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dissertation entitled

THE ECONOMIC VALUE OF ENVIRONMENTAL RISK INFORMATION: THEORY AND APPLICATION TO THE MICHIGAN SPORT FISHERY

presented by

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has been accepted towards fulfillment
of the requirements for

Ph.D. degree in Agricultural Economics

Major professor

Date April 7, 1994

THE ECONOMIC VALUE OF ENVIRONMENTAL RISK INFORMATION: THEORY AND APPLICATION TO THE MICHIGAN SPORT FISHERY

By

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A DISSERTATION

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

DOCTOR OF PHILOSOPHY

Department of Agricultural Economics

1994

ABSTRACT

THE ECONOMIC VALUE OF ENVIRONMENTAL RISK INFORMATION: THEORY AND APPLICATION TO THE MICHIGAN SPORT FISHERY

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Tests of sport fish in the Great Lakes region have found traces of a variety of chemical residues. In sufficient doses some of these chemicals are suspected of causing adverse human health effects. In response to this problem, all of the governmental jurisdictions bordering the Great Lakes provide anglers with "Public Health Advisories" which list sites and species known to be contaminated and offer advice on how to reduce the risk of exposure.

This study asks whether Michigan's current advisory has value to anglers and how that value might be enhanced. Specifically, the study examines the value of two advisory alternatives -- testing a greater number of sites and providing a list of relatively safe sites. The report first reviews a Bayesian definition of information and its value. It proves that two common definitions of information value are algebraically identical. It also clarifies a confusion in the literature between information value and the welfare effects of changes in environmental quality.

The study then applies the framework to an evaluation of Michigan's advisories. It demonstrates that information value is nondecreasing in informativeness and fineness. It also shows that increased testing increases the informativeness of advisory information while listing safe sites increases fineness. The conceptual model also concludes that advisory value depends on (1) the possibility of behavioral change in response to information, (2) the perceived

severity of health effects associated with exposure to contaminated fish, and (3) the perceived accuracy of the advisory.

Focus group and interview pretesting produced a contingent valuation survey that was sent to licensed anglers in Michigan. The analysis concludes that anglers are probably willing to pay little for additional testing that does not also list safe sites. However, willingness to pay for an advisory that lists safe sites is positive and increasing in the number of sites tested. Nonlinear functional forms suggest that marginal WTP may be decreasing as the number of sites tested increases.

Acknowledgements

In completing this research and my doctoral program, I owe the greatest debt to my major professor, John Hoehn. John's emphasis on quality research contributed considerably to the development of my research and writing skills and to the overall quality of my graduate education. John's dedication to teaching and his breadth of knowledge made him an excellent major professor and mentor. He was supportive and accessible and deserves a large measure of the credit for both the quality of my graduate education and of the dissertation research. Of course, I accept responsibility for the remaining deficiencies in either area.

The other members of my committee also contributed significantly to my education and dissertation research. Eileen van Ravenswaay's insights and experience were particularly helpful in the process of designing the survey. She also taught me a great deal about how to be an effective teacher. Allan Schmid consistently challenged me to view economics and my research from a different perspective. His influence will hopefully prevent my thinking from becoming too narrowly focused by my formal training in economics. Ted Graham-Tomasi, though a late addition to my guidance committee, helped with the conceptual and empirical components of the research.

Many others also contributed to my research. I would like to thank John Hesse of the Michigan Department of Public Health and Douglas Jester of the Fisheries Division of the Michigan Department of Natural Resources for their help in defining the practical aspects of the research problem. I would also like to thank Christine Waggoner of the MDNR's Surface

Water Quality Division for her help in clarifying aspects of the current advisory program and the practical implications of alternatives. Finally, I wish to thank the Michigan Sea Grant College Program for the generous support of my doctoral research.

In my many years at MSU too many people to mention individually have helped me educationally, personally, administratively, and financially. My family and the many friends and colleagues I've found here helped me maintain a health perspective on life. The friends I've made are more important than any degree that I will take from here. Also, without Gayle's love and support, the hours away from the office would have been much less fulfilling and the presciently announced celebratory pig roast would not have been.

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Chapter One

Michigan's Public Health Advisories

Tests of sport fish in the Great Lakes region have found traces of a variety of chemical residues. In sufficient doses, some of these chemicals are suspected of causing adverse human health effects. Of most concern are mercury and suspected carcinogens such as PCBs, DDT, dieldren, toxaphene, and chlordanes (Bro et al. 1987, Humphrey 1974). Studies of accidental exposure to mercury and PCBs suggest that health effects may include skin problems, developmental retardation in children, nervous system damage, cancer, and death (Gaffey 1983, Kuratsune 1989, Jacobson et al. 1984, Marsh 1987, Eccles and Annau 1987). While acute health effects most likely result from exposure levels much greater than those faced by Great Lakes fish eaters, there remains the concern that fish consumers may suffer long term chronic health problems (Bro et al. 1987).

Because fish can accumulate some toxins to levels thousands of times greater than that found in the water, fish eaters suffer a potentially greater exposure than those who do not eat fish (Connor 1984). Humphrey (1983, 1974) found blood concentrations of PCBs and mercury to be significantly higher in consumers of Great Lakes fish than among those who did not eat fish. Concentrations were positively related to the quantity of fish consumed. Also, women who consume Great Lakes fish often have elevated levels of PCBs in their breast milk (Schwartz et al. 1983).

In response to this problem, all of the governmental jurisdictions bordering the Great Lakes provide anglers with information about chemical residues in fish. These warnings most often take the form of public health advisories which list sites and species known to be contaminated and offer advice about how to reduce the risk of exposure (Hesse 1990).

The budget for chemical analysis and printing costs constrain the type and quantity of information included in Michigan's current advisory. Within these constraints, the content of the advisory is determined primarily by state fisheries and health risk experts with little public input. While budget constraints and the opinions of experts are relevant considerations in program design, cost benefit analysis suggests that the benefits to affected individuals are also pertinent (Mishan 1976). However, the fact that the advisories are not priced makes assessment of their value (benefit) difficult.

This study develops and applies methods to estimate the value of advisory information about sport fish contamination to anglers. Conceptually, it defines information value and reviews the economic comparison of information systems. Empirically, it adapts the contingent valuation method to obtain measures of willingness to pay for health risk information. The case study focuses on estimating the value of two specific additions to Michigan's existing public health advisory program. This knowledge should aid state agencies in making tradeoffs between the costs of providing different types of information and the benefits to the affected population.

The remainder of this chapter reviews the information contained in Michigan's advisory. It also examines the information activities of other states and provinces in the Great Lakes region. The review of information strategies used by other jurisdictions helps identify specific alternatives to Michigan's current approach. Finally, the chapter outlines specific thesis objectives.

Michigan's Public Health Advisories

The Michigan Department of Public Health (MDPH) has issued annual public health advisories in some form since 1970. Since 1977, the Michigan Department of Natural Resources (MDNR) has published the advisory in the back of the annual "fishing guide" distributed to anglers when they purchase a license. The MDPH also issues a news release accompanying the annual advisory as well as periodic releases when new information becomes available, about once or twice a year. They also make a special effort to target particularly vulnerable groups. For example, through direct contact and articles in professional journals, the MDPH has informed childbirth educators and general physicians about the special health concerns for women of childbearing age associated with consuming contaminated fish. Also, the MDNR has recently begun to post advisories at public access sites where contaminants have been found.

Information Content of Advisories

Michigan's current advisory presents information in three forms: text, graphics, and tables. The text of the advisory contains a brief description of some chemicals found in Michigan fish, the sources of the chemicals, and possible health effects. It also warns that concentrations of contaminants are likely to be higher in larger or older fish, predator species, fatty fish, and carp or catfish. It suggests that anglers who intend to eat their catch trim the fat and skin from fillets and cook them so that fat can drain away. A graphic presentation illustrates the suggested method of trimming fish.

Since 1989 the advisory has also included a textual warning about mercury in inland lakes. This warning states that mercury contamination is widespread in the North Central United States and Canada. It suggests that anglers eat no more than one meal per week of rock bass, perch, or crappie over nine inches in length; largemouth bass, smallmouth bass, walleye, northern pike, or muskie of any size from any inland lake. The advisory warns nursing mothers, pregnant women, women who intend to have children, and children under the age of 15 against eating more than one meal per month of these fish.

Finally, the advisory also contains a table listing sites that have been found to be contaminated. For each site, the table lists the species and sizes of fish that are contaminated, the specific chemical responsible for the advisory, and suggested consumption restrictions. The advisory contains three specific categories of consumption advice based on the proportion of sampled fish for which contaminant levels exceed state standards. When fewer than 10 percent of tested fish contain excessive contaminant levels, the advisory does not suggest any consumption restrictions. If 11 to 49 percent exceed these levels, consumption is recommended not to exceed one meal per week. The advisory suggests no consumption if over 50 percent of the sampled fish exceed trigger levels for any contaminant. In addition, nursing mothers, pregnant women, women who intend to have children, and children under the age of 15 are warned against eating any fish from either of the restricted categories (Hesse 1990).

Sampling and Testing Procedures

The state of Michigan has tested contaminant levels in sport fish regularly for more than twenty years. The sampling and testing procedures currently in use have been in place since 1987. In the four year period from 1987 to 1990 the state tested 4,072 fish from 260 sites. This amounts to an average of 1,018 fish from 65 sites annually.

Under the current program, the Surface Water Quality Division of the Michigan Department of Natural Resources annually compiles a list of proposed test sites. Several criteria influence site selection. First, the state tests a subset of a preselected group of "trend monitoring" sites every year on a four to five year rotation in order to identify trends in contamination levels. Second, the state may choose to test a site if a contamination problem is suspected. These "problem evaluation" sites might include collection points near known waste contamination sites or industrial discharges. In addition, a number of previously tested problem evaluation sites are retested to determine if contaminant levels have changed. Finally, the MDNR may select particular sites if it receives enough public requests for testing. Priority is also given to sites that receive heavy fishing pressure. When a list of proposed sites is compiled, it is distributed to other agencies within state government for comment. Sites may be added to or

removed from the list based on this feedback. The total number of sites tested each year is constrained by the budget for chemical analysis which in 1992 totalled $320,000. [1]

Once a list of sites is agreed upon, employees of the Fisheries Division or the Surface Water Quality Division of the MDNR visit the site and capture fish for testing. They take fish by netting or shocking, depending on the characteristics of the site. The species sampled depend on the reason for testing. If the site is being tested for mercury, two top predator species are sampled. If the site is a problem evaluation site, carp and a top predator species are sought. Sometimes a particular species may be targeted if specific data is needed.

Once fish are collected the MDPH analyzes them for the presence of 28 separate chemicals. The preparation of fish for analysis depends on the species and how they are most often prepared for consumption. For most Great Lakes species, tests are conducted on skin-on fillets of individual fish. For carp and catfish, skin-off fillets are used.

Information Alternatives

The advisories issued by various jurisdictions in the Great Lakes region differ in a number of dimensions. These differences suggest a feasible set of alternatives to Michigan's current advisories. Differences include (1) the way advisories are published, (2) the trigger levels used to generate specific advice, (3) the specific categories of advice issued, (4) the sampling and analysis of fish, and (5) the type of information included (Foran and Vanderploeg 1989, Hesse 1990).

Most jurisdictions publish advisories as part of the pamphlet of fishing regulations and also distribute advisories in a separate booklet. Exceptions are Pennsylvania and Ohio which currently publish advisories only through press releases. Michigan distributes a brochure targeted at women of childbearing age and places posters at public access sites in addition to

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[1] Personal communication with Christine Waggoner, Surface Water Quality Division, Michigan Department of Natural Resources.

printing the formal advisory in the fishing regulations. Most states update advisories annually. Exceptions are Wisconsin which updates twice a year and Minnesota which updates every two years. Ontario publishes consumption advisories in a large booklet separate from fishing regulations and updates annually.

Jurisdictions also differ in the specific warnings they issue and in the contaminant levels that trigger the warnings. For example, the states bordering Lake Michigan issue three categories of advice based on the percentage of fish in a sample that contain levels of any contaminant exceeding FDA action levels. New York also uses FDA action levels to initiate three specific warnings but uses a method of combining measured concentration levels that accounts for possible interactions of contaminants. Minnesota is the only state that does not link advisories to FDA action levels. Minnesota uses the detection limit for PCBs and dioxins to trigger consumption warnings. Detection limits for these chemicals are two orders of magnitude smaller than FDA action levels. For mercury, Minnesota uses a trigger level an order of magnitude smaller than FDA action levels. Ontario issues six categories of advice based on trigger levels that are very close to FDA levels.

All jurisdictions except Ohio include special warnings for women and children. The wording of these warnings differs, but they are essentially the same except for the age at which the warning takes effect for children. All jurisdictions also offer preparation and cooking suggestions that can reduce risk. Ontario and Wisconsin include much greater detail about types of contaminants, sampling and analysis techniques, and potential health risks than other advisories. Judging by the number of warnings issued, some jurisdictions appear to test a much greater number of sites. For example, Illinois listed only seven sites in 1986 while Ontario listed 1,700 in 1990.

Probably the greatest difference in the type of information provided is the inclusion of information about fish that are found not to contain dangerous levels of contaminants. Michigan and all other states except Minnesota list a site in the advisory only if tests of fish from that site indicate the need for consumption restrictions. Many tested fish do not contain levels of contaminants sufficient to warrant a restriction, but this information is not published. Ontario and Minnesota are the only jurisdictions that list test results from all water bodies and species tested.

Alternatives to Michigan's current advisory range from eliminating the program altogether to an expanded program similar to Ontario's. Not all of these alternatives are politically or economically feasible. Discussions with state officials revealed two informational changes they view as desirable and would like to incorporate in future monitoring plans and advisories. [2] The first is to publish results of all tests regardless of whether chemical concentrations warrant a consumption restriction. During the period from 1987 to 1990 the state of Michigan tested 260 separate sites. This testing program generated 13 specific consumption warnings. Thus, a program that listed all tested sites could have provided information about 247 relatively safe sites. The primary constraint in implementing this policy change is printing costs.

A second alternative that interests state officials is to test a greater number of sites. Michigan contains over 5,800 publicly accessible fishing sites. These include about 3,600 inland lakes, 2,200 sites on rivers and streams, and the Great Lakes. The current budget permits testing about 65 sites per year. Some of the testing effort is directed at trend monitoring sites so only about 30 new sites are tested each year. At current testing rates it will take many years to gather information on all of Michigan's water bodies. Information about a greater number of sites would provide anglers a broader base of knowledge about the risks associated with their fishing choices. With this information they could make choices more consistent with their preferences for risk bearing. Survey results suggest that anglers are also interested in information about a greater number of sites. A survey of Ontario anglers in 1989 asked for suggestions for improving advisory information. Respondents most frequently suggested increasing the number of sites and species tested [3] (Ontario 1990).

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[2] Personal communication with John Hesse, Chief, Environmental Health Assessment Division, Michigan Department of Public Health.

[3] Ontario's advisory already lists sites that were tested and found to be safe. Therefore, respondents did not suggest listing safe sites among the desired improvements.

Thesis Objectives

This research has three specific objectives related to the problem of providing information about fish contamination in Michigan. The first is to develop a conceptual foundation for assessing the value of different types of contamination information. The framework links a compensating variation measure of willingness to pay (WTP) to changes in expected utility measured in a Bayesian model. The conceptual model generates hypotheses about the value of different types of information. It also yields hypotheses about the distribution of information benefits across different types of individuals.

The second objective is to develop a contingent valuation (CV) survey instrument to measure WTP for specific information related to fish contamination. The survey assesses anglers' perceptions of risk and their current angling practices. Focus groups provide insights into anglers' cognitive processes concerning risk and the aspects of the contamination problem they believe to be important. Few studies have used focus groups to explore attitudes about environmental risks and the research yields some insights into their application and interpretation.

The third objective is to obtain estimates of anglers' WTP for two types of contamination information: (1) information about which locations have been found to be safe, and (2) information obtained from testing a greater number of sites. The state of Michigan should find the estimates useful as a measure of benefits to compare with the costs of obtaining and distributing information.

Outline of Research

The remainder of this report develops the conceptual and analytical tools needed to measure the value of information about contamination, describes the estimation of information value for the case of sport fish contamination in Michigan, and develops the policy implications of the empirical findings. Chapter two reviews the theory of information value and explores the conditions under which different information systems can be compared. Chapter three analyzes the welfare impacts of alternative information systems and develops specific behavioral and distributional hypotheses. Chapter four discusses the methods used for data collection and analysis and reports descriptive statistics. Chapter five describes the estimation of WTP measures and discusses results. Chapter six summarizes research findings, reviews their policy implications, and suggests areas for future research.

Chapter Two

Economic Comparison of Information Systems

This research investigates the value of information about food and environmental contamination. In particular, it asks whether current advisories about chemical residues in Michigan's sport fish have value to anglers and how different types of information might enhance that value. This chapter outlines a conceptual framework for the analysis of information value. It also explores the economic comparison of different types of information.

The analysis uses the Bayesian model to describe how individuals incorporate information into their decision processes. The chapter begins by defining information and explaining the characterization of information in terms of a likelihood function. It also demonstrates how the Bayesian framework combines prior beliefs and new information to form posterior beliefs. The definitions and analysis of the section aid in understanding the remainder of the chapter.

The chapter also reviews the literature on information value and the economic comparison of information alternatives. The review has two objectives. The first is to develop a clear conceptual understanding of information and its value. The literature contains two definitions of ex ante information value. The algebraic similarity of the two definitions has contributed to contradictory conclusions about the sign of ex post information value. Both Graham-Tomasi (1988) and Pope (1985) conclude that ex post information value may be negative. The analysis of this chapter shows that information value is nonnegative ex ante and ex post. It demonstrates that the confusion about ex post value is caused by a failure to distinguish between nonnegative information value and the possibly negative welfare effects associated with changes in the environment. The chapter also proves that the two definitions of ex ante information value are algebraically equivalent if probabilistic beliefs are updated using Bayes' rule.

The second objective of this chapter is to systematically link characteristics of information systems to economic value. The analysis defines an ordering of information systems based on the concept of informativeness -- a measure of how well an information system predicts states. It then shows that informativeness is synonymous with economic value. It also defines the concept of fineness as a special case of informativeness. Fineness measures the relationship between signals and states that are relevant to decision making. Two propositions summarize the relationships between informativeness, fineness, and economic value.

Characteristics of information users may also influence information value. However, the links between individuals' characteristics and information value are weaker and more difficult to assess empirically than those between information value and characteristics of information systems. The analysis also develops the proposition that information value is nonincreasing in the perceived utility of outcomes.

Information and Probabilistic Beliefs

The literature defines an information system as a set of signals (Hirshleifer and Riley 1979). A signal is a message about how likely each of several unknown states is to occur. For example, a weather forecast service produces signals about the likelihood of future states of "rain" or "dry". Michigan's public health advisory issues signals that distinguish between states of "safe" or "unsafe" levels of chemical residues in fish. Specifically, the current advisory issues an explicit signal to "restrict consumption" when sites are "unsafe". [1] An information system that issues only one signal also produces an implicit signal associated with

[1] Unless specified otherwise, the examples in this chapter and the next do not distinguish between the two levels of consumption restrictions suggested by the advisory. In the examples, the "restrict consumption" signal represents both the signal to restrict consumption to no more than one meal per week and the signal to consume none of the fish.

the absence of the explicit signal. For instance, the current advisory provides the explicit signal to "restrict consumption" and an implicit signal of "no report".

The Bayesian model assumes that individuals have prior beliefs about the probabilities of different states. Information is defined as a signal that changes probabilistic beliefs (Chavas and Pope 1984). For instance, prior to reading the public health advisory, an angler may perceive the probability of contamination in fish from a favorite site to be low. This perception represents the angler's prior belief about the probability of the state of "safe" relative to a state of "unsafe". Suppose the angler then discovers that the advisory issues a signal to "restrict consumption" of fish from that site. This message may alter prior beliefs about whether fish from the site are "safe" or "unsafe" to eat. The Bayesian model defines the informed perceptions of state probabilities as posterior beliefs.

This section introduces the terminology and analytics of the Bayesian approach. It first defines the likelihood function that the Bayesian framework uses to represent the information content of signals. It then introduces Bayes' rule which formally describes the formation of posterior beliefs from prior beliefs and new information. Several examples demonstrate that the prior beliefs and new information influence posterior beliefs in proportion to weights attached to each. These weights represent the relative confidence people have in prior beliefs and in information.

Representing Information: The Likelihood Function

The Bayesian likelihood function describes the relationship between states and signals. It summarizes the informational content of signals. For each possible state, the likelihood function defines the conditional probability that the information system will generate a particular signal given that the state is true. Thus, two states and two signals yield four likelihood probabilities. The likelihood function generates twelve likelihood probabilities if there are four states and three signals .

States	Signals	
	No Consumption Restriction (NCR)	Restrict Consumption (RC)
Safe	P(NCR|safe)	P(RC|safe)
Unsafe	P(NCR|unsafe)	P(RC|unsafe)

Figure 2.1 – Likelihood Probabilities

Figure 2.1 illustrates the likelihood probabilities associated with an information system that provides signals of "no consumption restriction" (NCR) and "restrict consumption" (RC) associated with "safe" and "unsafe" states of chemical contamination. P(NCR|safe) represents the probability (likelihood) that the information system generates a "no consumption restriction" signal when a site is "safe". The likelihood P(NC|safe) is the probability of a "restrict consumption" signal when a site is "safe". Similarly, when a site is "unsafe", P(RC|unsafe) is the probability of a "restrict consumption" signal and P(NCR|unsafe) is the probability that the information system identifies an "unsafe" site as "safe".

An information system must generate a signal regardless of the state that ultimately occurs. Thus, the probabilities in the rows of Figure 2.1 sum to one -- P(RC|safe) plus P(NCR|safe) equals one and P(RC|unsafe) plus P(NCR|unsafe) equals one. Likelihood probabilities over states (columns in the figure) do not necessarily sum to one. Suppose a test for contaminants never generates a false positive. This implies that P(RC|safe) equals zero and P(NCR|safe) equals one. It does not imply that the test never produces a false negative. Therefore, P(RC|unsafe) does not necessarily equal zero and P(NCR|unsafe) does not necessarily equal one.

Likelihoods reflect subjective perceptions of the link between states and signals. In simple physical models, individuals may choose likelihoods that reflect the physical or statistical characteristics of a testing environment. However, when the link between states and signals is less certain, likelihoods may appear much more subjective. As an example of the former case, consider the problem of estimating the proportion of defective units in a production run from a representative sample. The binomial distribution describes the statistical relationship between the true proportion of defectives and the number found in the sample (Winkler 1972, Freund 1962).

The binomial distribution

$$P(r \mid n, p) = \binom{n}{r} p^r (1 - p)^{n-r}$$

describes the likelihood of observing r defective units in a sample of size n (the signal) given that p is the true proportion of defectives (the state). For example, suppose testing finds three defectives in a sample of 20 units. The test produces a signal that the proportion of defectives is .15 (3 ÷ 20). The likelihood of receiving this signal depends on the true proportion of defectives. If the true state is ten percent defectives, the likelihood of receiving the above signal is $P(3 \mid 20,.1) = .19$. Substituting other possible states for .1 in the binomial formula yields the likelihoods of receiving the signal of 15 percent defectives given that other states are true. The likelihood of finding 15 percent defectives in the sample is greatest when there are really 15 percent defectives in the production run.

When available, individuals may base the choice of likelihoods on past observations of the association between states and signals. Several studies of the value of weather information to farmers used historical data on the relationship between forecasts and actual weather patterns to calculate likelihoods (Baquet et al. 1976, Tice and Clouser 1982, Byerlee and Anderson 1969). Specifically, these studies derive the likelihood of receiving a forecast of rain when it actually will rain from the historical record of the association of actual rain with a rainy forecast.

These examples illustrate cases where likelihoods have a strong foundation in statistical or physical processes. However, likelihoods essentially reflect subjective perceptions of the information content of a signal. Even likelihoods from the examples above are subjective. For example, farmers may believe that the accuracy of weather forecasts changes over time. Similarly, plant managers may believe that sampling for defective items is not random.

Some situations seem to offer little substantive basis for the choice of likelihoods. This seems particularly true in the case of chemical contamination of food and the environment where even experts disagree about the associated health risks. The lack of consensus among experts confronts consumers with a number of contradictory messages. How individuals evaluate these messages depends on a number of factors. For example, an individual may question the ability of tests to identify different concentrations of chemical residues or question whether an information provider accurately reports test results. Factors such as these may affect the perceived association between signals and states.

The Effects of Prior Beliefs and Information on Perceived Risks

Bayes' rule formalizes the way the Bayesian model combines prior beliefs and new information to form posterior beliefs. Consider an information system that generates a set of signals $Y=\{y_1,y_2,\ldots,y_I\}$ related to a set of states $S=\{s_1,s_2,\ldots,s_K\}$. Formally, Bayes' rule states

$$(2.1) \qquad P(s_k \mid y_i) = \frac{P(s_k)\, P(y_i \mid s_k)}{P(y_i)}$$

where $P(s_k)$ is the prior probability of state s_k, $P(s_k \mid y_i)$ is the posterior probability of state s_k given signal y_i, $P(y_i \mid s_k)$ is the likelihood probability of receiving signal y_i given state s_k, and $P(y_i) = \Sigma_k P(s_k)\, P(y_i \mid s_k)$ is the probability of receiving signal y_i.

The relative effect of information on posterior beliefs depends on the relative confidence an individual has in information relative to prior beliefs (Hirshleifer and Riley 1979). An individual who is very confident of prior beliefs will not be easily swayed by new information. Conversely, information of any quality may strongly influence an individual with little confidence in prior beliefs. Confidence measures the strength of beliefs and is reflected in prior and likelihood probabilities. An individual who is very confident that a particular state is true will assign a relatively high prior probability to that state. Similarly, an individual with a great deal of confidence in a signal will believe receipt of the signal to be very likely for one state and relatively unlikely for other states. Confidence in a signal implies that one likelihood probability associated with the signal is large relative to the others.

Greater confidence in prior beliefs or likelihoods implies greater posterior confidence. Consider how posterior probabilities change with changes in priors and likelihoods.

(2.2a) $$\frac{\partial P(s_k|y_i)}{\partial P(s_j)} = \frac{P(y_i|s_k)\,P(y_i) - P(y_i|s_k)^2\,P(s_k)}{P(y_i)^2} \geq 0 \text{ for } k=j$$

(2.2b) $$\frac{\partial P(s_k|y_i)}{\partial P(s_j)} = \frac{-\,P(y_i|s_j)\,P(y_i|s_k)\,P(s_k)}{P(y_i)^2} < 0 \text{ for } k\neq j$$

(2.2c) $$\frac{\partial P(s_k|y_i)}{\partial P(y_i|s_j)} = \frac{P(s_k)\,P(y_i) - P(s_k)^2\,P(y_i|s_k)}{P(y_i)^2} \geq 0 \text{ for } k=j$$

(2.2d) $$\frac{\partial P(s_k|y_i)}{\partial P(y_i|s_j)} = \frac{-\,P(s_k)\,P(s_j)\,P(y_i|s_j)}{P(y_i)^2} < 0 \text{ for } k\neq j$$

As the prior probability of a state increases, so does the posterior probability of that state for each signal (equation 2.2a). Increases in the prior probability of a state reduce the posterior probability of other states (equation 2.2b). Similarly, for a given signal, greater likelihood associated with a given state increases the posterior probability of that state while reducing the posterior probabilities of other states (equations 2.2c and 2.2d). Thus, greater confidence in the priors and/or the likelihoods increases the confidence of the posterior.

This discussion leads to a natural interpretation of confidence in terms of the spread of a distribution. Greater confidence in prior beliefs implies that more probability is concentrated on a single state. Greater confidence in a signal implies a greater likelihood that the signal is associated with one state as opposed to others. The relationship between formal measures of the spread of the prior and likelihood distributions and posterior beliefs depends on distributional assumptions. For example, when priors and likelihoods are normally distributed, Kihlstrom (1974) shows that the posterior estimate of the mean, $E(\mu)$, is the sum of prior and likelihood means weighted by inverses of the prior and sample variances respectively.

(2.3) $$E(\mu) = \frac{\theta}{\theta + \phi} \mu_s + \frac{\phi}{\theta + \phi} \mu_p$$

where $E(\mu)$ equals the posterior estimate of the mean, θ equals the inverse of the sample variance, μ_s equals the sample mean, ϕ equals the inverse of the prior variance, and μ_p equals the prior mean. Kihlstrom defines θ and ϕ as measures of confidence, Zellner (1971) refers to them as precision parameters, and Winkler (1972) calls them measures of uncertainty.

As the variance of the prior declines (confidence in the prior increases), ϕ increases, and the weight attached to the prior mean increases. Thus, as confidence in the prior increases, the effect of prior beliefs on posterior beliefs increases relative to the influence of information. Similarly, increased confidence in information implies a smaller sample variance, an increase in θ, and greater relative weight attached to information.

