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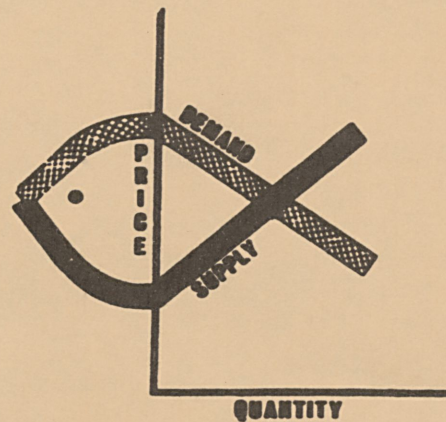
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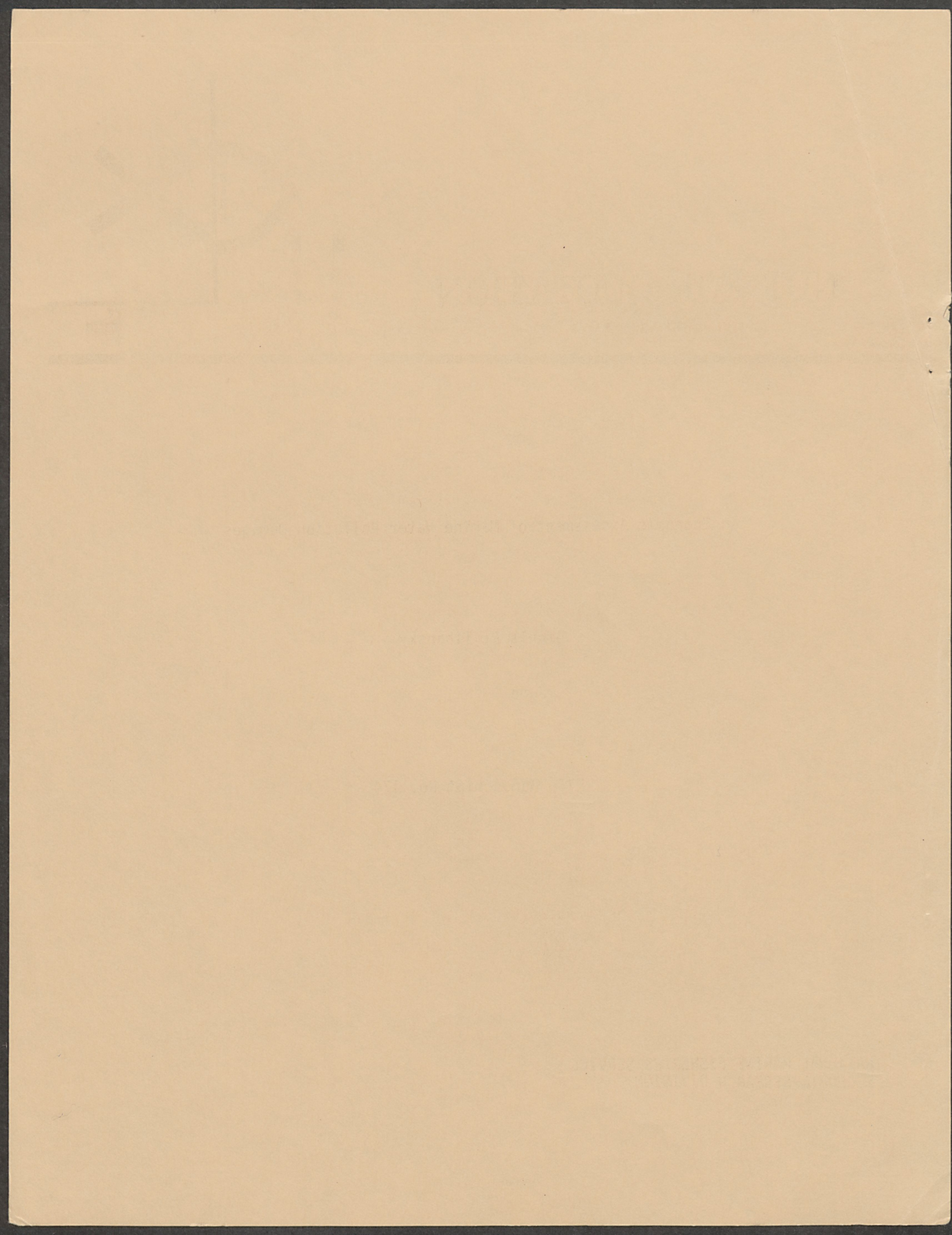
An Economic Assessment of Marine Water Pollution Damages

by

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AN ECONOMIC ASSESSMENT OF MARINE WATER POLLUTION DAMAGES

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## AN ECONOMIC ASSESSMENT OF MARINE WATER POLLUTION DAMAGES

### ABSTRACT

For centuries man has used coastal waters and the seas as a receptacle for wastes. Although the oceans have an enormous capacity to assimilate wastes, this limit is now being exceeded, or at least threatened, in many parts of the world. The resulting damages affect not only ecological stability and survivability of aquatic life, but also human uses and enjoyment of marine water. This paper identifies beneficial water uses impaired by marine pollution and evaluates them in an economic framework.

Economic damages from current levels of pollution are estimated along shorelines of the United States. Ranges of damage values are assumed to reflect uncertainty and incompleteness of the data base. Water uses that are assessed include commercial fishing, recreation (boating, sports fishing, swimming, and beach picnicking), and navigation. At the international level, the severity of marine pollution is evaluated in a qualitative sense. Documented damages to recreational beaches and commercial fisheries are cited, and specific marine pollution problems are recognized for various countries. To date, economic analyses of international pollution control strategies have received minimal attention, although legal policies on cooperation are evolving.

## AN ECONOMIC ASSESSMENT OF MARINE WATER POLLUTION DAMAGES

"Technology [of the seas and oceans] has advanced without due attention to pollution, its economic aspects in particular. Calculations of profit and loss--including all costs--have never been made. Very often only the immediate profits of a technical achievement are considered while the costs of accompanying damage are neglected" (Swedish Royal Commission, 1967).

### INTRODUCTION

There is a general consensus among nations that water pollution reduces or impairs beneficial uses of the environment. The once-popular notion that rivers can be used indiscriminately as waste receptacles is waning. But for ocean pollution, such changes of opinion are taking longer to evolve. The oceans cover over 70 percent of the earth and contain 140 million square miles of water surface. With such an enormous assimilative capacity, they are often considered vast enough to accept limitless quantities of waste discharges.

According to a United Nations scientist, "...in spite of years of lip service to the idea of conserving natural resources and halting the deterioration of the environment, prevention of pollution, particularly marine pollution, has advanced very little" (Loftis, 1972, p. 35). Lack of concern denies the importance of the oceans as key elements in affecting the global environment and providing the base for the earth's hydrologic system. Marine waters are being contaminated daily by the dumping of sewage, oil and hazardous materials spills, detergents, radioactive wastes, pesticides, and toxic metals. In many cases, the capacity of the marine environment is exceeded by the intrusion of these wastes. This is particularly evident along estuarine areas and the inshore edge of the continental shelf, which are more vulnerable to pollution than other marine areas.

Ocean resources are economically valuable to all nations, providing both necessities, such as food and minerals, and luxuries, such as recreation and other amenities. The coastlines of the United States, for example, provide transportation and recreation services for 60 percent of the national population. The potential productivity of the oceans, by aquaculture or other means of cultivation, is enormous. In total tonnage, marine plants are roughly six times as abundant as their terrestrial counterparts, but only a small portion of this productivity is currently utilized by man (Firth, 1969, p. 222).

The total economic value of marine activities cannot be estimated precisely, since some ocean activities, such as sightseeing and aesthetic

appreciation, lack simple quantification. The impact that water pollution has on this value is even harder to quantify. First, it is difficult to segregate effects of water pollution from other damaging effects, such as climatological changes in the case of fish kills. Second, the competitive market does not correctly evaluate externalities, which are unit economic damages levied not on the original polluter but on another party. A common example is the destruction of commercial fisheries by coastal waste emissions. Although the waste emitter is legally responsible for damages incurred by reduced fish yield, the market system does not adjust his costs accordingly. Third, certain damages to water use are difficult to evaluate in economic terms. The loss of sports fishing areas poses such a problem. To the sports fisherman, damages are dependent not only on his angling failure but also on his dissatisfaction with the marine surroundings. Willingness-to-pay for improved water quality should reflect this value, but personal interviews and other methods of extracting such information have yet to be developed to provide credible or unbiased results.

Fourth, there is the problem of estimating net benefits rather than gross benefits. If maximization of social welfare is the goal of water quality management, then the benefits that result must be weighed against the costs. In the case of recreation, the benefit is not simply the economic impact of increasing water-based activities. Subtracted from this impact must be the economic value of substitute activities which would have occurred had water quality not improved. Fifth, and perhaps most important, there is a paucity of data on marine activities as affected by pollution. In the United States, fragmentary information exists on economic impacts in major estuaries, but not along coasts which account for approximately 90 percent of all marine recreation expenditures (Whitman, 1966, p. A-33). Moreover, few studies exist on the biological effects of pollutants in marine areas. Most predictive models are based on bioassays and experiments in simulated marine environments and artificial laboratory designs, which may not adequately reflect marine conditions.

Despite these limitations, attempts can be, and have been, made to estimate economic losses from polluted water. This paper reviews some of these attempts, but, more importantly, provides an original and more comprehensive analysis of benefit potentials. Economic revenues from international as well as American marine activities are briefly summarized, after which major pollutants are identified as they impact beneficial water uses. Marine pollution damages are calculated for coastal areas along the United States in base year 1970. Economic activities considered include commercial fishing, recreation (swimming, fishing, and boating), and navigation (collisions with floating solids). Ranges of damage values are calculated to reflect incompleteness and uncertainties of the data base. The methodologies used in these calculations are outlined and assessed in terms of their ability to measure social welfare. Other commonly used methods are also identified, and reasons are given for rejecting them. The final section of the paper reviews world-wide levels of marine pollution and identifies, in a qualitative sense, those countries whose economic damages are likely to be the most significant.

## MARKET VALUE OF OCEAN RESOURCES

Products and services dependent on marine waters are of notable economic value. In 1970, the world nominal catch from all commercial fisheries totalled 69.6 million metric tons, with about half of this total from Asian countries and the Soviet Union. The landing value of all catches was almost \$8.2 billion, of which slightly more than 50 percent was caught along coastal shores (Food and Agriculture Organization, 1972, pp. 12, 15, 22). Ocean freight shipment costs were practically double fishery revenues. On the other hand, the recovery of minerals has a relatively small value. World oil and gas production from the ocean floor is worth only half that of commercial fishing, while extraction of the remaining minerals adds only \$0.25 billion (Holt, 1966).

The recreational value of oceans is not well documented, except to a limited extent for the United States. These estimates reveal that in 1964 all leisure activities along continental-shelf regions entailed expenditures of \$3.9 billion (Battelle Memorial Institute, 1966, p. x). Swimming was by far the most popular activity at \$1.5 billion, followed by sports fishing, \$0.8 billion, and pleasure boating, \$0.7 billion. With the demand for outdoor recreation increasing at an average of 10 percent per year (Outdoor Recreation Resources Review Commission, 1962, p. 1), which, incidentally, is six times greater than population growth, the 1970 equivalent of total expenditures could easily exceed \$6 billion. Table I delineates total income (in 1964 dollars) into major shoreline activities. The dominant position of the transportation sector is self-evident. The category, health and welfare, includes water quality control, desalination, and related costs. By 1970, commercial fish landings were valued at \$613 million, an increase of almost 60 percent, inflated to 1970 dollars (National Marine Fisheries Service, 1972, p. 20). Furthermore, salt water fishermen spent \$1.2 billion in 1970 or, equivalently, \$129 per person (Bureau of Sports Fisheries and Wildlife, 1973, p. 10). More expenses are incurred on the Atlantic seaboard than on the Gulf and Pacific coasts combined.

## BENEFITS OF POLLUTION CONTROL

It is virtually impossible to evaluate the total economic aspects of marine resources. The coastal seas, estuaries, and bays provide an abundant food supply, which is only partially assessed in the commercial market. Private catches and sports fishing are another source of food value. The use of these waters for swimming, skin diving, boating, surfing, sports fishing, or simply enjoying the beauty of the marine environment is increasing at a rapid rate, not only for persons living close to the shore but for vacationists as well. Each of these activities has an economic value, whether it is measurable directly in the market place or imputed from social preferences and utility of the user.

Many believe it is in their economic interest to dispose of wastes in marine waters without costly treatment. The total damages and health hazards implicated by seawater pollution are calculated to a very limited extent,



Economic Sector	Expenditure (\$ million)
Defense and Space	\$ 1,319
Fishing and Aquaculture	345
Health and Welfare	372
Marine Engineering	2,320
Mining and Petroleum	1,704
Recreation	3,855
Research and Development	232
Transportation (1963)	11,280
Total	\$21,427

TABLE I. ECONOMIC ACTIVITIES IN COASTAL AREAS OF THE UNITED STATES, 1964

not because few damages exist, but rather because they are difficult to assess. Although economic evaluations are admittedly complex, they should be recognized and conducted in a more comprehensive manner to ensure more accurate comparisons of pollution control cost and benefit tradeoffs.

