SESSION III. Conceptual Needs for Marine Pollution Policy

ECONOMIC VALUATION OF MARINE WILDLIFE: DOES EXISTENCE VALUE EXIST?

by

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Abstract: Yes.

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Crucial to the implementation of the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA, 1980) is development of viable and appropriate methods for assessing natural resource damage in polluting incidents. Regarding marine ecosystems, damage assessment methodology must address the increased potential for the occurrence of damaging incidents affecting marine resources as coastal development proceeds. Only some marine resources are transacted in commercial markets so that only a portion of societal values lost are revealed through market values. Though it is generally recognized that additional societal losses associated with damage to non-marketed biological systems should be evaluated, ongoing discussions under the CERCLA have yet to determine how such values should be quantified.

As evidenced by strong public support for the Marine Mammals Protection Act (1972) and various incidents such as Alaskan residents' protest of the live capture of non-endangered killer whales in 1984, society places some value on preservation of marine wildlife. Clearly, optimal policy choices are hindered by the uncertainty associated with the likelihood of damaging incidents) the extent of their effect on marine wildlife, and society's value associated with such effects. The following discussion will address this last issue in a presentation of results of a contingent valuation study conducted to determine Californians' economic values for protected marine mammals. Analysis of results will incorporate a discussion of non-market valuation issues which must be addressed if wildlife valuation is to be meaningful in a policy context.

Previous authors have argued convincingly for consideration of total economic value of natural resources, of which market value is of ten just a subset (see, e.g., Randall and Stoll, 1983, Boyle and Bishop, 1985). In this regard, two methodologies -- the travel cost method and the contingent valuation method (CVM)-- have been used in recent years in a large number of environmental quality and recreational settings. In the context of public policy, benefits estimation of public natural resource programs has taken on greater importance in the current era of fiscal responsiblitly; thus, use of both methods has received greater attention and acceptability. For example, explicit measurement of recreational/aesthetic benefits is required by the Water Resources Council (unit day values), the U.S. Forest Service's Resource Planning Act (values for hunting and fishing), and the Bureau of Land Management's Rangeland Investment Policy Act. And, under the Marine Mammals Protection Act (Section 2(6)), marine mammals are "resources of great international significance, aesthetic and recreational as well as economic, and it is the sense of Congress that they should be encouraged to develop to the greatest extent feasible commensurate with sound policies of resource management" (emphasis added).

However, very little research has been conducted to quantify the non-market benefits associated with wildlife. Of the few studies which exist, almost all have been directed at valuing consumptive uses; i.e., the recreational values for hunting and fishing. The travel cost method, especially, has been refined considerably through a large number of applications (see, e.g., McConnell and Strand (1981), Miller and Hay (1984), and Huppert and Thomson (1984)). Though these studies have demonstrated the feasibility of deriving consumer surplus values associated with hunting and fishing, these measures do not include non-consumptive values which may exist. This is probably a non-issue for many managed fish stocks and animal populations, but it may be a problem for estimating valuations for marine wildlife where hunting and fishing are either disallowed or not desired, and even sitings are not common.

The contingent valuation method has been applied in a very small number of studies in order to elicit estimates of individuals' values for animal species. The CVM study cited most frequently is perhaps that of Bishop and Heberlein (1979) in which the consumer surplus value for goose hunting in Wisconsin was investigated. Another CVM study conducted by mail was reported by Brookshire, Eubanks, and Randall (1983). This study asked hunters to reveal willingness to pay for future hunting permits for grizzly bear and bighorn sheep. Hunters were also asked for non-use values, i.e. willingness to pay to observe the animals, but Stoll and Johnson (1984) conducted the first willingess-to-pay survey of non-hunters for a protected wildlife population. This study elicited values for whooping cranes which can be observed at the Aransas Refuge in Texas. In two recent studies, Boyle and Bishop (1985) and Hageman (1985) investigated non-market valuations for wildlife populations which are neither hunted nor are they always observable in the wild. What follows is a discussion of results from the latter study.

Before proceeding, it is useful to outline the types of benefits for which marine mammals are valued. Mendelsohn (1984) has compiled a comprehensive list of relevant benefits which is presented here without elaboration. These are: consumptive and non-consumptive recreation, indirect recreation by way of media exposure (films, books), bequest value, "chemical mining,'" research on chemicals and genetics, experimental value, pest control, enhancement of other desired species (i.e., importance in the food chain), option and quasi-option values, and existence value. After a generally persuasive discussion of each, Mendelsohn argues that use values only are relevant for measurement of the benefits of preserving endangered species. The utilitarian argument is that all other non-use values, such as option value or existence value, are in fact use values which are being double-counted in benefits elsewhere. For example, the argument is posited that existence value does <u>not</u> exist, and that if people were allowed <u>no</u> information on the animal stock (precluding not only visits, but also media information), then willingness-to-pay for blind faith in the animals' continued existence would be zero.

We take issue with the strictly utilitarian approach to value measurement for marine mammals and other animal populations. It <u>may</u> be true that existence value is zero when it is narrowly defined to preclude all direct and indirect exposure to the animals or information about the animals, but this is strictly conjecture. Even if we accept the conjecture, the question arises as to how, then, are total use values to be measured? Mendelsohn argues that these values are capture in payments for movies, television documentaries, live zoo and aquarium exhibits, books, and artwork. However, an effort to enumerate the large number of multi-media exposures for any particular animal and to thus estimate the total willingness-to-pay for that species would generally be such an enormous task as to render it an impossible endeavor. Furthermore, conversations with individuals frequently reveal that at least some people adamantly claim their values are <u>not</u> tied to Utilitarian concerns. Even if we concede that such individuals actually value animal species because of what might be defined broadly as a utilitarian concern for ecological integrity which is necessary for the human species' long-term survival, we would argue that the issue is one of semantics.

For the purposes of the study described in the next sections, existence value is defined as the maximum willingness-to-pay for those benefits which are not tied to direct use (neither consumptive nor non-consumptive). By direct non-consumptive use, we are referring to current or future on-site observation of animal populations. The distinction is important because it allows individuals to indicate their values even though current or future uses are not intended. In this way, damage assessment for detrimental effects of marine pollution on wildlife need not be tied necessarily to losses in observation/recreation opportunities. In the section which follows, the CVM survey structure is described and results are provided which speak to potential biases discussed in the CVM literature. Also, valuation estimates of California households are reported for four marine mammal populations. Differences between values are discussed, and several issues relevant for the appropriate application of such value estimates are addressed. For example, do households have a specific value for each animal population versus marine mammals (or perhaps ecosystems) in general? Can households provide information on the value they attach to incremental changes in wildlife populations? If sampled households can provide valuations for losses of marine wildlife, are the responses representative of the affected population in the event of marine pollution, and what is the appropriate population over which to aggregate? For marine wildlife, does existence value exist?

APPLICATION OF THE CVM IN MARINE MAMMALS VALUATION

Analysis of the usefulness of the CVM for marine mammals valuation is based upon the results of a survey mailed from San Diego State University in 1984. The sample population was 1,000 California residents. Names and addresses were randomly chosen from telephone books according to the population distribution of the state (based upon the U.S. Census of Population 1980) - 21.9% were were sent to San Francisco/Oakland/San Jose, 48.6% to Los Angeles/Long Beach/Anaheim, 7.4% to San Diego County, 3.6% to Sacramento, 9.7% to other urbanized areas. and 7.6% to rural areas (places With less than 2,500 residents.)

Survey Description.

Following Dillman (1978), the survey procedure consisted of three mailings. The first included an introductory letter which out1ined the purpose of the survey and assured confidentiality, a brief description/ directions sheet, two descriptive sheets on the mammal groups to be evaluated, a questionnaire, two yellow answer sheets, and a self-addressed stamped return envelope. The second mailing was a reminder postcard sent to those households from which responses had not been received. The third mailing was another letter accompanied by a second copy of the survey materials.

The four species of mammals which were described to the respondents are representative of marine mammals in California. All surveys requested responses for bottlenose dolphins, California sea otters, and northern elephant seals. However, half of the surveys also asked respondents to provide responses for gray whales, whereas half were asked to answer for blue whales. The first whale population is quite abundant and can be viewed easily on whale watching tours or from the coast, whereas the second is quite rare (some researchers believe the blue whale population to be beyond recovery) and virtually impossible for anyone but researchers to observe. These four particular species were chosen in order to represent a spectrum of attributes - appealing versus unattractive (sea otters versus elephant seals), visible versus inaccessible, large versus small, familiar versus unfamiliar, endangered versus non-endangered.

In the descriptions of the four species, the following information was provided:

(1) A typical picture of one or more animals in the wild. Appealing pictures or textbook drawings were avoided in order to approximate a typical viewing experience.

(2) A small map indicating the range of each population.

(3) A scale Of population levels and dates at which they have occurred in the past. For all mammals, the following scale applied:

A. a best estimate of the undisturbed population, before human activity. This scenario was dated to show when excessive hunting of the animal began off the California coast.

B. an incremental increase in the population above current level C, but below the historical maximum A.

C. the 1984 population level which exists under protective legislation.

D. a population level which reflects a best estimate of the historical low number of animals when hunting was allowed. This “no protection" case was dated to provided information on what happened to the populations when hunting was unregulated. (This was not relevant for dolphins since the California population has not been hunted.)

(4) History: A brief discussion of the anima1s and information on on whether or not they have been considered to be in danger because of human and/or natural causes.

(5) Current population: Estimates of the number of animals off the California coast and how these populations are changing.

(6) Worldwide: How the California population compares to the worldwide numbers of these animals. For example, are there many other animals of this same type found around the world? Or are most or all of this type of animal found along California's coast?

(7) Seeing the animal: How accessible the anima1s are for viewing and and photographing in the wild. The respondent was referred to the map which illustrates range. Also, some rough figures were provided on the average number of animals per square mile of ocean near the shoreline within the range for each of the situations A-D. The respondent was advised to use this information to get some idea of his/her chances of seeing the animals.

The questionnaire itself was divided into three parts--travel cost information, the CVM study, and socio-economic questions. In Part I, titled "Seeing the Animal," a brief orientation was provided in the introductory questions which ask respondents to report exposure to a species through communications media, captive display, or actual observation in the wild. (According to Dillman, as a means of encouraging respondents to continue, the first questions should be ones which require little effort and which will have "yes" answers for most people.) The remainder of this part attempted to identify travel behavior for respondents who reported recent observation in the wild; those who did not report recent observation were referred to Part II.

Part II, titled "Importance of the Animal," used the CVM to elicit valuation responses from both users (i.e., observers) and non-users. The responses to Part I and Part II were recorded on the first page of the yellow answer sheets. The respondents reread the questions in Parts I and II four times, answering all questions for whales first, then for bottlenose dolphins, California sea otters, and northern elephant seals. The answer sheet was divided into five columns. The first column gave brief instructions for each question, and each of the other columns provided answer spaces for the same questions asked for each of the four species. At the bottom of the answer sheet, a payment " bid card" (as suggested by Carson and Mitchell (1984) to allow respondents to focus on their bid without creating starting point bias) was provided for use in the WTP questions. Payment choices ranged from $0 to $200, with low values incremented by small amounts. Values from $20 to $100 were incremented by $5, and over $100 by larger amounts.

The second and final page of the answer sheets was entitled "About You." On this sheet, individuals were asked to provide confidential information on socio-economic variables: number of residents in the household, age and sex of respondent, employment and annual income, years of education, and whether or not hunting/fishing or membership in an environmental group applied to adult members of the household. Also, an "Avidity Scale" was described, on which respondents were asked to indicate their avidity on a 0-10 scale for each of the following: swimming, sailing, surfing, sunning at the beach; ocean activities which require a motorized boat; fishing for sport (shellfish and billfish) in the ocean; protection of ocean animal populations; protection of any animal population if endangered; and preservation of "wilderness" types of arias where no human development or machinery are allowed.

In the past, many valuation studies have utilized face-to-face interviews to collect data. However, budget constraints have led

PART II. IMPORTANCE OF THE ANIMAL

Please answer the following questions whether or not you have seen this animal in the wild or elsewhere. Some people believe that hunting (if allowed), pollution and fishing nets in the ocean could destroy many marine mammals. Some people even believe that without protection these animals might not survive in the ocean off the California coast. This animal is protected by government programs which, of course, have costs. The following questions are designed to find out how much your household values protection of this animal.

9. Please look at the chart shown on the left-hand side of the Description Sheet for this animal. The level marked C shows the current population size. Assume for a moment that this animal is no longer protected from hunting or other types of damage. Assume also that without protection, the population would fall to Situation D. This would of course, decrease your chances of seeing the animal and could also endanger the population. Please look over the descriptions about the animal as you think about moving from C to D. Suppose that the only way of avoiding Situation D is if households were willing to contribute to a fund specifically used for this purpose. Suppose also that each household in the nation were required to pay the average amount of all households' answers to the following question, rather then the actual amount of your response. What would be the maximum amount (in dollars) your household would be willing to pay per year into the fund to protect this animal and prevent Situation D? PLEASE CHOOSE YOUR ANSWER FROM THE PAYMENT CHOICES SHOWN AT THE BOTTOM OF THE YELLOW ANSWER SHEET.

10. Suppose a survey such as this was conducted, but the average responses to Question 9 did not provide enough funds to prevent Situation D. Please look at the payment choices at the bottom of the yellow answer sheet and indicate any additional amount over and above your response to Question 9 which your household would be willing to pay at most per year into the fund to prevent Situation D.