If priors and likelihoods are distributed according to the beta distribution, confidence is defined in terms of the quantity or statistical quality of beliefs. Viscusi and O'Connor (1984) investigate changes in risk perceptions for workers in the chemical industry in response to new risk information. They describe priors and likelihoods with a beta distribution and show that the posterior estimate of risk is the sum of prior risk and sample (information) risk weighted by the relative number of observations reflected in priors and information.

(2.4) $$p^* = \frac{\xi}{\xi + \gamma} s + \frac{\gamma}{\xi + \gamma} p$$

where p^* equals the posterior risk of accident, s equals the risk of accident conveyed by information, p equals the perceived prior risk of accident, ξ equals the number of observations reflected in information, and γ equals the number of observations reflected in prior beliefs.

An experienced worker may develop perceptions of chemical risks from years of observation. Such a worker may believe γ to be large relative to ξ. Viscussi and O'Connor's model implies that the worker's posterior perceptions of risk would depend largely on prior beliefs -- confidence in prior beliefs is high relative to confidence in information. On the other hand, a worker may have a great deal of confidence in a large scale study of chemical risks. This belief implies a larger ξ and increases the influence of information on posterior perceptions of risk.

Viscussi and O'Connor refer to the weights associated with s and p as measures of precision. These weights are conceptually equivalent to the measures of confidence developed in the context of the normal distribution.

Information Value

The following analysis shows that information has value because it helps people avoid mistakes. For example, an individual may wish to avoid chemical residues in wild game. Prior to news reports of mercury in pheasants, a hunter may have consumed pheasant with little perceived risk. Information about mercury contamination changed many hunters' perceptions of the health risks associated with eating pheasant (Shulstad and Stoevener 1978). Because they were informed, these individuals had the option of changing consumption behavior to avoid exposure. Without information they would have continued their pre-information consumption -- a mistake if informed -- and may ultimately have suffered an unexpected adverse health outcome.

This section reviews two definitions of information value -- one that expresses information value in terms of mistakes, and one that does not. The analysis proves that the two definitions are algebraically equivalent. The definition that does not identify mistakes has been misinterpreted to imply that information can make people worse off. The section shows this result to be caused by a confusion between ex post signal value and the welfare effects associated with contamination. It concludes by providing a clear distinction between the different welfare effects associated with contamination and information. The analysis shows that information value is always nonnegative and that welfare losses due to contamination are larger if consumers are uninformed.

Information Value: Two Definitions

Suppose anglers' utility depends on attributes of a fishing experience. Anglers select attributes by choosing levels of specific fishing behaviors, $\mathbf{q}=\{q_1,q_2,\ldots,q_L\}$. These behaviors may include the choice of a fishing site and the species, size, and quantity of fish to consume. Suppose anglers also care about the state of health. The advisory suggests that health may depend on the level of chemical residues in fish consumed, s, and on behavioral choices that avert risk. Thus, to the extent that some behavioral choices reduce the risk associated with chemical residues, health, h, depends on s and **q**. However, current public health advisories are not sufficient to identify with certainty which fish contain harmful chemical residues. Therefore, anglers are uncertain of the health consequences associated with specific fishing behaviors.

Under conditions of uncertainty, economic decision theory suggests that people maximize expected utility over possible states of nature (von Neumann and Morgenstern 1944). Anglers have only probabilistic knowledge about the occurrence of states of contamination. Under these conditions, the angler's maximization problem is

$$\max_{\mathbf{q}} \int u(\mathbf{q},h(\mathbf{q},s))\, P(s)\, ds$$

where P(s) is the prior probability distribution over the alternative states or levels of contamination. Individuals continually update probabilistic beliefs as new information becomes available. Therefore, prior beliefs at any time are the posterior probabilities associated with the last information received. Priors implicitly depend on all prior information. However, for simplicity, the notation used in this paper suppresses the conditional aspect of prior beliefs.

Define $\mathbf{q}^*$ as the vector of behavioral choices that maximizes expected utility given prior beliefs. The angler's prior maximal expected utility is therefore

(2.5) $$u_p = \int u(q^*,h(q^*,s))\ P(s)\ ds.$$

Now suppose the angler receives a signal about contamination of fish. After receiving the signal, y, the angler uses Bayes' rule to form posterior probabilities $P(s|y)$. The angler's maximization problem is now

$$\max_q \int u(q,h(q,s))\ P(s|y)\ ds.$$

Define q^y as the optimal action given signal y. The angler's posterior maximal expected utility associated with receipt of signal y is

(2.6) $$u_y = \int u(q^y,h(q^y,s))\ P(s|y)\ ds.$$

Each signal may cause a different change in beliefs and a different optimal action. The Bayes' strategy defines the optimal behavior for each possible signal. Ex ante, prior to receipt of a particular signal, an individual will be uncertain about which signal is forthcoming. The expected utility associated with the information system will then be the expected utility of following the Bayes' strategy (Hirshleifer and Riley 1979). For example, suppose the information system contains I signals, $Y=\{y_1,y_2,\ldots,y_I\}$. The expected utility associated with the Bayes' strategy is

(2.7) $$u_Y = \int \int u(q^y,h(q^y,s))\ P(s|y)\ ds\ P(y)\ dy$$

where:

$$P(y) = \sum_{k=1}^{K} P(s_k)\ P(y|s_k)$$

defines the probability of receiving signal y. Therefore, the ex ante expected utility associated with information system Y is the expectation of ex post expected utilities of signals (equation 2.6) with respect to the probability of receiving each signal.

Anderson et al. (1977) define the ex ante value of information as the difference between the expected utility of the Bayes' strategy and the expected utility of the prior optimal act (equation 2.5)

(2.8)
$$v_Y = u_Y - u_p$$
$$= \int \int u(\mathbf{q}^y, h(\mathbf{q}^y, s))\, P(s \mid y)\, ds\, P(y)\, dy - \int u(\mathbf{q}^*, h(\mathbf{q}^*, s))\, P(s)\, ds.$$

Equation 2.8 states that ex ante information value is the difference between expected utility with information and expected utility prior to being informed. This definition has two conceptual limitations. First, it is not clearly consistent with the conceptual source of information value as helping to prevent mistakes. A prior act is a mistake only when evaluated in light of posterior perceptions. The Anderson et al. definition does not identify mistakes. Second, the definition has no ex post analogue.

Hirshleifer and Riley (1979, 1992) propose a definition of information value that is intuitively consistent with both ex post and ex ante values. They define both ex post and ex ante values in terms of mistakes. To illustrate, consider an individual who chooses a course of action without knowledge of a signal, y, that would change probabilistic beliefs. Once the signal is received, the individual may view prior behavior as a mistake. Given receipt of a signal y, the expected utility associated with the (mistaken) prior act is

(2.9)
$$u_m = \int u(\mathbf{q}^*, h(\mathbf{q}^*, s))\, P(s \mid y)\, ds.$$

By definition, $\mathbf{q}^*$ does not maximize expected utility given posterior beliefs $P(s \mid y)$. Therefore, $\mathbf{q}^*$ is a mistake when evaluated relative to posterior beliefs. Signal y makes behavioral change possible and prevents the mistake. The utility value of a signal is the difference between the expected utility of the optimal act when aware of the signal (equation 2.6) and the expected utility of the mistake (equation 2.9).

(2.10)
$$v_y = u_y - u_m$$
$$= \int u(\mathbf{q}^y, h(\mathbf{q}^y, s))\, P(s \mid y)\, ds - \int u(\mathbf{q}^*, h(\mathbf{q}^*, s))\, P(s \mid y)\, ds$$

Equation 2.10 defines (in utility terms) the ex post value of signal y.

Hirshleifer and Riley define the ex ante value of the information system $Y=\{y_1,y_2,\ldots,y_I\}$ as the expectation of ex post signal values with respect to signal probabilities

$$(2.11)\qquad v_Y = \int \left\{ \int u(q^y,h(q^y,s))\, P(s\,|\,y)\, ds - \int u(q^*,h(q^*,s))\, P(s\,|\,y)\, ds \right\} P(y)\, dy.$$

The definitions of ex ante information value in equation 2.8 and 2.11 are algebraically identical if posteriors are formed from priors using Bayes' rule. The following proof shows the difference between the two definitions to be zero and thus proves the equivalence.

The Anderson et al. definition of equation 2.8 can be written as

$$(2.12)\qquad v_A = \int \left\{ \int u(q^y,h(q^y,s))\, P(s\,|\,y)\, ds - \int u(q^*,h(q^*,s))\, P(s)\, ds \right\} P(y)\, dy$$

since $\int P(y)\, dy = 1$.

The expression of equation 2.12 appears similar to Hirshleifer and Riley's definition in equation 2.11. However, equation 2.12 uses prior beliefs to evaluate the prior act. Equation 2.11, on the other hand, uses posterior beliefs and defines the prior act as a mistake. The difference between equations 2.12 and 2.11 is

$$(2.13)\qquad v_A - v_Y = \int \int u(q^*,h(q^*,s))\, P(s\,|\,y)\, ds\, P(y)\, dy - \int u(q^*,h(q^*,s))\, P(s)\, ds.$$

Expanding the posterior probabilities with Bayes' rule yields

$$\int \int u(q^*,h(q^*,s)) \frac{P(s)P(y|s)}{P(y)} ds\ P(y)\ dy - \int u(q^*,h(q^*,s))\ P(s)\ ds$$

$$= \int \int u(q^*,h(q^*,s))\ P(y|s)\ P(s)\ ds\ dy - \int u(q^*,h(q^*, s))\ P(s)\ ds.$$

Changing the order of integration in the first term and rearranging yields

$$\int u(q^*,h(q^*,s))\ P(s) \int P(y|s)\ dy\ ds - \int u(q^*,h(q^*,s))\ P(s)\ ds. \tag{2.14}$$

The Bayesian model implies $\int P(y|s)\ dy = 1$. Thus, expression 2.14 reduces to

$$\int u(q^*,h(q^*,s))\ P(s)\ ds - \int u(q^*,h(q^*,s))\ P(s)\ ds = 0.$$

Therefore, the two definitions are the same.

Information value is nonnegative. Consider the definition of ex post signal value in equation 2.10. By definition, q^y is the optimal act associated with posterior beliefs $P(s|y)$. Thus, the second term on the right hand side of equation 2.10 can not be greater than the first. Therefore, the ex post value of a signal is nonnegative. As the sum of ex post signal values, ex ante information value must also be nonnegative.

Information Value and Related Welfare Effects

Graham-Tomasi (1988) and Pope (1985) conclude that ex post signal value may be negative. This section shows that this contradiction arises from a confusion between information value and other welfare effects associated with contamination.

Consider an angler with beliefs P(s) about the probability of chemical residues in fish. The angler's expected utility is

$$u_p = \int u(q^*,h(q^*,s))\ P(s)\ ds \tag{2.15}$$

where q^* represents optimal behavior given P(s). Define this as the prior utility of the prior act.

Suppose the angler is ignorant of a signal, y, about a contamination incident. If informed, the signal would produce posterior beliefs $P(s|y)$ and new optimal behavior q^y. To avoid issues of risk perception, assume that informed perceptions of risk are correct. Ignorance does not shield uninformed anglers from actual conditions. Both informed and uninformed anglers face possible future health effects determined by $P(s|y)$. In light of informed perceptions, the prior optimal act is a mistake. The expected utility of the mistake, u_m, is

$$u_m = \int u(q^*,h(q^*,s))\, P(s|y)\, ds. \tag{2.16}$$

Define this as the posterior utility of the prior act.

Contamination and ignorance of signal y cause a welfare loss equal to the difference between the posterior utility of the prior act, u_m, and the prior utility of the prior act, u_p.

$$u_m - u_p = \int u(q^*,h(q^*,s))\, P(s|y)\, ds - \int u(q^*,h(q^*,s))\, P(s)\, ds \tag{2.17}$$

By definition, q^* is the optimal act given beliefs $P(s)$. Therefore, the first term on the right hand side of equation 2.17 can not be larger than the second and the expression is unambiguously nonpositive.

Ignorance forces the uninformed angler to continue prior behavior, q^*, even though this would be a mistake if informed. If aware of signal y, the angler would choose behavior q^y and avoid the mistake of continuing the prior optimal act. The posterior utility of the posterior act is

$$u_y = \int u(q^y,h(q^y,s))\, P(s|y)\, ds. \tag{2.18}$$

Information prevents an individual from making the mistake of continuing prior behavior when informed risk perceptions dictate a different choice. Thus, the informed angler experiences a welfare change equal to the difference between the posterior utility of the posterior act, u_y, and the prior utility of the prior act u_p

$$u_y - u_p = \int u(q^y,h(q^y,s))\, P(s|y)\, ds - \int u(q^*,h(q^*,s))\, P(s)\, ds. \tag{2.19}$$

Equations 2.17 and 2.19 differ only in that the angler becomes informed. The difference

$$v_y = (u_y - u_p) - (u_m - u_p)$$
$$= \int u(q^y,h(q^y,s))\, P(s\,|\,y)\, ds - \int u(q^*,h(q^*,s))\, P(s\,|\,y)\, ds$$

is thus the ex post value of the signal y. This equals the ex post value of signal y given by equation 2.10.

The analysis above illustrates the three distinct welfare effects associated with a contamination incident and information.

1. Contamination causes a gross welfare loss (equation 2.17) as individuals continue prior behavior in ignorance of potential exposure to contaminants. The gross welfare loss is the difference between the posterior utility of the prior act and the prior utility of the prior act. This loss has two sources, (1) environmental contamination, and (2) being unable to change behavior in response to contamination.

2. Information allows people to choose behavior consistent with informed perceptions of risk. Information has value because it prevents the continuation of mistaken prior behavior. The ex post value of a signal is the difference between the posterior utility of the posterior act and the posterior utility of the prior act. Information value equals the change in gross welfare loss associated with the opportunity to change behavior.

3. The opportunity to engage in risk averting behavior reduces the magnitude of gross welfare loss to a welfare change net of information value. Net welfare change (equation 2.19) is the difference between gross welfare loss and

information value. It is measured by the difference between the posterior utility of the posterior act and the prior utility of the prior act.

The gross welfare loss associated with changes in environmental contamination and ignorance (equation 2.17) is unambiguously nonpositive. Information value is nonnegative. The net welfare change (equation 2.19) may be positive or negative. A signal about environmental contamination may cause an individual to forego valued activities in order to reduce risk. A number of studies document sales or consumers' surplus losses as a result of news about food or environmental contamination (Shulstad and Stoevener 1978, Swartz and Strand 1981, Foster and Just 1989, Smith et al. 1988, van Ravenswaay and Hoehn 1990, Mowen 1980, Brown 1969, Hamilton 1972, Schuker 1983). Environmental improvements may cause a positive net welfare change. Improved environmental quality may encourage an individual to give up some risk averting behaviors and reacquire foregone valued activities. These individuals will enjoy greater expected utility after being informed of the improvement than before -- they will experience a net welfare gain.

Pope (1985) and Graham-Tomasi (1988) mistakenly claim that ex post signal value may be negative. They both confuse ex post signal value with the net welfare change of equation 2.19. The similarity of the two definitions of ex ante information value contributes to this confusion. The authors mistakenly try to extract a measure of ex post signal value from the definition of information value given by equation 2.12.

Determinants of Information Value

Information value depends on, (1) prior risk, (2) behavioral change, (3) the utility function, and (4) the information system itself (Hilton 1981). Gould (1974) and Hess (1982) show that the effect of prior risk on information value is indeterminant without restricting the form of the utility function. Specifically, Gould shows that increased risk in the Rothschild-Stiglitz

(1970) sense [2] increases information value only when utility is linear in states. Furthermore, even though increased Rothschild-Stiglitz risk implies a mean preserving increase in variance, increased variance of the distribution of priors does not imply increased information value.

The relationship between information value and behavioral change is straightforward -- information has value only if it changes behavior. Consider the definition of ex post signal value given by equation 2.10. If behavior does not change, $q^y = q^*$, and the expression reduces to zero. Since ex ante information value is the expectation of ex post signal values, information has no value ex ante if behavior is unchanged for every signal.

Proposition (Behavioral Change) - Ex post, a signal has no value if it does not change behavior. Ex ante, information has no value if there is no possibility of behavioral change in response to any signal.

The relationship between information value and the utility function is also relatively straightforward. Consider the ex post value of a signal given by equation 2.10. The derivative of ex post signal value with respect to the expected value of the mistake (the second term) is negative. Thus, the lower the expected utility associated with the mistaken prior optimal act, the greater the value of a signal.

The ex ante value of information is the expectation of ex post signal values. Since the value of each signal is nonincreasing in the expected utility of the prior act, the ex ante value of information is also nonincreasing in the expected utility of the prior act.

Proposition (Utility of Mistake) - The value of information is nonincreasing in the utility of the possibly mistaken prior optimal action.

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[2] A distribution $F_1(x)$ is Rothschild-Stiglitz riskier than a distribution $F_2(x)$ if and only if the distributions have the same mean but $F_2(x)$ has more weight near the mean.

Finally, the value of information depends on characteristics of the information system itself. Control over specific aspects of an information system provide the greatest opportunity for an information provider to influence the value of information to users. The links between information system characteristics and value are the key results of this chapter. The following section reviews the relationship between the fineness and informativeness of information and its economic value.

The Value of Fineness and Informativeness

Information systems can be ordered by their "informativeness". This section shows that informativeness is synonymous with economic value. Informativeness measures the probabilistic strength of the association between a signal and a given state. A perfectly informative signal identifies with certainty which state will occur. A perfectly informative information system contains only perfectly informative signals. Perfect informativeness is necessary but not sufficient for perfect information. Perfect information must also identify states that are relevant to decisions (Nermuth 1982). The concept of fineness measures the relationship between signals and decision relevant states (Marschak and Miyasawa 1968). Fineness is a special case of informativeness.

The following example illustrates the concepts of informativeness, fineness, and decision relevance in the context of the current public health advisory. With respect to mercury, Michigan issues a warning to restrict consumption to no more than one meal per week if, (1) the site is tested, and (2) mercury concentrations fall between .5 and 1.5 parts per million (ppm). The advisory suggests no consumption if, (1) the site is tested, and (2) concentrations of mercury exceed 1.5 ppm. Finally, the advisory does not issue any specific warning if, (1) the site has not been tested, or (2) the site was tested but mercury concentrations were below .5 ppm. Thus, the advisory issues three signals relevant to mercury contamination, (1) no consumption, (2) restrict consumption, and (3) no report.

Suppose anglers accept that the concentrations used to trigger different signals are relevant to their utility and behavioral choices. Therefore, the signals issued by the advisory identify the states that are relevant to anglers' decisions. Table 2.1 illustrates likelihoods that an angler might assign to the advisory signals. It also shows the posteriors implied by the likelihoods and prior beliefs.

Table 2.1 - Informativeness

Likelihoods P(Signal | State)

States	Signals		
	No Report (NR)	Restrict Consumption (RC)	No Consumption (NC)
≤.5 ppm	P(NR | ≤.5) = .8	P(RC | ≤.5) = .2	P(NC | ≤.5) = 0
.5-1.5 ppm	P(NR | .5-1.5) = .8	P(RC | .5-1.5) = .2	P(NC | .5-1.5) = 0
≥1.5 ppm	P(NR | ≥1.5) = .8	P(RC | ≥1.5) = 0	P(NC | ≥1.5) = .2

The likelihoods of Table 2.1 reflect varying degrees of informativeness. The angler in the example believes the "no report" signal to be equally likely for each state. The likelihoods imply that the "no report" signal provides no information about which state is more likely -- the signal is uninformative (Nermuth 1982). Since the "no report" signal provides no information about the probability of occurrence of states, the posteriors associated with the signal equal prior beliefs.

The "restrict consumption" signal is more informative. The angler believes the signal to be issued with probability .2 when measured concentrations are between .5 and 1.5 ppm, with

Table 2.1 - (Continued)

Posteriors P(State|Signal)

States	Signals		
	No Report (NR)	Restrict Consumption (RC)	No Consumption (NC)
$\leq .5$ ppm	$P(\leq .5 \mid NR)$ $= \frac{.8 \cdot P(\leq .5)}{P(NR)}$ $= P(\leq .5)$	$P(\leq .5 \mid RC)$ $= \frac{.2 \cdot P(\leq .5)}{P(RC)}$ $< P(\leq .5)$	$P(\leq .5 \mid NC)$ $= \frac{0 \cdot P(\leq .5)}{P(NC)}$ $= 0$
.5-1.5 ppm	$P(.5\text{-}1.5 \mid NR)$ $= \frac{.8 \cdot P(.5\text{-}1.5)}{P(NREP)}$ $= P(.5\text{-}1.5)$	$P(.5\text{-}1.5 \mid RC)$ $= \frac{.2 \cdot P(.5\text{-}1.5)}{P(RC)}$ $< P(.5\text{-}1.5)$	$P(.5\text{-}1.5 \mid NC)$ $= \frac{0 \cdot P(.5\text{-}1.5)}{P(NC)}$ $= 0$
≥ 1.5 ppm	$P(\geq 1.5 \mid NR)$ $= \frac{.8 \cdot P(\geq 1.5)}{P(NREP)}$ $= P(\geq 1.5)$	$P(\geq 1.5 \mid RC)$ $= \frac{0 \cdot P(\geq 1.5)}{P(RC)}$ $= 0$	$P(\geq 1.5 \mid NC)$ $= \frac{.2 \cdot P(\geq 1.5)}{P(NC)}$ $= 1$

$$P(NR) = .8 \cdot P(NR \mid \leq .5) + .8 \cdot P(NR \mid .5\text{-}1.5) + .8 \cdot P(NR \mid \geq 1.5)$$

$$P(RC) = .2 \cdot P(RC \mid \leq .5) + .2 \cdot P(RC \mid .5\text{-}1.5) + 0 \cdot P(RC \mid \geq 1.5)$$

$$P(NC) = 0 \cdot P(NC \mid \leq .5) + 0 \cdot P(NC \mid .5\text{-}1.5) + .2 \cdot P(NC \mid \geq 1.5)$$

probability .2 when concentrations are below .5 ppm, and with probability zero when concentrations exceed 1.5 ppm. Receipt of the "restrict consumption" signal provides some information -- it implies that actual concentrations are equal to or below 1.5 ppm. However, it provides no information to distinguish between the states of $\leq$.5 ppm and .5-1.5 ppm. Because it contains some information, the "restrict consumption" signal alters prior beliefs. It increases the perceived probability that concentrations are either less than .5 ppm or between .5 and 1.5 ppm and eliminates the chance that concentrations are above 1.5 ppm.

Finally, the angler believes that the "no consumption" signal is perfectly informative -- it reveals with certainty that concentrations exceed 1.5 ppm. The posteriors associated with the signal reflect this certainty.

This example demonstrates that the informativeness of a signal does not depend on absolute likelihoods. Instead it depends on relative likelihoods associated with a signal. The distribution of likelihoods over states for a given signal determines the signal's influence on prior beliefs. The example also links the earlier notion of confidence (loosely measured by the spread of a distribution) to the concept of informativeness. The distribution of likelihoods for the uninformative "no report" signal is flat (McGuire 1972) or diffuse (Winkler 1972). This terminology implies a uniform distribution with no concentration of probability on any state. An uninformative signal is synonymous with no confidence. Similarly, anglers have complete confidence in the perfectly informative "no consumption" signal. The completely concentrated distribution of likelihoods reflects this confidence. This research uses the term informativeness.

The example above assumed that the states identified by signals are relevant to anglers' behavioral choices. Suppose instead that anglers believe they can safely eat one meal per month of fish with mercury concentrations between 1.5 and 2.0 ppm. The existing "no consumption" signal does not distinguish finely enough between contamination levels to be entirely decision relevant to these anglers. Table 2.2 illustrates the likelihoods and posteriors associated with decision relevant states when signals remain as they appear in Table 2.1. In

Table 2.2 - Fineness

Likelihoods P(Signal | State)

States	Signals		
	No Report (NR)	Restrict Consumption (RC)	No Consumption (NC)
≤ .5 ppm	P(NR | ≤ .5) = .8	P(RC | ≤ .5) = .2	P(NC | ≤ .5) = 0
.5-1.5 ppm	P(NR | .5-1.5) = .8	P(RC | .5-1.5) = .2	P(NC | .5-1.5) = 0
1.5-2.0 ppm	P(NR | 1.5-2.0) = .8	P(RC | 1.5-2.0) = 0	P(NC | 1.5-2.0) = .2
≥ 2.0 ppm	P(NR | ≥ 2.0) = .8	P(RC | ≥ 2.0) = 0	P(NC | ≥ 2.0) = .2

this example, the "no consumption" signal is no longer perfectly informative because it does not distinguish between decision relevant states.

The above examples illustrate that informativeness depends on both the ability of a signal to identify a state [3] and on the description of identified states relative to states that are decision relevant to information users. The remainder of this section relates the notions of fineness, decision relevance, and informativeness to information value.

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[3] The state that a signal identifies is irrelevant. For instance, a "no consumption" signal that anglers perceive identifies a site with mercury concentrations below .5 ppm 90 percent of the time is still quite informative.

Table 2.2 - (Continued)

Posteriors P(State | Signal)

States	Signals		
	No Report (NR)	Restrict Consumption (RC)	No Consumption (NC)
$\leq .5$ ppm	$P(\leq .5 \mid NR)$ $= \frac{.8 \cdot P(\leq .5)}{P(NR)}$ $= P(\leq .5)$	$P(\leq .5 \mid RC)$ $= \frac{.2 \cdot P(\leq .5)}{P(RC)}$ $> P(\leq .5)$	$P(\leq .5 \mid NC)$ $= \frac{0 \cdot P(\leq .5)}{P(NC)}$ $= 0$
.5-1.5 ppm	$P(.5\text{-}1.5 \mid NR)$ $= \frac{.8 \cdot P(5.\text{-}1.5)}{P(NR)}$ $= P(.5\text{-}1.5)$	$P(.5\text{-}1.5 \mid RC)$ $= \frac{.2 \cdot P(.5\text{-}1.5)}{P(RC)}$ $> P(.5\text{-}1.5)$	$P(.5\text{-}1.5 \mid NC)$ $= \frac{0 \cdot P(.5\text{-}1.5)}{P(NC)}$ $= 0$
1.5-2.0 ppm	$P(1.5\text{-}2.0 \mid NR)$ $= \frac{.8 \cdot P(1.5\text{-}2.0)}{P(NR)}$ $= P(1.5\text{-}2.0)$	$P(1.5\text{-}2.0 \mid RC)$ $= \frac{0 \cdot P(1.5\text{-}2.0)}{P(RC)}$ $= 0$	$P(1.5\text{-}2.0 \mid NC)$ $= \frac{.2 \cdot P(1.5\text{-}2.0)}{P(NC)}$ $> P(1.5\text{-}2.0)$
≥ 2.0 ppm	$P(\geq 2.0 \mid NR)$ $= \frac{.8 \cdot P(\geq 2.0)}{P(NR)}$ $= P(\geq 2.0)$	$P(\geq 2.0 \mid RC)$ $= \frac{0 \cdot P(\geq 2.0)}{P(RC)}$ $= 0$	$P(\geq 2.0 \mid NC)$ $= \frac{0 \cdot P(\geq 2.0)}{P(NC)}$ $> P(\geq 2.0)$

$$P(NR) = .8 \cdot P(NR \mid \leq .5) + .8 \cdot P(NR \mid .5\text{-}1.5) + .8 \cdot P(NR \mid 1.5\text{-}2.0) + .8 \cdot P(NR \mid \geq 2.0)$$

$$P(RC) = .2 \cdot P(RC \mid \leq .5) + .2 \cdot P(RC \mid .5\text{-}1.5) + 0 \cdot P(RC \mid 1.5\text{-}2.0) + 0 \cdot P(RC \mid \geq 2.0)$$

$$P(NC) = 0 \cdot P(NC \mid \leq .5) + 0 \cdot P(NC \mid .5\text{-}1.5) + .2 \cdot P(NC \mid 1.5\text{-}2.0) + .2 \cdot P(NC \mid \geq 2.0)$$

Fineness

Marschak and Radner (1972) develop a comparison of information systems on the basis of fineness. The concept of fineness defines the description of signals. Marschak and Radner define an information system Y to be finer than a system X if at least two signals in Y are subsets of at least one signal in X. They prove that Y is at least as valuable as X if Y is finer than X. The following analysis reviews the comparison of information values on the basis of fineness. It then relates fineness to decision relevance.

Suppose that signals from X are related to signals from Y in the following manner.

$$x_1 = \{y_1, y_4\}$$

$$x_2 = \{y_2\}$$

$$x_3 = \{y_3\}$$

An individual who observes X can distinguish between three possible states and has three possible behavioral responses. An individual who observes Y can distinguish between four possible states and has four possible behavioral responses which include those associated with observing X. Thus, a person who observes Y can be no worse off than a person observing X. The concept of fineness imposes a partial ordering on information systems. The ordering is only partial because information systems that use noncomparable partitions of the state space can not be ordered (Marschak and Miyasawa 1968).

