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Title: THE EFFECTS OF ENVIRONMENTAL CONTAMINANTS ON THE VALUE OF OUTDOOR RECREATION: MERCURY AND PHEASANT HUNTING IN OREGON

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Herbert H. Stoevener

An evaluation of the benefits and costs of environmental contamination must include the effects of that contamination on all members of society. The behavior of individuals can be altered either involuntarily, through the actions of a biological relationship, or voluntarily, as they attempt to avoid exposure to such effects.

The objectives of this thesis include the expansion of the methodology for evaluating recreational benefits to include the effects of environmental contaminants on recreationists' behavior. To the extent that behavioral changes are associated with voluntary changes in human actions, information will always be involved in initiation of behavioral changes. Thus the flow of information concerning the level of environmental contamination has been added to the

recreationist's behavioral choice model as an additional quality variable.

Mercury concentrations in excess of the U. S. Food and Drug Administration's maximum allowable limit of 0.5 parts per million have been accumulated in some of Oregon's pheasants as the result of feeding on seed and greenery treated with mercury chemicals. The effects of mercury use on the behavior of pheasant hunters were isolated using the expanded recreationist's behavioral choice model. Information describing the level of mercury contamination of the pheasants and the possible health hazards to individuals consuming mercury was available to most individuals through the mass media.

An economic measure of the effects of mercury contamination on the pheasant hunters of Oregon can be estimated by examining the change in the economic value of pheasant hunting which accompanies the change in hunter behavior. Only when the information concerning the mercury contamination misleads the hunters, will the value of their altered behavior be an inappropriate measure of this externality of mercury use.

Multiple regression of aggregate time series data was used to estimate the effects of information concerning mercury contamination on the demand for pheasant hunting days per hunter per season and the number of hunters per season. A significant reduction in the number of pheasant hunters was attributed to the knowledge of mercury contamination in the pheasants. This amounted to a loss of 17,062 hunters during Oregon's 1971 pheasant hunting season. The demand for pheasant hunting days of those hunters who remained in the hunter population was found to be unaffected by the knowledge of mercury contamination or by associated changes in hunter numbers and success.

To estimate the economic value of the effects of mercury contamination on the pheasant hunters of Oregon, the demand for hunting in each of three study areas was estimated. These areas, Malheur County, Umatilla County, and the Willamette Valley, corresponded to those areas where pheasants had been tested for mercury concentrations. Data for empirical estimation of the demand functions were obtained from the Oregon State Game Commission's 1971 Hunter Survey. As such, measurements on the economic variables of expenditures and income were not available. Thus, various assumptions were required to develop the demand models. The final estimates of economic loss to society rely heavily on these assumptions.

Two methods of estimating the demand equations were used. The trade-off method used one-way measured distance from the hunter's residence to the hunting area as a composite variable representing both the effects of transfer costs and travel time costs on the demand for pheasant hunting. The coefficient of this composite variable was then divided into the separate effects of transfer costs and travel time costs on the basis of an assumed trade-off function. The trade-off function was developed from the demand curve for big game hunting in Oregon as estimated by Nawas (1972).

The traditional transfer cost method of estimating demand was also used. The resulting estimates serve as a check on those estimates developed through use of the trade-off method.

A weighted average consumer's surplus per hunter per season was then computed where the weights were proportional to the actual decreases in hunter numbers in each of the three study areas. This weighted average consumer's surplus represents the loss of net economic value per hunter for those hunters who discontinued hunting in an effort to avoid the effects of mercury contamination.

Using pheasant hunting days per hunter as the dependent variable, the estimate generated through use of the trade-off method serves as an upper bound on the average consumer's surplus per hunter. The upper bound had a value of $278.31 per hunter per season. The estimate generated using the transfer cost method serves as the lower bound and equals $222.57 per hunter per season. Thus the net loss in the value of Oregon pheasant hunting which can be attributed to the use of mercury fungicides in Oregon has an upper bound of 4.7 million dollars and a lower bound of 3.8 million dollars.

The loss of 17,062 hunters would imply a decrease in revenues to those merchants who provide goods and services to Oregon pheasant hunters. This loss was found to be in the range of $160, 894.66 to $281, 181.76. This estimate does not include the multiplier effect or any investment expenditure for durable equipment such as shotguns, campers, special clothing or other equipment.

To the extent that hunters substituted other goods and activities for their pheasant hunting experience, these funds would be spent and could result in either increased or decreased revenues within the state depending on the relative multiplier effects.

The Effects of Environmental Contaminants on the Value of Outdoor Recreation: Mercury and Pheasant Hunting in Oregon

by

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I. INTRODUCTION

Public concern over environmental contamination has been increasing continually over the last decade. Rachel Carson's book, Silent Spring (1962), focused public attention on the use of persistent pesticides and the environmental effects which were suspected to accompany their use. In the fall of 1969, United States officials recognized mercury as an environmental pollutant of international importance. Both federal and state agencies began investigations into the sources and effects of mercury pollution. This thesis will investigate a non-market cost of mercury contamination: its effect on the value of outdoor recreation.

Case Study - The Use of Mercury Fungicides in Oregon

Mercury concentrations in excess of natural background levels have been accumulated in Oregon pheasants as the result of feeding on seed or greenery treated with mercury chemicals (Buhler, Clays, Rayner, 1971). Mercury once ingested by a pheasant will be present in its muscles, and physiological effects in the bird may result (Borg *et al.*, 1969). Food chain effects also result. If other wildlife or humans feed on mercury contaminated pheasants they too may suffer sublethal chronic effects from the mercury ingested.

The primary use of pheasants is as a game bird for hunting and observation. Thus, the primary externalities of mercury fungicide use as it affects the pheasants of Oregon would be borne by the pheasant hunter population.

In the fall of 1970, just prior to the opening of pheasant hunting season, Oregon State's Game Commission, Board of Health, Department of Agriculture, Environmental Quality Commission, Fish Commission, and the Environmental Health Sciences Center of Oregon State University issued a joint public statement on potential hazards of mercury in Oregon's environment (Oregon State Game Commission *et al.*, 1970). This statement pointed out the toxic nature of mercury, the characteristic symptoms of chronic mercury poisoning, and described the recent cases of people being poisoned by ingestion of foods with high concentrations of organic mercury.[1/] The Oregon Game Commission had begun testing the pheasants of the state to determine if potentially harmful levels of mercury were present. Eight of the 94 pheasants analyzed in April and August of 1970 exceeded the Food and Drug Administration's maximum

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[1/] For the world background of the mercury pollution problem see Appendix A.

allowable limit for mercury of 0.5 parts per million. Further tests were to be taken during the pheasant hunting season. Closure of the pheasant season because of the presence of mercury in the birds was not contemplated. It was considered unlikely that the small bag limit of three birds, and limited success of pheasant hunters would create an opportunity for a person to consume a damaging dose of mercury. It was acknowledged though that the detected levels of mercury were cause for concern (Oregon State Game Commission *et al.*, 1970).

Idaho's Fish and Game Department had also run tests on their pheasants, and in September 1970 announced that over one-fourth of the 300 birds tested contained over 1 part per million mercury. The Department recommended that (1) persons not eat more than one meal per week of pheasant, (2) pregnant women avoid food with a known or suspected mercury content, and (3) the backs and all giblets of pheasant be discarded (Idaho Game Commission, 1970). The majority of the mercury present in the pheasant tissue in both Oregon and Idaho was in the form of methylmercury, a form which is extremely toxic to man.

These announcements of the presence and dangers of mercury in pheasants came on the heels of 25 or more articles, which appeared in national periodicals from May 1969 to September 1970, proclaiming mercury as a new environmental threat and telling of the harmful effects it could inflict.

Final results of the Oregon study were available in February 1971 (Buhler, Clays, Rayner, 1971). Sixty-nine percent of the birds examined from Malheur County, Umatilla County, and the Willamette Valley contained concentrations of mercury in their breast muscle in excess of background levels. Considerably higher liver/muscle concentration ratios were exhibited by birds collected from Malheur County during April and October, from Umatilla County during October, and from the Willamette Valley during October and especially December. This suggests that these birds had recently been exposed to additional amounts of mercury. These periods of highest liver-muscle ratios were in good agreement with the planting dates for the mercury treated seed crop grown in the three areas. This finding was in agreement with research done in Sweden (Borg et al., 1969), Canada (Fimreite, Fyte, and Keith, 1969), and other sections of the United States (Lambou, 1972) that the primary source of mercury for the pheasants is mercury treated seed.

The period of highest liver/muscle ratios also coincided with the Oregon pheasant hunting season. The season usually begins the third weekend of October, and a large portion of the birds are bagged opening weekend.

The facts of possible harmful mercury levels in pheasants were presented to the public. How has this information affected the behavior of Oregon's pheasant hunters? Has the net economic value of pheasant hunting in Oregon been affected by the mercury warnings?

The answers to these questions would be a valuable input into the decision process for determination of a mercury fungicide use policy.

This thesis is primarily concerned with developing a means of evaluation which will allow for the systematic consideration of chronic and suspected environmental effects of persistent pesticide use in the determination of pesticide use policy. Edwards (1969), in an effort to aid public decision-makers in the choice of pesticide use policy, developed a benefit-cost model which incorporated a value for the externalities generated by the use of persistent pesticides. However, in estimating the externalities generated by pesticide use in Dade County, Florida, only acute external effects were valued. Edwards argues that without an established relationship between chemical use and environmental effects, information on the suspected effects of chemicals cannot be introduced into the benefit-cost decision model.

Castle and Stoevener (1970) argue that at least one of three technical conditions must exist to provide a necessary condition for public intervention into the market allocations of resources. These conditions are the existences of technological interdependencies, indivisibilities, or public goods. In respect to the use of persistent pesticides, technological interdependencies are suspected.