Marine pollution may be generally defined as any residual of human production or consumption, having a detrimental effect on the marine environment. Any beneficial use of the marine resources which is impaired or prevented by pollution constitutes a damage. Waste disposal is common practice in marine areas, but it becomes a detriment when the assimilative capacity of the receiving water is exceeded. Other water uses must be considered in evaluating the effects of pollution. Some of these include the following (McKee, 1967, p. 261):

- swimming, surf bathing, and skin diving;
- beach picnicking and aesthetic enjoyment;
- boating and navigation;
- water skiing and other marine sports;
- propagation of fish, shellfish, and other animals;
- propagation of kelp and other aquatic plants;
- commercial and sports fishing;
- industrial water supply;
- municipal water supply (after demineralization).

The economic value of these uses differs by geographic locality, by season, and by the level of satisfaction of the user. In some cases, these uses conflict, i.e., swimming and fishing in the same area. Property values are lowered by polluted water, but their values probably incorporate the impacts of the above water uses.

Major categories of pollutants can be identified as they affect marine water use. Bacteria, virus, and other biological organisms are one category linked to certain illnesses, such as dysentery, typhoid fever, and cholera. Decomposable organic matter absorbs oxygen in coastal waters, thus killing fish and other aquatic life, producing offensive smells and causing general unsightliness. If excessive, this type of pollutant will reduce recreational enjoyment of the shoreline. Inorganic salts and minerals, which are not ordinarily removed by conventional treatment, can make ocean water unsuitable for drinking, irrigation, and for water intake by industries. Because of restrictive costs of desalting water, inland water supply sources are tapped. As economic activity and population increase along the coasts, however, excessive water demands could make oceanic supplies more favorable.

Plant nutrients, i.e., phosphates and nitrates, can promote thick algal blooms and weed growths, thus blocking sunlight into the water and deterring bottom growths. They can also be hazards to shipping activities. Oily substances may be deleterious to fish life, reduce recreational activity along oily beaches, and reduce reoxygenation in the marine environment by screening the ocean surface from the air. Floating debris is another type of pollutant that obstructs navigation, poses a health and safety hazard, and makes the shoreline unattractive. Toxic agents and poisons, ranging from metallic

salts to synthetic chemicals and pesticides, are lethal to aquatic life. If they are ingested and stored in commercial fish products, e.g., mercury in shellfish, their consumption by humans may lead to serious illness or even fatalities.

Other categories of pollutants include thermal discharges and radioactive particles. Although these categories have not yet caused serious damage to the marine environment, they are potentially large threats in view of future prospects of siting many nuclear power plants along the coasts, especially in the United States. Silting and erosion are frequently occurring in such large quantities that they are destroying recreational beaches and estuarine ecosystems. All of these pollutants can affect beneficial uses of water adversely or even catastrophically.

Table II shows the relative impact of the primary marine pollutants on beneficial water uses. This diagram is adapted from water quality standards and matrix representations of the compatibility existing between various estuarine-dependent activities (Rogerson, 1970; National Council on Marine Resources and Engineering Development, 1969). The most important effects are associated with commercial fishing, recreation, and residential housing developments. The economic magnitude of each impact depends on the strength and composition of marine pollutants in the water, their distance from the shore or water use regions, the intensity of water use, and the value (actual or imputed) of goods or services realized in the marine environment.

#### ESTIMATES FOR THE UNITED STATES

Regional damages from marine pollutants can be evaluated, to some extent, in an economic framework. The extent of analysis depends on the availability of data on such factors as water quality, the intensity and variety of water uses and their economic value, and the degree of curtailment of water uses by pollution. Such information is lacking in sufficient detail to permit a comprehensive damage assessment for most countries of the world.

In the United States, however, there have been several surveys of coastal activities related to water quality. Because of the extensiveness of the shorelines covered, such information is piecemeal and is usually based on subjective frequency counts. Nevertheless, extrapolations of sample surveys can provide at least a crude approximation, or an order of magnitude estimate, of the economic benefits of waste control in U.S. coastal waters. The analysis in this study focuses on three water uses--commercial fishing, recreation (both water-based and water-enhanced), and navigation. Although these activities comprise a partial assessment of total value, they are basic criteria for the implementation of water quality standards.

Marine water quality has deteriorated extensively off U.S. shores as a result of municipal, industrial, agricultural, and other waste discharges. Detailed water quality data are available for several estuaries with severe problems, but limited or no data exist for other coastal areas. Figure 1 depicts the severity of pollution effects to marine ecosystems (Federal Water Pollution Control Administration, 1969a, pp. IV-403 to IV-413). As

WATER USE	OVERALL POLLUTION DAMAGE LEVEL	Biochemical Oxygen Demand	Coliform Bacteria	Floating Debris	Nutrients Excess	Oil Pollution	Toxic Matter	Turbidity and Siltling
Commercial Fishing	High	X	X	X	X	X	X	X
Mining Industries Petroleum Bottom Mining	Very Low Low							X X
Navigation Harbors Channels Ocean	Medium Low Very Low			X X X		X X		X X
Property Development Housing Commercial Industrial	High Medium Low	X X		X X X	X X	X X		X X
Recreation Boating Sightseeing Sport Fishing Swimming	High High High High	X X X X	X X	X X X X	X X X X	X X X X	X X	X X X X
Water Supply Municipal Industrial	Low Very Low	X	X	X X	X X	X	X	X
Waste Disposal Sewage	Very Low							

TABLE II. RELATIVE EFFECTS OF MARINE POLLUTANTS ON COASTAL ACTIVITIES.

a national average, 38 percent of all estuarine habitat has remained unchanged. This is actually an upper bound estimate since many of these estuaries have not been studied thoroughly. The middle Atlantic region has the highest proportion of damaged ecosystems, although the Chesapeake Bay, the Gulf states, and the California coast have more severe problems. In California, however, there are relatively few estuaries, so that other coastal sections predominate. While these water quality impacts are related to ecological instability, they also relate to human water uses. Commercial fishing, for example, is likely to be more successful in a healthy ecosystem than one whose aquatic life is imperiled.

#### ESTIMATING COMMERCIAL FISHING DAMAGES

The first economic damage to be estimated is the response of commercial fisheries to water quality control. Economic analysis of fisheries is limited despite the fact that such analyses are needed to direct policies for protection of rich fishery resources along U.S. coasts. Several outstanding models can be cited (Crutchfield and Zellner, 1962; Smith, 1968; Turvey, 1964), but these studies address problems of access into the fishery market rather than pollution problems per se. Unless damages to polluted fisheries are evaluated in terms of social welfare, other competing demands for marine waters may take priority even if they are less valuable.

The valuation of commercial fishing benefits is usually based on total gains in revenue. It is argued in the case of shellfishing that pollution causes closures of fishing areas, and if water quality improves, these areas would again open as additional revenue sources. The usual assumption is that a specific increase of open fishing areas provides the same percentage rise of income.

A fallacy with this logic is the underlying assumption of constant price. For illustration, Figure 2 portrays the relation between consumer demand for clams and the average landing price. According to actual calculations for the U.S. market (Bell, 1970, p. 139), the price elasticity is  $-.6$ , which accounts for the steepness of this curve. Given the fact that total revenue equals the product of price times quantity, any increase in quantity along the demand curve will lower the price proportionately more. Hence, overall revenue will drop, not rise.

Another approach defines benefits as the net value of fish preserved. While gross revenues are used to estimate the value of the fishing sector to a regional economy, they are not directly comparable with other projects whose impacts are measured in net terms. Net benefits are estimated as the difference between gross revenues and costs. As a general rule, the Federal Power Commission assumes that costs can be taken as 80% of the marketed value of the catch (Federal Power Commission, 1957, p. 9). Another agency excludes marketing costs and uses a 62% factor (Canadian Department of Fisheries, 1955). Still another study goes one step further and estimates net benefits to state income as a fixed percentage adjustment, called a net multiplier, of the wholesale value of the catch. While net

revenue is a better measure of welfare gains than gross estimates, it does not consider willingness-to-pay and social preferences by the consumers.

A more simplistic approach than the above is to count the number of fish killed or foregone because of poor water quality and to attach a fixed economic value to each fish. Unit values differ according to the type and size of fish. This evaluation is commonly practiced in estimating losses from fish kills. Such values are necessary, according to the fish conservation groups, to protect certain species from being pursued or captured by anglers. According to the American Fisheries Society, "The purpose of a monetary value list for fish is for a fair and reasonable assessment of a fish's value for collecting compensation for the destruction and/or loss of fish due to water pollution" (Spencer, 1970). The merit of this approach is that it recognizes the economic implication of ecological instabilities resulting from fish losses. However, the value is often based on the cost of restocking the water with fish specimens rather than welfare gains to the consumer. The ultimate purpose of fishery management is "intended for the benefit of man, not fish" (Burkenroad, 1953).

A better method of measuring social benefits relates to the demand curve (refer again to Figure 2). The intersection of the demand and supply curves determines the equilibrium price and quantity. Each point on the demand curve should reflect what individuals are willing to pay for the associated level of fish consumption. Obviously, some consumers are willing to pay more than the market price (to the left of the equilibrium point). These customers are thus benefiting from lower prices, and this difference represents a "consumer's surplus". The exception, of course, is the marginal user (at the equilibrium point) who actually pays what he considers as the maximal price. The downward slope of the demand curve expresses this phenomenon. Total welfare for all consumers is measured as the area bounded above by the demand curve and below by the horizontal price line. If fish prices should fall, then an extra portion of consumers' surplus would be added. The gap between the equilibrium price and the actual worth widens for non-marginal consumers. This additional region denotes the net benefit to be derived. In the case of commercial fisheries, as water quality improves, more supply areas become available for fishing. Consequently, fishing effort declines and perhaps travel costs also decrease for the same amount of catch. The resultant fall in the supply curve implies more consumers' surplus and, equivalently, the realization of net benefits.

The consumers' surplus technique is used in this study to estimate net benefits of pollution control to marine fisheries. A range of estimates is obtained, depending on the extent to which fisheries are affected and the sensitivity of marine fish species to pollution levels. To obtain a lower bound estimate, it is assumed that only certain shellfish, namely clams and oysters, are affected. Furthermore, the affected catch is within three miles of the shoreline, since most waste discharges are evident close to land.\*

\* It should be noted, however, that evidence also exists for major pollution problems in marine waters distant from seashores. A recent survey by the National Oceanic and Atmospheric Administration revealed that oil

U.S. consumer demand functions have been estimated for the primary marine fish products (National Marine Fisheries Service, 1972). These functions estimate demand fluctuations in terms of the real price change per unit product. Given price elasticities for the United States, current average price, and quantity of fish consumed, an aggregate demand curve can be derived. Figure 2 indicates such a derivation for clam sales. Average landing (exvessel) prices paid directly to fishermen are quoted in marine fisheries yearbooks (National Marine Fisheries Service, 1972, p. 66). The final consumer demand curve should be based on retail price, which is roughly three times the landing value per unit of catch (Bell, 1970). But the actual retail price varies considerably, depending on the degree of fish processing, the distance that the fish product is transported, the number of intermediate wholesalers and retailers, and a host of other factors. Because of these complexities, landing price is assumed in the demand analysis, which should lead to a conservative estimate of consumer benefits.

Supply has been analyzed less extensively than demand for commercial fish. Generally, supply curves analogous to that in Figure 2 are assumed. As the quantity of fish increases, it becomes successively more expensive to catch the last (marginal) fish. Moreover, if too many fish are caught, the reproductive capacity of the remaining marine population is reduced, thereby introducing the concept of maximum sustainable yield. The backward curvature in the hypothetical supply curve accounts for over-fishing and consequent drops in yield.

The quantity at which maximum sustainable yield occurs, however, is subject to widespread debate. Even its existence at current trends of fish exploitation is occasionally refuted. The potential of marine fisheries has been grossly underestimated by fisheries experts. For example, the United Nations Food and Agriculture Organization concluded that world fish production could double from 1953 to 1960 without damaging the potential yield, but this growth was exceeded by 1956 (Food and Agriculture Organization, 1951). Rather than derive an actual supply curve from limited and uncertain information, a hypothetical relation is assumed.

As water quality improves, the equilibrium point should shift as marginal costs of fishing change. In the case of shellfish supply, cleaner marine waters imply the opening of a number of previously closed fishing areas. It is assumed\*\* that a certain percentage increase in open areas yields the same.

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(Cont.) globules and plastic debris in massive proportions extend over 700,000 square miles of ocean surface from Cape Cod to the Caribbean Sea (White, 1973, p.1).

\*\* The actual shift in supply depends on the marginal cost of producing, i.e., catching, fish. As more shellfishing areas open, for example, travel costs incurred in finding the fish should decline, along with reduced costs of removing oil slicks and other wastes from fishing equipment or repairing ships that collide with floating debris. These factors would contribute to a downward shift of supply, but whether they are important enough to shift the curve as assumed remains to be proven.

relative increase in availability of consumer products. The resulting shift of supply moves the equilibrium of supply and demand to a lower price. The increase in consumer surplus thus gives an estimate of social welfare gains.