Proposition (Fineness) - Information value is nondecreasing in the fineness of signals that identify decision relevant states.

This result has implications for the relative value of information systems that combine or separate signals. Combining two or more signals in an information system into a single decision relevant signal can not increase the value of the system. Similarly, separating a signal into two or more decision relevant signals can not decrease the value of an information system (Marschak and Miyasawa 1968).

The above result applies only if the signals y_1 and y_4 are decision relevant. Suppose the signal x_1 is decision relevant but y_1 and y_4 distinguish between states too finely to affect an individual's utility. If the individual can costlessly conclude that y_1 and y_4 provide the same information as x_1, then systems X and Y are equally valuable. However, information users may incur monetary and nonmonetary costs associated with combining signals. For example, it may take time, money, and significant cognitive effort to determine the decision relevant states implied by irrelevant signals. These costs affect the expected utility associated with information (Marschak and Miyasawa 1968).

To illustrate, include in an angler's utility function an argument that reflects the effort required to interpret information, $e(\cdot)$. The ex ante expected utility associated with information system Y is then

$$(2.20) \qquad \int \int u(q^y, h(q^y,s), e(y))\, P(s\,|\,y)\, ds\, P(y)\, dy$$

where $e(y)$ is the effort required to interpret or make use of signal y. Suppose $e(y)$ is minimized when Y contains all possible decision relevant signals. If Y aggregates some decision relevant signals, more effort is required to identify decision relevant states. Similarly, if Y issues signals that are finer than decision relevant states, information users may need to expend effort to aggregate the signals to make them decision relevant. Furthermore, assume that utility is nonincreasing in the effort required to use information -- $\partial u(\cdot)/\partial e(\cdot) \leq 0$.

Assume that systems Y and X define comparable partitions of the state space and that Y is at least as fine as X. Furthermore, suppose signals from an information system Y require more effort to use than those from a system X. Thus, $e(y) \geq e(x)\ \forall\ y \subseteq x$. Then

$$\text{(2.21)} \qquad \int \int u(q^x, h(q^x, s), e(x))\, P(s \mid x)\, ds\, P(x)\, dx$$

$$\geq \int \int u(q^y, h(q^y, s), e(y))\, P(s \mid y)\, ds\, P(y)\, dy$$

and X is at least as valuable as Y. [4] Marschak and Miyasawa (1968) emphasize that it is not possible to order information system values without knowing e(·) and its effect on u(·).

Providing additional information may also cause people to forget other relevant information. Magat et al. (1988) conclude that people may systematically forget some aspects of hazard warnings if presented with too much information. This result suggests that effective information programs must be carefully designed to provide information that is relevant to consumer decisions without overloading them with irrelevant or confusing information.

The preceding discussion implies that adding signals to an information system does not necessarily increase information value. Additional signals may actually reduce value if, (1) they do not identify decision relevant states, (2) they increase the effort required to use information (whether they are decision relevant or not), or (3) they overwhelm other important signals.

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[4] An information system X is at least as valuable as a system Y if the expected utility of the Bayes' strategy associated with X is greater than or equal to that associated with system Y. Using the definition of ex ante information value given in equation 2.8, information system Y is at least as valuable as system X if

$$\int \int u(q^y, h(q^y, s))\, P(s \mid y)\, ds\, P(y)\, dy - \int u(q^*, h(q^*, s))\, P(s)\, ds$$

$$\geq \int \int u(q^x, h(q^*, s))\, P(s \mid x)\, ds\, P(x)\, dx - \int u(q^*, h(q^*, s))\, P(s)\, ds$$

or

$$\int \int u(q^y, h(q^y, s))\, P(s \mid y)\, ds\, P(y)\, dy$$

$$\geq \int \int u(q^x, h(q^x, s))\, P(s \mid x)\, ds\, P(x)\, dx.$$

Thus, system X is at least as valuable as system Y if the expected utility of the Bayes' strategy associated with X is not less than that associated with Y.

Informativeness

Fineness is a special case of a more general characteristic of informativeness (Marschak and Miyasawa 1968, Marschak and Radner 1972). Intuitively, information should be more informative as signals become more accurate predictors of states (Hilton 1981). Hilton's use of the term accuracy with regard to informativeness can be misleading. To illustrate, consider the example of a weather forecast service. The common interpretation of the term accuracy implies that a forecast of rain most often predicts a state of rain. However, a forecast of rain that is most often followed by dry weather, while being inaccurate, is still informative with regard to decision making -- it informs an individual that dry weather is most likely.

With respect to a matrix of likelihoods such as Figure 2.1, increasing accuracy implies increased diagonal elements and decreased off-diagonal elements. [5] Perfect accuracy implies diagonal elements equal to one and off-diagonal elements equal to zero. Perfectly informative information also implies likelihoods of zero and one. However, the ones need not lie on the diagonal -- signals do not necessarily predict their corresponding states. Therefore, perfectly accurate information is a special case of perfectly informative information. This section reviews the formal conditions under which one information system may be said to be at least as informative as another. Accuracy as defined above is irrelevant to informativeness and value. Therefore, the remainder of this report uses the term informativeness.

Blackwell (1953) defines relative informativeness in terms of stochastic transformations. Suppose signals from an information system, $Y=\{y_1,y_2,\ldots,y_I\}$, are not directly observed. However, an information system, $X=\{x_1,x_2,\ldots,x_J\}$, yields signals that are related to signals from Y. An example might be the case where signals are relayed (perhaps imperfectly) through a third party. Define h(y, x) as the function that relates signals from Y to signals from

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[5] This illustration assumes a likelihood matrix organized such that the signal of column n predicts the state of row n.

X. This function has the same interpretation as the likelihood function -- it generates conditional probabilities, $P(x|y)$, of receiving final signal x when the initial signal is y.

Combining probabilities $P(x|y)$ with the likelihoods associated with Y yields the probabilities $P(x|s)$ that relate signals from X to states.

$$(2.22) \qquad P(x|s) = \sum_{y=1}^{Y} P(y|s)\, P(x|y)$$

To ensure that these likelihoods satisfy the restriction that likelihoods sum to one across signals for a given state, h(y, x) must be nonnegative and for each $y \in Y$, $h(y, \cdot)$ must be a probability measure over X (Nermuth 1982). This implies

$$(2.23) \qquad \sum_{y=1}^{Y} P(x|y) = 1.$$

The function h(y, x) is a stochastic transformation if it is nonnegative and satisfies equation 2.23. The stochastic transformation, in effect, introduces an additional layer of uncertainty between signals from Y and states. Thus, in addition to imperfections in the information system Y, there may be imperfect translation between signals from X and signals from Y. Given this interpretation, system Y should be no less informative than X.

Blackwell demonstrates that an information system Y is at least as informative as a system X if, (1) X is derived from Y as described by equation 2.22, and (2) the function generating probabilities $P(x|y)$ is a stochastic transformation. Thus, information systems related through stochastic transformations can be ranked on the basis of informativeness.

Information value is nondecreasing in informativeness (Marschak and Miyasawa 1968, Kihlstrom 1984, Blackwell and Girschik 1954). The following proof (presented in summation notation for convenience) is based on Marschak and Miyasawa.

Consider information systems $Y=\{y_1,y_2,\ldots,y_I\}$ and $X=\{x_1,x_2,\ldots,x_K\}$. Further, suppose that system Y is at least as informative as X. This implies a stochastic transformation h(y, x) that generates probabilities $P(x|y)$ such that

(2.24) $$P(x_k|s_j) = \sum_{i=1}^{I} P(y_i|s_j)\, P(x_k|y_i)$$

and

$$\sum_{i=1}^{I} P(x_k|y_i) = 1.$$

In summation notation the expected utility of the Bayes' strategy associated with system Y is

(2.25) $$u_{by} = \sum_{i=1}^{I} P(y_i) \sum_{j=1}^{J} P(s_j|y_i)\, u(q^{yi},s_j)$$

$$= \sum_{i=1}^{I} \sum_{j=1}^{J} P(s_j)\, P(y_i|s_j)\, u(q^{yi},s_j)$$

where q^{yi} is the optimal act given signal y_i.

Similarly, the expected utility of the Bayes' strategy associated with system X is

(2.26) $$u_{bx} = \sum_{k=1}^{K} \sum_{j=1}^{J} P(s_j)\, P(x_k|s_j)\, u(q^{xk},s_j)$$

$$= \sum_{k=1}^{K} \sum_{j=1}^{J} P(s_j) \sum_{i=1}^{I} P(y_i|s_j)\, P(x_k|y_i)\, u(q^{xk},s_j) \quad \text{(using equation 2.24)}$$

where q^{xk} is the optimal act given signal x_k.

Rearranging terms yields

(2.27) $$u_{bx} = \sum_{k=1}^{K} \sum_{i=1}^{I} P(x_k|y_i) \sum_{j=1}^{J} P(s_j)\, P(y_i|s_j)\, u(q^{xk},s_j).$$

By definition, q^{yi} is the optimal (expected utility maximizing) action given likelihoods associated with signal y_i. Thus

(2.28) $u_{bx} \leq u_{by}$

or

$$\sum_{k=1}^{K} \sum_{i=1}^{I} P(x_k | y_i) \sum_{j=1}^{J} P(s_j)\, P(y_i | s_j)\, u(q^{xk}, s_j).$$

$$\leq \sum_{k=1}^{K} \sum_{i=1}^{I} P(x_k | y_i) \sum_{j=1}^{J} P(s_j)\, P(y_i | s_j)\, u(q^{yi}, s_j)$$

Using the restriction $\Sigma_i\, P(x_k | y_i) = 1$ from equation 2.24, the second term reduces to

(2.29) $$\frac{1}{K} \sum_{j=1}^{J} \sum_{i=1}^{I} P(s_j)\, P(y_i | s_j)\, u(q^{yi}, s_j)$$

which is the expected utility of the Bayes' strategy associated with system Y, mutliplied by a constant that is less than one. Thus, from an earlier result (see footnote on page 36), system Y is at least as valuable as system X.

Proposition (Informativeness) - Information value is nondecreasing in informativeness.

This proposition holds for all prior distributions and all payoff functions.

Summary and Implications

The analysis of this chapter demonstrates that information can not make people worse off. Information has positive ex post value if it causes a change in behavior. Ex ante, information has positive value if there is a possibility that it will change behavior. Information value is zero only if no behavioral change is possible. This result implies that information systems should distinguish only between states that matter to information users -- the states should be decision relevant. Information users will likely differ in the states considered to be decision relevant. Information system design will benefit from knowledge of the user's perceptions and information needs.

The chapter also shows that increasing the number of signals associated with decision relevant states can not decrease the value of an information system. This result assumes that all signals are equally costly to use. However, information systems may produce signals that differ in the cognitive, monetary, or time costs required to interpret or use them. Other things equal, an information system that produces signals that are costlier to use will have lower value. In terms of information system design, this result implies that the mental effort, monetary costs, and time associated with interpreting and using information should be considered.

The analysis also concludes that information value is nondecreasing in informativeness. Informativeness is a measure of the identifiability of states from signals. This result implies that value can be enhanced by strengthening the perceived probabilistic link between a signal and a particular state. To the extent that an information provider can increase users' perceptions of the informativeness (confidence) of signals, information value can be increased.

Finally, information value is nonincreasing in the perceived utility associated with making a mistake. In the context of chemical residues in food or in the environment, this implies that particularly vulnerable groups may value information more highly. An information provider may wish to make a special effort to inform such groups.

Chapter Three

The Value of Alternative Public Health Advisories

This chapter applies the framework of the previous chapter to an evaluation of anglers' willingness to pay for changes in Michigan's public health advisory. It first links the utility based definition of information value to a monetary willingness to pay (WTP) measure based on the expenditure function. It then examines the value of two proposed changes in the format of Michigan's current public health advisory (1) testing a greater number of sites, and (2) including a list of tested sites where chemical residues pose little or no health risk. The analysis links advisory alternatives to changes in informativeness and fineness and thus to changes in value.

Beliefs about information accuracy also influence the perceived link between states and signals. This chapter defines accuracy in the context of the public health advisory. It then shows that increasing accuracy is synonymous with increasing informativeness (value.) The chapter also develops the relationship between advisory value and the perceived severity of health effects. The primary objective of the chapter is to develop specific, testable hypotheses regarding the value of alternative advisory formats to individual anglers.

Anglers' Willingness to Pay for Information

The utility anglers enjoy from fishing depends on various aspects of the fishing experience. These may include the species, number, and size of fish caught (Vaughan and Russell 1982), characteristics of a fishing location (Graham-Tomasi 1986), or the presence or absence of chemical residues in fish (Kikuchi 1986). In addition, anglers would be expected to positively value a present and future state of good health.

The presence of chemical residues in some of Michigan's sport fish implies that choices about specific characteristics of fishing may affect anglers' health. The public health advisory suggests that the risk of health effects depends in part on the size or species of fish consumed, the frequency of consumption, the choice of fishing sites, the age and gender of the consumer, and methods of preparing fish for consumption. Therefore, anglers must balance the utility of specific aspects of the fishing experience against the value of perceived changes in health that may result from different actions.

Define utility as a function of specific fishing behaviors, $\mathbf{q}=\{q_1,q_2,\ldots,q_L\}$, and the state of health, h. The expected state of health is a function of the state of contamination that is perceived to exist, s, and the behaviors chosen. Thus, the utility function is

$$u = u(q, h(q, s)) \tag{3.1}$$

The level of contamination, s, is not known. Therefore, the state of health, $h(\cdot)$, is a random variable. Furthermore, the functional relationships between behavioral choices and exposure and between exposure and health effects are subject to a great deal of uncertainty (Bro et al. 1987, Paradis et al. 1988). Anglers are assumed to choose fishing activities to maximize expected utility with respect to the perceived probabilities of different states and subject to a budget constraint.

The previous chapter derived measures of information value and welfare changes by maximizing the expectation of the utility function of equation 3.1. The resulting measures defined value in terms of utility. The remainder of this section defines the utility measures of the previous chapter in terms of the expenditure function. The expenditure function yields monetary measures of information value and welfare change.

The dual problem is to choose fishing behavior to minimize expenditures subject to a constant level of expected utility. The expenditure function

$$e = e(\mathbf{p}^0, u^0, P(s)) \tag{3.2}$$

where $\mathbf{p}^0=\{p_1,p_2,\ldots,p_L\}$ is the initial vector of prices associated with attributes $\mathbf{q}$, u^0 is the level of expected utility, and P(s) represents the prior distribution of s, is the solution to the dual minimization problem. The expenditure function represents the minimum income necessary to attain utility u^0 given prices $\mathbf{p}^0$ and risk perceptions P(s) (Deaton and Muellbauer 1980).

Since fishing in public waters is not explicitly sold in a market, the price associated with different fishing activities, p^0, is not observable. However, anglers do incur costs in pursuing their sport. These may include travel costs, boat rental, charter fees, bait and tackle costs, and the value of time. These costs may vary across activities. For example, fishing for salmon or trout on the Great Lakes requires access to a boat and specialized equipment. Also, an angler may incur greater travel and time costs to reach sites with certain species or aesthetic characteristics. License fees also differ by species. In Michigan a special stamp is required to catch salmonoids (trout and salmon).

Welfare Effects of Contamination and Information

Contamination of sport fish can cause a welfare loss for anglers. The gross loss due to contamination is the welfare change associated with an increase in risk when behavioral adjustment is not permitted. An expenditure function that restricts behavior $\mathbf{q}$ to $\mathbf{q}^0$ can not be derived from empirical demand functions. However, the restricted expenditure function can be defined in terms of the unrestricted expenditure function (Foster and Just 1989). Consider a price vector $\mathbf{p}^1$ that maintains u^0 and $\mathbf{q}^0$ when a signal changes perceived risk from P(s) to P(s | y). The restricted expenditure function can then be expressed as

(3.3) $$e(\mathbf{p}^0,u^0,P(s|y),\mathbf{q}^0) = e(\mathbf{p}^1,u^0,P(s|y)) + (\mathbf{p}^0 - \mathbf{p}^1)\mathbf{q}^0$$

where $(\mathbf{p}^0 - \mathbf{p}^1)\mathbf{q}^0$ is an adjustment for the change in actual expenditures required to purchase $\mathbf{q}^0$. Equation 3.3 is a monetary measure of the utility associated with a mistake. The monetary measure of the ex post gross loss of welfare, ν_g, associated with contamination is thus

$$(3.4) \qquad \nu_g = e(p^0, u^0, P(s|y), q^0) - e(p^0, u^0, P(s), q^0)$$
$$= e(p^1, u^0, P(s|y), q^1) + (p^0 - p^1)\, q^0 - e(p^0, u^0, P(s), q^0)$$
$$= e(p^1, u^0, P(s|y), q^1) - m^0 + (p^0 - p^1)\, q^0.$$

This welfare effect is the change in income required to maintain utility u^0 when perceptions of risk change from P(s) to P(s|y) but consumption is restricted to q^0. Equation 3.4 is the monetary equivalent of the gross welfare loss defined in utility terms in the previous chapter.

Ignorance restricts anglers to uninformed behavior. Information has value because it permits anglers to adjust optimally to changed levels of risk. The ex post value of a signal that causes a change in risk perceptions from P(s) to P(s|y) is the difference in the utility associated with optimal adjustment and that associated with being forced to continue prior behavior in light of changed perceptions of risk. The monetary measure of ex post signal value

$$(3.5) \qquad \nu_i = e(p^0, u^0, P(s|y), q^0) - e(p^0, u^0, P(s|y), q^1)$$
$$= e(p^1, u^0, P(s|y)) - e(p^0, u^0, P(s|y), q^1) + (p^0 - p^1)\, q^0$$

is the difference in expenditure required to maintain initial utility under posterior risk perceptions when ignorance makes behavioral adjustment impossible.

Information value is nonnegative because the expenditure required to maintain u^0 when consumption is restricted must be at least as great as when consumption is allowed to adjust. For risk averters, the value of information is also nondecreasing in the relative riskiness of the prior and posterior distributions over states, s. Define a distribution, P(s), to be riskier than P(s|y) when all risk averters prefer P(s|y) to P(s) (Rothschild and Stiglitz 1970). The greater the difference in expected utilities associated with P(s) and P(s|y) (the greater the riskiness of P(s) relative to P(s|y)), the greater the difference between prior and posterior consumption, q^1 and q^0, and the greater the difference between $e(p^0, u^0, P(s|y), q^0)$ and $e(p^0, u^0, P(s|y), q^1)$.

The nonnegative value of information can not increase the gross welfare loss associated with contamination. A monetary measure of the net welfare loss is the change in income necessary to maintain u^0 at prices $\mathbf{p}^0$. This measure is net of information value because it permits behavioral response to information. In terms of the expenditure function the net welfare loss, ν_n, is

$$\nu_n = e(\mathbf{p}^0, u^0, \Theta^1, \mathbf{q}^1) - e(\mathbf{p}^0, u^0, \Theta^0, \mathbf{q}^0) \qquad (3.6)$$

$$= e(\mathbf{p}^0, u^0, \Theta^1, \mathbf{q}^1) - m^0$$

where m^0 is initial income. The net welfare loss can also be derived by subtracting the gross welfare loss (equation 3.4) from information value (equation 3.5). The net welfare change measure implies that anglers are able to make behavioral adjustments to changes in risk perceptions. This research measures the value of information given in equation 3.5.

Advisory Characteristics and Value

Of the determinants of information value, information providers have the most control over characteristics of the information system -- the fineness and informativeness of signals. This research asks how the state can enhance the value of the public health advisory. Therefore, the most important hypotheses are those that relate characteristics of information systems to value.

Michigan's current public health advisory contains limited information. Of more than 5,800 fishing sites in the state, only 350 have ever been tested for the presence of chemical residues. The MDNR tests about 30 new sites each year. The advisory informs anglers only of the sites where chemical residues were found to exceed state standards. It does not tell them about relatively safe sites where testing found no chemical residues or residues below state standards.

An advisory program that tells anglers only about unsafe sites discloses only part of the collected information. Define such a program as one of "partial disclosure." A program that also tells anglers about relatively safe sites fully discloses available information. Define such a program as one of "full disclosure." The remainder of this report uses the terms partial and full disclosure to describe respectively an advisory program that does not list safe sites and one that does.

This research explores the value of testing a greater number of sites annually under both partial and full disclosure advisories. Ex ante, nonzero information value depends on the possibility of behavioral change. If an angler would not change behavior for any possible signal provided by the advisory, the advisory has no value. This section first explores situations where the advisory may have no value. It then shows that full disclosure does not decrease the fineness (value) of the advisory. It also shows that testing more sites does not decrease the informativeness (value) of the advisory. It concludes with a statement of specific hypotheses regarding the relative value of partial and full disclosure advisories.

Advisory Value and Behavioral Change

Information value is nonnegative. It is strictly positive ex ante only if (1) at least one of the possible signals would cause an ex post behavioral change, and (2) at least one of the signals that would cause behavioral change has a nonzero probability of occurrence. This section identifies groups of anglers for whom the advisory would not cause a change in behavior and thus would have no value.

First, an angler will not find the advisory valuable if unaware of it. Furthermore, even if aware of the advisory, an angler may not consider changing behavior if current behavior is perceived to entail little or no risk. This group might include catch and release anglers who do not eat fish, individuals who eat only species known to be safe from a tested site, or those who do not believe in or do not care about the advisory. Also, anglers who believe with certainty that current and anticipated future behavior poses no health risk will not anticipate receiving a signal that would cause a behavioral change -- the probability of receiving a useful signal is perceived to be zero.

Another group of anglers who might not change behavior in response to advisory information are those for whom the utility cost of behavioral change is high. For these people, other considerations may be more important than health concerns. For example, an angler may choose a particular site for convenience -- it may be close to home or a favorite vacation spot. An individual may also choose a site, species, or consumption pattern because of tradition. The convenience or tradition associated with a site, species, or consumption pattern may outweigh health considerations. These anglers may not consider changing behavior regardless of specific advisory warnings. [1]

Other anglers may have few affordable options for inexpensive food sources other than sport caught fish. For example, some anglers may depend on sport fishing for food. These individuals may also be unable to afford the time or travel costs to fish at a different site if the advisory listed a currently used site as unsafe. For these anglers the consideration of nutrition may outweigh health concerns.

This subsection identified groups of anglers who may not change behavior in response to any type of advisory information. However, many anglers would anticipate a behavioral change in response to the advisory. The remainder of this section examines how advisory alternatives influence value for those who would consider a behavioral change. The analysis of each alternative specifically considers the decision context and type of behavioral change the alternative might bring about.

Value of Full Disclosure

The current advisory contains two signals about chemical residues at specific sites. First, it issues a warning to "restrict consumption" if the site has been tested and chemical residues have been found to exceed state standards. [2] Second, the advisory issues an implicit "no

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[1] Kihlstrom (1974) finds that people who's preferences are strongly skewed in favor of one product or another are less likely to demand information about product quality. This result implies that those with a strong preference for a particular behavior (perhaps because of convenience or tradition) are less likely to change behavior and are thus less likely to find information valuable.

[2] In this discussion, "restrict consumption" encompasses both restricted signals from the current advisory -- the signal to eat no more than one meal per week and the signal to eat none of a certain species.

report" signal if (1) a site has not been tested, or (2) the site was tested but chemical residues did not exceed state public health standards. This section shows that full disclosure of test results does not decrease the fineness of information and thus does not decrease the value of the advisory. It also provides an intuitive description of how full disclosure increases an angler's welfare.

Sites that receive the "no report" signal in the current advisory fall into three categories. They may be (1) tested and found to pose little or no health risk, (2) not tested and pose little or no health risk, or (3) not tested and contain residues above state standards. A full disclosure advisory program creates a separate signal for sites in the first category. Such an advisory would contain two explicit signals, "restrict consumption" and "no consumption restriction", and an implicit signal of "no report". The "no consumption restriction" signal would apply to tested sites that pose little or no health risk.

The "no consumption restriction" signal applies to a subset of the sites that receive a "no report" signal under the current advisory. Therefore, from the definition in the previous chapter, a full disclosure advisory provides finer information than the current advisory. Thus, the addition of a signal of safety can not decrease the value of the advisory.

Hypothesis (Full Disclosure) - A full disclosure advisory program will be at least as valuable as a partial disclosure advisory.

Consider how listing safe sites actually improves an angler's welfare. Assume the angler does not belong to the previously identified groups who would not consider a behavioral change in response to the advisory. Further, suppose the angler wishes to avoid eating too much contaminated fish. The quantity that constitutes "too much" may correspond to suggested consumption restrictions from the advisory. It may also depend on personal perceptions.

Under the current advisory, an angler who wishes to avoid eating contaminated fish would choose to fish at a "no report" site unless other considerations were more important. If fishing at an unsafe site, the angler may choose not to eat the fish or at least choose to limit consumption. The willingness to make behavioral choices in response to signals implies that the angler attaches a strictly positive ex ante value to the advisory information.

Under the current partial disclosure program there is a chance that a "no report" site is really unsafe. Therefore, there is a chance that the choice to eat fish only from "no report" sites is a mistake. The addition of a "no restriction" signal to the advisory greatly increases the chance of correctly identifying a safe site. Thus, it reduces the chance of making the mistake of eating too many contaminated fish.

This analysis also applies to an angler who decides not to eat fish from any site because of the chance of eating contaminated fish. For this angler, continuation of the current advisory is not valuable -- behavior is unchanged regardless of the signal. The addition of a "no consumption restriction" signal increases the chance of correctly identifying a safe site and reduces the chance of mistakenly eating contaminated fish. Greater certainty about the chance of contaminants at a site may cause the angler to begin eating fish from "no restriction" sites. For this angler, a full disclosure advisory may have value while a partial disclosure program would not.

Value of Testing More Sites

This section demonstrates that testing more sites can not reduce the value of either a full or partial disclosure advisory program. The analysis first derives likelihoods for both advisory formats. It shows that likelihoods depend on the probability of testing. It then models a reduction in the probability of testing as a stochastic transformation of the likelihoods associated with reduced testing. The stochastic transformation implies that a program with more testing is at least as valuable as a program with reduced testing. The section also provides an intuitive illustration of how increased testing might increase advisory value.

The probability tree of Figure 3.1 illustrates how anglers might form likelihood probabilities from knowledge of the current testing program. The first column lists the

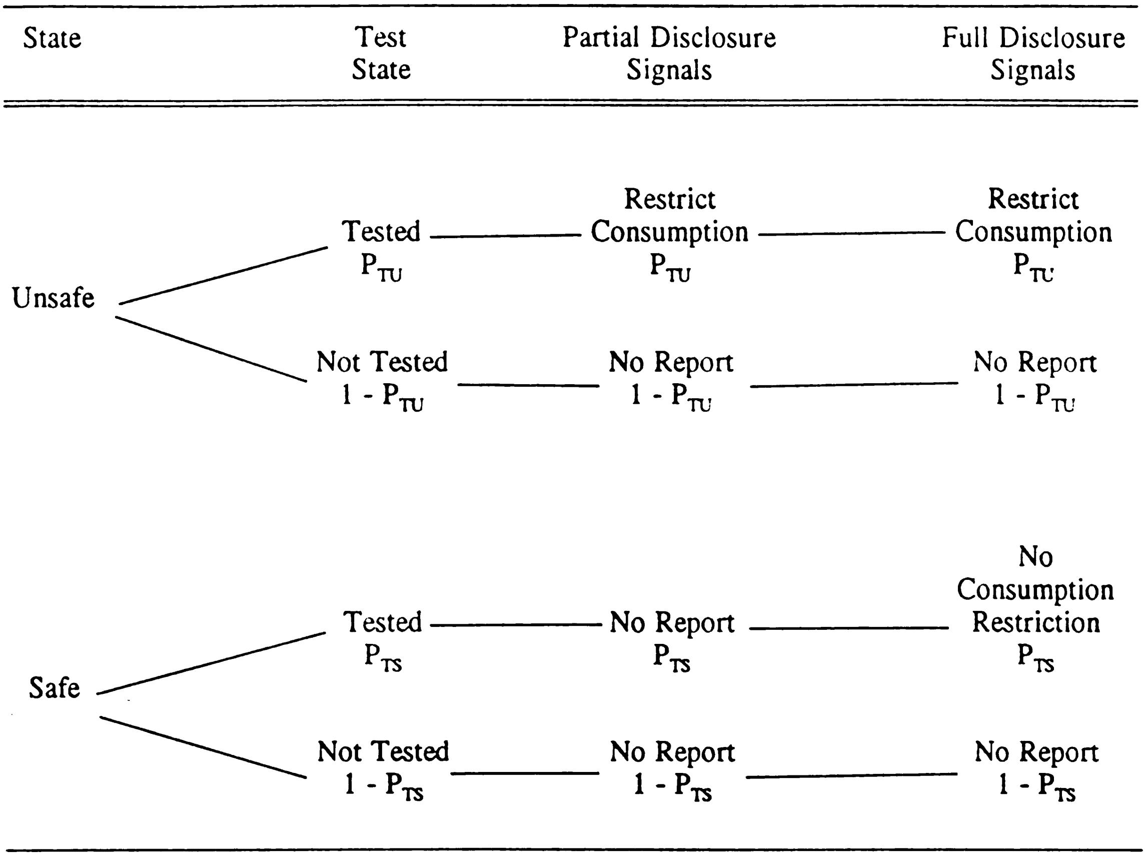

Figure 3.1 - Determination of Likelihood Probabilities

posible states of contamination at a site -- "safe" or "unsafe." Likelihoods assume that these states are given. With the current limited testing program, a site may or may not be tested. The second column lists possible "test states" -- tested and not tested. Assume the angler believes that the testing procedure is perfect -- tests always correctly identify a site's state. Define the perceived probability of testing a safe site as P_{TS}. Similarly, define P_{TU} as the probability of testing an unsafe site. Since the MDNR targets testing to sites suspected of being unsafe, P_{TS} does not necessarily equal P_{TU}. Under these assumptions, the probability that an unsafe site will be tested and found to be unsafe is the probability that it is tested, P_{TU}. The current advisory issues a signal of "restrict consumption" in this instance. The third column lists possible signals associated with the current partial disclosure advisory and their associated likelihood probabilities.