The public decision-maker is faced with positive net private benefits arising from the use of persistent pesticides, non-private costs to society resulting from the acute effects of the pesticides, and suspected chronic effects to both man and wildlife which may result from the use of the pesticides. These suspected effects, if correct, would represent increased public costs. If a decision to restrict the use of the pesticide is made when private net benefits exceed the value of proven externalities, it can only be justified on the basis of a social value judgment, Specifically, the value judgment is that 1) the use of the pesticide will automatically and inevitably affect the consumption or production of individuals not using the pesticides, 2) that the value of these effects will be greater than the net private benefit derived from the pesticide use, i.e., a portion of the suspected effects must in fact result; and 3) that public intervention will result in social benefits greater than social costs.

An important aspect of the evaluation of a pesticide use policy is concerned with the effects of this policy on those individuals who are not directly involved in the decision to use the pesticide. It is these individuals who bear the external costs of pesticide use. Their behavior can be altered either involuntarily, through the actions of a biological relationship as in the case of acute or chronic pesticide poisoning, or voluntarily, as they attempt to avoid exposure to such effects. Thus, the evaluation of externalities involves the valuation of behavioral changes and the costs associated with those changes.

It is the objective of this thesis to isolate the effects of mercury use on the behavior of pheasant hunters. To the extent that behavioral changes are associated with voluntary changes in human actions, information will always be involved in initiation of behavioral changes. Information on the suspected effects of mercury use has been available to most individuals through the mass media. Thus, behavioral changes are expected as hunters react to this information.

An economic value of the effects of mercury on the pheasant hunters of Oregon can be estimated by examining the change in the economic value of pheasant hunting which accompanies the change in pheasant hunter's behavior. Only when the information about mercury misleads the hunters, will the value of their altered behavior be an inappropriate measure of this externality of mercury use.

Objectives

1) Expand the methodology for evaluating recreational benefits to include the effects of environmental changes on recreationists' behavior.

2) Empirically isolate the effects which certain information flows through the mass media concerning mercury contamination of pheasants have on the behavior of Oregon pheasant hunters.

3) Estimate the change in the net economic benefits derived from pheasant hunting which accompanied the perceived environmental changes.

Outline of the Thesis

Chapter II contains a brief development of the consumer's behavioral choice model for recreation. This model is then expanded to include an index of information on the level of environmental contamination as an additional quality characteristic of the recreation experience. The expanded model will then be applied to pheasant hunters to determine the impact of information concerning the level of mercury contamination on the recreational value of pheasant hunting.

Chapter III includes the specification of the statistical models to be used in estimation of the demand for Oregon pheasant hunting, as well as a discussion of the data to be used as empirical measures of each variable. The estimation of the time series models for the number of pheasant hunting days per hunter per season and the number of pheasant hunters will be conducted in Chapter IV.

Chapter V presents estimates of the cross-sectional demand equations for pheasant hunting and the estimates of the average consumer's surplus for hunters in each hunting area.

An estimate of the net loss in the value of Oregon pheasant hunting which can be attributed to the mercury contamination of Oregon pheasants is presented in Chapter VI. Also discussed in Chapter VI are the limitations of the various estimation methods and the conclusions and implications of the study.

II. THE CONSUMER'S BEHAVIORAL CHOICE MODEL: AN EXPANSION TO INCLUDE THE EFFECTS OF ENVIRONMENTAL CONTAMINANTS

The works of Hotelling (1949), Clawson (1959), and Brown, Singh, and Castle (1964) in valuing the benefits derived from recreation resources have developed the consumer's behavioral choice model for outdoor recreation to include price (P), income (Y), and distance (D) as explanatory variables. The importance of quality of the recreation experience in the determination of the value of a recreation resource was first developed by Stevens (1966).

In the evaluation of the effects of water pollution on the direct benefits derived from fishing in Yaquina Bay, Stevens (1966) used fishing success as a measure of the quality of the recreational experience. This specification assumed that anglers would consider changes in success caused by pollution in the same manner as success changes caused by other factors. The assumption requires that the effects of pollution are non-injurious to humans and do not greatly affect the edibility or performance capability of the fish. When examining the effects of persistent pesticides in general and mercury specifically these basic assumptions do not hold. In fact, it is the suspected harmful effect to both humans and wildlife which causes the use of persistent pesticides to be questioned.

Thus another "quality" variable must be developed. In the case of pheasant hunting, it is hypothesized that the quality of the recreational experience, as it would be affected by the use of mercury fungicides, will vary with the hunter's knowledge of the effects of mercury. That is, the characteristics of the pheasant hunting day will be altered with the knowledge that the pheasants to be bagged may contain elevated mercury levels potentially harmful to the hunter. To test this hypothesis it is assumed that the hunter's knowledge can be represented by the level of information available to the hunter through the mass media on the presence and dangers of mercury in the pheasants.

The hypothesis draws support from the reaction of pheasant hunters in Montana and fishermen in Michigan. After mercury was found in the upland game birds of Alberta in the fall of 1969, various state and federal agencies became involved in the search for environmental pollution by mercury. The following is an excerpt from an article which appeared in The Oregonian, August 31, 1970.

> Across the border, Montana officials obtained some hasty samplings and shipped them to a Michigan state lab where similar residues were found. State game officials mindful of the political consequences of closing down hunting seasons that bring in millions of "outside" money each fall, merely issued a warning about eating the meat.[2/]
>
> To their dismay, just the warning was enough to cut

[2/] The news release of the Montana State Department of Health Division of Environmental Sanitation appears as Appendix B.

state revenues by 25 percent.

Following the experience of Alberta and Michigan, the Michigan and adjacent Canadian health agencies examined not only pheasants in that area but also local fish life. Early in 1970, when dangerous levels of mercury contamination were found in various species of fish in Lake St. Clair between Huron and Erie, and in the St. Clair River, all commercial fish were seized and all fishing, sport and commercial, was banned by Canadian and Michigan authorities.

This created a controversy, mainly from professional guides and service industries that depended upon revenues from sportsmen and tourists, and from the commercial fishing interests.

The governor subsequently lifted the total ban to permit a catch-and-release fishery starting Memorial Day. Despite this, business remained poor. There, as in Montana, it was proved again that people go hunting and fishing, not only for sport, but also to eat what they catch.

The Consumer's Choice Model

The rational consumer attempts to maximize his utility, U, by the consumption of various amounts of goods and services say Q_1 and Q_2.

$$(1) \quad U = U(Q_1, Q_2)$$

subject to his fixed budget constraint

$$(2) \quad y = p_1q_1 + p_2q_2$$

where y represents the consumer's fixed income for purchasing the two commodities, the p_i represents the unit price of the i^{th} commodity.

The consumer will allocate his budget so that the ratio of marginal utilities from all goods and activities just equals the ratio of their respective prices. Thus the optimum combination of goods and activities depends not only on their relative prices, but also on their relative marginal utilities. If, for any reason, the characteristics of a good should change so that the relative marginal utility of any two goods would be affected, a new optimum combination of the goods and activities would result (Lancaster, 1966).

A unique set of indifference curves can be constructed from the utility function of a representative pheasant hunter. It is assumed that the representative pheasant hunter's utility function is a monotonic reflection of the preferences of the pheasant hunter population, sloping downward to the right and exhibiting diminishing marginal rates of substitution throughout its range. If for any reason the preferences of any individual member of the pheasant hunting population change, this shift would be reflected in a change in the shape of the indifference curves of the representative pheasant hunter. The indifference map is depicted in Figure 1.

Q_1 is the number of days of pheasant hunting per season taken by the representative pheasant hunter, and Q_2 represents units of all non-pheasant hunting goods and activities. U_0 and U_1 depict the levels of utility derived from various combinations of Q_1 and Q_2. With relative prices P_1 and P_2, income Y_0, level of expected success