Shellfish area closure data in Figure 3 portray increases in expected catch if marine water pollutants are abated. Since most clams and oysters are caught along the Atlantic and Gulf shores, pollution control in these waters would affect benefits most significantly. Figure 2 shows the increased catch of clams from pollution control. It is estimated that total supply in 1970 rises from 38.8 to 48.9 million pounds. With an overall price elasticity of  $-.60$ , unit price falls from \$0.58 to \$.39 per pound. Net benefits are then approximated as \$8.1 million. For oyster supply, similar calculations give \$15.4 million. Net benefits are larger for oysters since their total landing value is 38% higher than that of clams at current market conditions and a larger share of their total catch is attributed to the Gulf coast, which has a larger fraction of closures than Atlantic coast shellfish regions. The sum of net benefits for these two classes of shellfish is \$70.9 million.

An upper bound estimate of benefits results from the inclusion of more commercial fish species. In addition to clams and oysters, finfish caught near the shoreline are highly susceptible to contamination from oil spills, toxic metals, sewage, and other waste discharges. Adding consumers' surplus for this product to above calculations gives total benefits of \$37.5 million. Other marine fish, such as kingfish, tuna, and salmon, are also harmed by pollution, but the total extent of these damages is currently too difficult to ascertain.

These estimates must be interpreted with caution. They are derived from demand curves valid near the equilibrium point but not necessarily over the entire range of the price variable. As price approaches zero, for instance, the quantity demanded probably does not increase as rapidly as each curve implies. Rather, there may be a "saturation level", beyond which the consumer does not gain satisfaction, no matter how low the price is set.

#### DOCUMENTED LOSSES OF COMMERCIAL FISHERIES

Published estimates of commercial fishery losses from pollution focus on localized problems, although there are at least two national estimates. Most damage estimates pertain to lost landing revenue to fishermen rather than retail or market value. Figure 4 depicts the dollar value and geographic area of these foregone catches. Fish kills (Boughey, 1971, p. 357; Anonymous, 1971a; Anonymous, 1970, p.4-A) are evaluated by assuming that each counted fish is worth \$0.10, which is generally a very conservative value for mature commercial fish (Spencer, 1970, pp. 6-20). Retail losses in Puget Sound are converted into landing price equivalents by assuming a 3:1 ratio of their relative magnitudes. Catches of kingfish, swordfish, and tuna in the Pacific Ocean decreased substantially because of government rules limiting the mercury content of fish (McMillin, 1973; Weddig, 1973). It appears, however, that most of this mercury may be natural in origin rather than man-made. The "Red Tide" scare in New England not only reduced lobster and fish sales by several million dollars but also caused unemployment of fishermen, who would



have earned \$91,000 in 1972 (Anonymous, 1972). Other estimates on the map illustrate the wide range of effects of waste discharges on a number of marine species, ranging from clams to salmon (Howard, 1973; Anonymous, 1971b; Council on Environmental Quality, 1970, p. 17; Federal Water Pollution Control Administration, 1969a, pp. 174-299, 475-480; Smith, 1973; Wallace, 1973). Another estimate not included on the map was the loss of oysters from shellfish area closures in New Haven Harbor, Connecticut (Federal Water Quality Administration, 1970, Table 17). The foregone value of small, seed oysters amounted to \$578,000 in 1967, but upon maturity they would yield a large potential revenue of \$6,688,000. Annual revenue losses provide only an incomplete perspective of total damages. Over the past 65 years, environmental changes along the Connecticut coast have caused declines in shellfish production totalling more than \$1 billion (Federal Water Quality Administration, 1970, Table 17). Furthermore, the initial effects on lost fishermen's wages are multiplied throughout the economy by factors typically between five and ten.

National loss estimates are based on the proportion of shellfishing areas closed from pollution. The National Marine Fisheries Service estimates total losses of \$12 million (Bale, 1971, p.9). This assumes that only clams and oysters are affected since they are immobile and harvested primarily within bays and estuaries. The Council on Environmental Quality, (Council on Environmental Quality, 1970, p. 17), on the other hand, assumes that all shellfish, including lobsters, shrimp, and crabs, are affected by contamination. Its estimate is \$63 million based on closure of one-fifth of the nation's shellfish beds and a corresponding loss of potential revenue.

#### ESTIMATING RECREATION DAMAGES

Several methods are used to assess the economic importance of recreation. These include the expenditure method, cost accounting, the GNP contribution approach, property value assessment, private market price surrogates, and willingness-to-pay. Historically, the most common method of measuring benefits is by expenditure or cost accounting. Either total expenditures by the recreationist or the costs of providing the facilities are assumed. In the case of net benefits, the two income streams are subtracted from each other. The rationale behind these methods is that expenditures denote what the tourist is willing to pay, while costs are not incurred unless they represent a lower bound of potential benefits.

There are several fallacies with this logic. The expenditure method does not adequately measure "the intangible values to the persons enjoying recreation. In the first place, many so-called recreational expenditures are normal expenditures made under slightly different circumstances. ...and, in the second place, even those expenditures which are over and above normal living costs are not necessarily measures of the recreational enjoyment but are the price paid for certain goods and services for which there are established market values" (Trice, Wood, 1967). The cost method lacks validity since its use implies, by circular reasoning, that any water quality program is thus justified (Brown, et al, 1964). Indeed, actual benefits could be far less than associated costs.

The gross national product approach estimates the contribution of recreation to GNP. The impact of the recreation industry's revenues on other sectors in the economy (resulting from increased employment in tourism) is identified as secondary benefits. Unfortunately, GNP measures investment costs rather than the value of public goods, thereby neglecting social benefits.

The property value approach attempts to relate recreational development to increases in land value. A major difficulty is separating out the effects of recreation from other project benefits and social amenities. Some economists argue that in most cases, "not all of the recreational benefits will be capitalized into land values and therefore will not be measured in land value increases" (Knetsch, 1964, p.1).

There is also the method of applying market prices for private recreation activities to all forms of recreation. This assumption does not recognize the inherent distinction between private and public facilities. The former has the advantage of exclusion while the latter is generally less expensive and therefore tends to lower the market price of substitute activities.

Most economists favor the willingness-to-pay approach, which is also recommended here. Conceptually, the recreationist is willing to pay a certain amount for the enjoyment of recreational facilities. This amount may be different from what he actually spends. Personal interviews are often conducted to extract such information, but answers from the respondent may be biased. The response might give a lower-than-actual value if he felt that his true response would increase the market price. On the other hand, he might be on the high side if he wanted to "impress" the interviewer.

The demand curve should depict what the recreationist is willing to pay for various quantities, i.e., user days, of recreation. As the price of each unit of recreation decreases, the usual downward sloping demand curve is assumed, implying that at the equilibrium price, some consumers are paying less than what they consider leisure time to be worth. Similar to the case of commercial fishing benefits, these consumers are realizing a net gain. Consumer surplus is again a meaningful measure of the net benefits.

To formulate demand curves in a real situation is complicated. Obvious problems of bias in willingness-to-pay estimates reduce the credibility of final results. One way of avoiding this problem is to estimate travel costs only, wherein demand is a function of distance travelled (a proxy for the price variable). The closer one lives to the recreational area, the less he pays. By drawing concentric circles and estimating the number of participants travelling from each zone, a demand curve is generated. Of course, travel cost is not the only expense involved, but it is more easily estimated than others and is therefore popular in actual studies.

Recreational benefits from marine pollution control are difficult to estimate because of the scarcity of data. However, fragmentary information can be used to obtain a crude approximation. For the United States, there is one fairly comprehensive survey of coastal beaches closed from pollution (Brown, Moser, and Shenton, 1972). This study focused on recreational activities and ameni-

ties in Chesapeake Bay and the California shores and involved a survey of government officials in all states. In spite of more than 200 closures from 3,000 inventoried beaches, it was concluded that, "present beach closure enforcement procedures appear inadequate to protect public health" (Brown, Moser and Shenton, 1972). Sewage accounted for more than three-fifths of all reported miles of closed beach. Although many beaches closed temporarily for only a few days, roughly one-half remained inactive over the entire year.

As might be expected, many states have no formalized report system on beach closures. Their estimates on closures were thus based on subjective opinion. Some states failed to reply to the survey, so that the beach inventory is incomplete. Nevertheless, for purposes of this study, results of the inventory were compiled wherever possible on a state basis. Then they were aggregated by major coastline as depicted in Figure 5. Miles of beach closure are adjusted to reflect inactivity over a full season. That is, if a beach was closed for less than a season, only half of its length is assumed to be accessible to the public. (Despite posted warnings that beaches are unsafe or risky to health, some recreationists ignore closure rules).

Given the proportion of beaches closed in each coastal region, the next set of required data is total demand for marine water-related activities. In 1960, total participation days were inventoried by state for beaches maintained by municipalities and counties (Campbell, LeBlanc, and Mason, 1961). Statistics were collected for beaches, marinas, boat launching ramps, fishing piers, and parks. But the data were incomplete for several reasons. Some state officials did not compile such information. Others made intuitive estimates, which, when compared with similar data from adjacent states, differed by several orders of magnitude. Moreover, only public beaches were surveyed although their total length is less than 5 percent of that for private beaches. Yet the public areas are, for the most part, most easily accessible from large population centers as shown in Figure 5.

This survey of recreational shoreline use was updated to 1970 by trend analysis. First, for each recreational activity, total participation days per state were adjusted by population growth in that region. Second, the resulting estimates were adjusted by a national average increase in the portion of all residents sharing in that activity. Third, this portion is modified, in turn, by the growing number of days (or occasions) that each recreationist spends annually. Estimates are thus derived for current demand in each coastal region of the United States. Finally, to account for beaches other than those on county and municipal lands, each regional estimate is multiplied by a common ratio. This ratio equals total estimated 1970 demand for shoreline activities in the nation, divided by the sum of partial estimates calculated above. The total national estimate is available from a comprehensive economic report of marine activities (Battelle Memorial Institute, 1966, pp. III-73 to III-75). Since the total estimate is not disaggregated by region, above calculations are necessary to account for coastal variations in beach popularity. Shore fishing demand is the only original estimate unmodified by national totals. This seems reasonable since national figures pertain to saltwater fishing, which, unlike shore fishing, usually takes

place far enough from shore not to be affected by pollution.

After beach attendance figures are estimated, the next phase of the calculations is to estimate how water quality control impacts recreation demand. Participation days foregone by water pollution are assumed proportional to the percentage of beach closures in each coastal area. Applying this percentage to the above estimates of beach activity days gives a measure of the potential increase in demand. This shift in demand in response to a greater supply of beaches implies at least two positive changes in net benefits. New participants enter the recreation market, and some original consumers recreate more often and reduce travel costs since open beaches are more readily accessible.

With increased demand, more expenditures can be expected along beach resorts. Economic benefits of beach cleanup can now be approximated. The appropriate measure is consumer surplus, which should be derived from recreation demand functions. However, since beach demand models are not published in the literature, a surrogate measure of benefits is chosen. Per capita expenditures at typical beaches in 1970 can be derived from the above report (Estelle Memorial Institute, 1966, pp. III-73 to III-75). The average camper along the U.S. coast spends \$3.94 per activity occasion for such items as swimming apparel, beach entrance fees; travel, food, and lodging. Boating enthusiasts spend \$8.85; saltwater fishermen, \$9.26; and park attendees, \$3.51.

For earlier remarks, these expenses are not adequate measures of consumer surplus, although they reveal the magnitude of marginal willingness-to-pay. However, the Delaware Estuary study (Tomazinis and Gabbour, 1966, pp. 44-54) does provide a range of unit benefit values, which are smaller, but comparable in size, to these expenses. Based upon per capita solutions for the best water quality levels in the Delaware Estuary model, new swimmers benefit by \$0.75 - \$1.50 per activity day; boaters, \$1.20 - \$1.90; fishermen, \$1.20 - \$2.20; and park enthusiasts (picnickers), \$1.00 - \$1.50.

Using these unit values, net benefits from increased recreation demand in the U.S. are roughly \$12.7 - \$22.1 million. More than 55 percent of these benefits are realized on the Pacific coast, with most of the remaining benefits on the Atlantic seaboard. Few beach closures along the Gulf coast account for its small share of only 2 percent of total benefits. This share seems inconsistent with the fact that over 25 percent of Gulf coast areas are closed to shellfishing. But sanitary conditions for shellfishing waters are far more stringent than those for drinking water and recreation.

Additional benefits accrue from improved access to a larger number and variety of recreation sites. If each current participant saves \$.05 - \$.10 on travel for each day's outing, national benefits would increase by \$8.2 - \$16.4 million. Assuming that 20 percent of the populace changed spending patterns, total national benefits to the nation are thus in the range, \$20.9 - \$38.5 million for 1970.

These estimates are based on the crucial assumption that the percentage of beach closures is matched by the same decrease in potential demand. The actual decrease in attendance is likely to vary by geographic area. In congested urban areas like New York City, many dwellers do not own cars and thus are unlikely to travel far enough to reach clean beaches. On the other hand, residents along rural shores have greater access to distant shores and can more easily substitute one resort for another. On some Long Island beaches, pollution alerts decreased participation days by 50 percent (contrary to the recommended 100 percent). But clean neighboring beaches were also affected almost simultaneously by this adverse publicity, some losing 25 percent of normal attendees (Federal Water Pollution Control Administration, 1969a, pp. IV-480 to IV-483).