11. Your maximum yearly payment is found by adding together the numbers you gave in Question 9 plus Question 10. Please write this total next to #11 on your answer sheet.

The questionnaire was structured to avoid several potential problems. The discussion below addresses several areas about which criticisms of the CVM have been raised due the potential for bias.

Strategic Behavior

To reduce the likelihood of strategic behavior in the reporting of valuations, an incentive-free payment mechanism was introduced. Respondents are asked to report annual WTP for their household, given that the actual payment would be an average of all respondents valuations. Furthermore, to encourage true revelation of preference and avoid free riding behavior, the stipulation was made that all individuals would be required to contribute this amount in the hypothetical situation.

Even so, some strategic behavior could still exist on the part of individuals who strongly favor or disfavor the pub1ic good. Therefore, one reason for collecting socio-economic data later on in the survey is to enable us to identify outliers when the results are analyzed. This allows for some control on the few respondents who may attempt to behave strategically. Rational individuals who are not behaving strategically may be expected to report a maximum WTP which reflects perceived benefits at the margin. Perceived benefits, or utility can be expected to be a researchers to turn to mail and telephone survey techniques instead. Dillman (1978) describes a number of tested techniques which not only help to insure that interview bias does not result, but also enhance response rates. This survey incorporated many of these techniques; for example, each introductory letter was personally addressed and hand signed. Also, though budgetary limitations prohibited offering respondents any financial incentives for filling out their questionnaires, some incentive was provided by promising to send respondents a copy of the study results. However, Dillman also suggests the use of a booklet form for the questionnaire, ideally with an appealing cover illustration. Unfortunately, printing costs made this impractical for this CVM study. Because several species were of interest, a booklet would have been quite large if questions were repeated several times so that answers could be made on the booklet. Thus, it seemed more reasonable to use one questionnaire for all species, and employ one answer sheet which also made clear the idea that four different species were being valued but the approach was the same in all cases.

Methodological/Theoretical Issues

The initial contingent valuation questions are shown below. The individual is referred to the description sheets for the animal population and asked to state a willingness-to-pay amount to avoid moving from the current Situation C to Situation D. The payment vehicle of an earmarked fund was chosen to avoid the negative connotations which generally attend tax payments. Since we are referring to free roaming animal species, a user fee did not seem to be an appropriate payment vehicle, especially since it was not expected *a priori* that all households would have observed or plan to observe all of the species in the wild.

function of income and perhaps other variables. For example:

U(income, location of residence, family size, age, occupation, education previous exposure to marine mammals or other wildlife, avidity for marine recreation and/or wildlife conservation, etc.)

If econometric analysis indicates that an individual's WTP deviates significantly from the reported WTP of individuals with similar socio-economic characteristics, this may indicate strategic behavior and this data point can be removed (see Section V for a detailed discussion of this procedure).

However, as noted previously, strategic behavior is rarely identified in CVM studies. (For example, in a CVM study by Brookshire in which campers were asked to state their WTP to preserve a recreational site, the only case of strategic behavior appeared to be an economist who happened to be vacationing at the site with his family.) Generally, we would expect people to have little incentive to report biased WTP due to the hypothetical nature of the questions.

Hypothetical Bias

The willingness-to-pay questions were structured to provide as much consequence realism as possible. Population characteristics (threatened/ endangered status accessibility for viewers, uniqueness, range) were described in order to determine if respondents take such information into account when stating valuations for different species of mammals.

The first question, willingness-to-pay to avoid deterioration from the current Situation C to Situation D was based upon historical evidence of drastic reductions in the respective marine mammal populations when protection was neither funded nor enforced. To further encourage participants to provide considered WTP responses, individuals were asked to consider all monthly expenses (utilities and home expenses, entertainment, food and clothing, education, or charity) when making a final valuation estimate. This was included to counter a criticism of the CVM that individual's values are estimated in partial equilibrium.

The willingness-to-pay response to prevent deterioration from C to D can be depicted graphically using indifference curve analysis, as shown in Figure 2. If environmental degradation (reduction in marine mammal populations) is depicted along the horizontal axis, and (B_1, G_1) represents an individual's current position on indifference curve I_0, then the maximum WTP to prevent deterioration to X_1 is Y an equivalent variation measure (EV_D). In this case, the property rights do not rest with the respondent. However, the respondent may also be asked to state a willingness-to-pay to obtain an improvement from X_0 to X_1. The compensating variation measure (CV_I) will be equal to EV_D for the same change in environmental quality. Thus, it is valid to state the willingness-to-pay question in terms of either the deterioration or improvement situation since the magnitude of the stated value will be the same in either case.

Payment Vehicle Bias

In order to avoid protests due to use of increased tax payments as a payment vehicle, individuals were asked to state WTP into a preservation fund to be used to protect marine mammals.

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Information Bias

Given our desire to encourage a higher response rate by limiting the survey's length, we provided as much information on each species as one-half page would allow. This included the historical setting, population status and location, potential for siting, and a picture of the animal. Every effort was made to avoid making sympathetic statements about endangered species or to show aesthetically appealing pictures/scenes which would not be viewed in actual sitings in the wild.

Protests

Aside from individuals who wrote to say they could not or would not respond, we also used the following question to identify protest bids:

12. On the first yellow answer sheet, please circle the answer from the choices below which best describe your reason for responding to Questions 9 and 10 as you did.

    A. CHOSE BEST ESTIMATES OF WHAT SHOULD BE PAID TO PREVENT SITUATION D.
    B. DO NOT FEEL WE SHOULD PAY, BUT THE GOVERNMENT SHOULD.
    C. THE FUND DESCRIBED IS AN INAPPROPRIATE WAY TO PROTECT THIS ANIMAL.
    D. COULD NOT AFFORD ANY MORE.
    E. UNWILLING TO ESTIMATE DOLLAR AMOUNTS EVEN THOUGH HOUSEHOLD VALUES THIS ANIMAL.

Those respondents who stated a zero WTP, and also answered "B", "C", or "E" were identified as protestors and were removed from the sample.

ANALYSIS OF RESULTS

In response to the first mailing and follow-up reminder cards, 121 questionnaires were completed and returned. After the final mailing in which a second copy of the questionnaires was enclosed for individuals who had not yet responded, a total response rate of 21%; was achieved. Of this total, eleven were identified as protests either by the response to the control question or by the respondent’s written explanation. (This included some, but not al1, of the zero WTP responses received). Fourteen individuals either misunderstood the questionnaire or filled out only portions of it.

There remain 180 usable responses for whales (93 gray and 87 blue), 175 for dolphins, and 174 for sea otters and elephant seals (i.e, some individuals filled out their questionnaire for only some species, leaving the others blank).

Contingent Valuation Responses

Missing values for all variables except the WTP data were replaced by estimates derived by using the modified first order regression method for estimating missing observations. Madalla (1977) reports this is the preferable method when the correlation between variables is less than 0.5. A preliminary inspection of the correlation matrix without missing observations indicated low correlation values. The value of the maximum WTP per year per household (question #11) adjusted by reported values for #14a (adjustment to WTP after discussing income constraints) is used as the final WTP estimate. Means and standard deviations for WTP were calculated for each of the four species, by survey group (blue whales or gray whales in the first column). The eight groups were viewed separately at first to determine whether the effect of having blue whales versus gray whales resulted in statistically different responses for each of the four species. Mean values with standard deviations are reported in Table 1.

Using Student's t-tables, equality of means by species was tested with the following results (t-statistics, degrees of freedom are shown in parentheses below):

H_o: Gray Whales = Blue Whales (-0.237,178)

H_o: $Dolphins_G = Dolphins_B$ (-0.167,173)

H_o: $Sea\ Otters_G = Sea\ otters_B$ (-0.162,172)

H_o: $Elephant\ Seals_G = Elephant\ Seals_B$ (-0.21,172)

In all cases, the null hypotheses are accepted at a confidence level greater than 99%. Data were then pooled into four groups, by species.

Since some previous analyses of the results of mail surveys have provided evidence that responses from follow-up mailings do not affect the results derived from responses to initial mailings (see Goudy 1978 and Wellman et al. 1980), we compared the WTP responses and the answers to socio-economic questions from the first 121 respondents (Data Set I) to the responses received after the final mailing (Data Set II). Because there is no reason to believe *a priori* that the two data sets are not independent samples, a t-test was performed on the difference in means for each species in the early data set and late data set. The results shown in Table 2 indicate that the responses received after the final mailing were not statistically different (confidence interval exceeding 99%) than those received earlier. Furthermore, responses to socio-economic characteristics in Data Set I were compared to those in Data Set II. For every variable, a t-test on the difference in means indicated that the socio-economic characteristics of early respondents were not statistically different than the characteristics of later respondents. However, in order to decrease the chances of making a Type I or II error, the entire sample was used for analysis in the discussion which follows.

Mean responses to the Initial willingness-to-pay question (#9) are shown In Table 3 for the four species. These values reflect the initially stated annual WTP per household. In order to investigate the bidding behavior of respondents, t-statistics were estimated, by species, to determine if the mean response to question #10 is significantly different from zero. This question asked the respondent to state any amount he/she would be willing to pay over and above the WTP stated initially in order to assure the present situation (marine mammal protection) as opposed to the no protection scenario. The t-statistics are reported in Table 4. Furthermore, a similar test was performed on responses to #14a, the bid adjustment after the respondent's income constraint is discussed as follows:

14. Consider for a moment your household's budget. Some of the expenditures which which you are currently making would have to be reduced if you made your payment in Question 11 to prevent Situation D. With this in mind, would you like to revise your payment into the fund?

If NO, skip to Question 15.
If YES:

14a. Looking at the payment choices on the bottom, how much would you like to revise your payment? (For example, +50¢/year or -$1.00/year.) Please continue to Question 15.

15. If your household is still choosing to pay some amount into the fund for this animal, which of the following budget categories would you reduce in order to pay into the fund?

A. Utilities and home expenses
B. Entertainment
C. Food and clothing
D. Educational expenses
E. Charity contributions to other causes

Inspection of Table 4 reveals that the original willingness-to-pay is, in fact, much smaller than maximum willingness-to-pay (#9 and #10) (elicited by the question: "Suppose...the average responses...did not provide enough funds to prevent Situation D...Please indicate any additional amount over and above your [initial] response...") Previous studies (Schulze, Brookshire et al. (1983), Desvousges et al. (1983) and Burness et al. (1983), for example) have observed the same result, so that we conclude that the "bidding process" is important if the CVM is to provide evidence on maximum WTP. Furthermore, though the introduction of the household budget (Question 14) did result in some apparent decrease in WTP for each species, except sea otters, it turns out that these adjustments were not statistically different from zero. This result has been observed in previous studies (Burness et al. 1983 and Schulze, Brookshire et al. 1983.) It can be viewed as some evidence that Individuals provide considered information on their valuations to the preceding maximum WTP question under contingent conditions. In Cummings et al. (1984), it is suggested that finding this result is evidence that the application of CVM indicates that the WTP response is a "preference-researched bid" rather than a random number, and that income/commodity trade-offs were considered by respondents when they offered responses. Although this is not a complete counter to the issue of hypothetical bias, it does provide some evidence of introspective reporting of individuals' WTP values for marine mammal protection.

In order to include the preferences of those respondents who made adjustments to the WTP estimates, the adjusted value (Q11 ±Q14a) is retained for the remainder of this analysis. The correlation matrices for WTP, by species, and the socio-economic variables are shown in Tables 5, 6, 7 and 8. The following variables are defined as:

$$EXP = 1 + 2 + 3 + 4$$

$$AVM1 = (AV26 + AV27 + AV28)/3$$

$$AVM2 = (AV29 + AV30 + AV31)/3$$

These are indices, where EXP represents exposure to the mammal through the media, captive display, and on-site observation. This is the sun; of the respondent's answers to Questions 1, 2, 3, and 4, where yes = 1 and no = 0. The two average measures of avidity AVM1 and AVM2, are indices of enthusiasm for marine recreation and wildlife/nature conservation, respectively. AVM1 is the average of responses on the 0-10 scale in Questions 26-28; AVM2 is the average of responses on the 0 - 10 scale in Questions 20 - 31. Zero represents no avidity and 10 represents extreme avidity.

Inspection of Table 5 provides some information about the impact of the socio-economic characteristics on maximum WTP. Exposure to the mammals, avidity for marine recreation, and membership in environmental groups have very low, positive correlations with the willingness-to-pay responses. Mileage to the coast (the horizontal distance from city center of residence to the coastline) has an extremely low, negative correlation with WTP. Avidity for wildlife/nature conservation is somewhat more correlated with WTP, but the value though positive, is still quite low. Even income and education have fairly low correlations with WTP (though presence of outliers could be affecting this relationship.) Age is negatively correlated with WTP possibly due to the impact on WTP of responses by retired persons on fixed incomes.

Before proceeding with a discussion of the maximum WTP estimates, we must address the common criticism that some individuals who strongly favor or disfavor the public good being valued may have attempted to bias the results when reporting their WTP values. Even if we argue that the hypothetical nature of the study reduces the incentive for such intentional behavior, it is this hypothetical nature which could instead cause individuals to mistakenly misstate their true willingness-to-pay. A way to reduce these possibilities is to identify probable outliers in the data set and remove those responses. One method might be to simply eliminate observations which lie some X (say 10) standard deviations from the mean. However, this adjustment to the sample seems rather arbitrary and does not allow for any consideration of the respondent's characteristics (which could affect her/his stated WTP) relative to other respondents in the sample.