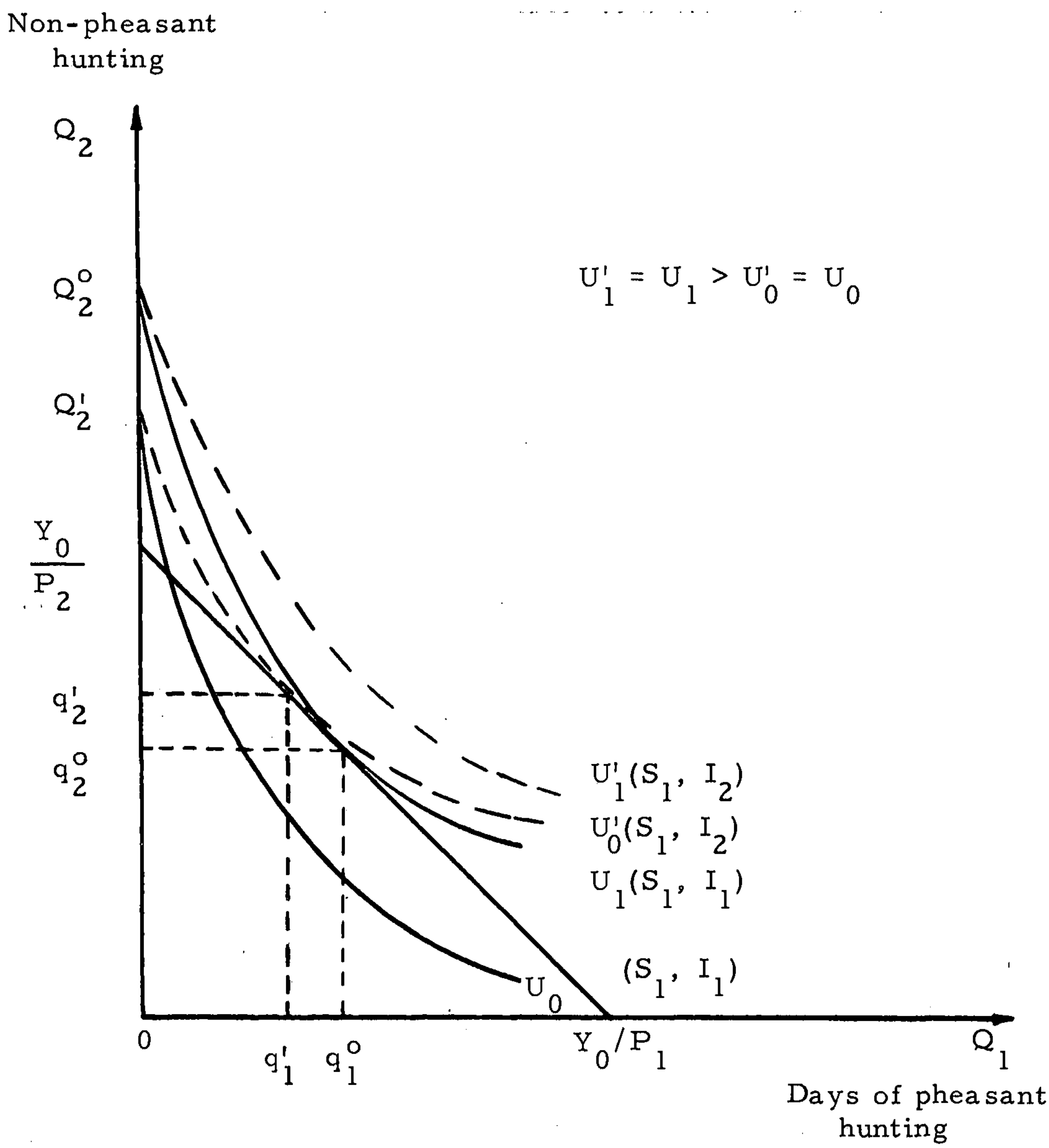

Figure 1. The optimal combinations of pheasant hunting days and non-pheasant hunting that a representative consumer would take if faced with varying levels of information on the presence of mercury in pheasants, for a constant level of success (S_1), given prices P_1 and P_2, and fixed income Y_0.

S_1, and level of information on mercury I_1, q_1^o days of pheasant hunting and q_2^o units of other goods and activities will be taken. This combination will be the utility maximizing combination and result in a level of utility of U_1.

If there is a change in the characteristics of Q_1, so that the consumer's preferences for it would change, the indifference curves will rotate about the y-axis intercepts.

To the extent that the edibility characteristics of the pheasant is an important quality characteristic of a pheasant hunter's experience, information concerning the presence of mercury in pheasants can be expected to affect the preferences of individuals for pheasant hunting days. Assuming that the marginal utility of pheasant hunting will decrease with an increase in the level of information on the presence and dangers of mercury in the pheasants from I_1 to I_2, the indifference map will rotate upward to the right. Thus the marginal rates of substitution will favor non-pheasant hunting goods and activities given constant relative prices and income. The representative pheasant hunter will now prefer combination ($q_1' < q_1^o$, $q_2' > q_2^o$) over any other attainable combination. He will attain a level of utility $U_0' = U_0 < U_1$.

The rotated indifference map depicted by U_0' and U_1 in Figure 1 is the representative indifference map for those hunters who remain in the pheasant hunter population with the knowledge that mercury may be present in the birds. The preferences of individuals who drop out of the pheasant hunter population in an effort to avoid exposure to mercury are presented in Figure 2. Under the initial conditions these hunters would also be consuming q_1^o days of pheasant hunting and q_2^o units of other goods and activities. However, as information on the presence and dangers of mercury in pheasant become available the indifference map will rotate upward to the right so that the indifference curve which intersects the Q_2 axis at Y_0/P_2 is entirely above and to the right of the price line, indifference curve U'_{-1} in Figure 2. For these hunters the point of maximum utility will be at ($q_1 = 0$, $q_2 = q_2'$) and no pheasant hunting days will be demanded at price p_1.

In general, fewer pheasant hunting days will be demanded by pheasant hunters as their level of knowledge on the presence and dangers of mercury in pheasants increases, _ceteris paribus_. This phenomenon is due to the assumed decrease in the marginal utility of the pheasant hunting day as the information on the presence and dangers of mercury in the pheasant increases. Both the demand for pheasant hunting days per hunter and the number of pheasant hunters are hypothesized to decrease.

Estimation of Social Cost

The effect of mercury use on the value of pheasant hunting will

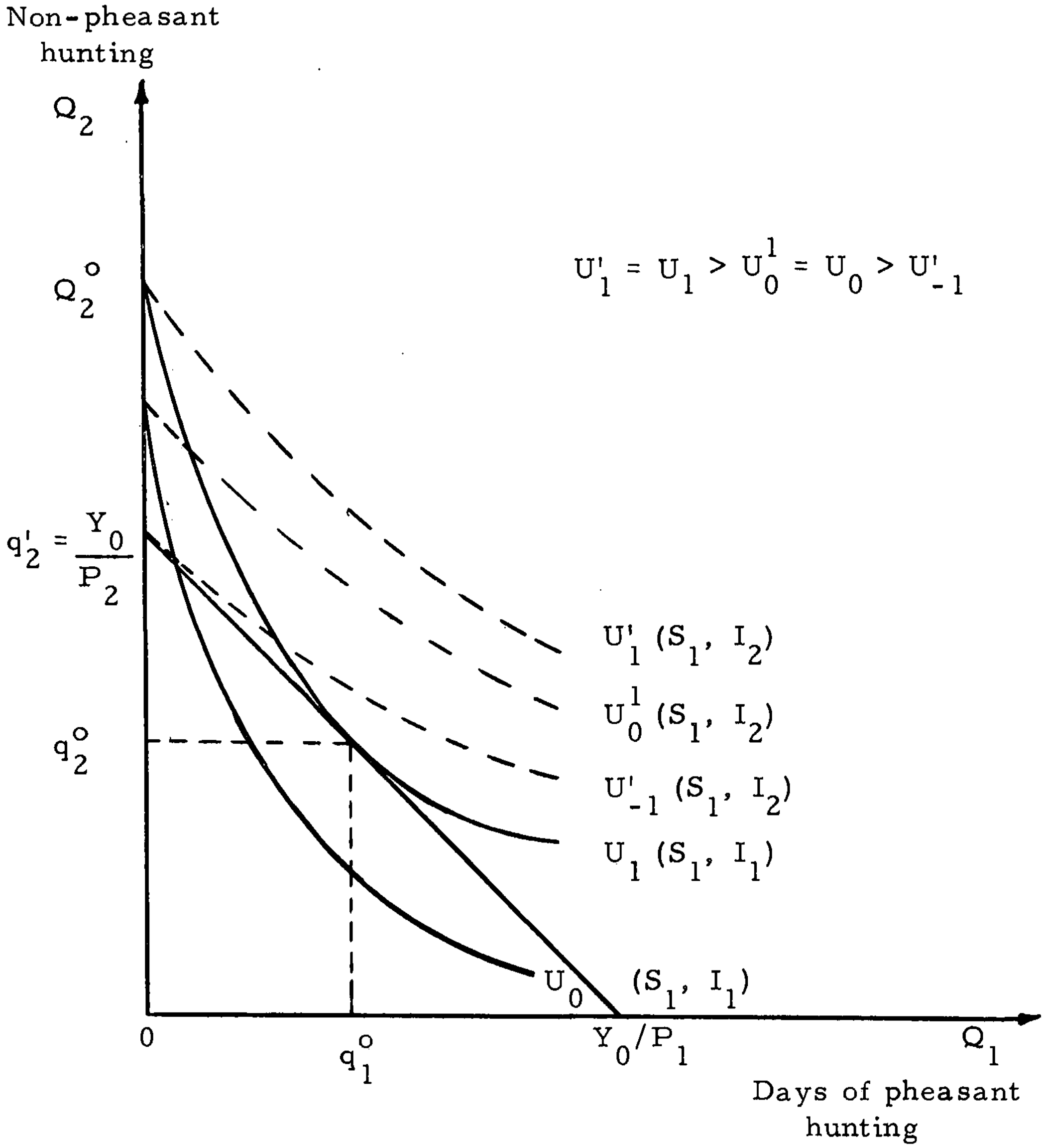

Figure 2. The optimal combinations of pheasant hunting days and non-pheasant hunting for those individuals who drop out of the pheasant hunter population as the result of the knowledge of mercury in pheasants, for a constant level of success (S_1), given prices P_1 and P_2, and fixed income Y_0.

be determined by estimating the change in the social benefits[3/] derived from pheasant hunting as a result of hunters obtaining information of the presence and dangers of mercury in the pheasant population. Various methods have been used for estimating outdoor recreation benefits. The model to be used in this analysis defines the net benefits derived from pheasant hunting as the consumers' surplus resulting from the consumption of pheasant hunting days. Consumer's surplus is defined in the Marshallian sense as the excess of the total expenditures which a consumer would be willing to pay for an item rather than go without it, over the amount which he actually does pay (Marshall, 1920). An economic measure of this surplus is the triangle like area below the demand curve and above the price line[4/]. To obtain an estimate of the consumer's surplus

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[3/] Social benefits are defined as the total of all benefits and costs accruing to any member of society as the result of a given action or decision, i.e., both the benefits and costs upon which a decision was made and the external benefits and costs which accompany the decision.

[4/] For a very complete development of the concept of consumer's surplus and its use in economic analysis, see Currie, Murphy, and Schmitz (1971).

In order to use the area under the demand curve as an estimate of consumer's surplus the marginal utility of money must be constant. If the marginal utility of money is not constant, adjustments would be required using the income compensating variation (Hicks, 1946).

Assuming constant marginal utility of money the consumer's surplus obtained from pheasant hunting prior to the knowledge of of pheasant hunters it is necessary to estimate both the demand and supply schedules for pheasant hunting in Oregon.

The supply curve is hypothesized to be perfectly elastic over the range of zero days to Q^*, the legal number of hunting days per season, and perfectly inelastic at Q^* [5/].

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mercury can be equated to the compensating variation in income of $(Q_2^o - Y_0/P_2)$ in Figures 1 and 2. With the knowledge of mercury and the rotation of the indifference curves, the new consumer's surplus for hunters remaining in the population will be represented by $Q'_2 - Y_0/P_2$ in Figure 1. No consumer's surplus would be present for individuals who discontinued hunting. The decrease in consumer's surplus for hunters who remain in the population will be equal to $Q_2^o - Q'_2$. Thus, $Q_2^o - Q'_2$ will equal the maximum amount of income the hunter would be willing to give up in order to be able to hunt uncontaminated pheasants, i.e., their loss of consumer's surplus.