#### DOCUMENTED LOSSES OF RECREATION DEMAND

Published estimates of recreational losses due to marine pollution are limited to a few beaches, which are among the most heavily visited in the United States. Figure 6 depicts relative magnitudes of economic damages along these shores. Prior to abatement efforts in San Diego Bay in 1968, approximately \$6 million was foregone annually in tourist income (Federal Water Pollution Control Administration, 1969b, pp. 233-239). If wastes are not adequately controlled from the San Joaquin River Basin, they will soon harm shoreline value near San Francisco. By 1990, recreational losses may total from \$2 to \$10 million (Federal Water Pollution Control Administration, 1967, p. 33). Oil spills could potentially cause enormous losses to major beaches near Los Angeles, Santa Barbara, and Long Island (Department of Interior and Department of Transportation, 1968; George Washington University, 1970, pp. 13-6 to 13-7). Even more striking is a potential property value loss of \$250,000,000 along 50 square miles of developed shoreline bordering San Francisco Bay (Federal Water Pollution Control Administration, 1967, p. 79). These damages would result from heavy industrialization, agriculture, and population centers around the Bay.

In the Santa Barbara, California, economy, tourist expenditures are so important that their direct impacts are projected almost six-fold throughout the region. Along the Delaware Estuary, less than complete abatement of wastes could result in substantial revenue increases not only for boating and fishing but also for land-based activities, such as picnicking, that depend on aesthetically pleasing ocean views. In Connecticut, commercial game breeders attributed duck kills to oil pollution and had to incur replacement costs. Moreover, Staten Island public officials estimated parking fee losses at \$30,000 from closing beaches whose water contained excessive levels of coliform bacteria (Federal Water Pollution Control Administration, 1969a, p. IV-464). If each car contained four persons each spending \$1.00, total revenue losses along this beach would be more than \$250,000.

In at least one instance, recreational losses were much smaller than property value and aesthetics damages attributed to pollution. After the famous Santa Barbara oil spill in early 1969, almost 40 miles of mostly private beaches were contaminated. An estimated \$2.5 billion in damage suits were filed by private parties, compared to oil removal costs of less than \$5 million (George

Washington University, 1970, p. 15-13). A majority of these suits came from property owners and conservationists, many of whom impute extremely high values on natural beauty of the marine environment. Of course, market prices do not usually reflect this extreme, and thus most of the appeals were rejected in the courts.

#### ESTIMATES OF NAVIGATION DAMAGES

Of all ocean-related activities, transportation generates the highest revenue. Sedimentation and siltation are constant problems in many American harbors and rivers, posing navigation hazards and sometimes shutting down economically important shipping routes. Although this problem is indeed serious, it is not addressed here. Another pollution problem analyzed in this paper is that of damages caused by floating debris in major ports. Special clean-up operations are supervised by the U.S. Army Corps of Engineers, but most of these programs fall short of complete removal. Floating wastes vary from small logs to huge wooden and metal sections that deteriorate from piers and vessels, are separated during storms, or are discarded by human activities. To identify that portion of debris discarded by man is infeasible due to the lack of data.

Typical damages to boats colliding with debris are rarely mentioned in the literature. In New York Harbor, however, several damages are documented (Conner, 1970). Sweeping drifts damaged excursion boats at a cost of \$1,300 - \$5,600 for each incident. A small fleet of U.S. Coast Guard vessels reported almost \$50,000 for overhauling damaged propellers. These maintenance costs exclude the impacts of time delays from accidents and health costs from human injuries and even fatalities. In the Port of New York alone, it is estimated that 2,300 drift-caused accidents occur annually to commercial craft and another 8,500 to recreational boats.

Economic benefits of debris control include the reduction of physical damages from collisions, enhanced value of shore property, reduced costs of waste disposal, reduced towing and stewarding charges, and fewer law suits from accident victims. Fire hazard reductions and fewer nuisances to recreation also result from control efforts.

The Corps of Engineers estimates that costs of maximal abatement are in the realm of \$100 million for the nation (U.S. Army Corps of Engineers, 1969). Over half of this amount must be distributed to the harbors of New York and Boston, reportedly faced with the worst floating solids problems. Annual (1969) benefits to be derived in U.S. marine harbors are estimated as follows: the Atlantic coast, \$14.2 million; the Gulf states, \$0.8 million; and the Pacific region, \$2.4 million; for a grand total of \$17.4 million.

These estimates pertain to fewer than 20 U.S. harbors, although they are among the largest in trading volume. Altogether, they handle almost one-third of annual cargo tonnage in all coastal ports (Bureau of the Census, 1971, p. 563). But other trading centers also must contend with floating debris. As a result, an upper bound damage of \$34.8, or twice the lower bound estimate, is assumed for the nation as a whole.

## SUMMARY OF NATIONAL ESTIMATES

Pollution control benefits have been estimated for three water use categories along U.S. coastal waters. Table III lists the range of these estimates and aggregates them for the nation. It is quite obvious that the list is only a partial coverage of total benefits, and that these estimates are preliminary and can be improved as more data and economic analyses become available. Intangible benefits, such as appreciation of aesthetics, are another important consideration and value, which could easily affect environmental policies more strongly than purely economic justifications.

## INTERNATIONAL DAMAGES FROM MARINE POLLUTION

Throughout the world the coastal waters, estuaries, and bays have played a major economic role. They are a primary source of food and protein diet, particularly in underdeveloped nations. Great population surges have occurred along many coastal belts, thus adding more emphasis on the use of the oceans' resources. The world-wide demand for swimming, sports fishing, and other recreational uses of the shoreline has increased at a tremendous rate. Commercial fish production has risen sharply--from a world harvest of 51.9 million tons in 1964 to more than 69.4 million tons by 1971 (Food and Agriculture Organization, 1972, p. A0-2). It is conservatively estimated that this output should reach 100 million tons or more by the end of the century (Meseck, 1962, pp. 23-37). The enjoyment and the exploitation of marine waters are becoming more frequent among all world inhabitants, since incomes are rising and transportation facilities are improving in both developed and developing nations.

In many parts of the world, the coastal belt, despite its relatively small area, accounts for a large proportion of the populace and major industrial centers. But existing sewage and other waste abatement facilities are inadequate almost universally. The international scope of pollution damages is dramatically assessed in the following two statements:

"In almost all of the developed countries there is a growing concern over the ever-increasing introduction into the water of chemicals and radioactive materials with carcinogenic, toxic, and physiological effects on man" (Pritchard, 1966, p. 173).

"In many industrialized countries there are large towns or factories on the banks of estuaries which, in consequence, are much more highly polluted than the fresh water streams emptying into them" (United Nations, 1968).

Marine pollution problems exist not only for advanced industrial nations but for developing ones as well. Indeed, the costs of pollution control are a serious concern to the latter group, whose financial resources are slender and who are in dire need of money for normal investments (Needler and Diop, 1970). A survey of 75 developing countries concluded that because of rapid population growth in most of these regions, pollution problems may

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Water Use	Estimate (\$ million)	
	Lower	Upper
Commercial Fishing <sup>a</sup>	\$23.6	\$37.5
Navigation <sup>b</sup>	17.4	34.8
Recreation <sup>c</sup>	20.9	38.5
Total	\$61.9	\$110.8

<sup>a</sup>Excludes catches of salmon, tuna, and swordfish.

<sup>b</sup>Pertains to boat accidents and reduced harbor property values.

<sup>c</sup>Excludes days lost by current beach enthusiasts.

TABLE III. SOME ECONOMIC DAMAGES FROM MARINE WATER POLLUTION  
IN THE UNITED STATES, 1970 ESTIMATES



double, or more than double, over each successive decade (World Health Organization, 1964, p. 180).

Figure 7 shows the extent of marine pollution in the world (Waldichyk and Andren, 1971). (It also indicates major inland lake problems.) Water quality levels are consistently low around industrialized areas of northeastern United States, southern Europe, and the Baltic Sea countries. But other heavily populated areas are also notably affected: the British coast, southeastern Australia, Japan, the northern fringe of South America, and western sections of the United States and the Middle East. The North and Baltic Seas are recipients of large discharges of sewage and industrial wastes. Marine pollution near Asian ports in Taiwan and Singapore is threatening aquaculture fields.

Isolated cases of pollution damages are far too numerous to cite in detail. However, a few cases illustrate the universal scope and magnitude of the problem. In 1967, pollution in Pacific waters near the United States killed an estimated 12 million fish (Boughey, 1971, p. 357), while residues of DDT and other organochloride pesticides were found in Antarctic seals and penguins, thousands of miles from the waste emission sources. The Torrey Canyon oil spill killed between 50,000 and 250,000 seabirds in the North Sea and North Atlantic regions (Sibthorp, 1969, p. 13). Along the Italian shore bordering the Tyrrhenian Sea, detergents discharged with industrial wastes and sewage are killing pine trees; and in Sweden, heavy sulfur dioxide and sulfuric acid emissions are blamed for massive fish mortality. Other interesting cases can be cited in North Africa and Canada. Oil spills were severe off the Egyptian coast when the Suez Canal was open. Recently the Canadian side of the St. Claire was closed to fishing because of the high mercury content of fish. One of the most tragic pollution-related episodes occurred several years ago in Japan. At least 41 people died and many others developed nervous disorders from the ingestion of mercury-contaminated shellfish caught in Amamata Bay (Irukayama, 1967).

There is an acute shortage of research on marine waste disposal effects. Presently, water pollution damages cannot be calculated for most marine areas of the world because of the lack of information both on water use and water quality. In fact, it is virtually impossible to evaluate the total economic aspects of seawater pollution because so little is known about the diffusion of wastes in the ocean. But since strong economic interests for the disposal of wastes exist, these actions must in some way be countered. Vast marine biological systems will be altered unless some assessment of water pollution damages is calculated. Of course, total damages and health hazards can be calculated in monetary terms only to a limited extent.

A qualitative judgment on world recreational losses can be deduced by culling the literature on beach contamination and closures. Of course, such information is piecemeal and highly incomplete. Figure 8 denotes some of the most highly publicized shorelines affected by oil pollution (Food and Agriculture Organization, 1971, p. 20; International Recreation Association, 1964; International Recreation Association, 1956; Smithsonian Institute, 1973; World

Health Organization, 1967). Significant economic losses of tourism have been reported in Germany, Norway, Italy, and American beaches, although these are by no means the only degraded shorelines.

Political pressures for cleaner water in recreation sites have markedly increased in the United States, the United Kingdom, France, Belgium, the Netherlands, and Germany. In very recent years, some developing countries have also recognized these problems. Tourism is a major source of income for many emerging economies. "In, for example, the Mediterranean and Latin American countries, the recreational value of fine sunny beaches and clear water is a major factor in attracting tourists. Unfortunately many of these beaches have become fouled by untreated sewage, which, while not perhaps creating a great risk to health, does present a major aesthetic problem" (World Health Organization, 1966, p. 12). Since the demand for recreation generally rises faster than income throughout the world (World Health Organization, 1966, p. 12), it is imperative that those countries depending on tourist expenditures maintain clean and aesthetically pleasing marine resorts.

Perhaps the most comprehensive international survey of marine pollution damages was conducted in 1966 by the Inter-Governmental Oceanographic Commission (United Nations, 1967). The practically unanimous conclusion from this survey indicated that although it is very serious, marine pollution is not adequately controlled or even recognized as a major problem. Primary effects of ocean pollution were identified with marine life and ecosystems, fisheries, recreation, and health. Figure 9 summarizes individual nations' responses to this survey. The largest variety of waste discharges was reported by the United Kingdom, the United States, South Africa, Germany, and Australia.

From this survey a qualitative comparison of national pollution damages is discernible. Probably the largest magnitude of per capita damages occurs in the United States and Italy. England, Germany, and South Africa follow in this ranking. If pesticides prove to be very harmful to aquatic life and human health, the Central American countries, such as Guatemala and Nicaragua, will also rank high on the list.

Since 1966, when this survey was conducted, rapid industrialization and urbanization along coastal belts have increased damages from pollution in other countries. Japan, the Soviet Union, Venezuela, Singapore, and Mexico are good examples. Pesticide contamination is a serious problem in Cuba, Mexico, the Netherlands, and other regions with an important agricultural economy. Metallic wastes are of major concern in Japan, Sweden, and the United States. Africa contends primarily with oil pollution damages, especially along the northern and western shores. On the other hand, there are some countries reporting relatively minor damages from marine pollution. Among these are New Zealand, the Spanish peninsula (except the southern tip), the eastern shores of the Soviet Union, and some parts of western Canada (as opposed to the eastern shores).

## INTERNATIONAL COOPERATION ON ECONOMIC STUDIES

Because it is easier to monitor pollutants and to detect their effects in rivers and lakes than in marine waters, less attention is devoted to the marine environment. This distinction is less apparent in maritime nations depending on the seas for a large share of their income, but, nevertheless, it seems to be true universally. Only when hazardous forms of pollution enter marine waters, is there a serious effort to rectify the problem. However, as the oceans--the ultimate sink of the world's river wastes--continue to accept biodegradable and especially conservative pollutants, environmental crises will mount. One country's waste discharges may well become another country's economic burden for control because of the gradual widespread diffusion of wastes by ocean currents. International problems of apportioning pollution-caused damage liabilities among offenders must eventually be addressed since pollutants can significantly interfere with beneficial uses of water. In some cases, the economic development and growth of a regional economy are at stake. New international agreements on the control of oil spills and ocean dumpings have been promulgated, but the economic issues involved have received scant attention.