In this study, identification of likely outliers is accomplished by using a diagnostic technique suggested by Belsley, Kuh and Welsch (1980). Use of the technique requires first, regressing explanatory socio-economic variables on the WTP estimates for all observations. In CVM studies, application of ordinary least squares (OLS) regression analysis to estimate WTP has generally yielded R values of 0.3 or less using cross-sectional data. The reason these regressions have little explanatory power is that utility functions which determine values for public goods tend to be highly individualized. In our example, we might hypothesize that residents nearer to the coastline would value marine mammals more highly than inland residents. However, there may be many inland residents who value the mountains and undeveloped nature, so that they too report a high value for species in general, including marine mammals. Thus, we would expect a variable like miles from the coast to have a negative coefficient when regressed on WTP, but it may not have a strong or even statistically significant effect.

WTP = f(EXP, MC, FSZ, AGE, Y, AV2)

where: WTP = Q11 ± Q14a
EXP = exposure to the animals through the news media, captive display, or on-site observation
MC = mileage of town of residence to the California coast
FSZ = family size; number of residents in the household
AGE = age of respondent
Y = annual household income
AVM2 = avidity index for species preservation/conservation

The other avidity type of variable, such as membership in environmental organizations and AVM1 were not included because they did not appear to affect WTP. Furthermore, they may be measuring the same effect as AVM2. The education variable was not included because, on theoretical grounds, it is too closely associated with income and could cause multicollinearity.

All data except miles to coast were taken directly from the returned answer sheets. Miles to coast were determined to be the horizontal map distance from the respondent's town of residence to the California coastline. A priori, we would expect exposure, income, and avidity to have a positive effect on WTP, and inspection of Table 6 reveals this to be the case. Family size decreases WTP, perhaps because it lowers per person income. (Inclusion of Y/FSZ rather than Y reduced the explanatory power of the equations.) As age of the respondent increased in this data set, WTP was reduced. This could be the result of having several retired individuals in the data set on fixed incomes. The coefficient on mileage to the coast has a negative sign, but it is never a significant variable based upon the t-statistics shown.

As shown in Table 6, removal of likely outliers resulted in an improved R^2 and also a statistically significant coefficient on income, as we would expect intuitively. Although the high standard error which results from the use of a cross sectional data set such as this does not allow use of these regression results to predict bids, the procedure does allow the removal of likely outliers, which enhances the reliability of the WTP estimates derived from the remaining data. In Table 7, a profile of the likely outliers is shown. For purposes of comparison, mean values for the remaining data set are provided in Table 8. Below, an index is provided for the questions for which mean response values are shown in Tables 7 and 8.

However, if an OLS regression has some theoretical justification (e.g., income has been shown to affect WTP in many previous CVM studies), it can be used to identify outlying observations. Belsley, Kuh and Welsch have developed a statistic which essentially re-estimates the coefficients in the WTP equation sequentially without each observation. If an observation significantly changes the coefficient that response is identified as a likely outlier. This technique has been applied in two previous CVM analyses, (Desvousges et al. 1982 and Brookshire et al. 1984). It seems an essential step since the possibilities of strategic behavior or hypothetical bias could result in incorrect valuations reported by some respondents.

After performing an OLS regression on the maximum, WTP responses for each species, we calculated (nxm) B-K-W statistics, one for each variable and each respondent on a particular species. Because economic theory supports the notion that WTP should be determined, to some extent, by income we used the B-K-W statistics on income as our gauge to identify outlying observation Following Desvousges et al. (1982) and Brookshire et al. (1984), the B-K-W statistic for a particular observation divided by the regression coefficient on income exceeded 03, the observation is labeled a likely outlier. The Interpretation is that the B-K-W statistic indicates that this observation alone caused a change in the coefficient on income in excess of 30%. The 30% gauge was a natural cut-off point in this study, since almost all coefficients were affected by less than 20% for all variables.

For all species, the same two individuals' responses were identified as outliers. In addition, a third respondent was Identified as an outlier in the dolphin and sea otter data sets. In other studies utilizing this technique, some outliers were identified which had WTP values very near the mean (i.e., if a respondent’s stated WTP was extremely unusual given his/her socio-economic make-up relative to similar types of respondents); however, in this study the outliers identified were, in fact, only the very high bids received. (For example, one respondent who bid $4QO/year wrote to say that the individual was strongly in favor of wildlife conservation, but expressed concern that similar households would respond by over-estimating true WTP.)

In Table 6, results of the OLS linear regression procedures are shown for the independent explanatory variables before identification of outliers and then after outliers have been removed from the data set. Based upon a preliminary inspection of the correlation matrices, the following variables were included:

The socio-economic profile of survey respondents is similar to that of average Californians. Based upon 1980 census figures, average household size is 2.68; for our respondents, the average is 2.67. Average age of the respondents is about 42 years; this compares to an average of 43.5 for the adult (over 19) population of California, as reported in the California Almanac (Fay et al, 1984). Average income per family for 1984 in California is $32,602/year (again, inflating 1980 Census figures to 1984 dollars.) Therefore, the average income of the survey respondents, approximately 635,000 per year, is near that of the general population of the state. Average education of respondents is 15.3 years (± 2.9), compared to a statewide average of 12.4 years in 1980. Again, the survey respondents exhibit a similarity to the general population of California.

The information gathered on avidity shows that the mean response to the questions about enthusiasm for marine recreation activities (AV26 - 28) is at or below the mid-point of 5. Mean avidity responses for wildlife/ wilderness preservation (AV29-31) were above the midpoint but below the maximum. In order to make comparisons between respondents' and average Californians' avidity for marine recreation/resources, a telephone survey was conducted. An independent sample of 425 California households was chosen, distributed over all areas of the state population of California. Respondents to the telephone survey answered questions only related to avidity, as shown below:

Hello,

My name is ______________________________. I'm a student at San Diego State University, and I'm working on a project to find out how Californians feel about ocean resources and recreation in our state. If you don't mind, I'd like to ask your opinion on six questions. It will only take two or three minutes of your time

Picture a scale from 0 to 10 on which you can rank your avidity (desire or enthusiasm) for the things I'll describe. 0 means no avidity. 10 means extreme avidity. 5, or course, is something in between the two extremes.

On this scale, please give me the number from 0 to 10 you'd choose to represent your avidity for:

Q-1 Swimming, sailing, surfing, and sunning at the beach, 0 to 10?
Q-2 Ocean activities which require a motorized boat, 0 to 10?
Q-3 Fishing for sport in the ocean (for example, shellfish and billfish), 0 to 10?
Q-4 Protection of ocean animal populations, 0 to 10?
Q-5 Protection of any animal population if it is endangered, 0 to 10?
Q-6 Preservation of wilderness types of areas, 0 to 10?

That's the last question. Thank you very much for your time.

No mention of marine mammals was made so that responses would reflect general avidity for the activities/issues discussed. However, the six questions asked were identical to the last six questions (26-31) on the mail survey. Eighty-three percent of the households called were at home; of these, 71% answered all six questions. The following averages from 250 Californians' responses were obtained.

	Telephone Survey		Mail Survey	
	Mean	Standard Deviation	Mean	Standard Deviation
AV26	7.1	2.9	5.5	3.2
AV27	4.9	3.4	2.6	3.1
AV28	5.3	3.6	2.0	2.7
AV29	8.8	1.9	6.9	2.7
AV30	9.2	1.7	7.3	2.6
AV31	9.1	1.5	7.8	2.6
AVM1 (Average of 26, 27, 28)	5.8 1	2.6 1	3.4 1	3.0 1
AVM2 (Average of 29, 30, 31)	9.1	1.5	7.3	2.6

Hypothesis tests for equality of means between the two surveys indicate that the mean avidity values reported in the mall survey are not statistically greater than the mean values for avidity stated in the telephone survey (greater than 99% confidence for all questions). This result provides further evidence that the respondents who mailed their valuations for marine mammals are no more avid about marine resources or environmental protection than the typical California household.

Data on the miles to coast variable were not provided by the respondents. These were calculated by estimating the horizontal distance from city centers of residents in the sample to the California coastline. At the outset of the study, every effort was made to draw survey names from cities and towns around the state based upon the total population distribution. For the surveys mailed, the miles to coast from city centers averaged 21.8 miles, largely due to the fact that 78% of the population lives in the San Francisco, Los Angeles, or San Diego Areas.

Although information on the average distance of residence from the coast for all California residents is not readily available, we were able to tabulate what proportion of the population lives within 100 horizontal miles from the coast. It turns out that 95.7% of Californians reside in cities whose centers are 100 horizontal miles from the coast, whereas 99.1% reside within 130 miles from the coast. This is relevant for our study because over 12% Of the respondents who returned completed questionnaires lived in excess of 70 miles from the coast, and maximum mileage was 130 miles (3 respondents.)

In Table 9, the means and standard deviations of the maximum WTP responses are shown, stated by respondents as the amount per household per year. These are the values _after_ likely outliers have been identified and removed using the B-K-W procedure discussed above. For purposes of comparison, the values for the entire data set are shown in parentheses. When outliers are removed from the data set, mean WTP estimates decline somewhat with a rather dramatic decrease in their standard deviations. This reduces the coefficient of variation (standard deviation divided by expected value) by 22% for whales, about 33% for dolphins and elephant seals, and 50% for sea otters.

The overall mean WTP across all species is $20.21. Since most respondents, 171 out of 178, provided WTP estimates for all four species we can pair those responses by species and calculate t values to determine if the differences in responses from one species to another were significantly different from zero. The results are shown in Table 10. (Since the same respondents answered for all four species, these four mean values were not drawn from independent samples, and so a t-test on the difference of means would not be valid.)

These results indicate that respondents appear to have made some distinction in reporting WTP for different species. The difference in mean values reported for whales and sea otters is not significantly different from zero, but the difference between whales and dolphins or elephant seals is significantly greater than zero. Likewise, the difference between mean WTP for sea otters and elephant seals is significantly greater than zero, and approximately so for the difference between the means of WTP for sea otters and dolphins also. However, the difference between mean WTP for dolphins and elephant seals is not statistically greater than zero.

There might be several reasons for the evidence of some statistically significant differences in WTP between species shown in Table 10. It might be argued that gray whales and sea otters are easier to observe in California and therefore may have more non-consumptive use value. However, blue whales were generally not seen by respondents, yet mean values for them were statistically the same as for gray whales. Also, public exposure to bottlenose dolphins is probably as great, since the wild population lives within a few hundred yards of southern California beaches and the popular dolphin shows at oceanaria also use bottlenose dolphins. Thus, if WTP were attributable largely to " cuteness" and "intelligence", it would seem that bottlenose dolphins would rank at least as highly as sea otters.

One difference which may explain the relatively higher mean valuations for whales and sea otters could be current population status, as described in the species information sheets. Sea otters are a threatened species and are found in California in very small numbers; the same is true for blue whales. This, is not true for gray whales, though heightened public awareness about the past endangered condition of the species off California’s coast may affect public values regarding this species.

CONCLUSIONS AND CAVEATS: SOME THOUGHTS ON APPLICATION OF CVM RESULTS

Program Benefits: Aggregating over Affected Households

In Table 9, evidence is provided from the CVM study that the average willingness-to-pay per household in the sample is $23.95, $17.73, $20.75, and $18.29 for protection of the current populations of gray and blue whales, bottlenose dolphins, California sea otters, and northern elephant seals, respectively . Although the payments for whales and sea otters are statistically greater than payments for dolphins and elephant seals, indicating that respondents value these species differently, it might not be true that this implies a total average WTP of $80.72 for all four mammal populations (the sum of the individual averages). Kahneman (1984) has suggested that because of their inexperience in making direct payments for environmental goods, individuals may be drawing upon an “environmental account” in the case of each stated WTP.

Along these lines, we might reason that since the initial instructions to the individual explained that the purpose of the survey was to elicit public valuations for marine mammal protection programs, then some basic amount is budgeted to the "marine mammal protection account" (say, for example, an average amount of $10), and additional amounts represent the respondent's willingness-to-pay for protection of the specific species of mammal discussed. The sum of these marginal benefits from protection of each species would then be the maximum willingness-to-pay for all marine mammals protected.

However, even if this were the case, we do not have information on the proportion of the WTP estimates reflecting the general "marine mammal account." Thus, to avoid over-estimating societal benefits attributable to marine mammal protection programs, we will use only one WTP estimate in aggregating over all California households. Assuming the respondents' average WTP of $23.95/year per household for whales is representative of average Californian households, and including only households in cities within 100 horizontal miles from the coast (95.14% of the total), we arrive at the following measure of program benefits to Californians:

$$\text{Annual Aggregate Benefits} = \$23.95 \times (23{,}667{,}902/2.68).9514$$
$$= \$201.23 \text{ Million (1984 dollars).}$$

This estimate of annual program benefits, slightly greater than 200 million dollars is an aggregate for California households where the 1980 Census of Population for California is divided by 2.68 persons per household. This measure of benefits is for Californians only. It may be that residents of other states also benefit from marine mammal protection, but only a national CVM study would determine the average value of national WTP.