Similarly, the advisory issues a "no report" signal for an unsafe site only when it has not been tested. This occurs with probability $1-P_{TU}$. A safe site receives a "no report" signal whether it has been tested or not. Therefore, the likelihood probability of a "no report" signal given that a site is safe is the probability of testing the site plus the probability that the site is not tested. This probability is one. Table 3.1 summarizes the likelihoods and associated posteriors for the current advisory. The probabilities P_U and P_S are the prior probabilities of states of unsafe and safe respectively.

Testing more sites does not change the posterior probability that a "restrict consumption" signal implies an unsafe site. The signal is perfectly informative regardless of the level of testing. However, increased testing does increase the posterior chance that a "no report" signal implies a safe site. Increased testing increases the chance that an unsafe site will be identified and listed as such. Thus, the "no report" sites are more likely those that have been tested and

Table 3.1 - Likelihoods and Posteriors for Partial Disclosure

	Likelihoods		**Posteriors**	
States	Signals		Signals	
	Restrict Consumption (RC)	No Report (NR)	Restrict Consumption (RC)	No Report (NR)
Unsafe	P(RC|unsafe) $= P_{TU}$	P(NR|unsafe) $= 1 - P_{TU}$	P(unsafe|RC) $= 1$	P(unsafe|NR) $= \frac{P_U(1-P_{TU})}{P_U(1-P_{TU})+P_S}$
Safe	P(RC|safe) $= 0$	P(NR|safe) $= 1$	P(safe|RC) $= 0$	P(safe|NR) $= \frac{P_S}{P_U(1-P_{TU})+P_S}$

found to be safe. [3] Therefore, testing more sites increases the chance that a site chosen from among the "no report" sites is safe. The following analysis uses stochastic transformations to formally demonstrate that increased testing implies increased informativeness.

In matrix notation, [4] the likelihoods associated with the current advisory from Table 3.1 are given by

(3.7)
$$\begin{bmatrix} P_{TU} & 1-P_{TU} \\ 0 & 1 \end{bmatrix}$$

where row one corresponds to a state of unsafe, row two corresponds to a state of safe, column one represents the "restrict consumption" signal, and column two represents the signal of "no report."

Now suppose the state tests fewer sites each year. Less testing reduces the probability that an unsafe site will be tested. Represent this reduction by multiplying P_{TU} by a positive constant α belonging to the interval [0,1]. The resulting likelihood probabilities are

(3.8)
$$\begin{bmatrix} \alpha P_{TU} & 1-\alpha P_{TU} \\ 0 & 1 \end{bmatrix}.$$

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[3] In the extreme, when the probability of testing is one, the "no report" signal is equivalent to providing a list of safe sites.

[4] To simplify notation this chapter uses matrices to describe likelihoods and stochastic transformations. Consider a setting with states $S=\{s_1,s_2,\ldots,s_J\}$ and two alternative information systems, $X=\{x_1,x_2,\ldots,x_K\}$ and $Y=\{y_1,y_2,\ldots,y_I\}$. The likelihoods associated with systems X and Y can be represented by the matrices X_L (S x K) and Y_L (S x I) respectively. The stochastic transformation from Y_L to X_L takes the form of a matrix H (I x K)

$$H(y,x) = \begin{bmatrix} h_{11} & h_{12} & \cdots & h_{1K} \\ h_{21} & h_{22} & \cdots & h_{2K} \\ \vdots & \vdots & \vdots & \vdots \\ h_{I1} & h_{I2} & \cdots & h_{IK} \end{bmatrix}$$

where h_{ik} is the probability of receiving signal x_k from X when Y produces y_i. The matrix H(y,x) must be a non-negative, row stochastic (elements of rows sum to one) Markov matrix. This implies that h_{ik} lies on the interval [0,1] for each i and k (Kihlstrom 1984). In matrix notation, information system Y is at least as informative (valuable) as X if there exists a stochastic transformation H such that X=Y H.

The equation

(3.9)

$$\begin{bmatrix} \alpha P_{TU} & 1-\alpha P_{TU} \\ 0 & 1 \end{bmatrix} = \begin{bmatrix} P_{TU} & 1-P_{TU} \\ 0 & 1 \end{bmatrix} \begin{bmatrix} \alpha & 1-\alpha \\ 0 & 1 \end{bmatrix}$$

relates the likelihoods associated with testing fewer sites to the likelihoods associated with the original level of testing.

The second matrix on the right hand side of equation 3.9 is a stochastic transformation. Therefore, the likelihoods in the first matrix on the right hand side (the likelihoods associated with testing more sites) are more informative (more valuable) than the likelihoods on the left hand side of the equation (the likelihoods associated with less testing). The more informative likelihood matrix also conforms to the intuitive notion of informativeness. P_{TU} is larger than αP_{TU} and 1 is larger relative to $1-P_{TU}$ than to $1-\alpha P_{TU}$. Therefore, with a greater probability of testing, the "restrict consumption" signal is more likely when a site is unsafe. The probability of the "restrict consumption" signal for a safe site remains zero. [5] The "no report" signal is relatively more likely when a site is safe.

Similarly, increased testing can not reduce the informativeness (value) of a full disclosure advisory. The fourth column of Figure 3.1 lists the signals that a full disclosure advisory would assign to different state and testing combinations. Likelihoods are the same as those associated with a partial disclosure advisory except that a tested safe site receives a "no consumption restriction" signal.

Table 3.2 summarizes the likelihoods and posteriors associated with a full disclosure advisory. Testing more sites does not increase the probability that a "restrict consumption" or a "no consumption restriction" signal identifies an unsafe or safe site respectively -- the signals are both perfectly informative and posteriors for both signals reflect certainty. However,

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[5] Note that in this example the "restrict consumption" signal is perfectly informative regardless of the level of testing.

Table 3.2 - Likelihoods and Posteriors for Full Disclosure

Likelihoods

States	Signals		
	No Restrict Consumption (RC)	Consumption Restriction (NCR)	No Report (NR)
Unsafe	P(RC|unsafe) $= P_{TU}$	P(NCR|unsafe) $= 0$	P(NR|unsafe) $= 1 - P_{TU}$
Safe	P(RC|safe) $= 0$	P(NCR|safe) $= P_{TS}$	P(NR|safe) $= 1 - P_{TS}$

Posteriors

States	Signals		
	Restrict Consumption (RC)	No Consumption Restriction (NCR)	No Report (NR)
Unsafe	P(unsafe|RC) $= 1$	P(unsafe|NCR) $= 0$	P(unsafe|NR) $= \frac{P_U(1-P_{TU})}{P_U(1-P_{TU})+P_S(1-P_{TS})}$
Safe	P(safe|RC) $= 0$	P(safe|NCR) $= 1$	P(safe|NR) $= \frac{P_S(1 - P_{TS})}{P_U(1-P_{TU})+P_S(1-P_{TS})}$

testing more sites increases the chance that a "no report" signal identifies a safe site. The following analysis using stochastic transformations formally proves that more testing does not decrease the informativeness (value) of a full disclosure advisory.

Represent a reduction in the probability of testing a safe site, P_{TS}, by multiplying by a constant β belonging to the interval [0,1]. Define the first column of the likelihood matrices to correspond to a signal of "restrict consumption", the second column to a signal of "no consumption restriction", and the third column to the signal of "no report." The likelihoods associated with reduced testing are derived from the original likelihoods through the stochastic transformation

(3.10)

$$\begin{bmatrix} \alpha P_{TU} & 0 & 1 - \alpha P_{TU} \\ 0 & \beta P_{TS} & 1 - \beta P_{TS} \end{bmatrix}$$

$$= \begin{bmatrix} P_{TU} & 0 & 1 - P_{TU} \\ 0 & P_{TS} & 1 - P_{TS} \end{bmatrix} \begin{bmatrix} \alpha & 0 & 1 - \alpha \\ 0 & \beta & 1 - \beta \\ 0 & 0 & 1 \end{bmatrix}$$

The transformation reduces the probability of receiving the perfectly informative signals of "restrict consumption" and "no consumption restriction". It also increases the chance of an uninformative "no report" signal for both states. Therefore, increased testing can not reduce the informativeness (value) of the advisory.

An ordering based on informativeness does not require that a signal is correct in the sense that a "restrict consumption" or "no report" signal most likely corresponds to a state of unsafe and safe respectively. A signal can be no worse (no less valuable) than uninformative. Likelihoods for an uninformative signal are equal across states. As any likelihood probability associated with a signal increases relative to the others (whether correct or incorrect) the signal becomes more informative (valuable). Suppose anglers perceive the "restrict consumption" signal to be most likely when a site is really safe. As the perceived likelihood of receiving the signal when a site is safe increases, so does its informativeness and value even though it is incorrect. [6]

The analysis above yields the following hypotheses.

Hypothesis (Testing More Sites) - An advisory program that tests a greater number of sites increases the informativeness of both a full and partial disclosure advisory program. Thus, increased testing does not reduce the value of either advisory program.

Consider how testing more sites improves anglers' welfare. Suppose an angler's behavior is guided by a desire to avoid eating too much contaminated fish. One possible response to a partial disclosure advisory is a choice not to eat fish because the chance of eating contaminated fish is too high. The analysis above demonstrates that testing more sites increases the chance that a "no report" site is safe. Therefore, more testing increases the chance of identifying a safe site and reduces the chance of mistakenly eating contaminated fish. For anglers who begin eating fish because of a greater chance of identifying a safe site, increased testing has value.

Another possible response to a partial disclosure advisory is a choice to eat fish only from "no report" sites. Because this choice is in response to an advisory signal, it implies a strictly positive ex ante value to the current advisory program. Testing more sites may not change an angler's strategy in response to signals. However, it does increase the probability of receiving a "restrict consumption" (RC) signal relative to the probability of a "no report" (NR) signal. Signal probabilities are given by

$$P(RC) = P(\text{unsafe})\,P(\text{tested})$$

$$P(NR) = P(\text{unsafe})(1 - P(\text{tested})) + P(\text{safe})$$

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[6] To avoid confusion, but with no loss of generality, the examples and analysis of this report assume that signals are corrct.

As P(tested) increases, P(RC) increases and P(NR) declines.

An increase in the probability of a "restrict consumption" signal increases ex ante information value only if the expected utility associated with the "restrict consumption" signal is greater than that associated with the "no report" signal. Consider an angler who would continue to fish at "no report" sites. The "no report" signal causes no behavioral change and has zero ex post value. The ex post value of a "restrict consumption" signal is the difference between the expected utility of eating fish from a "no report" site and the expected utility of eating fish from a "restrict consumption" site (a mistake). The ex post utility of eating fish from a "no report" site is

$$\begin{aligned} u_{nr} &= P(\text{unsafe}|NR) \cdot u(\text{eat, unsafe}) \\ &+ P(\text{safe}|NR) \cdot u\,(\text{eat, safe}). \end{aligned}$$

The "no report" signal does not identify states with certainty. Therefore, a "no report" site may be "safe" or "unsafe". The expected utility of eating fish from a "no report" site is the probability that the site is unsafe multiplied by the utility of eating unsafe fish plus the probability that the site is safe multiplied by the utility of eating safe fish.

The "restrict consumption" signal always identifies an "unsafe" site. Therefore, the utility associated with eating fish from a "restrict consumption" site is

$$u_{rc} = u(\text{eat, unsafe}).$$

The ex post expected utility of the "restrict consumption" signal is

$$\begin{aligned} u_{nr} - u_{rc} &= (P(\text{unsafe}|NR) - 1) \cdot u(\text{eat, unsafe}) \\ &+ P(\text{safe}|NR) \cdot u(\text{eat, safe}) \geq 0. \end{aligned}$$

Therefore, testing more sites increases the probability of receiving the more valuable "restrict consumption" signal relative to the less valuable "no report" signal. The ex ante value of the advisory is the sum of ex post signal values weighted by signal probabilities. Therefore, an advisory program that tests more sites is more valuable than one that tests fewer sites.

Testing more sites makes receipt of a more informative signal more likely, increases the chance of correctly identifying the state, and reduces the chance of mistakenly eating contaminated fish. This analysis applies also to a full disclosure advisory format. Increased testing increases the chance of receiving the perfectly informative "restrict consumption" and "no consumption restriction" signals and reduces the chance of receiving the completely uninformative "no report" signal.

Increased testing with full disclosure also increases the number of sites available to an angler who wishes to avoid chemical residues. Greater testing increases the number of known safe sites. If an angler anticipates fishing at sites that are currently untested, more testing can only increase the number of safe alternative sites.

The analysis above assumes anglers attempt to avoid eating too much contaminated fish. Testing more sites will not change the decision setting for an angler who knowingly eats fish from contaminated sites -- the alternative is still to fish at a "no report" site which is possibly contaminated. Testing more sites will not increase advisory value for such anglers.

Accuracy, Perceived Severity of Health Effects, and Advisory Value

The analysis of the previous section assumes that the testing procedure perfectly identifies the presence or absence of chemical residues in fish. This section examines the case where anglers perceive tests to be imperfect. Anglers may perceive signals to be imperfect predictors of states because of (1) questions about the technological ability of tests to identify contaminant levels, (2) doubts about the adequacy of scientific knowledge linking exposure to health effects, or (3) a belief that the MDNR does not accurately report test results (Krieger and Hoehn 1991). Define these factors as affecting the perceived accuracy of the advisory. The first part of this section uses stochastic transformations to demonstrate that increased accuracy is synonymous with increased informativeness. This section also examines how advisory value might differ among individuals with different perceptions of health outcomes resulting from exposure to chemical residues in fish.

The following analysis maintains the assumption that signals are essentially correct -- signals of "restrict consumption" and "no consumption restriction" most likely correspond to states of unsafe and safe respectively. The term accuracy as used here refers to the strength of the correct association. The conclusions of the analysis apply as well to a situation where signals are incorrect.

Perceived Accuracy of Information

The probability tree diagram of Figure 3.2 illustrates the formation of likelihoods when the link between states and signals is not perfect. The figure differs from Figure 3.1 by the addition of a column labeled "Reported Test Outcome" that accounts for possible inaccuracies in reported signals. Define P_{UU} as the probability that a test result of unsafe is issued when a site is unsafe. Similarly, P_{SS} represents the probability that a test result of safe identifies a safe site. These probabilities may be less than one for any of the three reasons listed above. The signals of "no report" and "restrict consumption" become more accurate with increases in P_{SS} and P_{CC} respectively.

A perception that tests are inaccurate weakens the probabilistic link between states and signals and reduces the informativeness of either a partial or full disclosure advisory. The likelihoods associated with less accurate information can be derived from the more accurate likelihoods of Table 3.1 using the stochastic transformation

(3.11)

$$\begin{bmatrix} P_{TU} P_{UU} & 1 - P_{TU} P_{UU} \\ P_{TS} (1 - P_{SS}) & 1 - P_{TS}(1 - P_{SS}) \end{bmatrix} = \begin{bmatrix} P_{TU} & 1 - P_{TU} \\ 0 & 1 \end{bmatrix}$$

$$\cdot \begin{bmatrix} P_{UU} + \frac{P_{TS}}{P_{TS}} (P_{TU}-1)(1-P_{SS}) & (1-P_{UU}) - \frac{P_{TS}}{P_{TS}} (P_{TU}-1)(1-P_{SS}) \\ P_{TS} (1 - P_{SS}) & 1 - P_{TS}(1 - P_{SS}) \end{bmatrix}$$

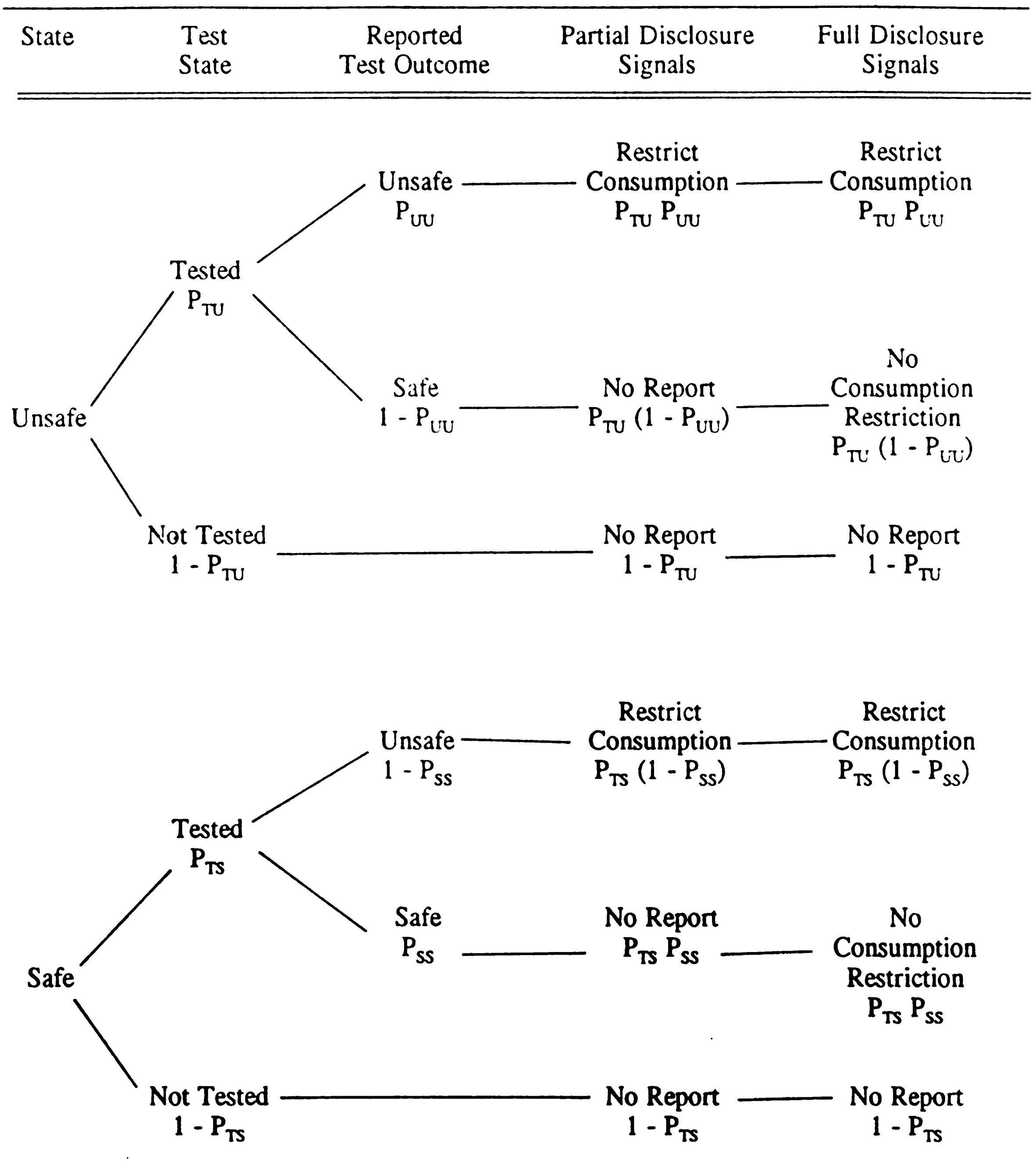

Figure 3.2 - Likelihood Probabilities with Imperfect Tests

The second matrix on the right hand side of equation 3.11 is a stochastic transformation. The first matrix on the right hand side is the matrix of likelihoods from Table 3.1. The left hand side matrix contains the less accurate likelihoods derived from Figure 3.2. Therefore, a less accurate partial disclosure advisory is no more informative (valuable) than a more accurate advisory.

Similarly, the stochastic transformation

(3.12)

$$\begin{bmatrix} P_{TU} P_{UU} & P_{TU}(1 - P_{UU}) & (1 - P_{TU}) \\ P_{TS}(1 - P_{SS}) & P_{TS} P_{SS} & (1 - P_{TU}) \end{bmatrix}$$

$$= \begin{bmatrix} P_{TU} & 0 & 1 - P_{TU} \\ 0 & P_{TU} & 1 - P_{TU} \end{bmatrix} \begin{bmatrix} P_{UU} & (1-P_{UU}) & 0 \\ (1 - P_{SS}) & P_{SS} & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

relates the likelihoods associated with a less accurate full disclosure advisory and the more accurate likelihoods associated with the same advisory. Therefore, increases in perceived accuracy can not reduce the informativeness (value) of a full disclosure advisory.

The following hypothesis summarizes the results of this section.

Hypothesis (Perceived Accuracy of Tests) - The value of either a partial or full disclosure advisory is nondecreasing in the perceived accuracy of the advisory.

Perceived Severity of Mistake

Information value is nondecreasing in the perceived utility loss associated with mistaken prior action. In the context of sport fish contamination, a mistake is an action that leads to unacceptable exposure to chemical residues. What is unacceptable depends on the utility associated with the perceived health consequences of exposure. Thus, the more severe the perceived health consequences of exposure to chemical residues, the greater the ex post value of the current advisory and the greater the ex ante value of alternative advisory formats.

Consider the definition of information value given by equation 3.5. The equation defines the value of information as the change in income necessary to maintain initial (pre-information) utility when behavioral adaptation to informed perceptions of risk is not possible. The greater the perceived utility penalty associated with continuing initial behavior in light of increased risk, the greater the change in income necessary to compensate an individual for being unable to change behavior. Decreases in the perceived utility of $\mathbf{q}^0$ given $P(s|y)$ increase the expenditure necessary to maintain u^0 and thus increase information value.

Hypothesis (Perceived Disutility of Exposure) - The greater the perceived utility loss as a consequence of exposure, the greater the value of information.

Summary

A full disclosure advisory is at least as valuable as a partial disclosure advisory. Furthermore, the value of either advisory is nondecreasing in the number of sites tested. Whether the value of the additional information is zero or strictly positive depends on whether anglers change their behavior. Behavioral responses to increased testing might include (1) ceasing fishing, (2) eating fewer fish, (3) eating smaller fish, (4) eating only certain species, (5) not fishing at some sites, or (6) changing the way fish are prepared for consumption. Full disclosure may lead to site choices that favor safe sites or to changes in catch and consumption patterns from safe sites.

The value of advisory information also depends on anglers' perceptions of advisory accuracy. Perceived accuracy may depend on beliefs about the testing procedure or trust in the integrity of the information source. This finding suggests two approaches to increasing advisory value. First, educating anglers about the advisory program may increase the perceived accuracy of the advisory and thus its value. Second, many anglers seem to believe the MDNR to be too politicized to provide accurate information. Identifying the advisory with a more trusted source may increase its perceived accuracy and thus its value.

Chapter Four

Data Collection:
A Contingent Valuation Mail Survey of Licensed Anglers

Most empirical estimates of information value depend on observed changes in market behavior. For example, Foster and Just (1989) base their estimate of the ex post value of information about milk contamination on changes in surplus measures for milk consumers. Studies of the ex ante value of weather information to farmers estimate values with respect to changes in production of a marketed output (Tice and Clouser 1982, Baquet et al. 1976, Byerlee and Anderson 1969).

Direct application of these empirical techniques to the problem of sport fish contamination is difficult because no formal market exists for the contaminated good (sport fishing). In this situation, non-market valuation methods can often produce estimates of value. This research uses a contingent valuation (CV) mail survey of licensed anglers in Michigan to estimate WTP for additional information about chemical residues in sport fish.

The CV approach asks individuals their WTP for a good in a hypothetical market setting. Whether the resulting contingent choices correspond to actual market choices depends in part on the description of the hypothetical market. Consumer behavior in actual markets depends on a variety of factors. These include characteristics of the good, characteristics of the payment, and the market itself (Fischhoff and Furby 1988). These factors exist explicitly in a hypothetical market only if they are included in the description of the market provided by the researcher. If a CV survey does not adequately describe the factors relevant to a decision, stated behavior will depend on what the respondent assumes. If respondents' assumptions do not correspond to the market context envisioned by the researcher, the values obtained may not be those desired.

The challenge of successful CV research is to clearly describe all relevant aspects of the good, the payment, and a credible market, and to word questions clearly so as to avoid ambiguity (Mitchell and Carson 1989). Thus, the design of the CV survey is crucial to obtaining good data. The implementation of a mail survey may also affect the quality and quantity of usable responses. Important considerations include the physical appearance of the survey instrument, the wording, order, and format of questions, the timing of mailings, and the process of following up on those who are slow to respond (Dillman 1978).

This chapter reports on a CV mail survey of 1,578 licensed Michigan anglers. The survey focused on anglers' WTP for changes in the current public health advisory. The chapter first reviews the design and implementation of the survey. It illustrates the importance of focus group and one-on-one interview pretesting. Pretesting ensured that questions were both meaningful to respondents and consistent with research needs. The second section of the chapter provides a statistical summary of survey responses. It examines respondents' socio-economic characteristics, fishing behavior, and beliefs about the advisory. It also compares respondents' socio-economic characteristics to those of other surveys of Michigan anglers and reports the findings of a phone follow-up designed to assess possible nonresponse bias.

Survey Design and Implementation

A contingent valuation survey should clearly communicate ideas to potential respondents (Mitchell and Carson 1989). If respondents interpret questions differently than researchers, questions may not measure intended concepts. Questions that use language and concepts that are familiar and meaningful to anglers facilitate clarity and reduce misinterpretation (Fischhoff and Furby 1988, Desvousges and Smith 1988). This section reports on the use of a mail pretest, focus groups, and one-on-one interviews in the design of the CV mail survey used in this research. It focuses on the role of each in formulating clear and meaningful questions and response categories. The section also describes the physical implementation of the mail survey.

Survey Design

The process of survey design began with three focus groups. Each group contained four to six licensed anglers from the Lansing, Michigan area. The focus group discussions concentrated on exploring how anglers think about chemical residues in fish, the language they use to talk about it, and how they think about and respond to the current advisory. Insights from focus groups aided in designing a draft questionnaire.

Iterative one-on-one interviews with twelve licensed anglers from the Lansing, Michigan area further refined the draft questionnaire. Interview participants were asked to think aloud as they responded to the questionnaire. Each round of interviews stimulated changes in the questionnaire draft that were tested in the next round. The iterative interviews identified questions that were unclear or ambiguous and helped assess the adequacy of response choices. They were particularly useful in identifying assumptions respondents made about factors not explicitly mentioned in the questionnaire. They also helped identify irrelevant and redundant questions that could be removed or combined with other questions, thus reducing the length of the questionnaire from 46 to 15 questions. Also, to improve readability, the printed format of the questionnaire was increased from a booklet measuring 5½ by 8½ inches to one measuring 8½ by 11 inches and the type size increased. Appendix A contains a complete copy of the final questionnaire.

This section reports on the design of survey questions to measure anglers' WTP for advisory alternatives and the factors hypothesized to affect WTP. The section first describes the design of the central WTP questions. It then describes the measurement of explanatory variables. The discussion emphasizes how mail, focus group, and interview pretests influenced the final form of specific questions.

Eliciting WTP

A clearly described and credible hypothetical market is a crucial component of a CV survey (Mitchell and Carson 1989, Hoehn and Randall 1987). Important aspects of the market include a description of the good to be valued, how it differs from what is currently available to respondents, and a proposed method of payment that respondents accept and believe to be credible. The survey also describes a decision setting that elicits WTP. This section describes the evolution of the valuation questions used to elicit anglers' WTP for additional information about chemical residues in Michigan's sport fish. It focuses first on the development of descriptions of the current and alternative advisory programs. It then explains the choice of a payment vehicle and bid elicitation format.

Description of Advisory Alternatives

A challenge in this particular survey was to clearly explain subtle changes in a complex information program. Valid measures of WTP for additional information depend on respondent's clear understanding of the content of currently available information. Pretests suggested that anglers had very different perceptions of the information content of the current advisory. Focus groups revealed that many anglers have greater confidence in the scope of advisory information than is warranted by actual testing. Many participants stated a belief that most sites had been tested. The state has actually tested less than three percent of all sites. A belief that most sites have been tested implies a belief that a site not listed in the advisory as unsafe has probably been tested and found to be safe.