Questions of enforceability of economic damage liabilities are being considered, but they have not yet been resolved. At this point in time, legal enforcement is secondary to self-imposed actions of control based on respect and concern for another nation's welfare. This principle is aptly stated in a German document (Fischerhof, 1961, p. 9):

"The present position in international law as regards disputes relating to water pollution may be assimilated in the perhaps only very slightly attractive formula that every State must take sufficient account of the interests of other states. ... This obligation does not, however, directly found a claim for abatement or compensation on the part of the other states; it merely constitutes an obligation to formulate the mutual rights and duties of the two states by the conclusion of a special agreement under international law."

## CONCLUSION

Over the past several decades, the growing development and attendant pollution problems of coastal areas have caused significant destruction of marine ecosystems and have begun to restrict the use of coastal regions for other beneficial purposes.

This study demonstrates that pollution control damages can be calculated for some marine activities, particularly in estuarine and coastal waters most vulnerable to effects of concentrated waste discharges. Estimates of damages are preliminary and crude, however, due to the current lack of information on water quality conditions and water use demands. They will be refined as more data is collected and analyzed on coastal environments and activities.

Estimated damages to commercial fisheries and recreation are based on the extent of closures of polluted marine areas that cater to these activities. Economic values are attached to each unit of damage. For example, the total value of a fishing day foregone because of pollution is assumed to be the typical daily expenditure by a saltwater sports fisherman. Net benefits, in contrast, are calculated as the consumer surplus gained by prohibiting waste discharges into the marine environment (coastal waters). Of course, the associated costs of control may be prohibitive for complete waste removal. A cost-benefit analysis is necessary to find the optimal level of water quality, wherein benefits gained from additional control are matched by increasing (marginal) costs.

A major difficulty with assessing the economic value of ocean resources is that they are usually aggregated with other resources and cannot be easily distinguished from them. Moreover, economic impacts per unit damage vary over tremendous ranges, depending not only on the region and the pollutants being studied but also on the method chosen for the assessment. The value of beach recreation is a case in point, as the following remark indicates:

"The present statistics on national expenditures on oceanic recreation are in such a sad state that estimates for these activities in the United States range from \$50 million in 1964 according to one source, to an estimated \$3.86 billion in 1964 from another. Granted that estimates probably were not made on a strictly comparable basis, at least part of this 72-fold discrepancy is due to the fact that statistics on expenditures for fishing, swimming, boating, and related equipment do not distinguish between marine-oriented activities and inland-oriented activities in streams and lakes" (Spangler, 1968, p. 99).

The overall impact of direct expenditures on the rest of the economy, called secondary benefits, is even more confusing to interpret. Tourist expenditures, for example, filter throughout the economy and generate additional income and employment in the region. But to assess these higher order effects is extremely difficult, particularly in estuarine (sub-regional) economies that are highly intertwined with the larger economy. Generated income multipliers have been estimated for commercial fishing and swimming expenditures in Narragansett Bay, Rhode Island (Rorholm, Lampe, and Farrell, 1967), but such information is not available for most regions. In spite of the magnitude of total revenue generated beneficial water uses, the important concept in measuring net benefits is the change in consumer surplus. If this measure is a small fraction of total revenue, then the use of revenue as a proxy for consumer surplus would grossly exaggerate the inherent value of clean water.

Most benefit estimates pertain to the time frame of a single year, but they should be envisioned in a dynamic framework. Because benefits result

from ongoing uses of marine resources, their present value (discounted over future periods) is a more realistic measure of worth than the single-year estimate. Indeed, a one-year "snapshot estimate" could be misleading, as Figure 10 demonstrates. For pollution control in San Diego Bay, the total benefit-cost ratio in 1968 is less than three, whereas it increases to a projected ratio of four by the year 2000 (Federal Water Pollution Control Administration, 1969b). The rapid rise of recreational demand relative to abatement needs explains this discrepancy and must therefore be recognized in any cost-benefit analysis.

Although consumer surplus is recommended as a measure of benefits, it fails to capture all welfare gains of pollution control. An important concept neglected by ordinary demand analysis is option demand. Some individuals are willing to pay for water quality enhancement even if they are not the immediate recipients of the benefits. Perhaps they foresee benefits for themselves in the future or for their future generation. Some consumers are willing to financially support environmental programs because they are risk averse. If there is even the slightest probability of damages to the marine ecosystem, they will demand more stringent water quality standards. The market price of pollution control is secondary to their more personal evaluation of the priceless value of marine resources. If these extra benefits are added to typical ones based on immediate demand for water-related amenities, then social preferences of each consumer will be more fully assessed.

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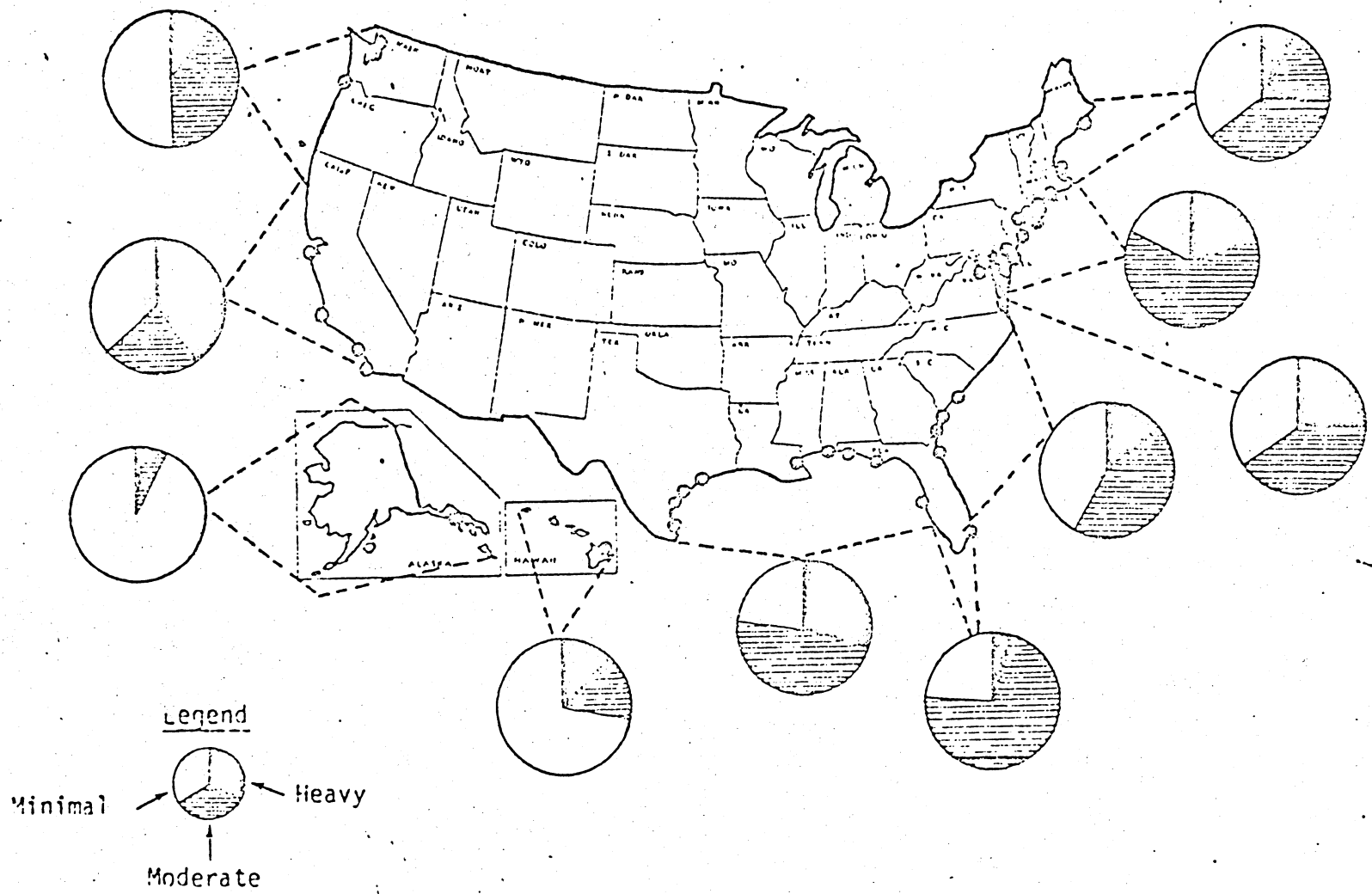