The reliability of this estimate of aggregate benefits in California depends upon first the existence of bias in the WTP estimates, and second the extent to which average respondents' values represent average Californians'. With respect to bias, every attempt was made to encourage informed responses by furnishing information about the marine mammals being valued. Furthermore, accepted techniques were utilized for discouraging strategic behavior. To further reduce the effect of strategic and/or hypothetical bias, likely outliers were identified and removed. Evidence is presented that individuals had considered income/commodity trade-offs when stating their maximum WTP values because they did not significantly adjust their bids when given the opportunity to re-evaluate within their income constraint. Also, individuals' behavior was in accord with theoretical precepts; i.e., the WTP values shown in Table II for increments to the marine mammal populations are diminishing, as we would expect for situations of decreasing scarcity.

A problem with mail surveys of this type is the low response rate. While surveys mailed to special interest groups generally attain response rates of 75% or greater, this type of survey must, of necessity, be directed at a random sample of the population. As a result, CVM researchers mailing questionnaires to a random population rarely attain response rates in excess of 35%. This may lead to questions about the representativeness of the responses relative to the average individuals; for example, if only overly concerned individuals returned their questionnaires, then the WTP averages may be upwardly biased. In this study, inspection of the socio-economic characteristics in Table 8 leads us to posit that respondents are in fact, representative of average Californians. This position is further supported by the fact that respondents' avidity for marine recreation and environmental issues was no stronger than avidity rankings provided by Californians in an independent telephone survey.

Appropriate appplication of CVM results must address the issue of the relevant population over which aggregation is performed. In this estimate, we included most of the population of California since our survey responses were returned from a large spectrum of areas, urban and rural, north and south, and beach and non-beach communities. Most importantly, there was almost no correlation of the stated willingness to pay with the respondents' distance of residence from the coastline. Thus it seems reasonable to aggregate over 3.1 million of California's 8.3 million households. Furthermore, it may be that residents of other states also benefit from marine mammal protection, but a national CVM survey was not conducted. However, in their whooping crane valuation study, Stoll and Johnson (1984) found that option price/existence value reported by out-of-state non-users was 75% - 100% of the option price/existence value reported by in-state residents.

Valuing Individual Species of Marine Wildlife

In some instances, damages to an individual species may require valuation of one animal population. For example, the California sea otter is listed as a threatened species due to its susceptibility to potential oil spills in the marine environment. Again, based upon Kahneman's (1984) environmental account framework, we might posit that respondents in a CVM

The Existence of Existence Value

The results in Table 12 have important policy implications. Even when there has been no “use,” individuals still explicitly stated that option price/existence value associated with marine mammals is 15.2 times as great as use value for northern elephant seals, 9.3 times as great for blue and gray whales, and 7.4 times as great as use values reported for bottlenose dolphins and sea otters. Pure existence value, without any current or future option to observe the wildlife populations, is 11.6 times as great as use value for the seals, 7.3 times as great for the whales, and 5.5 times as great for the dolphins and sea otters. These results provide evidence that existence values for marine wildlife, where all on-site “use” is precluded, are significantly greater than use values, and they vary for different environmental goods. Even if marine mammals are inaccessible for viewing and impart no regional tourism impacts, societal damages due to marine pollution can still occur. Evidence of the mmeasure of such damages can be found by investigating the existence values which households attach to preservation of marine mammal populations.

Exp. 1:	journalistic media exposure to the animal yes = 1; no = 0 (whales, dolphins, sea otters, elephant seals)
Exp 2:	exposure to live animals in captive display yes = 1; no = 0 (whales, dolphins, sea otters, elephant seals)
Exp 3:	exposure to the animals in the wild yes = 1; no = 0 (whales, dolphins, sea otters, elephant seals)
Exp 4:	exposure to the animals in the wild off California's coast in 1983 yes = 1; no = 0 (whales, dolphins, sea otters, elephant seals)
MC:	number of miles residing from the California coast
Fam. Size:	number of residents in the household
Age:	age of respondent
Sex:	sex of respondent female = 1; male = 0
Income:	annual household income
Education:	respondent's years of education
Hunt/fish:	any hunting/fishing done by a household member? yes = 1; no = 0
Env.Org.:	any resident a member of an environmental organization?
AV26-28:	Avidity scales for non-fishing and fishing marine recreation 0 = none; 10 = extreme avidity
AV29-31:	Avidity scales for species conservation and wilderness preservation 0 = none; 10 = extreme avidity

The response data in Table 8 warrant some discussion on the ability of surveys to elicit information about WTP to protect specific wildlife groups. Familiarity with the animals through communications media (Exp 1) is quite high, near 80% for all groups except the northern elephant seal about which only 60% had previous information. Of interest are the number of yes response to the other three exposure categories. For whales, 30% of the respondents reported seeing gray or blue whales in live captive displays, and 47% reported having seen northern elephant seals. The former is impossible and the latter highly unlikely. Furthermore, while reporting of 1983 on-site sitings of dolphins and sea otter (Exp 4=23% of respondents) is reasonable, some of the individuals who sited whales were those with blue whale questionnaires. Also, 23% reported on-site observation of northern elephant seals. Again, the two latter sitings are highly improbable for anyone but trained biologists. Thus, if we believe respondents are attempting to answer honestly, we might hypothesize that they are able to distinguish by sub-orders, since the pictures and information supplied should allow respondents to group animals into categories such as whales, dolphins/porpoises, sea otters, and seals/sea lions. However, at least some respondents are either unable or unwilling to make the more narrow species distinction (e.g., northern elephant seals) requested in this survey.

survey may be stating some amount which is a base amount for the wildlife category in general. The similarity of stated willingness to pay for each of the four mammal groups lends some suppport for this hypothesis, though it does appear that some additional amount over and above the "base" is added for particular species of marine wildlife. If, for example, we posit that the base amount is, at most, that stated for the least valued species in the survey, the dolphin, then the additional amount stated as a willingness to pay strictly for protection of the California sea otter is the difference -- or $3.02 per household annually (see Table 9). Aggregating over 8.4 million households in California, the annual societal value attached to preservation of the California sea otter is approximately $25.4 million. Again, this estimate does not include values which may exist for non-Californians; in the case of this animal, such values undoubtedly exist for some individuals, as evidenced by a worldwide membership in and contributions to a non-profit organization formed to support actions to protect the sea otter.

Valuing Incremental Changes in Marine Wildlife Populations

A difficult valuation task is that of determining societal losses associated with incremental reductions in wildlife populations in the event of a marine pollution incident. Although this study looked at animal population reductions only in the context of reducing the species' to historical lows before protection programs were enforced, some evidence of individuals' ability to place values on incremental changes (but improvements) in the marine environment is provided in Table 11.

The WTP responses reported in Table 9 were elicited by a hypothetical situation wherein respondents were asked to estimate their willingness-to-pay to avoid a reduction in the mammal populations below current levels without public protection programs. Respondents were also asked to provide estimates of WTP to obtain incremental increases in the levels of current mammal populations. Given that Situation C is defined as the current population level, Situation B is an increment over the current level (between C and A), and Situation A is a final increment up to the historically high level (before hunting by non-natives). The WTP responses to the questions (Question 16: C → B, Question 17: B → A) are shown in Table 11. Again, it appears that responses are generally higher for whales and sea otters than for dolphins and elephant seals.

Although the willingness to pay values shown in Table 11 are for increases in the marine mammal populations, it does appear that the respondents exhibit diminishing marginal utility when valuing incremental changes. Furthermore, it may be reasonable to assume that the stated WTP values for increments to the populations are rough estimates for decrements to those animal groups, if the decrements are not large enough to reduce the populations to the endangered levels (as in the values shown in Table 9). Also, future research efforts could incorporate questions on willingness to pay to avoid incremental losses in marine wildlife populations.

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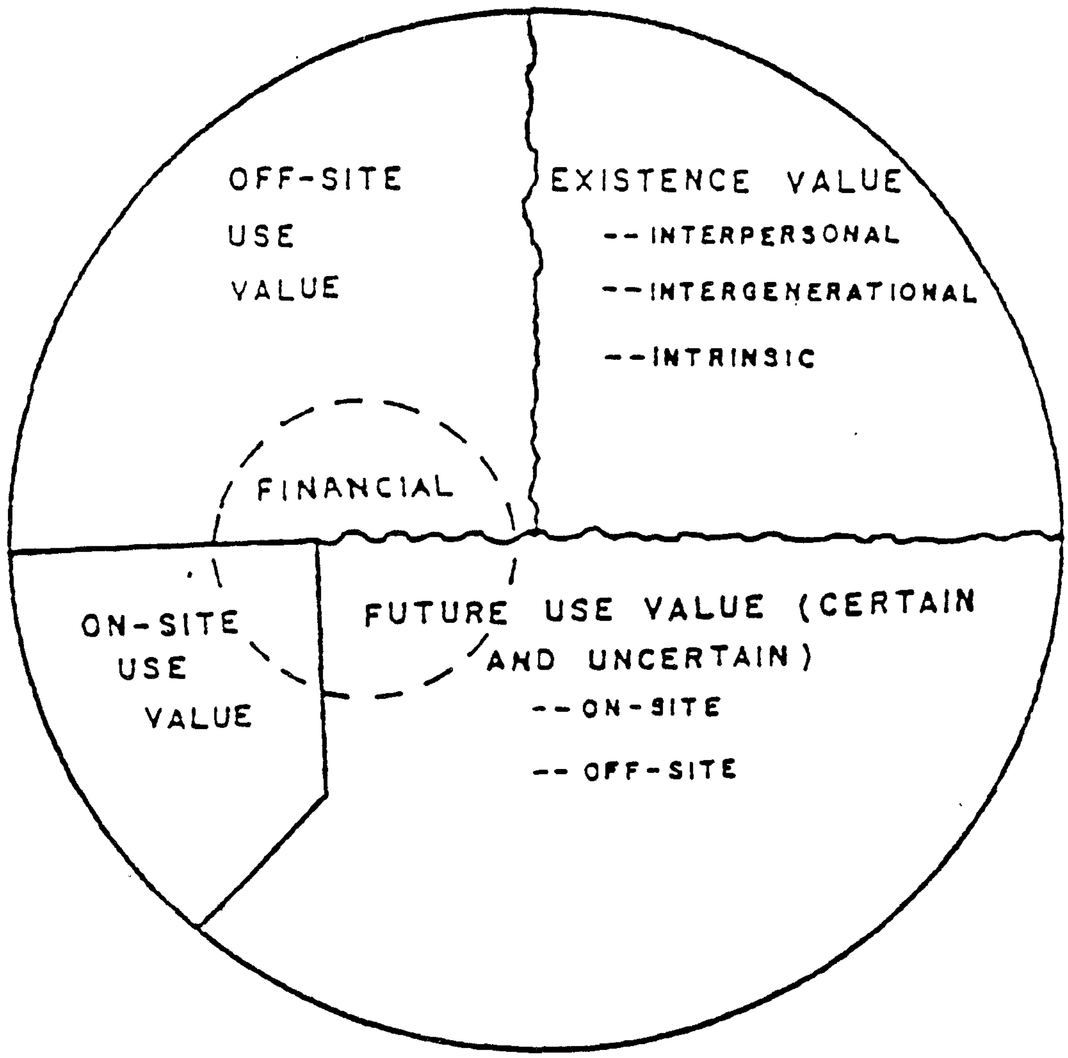

Figure 1. Total value framework.
(from Randall and Stoll, 1983)

Table 1. MEAN WTP/YEAR PER HOUSEHOLD, BY SURVEY GROUP

Gray Whales first
n=93

	Gray Whales	Bottlenose Dolphins	Sea Otters	Elephant Seals
Mean	$26.98	$22.00	$26.12	$21.69
Standard eviation	49.10	43.61	45.38	41.46

Blue Whales first
n=87

	Blue Whales	Bottlenose Dolphins	Sea Otters	Elephant Seals
Mean	$28.78	$23.16	$24.97	$23.13
Standard Deviation	52.56	48.26	48.40	49.06

Table 2. MEAN WTP/YEAR PER HOUSEHOLD, BY RESPONSE GROUP[a]

	Whales Blue and Gray		Bottlenose Dolphins		California Sea Otters		Northern Elephant Seals	
	I	II	I	II	I	II	I	II
Mean	$28.98	$26.15	$25.86	$17.62	$27.63	$22.49	$25.03	$18.46
Standard Deviation	56.58	40.54	56.11	22.43	57.09	24.37	55.82	20.89
t-statistic[b] (degrees of freedom)	.37 (178)		1.17 (173)		.71 (172)		.94 (172)	

[a] Response Set I received after initial mailing and reminder; Response Set II received after final mailing.

[b] The null hypothesis, $mean_I = mean_{II}$, is rejected for $t \geq 2.617$ (99% confidence).

Table 3. INITIAL BID[a]

	Whales Gray and Blue	Bottlenosed Dolphins	California Sea Otters	Northern Elephant Seals
Mean	$16.29	$13.90	$15.47	$13.57
Standard Deviation	27.12	25.68	26.69	25.02

[a] Responses to question #9. (See the survey, Appendix to Chapter IV.)

Table 4. ADJUSTMENTS TO BID[a]

	Whales (Gray and Blue)		Bottlenosed Dolphins		California Sea Otters		Northern Elephant Seals	
	#10	#14A	#10	#14A	#10	#14A	#10	#14A
Mean	+$12.34	-$ .77	+$ 9.29	-$ .62	+$ 9.96	+$ .13	+$ 9.23	-$ .42
Standard deviation	**27.59**	7.22	22.74	6.28	22.67	7.86	22.63	4.61
t statistic[b]	6.0	1.4	5.4	1.3	5.8	.2	5.4	1.2
(degrees of freedom)	(179)		(174)		(173)		(173)	

[a] See questions #10 and #14A in the survey, Appendix to Chapter IV.
[b] The null hypothesis, that the mean value shown is significantly different from zero, is rejected for $t \geq 2.617$ (99% confidence).