To provide anglers with an accurate and common point of reference, the questionnaire described the information content of the current advisory program. It told respondents how many sites had been tested and that the advisory listed only those sites that were tested and found to be unsafe. The initial survey draft (reproduced in Figure 4.1) contained three WTP questions. The first question described the testing environment and information content

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1. Fish from all of Michigan's Great Lakes have been tested for chemical residues. Michigan also contains 11,000 or so inland lakes and over 36,000 miles of rivers and streams. Only **331** tests have been conducted on these inland waters.

   The current advisory contains a list of water bodies where fish have been found to be **unsafe**. Water bodies that have been tested and found to be **safe** are not listed in the advisory.

   Suppose the state could no longer afford to test fish and print advisories unless fishing license fees were increased. Would you rather, (1) **eliminate** the current advisory program and keep fishing license costs the same, or (2) **keep** the advisory if it meant increasing license costs by **$3.00**? (Circle one number)

   1. Eliminate the advisory
   2. Keep the advisory

2. Suppose that an up-to-date list of **600** sites that had been tested and found to be **safe** could be printed in the advisory if money for printing was available.

   Would you rather, (1) **keep** advisories as they are and keep fishing license costs the same, or (2) **include** a list of **600** safe sites if it meant increasing license costs by **$2.00**? (Circle one number)

   1. Keep advisories the same
   2. Include list of safe sites

3. Only **331** tests for chemical residues have been conducted in Michigan's inland waters. About **30** new sites are tested each year.

   Suppose more sites could be tested if license fees were increased.

   Would you rather, (1) **continue** to test about **30** sites per year and keep fishing license costs the same, or (2) **increase** testing to **100** new sites per year if it meant increasing license costs by **$4.00**? (Circle one number)

   1. Continue current testing
   2. Increase testing

Figure 4.1 - Initial Wording of WTP Questions

of the current advisory program. It then asked anglers' WTP to continue the current program. The primary purpose of this question was to provide a clear description of the current program. The second question proposed a full disclosure advisory and again asked for respondents' WTP. The third question asked for anglers' WTP for testing a greater number of sites each year.

One-on-one interviews revealed two problems with the initial format of the WTP questions. First, the questions did not adequately emphasize the important aspects of the current advisory program or clearly identify the changes offered by the proposed alternatives. When questioned during interviews, participants were often unable to clearly recall the information contained in the current advisory or clearly state the differences between the advisory alternatives. Second, the second and third questions described changes in the advisory in terms of numbers of sites tested or listed as safe. However, the program description contained in the first question did not identify the total number of sites. In the absence of an explicit denominator, respondents made different assumptions about the proportion of sites tested under the proposed programs.

To remedy these problems, the next draft of the questionnaire separated the description of the current advisory program from questions of WTP for program alternatives. The description of the current advisory (Figure 4.2) included a more explicit definition of the total number of fishing sites in the state. Discussions with MDNR officials refined a definition of sites that reflects those used for testing and advisory purposes. The description also presented the important aspects of the current program and proposed changes more clearly. Interviews were particularly useful in improving the brevity and clarity of the description. Participants in subsequent interviews seemed to quickly and accurately identify important features of the current advisory program when presented in the form of Figure 4.2.

Figure 4.3 reproduces an intermediate form of the WTP questions presented with the program description of Figure 4.2. The revised format improved on the initial questions of Figure 4.1 by presenting important aspects of program alternatives in tabular form and by

Michigan's Public Health Advisory

There are more than 5,800 public fishing sites in Michigan - 2,200 sites on rivers and streams, 3,600 inland lakes, and the Great Lakes. The state has tested 350 of these sites for chemical residues in fish. About 30 new sites are tested each year.

The current public health advisory tells you:

- that you should not eat too much fish from *any* inland lake because of widespread mercury contamination, and

- it lists 50 sites where fish contain chemical residues *above* state limits.

The advisory does not tell you about:

- the 300 tested sites where chemical residues *do not* exist or are *below* state limits.

The advisory program could be changed.

- **The advisory could list tested sites where chemical residues *do not* exist or are *below* state limits.**

- **More than 30 new sites could be tested each year.**

These changes would increase the amount of information in the advisory but they would also cost more money.

Figure 4.2 - Final Description of Current Advisory

Table 1 - Advisory Programs and their Cost to You

Program Options	Current Advisory	Program A	Program B
Lists tested sites where non-mercury residues pose little or no health risk.	No	No	Yes
Number of new sites tested each year.	0	30	0
Cost to you in highler license fees.	$0	$5	$3

In the next two questions suppose anglers could vote on Programs A and B. Vote *for* the program if it is worth the additional cost to you. Vote *against* the program if it is not worth the additional cost.

1. Would you vote for Program A if it permanently increased your yearly license cost by $5.00, or vote against it and keep the Current Advisory at no additional cost?

   1. **Vote for Program A**
   2. **Vote against Program A and keep Current Advisory**

2. Would you vote for Program B if it permanently increased your license cost by $3.00, or vote against it and keep the Current Advisory at no additional cost?

   1. **Vote for Program B**
   2. **Vote against Program B and keep Current Advisory**

Figure 4.3 - Intermediate Form of WTP Questions

placing greater emphasis on voting as a choice mechanism. Focus group results suggested that information presented in tables was often more likely to be read and more easily understood than textual information. The resulting tabular comparison of advisory programs in the revised WTP format increased the ease with which interviewees understood and were able to accurately recall program differences.

Interviews with the revised questionnaire draft revealed that respondents did not always view the two alternative programs as independent. When asked WTP for testing more sites a respondent might say, "well, if I'm already paying X dollars to list safe sites...". If respondents do not perceive the programs to be independent, reported WTP will depend on the order in which the questionnaire presents program alternatives and it will be difficult to determine the separate value for full and partial disclosure advisories. The final form of the WTP questions (Figure 4.4) addressed the problem of independent programs by asking respondents to value only one program alternative. The proposed alternatives consisted of a partial disclosure or a full disclosure advisory, each with increased testing.

Payment Vehicle

The questionnaire proposed a permanent license fee increase as the payment vehicle for proposed program alternatives. The license fee payment vehicle is appealing because fees are collected by the state and people link them directly to spending on state programs. An alternative payment vehicle of selling a separate advisory booklet was tested in focus groups and interviews. The booklet did not adequately capture WTP for information because it is difficult to exclude people from access to advisory information. Many people stated they would read the booklet without buying it or share one with friends. The following comments typify reactions to the booklet.

> "...we couldn't [buy the booklet] or we'd have to go in with some friends or go borrow somebody's book."

> "And I think that's what would happen. I think a lot of people would stand at the counter and look up their section and then go on."

Your Vote on Advisory Programs

The table below shows two advisory programs. The "Current Advisory" is Michigan's current advisory program. "Program A" is a different program that could be put in place.

Program Options	Current Advisory	Program A
Lists tested sites where chemical residues are *above* state limits?	Yes	Yes
Lists tested sites where chemical residues do not exist or are *below* state limits?	No	Yes
Number of new sites tested each year.	30	110
Cost to you in higher fishing license fees.	$0.00	$.40

Suppose the Michigan Department of Natural Resources (DNR) sent you a ballot to vote "for" or "against" Program A. If a majority of anglers vote "for" Program A, it will replace the Current Advisory. If a majority vote "against" Program A, the Current Advisory will be continued.

1. Would you vote for Program A if it permanently increased your yearly license cost by $.40, or vote against it and keep the Current Advisory at no additional license cost?

   1. Vote for Program A
   2. Vote against Program A and keep Current Advisory
   3. Don't know or no opinion

Figure 4.4 - Final Form of WTP Question

> "I'd probably stand there and look through it, look up my site and set it back down."

By contrast, the license fee payment is more difficult to avoid if respondents wish to continue fishing.

Some pretest participants objected to the license fee payment vehicle. Several focus group participants thought it unlikely the money collected would actually be used to improve advisories. As a basis for these beliefs, participants cited several past examples of state reallocation of collected funds. One participant phrased his concerns as follows:

> "I wouldn't mind paying a little bit more in a fishing license if they earmarked that's what it's going for. ...if they're not taking money away from the other part of the license to do something else with."

The final questionnaire used the license fee payment vehicle instead of the booklet. Respondents who reject the referendum because they object to the use of license fees are reacting to a relevant dimension of the described market context. Empirical WTP estimates will ultimately reflect reactions to many contextual factors. This is also true of WTP estimates derived from observed market behavior -- actual market choices also depend on the many contextual dimensions that define a market.

Bid Elicitation

The study used a referendum format for bid elicitation. The referendum format is probably easier for respondents than open-ended questions (McConnell 1990, Hanemann 1985, Cameron 1988, Freeman 1993). The decision to accept or reject a good at a given price is the most common type of market transaction people make. Also, people are familiar with the idea of voting on public programs. Ballots often contain measures offering public goods such as schools, water and sewer systems, or roads, for a given increase in taxes or fees (Mitchell and Carson 1989). In addition, the referendum format provides incentives for respondents to honestly reveal WTP. Hoehn and Randall (1987) examine the problem of strategic overstatement or understatement of values in CV surveys. They conclude that an individual's optimal strategy in response to a referendum format is to state true WTP.

Finally, the survey also described the institutional context under which advisories were funded and issued. A number of respondents throughout the pretest process voiced strong feelings about the integrity of the MDNR. Typical of these responses were:

> "People come from all over the United States to fish here and if the state MDNR tells people just how contaminated some of these fish are, that would scare a lot of them away."

> "I think the MDNR is more politicized than the Department of Health. They listen to too many special interests..."

In general, respondents seemed to view the MDNR as the source of the advisory even though the advisories are actually issued by the MDPH. When questioned, respondents seemed to believe the MDPH more likely than the MDNR to provide accurate information. To facilitate comparison of different information sources, the final questionnaire design was a split sample with both the MDNR and MDPH as the stated source of the advisory.

Explanatory Variables

The conceptual framework suggests that four classes of variables influence anglers' WTP for advisory alternatives. These are (1) information content, (2) the possibility of behavioral change to avert risk, (3) perceived accuracy of the advisory, and (4) the perceived severity of health consequences resulting from consumption of contaminated fish.

Program Variables

The questionnaire described alternative programs in terms of (1) the number of new sites tested each year, (2) whether the program fully or partially discloses test results, (3) the annual cost in higher license fees, and (4) the state agency that issued the advisory. The experimental design consisted of combinations of three different testing levels, ten levels of program cost, two levels of information disclosure, and two state agencies responsible for the advisory. A complete factorial design over these factors defined 120 separate versions of the questionnaire. Table A.1 in appendix A defines the questionnaire versions.

The questionnaire offered testing levels of 110, 620, and 1,240 new sites per year. Two considerations influenced the choice of testing levels. First, the chosen levels define programs that differ significantly in both the absolute number of sites tested and in the proportion of total sites tested. A mail pretest of the survey revealed no significant difference in WTP for programs that tested 100, 200, 300, or 600 sites annually. This result may reflect a poorly designed pretest that did not adequately describe program differences. It may also imply that respondents did not view the program differences to be meaningful. The larger range used in the final survey makes it more likely that respondents perceive the programs to be significantly different. A second consideration was to choose testing levels that were identified as physically feasible during interviews with state officials.

In addition to testing levels, the survey also presented the respondent with a program cost. The literature addresses two issues concerning the structure of program costs (bids) offered in dichotomous choice CV surveys -- the choice of bid levels and the number of surveys to use with each level. Two recent studies address these issues in the context of CV survey design (Kanninen 1993, Cooper 1993).

Kanninen and Cooper propose complex methods for the choice of bids that minimize the variance of the WTP estimator. The general thrust of both approaches is to use prior knowledge about the distribution of WTP to attempt to cluster bids around the true mean WTP. This minimizes the number of surveys "wasted" on bids far from the mean. Kanninen proposes a sequential interview process with each step using past responses for prior information about true WTP. Her approach is not readily adaptable to mail surveys because of the slow response time. Cooper suggests using a pretest to determine an empirical distribution of bids. He divides the distribution into equal probability increments and sets bids at the boundaries. He then uses a complex algorithm to jointly determine the variance minimizing number of bids and the allocation of different bids across surveys.

Duffield and Patterson (1991) and Boyle et al. (1988) also address the distribution of bids across surveys. Although their approaches are not optimizing methods, they also employ an empirical distribution of WTP and attempt to cluster the bulk of offered bids around mean WTP.

This study employs a mail pretest to gain some prior knowledge about the distribution of WTP. However, it does not use the methods reviewed above to determine optimal bids or allocations. The pretest asked valuation questions that were somewhat different than those used in the final survey. The questionable quality of the pretest data relative to the final WTP questions seemed to dictate a conservative approach that reduced the risk of clustering many offered bids around a point far from the true mean.

A mail pretest of a sample of 200 licensed anglers in the Lansing, Michigan area asked anglers' WTP for advisory alternatives in an open ended format. The pretest produced 44 completed surveys. Responses to the pretest defined a cumulative distribution of WTP. The cumulative distribution was initially divided into 32 equal probability increments. The WTP levels associated with the boundaries of these increments were considered as possible bid levels. The final design set bid levels at every fourth boundary over most of the empirical distribution. However, to obtain more information about the relatively flat upper tail of the distribution, the higher bids were spaced more closely. Also, selected increments began at the third boundary from a probability of zero.

The final design used bid levels of $.40, $.95, $1.45, $1.90, $2.85, $4.10, $5.55, $8.75, and $14.50. The empirical probability that WTP was greater than or equal to these bids was .94, .81, .69, .56, .44, .31, .19, .09, and .03 respectively. In addition, the design included a relatively large tenth bid level chosen in hopes of eliminating any positive response and avoiding the problem of arbitrarily truncating the empirical distribution. The upper bid amount was $41.00. The final experimental design used equal numbers of surveys containing each bid.

In addition to the issues discussed above, focus group results raised one other important consideration in the choice of bid amounts. When asked their WTP for a particular program, participants often conditioned responses on perceptions of a reasonable cost of providing the program. Respondents seemed concerned about not paying more than a fair share of the costs. The following responses illustrate the nature of this concern.

> "Well, I have no idea how much this [publishing a list of safe sites] costs so it's really kind of hard to sit here and hem and haw over how many dimes I would...actually give towards it."
>
> "...for a 30 page pamphlet or something, five bucks, well, they're just making money off it."
>
> "What's it cost to test a site? ...So, how many fishing licenses do they sell in a year? I mean, if they tack on 50 cents a fishing license, how much money..."

Fortunately, the bids derived from the empirical distribution corresponded reasonably well to estimates of actual program costs. State officials estimated that about 100 additional sites could be tested for each $1.00 increase in license fees. [1] This implies actual costs ranging from about $1.10 to $12.40 for the testing levels used in the questionnaire.

Behavioral Change

The questionnaire asked how respondents had changed behavior as a result of the current advisory. It also asked for anticipated behavioral change in response to a list of safe sites or a report of unsafe for a respondent's favorite site and species. The advisory suggests a number of changes in behavior that can reduce risk. The research used focus groups to explore which of these actions anglers were aware of and which they were likely to use. These discussions influenced the form of pretest questions dealing with behavioral change.

Pretest questions asked if respondents would make specific behavioral changes in response to a given change in the advisory. Interviews revealed that response choices for this format were not nearly rich enough. Participants often mentioned behaviors that were not included

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[1] Personal communication with Christine Waggoner, Surface Water Quality Division, Michigan Department of Natural Resources.

among the response categories offered in early drafts of the questionnaire. As an example of the issues that arose when designing these questions, consider the question to assess behavioral response to the listing of safe sites. Figure 4.5 lists both the pretest and final versions of this question.

The final version of the question improves on the pretest version in two ways. First, the answer to the question would likely depend on whether a respondent believed that currently used sites would be listed as safe or not. The pretest version provides no means to determine what assumptions respondents make regarding currently used sites. Second, the pretest version seems to lead the respondent by asking for response to a specific behavioral change (fish at a safe site) that the researcher believed to be important. The final version conditioned responses on currently used sites and provides a list of alternatives derived from interviews -- response categories respondents believed to be relevant.

Risk

The format of questions for assessing risk perceptions changed very little between the pretest and final versions of the questionnaire. The questionnaire asked respondents for their guess about the probability of having health problems someday because of chemical residues in fish. Response categories covered a roughly logarithmic scale. These were:

1. No chance	6. 1 in 100
2. 1 in a million	7. 1 in 10
3. 1 in 100,000	8. 1 in 5
4. 1 in 10,000	9. 1 in 2
5. 1 in 1,000	10. Certain to happen

Focus group and interview participants generally perceived very small risks associated with chemical residues in fish. The logarithmic scale concentrates responses around small risks and follows the approach of other studies designed to measure small perceived risks (van Ravenswaay and Hoehn 1991).

People generally found the question about risk difficult. Subsequent interviews focused on the source of difficulty. In general, respondents seemed to have little problem interpreting

Initial Question

1. If sites that were tested and found to be **safe** were listed in the "Public Health Advisory" would you try to fish at those sites rather than sites that were not listed? (Circle one number)

   1. Yes
   2. No

Final Question

1. In addition to the list of unsafe sites, suppose the advisory listed all tested sites where chemical residues in fish did not exist or were below state limits. If your favorite sites had *not* been tested would you...? (Circle all that apply)

   1. **Continue to fish at your favorite sites**
   2. **Stop eating fish from your favorite sites**
   3. **Fish only at sites where chemical residues are below state limits**
   4. **When choosing a new site, be more likely to go to a site where chemical residues were below state limits**

Figure 4.5 - Behavioral Change Questions

risks as stated. One participant interpreted the logarithmic scale as linear but soon realized his mistake. The hesitation in responding to the question arose primarily from uncertainty about the accuracy of the guess. A typical reaction when asked to guess about the probability of a health problem was:

> "I don't know. ... really, really slim I think. I don't think it's no chance. I'll guess one in a million. I'm really not sure."

The final version of the questionnaire also measured the degree of certainty associated with perceived risk by asking how sure people were of their guess. Other researchers have also successfully used this approach to assess respondents certainty about probability estimates (van Ravenswaay et al. 1992).

Information Accuracy

The conceptual model identifies three factors that may affect the perceived accuracy of the advisories. These are (1) the perceived accuracy of tests to identify chemical residues in fish, (2) the perceived adequacy of scientific knowledge linking exposure to health effects, and (3) beliefs about whether the state will accurately report test results. Interviews and the mail pretest revealed that few people questioned the accuracy of the tests themselves. Consequently, the final form of the questionnaire eliminated the question to assess perceived test accuracy. Pretesting resulted in relatively minor changes in the wording and format of questions addressing the other two sources of perceived accuracy.

Sampling Frame and Survey Implementation

Chemical residues in Michigan's fish potentially affect three groups of individuals. These include currently licensed anglers, those who do not fish but would if residues were not present, and those who do not fish but eat fish caught by others. For practical and conceptual reasons, this research focused on currently licensed anglers. From a practical perspective, licensed anglers are an easy group to identify -- the MDNR obtains names and addresses when a license is purchased. Those who do not fish because of chemical residues and those who eat fish caught by others are relatively difficult and expensive to identify.

The group who would fish if contaminants were not present is likely small. A casual examination of fishing license sales records revealed no obvious decrease associated with the appearance of advisories in 1970. The sampling frame does not include this group because of the difficulty and expense of identifying and reaching them.

It is difficult to determine the number of people who eat fish caught by others. This group includes people who purchased fish in restaurants and stores and those who receive fish from acquaintances. Twenty percent of New York anglers reported giving away some of their catch (Knuth and Velicer 1990). Furthermore, commercial fishing operations in Michigan landed 15.7 million pounds of fish in the Great Lakes in 1988 (Michigan Department of Natural Resources 1990). This research examines the value of advisories designed to influence sport angling behavior. Thus, while the group of people who consume fish they do not catch is potentially large, they are not as likely to be directly influenced by the advisory.

The sampling frame for this research consisted of individuals who purchased a Michigan fishing license for the 1991 fishing season. [2] The Fisheries Division of the MDNR provided a random sample of 1,578 anglers licensed to fish in 1991. Information provided for each angler included, name, address, birth date, and type of license purchased. Rodabaugh (1987) reports that between 12.5 percent and 14.5 percent of surveyed anglers fished without purchasing a license. This figure reflects the actions of anglers who reside within one mile of the Shiawassee River and may represent the more casual anglers. Whatever the composition of this group, this survey did not reach them.

Design and implementation of the survey followed Dillman's (1978) total design method (TDM). The TDM stresses the many small details which, taken together, have a potentially

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[2] Michigan fishing licenses are valid through the end of March of the year following their issue.

large impact on response rates and the quality of data from mail and phone surveys. Following the TDM, the first mailing of 1,578 surveys was sent on Tuesday, February 9, 1993. The surveys were followed in one week by a reminder postcard to prompt response and to thank those who may already have responded for their participation.

Three weeks after the initial mailing, a second copy of the survey was sent to the 1,012 members of the sample population who had not yet returned a completed questionnaire. Finally, seven weeks after the first mailing, a third copy of the questionnaire was sent by certified mail to the 576 people who had not responded to the previous mailings. Of the 1,578 surveys originally sent, 230 were returned as undeliverable yielding a final sample of 1,348 anglers. The survey achieved an overall response rate of 73.4 percent of deliverable surveys (990 returned surveys.) Figure 4.6 graphs the pattern of returns and illustrates the effect of each contact with respondents. Appendix A reproduces the cover letters sent with each mailing and the text of the reminder postcard.

Each contact prompted an increase in overall response. However, the magnitude of the response decreased with each contact as the remaining individuals were less inclined to complete the questionnaire. The first mailing obtained a response rate of 30 percent; the second, 25 percent; and the third, 24 percent. It is surprising that the final mailing elicited almost the same rate of response as the second. The following comment from a returned questionnaire suggests that the use of certified mail may have increased response rates relative to regular mail.

> "In-as-much that you have gone to the expense of sending this via certified mail, I felt that it would behoove me to fill out and return. ... I do admire your efforts in safeguarding the health and safety of Michigan sportsmen." (respondent #2385)

However, the third contact also ran the risk of angering people. The following comment expresses a common theme a bit more creatively than usual. This was written on the cover letter and returned without a completed questionnaire.

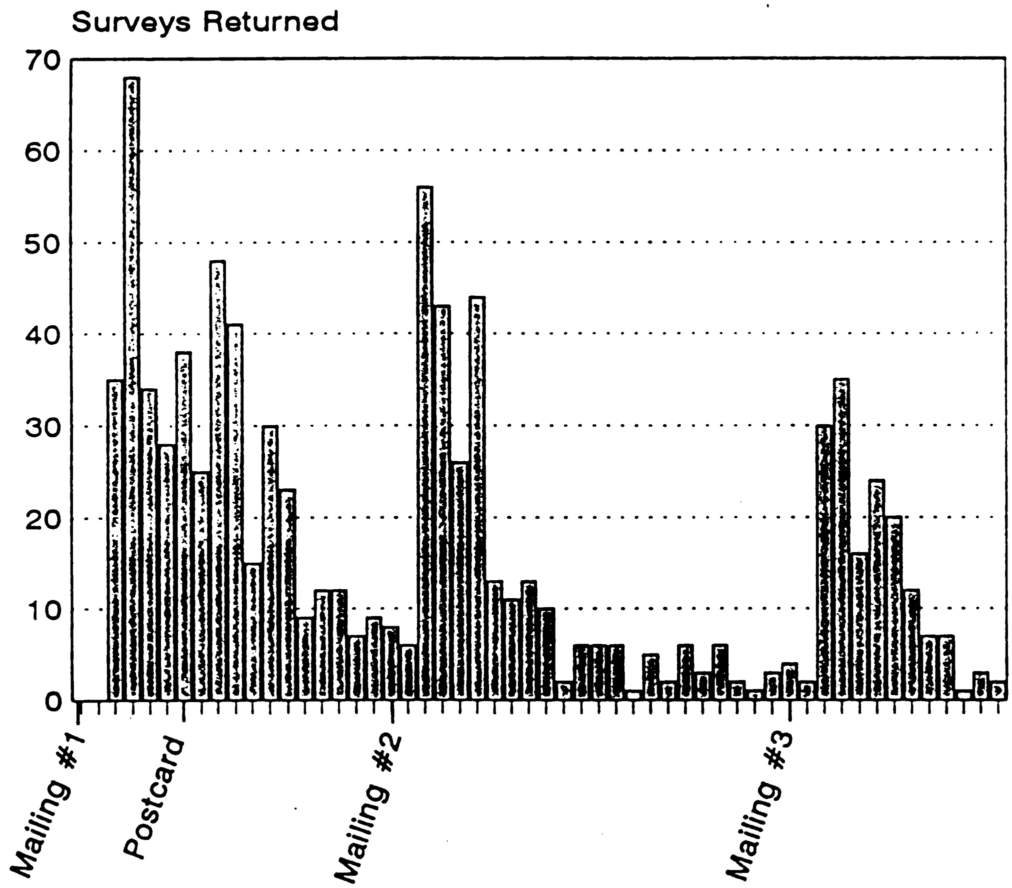

Figure 4.6 - Pattern of Survey Response

> "You can take this as my answer, if I were interested in answering this questionnaire I would have sent the first one back. ... Now that you've wasted enough of the taxpayer's money to mail me three envelopes @ $1.52 each, you can save us all some money and use this paper constructively the next time you visit your favorite john. Thank you very much for your time." (respondent #1105)

The use of certified mail also angered some people who made a special, time consuming trip to the post office to pick up what they assumed was important mail. The negative reaction has prompted some researchers to abandon the certified mailing. Casual observation seems to indicate little negative effect on response rates. [3] The certified mailing resulted in 150 additional completed questionnaires -- about 15 percent of the overall response.

Survey Results

The survey produced 789 complete questionnaires -- 79.7 percent of the 990 returned. Neither item nor survey non-response seems to be significant in this study. Table 4.1 reports non-response rates for each survey question. Not surprisingly, respondents were most reluctant to reveal income. Item non-response presents a problem in this study only if the referendum choice of those who chose not to respond to a question -- and are thus omitted from the analysis -- differs significantly from choices of respondents.

Respondents and non-respondents to specific questions differed significantly in this respect only for the question that asked about objections to using a license fee increase to pay for additional information. The direction of causality in responses is difficult to determine. Respondents may have refused to answer the valuation question because they objected to the payment vehicle. Conversely, respondents may have registered a strong objection to the license fee increase to justify not answering the valuation question.

The license information from MDNR also contained age and gender for the entire sample. The proportions of male anglers in the overall sample (81.1%) and the respondent sample

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[3] Personal communication with John Stoll, University of Minnesota.

Table 4.1 - Item Nonresponse

Question		Frequency of Nonresponse	Percent Nonresponse
Question 15:	Income	128	12.9
Question 2:	Fishing frequency	59	6.0
Question 4:	Risk	45	4.6
Question 9:	Referendum	39	3.9
Question 13:	Best information source	32	3.2
Question 7:	Behavioral response to current advisory	36	3.6
Question 3:	Consumption frequency	36	3.6
Question 1:	Other activities	36	3.6
Question 6:	Perceived risk reduction	36	3.6
Question 8:	Concern about residues	31	3.1
Question 10D:	Advisory accuracy	30	3.0
Question 14:	Education	28	2.8
Question 5:	Certainty about risk	28	2.8
Question 10B:	Scientific knowledge	25	2.5
Question 11:	Behavioral response to safe list	24	2.4
Question 10A:	Protest	23	2.3
Question 10C:	Likelihood of fatal outcome	20	2.0
Question 12:	Behavioral response to more testing	17	1.7
Complete Surveys		789	76.1

(82.0%) are statistically identical for $\alpha=.5$. Also, the average age of respondents, 44.9 years, does not differ significantly from the average age of the overall sample (44.1 years) for $\alpha=.001$.

Phone interviews with 23 survey non-respondents provided information about the extent of survey non-response bias. The interview asked for (1) beliefs about whether the advisory understates health risk from chemical residues, (2) the perceived likelihood that health effects are fatal, (3) objections to increasing license fees to pay for better advisory information, and (4) education level. The questions corresponded exactly to the wording of survey questions 10 (parts 4, 3, and 1) and question 14 respectively. These questions were chosen because they were conceptually important and closely correlated empirically with WTP. Table 4.2 reports results of statistical tests of the null hypotheses that mean responses to these questions were the same for the populations of respondents and non-respondents. The tests reveal no statistically significant difference between the two groups for $\alpha=.01$. The remainder of this section provides a statistical summary of collected data.

Socio-Economic Characteristics of Respondents

Information about the sample provided by the MDNR included data on gender and age. In addition, the survey asked about the respondents' education and income. These variables provide a means of comparing some socio-economic characteristics of respondents with samples obtained in other studies. Chief among comparable studies of Michigan anglers is the 1984 MDNR mail survey of 10,948 licensed anglers. Mahoney et al. (1986), Kikuchi (1986), and Jones and Sung (1991) report results of the MDNR study.

