic damage to individuals that value the right of fish and wildlife to exist or remain unharmed in pristine environments.

A study could be made of the economic cost incurred when individuals of some subpopulation of a noncommercial species (e.g., birds, mammals) become entangled in or ingest marine debris. This study could involve the threat of extinction or only the loss in social value when a small number of a species are lost or harmed. The study should be based on a national survey since many individuals outside coastal areas will experience this type of loss.

Fouling of Vessels and Fishing Gear

When vessels and their gear are impaired by contact with marine debris, there are two kinds of costs: a) the repair and replacement cost for the damaged gear and b) the opportunity cost of the vessel and gear when it is not in productive service. Commercial fishing or shipping impacts entail market losses, but for recreational boating, market and nonmarket losses must be considered. Two projects could be undertaken to quantify the incidence of impairment and the magnitude of costs.

1. Investigate the incidence of impairment for each of the following industry groups: commercial fishing, shipping, and recreational boating. Research should attempt to quantify the extent of the problem nationally and identify regions of critical concern.

2. Estimate the magnitude of costs for each of the three industry groups above. These could be small surveys among owners or operators in each of the industry groups. Areas

identified as representing the most severe problems should be used for each industry group.

Commercial and Recreational Fisheries

The greatest impact of marine debris on fish stocks is, apparently, the ghost fishing phenomenon. A secondary, but potentially large, impact is the possibility that consumer perception of contamination of fish stocks by marine debris can influence the demand and price of related fish products. This impact could extend to recreational fisheries because one of the main components of value in the recreational fishery is the consumption of fish.

1. Ghost fishing. Ghost fishing has an economic cost in terms of the wasted resource. For commercial fisheries it is the market value of the lost product, whereas for recreational fisheries it is the lost value due to lower catch rates. This project should involve both biologists and economists. Current economic research on the impact of catch rates on recreational fishing demand and value could be utilized in assessing the cost of ghost fishing.

2. The impact of perceived contamination on the price of and demand for fish. A project which collects and describes incidents of market effects (i.e., commercial fisheries only) from perceived contamination would provide at least some evidence of the economic costs of marine debris. A survey of the economics literature and of knowledgeable people to gather these incidents in the form of a research report should be conducted. Additional studies could follow, if warranted.

Compliance and Incentives

The greatest challenge in resolving the marine debris problem will be in finding and implementing the right mix of market-based incentives and enforcement to bring about compliance with various laws and regulations on the disposal of debris. The following projects would investigate the use of fees and incentives as part of the marine debris solution.

1. Deposits on the return of nondegradable products. The efficiency of deposits on beverage containers as a means of controlling land debris is well documented. This research project would investigate the potential for deposits for the return of plastic marine debris. It should focus on coastal states which have experience with deposit systems.

2. Fees on the use of nondegradable materials. Business firms and households are good at allocating scarce resources which they must pay for. Fees on plastic would be an incentive to substitute other materials. However, business firms must be treated differently from the household sector because

foreign firms could simply displace domestic firms. Foreign made products using a host of nondegradable but cheaper materials could replace domestically produced goods made of more expensive degradable materials. This project would investigate the feasibility of fees on potential debris in the marine environment.

3. Investigation of the economic gains that can accrue to a particular region as a consequence of consolidating waste handling facilities. New U.S. laws require that vessels bring their nondegradable waste to port. Ports are required to handle the solid waste. Within particular regions, it may be very costly for ports to handle all of the vessel-borne waste. An economic study of the costs of onshore waste handling would prepare ports for the resource demands and for setting port fees. When the costs differ among ports, there may be incentives to use different ports. Further, there are incentives to dump trash if fees are based on the amount of trash that is brought ashore.

4. Investigation of alternatives to traditional methods of compliance. Policies combining punishment and reward which partly subsidize the adoption of compliance techniques and impose clear penalties for the absence of compliance are used elsewhere in government regulation. This research program, would study compliance programs which include education, incentives, and penalties for a specific portion of the industry.

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