For hunters who discontinued hunting entirely the value of $Q_2^o - Y_0/P_2$ will equal their loss in consumer's surplus.

While the income compensating variation is the theoretically correct measure, empirical estimation of it is difficult. Burns (1973) believes that under most circumstances the area under the demand curve and above the price line will result in the appropriate measure of consumer's surplus. See Burns (1973) for an evaluation of the various measures of consumer's surplus and the appropriateness of each measure in a given situation.

[5/] The assumption of a perfectly elastic supply curve implies that the regression of quantity on price constitutes a consistent estimator of the law of demand, if errors affecting supply and demand are mutually independent (Malinvaud, p. 509-10, 1966 ed.).

The supply for pheasant hunting days can be represented by

$$P_i = \alpha + b_1 D_i + e_i$$

The supply schedule facing hunter i is represented by SS, in Figure 3, intersecting the price axis at P_{xi} · P_{xi} is the transfer cost per day and includes all expenditures to and from the hunting site and all on-site expenditures on a per day per person basis. Travel costs to and from the site usually make up a considerable proportion of the transfer costs. Thus, as the distance from the hunter's residence to the hunting area increases, the transfer costs per hunting day increase and the elastic portion of the supply curve will shift upward. Likewise as distance decreases, transfer costs decrease and the elastic portions of SS shift downward. These shifts in the supply schedule will trace out a transfer cost-consumption relationship. If it is assumed that all individual hunters traveling the same distance face identical alternatives to the selected hunting

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where

P_i = price/day for the i^{th} individual

D_i = distance from the residence of the i^{th} hunter to the hunting area.

Distance is assumed to be an exogenous variable depending neither on price (P_i) or quantity (q_i). Thus the price per day of pheasant hunting is assumed fixed for any given hunter and would not react to variations in his demand.

If a perfectly inelastic supply schedule for pheasant hunting days were assumed, regressing quantity on price would result in an inconsistent estimator of demand elasticity (Malinvaud, 1966, p. 509-10). For a means of estimating a consistent lower absolute limit of the direct price elasticity in cases of perfectly inelastic supply functions see Houck (1965).

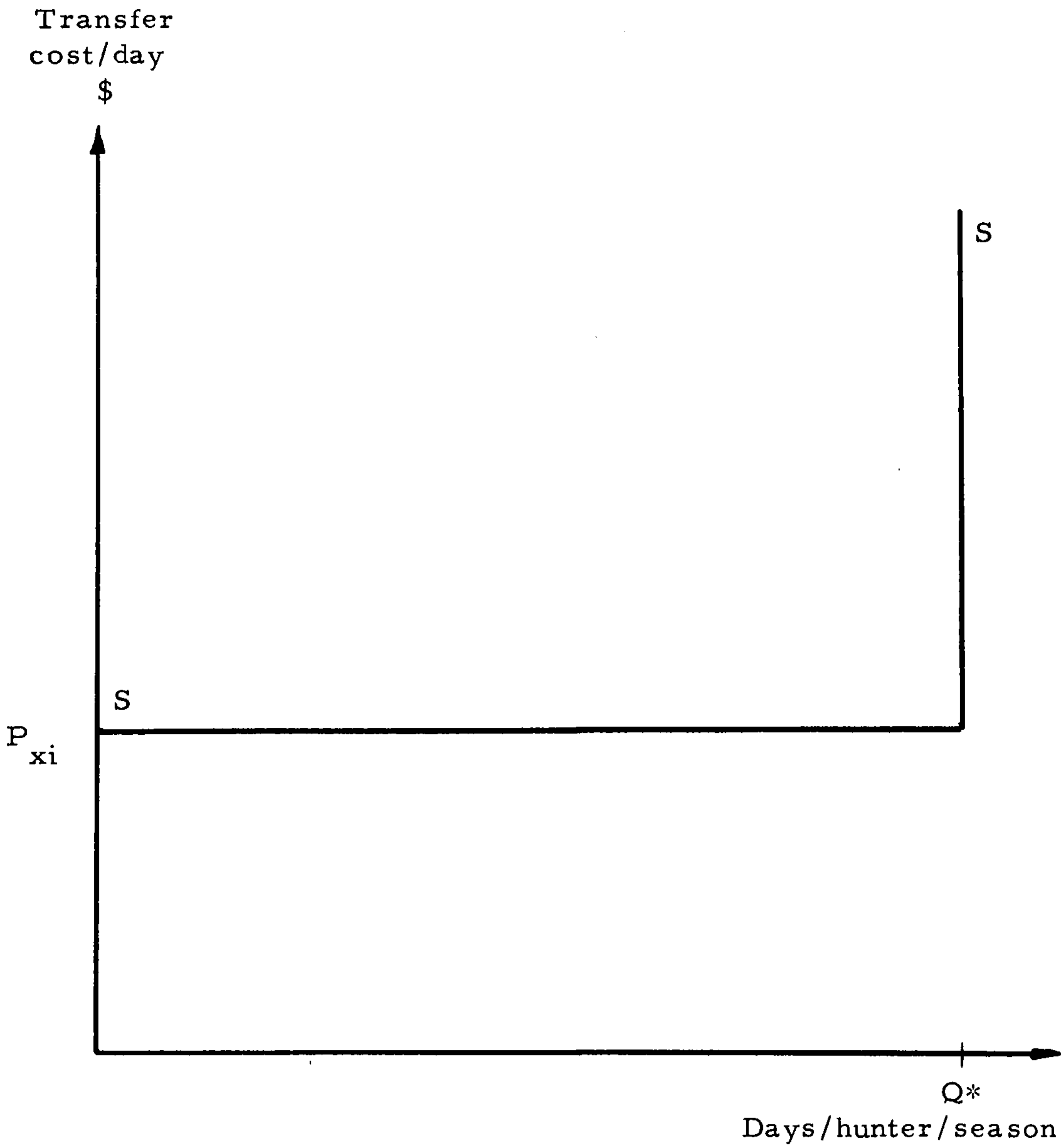

Figure 3. Hypothesized supply curve for pheasant hunting days facing individual pheasant hunter.

area and that all react identically to changes in transfer cost, then these costs taken with the corresponding quantities of days will reveal the underlying average demand schedule of pheasant hunters, AD on Figure 4, ceteris paribus. Let P_x be the average transfer cost incurred by pheasant hunters, and Q_x the average days of pheasant hunting consumed. Net benefits of pheasant hunting per hunter can now be estimated by the representative pheasant hunter's consumer surplus and will equal the area under the representative hunter's demand schedule and above the elastic supply schedule at $P_x = P_x$AB in Figure 4.

The social cost per hunter of mercury use as it affects pheasant hunting is defined as the net reduction in representative pheasant hunter's consumer surplus resulting from the information flows through the mass media on the presence and dangers of mercury in pheasants. The information flow would shift the demand curve from AD to CD', Figure 4. As the result, there would be a net social loss per hunter equal to CABE.[6/]

The total social cost of mercury use as it affects pheasant hunting will be equal to the decrease in aggregate consumer's

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[6/] The shift in the demand schedule need not be and probably will not be a parallel shift, i.e., both the slope and the intercept of the demand schedule would be expected to change given a change in the characteristics of the recreation experience. However, the new curve could not be to the right of the original one given a decrease in the marginal utility of the experience.

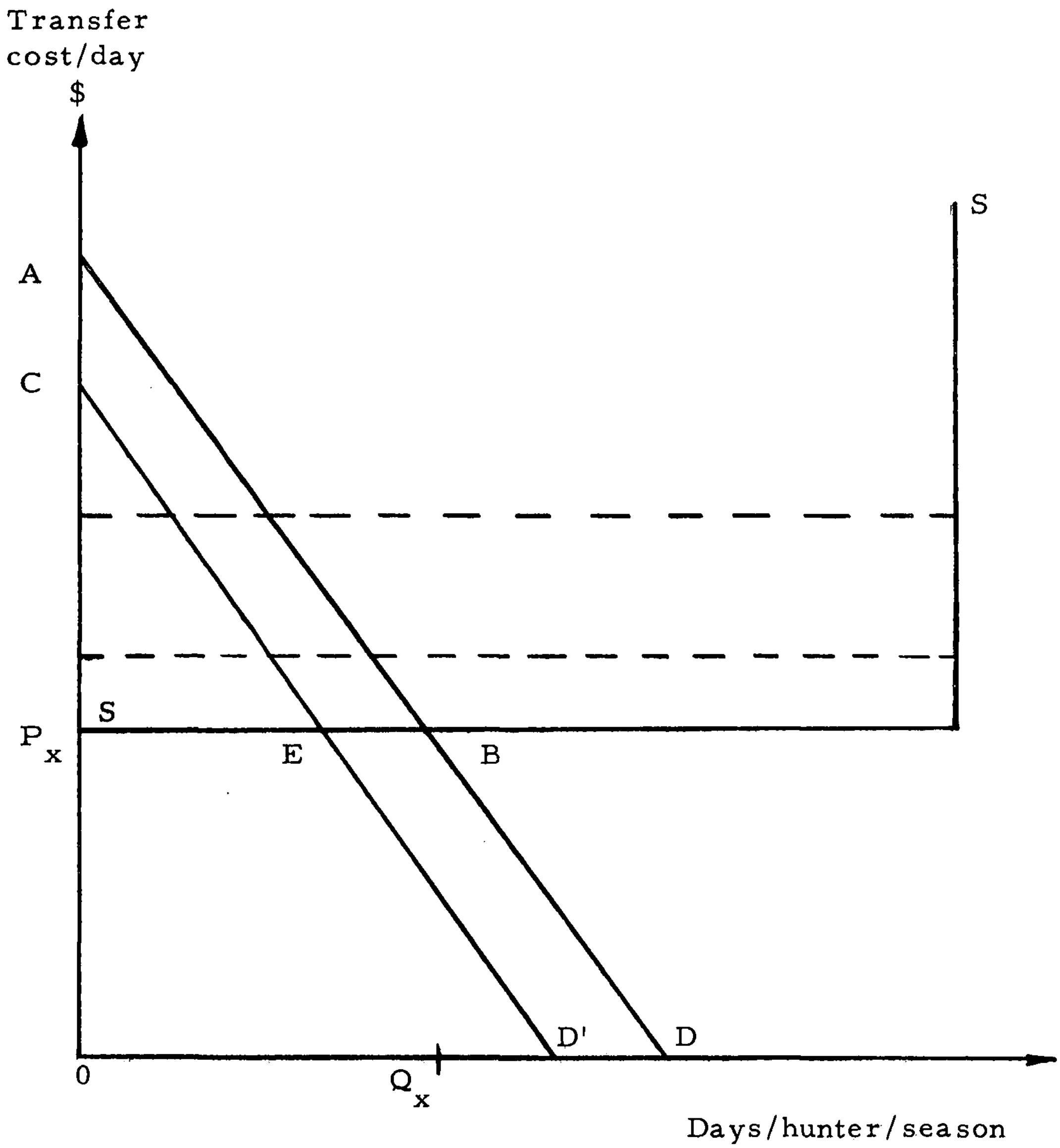

Figure 4. Representative pheasant hunters supply and demand schedules for pheasant hunting days.

surplus. Let H = the number of pheasant hunters in the absence of any information on the presence and dangers of mercury in the pheasant.