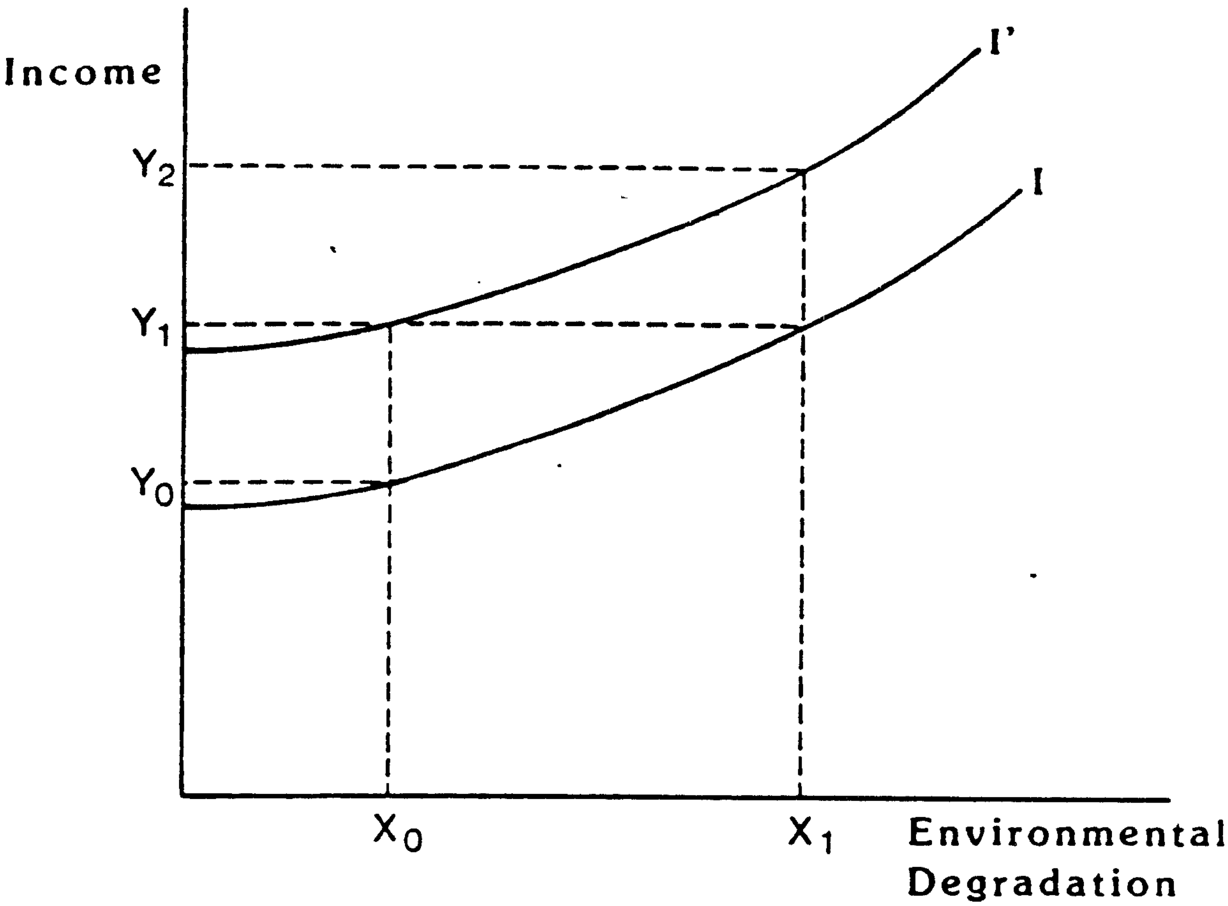

Figure 2. Comparison between willingness-to-pay and willingness-to-accept for changes in environmental quality.

Deterioration: $X_o \rightarrow X_1$

Maximum WTP = $EV_D = Y_1 - Y_o$
(property rights do not rest with respondent
Minimum WTA = $CV_D = Y_2 - Y_1$
(property rights rest with respondent)

Improvement: $X_1 \rightarrow X_o$

Maximum WTP = $CV_I = Y_1 - Y_o$
(property rights do not rest with respondent)
Minimum WTA = $EV_I = Y_2 - Y_1$
(property rights rest with respondent)

Table 5A: CORRELATION MATRIX, WHALES (GRAY AND BLUE)

	WTP	EXP	Miles	Fam.Sz	Age	Sex	Income	Educ.	Hunt/fish	Env.Org.	AVM1
WTP	1.										
EXP	.09	1.									
Miles	-.04	-.10	1.								
Fam. Sz.	-.05	.02	.03	1 .							
Age	-.15	.02	.02	-.01	1.						
Sex	.05	-.14	.11	.13	.08	1.					
Income	.09	-.04	-.05	-.43	-.12	-.11	1.				
Education	.12	.03	-.14	.16	-.18	-.19	.22	1.			
Hunt/fish	-.01	-.04	.15	.25	.23	-.01	-.10	-.22	1.		
Env. Org.	.09	.12	.06	-.23	.21	-.01	.03	.21	.02	1.	
AVM1	.16	.13	-.09	-.06	-.31	-.06	.01	.09	.37	.03	1.
AVM2	.24	.20	-.06	.03	.06	.04	.19	-.14	0.05	.33	.36

Exposure → (EXP)

avidity index (AVM1)

scale 0 to 10
how avid on ocean based recreation AVM1

about wildlife preservation AVM2

Table 6. ESTIMATED COEFFICIENTS, OLS REGRESSIONS
DEPENDENT VARIABLE=WTP (Q 11±Q 14A)
(t-values in parentheses).

	Whales (Gray and Blue)		Bottlenose Dolphin		California Sea Otters		Northern Elephant Seals	
	All Data	Without Outliers	All Data	Without Outliers	All Data	Without Outliers	All Data	Without Outliers
Constant	4.89	.98	4.94	-3.22	4.58*	-1.28	2.65	4.77
EXP	2.27	.84	4.33	3.65*	4.60	3.04*	5.72*	1.57*
	(.68)	(.43)	(1.58)	(2.64)	(1.77)	(2.16)	(2.38)	(1.21)
MC	-.003	.001	-.419	-.54	-.05	-.01	.03	.03
	(-.27)	(.16)	(-.38)	(-.98)	(-.46)	(-.20)	(.28)	(.47)
FSZ	-2.96	-1.34	-2.97	-1.20	-4.11*	-2.26*	-2.28	-1.16
	(-1.14)	(-.76)	(-1.25)	(-1.01)	(-1.69)	(-1.72)	(-.97)	(-.92)
Age	-.57*	-.37*	-.45*	-.19*	-.45*	-.21*	-.44*	-.24*
	(-2.33)	(-2.17)	(-1.97)	(-1.71)	(-1.98)	(-1.65)	(-1.94)	(-1.99)
$Y_{10,000}$	3.11*	3.13*	1.65	1.58*	1.78	1.67*	1.42	1.45*
	(1.88)	(2.76)	(1.09)	(2.09)	(1.14)	(1.98)	(.94)	(1.79)
AVM2	5.53*	4.00*	3.86*	2.41*	4.72*	3.36*	3.96*	2.54*
	(3.58)	(3.79)	(2.69)	(3.34)	(3.37)	(4.26)	(2.90)	(3.46)
Degrees of freedom	173	171	168	165	167	164	167	165
R^2	.08	.10	.07	.13	.08	.12	.08	.08

*Significant at the 95% level, $t \geq 1.645$.

Table 7. RESPONSES OF LIKELY OUTLIERS

Responses	OUTLIER 1 W	OUTLIER 1 B.D.	OUTLIER 1 S.O.	OUTLIER 1 E.S.	OUTLIER 2 W	OUTLIER 2 B.D.	OUTLIER 2 S.O.	OUTLIER 2 E.S.	OUTLIER 3[a] W	OUTLIER 3[a] B.D.	OUTLIER 3[a] S.O.	OUTLIER 3[a] E.S.
WTP/Year	350,	350,	350,	350	400,	400,	400,	400	150,	150,	150,	100
Exp. 1	yes,	yes,	yes,	yes	yes,	yes,	yes,	yes	yes,	yes,	yes,	yes
Exp. 2	no,	yes,	yes,	yes	yes,	yes,	yes,	yes	yes,	yes,	yes,	yes
Exp. 3	yes,	yes,	yes,	yes	no,	no,	no,	yes	yes,	yes,	yes,	yes
Exp. 4	no,	no,	yes,	no	no,	no,	no,	no	no,	no,	no,	yes
Miles to Coast	15				15				6			
Fam. Size	3				1				3			
Age	32				33				25			
Sex	Female				Male				Female			
Income	$50,000				$15,000				$50,000			
Education	18 Yrs				19 Yrs				12 Yrs			
Hunt/Fish	no				no				yes			
Env. Org.	no				no				no			
AV26	10				10				7			
AV27	1				0				9			
AV28	0				0				3			
AV29	10				10				7			
AV30	10				10				5			
AV31	10				10				5			

[a] An outlier for sea otter and dolphin data sets only.

Table 8. MEAN VALUES: WTP AND SOCIO-ECONOMIC CHARACTERISTICS (OUTLIERS REMOVED)

Variables	Whales	Bottlenose Dolphins	California Sea Otters	Northern Elephant Seals	Standard Deviation (Weighted Average)
WTP/Year	$23.95	$17.73	620.75	$18.29	$28.39
Exp. 1 (yes=1)	.78	.79	.80	.59	.43
Exp. 2 (yes=1)	.29	.82	.63	.47	.45
Exp. 3 (yes=1)	.35	.47	.53	.31	.49
Exp. 4 (yes=1)	.16	.17	.25	.10	.37
Miles to Coast	22.8	23.0	22.9	22.5	30.61
Family Size	2.67	2.67	2.69	2.68	1.45
Age	42.5	42.3	42.3	42.2	15.1
Sex (0=Male)	.39	.38	.39	.39	.49
Income ($/year)	$35,302	$35,314	$34,994	$35,081	$22,739
Education (years)	15.3	15.4	15.4	15.3	2.87
Hunt/fish (O=no)	.39	.37	.37	.38	.40
Env. Org. (O=no)	.19	.18	.18	.18	.40
AV26 (O-10)	5.5	5.5	5.6	5.6	3.2
AV27 (O-10)	2.6	2.5	2.5	2.6	3.1
AV28 (O-101	2.0	2.0	2.0	2.0	2.7
AV29 (O-10)	6.9	6.9	6.9	6.9	2.7
AV30 (O-10)	7.3	7.3	7.3	7.2	2.6
AV31 (0-10	7.8	7.8	7.7	2.6	

Phone survey had higher values

lost questions

Table 9. MEAN WTP/YEAR[a] PER HOUSEHOLD, (OUTLIERS REMOVED)[b]

	Whales (Gray and Blue)	Bottlenose Dolphins	California Sea Otters	Northern Elephant Seals
Mean	$23.95 ($27.85)	$17.73 ($22.57)	$20.75 ($25.56)	$18.29 ($22.39)
Standard Deviation	34.82 (50.67)	23.58 (45.80)	25.77 (46.73)	24.19 (45.16)
Number of Observations	178 (180)	172 (175)	171 (174)	172 (174)
t value[c]	9.18	9.83	10.52	9.89
Maximum	$250 ($400)	$135 ($400)	$132 ($400)	$145 ($400)
Minimum	SO ($0)	$0 ($0)	$O ($0)	$0 ($0)

a Q11± Q14A

b For comparison, values for all respondents, including likely outliers, are shown in parentheses.

c The null hyposthesis is WTP>O; reject if $t \geq 2.326$ (99% confidence).

Table 10. COMPARISON OF DIFFERENCE IN MEAN VALUES, BY SPECIES FOR PAIRED RESPONSES

H_o:	$\bar{W}-\bar{D}=0$	$\bar{W}-\bar{SO}=0$	$\bar{W}-\bar{ES}=0$	$\bar{SO}-\bar{D}=0$	$\bar{D}-\bar{ES}=0$	$\bar{SO}-\bar{ES}=0$
t-Statistic: (degrees of freedom-171)	3.529	1.057	2.172	1.601	.070	2.988
Reject; $t \geq 1.645$: (95% confidence)	yes	no	yes	no (very close)	no	yes

Table 12. MEAN WILLINGNESS-TO-PAY RESPONSES:[a]

BREAKDOWNS BY USE AND NON-USE

	Whales (Blue and Gray)	Bottlenose Dolphins	California Sea Otters	Northern Elephant Seals
Non-Consumptive Use	$ 2.34 (9.3%)	$ 2.21 (11.9%)	$ 2.49 (12%)	$ 1.16 (6.2%)
Option Price	$ 5.79 (22.9%)	$ 4.15 (22.4%)	$ 4.71 (22.6%	$ 4.16 (22.1%)
Existence Value	$17.15 (67.9%)	$12.20 (65.9%)	$13.62 (65.4%)	$13.50 (71.7%)

[a] Total WTP, the sum of each column, differs slightly from the values reported f n previous tables because a small number of respondents did not break down WTP into these categories. Their valuations were removed from the results shown in this table.