FIGURE 1. EXTENT OF ECOLOGICAL DAMAGES IN ESTUARINE ZONES OF THE UNITED STATES, 1969

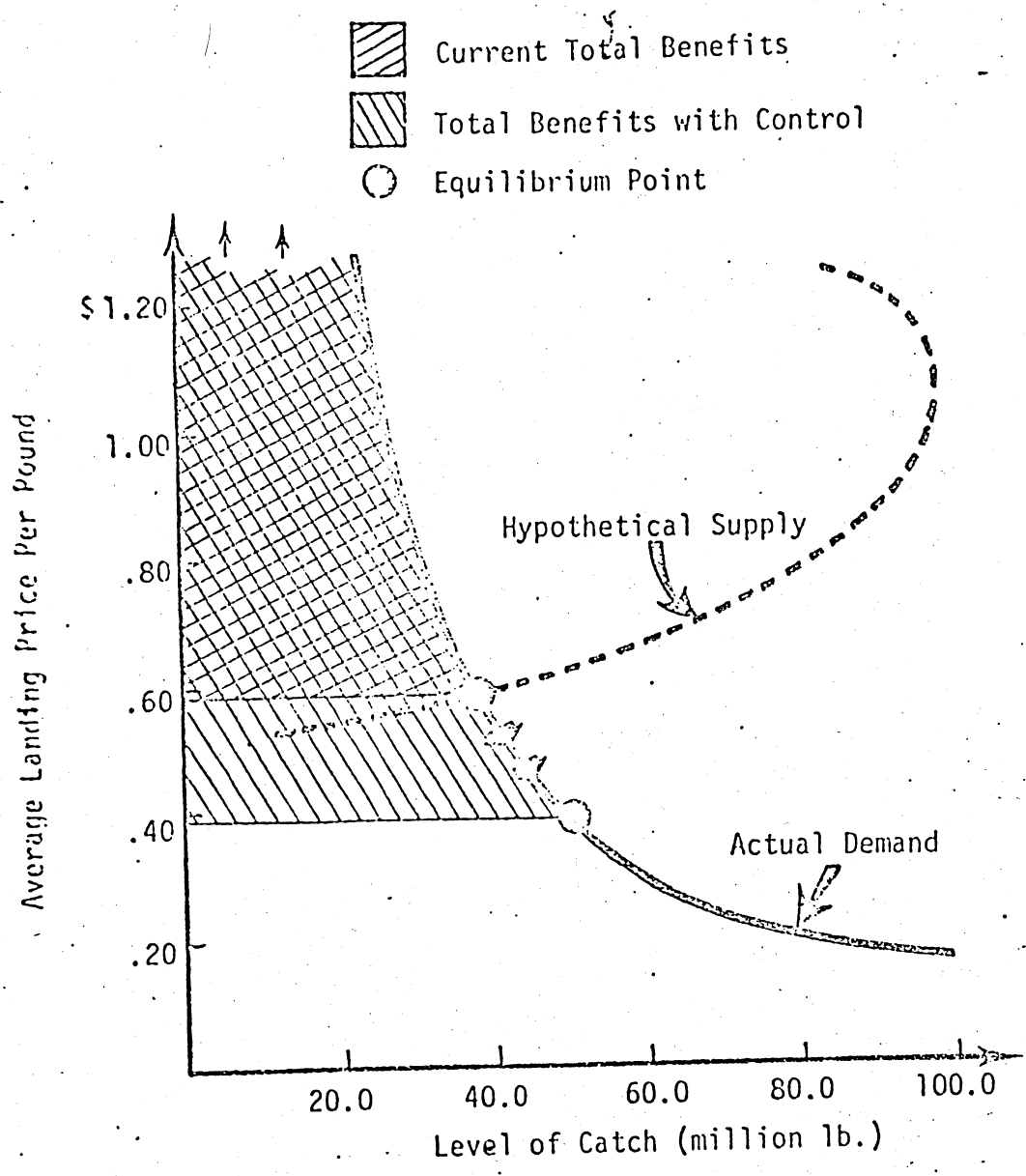


FIGURE 2. CALCULATION OF NET BENEFITS OF MARINE POLLUTION CONTROL TO CLAM FISHERIES IN THE UNITED STATES, 1970

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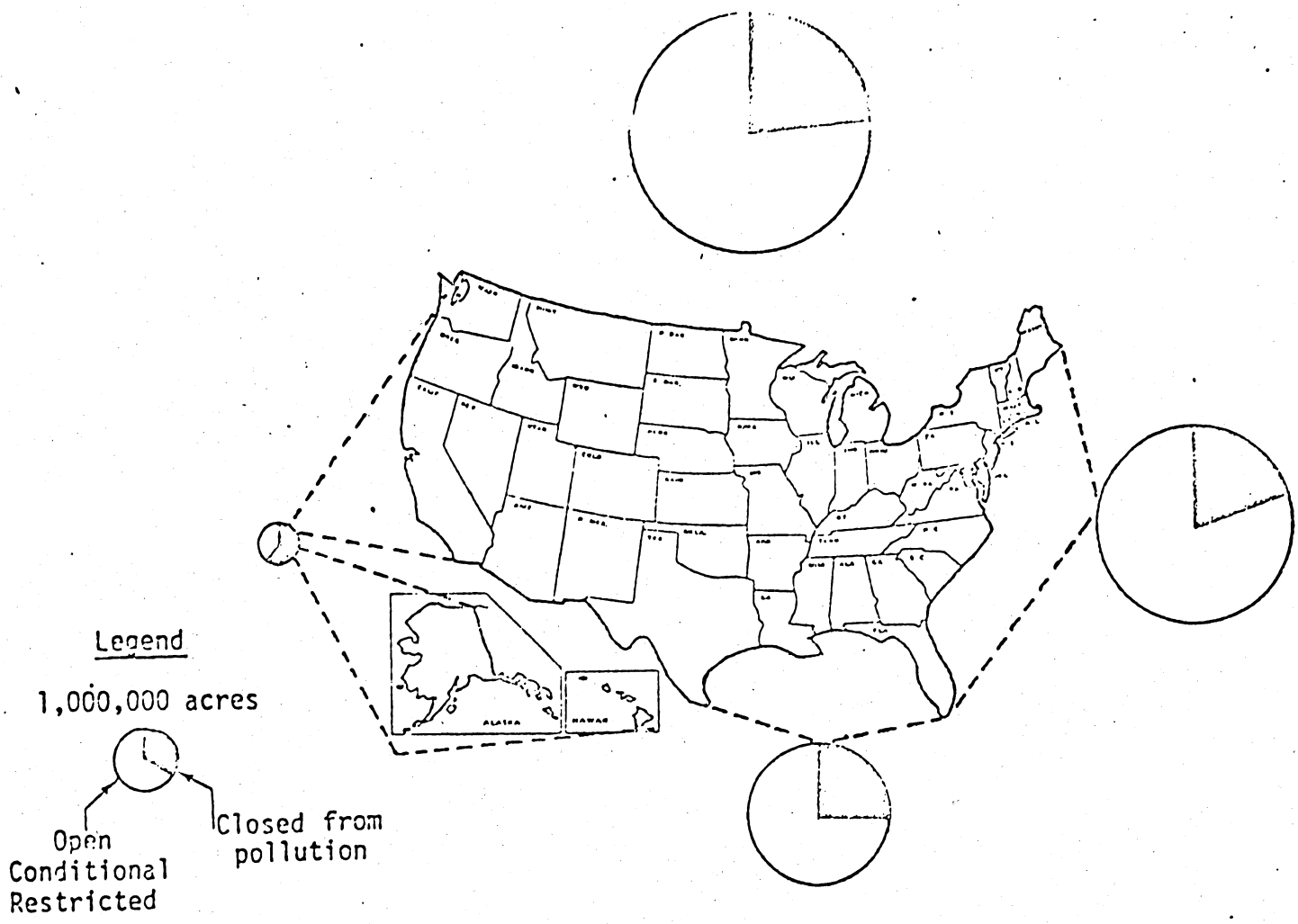
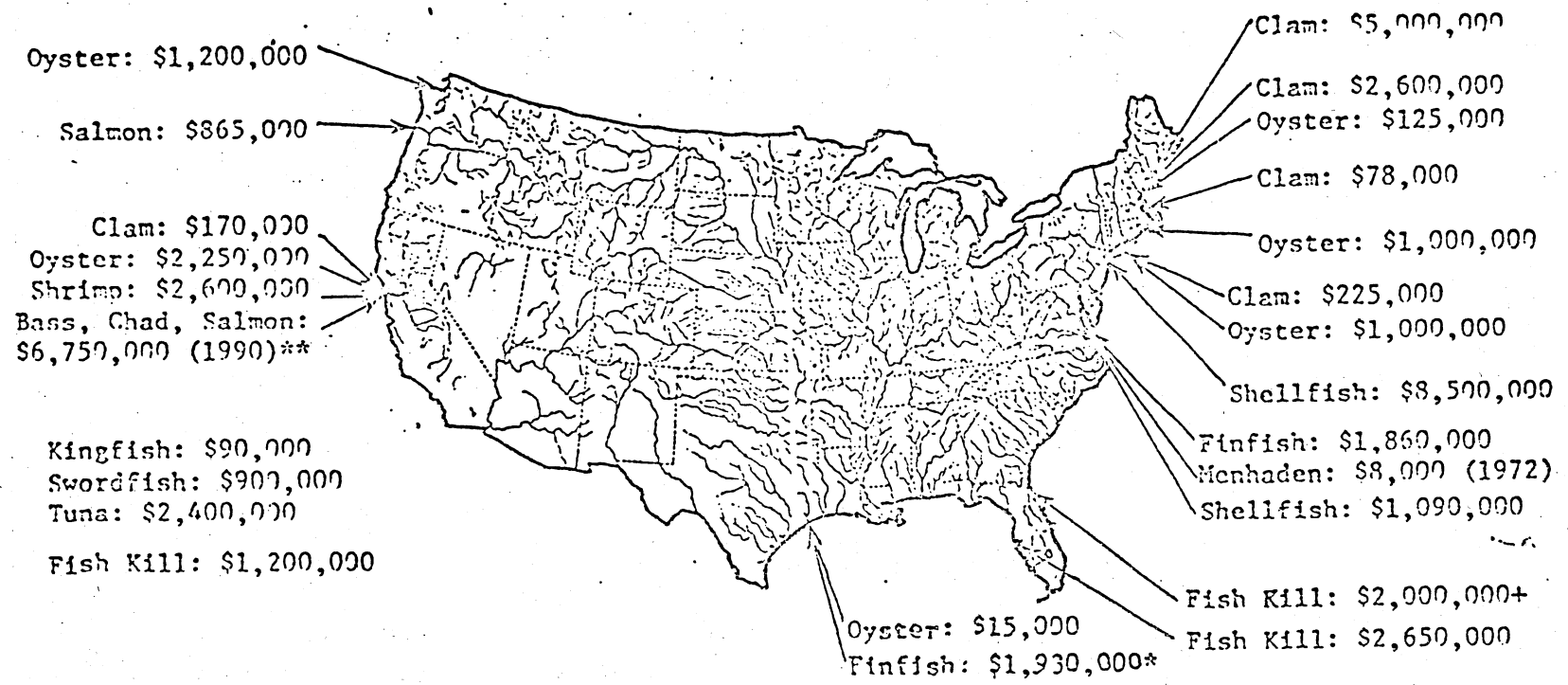


FIGURE 3. STATUS OF SHELLFISH AREAS ALONG COASTAL WATERS OF THE UNITED STATES, 1971



30



\*Potential loss from oil spills  
 \*\*Potential loss from inland drainage

FIGURE 4. COMMERCIAL FISHERY REVENUE LOSSES FROM MARINE WATER POLLUTION IN THE UNITED STATES, 1970

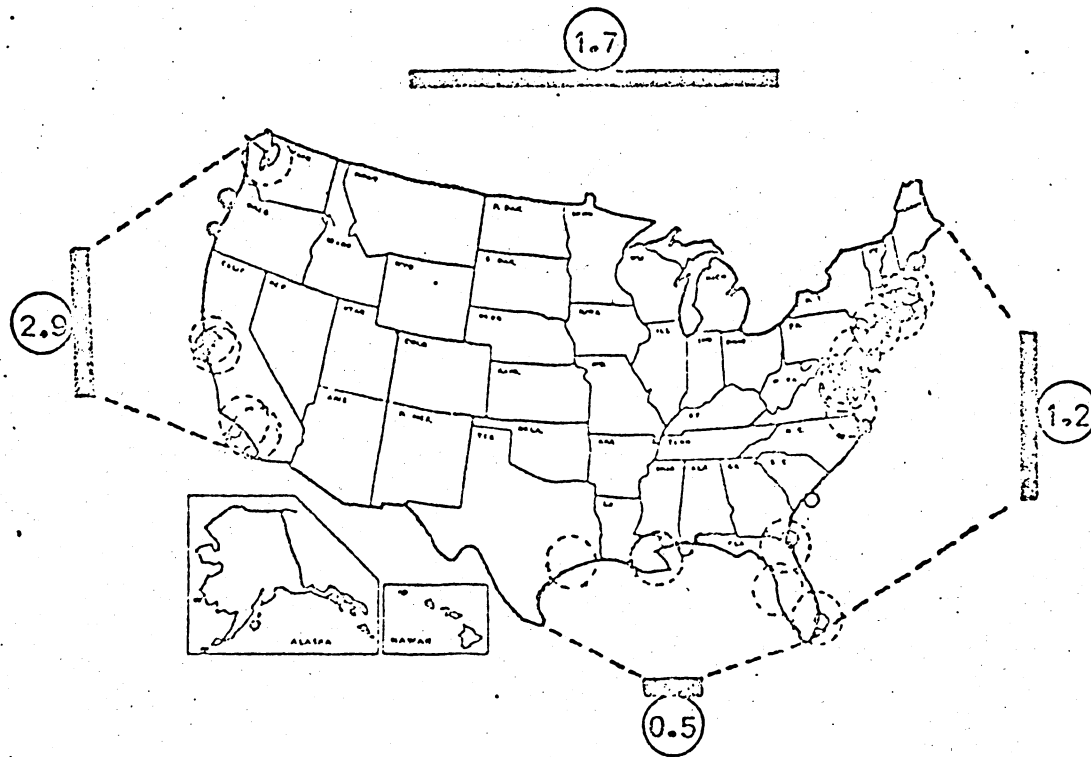
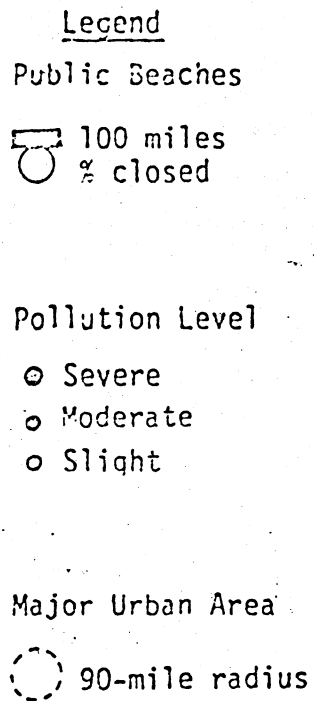