By horizontally summing the representative pheasant hunter's demand curve H times, the aggregate demand curve can be constructed. The aggregate demand curve in the absence of information is depicted by AR in Figure 5. The aggregate consumer's surplus is equal to the area of P_xAF or H times the area P_xAB. When information on mercury is introduced the number of pheasant hunters is hypothesized to decrease from H to H' in addition to a shift in the demand curve for those hunters who remain. The aggregate demand curve is now CT with total consumer's surplus equal to the area of P_xCG or H' times the area P_xCE. As a result, there would be a net loss to society, borne by the pheasant hunters equal to the reduction in the aggregate consumer's surplus of pheasant hunters. This loss is equal to the area (CAFG) or $[\ H\ (P_xAB)\ -\ H'\ (P_xCE)\ ]$.

The effect of information on the aggregate consumer's surplus is expected to result primarily from a decrease in the number of pheasant hunters. That is, those individuals who perceive a danger to their health from the presence of mercury in pheasant would be more likely to discontinue hunting entirely as opposed to decreasing the number of days they hunt.

For those hunters who continue to hunt pheasants, it is very

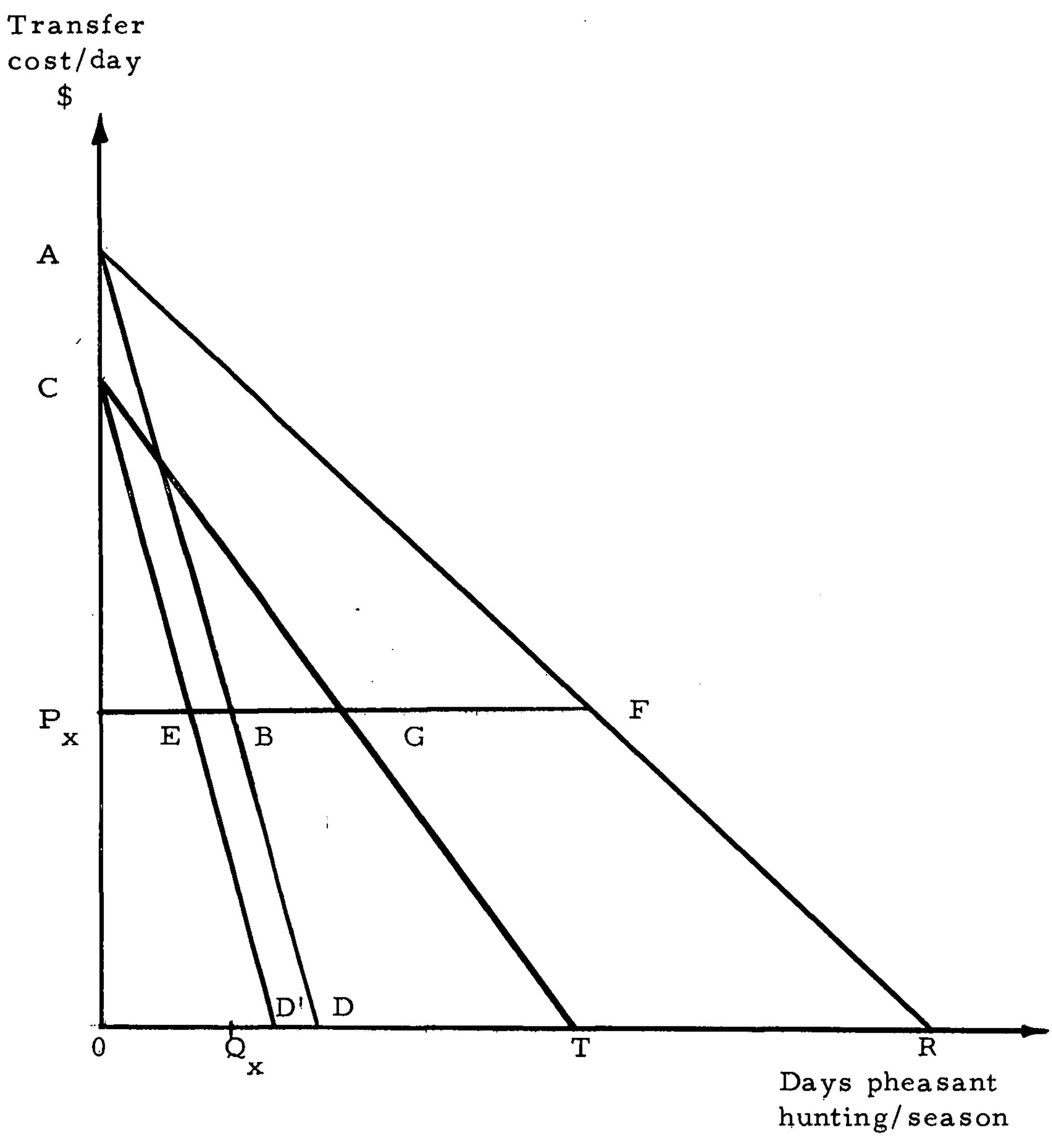

Figure 5. Aggregate demand schedules and consumers' surplus under alternative levels of information on mercury.

likely that only a portion will decrease their hunting. Thus, little change in the average pheasant hunting days per hunter per season would result.

For simplicity in the graphical presentation all characteristics of the recreational experience with the exception of the presence of environmental contamination have been held constant. There are, however, other characteristics of the experience which could vary in association with environmental contamination. It has been suggested that hunter numbers may decrease with increased contamination. Evidence is also building which links environmental contamination to decreases in the reproductive rate of various game species.[7/] Eventual decreases in success would be expected. Both hunter pressure and success are believed to be important characteristics of the pheasant hunting experience. The effects of changes in these associated characteristics on the demand for pheasant hunting will be discussed in Chapter III.

[7/] Spann *et al.*, reports that the reproductive success of pheasants maintained on mercury treated seed from the first through the second laying season was reduced both years, "ranging from 50 to 80 percent below the controls in 1969, and remaining 75 percent below controls in 1970" (1972, p. 330).

III. SPECIFICATION OF THE MODELS FOR THE DEMAND FOR PHEASANT HUNTING DAYS AND THE NUMBER OF HUNTERS RELATIONSHIP

An individual's demand for pheasant hunting days is hypothesized to be a function of the price per pheasant hunting day both in dollar costs and travel time costs, the prices of alternative commodities, his income, the length of the pheasant hunting season, and his utility function. Earlier it was suggested that information on the presence and danger of mercury can affect the utility derived from a pheasant hunting day. The amount of hunter competition, and the success of the hunt are also hypothesized to be important characteristics affecting the hunter's utility function. The individual's demand model for pheasant hunting days can be expressed as:

$$(4) \qquad Q = F(P, P_A, Y, T_1, T_2, H, S, I)$$

where

Q = Pheasant hunting days per hunter per season.

P = Real dollar transfer cost per pheasant hunting day (costs included; transportation, food, lodging, ammunition, and licenses).

P_A = Price of alternative commodities.

Y = Real income per capita.

T_1 = Travel time costs needed to reach the site, measured by one-way distance from the hunter's residence to the nearest border of the hunting area.

T_2 = Length of the hunting season in days.

H = Number of pheasant hunters.

S = Hunting success.

I = Index of the level of information concerning mercury in pheasants.

Choice of a Time-mode for Estimation

Transfer costs (P) and travel time (T_1) lack variability over time, but because of the geographic dispersion of hunters will vary cross-sectionally, i. e., across individuals. Success will vary over both time and across individuals. Cross-sectional differences in actual success within a given hunting area can be attributed to experience, knowledge, and luck, and would not be expected to be influenced by mercury induced changes in the pheasant population. Even so, these experience related success differences would affect the demand for pheasant hunting. A cross-sectional model (5) will be estimated to isolate the relationship between days of pheasant hunting, dollar transfer costs, travel time costs, and experience related success (S_E).

(5) $$Q = f_1 (P, T_1, S_E \mid P_A, Y, T_2, H, I)$$

Data on cross-sectional differences in prices of alternative commodities, income, and hunter competition unfortunately were not available. The effects of these variables in addition to the level of information, biologically induced success changes (S_B), and the length of the hunting season will be estimated using time series analysis (6).

$$(6) \qquad Q_t = f_2 (P_{A_t}, Y_t, H_t, I_t, S_{B_t}, T_{2_t} \mid P, T_1, S_E)$$

Specification of the Cross-sectional Demand Relationship

Data obtained from the 1971 Oregon State Game Commission hunter questionnaire will be used to develop the cross-sectional demand curve. These data represent the returns from a five percent sample of all individuals having a hunting license in 1971.