Table 4.3 compares gender, age, education, and average income of respondents to this survey with the MDNR survey. The proportion of male anglers responding to the MDNR survey is significantly greater than the proportion responding to this survey. The difference is probably due to a regulation enacted for the 1985 fishing season that required spouses of

Table 4.2 - Tests for Nonresponse Bias

Variable	Respondent Mean	Nonrespondent Mean	Test Statistic	Accept/ Reject?
Understate risk?	2.998	2.565	1.71	Accept
Chance of fatality	3.262	3.143	.49	Accept
Objection to fee	2.685	2.391	1.24	Accept
Education	4.292	4.391	.36	Accept

Respondent means reported for "understate risk", "chance of fatality", "objection to fee", and "education" reflect 960, 969, 967, and 962 observations respectively. Non-response means are based on 23 observations.

licensed anglers to purchase a license if they fish. Prior to the 1985 season, spouses of licensed anglers were permitted to fish without a license.

The average age of respondents to this survey (44.9 years) differs very little from the average age of respondents to the MDNR survey (44.2 years). However, information about the MDNR sample is insufficient for statistical comparisons of average respondent age for the two studies.

Respondents to this survey are slightly more educated than those from the MDNR survey. Over ninety percent (90.7%) of respondents reported having at least a high school diploma compared to 86.9 percent from the MDNR survey. This difference is significant for $\alpha = .01$. Similarly, 50.6 percent of respondents to this survey reported at least some college compared to 46.2 percent from the MDNR survey. This difference is significant for $\alpha = .05$. The 19.2 percent of respondents to this survey reporting a college degree is also significantly different from the 17.3 percent reported by the MDNR survey.

The higher levels of education found in this study mirror education trends in the state. In the period from 1984 to 1990 the proportion of the Michigan population with a high school

Table 4.3 - Socio-Economic Characteristics of Respondents

	Sample	Respondents	1984 MDNR Study [1]
Gender			
Male	81.1	82.0	94.3
Female	18.9	18.0	5.7
Age	43.3	45.5	44.2
Education			
Grade school only	N.A.[2]	3.5	5.8
Did not finish high school	N.A.	7.1	7.3
High school or GED	N.A.	30.2	38.1
Vocational or technical school	N.A.	8.6	N.R.[3]
Some college	N.A.	31.4	28.9
College graduate (BS or BA)	N.A.	9.7	11.5
Some graduate or professional school	N.A.	4.4	.8
Graduate degree (PhD, MD, MA, MBA)	N.A.	5.1	5.0
Average Income	N.A.	$39,230	$36,202[4]

[1] Reported in Mahoney, Jester and Stynes (1986) and Kikuchi (1986).
[2] N.A. means "Not Available".
[3] N.R. means "Not Reported".
[4] Converted to 1993 dollars from $26,285 in 1984 dollars.

Data reported in the "sample" column reflect a sample size of 1,578. Data on gender and age of respondents is based on the 990 respondents who returned surveys. Data on respondents' education and income is based on 962 and 862 observations respectively. Data from the 1984 MDNR survey reflects 10,948 completed surveys.

degree increased from 68.0 percent to 77.0 percent. Over the same period the proportion with college degrees rose from 14.3 percent to 17.3 percent (Statistical Abstract of the United States, 1984, 1990). Therefore, the significant difference in education between respondents to this survey and the MDNR survey does not necessarily imply that they represent different populations.

Finally, the average annual income of respondents to this survey is $39,230. This is not significantly different from the adjusted annual income of respondents to the MDNR survey ($36,202). The above results suggest that this survey and the 1984 MDNR survey reached the same population.

Angler Behavior

Most respondents (78.0%) reported fishing at inland lakes or ponds. Fewer reported fishing in rivers and streams (56.1%), the Great Lakes (54.6%), or other locations (5.2%). Other types of fishing sites mentioned included private ponds and out-of-state locations. Anglers also took more trips per year to inland lakes or ponds than to other types of fishing sites. Over all types of sites, anglers reported fishing an average of 29.1 days per year. Table 4.4 lists the percentage of respondents who reported fishing at each type of site and the average number of days per year they reported fishing at that site type.

A significant number of anglers (30.3%) reported fishing at only one type of site. Anglers may fish at only one type of site for several reasons. First, they may have a strong preference for certain species of fish or for a particular type of fishing. Second, they may prefer a specific site. Site preference may result from convenience -- close to home or vacation site -- or merely habit. The data reported in Table 4.5 seem to support the notion that anglers who fish at only one type of site are more casual than those who fish several types of sites. Anglers who fish only one type of site fish an average of 17.9 times per year. Those who fish two or three different types of sites fish an average of 26.7 and 43.6 days per year

Table 4.4 - Site Types Used

Site type	Percentage of Anglers Who Use Site Type	Average Number of Days Fished Per Year
Inland Lakes and Ponds	78.0	17.6
Rivers of Streams	56.1	13.3
Great Lakes	54.6	11.0
Other	5.2	1.4

Data in this table was taken from 931 surveys with complete responses to questions about fishing behavior.

respectively. In addition, anglers who fish fewer types of sites are less likely to eat what they catch.

Kihlstrom (1974) finds that people with strong preferences are less likely to change purchasing behavior in response to information about the quality of a product. Similarly, anglers with strong preferences for a particular site or type of fishing, for whatever reason, should be less willing to change sites or species than those who enjoy a wider variety of fishing experiences. The data in Table 4.5 seem to support this view. Anglers who fish only one type of site are less likely to change behavior than those who fish two or three types. If the advisory reported their favorite site to be unsafe they would be less likely to change sites and more likely to stop fishing than anglers who fish several types of sites.

Ex-Post Value of the Current Advisory

Ex post, the current advisory is valuable only if anglers change their behavior because of it. Table 4.6 lists the behavioral changes reported by survey respondents. Most anglers (63.9%) reported making some change in their behavior in response to the current advisory.

Table 4.5 - Diversity in Use of Site Types

	Number of Different Site Types Used		
	1	2	3
Percent of Anglers	30.3	34.8	33.0
Average Number of Days/Year	17.9	26.7	43.6
Consumption Frequency			
Do not eat fish	20.5	16.7	9.9
Response to current advisory			
Read advisory?	86.5	87.4	92.7
Eat less fish	24.0	22.7	27.9
Use different sites	10.2	16.9	19.5
Eat smaller fish	14.2	16.2	21.6
Eat different species	7.8	15.1	15.9
Prepare differently	21.2	30.8	41.9
Do nothing differently	39.9	35.0	32.0
Stop eating fish	6.4	4.6	2.3
Response to report that favorite site is unsafe			
Still fish at site	33.7	44.1	49.5
Eat fewer fish from site	16.3	20.2	23.6
Eat no fish from site	52.5	56.8	49.8
Fish at different site	34.8	41.0	39.7
Stop fishing	13.8	7.5	4.9

This table is based on 907 surveys for which questions 2, 3, 7, and 12 were answered.

Table 4.6 - Behavioral Response to Current Advisory

Behavioral Response	Percent	Single Behavior Percent
Did not change behavior	36.1	
Have not read the advisory	13.6	
Read advisory but do nothing different	22.5	
Changed behavior	63.9	
Prepare fish to eat differently	31.7	37.4
Eat fish less often	24.3	34.2
Eat smaller fish	18.3	10.9
Fish at different places	16.4	21.8
Eat different species of fish	14.7	15.0
Stopped eating fish	4.7	66.7

This table reports responses from 951 completed surveys.

The most common change was to prepare fish to eat differently (reported by 31.7 percent of respondents). This finding is consistent with focus group results. Other changes, in decreasing order of use were (1) eating fish less often (24.3%), (2) eating smaller fish (18.3%), (3) fishing at different places (16.4%), (4) eating different species of fish (14.7%), and (5) stopping eating fish (4.7%).

More than one third (36.1%) of respondents reported doing nothing differently because of the advisory. For this group, the current advisory has no value. However, 37.7 percent of those who reported no behavioral change also said they had not read the advisory. These anglers may value the current advisory if they had read it.

Table 4.6 also shows that anglers generally changed more than one aspect of their fishing behavior in response to the current advisory. The column labeled "single behavior percent" reports the proportion of respondents who made a particular behavioral change for whom that response was the only behavioral change made. Overall, 29.4 percent of respondents reported making only one type of change in behavior in response to the advisory.

The proportion of respondents who made a particular behavioral change their only response may reflect perceptions of the relative effectiveness of a particular response in reducing risk. Following this reasoning, respondents believed stopping fishing, preparing fish differently, eating fewer fish, fishing at different sites, eating different species, and eating smaller fish to be progressively less effective methods for reducing risk. However, the ordering of behavioral changes may also reflect the relative ease, both in physical and utility terms, of implementing the change.

Perceived Risk

Most respondents think their chances of suffering an adverse health effect from chemical residues in sport fish are small. Table 4.7 reports the distribution of perceived risk. The logarithmic scale of possible responses renders the mean perceived risk of 5.2 in 100 a misleading indicator of central tendency. A more revealing measure is the median of 1 in 100,000 chance of an adverse health effect.

The survey also asked respondents how certain they were about their reported chance of a health problem associated with chemical residues in fish. Table 4.7 also reports the percent of respondents for each level of perceived risk who were "very certain" of their guess. Not surprisingly, those who reported extreme risks ("Certain to happen" or "No chance") were more likely to be "very certain" their answer was correct.

This research also confirms that risk is a multidimensional concept. Rescher (1983) defines risk as determined by probability and outcome. Fischhoff (1978) lists perceived severity of the outcome as one of twelve factors that affect individual risk perceptions. This research finds support for the interdependence of probabilistic concepts of risk and perceived severity of outcome. The statistics of Table 4.8 demonstrate a strong correlation between

Table 4.7 - Perceived Risk of Adverse Health Effects

Perceived Risk	Frequency	Percent	Proportion Very Sure of Chance
No Chance	244	25.8	47.7
1 in 1,000,000	338	35.8	21.0
1 in 100,000	122	12.9	5.7
1 in 10,000	61	6.5	4.9
1 in 1,000	82	8.7	3.6
1 in 100	32	3.4	3.1
1 in 10	13	1.4	21.4
1 in 5	4	.4	0.0
1 in 2	3	.3	33.3
Certain to Happen	45	4.8	35.6

This table reports data from 944 surveys for which questions 4 and 5 were answered.

probabilistic perceptions of suffering a health effect and the perceived likelihood the effect will be fatal.

Information Quantity and WTP

Casual observation of the data supports the expected relationship between WTP and the amount of information provided by alternative advisory programs. The graphs of Figure 4.7 illustrate the proportion of respondents who would vote for the program as a function of program cost, number of sites tested, and whether safe sites are listed. The probability of accepting the program declines as cost increases. Also, acceptance probability increases with the number of sites tested. Listing safe sites produces a roughly parallel upward shift in acceptance proportions for both program costs and number of tested sites.

These results do not account for other factors that likely affect anglers' WTP for the advisories. Therefore, they do not illustrate anglers' WTP for testing more sites or providing

Table 4.8 - Probabilistic Perceptions of Risk and Severity of Outcome

Outcome Likely Fatal?	Mean Perceived Risk (x 10^3)
Strongly agree	219.1
Somewhat agree	90.6
Somewhat disagree	29.7
Strongly disagree	1.0

Table reflects data from 932 surveys for which questions 4 and 10 were complete.

full disclosure. However, they do suggest that respondents understood and responded in a coherent manner to the differences among alternative programs described in the questionnaire. They also suggest that respondents took the questionnaire seriously enough to provide a considered response.

Summary

More than anything else, this stage of the research emphasized the importance of interaction with potential respondents prior to and during the process of writing a questionnaire. Without such interaction, researchers must trust that respondents interpret questions and responses as they themselves do. They must also take for granted that questions are clear and unambiguous and do not elicit strong emotions or beliefs that may influence responses. Such assumptions in this study would have been a mistake. Pretest participants routinely interpreted questions, made assumptions, and reached conclusions that were unanticipated and inconsistent with the researchers' interests.

Through focus groups and repeated one-on-one interviews, the draft questionnaires were revised. The revisions generated a set of questions that were interpreted in a like manner by

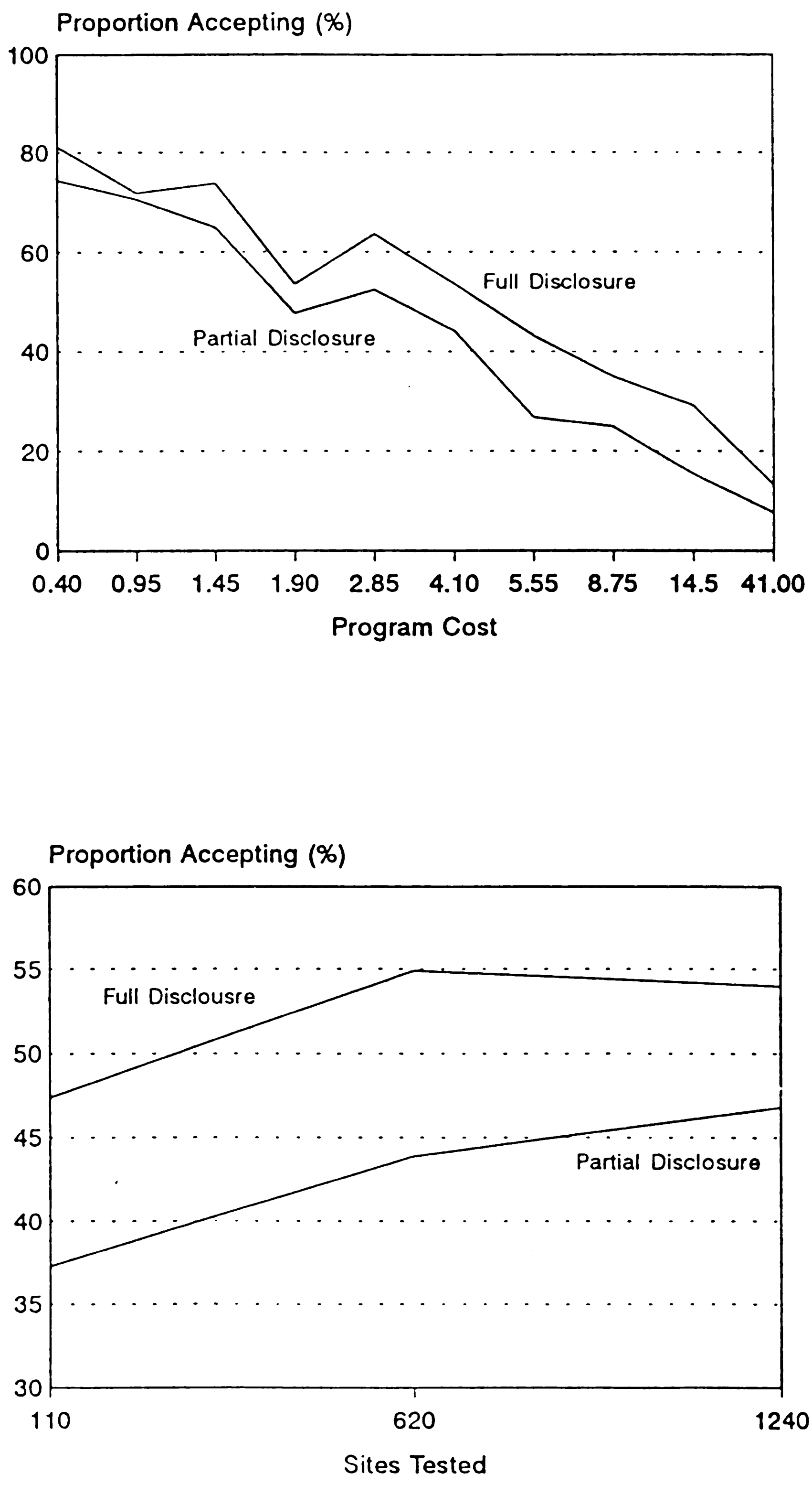

Figure 4.7 - WTP for Program Alternatives

most respondents. They also ensured that questions evoked interpretations consistent with the researcher's intentions. For example, revisions to the WTP question corrected a common but erroneous belief that the current advisory program had tested most sites. Revisions also clarified the differences between advisory alternatives and eliminated the problem of inter-dependent valuation when two several programs were offered. Also, revisions of questions about anticipated behavioral change included a richer set of response choices that corresponded more closely to those actually perceived as options by anglers.

Another specific lesson about the importance of pretesting involved the clarity of the questionnaire. Respondents who know little about the advisories may be confused by explanations that are clear to a researcher who is very familiar with the program. Without extensive pretesting, this questionnaire would have been confusing to many respondents and results would not have corresponded to research needs.

Chapter Five

Estimation of a Discrete Choice Model

This chapter defines the statistical model used to estimate WTP from collected data, describes the estimation process, and presents results. The first section reviews the conceptual link between utility theory and discrete choice estimation methods. The second section defines the statistical model used in the analysis. The remainder of the chapter reports and interprets regression results for three alternative functional forms of the empirical model.

Estimating WTP from Discrete Data

Referendum style questions yield binary WTP data -- respondents either accept or reject the program at the proposed price. Studies with binary data generally use discrete choice models to obtain parameter estimates for explanatory variables. Because of the binary nature of the dependent variable, discrete choice models typically estimate probabilities of accepting a program rather than estimating WTP directly. Suppose an individual angler's utility, u, depends on information, i, income, y, other observable personal characteristics (denoted by the vector a), and unobservable factors. The error term, ϵ, represents the unobservable component of utility. Thus, utility is defined as

(5.1) $$u = u(y,a,i) + \epsilon.$$

Let i equal one if the angler is informed and zero if uninformed. An angler will vote for an informative advisory program offered at price b if

(5.2) $$u(y-b,a,1) + \epsilon_1 - u(y,a,0) - \epsilon_0 \geq 0$$

Define x as a vector such that x=(y,a). Also define

$$x\alpha + b\beta = u(y\text{-}b,a,1) - u(y,a,0) \tag{5.3}$$

where α and β are parameters to be estimated. Then, the probability that a respondent will accept the program offered at price b is

$$\begin{aligned} &\Pr[u(y\text{-}b,a,1) + \epsilon_1 - u(y,a,0) - \epsilon_0 \geq 0] \\ &= \Pr[\epsilon_1 - \epsilon_0 \geq -(x\alpha + b\beta)] \\ &= F[-(x\alpha + b\beta)/\sigma] \end{aligned} \tag{5.4}$$

where $F(\cdot)$ is the cumulative distribution and σ the standard deviation of the error difference, $\epsilon_0\text{-}\epsilon_1$.

Similarly, the probability that a respondent will reject the program at price b is

$$\begin{aligned} &\Pr[u(y\text{-}b,a,1) + \epsilon_1 < u(y,a,0) + \epsilon_0] \\ &= 1 - F[-(x\alpha + b\beta)/\sigma]. \end{aligned} \tag{5.5}$$

Most empirical applications of discrete choice models treat program cost, b_i, as an explanatory variable. They then obtain parameter estimates α/σ and β/σ by maximizing the log likelihood function

$$\log L = \sum_{i=1}^{n} \{t_i \log[1\text{-}F(-(x_i\alpha + b_i\beta)/\sigma)] + (1\text{-}t_i) \log[F(-(x_i\alpha + b_i\beta)/\sigma)]\}. \tag{5.6}$$

where n is the number of observations, t_i equals one if respondent i accepted the program at price b_i, and t_i equals zero if the respondent rejected the program. If $F(\cdot)$ defines the cumulative normal distribution, equation 5.6 defines a probit model.

The parameter estimates from equation 5.6 represent marginal effects of explanatory variables on the probability of acceptance if a variance of one is assumed for the error difference, $\epsilon_0\text{-}\epsilon_1$. The marginal effect of explanatory variables directly on WTP (α and β) are not generally recovered because σ, α, and β are not separately estimated.

Cameron and James (1987) show that the coefficient of cost in the model of equation 5.6, (β/σ), is a point estimate of $-1/\sigma$. Therefore, σ can be calculated. The estimate of σ permits calculation of the vector α from the parameter estimates α/σ of equation 5.6. Thus, Cameron and James obtain parameter estimates that represent marginal effects of explanatory variables on WTP.

In application, Cameron and James suggest a more direct approach that eases computation of standard errors for estimates. They reparameterize the model of equation 5.6 and maximize the log of the likelihood function

$$\text{(5.7)} \qquad \log L = \sum_{i=1}^{n} \{t_i \log[1-F((b_i - x_i\alpha)/\sigma)] + (1-t_i) \log[F((b_i - x_i\alpha)/\sigma)]\}$$

with respect to α and σ. This study uses Cameron and James' model to estimate WTP for additional advisory information.

An Empirical WTP Function for Advisory Information

The preceding section showed how to obtain parameter estimates that represent the marginal effects of explanatory variables on WTP. This section defines the variables used to empirically explain variation in WTP for advisory information. Explanatory variables include (1) characteristics of the proposed program, (2) anticipated behavioral change in response to additional advisory information, (3) the perceived severity of health effects associated with eating contaminated fish, and (4) the perceived accuracy of information. This section defines empirical measures of these concepts from survey responses.

Variable Definitions

The questionnaire elicited discrete (accept/reject/no opinion) WTP responses for additional advisory information. The discrete variable CHOICE measures a respondent's vote on the referendum offered by the questionnaire. CHOICE is the dependent variable in the estimated equation. The remainder of this section defines the explanatory variables used in the analysis.

It also restates the research hypotheses in terms of the empirical variables. Table 5.1 summarizes variable specifications.

<u>Program Variables</u>

The conceptual framework hypothesizes that response to the referendum depends in part on characteristics of the offered program. Programs proposed in the questionnaire differ in (1) whether they are full or partial disclosure, (2) the number of sites tested, and (3) the cost in higher license fees. The current partial disclosure advisory program tests about 30 sites per year. A partial disclosure program described in the questionnaire provides more information than the current advisory only if it tests more than 30 sites. Therefore, respondents should evaluate a proposed partial disclosure program on the basis of the number of sites it tests above existing levels. PSITES represents a partial disclosure program in the empirical model. The variable PSITES equals the number of sites tested under a proposed partial disclosure program minus 30.

A full disclosure program provides additional information about all sites tested under a proposed program, not just unsafe sites. Therefore, a full disclosure program that tests 30 sites per year provides more information than the current advisory program. Respondents should base WTP for full disclosure on the total number of sites tested. The variable FSITES is the number of sites tested under a proposed program and represents a full disclosure program in the empirical model.

In addition to different marginal effects on WTP, full and partial disclosure programs may have different intercepts. FULLD defines a dummy variable that takes the value one for a full disclosure program and zero otherwise. The coefficient of FULLD estimates any shift in the WTP function related to full disclosure.

In terms of the two types of programs offered in the questionnaire, the program specific hypotheses of chapter three can be stated as:

Table 5.1 - Variable Definitions

Variable	Definition
CHOICE	Referendum choice 0 = voted against the program 1 = voted for the program
FSITES	Sites tested each year to which full disclosure applies = number of sites when full disclosure = 0 when partial disclosure
PSITES	Sites tested each year to which partial disclosure applies = number of sites minus 30 when partial disclosure = 0 when full disclosure
FULLD	Dummy variable for full disclosure 1 = full disclosure 0 = partial disclosure
FATAL	Health effect likely fatal 1 = yes 0 = no
BCHANGE	Anticipated behavioral response to unsafe favorite site and species 1 = change site or stop fishing 0 = otherwise
NCHANGE	Propensity for behavioral response to current advisory 1 = eats fish from unsafe sites or has not changed behavior in response to current advisory 0 = otherwise
USELIST	Anticipate a behavioral response to a list of safe sites? 1 = yes 0 = no
NOREAD	Has respondent read the advisory? 1 = no 0 = yes
SCIENCE	Agrees that scientists understand the risks associated with chemical residues in fish 1 = yes 0 = no
COLLEGE	College education? 1 = yes 0 = no

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1. WTP for either a full or partial disclosure program is nonnegative.

2. WTP for a full disclosure program is not less than WTP for a program of partial disclosure.

This research focuses on how to enhance the value of the advisory. The state has the most direct control over the number of sites tested and whether full or partial information is released. Therefore, the hypotheses relating program variables to WTP are the fundamental hypotheses of the study.

With respect to measurement, the hypotheses relating program variables to WTP are the most secure of the research. There is little measurement error in the program variables -- the link to underlying concepts is relatively strong. Pretest participants had little difficulty understanding the differences between program alternatives. Furthermore, participants seemed to carefully consider the program variables when making a choice about the proposed referendum.

Figure 5.1 summarizes the link between concepts related to research hypotheses, measured variables, and hypothesized effects on WTP. The first column lists concepts and corresponding variables. Column two lists the hypothesized effect of variables on estimated WTP. The Xs in columns three and four indicate whether a particular variable affects WTP for full disclosure, partial disclosure, or both. The table lists hypotheses in decreasing order of confidence in measurement -- the program hypotheses are the strongest and the hypotheses concerning perceived accuracy the weakest. Expectations with regard to the variable COLLEGE are not expressed as a formal hypothesis. Its placement at the bottom of the table does not indicate relative confidence in measures of the concept.

Perceived Severity of Outcome

The conceptual framework also suggests that WTP depends on the perceived severity of health effects associated with eating contaminated fish. Several studies suggest a link between

Concepts and Variables	Hypothesized Effect on WTP	Full Disclosure	Partial Disclosure
1. Partial Disclosure			
PSITES	Nonnegative		X
2. Full Disclosure			
FSITES	Nonnegative	X	
3. Perceived Severity			
FATAL	Nonnegative	X	X
4. Behavioral Change			
NCHANGE	Nonpositive		X
BCHANGE	Nonnegative	X	X
USELIST	Nonnegative	X	
NOREAD	Nonpositive	X	X
5. Perceived Accuracy			
SCIENCE	Nonnegative	X	X
6. Education			
COLLEGE	Nonnegative	X	X

Figure 5.1 - Concepts, Variables, and Hypotheses

perceptions of risk or severity and the likelihood that a health effect is fatal (Fischhoff 1978, Caudill 1992, Smith and Johnson 1988). Fischhoff identified the perceived likelihood of fatality as one of twelve factors that affect peoples' perceptions of risk. Caudill used factor analysis to explore perceptions of risk from groundwater contamination. He found the perceived likelihood of a fatal health effect to be a significant component of the severity factor. The variable FATAL in the empirical model measures the perceived likelihood of a fatal health effect and represents anglers' perceptions of severity. The following hypothesis relates WTP to beliefs about the likelihood of a fatal health effect.

3. WTP for either full or partial disclosure programs is nondecreasing in the perceived likelihood that outcomes are fatal.

The variable FATAL does not correspond to the underlying concept of perceived severity as well as measures of the program variables relate to intended concepts. Interview participants seemed to have well defined beliefs about the likelihood that a health effect would be fatal. However, FATAL does not capture beliefs about severity itself -- it is only a measure of the perceived likelihood of the most severe outcome, a fatality.

Pretest questions experimented with the terms "severity" or "seriousness" to measure degrees of perceived severity of health outcomes. However, participants often interpreted the questions as identical to the question that asked for a probabilistic guess about perceived risk. Thus, the terms severity and serious often elicited a response about the probability of a health effect rather than the intended concept of severity. The placement of the severity question immediately following the probability question may have influenced this interpretation. Additional pretesting may have developed a question that adequately measured perceived severity. However, lacking a good measure of perceived severity, this research relied on a measure of the perceived likelihood of a fatal health outcome.

<u>Anticipated Behavioral Change</u>

The conceptual model also suggests that anglers will be willing to pay for advisory information only if they anticipate changing their behavior in response. The questionnaire obtained relatively poor measures of anticipated behavioral change. Even with extensive pretesting, a mail survey is not well suited to capturing the richness of anglers' behavioral response to advisory information. The ex ante nature of the questions also increased the effort required of respondents to provide considered and meaningful answers. To decide about behavioral responses, respondents had to consider how the information might affect future fishing behavior without knowing the specific signals an advisory would provide.

This analysis includes two measures of anticipated behavioral change that apply to both full and partial disclosure programs. The variable BCHANGE identifies anglers who would change sites or stop fishing if the advisory listed a favorite species and site as contaminated. The variable NOREAD identifies anglers who have not read the advisory. A failure to read the current advisory may only mean that a respondent was unaware of the advisory. Once made aware (by the questionnaire or through other channels), this group may value advisory information. However, NOREAD may also identify respondents who know about chemical residues but are not concerned enough to read the advisory. To the extent that NOREAD identifies the latter group, it corresponds to anglers who should place little value on additional information.

The analysis also includes two measures of anticipated behavioral change that apply only to a single program. The variable USELIST indicates whether respondents anticipate changing behavior in response to a list of safe sites. Since a partial disclosure program does not list safe sites, USELIST applies only to the value of a full disclosure program. The variable NCHANGE identifies anglers who are not disposed to behavioral change. This group includes respondents who reported doing nothing differently in response to the current advisory. It also includes those who currently practice consumption behavior at odds with advisory recommendations -- those who reported eating one or more meals per week from inland lakes or the

Great Lakes. NCHANGE represents anglers' response to the current partial disclosure advisory. It does not imply a lack of behavioral response to a full disclosure advisory. Therefore, NCHANGE applies only to the value of a partial disclosure advisory.