Table 11. WTP/YEAR PER HOUSEHOLD, OUTLIERS REMOVED.

	Whales (Gray and Blue)	Bottlenose Dolphins	California Sea Otters	Northern Elephant Seals
C ⟶ B				
Mean	$ 6.95	$ 4.58	$ 6.12	$ 4.20
Standard Deviation	17.89	12.92	13.83	11.27
B ⟶ A				
Mean	$ 3.70	$ 2.78	$ 3.55	$ 2.57
Standard Deviation	11.86	11.19	11.40	10.09

Risk-Sharing and Liability in the Control of Stochastic Externalities

by

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I. Introduction

Many forms of pollution are stochastic in the sense that they result from accidental spills or releases rather than continuous (intentional) emissions. These include the highly publicized problems resulting from spills of hazardous substances during transport by land or sea and the contamination of groundwater supplies by unintentional releases from landfills. Recognition of these forms of stochastic externalities has given rise to questions concerning their control. For example, Just and Zilberman (1979) compare the effects of lump sum taxes and subsidizes on a firm's incentive to undertake safety. The control of oil spills through the use of liability rules has been studied by Conrad (1980) and by Opaluch and Grigalunas (1984). A more general treatment of the control of accidents appears in a series of papers by Shavell (1980, 1982, 1984a, 1984b).

The choice of any policy for controlling stochastic externalities generally has two effects: an incentive effect and a risk sharing effect. The incentive effect provides the impetus for films to take actions to increase safety and thus reduce the probability of accidents. The risk sharing effect stems from the fact that the policy choice dictates an allocation of risk and the amount of risk that parties must bear can have welfare effects. Although the incentive effects of alternative policies have been well-recognized, in general the risk sharing effects have been ignored. (An exception is Shave11 (1982).) However, recent liability cases and their ripple effects suggest that risk may be a very important consideration in decisions regarding activities that could impose substantial externalities.[1/] Thus, the allocation of risk under alternative policies would appear to be an important factor in the choice of a control policy.

The purpose of this paper is to analyze alternative policies for controlling stochastic externalities in terms of both their incentive and their risk-sharing effects. The policies that are considered depend upon whether the actions of the polluters that affect the probability of a given pollution event are observable or not. When actions are observable, regulation of those actions is possible and the policies considered include regulation and full liability (i.e. ex post liability for the full amount of damages). However, when actions are unobservable, regulation is not possible. Instead liability rules can be used to induce safety, and we consider alternative rules including zero, partial and full ex post liability. The paradigm that provides the basis for the analysis is the principal-agent model that is popular in studies of sharecropping. alternative wage contracts sad the organizational structure of firms. The relevance of this model to problems of environmental externalities was first noted by Shave11 (1979a).

The paper is organized as follows. In the next section, the pure risk sharing problem (without incentives effects) is presented to provide an understanding of the role of liability rules in the Pareto efficient allocation of risk. The following section presents the model for the case where actions are unobservable and thus incentives for safety must be provided. This section highlights the basic tradeoff between risk sharing and incentives when polluters are risk averse. Section IV compares the use of regulation and ex post liability when the polluter's actions are observable (and can thus be regulated). An interim summary of the results is then presented, followed by a discussion in Section VI of how those results and conclusions would change if insurance were available to spread risk. The final two sections discuss some limitations of the analysis that suggest referred to as the principal-agent problem, has been studied by many authors, including Stiglitz (1974), Ross (1973), Shave11 (1979a), Holmstrom (1979), and Grossman and Hart (1983). The analysis is generally in the context of sharecropping, labor contracts, insurance contracts, or the organizational structure of firms. In addition, Shave11 (1979a) discusses its applicability to a comparison of strict liability and negligence standards in controlling stochastic externalities such as oil spills. Leland (1978) has used A similar model to analyze OCS leasing policies. Our purpose here is to consider the application of the general framework used in this model to the question of risk-sharing for stochastic pollution.

In this context, the model takes the following form. Let c denote the value of clean-up costs or damages[4/] associated with a future pollution event. From the present perspective, c is viewed as a random variable since future clean-up costs are not known. In this discussion of optimal risk sharing, we assume that the distribution of c is not affected by the actions of the polluter. This assumption is relaxed in the following section where the problem of incentives is considered. Let f(c) be the amount paid by the polluter[5/] for clean-up, Thus, the costs that must be borne by the victim (or by the public sector) are equal to c-f(c). Note that if f(c) is constant, i.e. independent of c, then in a legal sense polluters have no ex post "liability" since the amount they pay does not depend on the damages actually incurred. The payment scheme is instead analogous to an ex ante payment to a trust fund to be used for clean-up. Alternatively, if $f'(c) \neq 0$ then polluters are subject to at least some ex post liability, with $f'(c)=1$ implying full liability.[6/]

Let $V(v_o-c+f(c))$ represent the victim's utility function and let $U(u_o-f(c))$ represent the polluter's utility function, where v_o and u_o are the directions for further research and implications of the analysis for the control of stochastic marine pollution.

II. Liability and Risk-Sharing Without Incentive Problems

Embodied in many federal statutes is an attempt to control environmental pollution through imposing strict liability for damages on the responsible parties [Opaluch, (1984)]. Although there are often limits on the nature and the extent of the liability,2/ the basic philosophy is that those responsible for the activity that is causing an environmental problem should pay the costs of clean-up or compensation. The use of this approach was intended to encourage all parties involved in the generation, transportation and disposal of polluting substances to take steps to minimize the possibility of environmental damage from their use. In addition, strict liability is often imposed through state or federal courts under the law of torts.

Although strict liability can be used as a way of internalizing the pollution externality,3/ it also has important implications for the allocation of risk. For example, since future clean-up costs or damages are uncertain and thus are viewed from the present as a random variable, a strict liability rule places all of the risk associated with the level of future costs on the responsible parties. Although this has advantages in terms of providing proper prevention incentives (see Section III), it is not necessarily an optimal allocation of the risk. We consider below a conceptual framework for analyzing optimal risk-sharing in the context of stochastic pollution.

The economic assessment of optimal risk-sharing is usually considered within the context of the more general problem of risk-sharing and incentives. This broader problem, embodied in what has generally been initial wealth levels of the victim and the polluter respectively. Then Pareto optimal risk-sharing is given by a liability rule f that satisfies

$$\max EV(v_o-c+f(c)) \text{ subj. to } EU(u_o-f(c))\geq\bar{U} \qquad (1)$$

where $\bar{U}$ is the polluter's reservation level of utility. The first order conditions for the optimal f require that

$$V'(v_o-c+f(c)) = \lambda U'(u_o-f(c)) \qquad (2)$$

where $\lambda \geq 0$ is the Lagrangian multiplier on the constraint in (1).[7]
Equation (2) defines the optimal level of risk-sharing between the victim and the polluter if the associated second order conditions are met.

To see the implications of (2) for the first best liability rule, differentiate (2) with respect c and solve for f'(c) to get

$$f'(c) = \frac{V''}{V'' + \lambda U''}. \qquad (3)$$

This highlights the importance of the second derivatives of the utility functions, which reflect the attitudes toward risk. For example, consider the implications of (3) in the context of the following alternative cases.

<u>Case 1</u>: Risk Averse Victim (V"<0), Risk Neutral Polluter (U"=0). In this case, (3). implies that f'(c) = 1, and thus f(c) = c+k for some constant k. As noted above, this corresponds to a full liability rule since any increases in clean-up costs are borne fully by the polluter. Thus, when the polluter is risk neutral but the victim is not (so that risk is costly to the victim but not to polluters), then full liability results in optimal risk-sharing with the polluter bearing the full risk associated with future clean-up costs.

<u>Case 2</u>: Risk Neutral Victim (V"=0), Risk Averse Polluter (U"<0). In this case, (3) implies that f'(c) = 0 so that f(c) = k. In other words, it is optimal in terms of risk-sharing for the polluter to pay a constant amount

that is independent of the actual realized clean-up costs. Under this rule, polluters have no ex post liability. They are shielded from the uncertainty associated with future clean-up costs and all of the risk is borne by the victim. This is optimal in this case because risk represents a cost to risk-averse polluters but not to a risk neutral victim.

<u>Case 3</u>: Both Victim and Polluter are Risk Averse ($V''<0$, $U''<0$). In this case, $0 < f'(c) < 1$. This implies that $f(c) \neq c+k$ and $f(c) \neq k$. In other words, neither the polluter nor the victim bears the full risk. Instead, risk is shared between them. The polluter is liable for some portion of realized costs, but he is not fully responsible for incremental changes in c. Of course, the optimal allocation of the risk between the two risk averse parties will depend upon the relative magnitudes of U" and V". In the special case where both U and V are quadratic, a fixed apportionment scheme ($f'(c) = \alpha$ for some constant α) is efficient, i.e. each party's ex post payment should be a fixed proportion of the damages regardless of the level of those damages. Under more general utility functions, however, the efficient apportionment will depend on the level of damages.

<u>Case 4</u>: Both the Victim and Polluter are Risk Neutral ($V''=U''=0$). In this case, a unique optimal risk-sharing rule does not exist. Since risk does not represent a cost to either the polluter or the victim, the allocation of risk does not have any welfare effects.

In summary, the pareto optimal rule for allocating risk between the victim and the polluter (in the absence of incentive problems) depends upon their risk attitudes. A full liability rule will yield optimal risk-sharing if polluters are risk neutral but not if they are risk averse. Polluters might be expected to be risk neutral if the magnitude of the possible damages is small relative to the operations of the firm. However, if the potential

2. <u>Claim</u>: If $U''=0$ and $V''<0$, then $V^{*}>\bar{V}$.

<u>Proof</u>: If $U''=0$, then $U'=\beta$ for some constant β and by (9b) and (11)

$$\beta(u_o-\bar{k}-\bar{a}) = \beta\cdot(u_o-k^{*}-a^{*}-p(a^{*})d)$$

$$\bar{k}+\bar{a} = k^{*}+a^{*} + p(a^{*})d.$$

$$k^{*} = \bar{k} - (a^{*}-\bar{a})-p(a^{*})d. \qquad \text{(A4)}$$

Furthermore, by concavity of V,

$$V[(1-p(\bar{a}))(v_o+\bar{k}) + p(\bar{a})(v_o+\bar{k}-d)]$$

$$> (1-p(\bar{a}))V(v_o+\bar{k}) + p(\bar{a})V(v_o+\bar{k}-d) = \bar{V}$$

$$V[v_o+\bar{k}-p(\bar{a})d] > \bar{V}. \qquad \text{(A5)}$$

Finally, when $U'=\beta$ then from (10) a^* minimizes $a+p(a)d$

$$a^{*}+p(a^{*})d \le \bar{a}+p(\bar{a})d$$

$$v_o+\bar{k}-p(\bar{a})d \le v_o+\bar{k}-(a^{*}-\bar{a})-p(a^{*})d. \qquad \text{(A6)}$$

$$V[v_o+\bar{k}-(a^{*}-\bar{a})-p(a^{*})d] \ge V[v_o+\bar{k}-p(\bar{a})d] > \bar{V} \qquad \text{(A7)}$$

where the first unequality assumes V is monotonic and the second follows from (A5).

Substituting (A4) into (A7) yields

$$V^{*} = V[v_o+k^{*}] > \bar{V}. \qquad \text{Q.E.D.}$$

FOOTNOTES

1/ Large settlements in recent liability cases have caused premiums for liability insurance to increase sharply. In some cases coverage has been eliminated. In response, many firms are reducing or withdrawing the provision of certain goods and services because of the inability to secure liability coverage at a reasonable cost. See the Wall Street Journal, January 21, 1986, page 37.

2/ For example, liability under the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) is limited to clean-up costs, other costs of remedial actions, and damages to natural resources. In particular, it does not include damages to third parties. Dollar limitations on liability exist under other statutes as well, including the Price Anderson Act in the case of nuclear accidents and several laws governing marine pollution (See Section VIII).

3/ This internalization is not necessarily perfect. See Opaluch (1984) and Shave11 (1984a, 1984b) for discussions of some problems associated with the use of liability rules to internalize externalities.

4/ We use the terms "clean-up costs" and "damages" interchangeably. However, in reality the two may be different and which one would be used as the basis for liability could vary from case to case.

5/ We assume that there is a single responsible party to avoid the problem of assigning liability and the potential for free-riding in the multiple polluter case. For a discussion of free-riding in principal-agent models, see Holmstrom (1982).

6/ Hereinafter, we use the term "full liability" rather than "strict liability" to refer to a liability rule where polluters must pay the full amount of damages. This is to avoid the potential confusion caused by the fact that it is possible to have "strict" (in the sense of "no-fault") liability for an amount that is less than total damages. Throughout the paper, our use of the term liability refers to no-fault liability, which may or may not be for the full amount of damages. In particular, we do not explicitly consider the negligence rule under which firms would be liable only if found to be negligent (although our treatment of regulation is similar to a negligence system under which firms never choose to be negligent). For a comparison of negligence and no-fault liability, see Shavell (1980, 1982).

7/ Because f is a contingency rule, i.e. it gives the level of liability contingent on a given realization of the random variable c, the first order conditions depend upon realized marginal utilities rather than expected marginal utilities. See Raiffa (1968) for a more detailed discussion.