FIGURE 5. INVENTORY OF POLLUTED BEACH CLOSURES IN THE UNITED STATES, 1972

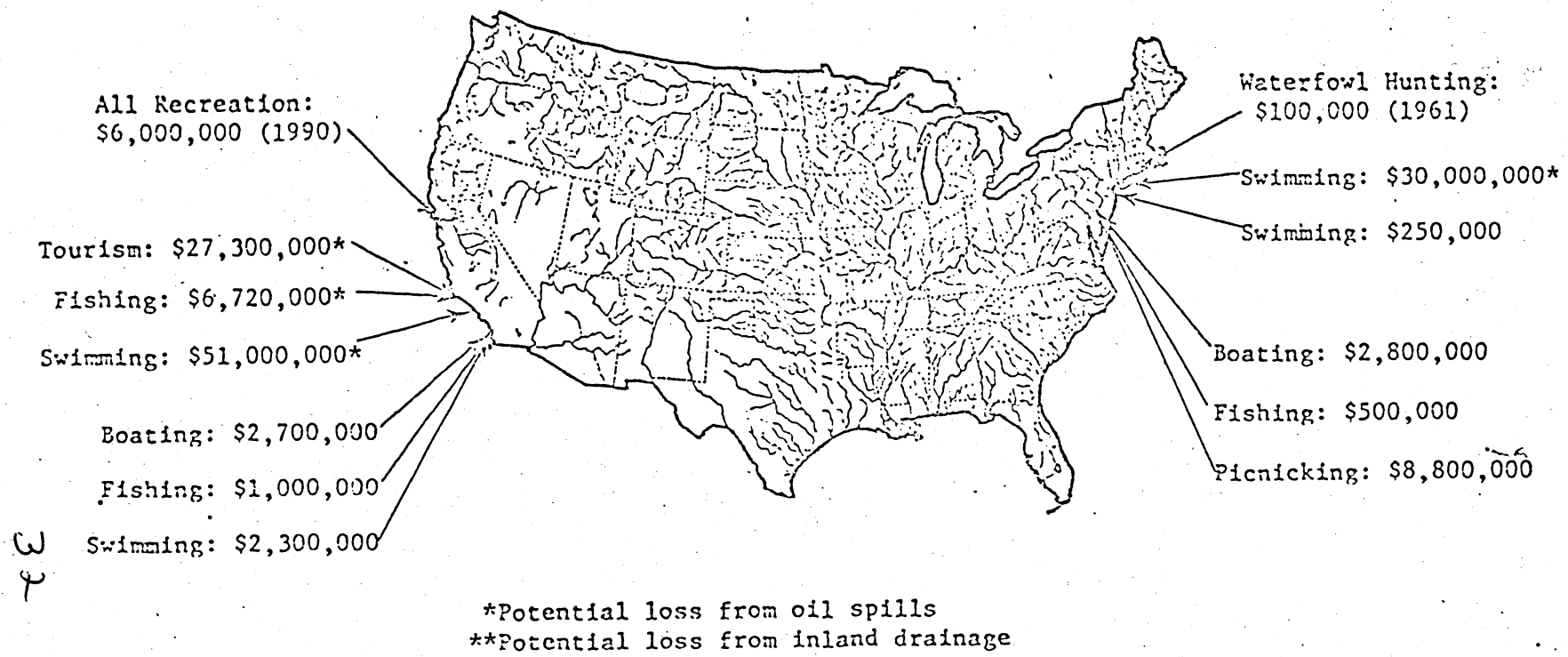


FIGURE 6. RECREATION EXPENDITURE LOSSES FROM MARINE WATER POLLUTION IN THE UNITED STATES, 1970

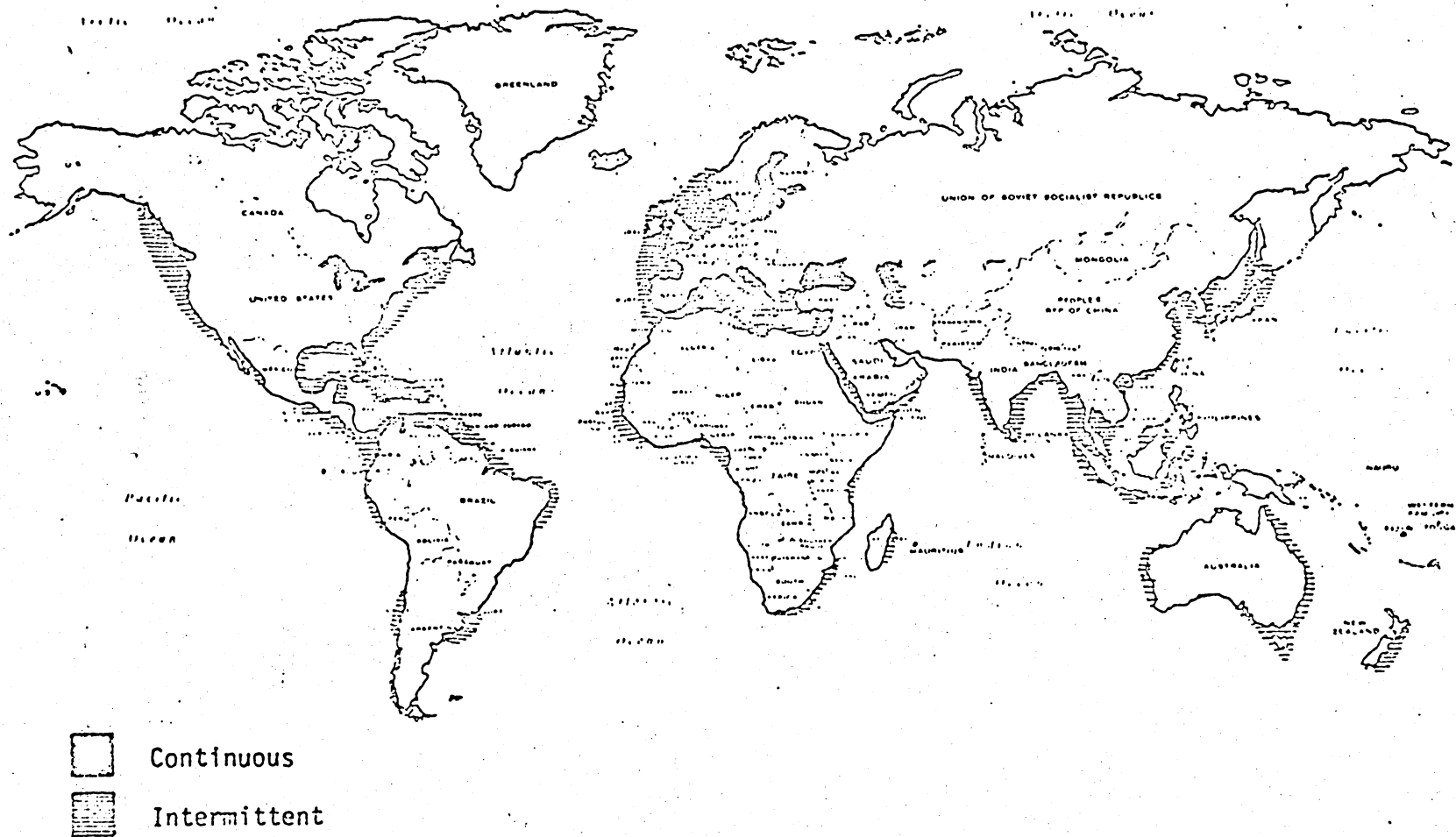
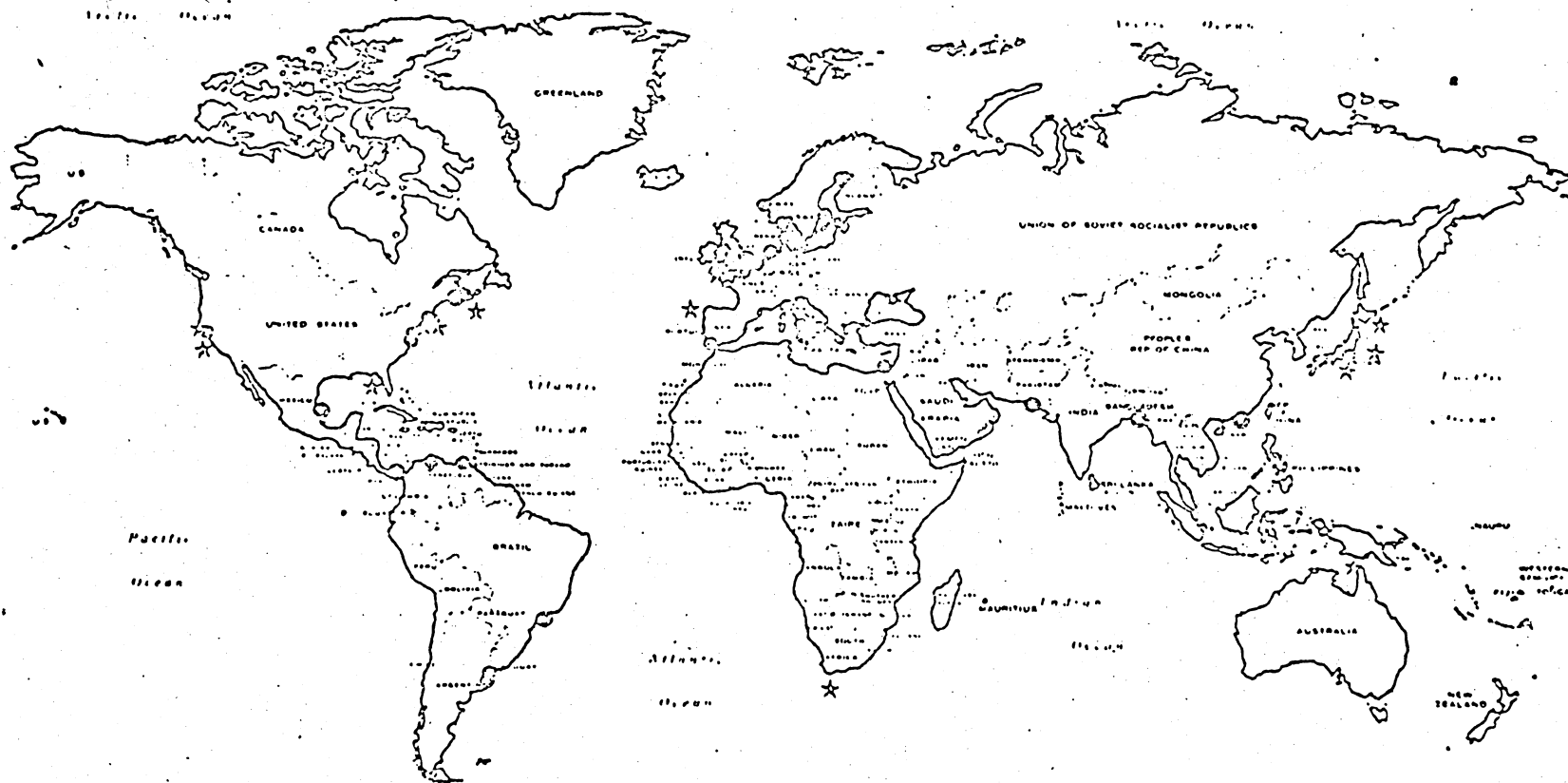