The sample data will be grouped into three geographic areas which correspond to the three regions where pheasants were collected and tested for mercury concentrations. These areas are Malheur County, Umatilla County, and the Willamette Valley (Benton, Lane, Linn, Marion, Polk, and Yamhill Counties). A separate estimate of the demand relationship will be estimated for each area.

Four pieces of information are available from each hunter: 1) home address, 2) county hunted, 3) number of days hunted small game, and 4) number of pheasants bagged. Thus two adjustments will be required in order to estimate the demand schedule. The number of days devoted to pheasant hunting must be determined and a price variable must be developed.

The Quantity Variable

The quantity variable to be used in the analysis is defined as the number of pheasant hunting days per hunter per season. Direct measurements on this variable were not available from the 1971 pheasant hunter survey. Thus, some means had to be developed to allocate the total days hunted small game among the species the hunter reported hunting.

In 1970, the number of days hunted each species was requested in the Game Commission's hunter survey and the results of that survey were reported for each of the habitat regions of the state. The average birds bagged per day, birds bagged per hunter, and days hunted per hunter for the state and each of three study areas for the 1970 season are reported in Table 1.

Telephone interviews with Game Commission personnel from each of the three regions were conducted. These interviews provided insights into hunter's behavior, the possibility of hunting more than one species in a single day, and the probable objective of the hunt when more than one species is reported. In addition each of the individuals contacted was asked for his subjective evaluation as to what portion of the total days hunted small game in his area was devoted to hunting pheasants.

On the basis of the 1970 statistics reported in Table 1 and the

Table 1. 1970 hunter survey statistics.[1]

	Statewide			Malheur			Umatilla			Willamette Valley		
	Birds/ Day	Birds/ Hunter	Days/ Hunter	Birds/ Day	Birds/ Hunter	Days/ Hunter	Birds/ Day	Birds/ Hunter	Days/ Hunter	Birds/ Day	Birds/ Hunter	Days/ Hunter
Pheasant	0.7	3.2	4.5	1.6	7.7	4.8	0.8	4.2	5.3	0.4	1.9	4.4
Quail	1.6	7.6	4.7	2.6	12.0	4.6	1.1	5.2	4.7	0.7	3.4	4.8
Chukar	1.9	7.8	4.0	2.3	9.2	4.0	1.2	5.8	4.8	0	0	0
Hungarian Partridge	0.8	3.5	4.6	0.7	3.2	4.6	1.0	4.3	4.3	N/R[3]	N/R	N/R
Blue & Ruffed Grouse	0.9	2.9	3.4	0[2]	0	0	1.2	3.7	3.1	0.8	2.9	3.8
Sage Grouse	0.8	1.9	2.3	0.8	1.8	2.2	0	0	0	0	0	0
Dove	2.4	10.4	4.3	3.9	10.9	2.8	2.1	11.8	5.6	2.0	9.3	4.6
Band-Tailed Pigeon	1.7	7.7	4.5	0	0	0	0	0	0	1.5	6.8	4.7

[1] Data obtained from 1971 Annual Report, Game Division, Oregon State Game Commission.

[2] Zero's reported when species is not found in the area.

[3] N/R - No data was reported for Willamette Valley area, though Hungarian Partridge are present there.

information obtained from regional game commission personnel, the author in consultation with Dr. Howard Horton of the Fish and Wildlife Department, Oregon State University, developed the allocation rule presented in Table 2. The allocation rule represents an estimate as to how a hunter would have allocated his total hunting days among the species he reported hunting.

Birds bagged of each species reported hunted in the 1971 season served as the allocation indicator. In general one day was allocated to a species for every 2M birds of that species reported bagged, where M is the average birds bagged per day during the 1970 season.

If a hunter were extremely successful in all his hunting, the total days allocated to all the species hunted would exceed the reported total. In such a case the bag limit was used to allocate days to each species, i. e., one day for each limit of birds bagged. In no case would more than the total days reported be allocated. Zero hunting days were allotted to quail or Hungarian partridge as all "experts" agreed that these species are usually taken as incidental kills or targets of opportunity while hunting pheasant or chukar.

The use of the allocation rule will be presented in an example developed from information provided on one of the returned Game Commission questionnaires.

Table 2. Allocation rules for allotment of total days hunted small game to each species reported hunted.

	Limit Birds/ Day	1970 Average Bag[1] Birds/Day	Necessary Number of Birds Bagged to Equal One Hunting Day Allotment
MALHEUR COUNTY			
Pheasant	3	1.6	3
Quail	8	2.6	NHDA[3]
Chukar Partridge	8	2.6	6
Hungarian Partridge	8	.7	NHDA
Blue & Ruffed Grouse	3	0[2]	NHDA
Sage Grouse	2	.8	2
Doves	10	3.9	6
Band-tailed Pigeon	8	0	NHDA
Wild Turkey	1	0	NHDA
Split remaining days 50/50 Pheasant-Chukar			
UMATILLA COUNTY			
Pheasant	3	.8	2
Quail	8	1.1	NHDA
Chukar Partridge	8	1.2	4
Hungarian Partridge	8	1.0	NHDA
Blue & Ruffed Grouse	3	1.2	2
Doves	10	2.1	4
Band-Tailed Pigeon	8	0	NHDA
Wild Turkey	1	0	NHDA
Split remaining days 75/25 Pheasant-Chukar			

Table 2. (Continued)

	Limit Birds/ Day	1970 Average Bag[1] Birds/Day	Necessary Number of Birds Bagged to Equal One Hunting Day Allotment
WILLAMETTE VALLEY			
Pheasant	2	.4	1
Quail	5	.7	NHDA
Chukar Partridge	4	0	NHDA
Hungarian Partridge	4	N/R[4]	NHDA
Blue & Ruffled Grouse	3	.8	1
Doves	10	2.0	4
Band-Tailed Pigeon	8	.7	1

Split remaining days 75/25 Pheasant-Doves.

[1] Data obtained from 1971 Annual Report, Game Division, Oregon State Game Commission.

[2] Zero's reported when species is not found in the area.

[3] No hunting days allotted to this species.

[4] N/R - No data was reported for Willamette Valley area even though Hungarian Partridge are present there.

UPLAND GAME

Did you hunt upland game in 1971? Yes /X/ No /_/ If you hunted game, how many days? 8 (number of days hunted)
If you hunted upland game, please indicate for each species the main COUNTY hunted and the number killed:

	Main County hunted	Number killed	Days Allotted
Pheasants	Malheur	6	2
Quail	Malheur	8	0
Chukar Partridge	Malheur	16	3
Hungarian Partridge			
Blue & Ruffed Grouse	Lane	1	1
Sage Grouse			
Doves			
Band-Tailed Pigeons	Lane	7	2
Silver Gray Squirrels			
Wild Turkey			
		Total	8

This hunter reports six pheasants bagged. Following the allotment rule for Malheur County two days would be allotted to pheasant hunting; no days would be allotted for the eight quail killed for these are considered to have been bagged while pheasant or chukar hunting. Three days are allotted for the 16 chukars bagged, and one day for the Blue or Ruffed Grouse and two days for the seven Band-Tailed Pigeons. This totals to eight days allotted which equals the number of days reported. If more than eight days had been reported, the excess days would have been allocated 50/50 to pheasant and chukar hunting. If fewer than eight days were reported the limit for each species would have been used to allocate the days.

The allotment rule was used to determine the number of days hunted for each of the 1,089 questionnaires returned which reported to have hunted pheasant in one of the three study areas. This represents 355 hunters in Malheur County, 222 hunters in Umatilla County and 512 hunters in the Willamette Valley.

The Price and Distance Variables

In the cross-sectional analysis of the demand for pheasant hunting, one-way measured distance in miles from the hunter's city of residence to the nearest edge of the hunting area will be used as a composite variable representing both the dollar transfer costs (P) and the travel time costs (T_1) of a pheasant hunting day. The coefficient of this composite variable will then be broken down into the separate effects of transfer costs and travel time on the basis of an assumed trade-off function.

The use of a composite variable which would combine transfer costs and travel time was first suggested by Cesario and Knetsch (1970) as a means of avoiding both specification bias and inefficiency due to multicollinearity in the estimation of recreational benefits. Knetsch (1963) described the serious conservative bias in the estimation of recreation benefits which results when the disutility of overcoming distance is assumed to be only a function of money costs. Brown, Singh, and Castle (1964), and Stevens (1966) attempted to remove this specification bias by inclusion of distance as an independent variable in the analysis. Distance was to represent two factors; the time costs involved in traveling the distance and the number of alternative recreational opportunities available to the recreationist. Because of the high correlation between distance and transfer costs the resulting estimates of the effects of both variables were unreliable. A dilemma resulted: inclusion of both transfer costs and distance meant inefficiency due to multicollinearity but dropping of one caused specification bias.

Cesario and Knetsch believe that if plausible assumptions can be made about recreationists' trade-off functions between transfer costs and travel time, a more accurate estimate of benefits can be made than could be obtained using either time or money costs alone. If the assumed trade-off function is realistic both specification bias and inefficiency due to multicollinearity can be avoided (Cesario and Knetsch, 1970).

Estimating the Trade-off Function

Nawas (1972) used an index of one-way distance to represent the travel time of a big game hunting trip and was successful in obtaining statistically significant estimates of the coefficients for both transfer cost and distance. The demand equations which Nawas estimated for big game hunting trips to various regions of Oregon will be used in this analysis to determine the relative effects of transfer costs and travel time in relation to the total effects of both variables in the demand for big game hunting trips.

In order to determine the separate effects of transfer costs and travel time on the demand for pheasant hunting days, two assumptions will be made.

1. Pheasant hunters do make trade-offs between transfer costs and travel time in determining their demand for pheasant hunting days, and
2. A pheasant hunter's trade-off function between transfer costs and travel time will be the same as a big game hunter's trade-off function.