Conceptually, anglers who do not anticipate using advisory information will be willing to pay nothing for information. However, the questionnaire does not perfectly capture anticipated behavioral change. Therefore, the empirical hypotheses stated here are weaker than the conceptual hypotheses.

4. Respondents who anticipate changing behavior in response to advisory information will be willing to pay at least as much for additional information as those who anticipate no behavioral change.

   a. Respondents who report that they would change behavior if the advisory listed their favorite site and species as unsafe will be willing to pay no less for advisory information than those who would not change behavior.

   b. Respondents who have not read the advisory will be willing to pay no more for additional information than those who have read the advisory.

   c. Respondents who would change behavior in response to a list of safe sites will be willing to pay no less for a full disclosure advisory program than respondents who would not change behavior.

   d. Respondents who have not changed behavior in response to the current advisory or those who currently practice consumption behavior at odds with advisory recommendations will be willing to pay no more for a partial disclosure advisory than those who have changed behavior or do not engage in risky consumption behavior.

Because of problems measuring anticipated behavioral change, the hypotheses listed above are somewhat exploratory. Rejection of a hypothesis does not necessarily imply that a particular behavioral change measure is unimportant -- it may mean only that the concept was not measured adequately.

Perceived Accuracy of Advisory

The perceived accuracy of advisory information should also affect WTP. However, the questionnaire obtains poor measures of perceived accuracy. Perhaps the most severe problem is that it measures separate dimensions of accuracy -- beliefs about the accuracy of scientific knowledge and the perceived accuracy of reporting. Measures of only some of the individual dimensions of perceived accuracy identify some of the anglers who believe the advisory to be inaccurate but not those who believe it to be accurate. For instance, a belief that any single dimension is inaccurate implies a belief that the advisory as a whole is inaccurate. Therefore, a respondent who believes any measured dimension to be inaccurate believes the advisory to be inaccurate. However, a respondent who believes all measured dimensions to be accurate may still believe the advisory to be inaccurate if they question the accuracy of an unmeasured dimension. Because the questionnaire does not measure all dimensions of perceived accuracy, it does not identify respondents who believe the advisory to be accurate.

The variable SCIENCE identifies anglers who believe the advisory to be inaccurate because scientific knowledge is inaccurate. The questionnaire asked whether respondents believed that the current advisory understated the risk from chemical residues in fish. The question did not capture perceived accuracy because it did not distinguish between respondents who believed the advisory overstated risk and those who believed it accurately portrayed risk. A belief that reporting is inaccurate also implies a belief that the overall advisory is inaccurate.

However, the questionnaire did not obtain an adequate measure of perceived accuracy of reporting. The empirical model includes only the variable SCIENCE as a measure of perceived advisory accuracy.

5. WTP for either a full or partial disclosure advisory program is nonincreasing in the perceived inaccuracy of scientific knowledge.

Because of measurement difficulties, expectations with regard to tests of the perceived accuracy hypothesis are low.

<u>Education</u>

The variable COLLEGE identifies respondents who reported at least some college education. Education should positively affect WTP for advisory information. More educated anglers should better understand the complex advisory and its implications.

Estimation and Tests of Hypotheses

The analysis uses the estimation approach suggested by Cameron and James (1987). The resulting estimated coefficients represent marginal effects of explanatory variables on WTP. Equations were estimated with Limdep's [1] MINIMIZE command. The command minimized the negative of the log likelihood function

(5.8)
$$\log L = \Sigma \{CHOICE_i \log[1-\Phi((COST_i-\beta x_i)/\sigma)] + (1-CHOICE_i)\log[\Phi((COST_i-\beta x_i)/\sigma)]\}$$

where:

$\beta x_i = \Sigma_i \beta x_i$

Φ = the standard normal cumulative density.

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[1] Limdep is a computer program that focuses on statistical analysis of limited dependent variables models (Greene 1991).

This section addresses the functional specification of the empirical model and tests of the hypotheses stated in the previous section.

Model Specification

The functional relationship between WTP and the explanatory variables listed in Table 5.1 can take many forms. A desirable specification should (1) be consistent with the conceptual framework, (2) facilitate tests of research hypotheses, and (3) accurately predict the referendum choice. The conceptual analysis suggests that the marginal value of testing with a full disclosure program is not less than with partial disclosure. Therefore, the specified empirical model separates the effects of the two programs on WTP. The variables PSITES and FSITES in the model of Table 5.2 represent the marginal effects of testing an additional site under partial and full disclosure respectively. The variable FULLD defines a shift variable for a full disclosure advisory.

An additional specification issue concerns the role of non-program variables in the empirical model. The non-program variables are FATAL, BCHANGE, NOREAD, NCHANGE, USELIST, SCIENCE, and COLLEGE. Two questions arise: (1) whether non-program variables affect WTP at the margin or whether they shift the WTP function, and (2) whether non-program variables are significant determinants of WTP. Appendix B presents results of likelihood ratio tests of hypotheses related to these questions. The tests fail to reject the hypothesis that interaction forms of the non-program variables can be jointly restricted to zero. Therefore, interaction forms of the non-program variables have no significant joint effect on marginal WTP and they do not appear in the regression models. The tests also reject the hypothesis that level (non-interacted) forms of non-program variables can be jointly restricted to zero. Therefore, the regression models include non-program variables in level form only.

WTP for Full Versus Partial Disclosure

Table 5.2 reports regression results for a linear WTP function. All non-program variables enter the model as deviations from mean values. The model supports the hypotheses that WTP for both full and partial disclosure advisories is nonnegative. For the average angler -- an angler with average values for non-program variables -- the estimated coefficient of FSITES represents marginal WTP for testing an additional site with full disclosure. An average angler is willing to pay $.0046 per tested site with full disclosure. Marginal WTP for full disclosure information is different from zero at the ten percent significance level. Marginal WTP for partial disclosure information -- the estimated coefficient of PSITES, $.0045 -- is essentially equal to marginal WTP for full disclosure. However, estimated marginal WTP for partial disclosure does not differ significantly from zero. This suggests that anglers are willing to pay less to test a site when the advisory releases only partial information than when it fully discloses test results.

The finding that marginal WTP for partial disclosure information is not statistically distinguishable from zero seems consistent with rational behavior. Additional testing with partial disclosure produces, at best, a small improvement in an angler's decision environment. For example, suppose an angler wishes to avoid eating contaminated fish. Short of not eating fish, the angler's rational choice with partial information is to eat fish only from no report sites. Assume the angler believes that 20 percent of the presently 5,500 no report sites are unsafe. The chance of eating contaminated fish while fishing only at no report sites is thus .20.

Now suppose tests of 200 additional no report sites identify 40 (20 percent) unsafe sites. The testing reduces the number of no report sites to 5,460 -- 5,500 original no report sites minus 40 sites newly listed as unsafe. It also identifies 40 of the 1,100 (20 percent of 5,500) unsafe sites. Therefore, 1,060 unsafe sites still exist among the 5,460 remaining no report sites. The revised chance that a no report site is unsafe is thus 19.4 percent -- a very small reduction in risk relative to 20.0 percent.

Table 5.2 - Estimated WTP for Full and Partial Disclosure

Variable	Coefficient Estimates
CONSTANT	.3457 (2.202)
FSITES	.0046* (.0027)
PSITES	.0045 (.0028)
FULLD	5.643* (3.151)
FATAL	7.245*** (2.120)
BCHANGE	1.702 (1.847)
NOREAD	-2.658 (2.777)
NCHANGE	-.3652 (2.645)
USELIST	15.612*** (2.979)
SCIENCE	2.688 (1.901)
COLLEGE	6.836*** (1.866)
Log-Likelihood	-428.67
% Correct Predictions	71.9%

* = significant for $\alpha = .1$
** = significant for $\alpha = .05$
*** = significant for $\alpha = .01$

Regression results for the linear model based on 758 observations.

All non-program variables enter as deviations from mean values.

Numbers in parentheses are standard errors.

A partial disclosure advisory tells anglers about unsafe sites without telling them about safe alternatives. In the absence of private information, the chance of unintentionally fishing at an unsafe site is the chance that a no report site is unsafe. A full disclosure advisory, on the other hand, tells anglers about relatively safe alternatives to either unsafe or no report sites. To the extent the advisory accurately identifies safe sites, full disclosure eliminates the risk of eating contaminated fish. Full disclosure would seem to bring about a non-trivial reduction in risk for an angler who wishes to avoid contaminated fish and believes that some no report sites are unsafe.

Estimated WTP for testing levels that imply no additional information provides a check of the correspondence between the estimated model and the behavioral implications of economic theory. The current advisory program tests 30 sites per year and provides partial disclosure of test results. A model consistent with theory should yield zero WTP for a partial disclosure advisory that tests 30 sites -- an angler should not be willing to accept an increase in license fees to continue the current advisory. The constant term of the model in Table 5.2 represents WTP for testing 30 sites with partial disclosure. [2] The fact that the constant is not statistically different from zero supports the implications of economically rational behavior.

The above argument also implies that estimated WTP for a full disclosure program that tests no sites should be zero. An angler should not be willing to pay a positive amount for an advisory program that provides no information. However, the positive and significant coefficient of the full disclosure dummy variable, FULLD, implies that anglers are willing to pay $5.64 for a full disclosure advisory that tests zero sites. The following section asks whether this counterintuitive result is an artifact of the linear model.

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[2] PSITES equals the number of sites tested minus 30. Therefore, the estimated constant term represents WTP for testing 30 sites with partial disclosure.

WTP for Full Disclosure

Suppose the data actually describe a marginal WTP function that is positive and decreasing and has an intercept near zero. A linear functional form fitted to the data may produce a relatively large positive intercept and overestimate WTP for small levels of testing. Table 5.3 reports results of two nonlinear models -- a quadratic and a square root model -- that examine the possibility that WTP is a nonlinear function of testing. The linear model implies that WTP for partial disclosure is insignificant. Therefore, the nonlinear models estimate WTP for full disclosure only. The models do not include the variables PSITES and NCHANGE because these variables apply only to partial disclosure. They also do not contain the variable FULLD that shifts the linear model for full disclosure.

The first two columns of Table 5.3 report the quadratic and square root models respectively. The conceptual results suggest that the constant term in both models should be zero -- anglers should not be willing to pay for no information. Statistically, the constant terms are not significantly different from zero. Likelihood ratio tests imply that restricting the constant terms to zero does not significantly affect the explanatory power of the estimated equations. [3] Therefore, the nonlinear models suggest that WTP for a full disclosure advisory that tests no sites is effectively zero -- a result consistent with conceptual expectations.

The estimates of Table 5.3 support the hypothesis that the WTP function for full disclosure may be nonlinear. The nonlinear terms are significant and suggest that marginal WTP is decreasing in the number of sites tested. Furthermore, a comparison of the quadratic and square root models with the restricted model in the final column suggest that the linear and

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[3] The likelihood ratio statistic associated with the null hypothesis that the constant term of the quadratic model can be restricted to zero is 1.06. The likelihood ratio statistic for restriction of the constant term of the square root model is .18. The χ^2 critical value for $\alpha=.1$ and 1 degree of freedom is 2.71. Therefore, the tests fail to reject the hypotheses that the constant terms in either model can be restricted to zero -- the restrictions are not significant.

Table 5.3 - Nonlinear WTP Functions

Variable	Quadratic Model	Square Root Model	Restricted Model
CONSTANT	3.332 (3.242)	-3.518 (8.453)	
FSITES	.0190 (.0127)	-.0176 (.0190)	
FSITES^2	$-.1055E^{-4}$ ($.8962E^{-5}$)		
FSITES$^{.5}$		1.026 (.8719)	
FATAL	8.175*** (3.068)	8.175*** (3.068)	15.205*** (5.975)
BCHANGE	.9659 (2.710)	.9659 (2.710)	.1225 (4.945)
NOREAD	-3.356 (3.989)	-3.356 (3.989)	6.963 (7.166)
USELIST	15.812*** (3.279)	15.812*** (3.279)	29.393*** (7.594)
SCIENCE	2.391 (2.774)	2.391 (2.774)	7.266 (5.211)
COLLEGE	7.875*** (2.691)	7.875*** (2.691)	12.992*** (5.303)
Log-Likelihood	-213.87	-213.87	-232.94
% Correct Predictions	74.8%	74.8%	73.3%

* = significant for $\alpha = .1$
** = significant for $\alpha = .05$
*** = significant for $\alpha = .01$

Regression results for the quadratic and square root models based on 397 observations for full disclosure of information.

All non-program variables enter as deviations from mean values.

Numbers in parentheses are standard errors.

nonlinear forms of FSITES are jointly significant in both nonlinear models.[4] Therefore, the nonlinear models are statistically superior to the restricted model.

Table 5.4 reports regression results for the final linear and nonlinear models of WTP for full disclosure. The linear model differs from the model of Table 5.2 because it estimates WTP for full disclosure only. Therefore, it does not include the variables PSITES, FULLD, or NCHANGE. The nonlinear models do not contain the insignificant constant terms found in the models of Table 5.3. Little statistical basis exists to choose among the three models of Table 5.4. There is no statistical difference in explanatory power and predictive accuracies are very similar -- 73.8 percent for the linear model, 74.0 percent for the quadratic, and 74.3 percent for the square root. Economic theory suggests a declining marginal WTP -- a rationale that favors the nonlinear forms. However, the analysis suggests no reason to prefer one nonlinear form over the other.

All three models of Table 5.4 support the hypothesis that WTP for full disclosure is nonnegative. As a consequence of the chosen functional forms, the nonlinear models imply negative marginal WTP for extremes in testing -- more than 870 sites for the quadratic model and more than 1,068 sites for the square root model. However, over a large relevant range of testing around current levels, both models imply that marginal WTP is positive and decreasing -- a result consistent with economic theory. Table 5.5 illustrates total and marginal WTP values for full disclosure implied by each of the three alternative models. Since marginal values from a linear function are not particularly meaningful, they are not included in the table.

Table 5.5 shows that total WTP for full disclosure is positive for testing levels between zero and 300 sites per year which represents a tenfold increase over current levels. Because of the large positive constant, the linear model of column one yields greater total WTP for

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[4] The likelihood ratio statistic associated with restricting FSITES and $FSITES^2$ in the quadratic model or FSITES and $FSITES^{.5}$ in the square root model to zero is 38.14. The χ^2 critical value for $\alpha = .01$ and 1 degree of freedom is 6.63. Therefore, the test rejects both restrictions -- the linear and nonlinear forms of FSITES contribute significantly to explaining variation in estimated WTP.

Table 5.4 - Final WTP Estimates

Variable	Linear Model	Quadratic Model	Square Root Model
CONSTANT	6.041*** (2.264)		
FSITES	.0046* (.0027)	.0300*** (.0074)	-.0103 (.0073)
$FSITES^2$		-.00002*** (.000006)	
$FSITES^{.5}$			.6756*** (.2322)
FATAL	7.863*** (3.044)	8.639*** (3.139)	8.027*** (3.016)
BCHANGE	.7247 (2.672)	1.088 (2.789)	.8874 (2.669)
NOREAD	-3.543 (3.979)	-3.208 (4.114)	-3.426 (3.965)
USELIST	15.897*** (3.283)	16.352*** (3.348)	15.749*** (3.251)
SCIENCE	2.440 (2.777)	2.566 (2.851)	2.374 (2.758)
COLLEGE	8.015*** (2.700)	8.005*** (2.775)	7.889*** (2.680)
Log-Likelihood	-214.60	-214.40	-213.96
% Correct Predictions	73.8%	74.0%	74.3%

* = significant for α = .1
** = significant for α = .05
*** = significant for α = .01

Regression results for the quadratic and square root models based on 397 observations for full disclosure of information.

All non-program variables enter as deviations from mean values.

Numbers in parentheses are standard errors.

Table 5.5 - Total and Marginal WTP for Full Disclosure Information

	Linear Model	Quadratic Model	Square Root Model
Total WTP for Full Disclosure			
Sites Tested			
0	$6.04	$0.00	$0.00
30	$6.18	$.88	$3.39
50	$6.27	$1.46	$4.26
100	$6.50	$2.82	$5.72
200	$6.96	$5.31	$7.49
300	$7.42	$7.44	$8.60
Marginal WTP for Full Disclosure			
Sites Tested			
0		$.0300	N.D.
30		$.0289	$.0513
50		$.0282	$.0374
100		$.0265	$.0234
200		$.0231	$.0136
300		$.0196	$.0092

N.D. means not defined.

relatively low levels of testing -- below 100 sites per year. However, estimated total WTP from the

square root model of column three surpasses that of the linear model at a level of testing of about 300 sites per year. Similarly, the quadratic model yields greater total WTP than the linear model for testing levels greater than or equal to 300 sites per year. Relative to the non-linear models, the linear model inflates total WTP for levels of testing near the current level.

The two nonlinear models differ primarily in the rate of change of marginal WTP. The quadratic model of column two implies a constant decline in marginal WTP as testing increases. The square root model implies a relatively large marginal WTP for small levels of testing (below about 50 sites). However, marginal WTP in the square root model declines rapidly at first and less rapidly as testing levels increase. Figure 5.2 graphically illustrates the relationship between marginal WTP for the quadratic and square root models.

Estimates of net benefits -- the difference between total WTP and total cost -- are probably most relevant to the practical questions that motivate this research. Discussion with MDNR officials produced a rough cost estimate of $.01 per angler to test an additional site. The marginal cost of providing a full disclosure advisory also includes the cost of printing information about an additional test. Pages must be added to the advisory in multiples of eight. Printing cost per angler to add eight pages to the advisory is about $.01. [5] Therefore, additional printing costs are near zero if additional information can be included in the existing space and may reach $.01 per angler if additional pages must be added.

Figure 5.2 graphs total values for the three estimated functional forms -- linear, quadratic, and square root. The figure also graphs two total cost curves. The curve TC1 corresponds to a marginal cost of testing of $.01 per angler per site. TC2 represents the total costs associated with a marginal cost of $.02 per angler per site.

The practical implications of the research are not particularly sensitive to either the choice of functional form or assumptions about testing and printing costs. The total WTP curves lie

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[5] Personal communication with Ned Fogle, Michigan Department of Natural Resources, Fisheries Division.

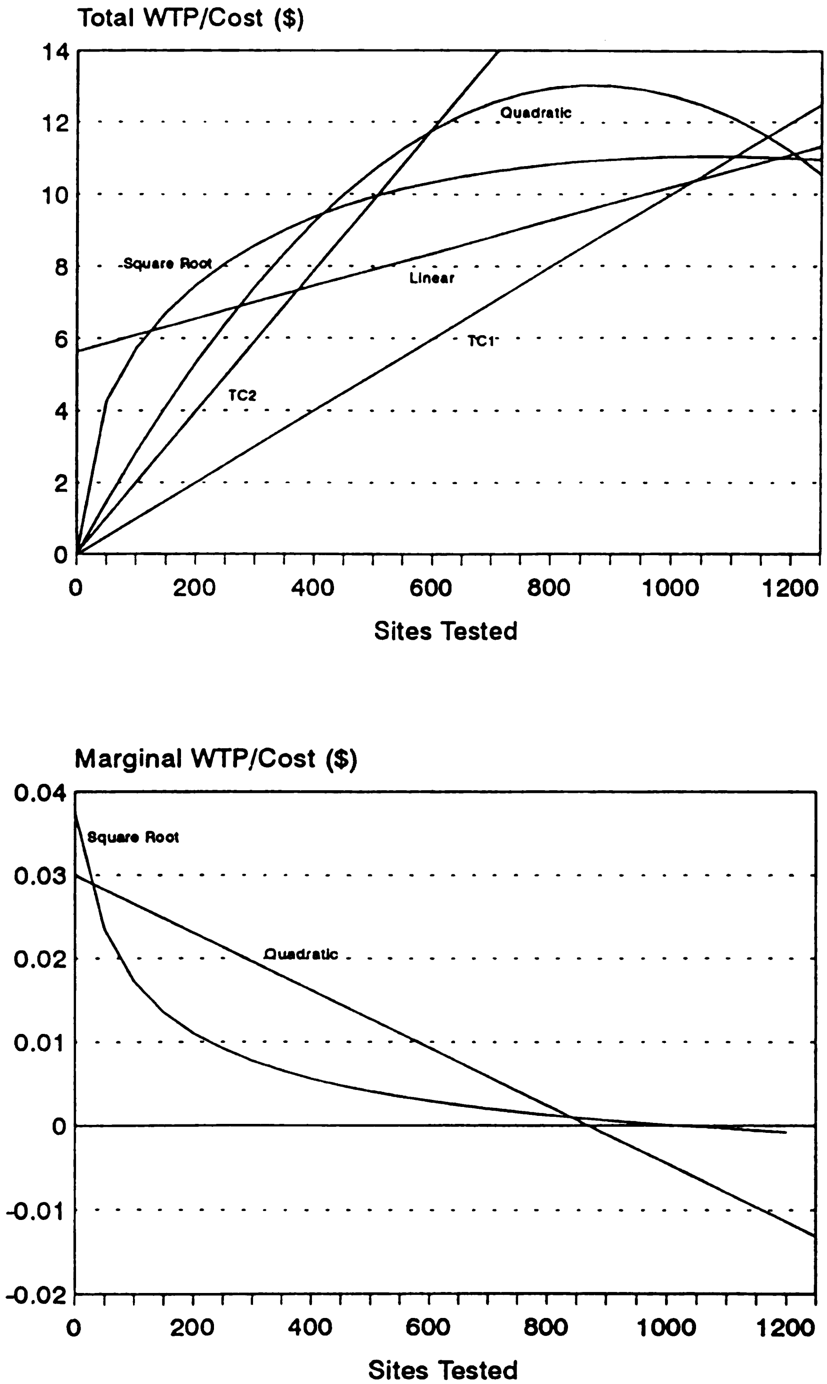


Figure 5.2 - Total and Marginal WTP for Full Disclosure Information

above the total cost curve TC1 for all testing levels below 1,100 sites -- the level where TC1 intersects total WTP for the linear model. Therefore, net benefits are positive for all three functional forms for all testing levels below 1,100 sites. Furthermore, even if actual testing costs are twice the estimated $.01 per site per angler, all three models yield positive net benefits for testing levels below 579 sites -- the level at which TC2 intersects total WTP from the quadratic model.

Predicted Probability of Accepting the Advisory Program

The probit model yields a normally distributed index of the probability that a respondent will accept the referendum. Table B.3 of appendix B reports the probity estimates from which index values are derived. The cumulative normal distribution evaluated at the index defines the probability of acceptance as a function of the explanatory variables that produce the index value. Figure 5.3 graphs the predicted probability that an average angler will accept a full disclosure program as a function of cost. The graph illustrates predictions of the linear model for each level of testing presented in the questionnaire. It also shows that the probability of acceptance is decreasing in program cost. Although they are not graphed, the quadratic and square root models also exhibit decreasing probability of acceptance as cost increases.

Table 5.4 shows the program costs that correspond to an estimated 50 percent chance of acceptance for three rates of testing near current levels -- 50, 100, and 150 sites. Each of the models predict that the probability of acceptance is increasing in the number of sites tested. Furthermore, if testing costs are about $.01 per angler per site, the models predict that a majority of anglers will accept a license fee increase that covers the cost of testing.

Tests of Hypotheses

A likelihood ratio test reported in appendix B fails to reject the hypothesis that the non-program variables can be jointly excluded from the empirical model. The test implies that,

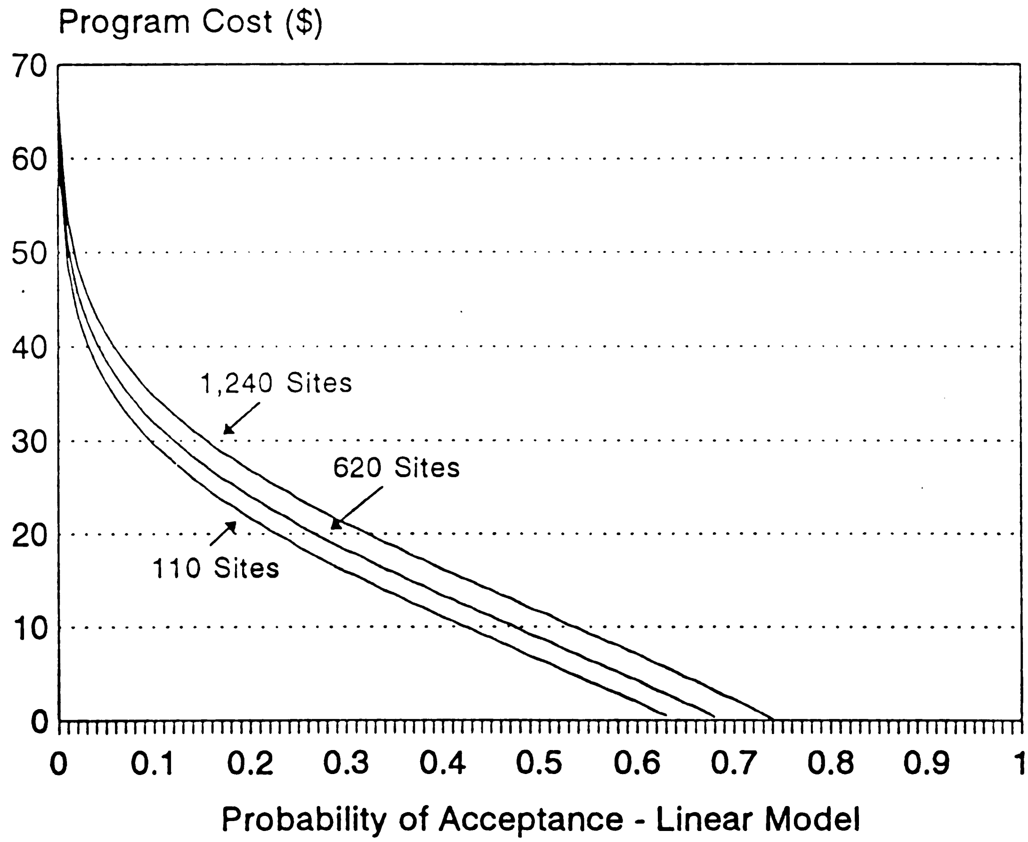


Figure 5.3 - Predicted Probability of Acceptance

Table 5.4 - Program Costs Associated with 50 Percent Probability of Acceptance

Sites Tested	Linear Model	Quadratic Model	Square Root Model
50	$6.22	$1.46	$4.26
100	$6.44	$2.82	$5.72
150	$6.67	$4.11	$6.72

jointly, the non-program variables contribute significantly to explaining variation in WTP. This section reviews conclusions about the hypotheses related to non-program variables. Whether survey questions related to these hypotheses accurately measured intended concepts is an empirical question. Failure to reject a particular hypothesis suggests that the corresponding variable may have captured the concept. Rejection of a hypotheses does not invalidate the model -- it may merely mean that the corresponding variable did not adequately measure the intended concept.

Non-program variables enter the estimated equation only in level form. Therefore, they shift the estimated WTP function and do not effect estimates of marginal WTP. All coefficients of non-program variables reported in Table 5.2 have signs consistent with the hypotheses of Figure 5.1. Strict interpretation of the level forms and estimated coefficients puts extreme demands on the estimation procedure and yields some counterintuitive conclusions. It is unlikely, for instance, that anglers who believe possible health effects to be fatal are willing to pay more at every level of testing than anglers who believe health effects are unlikely to be fatal. Failure to reject a hypothesis suggests only that a particular variable affects WTP, it implies little about the specific form or magnitude of the effect.

Perceived Severity of Outcome

The conceptual framework suggests that anglers who believe that the health effects of eating contaminated fish are likely fatal will be willing to pay at least as much for advisory information as those who believe fatality to be unlikely. The estimated coefficient of FATAL in the linear model is positive and significant. This result supports the hypothesized relationship between perceived likelihood of fatality and information value -- estimated WTP for advisory information is nondecreasing in the perceived likelihood of a fatal health outcome.

Behavioral Change

Anticipated behavioral change in response to advisory information also appears to significantly affect WTP. A likelihood ratio test reported in appendix B fails to reject the hypothesis that the four behavioral change variables can be jointly excluded from the estimated model. All four behavioral change measures have the expected sign -- BCHANGE and USELIST have a nonnegative effect on estimated WTP, NOREAD and NCHANGE have nonpositive effects. The signs are consistent with the general hypothesis that anglers who anticipate a behavioral change in response to additional information are willing to pay at least as much as those who do not foresee making a behavioral change.

The variable USELIST is the only behavioral change measure with a significant coefficient. However, the fact that the coefficients of the remaining behavioral change variables have the expected signs suggests that they captured some aspects of the intended concepts.

Perceived Accuracy of Advisory

The conceptual framework also suggests that information value is nondecreasing in perceived accuracy. The nonnegative coefficient of SCIENCE suggests that respondents who believe advisories to be inaccurate because of insufficient scientific knowledge are willing to pay no more for advisory information than other respondents.