FIGURE 7. TEMPORAL ASPECTS OF MARINE POLLUTION THROUGHOUT THE WORLD, 1971



- 34
- Documented Damages
  - Suspected Damages
  - ★ Major Oil Spill

FIGURE 8. SURVEY OF OIL POLLUTION DAMAGES TO RECREATIONAL BEACHES IN THE WORLD, 1970

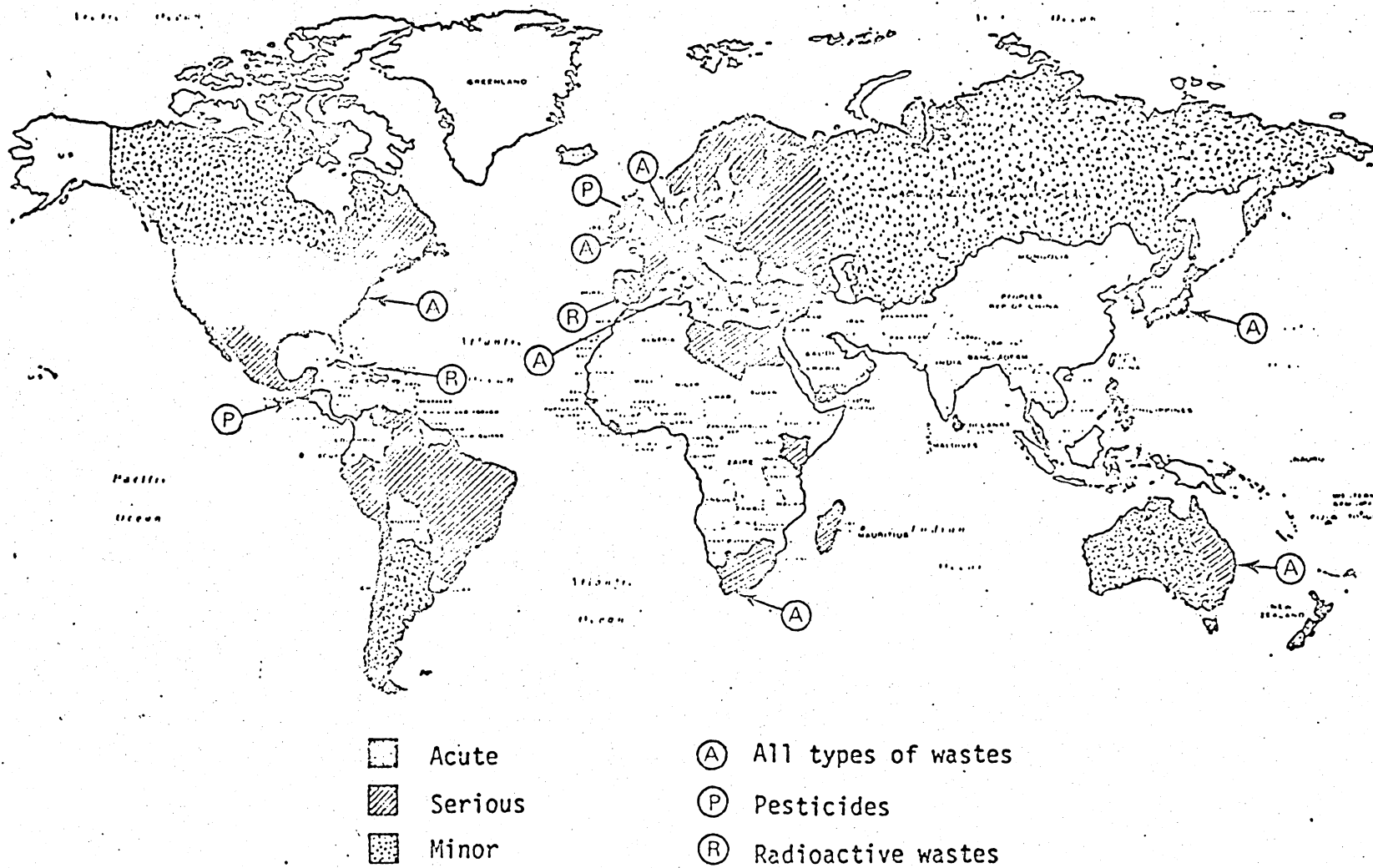


FIGURE 9. RELATIVE LEVELS OF MARINE POLLUTION DAMAGES IN SURVEYED COUNTRIES OF THE WORLD, 1966

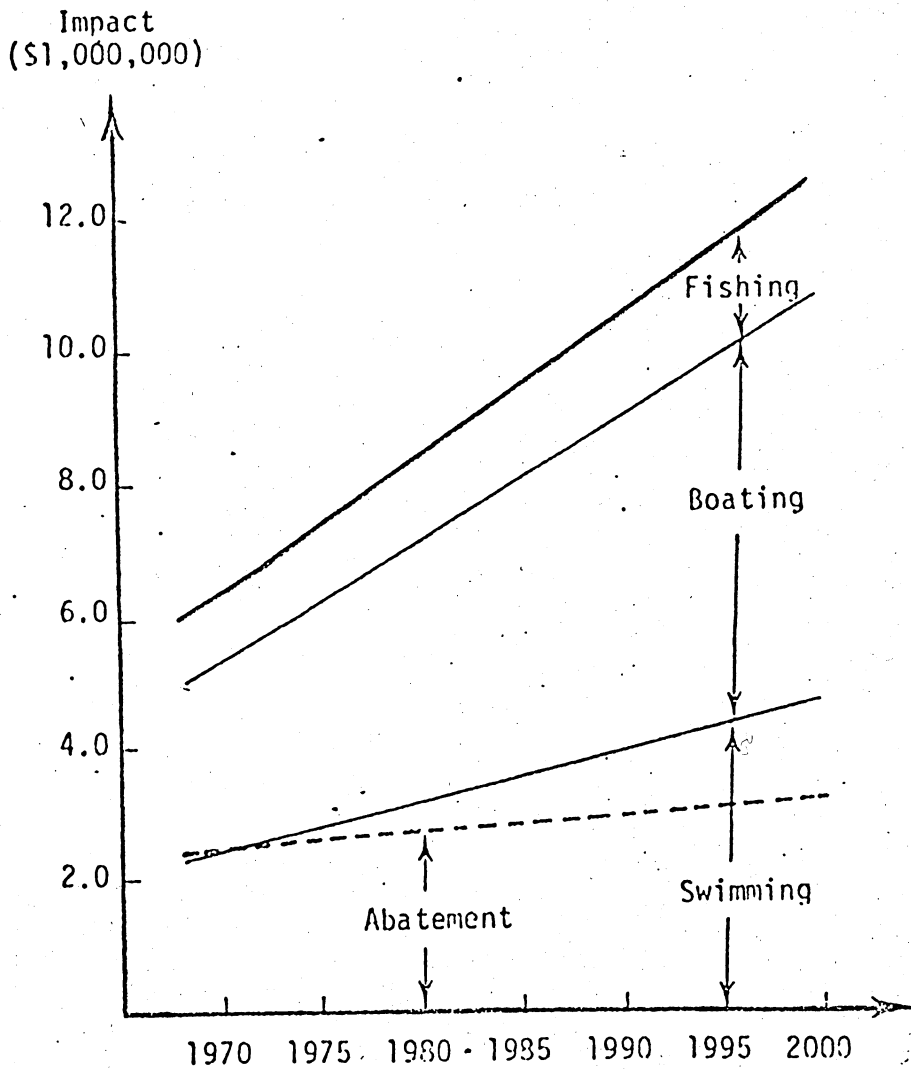


FIGURE 10. RECREATIONAL BENEFITS VS. ANNUAL COSTS OF WATER QUALITY CONTROL IN SAN DIEGO BAY, CALIFORNIA

## REFERENCES

- Anonymous. "Florida Fish Kill Led U.S. in 1969," St. Petersburg Times, January 14, 1971.
- Anonymous. "Oyster Loss in Galveston Bay," Texas Parks and Wildlife Department, Proceedings Shellfish Sanitation Conference (Houston, Texas), June 7, 1971.
- Anonymous. "Red Tide Loses Jobs in Maine," Portland Press Herald, November 2, 1972.
- Anonymous. "State to Ask for Millions in Oil Damages," St. Petersburg Times, December 10, 1970.
- Bale, H.E., Jr. Report on the Economic Costs of Fishery Contaminants, National Marine Fisheries Service, Department of Commerce (Rockville, Md.), October 1971.
- Battelle Memorial Institute. Development Potential of U.S. Continental Shelves (Columbus, Ohio), April 1966.
- Bell, F.W., et al. The Future of the World's Fishery Resources: Forecasts of Demand, Supply and Prices to the Year 2000 with a Discussion of Implications for Public Policy, National Marine Fisheries Service, Department of Commerce (Rockville, Md.), 1970.
- Boughey, A.S. Man and the Environment, The Macmillan Company (New York, N.Y.), 1971.
- Brown, R.P., Moser, W.H., and Shenton, E.H. "National Inventory of Recreational Beaches Closed by Pollution--1971", Plessey Environmental Systems (San Diego, California), June 1972.
- Brown, W.G., et al. An Economic Evaluation of the Oregon Salmon and Steelhead Sport Fishery, Technical Bulletin No. 78, Oregon State University, Agricultural Experiment Station (Corvallis, Oregon), 1964.
- Bureau of the Census. Statistical Abstract of the United States, 1971, Department of Commerce (Washington, D.C.), July 1971.
- Bureau of Sports Fisheries and Wildlife. National Survey of Fishing and Hunting, 1970, Department of Interior (Washington, D.C.), 1973.
- Burkenroad, M.D. "Theory and Practice of Marine Fishery Management," Journal du Conseil Permanent International pour l'exploration de la Mer, 18(3), January 1953.
- Campbell, R.D., LeBlanc, H.L., and Mason, M.A. "An Evaluation of the Shoreline Recreational Resources of the United States," George Washington University (Washington, D.C.), March 1961.



Canadian Department of Fisheries. Progress Report on the Economic Survey of Salmon Fishermen in British Columbia, 1953 and 1954 (Ottawa, Canada), 1955.

Conner, E.B. "Harbor Debris," Water Spectrum, pp. 9-13, Spring 1970.

Council on Environmental Quality. Ocean Dumping: A National Policy, U.S. Government Printing Office (Washington, D.C.), 1970.

Crutchfield, J.A. "Economic Value of Washington Commercial Fisheries, 1955," Pacific Northwest Business, pp. 5-15, July 1957.

Crutchfield, J.A., and Zellner, A. "Economic Aspects of the Pacific Halibut Fishery," Fishery Industrial Research, 1(1), Department of Interior (Washington, D.C.), 1962.

Department of Interior and Department of Transportation. A Report on Pollution of the Nation's Waters by Oil and Other Hazardous Substances (Washington, D.C.), February 1968.

Federal Power Commission. In the Matter of the Northwest Power Company, Project No. 2173, Commission Staff Brief (Washington, D.C.), March 1957.

Federal Water Pollution Control Administration. The National Estuarine Pollution Study, II, Department of Interior (Washington, D.C.), November 1969.

Federal Water Pollution Control Administration. Regional General Plan, San Diego County, 1990, Department of Interior (Washington, D.C.), 1969.

Federal Water Pollution Control Administration. San Joaquin Master Drain: Effects on Water Quality of San Francisco Bay and Delta (San Francisco, Calif.), January 1967.

Federal Water Quality Administration. New Haven Harbor: Shellfish Resource and Water Quality, Department of Interior (Needham Heights, Mass.), August 1970.

Firth, F.E. The Encyclopedia of Marine Resources, Van Nostrand Reinhold Company (New York, N.Y.), 1969.

Fischerhof, J.H. "Liability in National and International Law for Damage through Water Pollution," Die Wasserwirtschaft, 6: 1-18, 1961.

Food and Agriculture Organization. "Improving Fishery Resources and Means for their Development," Proceedings United Nations Conference on Conservation and Utilization of Resources, 7:28-35, United Nations (New York, N.Y.), 1951.

Food and Agriculture Organization. Pollution: An International Problem for Fisheries, United Nations (Rome, Italy), 1971.

- Food and Agriculture Organization. Yearbook of Fishery Statistics: 1971, 32, United Nations (Rome, Italy), 1972.
- George Washington University. Legal, Economic, and Technical Aspects of Liability and Financial Responsibility as Related to Oil Pollution (Washington, D.C.), December 1970.
- Holt, S.J. "The Food Resources of the Ocean," Scientific American, 221(3): 178-182, 187-194, 1966.
- Howard, G.V. National Marine Fisheries Service, Department of Commerce (Terminal Island, Calif.), Personal Communication, January 1973.
- International Recreation Association and National Recreation Association of Japan. Global View of Recreation, The World Recreation Congress (Osaka, Japan), October 12-14, 1964.
- Irukayama, K. "The Pollution of Minamata Bay and Minamata Disease," Advanced Water Pollution Research, 3:153-183, 1967.
- Knetsch, J.L. "The Influence of Reservoir Projects on Land Values," Journal of Farm Economics, 46(1):231-243, February 1964.
- Loftas, T. "The Oceans Have Become the Sinks of the World", CERES (Food and Agriculture Organization Review), 5(1):35, 1972.
- McKee, J.E. "Parameters of Marine Pollution--An Overall Evaluation," in Pollution and Marine Ecology, by T.A. Olson and F. J. Burgess (eds.), Interscience Publishers (New York, N.Y.), 1967.
- McMillan, D.C. President, Olympia Oyster Growers Association (Olympia, Washington), Personal Communication, January 1973.
- Meseck, G. "Importance of Fisheries Production and Utilization in the Food Economy," in Fish in Nutrition by E. Heen and R. Kreuzen (eds.), Fishing News Books Ltd. (London, England), 1962.
- National Council on Marine Resources and Engineering Development. Report of IPON Task Group to Committee on Multiple Use of the Coastal Zone (Washington, D.C.), April 1969.
- National Marine Fisheries Service. Fisheries of the United States, 1971, Department of Commerce (Washington, D.C.), 1972.
- National Recreation Association. Proceedings International Recreation Congress (New York, N.Y.), 1956.
- Needler, A.W.H., and Diop, B. "Pollution Prevention is Costly", CERES (Food and Agriculture Organization Review), 3(3):38-39, May-June 1970.
- Outdoor Recreation Resources Review Commission. Sport Fishing--Today and Tomorrow, Study Report No. 7, Department of Interior (Washington, D.C.), 1962.

- Pritchard, D.W. "Fisheries vs. the Exploitation of the Non-extractive Resources in Estuaries," in Exploiting the Ocean, Transactions of the 2nd Annual Conference of the Marine Technology Society (Washington, D.C.), June 27-29, 1966.
- Rogerson, J.S. "Legislation and Water Quality Control," World Dredging and Marine Construction, 6(12):22, 1970.
- Rorholm, N., Lampe, H.C., and Farrell, J.F. Economic Impact of Marine Oriented Activities--A Study of the Southern New England Marine Region, Report No. 7, University of Rhode Island (Kingston, R.I.), 1967.
- Sibthorp, M.M. Oceanic Pollution: A Survey and Some Suggestions for Control, The David Davies Memorial Institute of International Studies (London, England), 1969.
- Smith, E.T. Environmental Protection Agency (New York, N.Y.), Personal Communication, January 1973.
- Smith, V.L. "Economics of Production from Natural Resources," American Economic Review 58(b):409-431, 1966.
- Smithsonian Institution. Files on International Oil Spills, Center for Short-Lived Phenomena (Washington, D.C.), 1973.
- Spangler, M.G. A Preliminary Review of Alternative Federal Measures of Encouraging Private Investment Enterprise in Marine Resource Development, National Planning Association (Washington, D.C.), 1968.
- Spencer, S.L. Monetary Values of Fish, American Fisheries Society, The Pollution Committee (Montgomery, Alabama), 1970.
- Swedish Royal Commission. Report on Natural Resources, Stockholm, Sweden, November 1967.
- Tomazinis, A.R., and Gabbour, I. "Water Oriented Recreation Benefits" in Delaware Estuary Study by Federal Water Pollution Control Administration, Department of Interior (Philadelphia, Pa.), July 1966.
- Trice, A.H., and Wood, S.E. "Measurement of Recreation Benefits," Land Economics, 34(3):199-205, 1967.
- Turvey, R. "Optimization in Fishery Regulation," American Economic Review, 54(1):64-76, March 1964.
- United Nations. Environmental Pollution and Its Control, Document No. E/4457 AD1 (New York, N.Y.), 1968.
- United Nations. The Inter-Governmental Oceanographic Commission Report on Oceanic Pollution, the U.N. Economic and Social Council (Paris, France), August 1967.

- U.S. Army Corps of Engineers. A Study of the Need for and Feasibility of a Program for the Removal and Disposal of Drift and Other Debris, Including Abandoned Vessels, from Public Harbors and Associated Channels under the Jurisdiction of the Department of the Army, Department of Defense (Washington, D.C.), August 1969.
- Waldichyk, M., and Andren, L. World Map on Marine Pollution, in Pollution: An International Problem for Fisheries, Food and Agriculture Organization, United Nations (Rome, Italy), 1971.
- Wallace, D.E. Maine Department of the Sea and Shore Fisheries (Augusta, Maine), Personal Communication, February 1973.
- Weddig, I.J. President, National Fish Institute, Inc. (Washington, D.C.), Personal Communication, February 1973.
- White, R.M. News Release, National Oceanic and Atmospheric Administration, Department of Commerce (Washington, D.C.), February 13, 1973.
- Whitman, I.L. "Economic and Social Values of Estuarine Recreation," in The Economic and Social Importance of Estuaries, Battelle Memorial Institute (Columbus, Ohio), 1966.
- World Health Organization. Control of Water Pollution: A Survey of Existing Legislation, United Nations (Geneva, Switzerland), 1967.
- World Health Organization. Water Pollution Control, Technical Report Series No. 318, United Nations (Geneva, Switzerland), 1966.
- World Health Organization, WHO Chronical, 18, United Nations (New York, N.Y.), 1964.