(7) Let $\hat{Y} = \hat{\alpha} + \hat{\beta}_1 X_1 + \hat{\beta}_2 X_2 + \hat{\beta}_3 X_3 + \hat{\beta}_4 X_4$ be the estimated demand for big game hunting trips as estimated by Nawas (1972) where:

Y = average number of trips per hunter per season

X_1 = average transfer costs per trip per hunter

X_2 = the average measured one-way distance from the hunter's distance zone to the hunting region

X_3 = index of hunting success

X_4 = number of licensed hunters per family.

(8) $\lambda_1 = \hat{\beta}_1 / (\hat{\beta}_1 + \hat{\beta}_2)$ will then estimate the relative effect of transfer costs in relation to the total effects of transfer costs and

travel time and $\lambda_2 = \hat{\beta}_2/(\hat{\beta}_1 + \hat{\beta}_2)$ will estimate the relative effect of travel time.[8/]

The cross-sectional demand function for pheasant hunting days expressed in (5) will be estimated by applying ordinary least squares regression to:

(9) $Q = \alpha = + \gamma_1 D + \gamma_2 S + \varepsilon$

where:

Q = pheasant hunting days per hunter for the 1971 season

D = one-way measured distance from the hunter's residence to the nearest border of the county hunted

S = hunting success.

Because transfer costs are not included in (9) a specification bias will result. The effect of transfer costs on the quantity of pheasant hunting days will be taken up by the coefficient of the distance variable because of the high correlation of transfer costs and distance. That is $\hat{\gamma}_1$ will be biased, and include the effects of both transfer costs and travel time on the quantity of hunting days demanded.[8a/] It

[8/] The technique of estimating the trade-off function from earlier studies can only be used if the signs of the coefficients are expected to be the same in each study.

[8a/] The extent to which the biased coefficient of the distance variable will accurately reflect the joint effects of both transfer costs and travel time is impossible to predict without actual data on each of the variables. Theil (1971) points out how specification bias results due to an omitted variable.

Assume that the correct specification of the model includes K variables but only the first K-1 variables are used in the actual regression. Examining the coefficient of X_{K-1} which can represent distance in the actual regression,

$$E(\hat{\beta}^*_{K-1}) = \beta_{K-1} + \hat{\rho}_{K-1}\beta_{K-1}$$

where β_{K-1} represents the actual population parameters and is assumed that the biased coefficient of distance can be divided into that portion which represents the effect of transfer cost and the portion which represents the effect of travel time. To do this, the trade-off functions developed from the big game study (8) will be used. Given that λ_1 represents the effect of transfer cost relative to the total effect of transfer cost and travel time, then

$$(10) \qquad \lambda_1 \hat{\gamma}_1 = \hat{\beta}_P^*$$

will be the coefficient of transfer cost in the demand equation for pheasant hunting days. Likewise,

$$(11) \qquad \lambda_2 \hat{\gamma}_1 = \hat{\beta}_{T_1}^*$$

will be the coefficient of travel time, where travel time is measured by the one-way distance from the hunter's residence to the hunting area. Let (12) $\hat{\beta}_{S_E}^* = \hat{\gamma}_2$, then the demand equation for pheasant hunting days becomes

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$\hat{\rho}_{K-1}$ comes from the regression of the omitted K^{th} variable, transfer costs, on all those variables actually used in the regression.

$$X_K = \hat{\alpha} + \ldots + \hat{\rho}_{K-1} X_{K-1}$$

Since distance and transfer costs are highly positively correlated ρ_{K-1} will be positive. Thus $E(\hat{\beta}_{K-1})$ will include the effects of both variables. However $\hat{\beta}_{K-1}$ may overestimate or underestimate the joint effects of transfer costs and travel time depending on whether $\hat{\rho}_{K-1}$ is greater or less than the actual population parameter ρ_{K-1}. The direction of bias cannot be determined without actual data on transfer costs and travel time. If the joint effect were overestimated the resulting consumer's surplus estimates would be underestimated. If the joint effect were underestimated the resulting consumer's surplus estimates would be overestimated.

Based on the regressions developed using individual data for big game hunting in Oregon, there is reason to believe that the coefficient of distance will underestimate the joint effect. Thus the consumer surplus estimates are probably overestimated and would serve as an upper bound.

(13) $$\hat{Q} = \hat{\alpha} + \hat{\beta}_P * P + \hat{\beta}_{T_1} * T_1 + \hat{\beta}_{S_E} * S_E$$

Success Variable

A pheasant hunter's demand for pheasant hunting days is expected to be directly related to his hunting success. While his decision to hunt the first day is based on his subjective evaluation of his expected success, his decision to continue to hunt additional days would be based on his actual success on the preceding days of the season. Unfortunately data on daily success are not available.

Two measures of experience related success are available: the total birds bagged during the season and the average number of birds bagged per hunting day. Given that a positive probability of success is necessary to induce a hunter to hunt, most hunters would discontinue hunting if they experienced low or zero success. The effect of both total success (TS_E) and average success (S_E) on the demand for pheasant hunting days is expected to be positive, *ceteris paribus.*

Specification of the Time-series Demand Relationship

The elasticity of pheasant hunting demand with respect to prices of alternative commodities, information, income, biologically induced success changes, hunter pressure, and the length of the hunting season will be estimated using time series analysis. Observations over the period 1950 through 1971 will be examined. Price per pheasant hunting day, travel time costs, and experience related success changes are assumed to be constant over the time period considered. The elasticity estimates of information, hunter pressure, and biologically induced success changes will be used to "shift" the cross-sectionally estimated empirical demand functions. This will allow the effects of mercury use as exhibited in the level of information and biologically induced success changes to be measured by the changes in the consumer's surplus associated with each demand curve.

Price of Other Commodities

The price of alternative goods and activities, in theory, is equal to the weighted average of the prices of the goods and activities which comprise the alternative choices for a given consumer for the commodity in question, in this case pheasant hunting. The consumer's price index for goods and services will be used as the price of alternative commodities in the time series analysis.

The price structure faced by recreationists in general and pheasant hunters in particular has changed considerably over the period 1950-1971. With little change in the fee structure and either decreasing or constant real transfer costs per recreation day, outdoor recreation has become relatively cheaper than the necessities of life, as well as alternative forms of entertainment.

Thus, the demand for days of pheasant hunting is expected to increase with increases in the price of alternative commodities, *ceteris paribus*.

The Information Variable

Content analysis has been used to develop data on the level of information available to prospective hunters. It is a phase of information-processing in which communication content is transformed, through objective and systematic application of categorization rules, into data that can be summarized and compared (Holsti, 1968).

The Oregonian, being a statewide publication, was examined to find all articles relating to the presence of mercury in Oregon's pheasants and the effects on the health of individuals consuming mercury.

Four sources were used to locate all articles which appeared in The Oregonian. Dr. Donald Buhler of the Environmental Health Sciences Center, Oregon State University has been involved in the examination of the mercury in Oregon's environment from the inception of the study in the spring of 1970. Dr. Buhler and his staff had compiled a file of articles pertaining to mercury in the environment.

In order to assure that all articles would be located, the index file to The Oregonian compiled by the Multnomah County Library and The Oregonian's own clipping file on mercury were also examined. These files, like Dr. Buhler's, were rather complete for 1970 but the number of articles reported in 1971 was lower than anticipated.

The Oregonian's clipping file did provide the date, July 11, 1970, of the first article which it carried concerning the presence of mercury in wildlife and hazards associated with the ingestion of mercury.

It was decided that a complete reading of The Oregonian would be made to be sure that all articles pertaining to the presence and dangers of mercury in pheasant would be identified. A team of readers was hired and trained under the guidance of Ms. Pam

Bodenroeder, a sociologist with training and expertise in content analysis and leadership of content analysis teams.

Microfilm of The Oregonian from July 1, 1970 through November 15, 1971 was to be examined. November 15 was the cut-off date, that being the last edition of The Oregonian which could have influenced the behavior of Oregon's pheasant hunters during the 1971 season.

Given that the study had both limited time and money it was decided to examine the microfilms of 1971 issues first, since the 1970 data already obtained were believed to be complete.

Each microfilm tape was read by two analysts, so that one would serve as a check on the other. The analysts were instructed to record all articles which pertained to mercury, pheasants, tuna, swordfish, pollution, environmental contaminants, human health, pesticides, and fungicides.

These broad categories were selected to increase the reliability of the analysts. It was believed that articles related to mercury would not be as prominent in 1971 as they were in 1970. Dr. Robert Mason's experience in content analysis had shown the reliability of readers to be higher, the greater the number of articles which could be found, i. e., when the analyst would receive more frequent rewards for his search.

The recorded articles were then examined by the author to determine which articles related directly to mercury and its health effects.

The individual reliabilities of the analysts each averaged 93 percent for each of the 11 months of 1971 examined, within 95 percent confidence limits of 86 to 100 percent and 84 to 100 percent, respectively, i. e., each analyst recorded an average of 93 percent of the total articles recorded by both.

Due to the pressures of time, a deadline was given to the analysts for examination of the six months from July 1, 1970 through December 31, 1970. Only one student analyst had time available to meet the deadline. It was felt that one reading over the 1970 period would provide a check for the 1970 data already obtained from the three earlier sources.

The accuracy of the analyst dropped off extremely in examination of the 1970 microfilms. Fatigue on the part of the analyst and an orientation toward the small articles found in the 1971 issues are thought to have contributed to the results obtained. The 1971 articles had averaged 14. 2 inches compared to 30. 2 inches for articles in 1970. All major articles which appeared during July, August, September, and October of 1971 were missed while 100 percent reliability was obtained in November and December of 1970. The analyst had begun reading the December tape and worked back through July. Over the period of July through December the reliability of the three clipping files averaged 85 percent while the reliability of the microfilm analyst averaged 48 percent with 95 percent confidence limits of 72 to 99 percent and 1 to 96 percent, respectively.

Given the checks and counter checks, it is assumed that use of the four sources has isolated all the articles which appeared in The Oregonian concerning mercury in Oregon's pheasants and the presence and dangers of mercury in man's environment.

The July 11, 1970 article did cite mercury in the pheasants of other states; however, it was not until August 30, 1970 that the presence of mercury in Oregon's pheasants was explicitly reported.