Education

While not stated as a formal hypothesis, the estimated coefficient of COLLEGE is also consistent with conceptual expectations. The significance of COLLEGE as an explanatory variable suggests that education is an important determinant of an angler's response to the advisory.

Summary

The preceding analysis produces three primary conclusions. First, additional testing under the current partial disclosure advisory likely has little value to anglers. Second, WTP for a full disclosure advisory program is positive at current testing levels and increasing in the number of sites tested. Finally, full disclosure produces positive net benefits for a large range of testing levels around the current 30 sites per year. The final result is robust with respect to alternative functional forms and assumptions about the costs of providing a full disclosure advisory.

Chapter Six

Summary and Conclusions

This research had three primary objectives. First, it developed a Bayesian conceptual framework that linked characteristics of information systems to economic value. Second, it adapted CV techniques to obtain the empirical measures needed to test the conceptual hypotheses in the context of sport anglers' WTP for information about chemical residues in fish. Third, it asked the practical questions of whether Michigan's current public health advisory has value to anglers and how the state might enhance advisory value. The process of addressing these objectives produced useful insights in each of the three primary components of the research. Conceptually, it clarified the definition of information value relative to the welfare effects associated with contamination. It also emphasized the importance of pretesting in the design of an effective CV survey. Finally, it produced WTP estimates that may guide practical decisions about the future of Michigan's public health advisory program.

This chapter first reviews the findings from each of the components of the research listed above.. It also emphasizes the limitations of the findings and suggests areas where future research may prove fruitful.

Conceptual Conclusions

The research identified two measures of ex ante information value used in the literature. It showed them to be algebraically equivalent if posterior beliefs were formed using Bayes' rule. The conceptual development also clarified the difference between information value and the welfare loss associated with environmental contamination. Contamination of food or the environment may cause a loss of welfare as people engage in risk averting behavior. However, the loss would be greater if ignorance prevented the behavioral adjustment.

Confusion between nonnegative information value and negative welfare effects of contamination may influence public information policies. Johnson (1988) does not distinguish between WTP for information and welfare losses associated with EDB contamination of grain products. Furthermore, he defines ex post WTP for information relative to a state of "correct" information rather than the most recent posterior perceptions of risk. He concludes that information value may be negative if it is incorrect. However, the health risks associated with food and environmental contamination are never known with certainty. Furthermore, the best scientific estimates of risks change over time with the accumulation of evidence. Johnson's analysis suggests that it may not be in the public interest to release risk information when it may ultimately turn out to be incorrect. The conceptual results of this research suggest that health risk information cannot make people worse off and, therefore, should not be withheld.

Nonnegative information value does not imply that additional information will always improve welfare. Information has strictly positive ex ante value only if it creates the possibility of behavioral change -- the information must be decision relevant. Furthermore, the net value of information depends on its cost and the monetary and non-monetary costs of interpreting and using it. This suggests several practical considerations for the design of information programs. First, information will be more useful (valuable) if it identifies states that are relevant to information users' behavioral decisions. Second, informing people about risk reducing behaviors may enlarge the set of perceived behavioral responses to information and enhance the value of existing signals. Finally, information issued in a form that is easily understood and applied by users has a greater net value than complex information.

Designing an Effective CV Survey

The contributions of this research to the practice of CV relate to both the measurement of information value and the application of the CV approach. The research builds on the ex post analysis of Foster and Just (1989) and adapts the CV method to the analysis of ex ante information value. Results of focus group, interview, and mail pretests emphasize the importance of contact with the respondent population prior to implementation of a CV survey.

The process of survey design was one of the more educational aspects of this research. The CV survey instrument directly impacts the quality of the data and, ultimately, the analysis. Extensive pretesting influenced the survey used in this research in several ways. First, focus group research identified the language anglers used to think about chemical residues and the advisory. It also identified anglers' interpretation of the current advisory and the behavioral responses they considered effective. Second, iterative one-on-one interviews focused on respondents' interpretation of specific questions. The interviews were crucial to ensuring that questions measured intended concepts.

A comparison of WTP estimates from the pretest and final surveys emphasizes the importance of clear descriptions of the contingent market. The pretest survey asked for respondent's WTP for (1) continuation of the current advisory program, (2) a partial disclosure program that tested either 100 or 300 sites per year, and (3) a full disclosure program that listed either 200 or 600 safe sites. Figure 4.1 of chapter four illustrates the form of the three pretest WTP questions. An open ended question that asked for respondents' maximum WTP followed each of the questions. Table 6.1 lists mean WTP values for each program offered in the pretest. Statistical analysis reveals no significant difference in WTP between mean bids for any of the programs described for a level of significance of $\alpha = .01$.

The similarity of the mean bids suggests that respondents may not have understood or responded to the differences between programs. The uniformity of bids within surveys further supports the notion that respondents did not interpret the programs as intended. A majority of respondents (72%) stated the same WTP for full as for partial disclosure advisories and 56 percent stated identical WTP for the current advisory, full disclosure, and partial disclosure with increased testing. This result seems remarkable given the significant quantitative differences between proposed programs. However, the result could arise if (1) respondents

Table 6.1 - Pretest WTP Means

Program	Number of Sites	Mean WTP
Partial Disclosure	30	$3.49
Partial Disclosure	100	$3.57
Partial Disclosure	300	$3.06
Full Disclosure	200	$2.82
Full Disclosure	600	$2.95

understand the differences but do not perceive them to be large, (2) they understand the differences but do not view them as essential to the good or program to be valued, or (3) they do not clearly perceive the differences due to poor question design.

Additional interviews improved the clarity of the questionnaire. In particular, the final survey included an expanded description of the current advisory (Figure 4.2) and a tabular comparison of program alternatives (Figure 4.4). Participants in interviews with the final questionnaire format seemed to quickly and accurately identify important features of the current advisory program. They also exhibited a firm understanding of the differences between alternative programs.

The comparison of pretest and final WTP estimates suggests that poor survey design begets questionable data. In this case study, meaningful WTP responses depended crucially on a clear description of the contingent market. Pretesting, in turn, was a necessary step in the evolution of a clear survey. In retrospect, had the research proceeded from the initial draft of the survey without pretesting, many questions would not have measured intended concepts and the empirical results would likely have been meaningless.

Despite extensive pretesting, the survey had limitations. A great deal of prior effort focused on describing the existing program and proposed alternatives. As a result, measures of program variables provided strong tests of program hypotheses. However, the survey could probably have obtained better measures of many non-program explanatory variables. For example, both the conceptual framework and qualitative impressions from pretesting suggest that perceived accuracy is an important determinant of advisory value. The survey did not obtain adequate measures of perceived accuracy. Therefore, the empirical importance of perceived accuracy remains an unanswered question.

Also, the survey did not obtain good measures of anticipated behavioral change. The questions were poorly thought out in terms of anglers' actual behavioral options. For instance, the analysis ultimately relied on relatively complex combinations of responses to several questions to measure some aspects of behavioral change. More forethought and care in design would have identified and obtained these measures more directly. In general, more prior effort in designing questions related to non-program variables may have obtained better measures and stronger, more informative empirical conclusions.

Quantitative measures of respondents' understanding of the pretest and final questionnaire may strengthen the conclusions regarding the importance of pretesting. A simple test of comprehension could easily provide such measures. Also, the technique of verbal protocol analysis from psychology may provide more concrete measures of how people perceive and respond to different forms of pretest CV questions (Schkrade and Payne 1994). Such analysis could contribute to a researcher's understanding of how respondents think about CV questions. Thus, it could help ensure that respondents perceive and answer the questions the researcher intends to ask.

Another issue concerns the process of estimating WTP from discrete (referendum) data. The model used in this study assumes that WTP is normally distributed (Cameron and James 1987). However, discrete choice responses are often not normal (Duffield and Patterson 1991, Cooper 1993). If the normality assumption is incorrect, the parameter estimates from the probit model are inconsistent. Nonparametric estimation methods do not require a distributional assumption and may provide better parameter estimates if WTP is not normally distributed.

Several nonparametric techniques exist. Kriström (1990) suggests a simple nonparametric estimation approach. However, his approach is not easily applied to models that contain many explanatory variables. Greene (1990) describes an alternative nonparametric estimator -- the maximum score estimator. Future research could compare the predictive abilities of the parametric probit model against a nonparametric approach.

Policy Implications

The research revealed that a majority of surveyed anglers (63.9%) have changed their fishing behavior in response to the current advisory. Information has positive ex post value if it changes behavior. Therefore, most anglers appear to value Michigan's current public health advisory program. While the current advisory is valuable, the research also finds that many anglers are willing to pay a positive amount for some types of additional information.

Additional testing with only partial disclosure of test results produces little improvement in an angler's decision environment. It slightly increases the chance that fish from a site not explicitly listed in the advisory are safe to eat. Consequently, respondents to the CV survey were willing to pay nothing for additional testing under the current partial disclosure program. However, full disclosure of test results provides anglers with known safe alternatives to contaminated sites and significantly reduces the chance of eating contaminated fish. Respondents were willing to pay a significant amount for an advisory that fully disclosed test results.

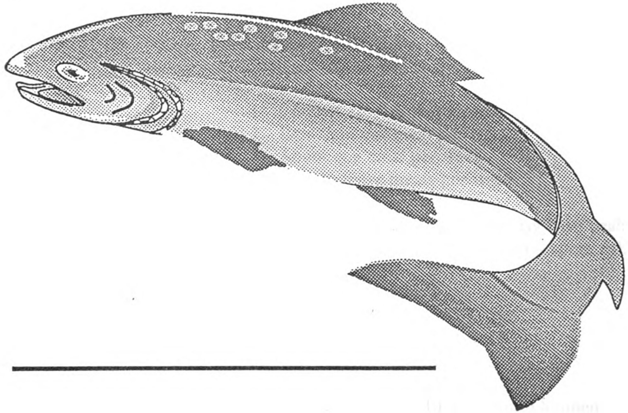
The value of a full disclosure advisory program is positive at the current level of testing and increasing with the number of sites tested annually. The results of this study do not reveal the optimal level of testing. However, the benefits of additional testing with full disclosure exceed the probable costs of providing the information for a wide range of testing around current levels. This result is robust for different assumptions about both the form of the WTP function and the cost of the advisory program.

The CV survey used in this research did not describe where additional testing would take place. Therefore, WTP estimates depend on respondent's assumptions about the geographical distribution of proposed testing. However, the perceived geographical pattern of testing may strongly influence angler's WTP for information. For example, an angler who fishes only in one area is not likely to value testing in other areas. Similarly, even anglers who are willing to substitute sites between geographical areas will likely be sensitive to the relative proximity of different locations. Travel costs and time constraints would imply a greater WTP for information about nearby areas than for those further away. Further research might help identify differences in information value across different regions of the state. The information might provide guidance for targeting future testing.

Appendices

Appendix A
Questionnaire and Related Materials

MICHIGAN'S SPORT FISH CONSUMPTION ADVISORIES



1. Do you regularly do any of the following? (Circle all that apply)

   1. Firearm or bow hunting
   2. Bird or wildlife viewing
   3. Camping
   4. None of the above

2. About how many times per year do you fish at the following types of sites? (Fill in numbers)

   ____ **Great Lakes**
   ____ **Inland lakes or ponds**
   ____ **Rivers or streams**
   ____ **Other** ____________________________

3. On average, throughout the year, about how often do you eat fish that you catch in Michigan? (Circle one number)

   1. I do not eat fish that I catch
   2. Less than one meal per week
   3. About one meal per week
   4. Two or more meals per week

4. What do you think is the chance that *you* will someday have health problems because of chemical residues in Michigan's sport fish? (Circle one number)

1. No chance	**6. 1 in 100**
2. 1 in a million	**7. 1 in 10**
3. 1 in 100,000	**8. 1 in 5**
4. 1 in 10,000	**9. 1 in 2**
5. 1 in 1,000	**10. Certain to happen**

5. How certain are you that your guess about the chance of a health effect is correct? (Circle one number)

    1. **Very uncertain**
    2. **Somewhat uncertain**
    3. **Somewhat certain**
    4. **Very certain**
    5. **I have no idea**

The public health advisory from the 1992 Fishing Guide is included with this questionnaire. Questions that mention the "advisory" refer to this insert.

6. Has the advisory helped you to avoid health problems from chemical residues in fish? (Circle one number)

    1. **Yes**
    2. **No**
    3. **I don't know**

7. As a result of the advice in the advisory, do you... (Circle all that apply)

    1. **I have not read the advisory**
    2. **Eat fish less often**
    3. **Fish at different places**
    4. **Eat smaller fish**
    5. **Eat different kinds of fish**
    6. **Prepare fish to eat differently**
    7. **Do nothing differently**

8. Are you concerned about chemical residues or other contaminants in other foods that you eat? (Circle one number)

    1. **Not at all concerned**
    2. **Somewhat unconcerned**
    3. **Somewhat concerned**
    4. **Very concerned**

Michigan's Public Health Advisory

There are more than 5,800 public fishing sites in Michigan - 2,200 sites on rivers and streams, 3,600 inland lakes, and the Great Lakes. The state has tested 350 of these sites for chemical residues in fish. About 30 new sites are tested each year.

The current public health advisory tells you:

- that you should not eat too much fish from *any* inland lake because of widespread mercury contamination, and

- it lists 50 sites where fish contain chemical residues *above* state limits.

The advisory does not tell you about:

- the 300 tested sites where chemical residues *do not* exist or are *below* state limits.

The advisory program could be changed.

- **The advisory could list tested sites where chemical residues *do not* exist or are *below* state limits.**

- **More than 30 new sites could be tested each year.**

These changes would increase the amount of information in the advisory but they would also cost more money.

Your Vote on Advisory Programs

The table below shows two advisory programs. The "Current Advisory" is Michigan's current advisory program. "Program A" is a different program that could be put in place.

Program Options	Current Advisory	Program A
Lists tested sites where chemical residues are *above* state limits?	Yes	Yes
Lists tested sites where chemical residues do not exist or are *below* state limits?	No	Yes
Number of new sites tested each year.	30	110
Cost to you in higher fishing license fees.	$0.00	$.40

Suppose the Michigan Department of Natural Resources (DNR) sent you a ballot to vote "for" or "against" Program A. If a majority of anglers vote "for" Program A, it will replace the Current Advisory. If a majority vote "against" Program A, the Current Advisory will be continued.

9. Would you vote for Program A if it permanently increased your yearly license cost by $.40, or vote against it and keep the Current Advisory at no additional license cost?

   1. **Vote for Program A**
   2. **Vote against Program A and keep Current Advisory**
   3. **Don't know or no opinion**

10. Do you agree or disagree with the following statements?

Circle best response

Statement					
It is OK to increase fishing license fees to pay for better public health advisories.	Strongly Agree	Somewhat Agree	Somewhat Disagree	Strongly Disagree	No Opinion
The health risks from chemical residues in fish are well understood by scientists.	Strongly Agree	Somewhat Agree	Somewhat Disagree	Strongly Disagree	No Opinion
If chemical residues in fish made someone sick, the illness would probably be fatal.	Strongly Agree	Somewhat Agree	Somewhat Disagree	Strongly Disagree	No Opinion
The advisory understates the health risks from chemical residues in Michigan's fish.	Strongly Agree	Somewhat Agree	Somewhat Disagree	Strongly Disagree	No Opinion

11. In addition to the list of unsafe sites, suppose the advisory listed all tested sites where chemical residues in fish did not exist or were below state limits. If your favorite sites had *not* been tested would you... (Circle all that apply)

    1. **Continue to fish at your favorite sites**
    2. **Stop eating fish from your favorite sites**
    3. **Fish only at sites where chemical residues are below state limits**
    4. **When choosing a new site, be more likely to go to a site where chemical residues were below state limits**

12. What would you do if next year's advisory said you should not eat any of your favorite species of fish from your favorite site? (Circle all that apply)

    1. **I would still fish at the site**
    2. **I would eat fewer fish**
    3. **I would not eat fish from the site**
    4. **I would fish at a different site**
    5. **I would stop fishing**

13. Which of the following groups do you trust to provide the *best* information about contaminants in Michigan's sport fish? (Circle one number)

1. Federal government
2. State government
3. A well known consumer's group
4. An environmental group
5. A university laboratory
6. Other ____________________

14. What is the highest grade of school you have finished? (Circle one number)

1. Grade school only
2. Did not finish high school
3. High school or GED
4. Vocational or technical school
5. Some college
6. College graduate (BS or BA)
7. Some college or professional school
8. Graduate degree (Phd, MD, MA, MBA)

15. **Which choice below best describes your household's expected before tax income from all sources for 1993? (Circle one number)**

1. $0 to $9,999
2. $10,000 to $19,999
3. $20,000 to $29,999
4. $30,000 to $39,999
5. $40,000 to $49,999
6. $50,000 to $59,999
7. $60,000 to $69,999
8. $70,000 to $79,999
9. $80,000 to $89,999
10. $90,000 to $99,999
11. $100,000 to $109,999
12. $110,000 to $149,999
13. $150,000 to $199,999
14. $200,000 and above

If you have any comments about this questionnaire please write them on this page.

When you are finished with the questionnaire, please fold it in half, place it in the enclosed business reply envelope, and return to:

Douglas Krieger
Project Director
Department of Agricultural Economics
Michigan State University
East Lansing, MI 48824-1039

Thank you very much for your help.

Chlorine bleach used in the paper industry contributes to dioxins in Michigan waters. This questionnaire is printed on recycled paper made from 100% post consumer stock and processed without chlorine bleach.

Survey Cover Letter

February 9, 1993

John Angler
123 Whitefish Dr.
Grayling, MI 99999

Dear Mr. Angler,

I am writing to you because you are a licensed angler in Michigan. You may have heard that chemical residues have been found in some of Michigan's sport fish. The state is concerned that anglers are aware of the problem and know how to protect themselves. To inform anglers, the Michigan Department of Public Health issues an annual "Public Health Advisory" that is printed in the back of the "Fishing Guide."

Testing fish and printing advisories is expensive. Because the state budget is limited, choices must be made about how many sites to test and the amount of information to publish. Knowing what kinds of information anglers find useful will assist the state in making these choices. This survey asks about your fishing choices and how you use different kinds of information about chemical residues.

I am interested in the opinions of different kinds of anglers. Your response to this survey is important even if you do not fish very often. It is important that the questionnaire is filled out by the person it is addressed to even if another person in your household fishes more often. The questionnaire should take about 10-15 minutes to complete.

Your participation in the survey is completely voluntary. You indicate your voluntary agreement to participate by completing and returning the questionnaire. Your responses will be kept completely confidential.

Thank you for your help with this research.

Sincerely,

Douglas J. Krieger
Project Director

Reminder Postcard

February 16, 1993

Last week you should have received a questionnaire asking for your opinions about Michigan's public health advisories concerning sport fish contamination.

If you have already filled out the questionnaire and returned it I thank you very much for your help. If not, please do so today. It is important that we receive you response if the results are to accurately represent the opinions of Michigan anglers. Your response will be greatly appreciated.

Sincerely,

Douglas J. Krieger
Project Director

Cover Letter for First Follow-up

March 2, 1993

John Angler
123 Whitefish Dr.
Grayling, MI 99999

Dear Mr. Angler,

About three weeks ago I sent you a questionnaire asking for your opinions about the Public Health Advisories regarding chemical residues in Michigan's sport fish. To date I have not received your completed questionnaire.

The results of this research will help the state design advisories that are more useful to anglers. This survey is a chance for you to let the state know whether or not you find the advisory information useful.

I am writing to you again to remind you to complete and return the questionnaire. I sent the questionnaire to a small sample of licensed anglers. To be accurate, it is essential that each person in the sample return their questionnaire. The questionnaire should be filled out be the person it is addressed to even if another person in your household fishes more often.

Your participation in the survey is completely voluntary. You indicate your voluntary agreement to participate by completing and returning the questionnaire. Your responses will be kept completely confidential.

In case your questionnaire has been lost or misplaced, a replacement is included with this letter.

Thank you for your cooperation.

Sincerely,

Douglas J. Krieger
Project Director

Cover Letter for Second Follow-up

March 30, 1993

John Angler
123 Whitefish Dr.
Grayling, MI 99999

Dear Mr. Angler,

I am writing to you about my study of Michigan's public health advisories regarding chemical residues in sport fish. I have not yet received a reply to the questionnaire I sent you.

Your response is very important. Past experience suggests that the opinions of those who do not return questionnaires are different from the opinions of people who do. For the study to be accurate, it is essential that I hear from you.

The results of the survey will be used to make choices about the future of the advisory program. State agencies are interested in insuring that the advisories meet the needs of anglers like yourself. The more accurately the survey represents the opinions of Michigan's anglers, the more useful it will be in making decisions consistent with angler's preferences.

I am sending this copy of the questionnaire by certified mail to insure delivery. In case my previous surveys did not reach you, I have enclosed a replacement copy of the questionnaire. I would ask that you complete and return it as soon as possible.

Your participation in the survey is completely voluntary. You indicate your voluntary agreement to participate by completing and returning the questionnaire. Your responses will be kept completely confidential.

Your contribution to the success of this study is greatly appreciated.

Sincerely,

Douglas J. Krieger
Project Director

Table A.1 - Factorial Design for Survey Variables

Survey Version	Number of Sites Tested (*sites*)	Full Disclosure? (*safesites*)	Bid (*bid*)	Survey Version	Number of Sites Tested (*sites*)	Full Disclosure? (*safesites*)	Bid (*bid*)
1	110	Yes	.40	31	110	No	.40
2	110	Yes	.95	32	110	No	.95
3	110	Yes	1.45	33	110	No	1.45
4	110	Yes	1.90	34	110	No	1.90
5	110	Yes	2.85	35	110	No	2.85
6	110	Yes	4.10	36	110	No	4.10
7	110	Yes	5.55	37	110	No	5.55
8	110	Yes	8.75	38	110	No	8.75
9	110	Yes	14.50	39	110	No	14.50
10	110	Yes	41.00	40	110	No	41.00
11	620	Yes	.40	41	620	No	.40
12	620	Yes	.95	42	620	No	.95
13	620	Yes	1.45	43	620	No	1.45
14	620	Yes	1.90	44	620	No	1.90
15	620	Yes	2.85	45	620	No	2.85
16	620	Yes	4.10	46	620	No	4.10
17	620	Yes	5.55	47	620	No	5.55
18	620	Yes	8.75	48	620	No	8.75
19	620	Yes	14.50	49	620	No	14.50
20	620	Yes	41.00	50	620	No	41.00
21	1240	Yes	.40	51	1240	No	.40
22	1240	Yes	.95	52	1240	No	.95
23	1240	Yes	1.45	53	1240	No	1.45
24	1240	Yes	1.90	54	1240	No	1.90
25	1240	Yes	2.85	55	1240	No	2.85
26	1240	Yes	4.10	56	1240	No	4.10
27	1240	Yes	5.55	57	1240	No	5.55
28	1240	Yes	8.75	58	1240	No	8.75
29	1240	Yes	14.50	59	1240	No	14.50
30	1240	Yes	41.00	60	1240	No	41.00

Appendix B

Specification Tests and Alternative Models

This appendix outlines specification tests for the empirical WTP model.

Specification Tests

Table B.1 lists regression results for three models -- an unrestricted model, a model containing non-program variables only in level form, and a model that excludes both interaction and level forms of the non-program variables. These models facilitate likelihood ratio tests of two hypotheses.

1. H_o -- Non-program variables do not affect marginal WTP for advisory information.

2. H_o -- Level forms of the non-program variables have no significant effect on estimated WTP.

The tests fail to reject the first hypothesis but reject the second. Therefore, the final model includes non-program variables in level form but not in interaction with program variables.

Marginal Effect of Non-Program Variables

The values of the log likelihood function for the unrestricted model and the model without interaction terms provide a test of hypothesis one. The likelihood ratio statistic for the null hypothesis that non-program interaction terms can be jointly restricted to zero is 2.16. The χ^2 critical value for 6 degrees of freedom and $\alpha=.01$ is 16.81. Therefore, the likelihood ratio test fails to reject the restrictions. Thus, the final model does not include interaction terms of the non-program variables.

Test for Exclusion of Non-Program Level Forms

In addition to the restrictions of the final model, the model without non-program variables also omits the level forms of non-program variables. The likelihood ratio statistic for this hypothesis (73.94) is well above the χ^2 critical value of 16.81 for 6 degrees of freedom and $\alpha=.01$. Therefore, the likelihood ratio test rejects the hypothesis and the model that retains level forms of the non-program variables is preferred.

Significance of Behavioral Change Variables

Table B.2 lists regression results for a model that, compared with the final model of Table B.1, jointly restricts the coefficients of the behavioral change variables to equal zero. The likelihood ratio statistic for the null hypothesis that the behavioral change variables are not jointly significant is 37.82. The χ^2 critical value for 4 degrees of freedom and $\alpha=.01$ is 13.28. Therefore, the test rejects the hypothesis -- the behavioral change variables have a significant joint effect on estimated WTP.

Table B.1 - Model Specification

Variable	Unrestricted Model	Final Model	Without Non-Program Variables
CONSTANT	.1668 (2.249)	.3457 (2.202)	-.1987 (2.414)
FSITES	.0046* (.0028)	.0045* (.0027)	.0042 (.0028)
PSITES	.0047* (.0029)	.0045 (.0028)	.0045 (.0031)
FULLD	5.844* (3.221)	5.643* (3.151)	6.822** (2.032)
FATAL	7.521** (3.598)	7.245*** (2.120)	
BCHANGE	2.568 (3.183)	1.702 (1.847)	
NOREAD	-4.216 (4.625)	-2.658 (2.777)	
NCHANGE	-3.731 (4.351)	-.3652 (2.645)	
USELIST	16.430*** (5.261)	15.612*** (2.979)	
SCIENCE	.3668 (3.249)	2.688 (1.901)	
COLLEGE	5.553* (3.267)	6.836*** (1.866)	
FATAL *x (fsites + psites)*	-.0006 (.0044)		
BCHANGE *x (fsites + psites)*	-.0012 (.0040)		
NOREAD *x (fsites + psites)*	.0028 (.0060)		
USELIST *x (fsites + psites)*	-.0009 (.0063)		
SCIENCE *x (fsites + psites)*	.0038 (.0043)		
COLLEGE *x (fsites + psites)*	.0020 (.0040)		
Log-Likelihood	-428.67	-429.75	-466.72
% Correct Predictions	72.2%	71.9%	66.9%

* = significant for $\alpha = .1$
** = significant for $\alpha = .05$
*** = significant for $\alpha = .01$

Regression results based on 758 observations for which complete data exists for all variables.

Numbers in parentheses are standard errors.

Table B.2 - Exclusion of Behavioral Change Variables

Variable	Coefficient Estimates
CONSTANT	.1473 (2.260)
FSITES	.0042 (.0027)
PSITES	.0047 (.0029)
FULLD	6.010* (3.181)
FATAL	9.158*** (2.183)
SCIENCE	3.070 (1.931)
COLLEGE	7.981*** (1.882)
Log-Likelihood	-448.66
% Correct Predictions	68.6%

* = significant for α = .1
** = significant for α = .05
*** = significant for α = .01

Regression results based on 758 observations.

All non-program variables enter as deviations from mean values.

Numbers in parentheses are standard errors.

Table B.3 - Probit Model Estimates

Variable	Linear Model	Quadratic Model	Square Root Model
CONSTANT	$.1916E^{-1}$ (.1240)		
FSITES	$.2523E^{-3}$* ($.1507E^{-3}$)	$.1601E^{-2}$*** ($.4190E^{-3}$)	$-.5725E^{-3}$ ($.4108E^{-3}$)
$FSITES^2$		$-.9202E^{-6}$*** ($.3512E^{-6}$)	
$FSITES^{.5}$			$.3742E^{-1}$*** ($.1344E^{-1}$)
PSITES	$.2477E^{-3}$ ($.1580E^{-3}$)		
COST	$-.5543E^{-1}$*** ($.6168E^{-2}$)	$-.5341E^{-1}$*** ($.7784E^{-2}$)	$-.5539E^{-1}$*** ($.8041E^{-2}$)
FULLD	.3128* .1723		
FATAL	.4016*** (.1194)	.4614*** (.1620)	.4446*** (.1622)
BCHANGE	$.9435E^{-1}$ (.1025)	$.5811E^{-1}$ .1487	$.4915E^{-1}$ (.1485)
NOREAD	-.1473 (.1507)	-.1714 (.2108)	-.1897 (.2106)
NCHANGE	$-.2024E^{-1}$ (.1455)		
USELIST	.8654*** (.1518)	.8733*** (.1564)	.8723*** (.1559)
SCIENCE	.1490 (.1047)	.1371 (.1495)	.1315 (.1497)
COLLEGE	.3789*** (.1017)	.4275*** (.1424)	.4370*** (.1426)
Log-Likelihood	-429.75	-214.40	-213.96
% Correct Predictions	71.9%	74.0%	74.3%

* = significant for $\alpha = .1$
** = significant for $\alpha = .05$
*** = significant for $\alpha = .01$

Regression results based on 758 observations for which complete data exists for all variables.

Numbers in parentheses are standard errors.

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