8/ Although the expected utility hypothesis is the paradigm used most frequently in economic models of decision-making under uncertainty, it has been subject to a great deal of criticism by man, economists, social. psychologists and decision analysts. See, for example, the survey by Schoemaker (1982).

9/ The question of whether compliance with regulations issued pursuant to environmental statutes preempts common law used to impose liability is the subject of considerable debate. Some argue that regulatory standards simply provide a minimum set of standards for conduct, while others argue that the creation of a comprehensive regulatory program should be viewed as an attempt by Congress to provide a substitute for common law. The debate was fueled by the 1982 Supreme Court decision in the case of Milwaukee vs. The State of Illinois. (For a discussion of the concerns and issues regarding that decision, see U.S. Senate Hearing 98-247.) Recently, several bills have been introduced in Congress that would significantly reduce the liability of firms that are in compliance with regulations.

10/ This could be important if policy decisions are made by bargaining in the political arena and polluters have sufficient political clout to prevent the adoption of policies that would reduce their expected utility.

11/ See footnote 9.

12/ This is consistent with Shavell's (1982) result that, when victims are risk neutral and injurers are risk averse, a first best solution is possible under a negligence standard but not under strict liability. If a firm is only held liable when it is found to have violated the due care standard (assumed known by all), i.e. compliance with the standard implies lack of negligence, then with risk neutral victims the negligence system is equivalent to regulation requiring the due care level of precaution. Note, however, that Shave11 compares strict liability and negligence to a first best solution that only requires that a resource constraint be met in terms of expected value, not in each state. Thus, it is not really an ex post transfer problem such as that considered here, i.e. Shavell's first best solution is not the Pareto optimal solution in the absence of incentive problems considered in Section II which implicitly imposes a budget-balancing constraint in each state.

13/ See Schoemaker (1982) for a survey of issues.

14/ For a discussion of the dynamic nature of the legal system, see Blume and Rubinfeld (1982).

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damages are large, firms might be expected to be risk averse, a conjecture that is supported by observed purchases of liability insurance. Risk aversion by polluters implies that, ceteris paribus, the victim should bear some (if he is also risk averse) or all (if HCI is risk neutral) of the risk associated with the level of future clean-up costs.

In many pollution cases, the "victim" can be best thought of as the public sector since public funds are used for clean-up. The question of risk aversion by the public sector has been addressed by Arrow and Lind (1970), who argue that public decisions should not reflect risk aversion if the risks can be spread sufficiently. In our context, this would suggest that, if the public's share of clean-up costs, c-f(c), is spread across many taxpayers, then the public should perhaps be viewed as risk neutral. However, if public funds are insufficient so that some part of the public's share of the damages are borne in the form of residual pollution, then these costs are borne not by the taxpayers in general but instead by those who live in the vicinity of the sites that receive less than full clean-up. In this case, the costs are not spread. Thus, public sector decisions should reflect private (i.e. victim) attitudes toward risk [Fisher (1973)] and under optima1 risk-sharing polluters would bear some (or all) of the risk.

III. Liability and Risk-Sharing with Incentive Problems

The above analysis assumes that the distribution of the random variable representing damages (i.e. clean-up costs) is not affected by the actions of polluters, and thus the only issue of concern is the allocation of risk. In reality, the behavior of polluters can often affect the probability of a given magnitude of damages. The appropriate policy response to this effect depends on whether the preventive actions are observable by the regulatory agency. If those actions are observable and can be monitored (and thus non-compliance detected), then direct regulation is possible. When preventive care cannot be easily monitored, then direct regulation is not possible, but an indirect incentive mechanism such as a liability rule can be used to induce a certain level of abatement or care. In this section, the above analysis is modified to include the need to induce a certain behavior when direct monitoring is not possible. In the following section, the possibility of using direct regulation is considered.

Let a be the level of safety or preventive care taken by the polluter and let g(o,a) be the density function of clean-up costs (damages) given a. In this case, the Pareto efficient payment scheme is given by the solution to

$$\max_{\{a, f(\cdot)\}} EV(v_o - c + f(c)) \qquad (4a)$$

$$\text{subject to} \quad EU(u_o - a - f(c)) \geq \bar{U} \qquad (4b)$$

$$EU_a = 0 \qquad (4c)$$

where the second constraint states that the polluter chooses the level of a that maximizes his expected utility.[8] This constraint reflects the need to motivate the polluter to undertake abatement. This problem can be written more explicitly as

$$\max_{\{a, f\}} \quad V(v_o - c + f(c))g(c,a)dc \qquad (5a)$$

$$\text{subject to} \quad U(u_o - a - f(c))g(c,a)dc \geq \bar{U} \qquad (5b)$$

$$[U(u_o - a - f(c))g_a - U'(u_o - a - f(c))g(c,a)]dc = 0 \qquad (5c)$$

where $g_a = \partial g/\partial a$. The optimal fee schedule must then satisfy the following condition:

$$V' = \lambda U' + \mu[(g_a/g)U' - U''] \qquad (6)$$

desirable in practice because of its simplicity and the difficulty of determining empirically the precise form of the optimal nonlinear liability rule. Note, however, that if the polluter becomes very risk averse as damages become very large, then the risk sharing effects would come to dominate the incentive effects and the efficient level of marginal liability would approach zero as damages increased. This would imply that at some point a cap on liability might be desirable.

where μ is the multiplier on the second constraint. As long as $\mu \neq 0$, i.e. there is a need to provide an incentive, this condition differs from the condition for optimal risk sharing given in (3). In other words, because of the need to motivate polluters indirectly to take care when their actions are not observable, in general the optimal fee schedule will differ from the one that would generate optimal risk sharing. This makes intuitive sense when one thinks, for example, about the special case of risk averse polluters and risk neutral victims. In this case, optimal risk sharing would imply that victims bear all of the risk, i.e. that the polluters not be subject to any ex post liability. However, in the absence of any liability (or enforceable regulations), polluters have no incentive to be cautious. Thus, there is a trade-off between risk sharing and incentives; greater liability implies greater behavioral incentives but also greater risk for polluters.

Of course, this trade-off disappears in special cases. For example, when polluters are risk neutral, i.e. U"=0, one can shove that $\mu = 0$ and thus the problem reduces to one of just optimal risk sharing. In this case, full. liability is optimal, since it provides the correct incentive for precaution while placing all of the risk on the risk neutral party. Likewise, when $g_a = 0$, i.e. when polluter's actions do not influence the distribution of c, then again the problem reduces to optimal risk sharing since polluters will choose a zero level of precaution regardless of the fee schedule.

In general, however, neither full liability nor a fixed payment that is independent of actual damages is optimal when the dual goals of risk-sharing and incentives are considered. Instead, as long as polluters are risk averse, some form of partial liability is preferred. The extent of that partial liability would depend on the extent of the polluter's and victim's risk aversion and the strength of the incentive effect.

IV. Ex Ante Regulation vs. Ex Post Full Liability

In the previous section, the assumption that the actions of polluters were unobservable implied that direct regulation was not possible, i.e. the fee paid by polluters could not be a function of a. However, if a is observable, then direct regulation is possible. In particular, a fee schedule of the form

$$f(c) = \begin{cases} 0 \text{ if } a \geq a^* \\ \infty \text{ if } a < a^* \end{cases} \tag{7}$$

would be equivalent to requiring the firm to abate to a* and then absolving the firm of any liability for actual damages incurred.[9] Thus, the basic framework outlined in the previous section can also be used to compare the use of ex ante regulation and ex post liability in controlling stochastic externalities.

Previous comparisons of these two approaches [e.g. Shave11 (1984a, 1984b), White and Wittman (1983), Johnson, Kolstad and Ulen (1985)] have assumed that all parties are risk neutral. They thus focus on the incentive effects of the two alternatives and ignore the risk sharing effects. In this case the relative desirability of the two approaches depends upon the assumptions that are made about system imperfections. For example, Shave11 (1984a) argues that the ability of polluters to escape successful suits or avoid full payment for damages because of asset availability tend to make regulation more desirable, while the inability of regulators to distinguish ex ante among firms threatening different levels of harm tends to favor the use of ex post liability rules. Johnson, Kolstad and Ulen (1985) consider the impact of evidentiary uncertainty, i.e. uncertainty about the legal standard that a potential polluter would be held to in court. In these

These results are consistent with what would be expected from the discussion in the previous sections, and they are proven in the appendix. However, when we move away from these special cases and allow both parties to be risk averse, then unambiguous statements about which policy approach is preferred can no longer be made even in the absence of system imperfections. The analysis suggests that something in between full liability and the sole use of regulation i.e. some form of partial liability plus regulation, would be efficient.

V. Summary So Far

If system imperfections (such as evidentiary uncertainty, the difficulty of proving responsibility and limitations on recoverable amounts) are ignored, then the above analysis suggests the following conclusions:

Case 1: Polluters are risk neutral. In this case, both in terms of efficiency and risk sharing, a system of full liability is efficient. Although polluters may be expected to be risk neutral with regard to small risks, the recent furor over the shrinking of the pollution liability insurance market suggests that for large environmental risks firms are not likely to exhibit risk neutrality.

Case 2: Polluters are risk averse, victims are risk neutral and all of the polluter's precautionary actions are observable. In this case regulation alone would be efficient. The allocation of risk would be efficient and the correct incentives could be maintained by setting and enforcing an appropriate regulatory standard. However, in reality, it is unlikely that victims of environmental damages will be risk neutral since the losses can be large relative to an individual's income and, even if government compensation for monetary damages is available, there are likely to be non-monetary cases, the inability of the regulation and liability approaches to ensure an efficient level of precaution stems from some assumed imperfection in the regulatory or legal system. In the absence of these imperfections, the two alternatives would be equally efficient. This result does not hold, however, when the assumption of risk neutrality is relaxed because the allocation of risk under the two approaches becomes a factor in determining their relative desirability. In this section, we demonstrate that even in the absence of system imperfections the two approaches are not equally desirable when risk aversion is allowed.

To simplify the analysis (and make it more comparable with previous work), assume that a pollution event (i.e. a spill or release) either occurs or does not occur and that if it occurs the damages are equal to d. Assume that: the actions of the polluter affect the probability that an accident will occur. Thus, the density function g(c,a) takes the form

$$C = \begin{cases} 0 \text{ with probability } 1-p(a) \\ d \text{ with probability } p(a), \end{cases} \tag{8}$$

where p(a) is the probability of an accident occurring given a precaution or safety level a.

Intuitively, the importance of risk aversion in determining the relative desirability of regulation and full liability can be seen by recalling the well-known fact that risk averse polluters should be willing to pay a premium to eliminate risk. Thus, if compliance with regulations would absolve them of ex post liability, risk averse polluters would be willing to be subjected to a regulatory standard that is more stringent than the level of care they would choose voluntarily under a full liability system. More specifically, let a be the level of precaution that maximizes the polluter's expected

VI. The Role of Insurance

The analysis in the previous sections implicitly assumes that risk averse parties are unable to transfer risk through the purchase of first party or liability insurance. In this section we discuss how the existence of insurance markets to spread risk would affect those conclusions. The existence of such markets should not, however, be taken for granted even (or perhaps especially) when risks are very large. For example, in theory under policies that impose risks on polluters (i.e. when $f'(c)\neq 0$), we would expect liability insurance to be available since risk averse polluters would generate a demand for it. Recently, however, the market for liability insurance has nearly collapsed. Thus, although historically they have been able to do so, risk averse polluters may no longer be able to purchase insurance to transfer all liability risks, especially those associated with low probability, high consequence (LP-HC) events. Since the availability of insurance affects the allocation of risk under the alternative policies, whether or not it exists is an important factor in analyzing those policies when polluters or victims are risk averse.

The impact of insurance on the efficiency of different liability rules has been studied by Shave11 (1982). The discussion here draws on some of Shavell's results and the well-known fact that a risk averse party can improve his welfare by purchasing actuarially fair insurance. We consider in turn the cases summarized in the previous section.

Case 1: Polluters are risk neutral. In this case, the possibility of purchasing liability insurance is irrelevant since risk neutral polluters would have no incentive to purchase actuarially fair insurance. Full liability is still the efficient approach in terms of both incentives and utility under full liability, i.e. $\tilde{a}$ maximize $EU(a) = (1-p(a))U(u_o-a) + p(a)U(u_o-a-d)$. Let $EU(\tilde{a}) = \tilde{U}$ be the firm's maximum expected utility under full liability. The firm should then be indifferent between a full liability system and a policy that couples ex ante payments to victims equal to the expected value of damages under full liability with a regulatory standard of $\tilde{s}$ defined by $\tilde{U} = U(u_o-p(\tilde{a})d-\tilde{s})$ where compliance with the regulation is a sufficient defense against liability. However, if the firm is risk averse then $\tilde{s}>\tilde{a}$. The difference $\tilde{s}-\tilde{a}$ is the risk premium the polluter is willing to pay to get rid of the risk borne under full liability. Thus, under regulation the victims can get more prevention for the same "price" (in terms of the polluter's expected utility).[10] However, by choosing regulation over full liability they are also subject to more risk. This risk is costless if they are risk neutral but not if they are risk averse. Thus, which of the two alternatives is preferred depends on how the victim trades off increased risk against increased protection.

To see this more explicitly, consider the Pareto efficient regulatory standard, $\bar{a}$. This is given by the solution to

$$\max_{a,k} \quad EV = (1-p(a))V(v_o+k) + p(a)V(v_o+k-d) \tag{9a}$$

$$\text{subject to} \qquad U(u_o-a-k) \geq \bar{U} \tag{9b}$$

where k is a lump sum transfer from polluters to victims. (If the efficient transfer $\bar{k}$ were negative, the transfer would be from victims to polluters.) This transfer represents an ex ante, i.e. state-independent, compensation or indemnification that keeps the polluter's utility level at $\bar{U}$. Note that, if polluters are absolved of tort liability by compliance with the standard,[11] then under the regulatory approach they bear no risk. All of the risk is borne by the victim. In this sense, regulation is equivalent to a fixed ex ante scheme where the fee is $\bar{a}+\bar{k}$.

Under the alternative policy of imposing full liability without any regulation, firms would be free to choose their level of precaution. Thus, the level of precaution under liability solves

$$\max_{a} \; (1-p(a))U(u_o-k-a) + p(a)U(u_o-k-a-d). \qquad (10)$$

Note that the solution is a function of k, which we denote a*(k). The level of k necessary to keep the polluter's expected utility at $\bar{U}$ is then implicitly defined by

$$EU = (1-p(a(k)))U(u_o-k-a(k)) + p(a(k))U(u_o-k-a(k)-d) = \bar{U}. \qquad (11)$$

We denote this solution k* and the corresponding level of precaution a* = a*(k*).

Since the expected utility of polluters has been held at $\bar{U}$ under both policies, we can compare the desirability of the two by comparing the expected utility of victims. Let $\bar{V}$ be the victim's expected utility under the efficient regulatory standard, i.e.

$$\bar{V} = (1-p(\bar{a}))V(v_o+\bar{k}) + p(\bar{a})V(v_o+\bar{k}-d), \qquad (12)$$

and let V* be the victim's expected utility under full liability, i.e.

$$V^* = V(v_o+k^*). \qquad (13)$$

Then regulation is preferred to full liability if $\bar{V}>V^*$, and vice versa.

<u>Result</u>:

(a) If victims are risk neutral and firms are risk averse, then $\bar{V}>V^*$, i.e. victims are better off under regulation than under a system of full liability;[12] (b) If polluters are risk neutral and victims are risk averse, then $V^*>\bar{V}$, i.e. full liability is preferred; and (c) Risk neutrality for both parties implies that the two approaches are equally efficient, i.e. $V^*=\bar{V}$.

damages that prevent full compensation. In addition, it is unlikely that all of the polluter's actions that influence the probability of a given magnitude of damages will be able to be controlled through regulations. Even if firms have safety procedures or equipment designed to reduce accidents, the care with which these procedures are followed or the equipment maintained is in general not easily (or cheaply) monitored by the regulatory agency.

Case 3: Polluters are risk averse, victims are risk neutral and some of the polluter's precautionary actions are not observable. In this case, sole reliance on regulation is not efficient (even though it optimally allocates risk) because it does not provide the correct incentive to undertake unobservable precautionary actions. Instead, it would appear to be preferable to use a system that couples regulation with a liability rule under which polluters are liable for something less than the full amount of damages, Although the use of ex post liability violates optimal risk-sharing, it is necessary to provide some incentive. In general a system of fixed apportionment, i.e. liability for a fixed proportion of damages regardless of their magnitude, is not efficient, although it might be a reasonable approximation to use in practice.

Case 4: Both polluters and victims are risk averse and all of the polluter's precautionary actions are observable. The efficient policy in this case would be similar to that for Case 3, but for different reasons. In general, some combination of regulation and liability would appear to be efficient, where the liability is for an amount less than the full damages. Here the use of liability is not necessary for incentive purposes but rather to reallocate risk, i.e. provide some form of ensured compensation for risk averse victims. The suggested compensation is not full, however, because full compensation would leave risk averse polluters bearing too much risk.

<u>Case 5</u>: Both polluters and victims are risk averse and some of the polluter's actions are not observable. Again, some form of less than full liability would appear appropriate. If some of the polluter's actions are observable, then coupling the liability system with a regulatory program for those actions would improve the incentive effects without altering its risk-sharing features. This case is perhaps the most likely case for large environmental externalities. It suggests that the joint use of regulation and liability to control stochastic pollution events, such as the combination of RCRA and CERCLA to address hazardous waste dangers, is not necessarily redundant. However, the full liability for clean-up costs imposed by CERCLA may place an inefficient amount of risk on polluters if firms are also held liable for the full amount of third party damages under common law.

In each of the above cases, the regulatory or liability policy would in general require a lump-sum, i.e. state independent, transfer between victims and polluters in order to maintain an acceptable level of expected utility for one of the parties. (This transfer has been denoted k.) It is an ex ante payment of compensation. When the payment is from polluters to victims (as might be expected under the sole use of regulation or less than full liability), it represents ex ante payment for imposing environmental risks and could take the form of fixed payments to a fund such as Superfund to be used for clean-up of existing problems. Alternatively, when the transfer is from victims to polluters (as might be expected under full liability), it represents ex ante payment for imposing financial risks on firms and could take the form of cost sharing or tax breaks to reduce the financial burden associated with undertaking substantial precautionary actions.

operators for clean-up costs and damages to natural resources that result from unauthorized discharges into the marine environment. However, in the absence of gross negligence or willful misconduct, the total amount of the liability is limited to a specified dollar amount.

The results discussed above suggest that this joint use of regulation and liability may be justified if the owners/operators of polluting vessels or facilities can undertake actions that affect the probability of a release occurring but are not easily observable (and thus subject to regulation). In addition, the dollar limits placed on their liability can be viewed as a means of sheltering risk averse polluters from some risk, again a goal that is consistent with the above results. However, limiting risk by putting a dollar cap on liability is not generally an efficient means of risk allocation.

In essence, the use of a liability cap implies a system of full liability for small damages and partial liability for large damages. Full liability for small damages is efficient in terms of both risk sharing and incentives if polluters can be considered risk neutral with respect to small damages. As noted above, partial liability for large damages is also efficient if polluters are risk averse with respect to large damages. However, implementing partial liability through a liability cap implies that marginal liability is zero beyond the amount of the cap, i.e. $f'(c) = 0$ for all c in excess of the cap. Since this violates Equation (6), it is not an efficient way to balance risk-sharing and incentive needs. The analysis suggests that a preferred approach would be to hold polluters liable for some percentage of damages once they exceed a certain level. Although theoretically that percentage should not be independent of the magnitude of damages (unless both U and V are quadratic), a constant percentage might be risk-sharing. Since victims bear no risk under full liability, their ability to purchase first party insurance is also irrelevant.

Case 2: Polluters are risk averse, victims are risk neutral and the polluter's actions are observable. Again, the availability of insurance does not change the previous conclusions. Regulation alone is still efficient. Victims have no interest in insurance because they are risk neutral and polluters will not purchase any insurance because they do not bear any risk under regulation.

Case 3: Polluters are risk averse, victims are risk neutral and some polluter actions are unobservable. The fact that some actions are unobservable implies that liability insurers will be unable to base premiums on the level of preventive action and as a result moral hazard will exist. Risk averse polluters will purchase less than full coverage for the risks they must bear (Shavell, 1979b). Shavell (1982) has shown that in this case the efficient liability rule is to either (1) impose full liability on the polluters or (2) prohibit liability insurance and impose an appropriate level of partial liability. The net effect of these two alternatives is the same, since under the first one polluters would purchase less than full coverage, leaving them with the same incentives and risks as under the second option. (The banning of liability insurance under the second option ensures that firms cannot further dilute the incentive effects of the partial liability through the purchase of insurance.) In addition, because victims are risk neutral, they are unaffected by the greater risk they bear under the second option.

Case 4: Both polluters and victims are risk averse and the polluter's actions are observable. It is in this case that the availability of insurance has the greatest potential for improving the outcome since the problem here is only a problem of risk sharing and not a problem of incentives. In the absence of insurance, efficiency requires that risk be divided between polluters and victims. However, if both first party and liability insurance are available, then both victims and polluters can eliminate their risk through the purchase of insurance and the allocation of risk becomes irrelevant. If, on the other hand, only liability insurance is available, then the use of full liability is efficient. Polluters will purchase actuarially fair insurance to transfer the risks they bear under full liability, but, since their actions are observable, insurers will base their premiums on those actions and thus firms will still face the proper incentives. Alternatively, if only first party insurance is available, then the use of a regulatory approach without liability shelters polluters from risk and victims can also avoid risk through the purchase of insurance. Thus, in this case, the choice of an efficient policy depends crucially on the availability of insurance.

Case 5: Both polluters and victims are risk averse and some polluter actions are not observable, Here the incentive problems are the same as in Case 3 because of moral hazard. If liability insurance is available, then the proposed policies are the same as well, provided that the risk averse victims can purchase first party insurance to cover the risks, they would bear under the second option where liability insurance is banned with polluters subject to only partial liability, If first party insurance is not available, then the use of full liability is the preferred option since the existence of liability insurance protects risk averse victims from risk.

VII. Conclusions and Limitations

Recent events regarding legal liability for damages due to stochastic pollution and the associated "insurance crisis" suggest that potential polluters exhibit risk aversion with respect to the uncertainty associated with damages. Furthermore, it seems likely that in most cases of stochastic pollution some of the actions of the potential polluter that affect the density function of damages are not easily subject to regulation. When these two conditions exist, the above analysis suggests the following conclusion: (1) If liability insurance is not available to transfer risks, then an efficient policy for the control of stochastic externalities would include the use of both regulation of observable actions and ex post liability. where the liability would be for an amount less than the full amount of damages; and (2) If liability insurance is available, then the use of full liability is efficient since risk sharing can be achieved through the purchase of insurance.

There are several caveats to this conclusion that reflect the limitations of the above analysis. First, as noted previously, imperfections in the regulatory and liability systems have not been included in the model. However, the results of Shavell (1984a) and Johnson, Kolstad and Ulen (1985) suggest that inclusion of system imperfections would not necessarily change the conclusion that the joint use of regulation and some ex post liability is desired.

Secondly, the model of decision making under uncertainty that is used here (the expected utility model) has been the subject of considerable criticism.[13/] The use of an alternative paradigm could lead to different conclusions since the implied perception of risk would be different.

Thirdly, the model used is a short run model that does not capture non-marginal adjustments by polluters or victims. To the extent that the different policies imply different expected costs for either polluters or victims, in the long run they would be expected to respond accordingly. For example, high expected costs under a full liability policy might cause individual firms to leave the industry. Alternatively, the prospect of large uncompensated damages might cause victims to relocate to areas of lower risk. These non-marginal behavioral responses would have implications for the long run effect of any policy choice.

Finally, the static nature of the model,[14/] the omission of administrative and legal costs, and the difficulty of empirically determining the risk aversion characteristics of polluters and victims should be kept in mind when interpreting the conclusions of the analysis.

VIII. Implications for Control of Marine Pollution

The conclusions from the above discussion have implications for the efficient control of marine pollution. The current approach to controlling stochastic forms of marine pollution employs a combination of regulation and ex post liability for damages due to releases of polluting substances. For example, regulations governing the use of the marine environment for transportation and waste disposal have been promulgated pursuant to a number of federal statutes, including the Ports and Waterways Safety Act, the Clean Water Act, the Coastal Zone Management Act, the Deepwater Port Act, the Marine Protection, Research and Sanctuaries Act, the Outer Continental Shelf Lands Act, and the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA). Several of these (Clean Water Act, Deepwater Port Act, and CERCLA) explicitly impose liability on vessel or facility owners or

APPENDIX

1. Claim: If V"=0 and U"<0 then $\bar{V}>V^*$.

Proof: If V"=0, then $V'=\gamma$ for some constant 7 and $\bar{V}=\gamma\cdot(v_o+\bar{k}-p(\bar{a})d)$ under regulation. Thus, since $V^*=\gamma(v_o+k^*)$, it is sufficient to show that $k^*<\bar{k}-p(\bar{a})d$.

When $V'=\gamma$, the first order conditions for (9) imply that $p'(\bar{a})d+1=0$ and thus that $\bar{a}$ minimizes a+p(a)d. This implies that

$$\bar{a}+p(\bar{a})d \le a^*+p(a^*)d$$

$$p(\bar{a})d \le (a^*-\bar{a})+p(a^*)d,$$

$$\bar{k}-p(\bar{a})d \ge \bar{k}-(a^*-\bar{a})-p(a^*)d. \qquad (A1)$$

Furthermore, by concavity of U,

$$U[p(x^*)(u_o-k^*-a^*-d)+(1-p(a^*))(u_o-k^*-a^*)]$$
$$> (1-p(a^*))U(u_o-k^*-a^*)+p(a^*)U(u_o-k^*-a^*-d). \qquad (A2)$$

Finally,

$$(1-p(a^*))U(u_o\ k^*-a^*)+p(a^*)U(u_o-k^*-a^*-d)=U(u_o-\bar{k}-\bar{a}) \quad (A3)$$

since both are equal to $\bar{U}$ by (9b) and (11).

Combining (A2) and (A3) yields

$$U[u_o-k^*-a^*-p(a^*)d] > U(u_o-\bar{k}-\bar{a}),$$

and thus, assuming U is monotonic,

$$u_o-k^*-a^*-p(a^*)d > u_o-\bar{k}-\bar{a}.$$

$$k^* \le \bar{k}-(a^*-\bar{a})-p(a^*)d < \bar{k}-p(\bar{a})d$$

where the last inequality follows from (A1). Q.E.D.