It is assumed that Oregon hunters would have reacted to information on mercury only after it has been established that Oregon pheasants have been exposed to mercury and may contain elevated mercury levels. Thus, those newspaper accounts of mercury in wildlife and humans which appeared prior to August 30, 1970 would have served only to sensitize the reader to the hazards of mercury.

If Oregon's pheasants had never been reported to contain elevated mercury levels, no voluntary behavioral changes would be expected. That is, not until the August 30th article would the quality characteristics of pheasant hunting in Oregon have been altered. Once hunters were aware of mercury in Oregon pheasants, any article expounding concern over mercury is assumed to reinforce the change in the quality characteristics of the pheasant hunting day as perceived by the pheasant hunter.

Preliminary analysis of The Oregonian articles found them to be predominantly one-sided. That is, mercury was consistently recognized as a source of concern due to its cumulative nature and harmful effects. Thus, the volume of information appears to be an appropriate measure of the level of information. Column inches was selected as a measure of the level of information available to pheasant hunters (Woodard, 1934).

The Length of the Hunting Season

As the number of legal hunting days per season increase, more close substitutes for a given day become available. This results in a decrease in the opportunity cost of a given hunting day. Thus, the demand for pheasant hunting days is expected to increase with an increase in the length of the hunting season, *ceteris paribus*.

Most hunters would agree that a primary determinant of their demand for pheasant hunting days is the opportunity cost of those days. Home and family responsibilities as well as alternative recreational activities compete with pheasant hunting for the non-working time of the hunter. As the legal number of days in the hunting season increases, there are more opportunities to schedule and reschedule activities so that more pheasant hunting days can be consumed.

Hunter Pressure

One of the qualities of a pheasant hunting day which attracts many a hunter is the ability to "get away from it all"; an opportunity to do something at your own pace while enjoying the natural surrounding in anticipation of the wild flush of a cock pheasant. With an increase in the number of hunters, ceteris paribus, a portion of the relaxing atmosphere is removed.

Hunters find themselves competing with one another, hurrying through fields to make sure to reach the birds first. It is hypothesized that the number of hunters will be negatively related to the average days of pheasant hunting demanded per hunter per season.

Statewide data on the number of pheasant hunters for each hunting season from 1950 through 1971 were obtained from the annual reports of the Game Division, Oregon State Game Commission.

Success

As the average success of a pheasant hunting day increases, the average number of pheasant hunting days demanded per hunter per season is hypothesized to increase, ceteris paribus. Data on the average number of birds bagged per pheasant hunting day for each season, 1950 through 1970, were obtained from the annual reports of the Oregon State Game Commission.

Year to year variations in average success are expected to be influenced by year to year variation in the pheasant population. To the extent that mercury fungicide use decreases the reproductive rate of pheasants, increases in mercury use would tend to lower the average daily success, ceteris paribus. Studies in Sweden have found reductions in reproductive rates of 10 to 20 percent for pheasants fed mercury treated seed (Borg, 1965).

If the level of mercury use can be assumed relatively constant over the period 1950 through 1971, and if assumptions can be made as to the decrease in success accompanying a given decrease in reproduction, then an additional effect of mercury on the demand for pheasant hunting can be estimated as a percentage of the elasticity of demand with respect to success.

Aggregate Consumer's Surplus

The preceding models are appropriate for explaining the number of hunting days per hunter and the average consumer's surplus, i. e., they are for the individual, not the hunting population. The aggregate demand for pheasant hunting days can be obtained by multiplying the individual's demand for pheasant hunting days by the number of hunters, H, that will hunt the area each season. The appropriate aggregate model is as follows:

$$(14) \qquad HQ = H[F(P, T_1, S, P_A, Y, T_2, H, I)]$$

where:

H = the number of individuals hunting for pheasant in each area during the season.

Thus a second relationship must be developed to estimate the effects which information on the presence and dangers of mercury in pheasants has on the number of pheasant hunters.

The Number of Hunters Relationship

The number of individuals hunting pheasant in Oregon is assumed to be a function of the real per capita income (Y), population (Pop), the degree of urbanization (%U), the level of expected success (ES) and the level of information concerning mercury in pheasants (I).

(15) $$H_t = H(Y_t, Pop_t, \%U_t, ES_t, I_t)$$

Primary interest is on the effect of informational flows on hunter numbers, thus a time series analysis will be required. Statewide data for the period 1950-1971 will be used to estimate the equation.

Percent of Urbanization

As the proportion of the population which live in urban areas increases, the number of pheasant hunters in that population is expected to decrease, *ceteris paribus*. This arises from two aspects of urbanization. First, land suitable for pheasant hunting is owned by a smaller number of individuals, thus accessibility to hunting land is more difficult for the urban dweller. Second is the increase in alternative forms of recreation available to the urban dweller without the necessity of travel that would be required for pheasant hunting.

Level of Expected Success

The number of pheasant hunters per season represents all individuals who hunted pheasant, whether for one day or 30 days. Thus, it is the level of expected success and not their actual success which enters into their decision to hunt. Two components are believed to contribute to the expected success of a prospective hunter: the average success of the hunters the previous season and the expected bird population for this season. Thus,

$$ES_t = f(S_{t-1}, B_t)$$

where

S_{t-1} = average birds bagged per day per hunter the previous season

B_t = measure of the expected bird population [birds/100 acres] [1 +(percentage hens) (average number of chicks per hen)]

Spring and summer population inventory figures reported in the Game Division's annual reports will be used to develop the measure of expected bird population (B_t).

Income

Since pheasant hunting can be considered primarily a form of recreation or leisure activity over the period 1950 through 1971, an increase in real per capita income would be expected to increase the number of pheasant hunters, *ceteris paribus*.

Real per capita income figures were obtained from Oregon Economic Statistics, 1972.

Information

The information variable as developed for the demand for the pheasant hunting days equation will be used in the number of hunters equation. As information concerning the presence and dangers of mercury increases, the number of pheasant hunters is hypothesized to decrease. The effect of information on the number of hunters is expected to be more significant than its effect on the days of pheasant hunting per hunter. That is, those individuals who perceive a quality change in the pheasant hunting experience are expected to drop out of the pheasant hunter population.

The estimation of the time-series models for the number of pheasant hunting days per hunter per season and the number of pheasant hunters will be conducted in Chapter IV. Estimates of the cross-sectional demand curves and the corresponding consumer's surplus estimates will be presented in Chapter V.

IV. ESTIMATING THE EFFECT OF MERCURY THROUGH TIME SERIES MODELS

A primary objective of this thesis is to determine what effect knowledge of the presence and dangers of mercury in Oregon's pheasant has had on Oregon's pheasant hunters. If the behavior of hunters has been influenced by information provided through the mass media, a measurement of this effect could be estimated by the change in the net economic value of pheasant hunting in Oregon.

To isolate the effects of information, two time series models were estimated. The first examines the effect of information, income, price of alternative commodities, length of hunting season, average success, and hunter pressure on the average number of hunting days taken per hunter per season. A second model estimates the effects of information, and other pertinent variables on the number of hunters.

In Chapter II it was suggested that information on the presence and dangers of mercury would rotate the indifference curves of pheasant hunters away from the pheasant hunting axis, resulting in a decreased demand for pheasant hunting in Oregon. Intuitively one would expect the decrease in demand to result primarily from hunters who drop out of the pheasant hunting population as a result of their increased knowledge about mercury in the pheasants. Those hunters who remain in the population after being presented with the information are not expected to alter their behavior significantly. As is the case with all communication, the effects of information concerning mercury will vary from individual to individual depending on the circumstances in which it is received, the characteristic of the individual, and the perceived creditability of the source (Holsti, 1968).

Time Series Models--the Days per Hunter Relationship

Yearly data over the period 1950 through 1971 have been used to estimate the effects of information, income, price of alternative commodities, length of hunting season, average success, and hunter pressure on the average number of pheasant hunting days per hunter per season. As developed in Chapter III, negative coefficients are expected for mercury information and hunter pressure. Increases in per capita real income, the length of the hunting season, average success, and price of alternative goods and activities are expected to influence positively the average number of hunting days per hunter.

Ordinary least squares regression was used to estimate the original days per hunter relationship, equation (16):

$$(16)\quad \hat{Q}_t = \underset{(-0.38)}{0.7080} + \underset{(3.34)}{0.0334}\,(D)_t^{*} + \underset{(2.13)}{0.0375}\,(P_A)_t^{**}$$

$$-\underset{(0.57)}{0.00047}\,(Y)_t - \underset{(0.15)}{0.1259}\,(S)_t$$

$$+\underset{(-0.50)}{0.0000004}\,(H)_t - \underset{(-1.46)}{0.00055}\,(I)_t$$

*significant at $\alpha = .01$ $\quad$ $^{*}R^2 = 0.915$

**significant at $\alpha = .05$ $\quad$ $\bar{R}^2 = 0.871$

D-W = 1.319

n = 22

where

Q_t = Average number of pheasant hunting days per hunter per season.

D_t = Length in days of the pheasant hunting season in year t.

P_{A_t} = Price of alternative commodities measured by the consumer's price index for year t.

Y_t = Average per capita real income for Oregon in year t.

S_t = Average success measured in birds bagged per day for year t.

H_t = Hunter pressure measured in number of pheasant hunters in year t.

I_t = Index of information on the presence and dangers of mercury in pheasants measured by the number of column inches of articles appearing in The Oregonian during the 12 months preceding the hunting season of year t. 9/

9/ Four measures of information were examined in estimating the days per hunter relationship; column inches in year preceding the hunting season, cumulative column inches in two years preceding the

The t-values for the coefficients appear in parentheses beneath the coefficients. The correlation matrix which accompanies (16) appears in Table 3.

Table 3. Simple correlation coefficients between the variables of the days per hunter equation (16).

	Q_t	D_t	P_{A_t}	Y_t	S_t	H_t	I_t
Q_t	1.000	0.903	0.763	0.747	-0.156	-0.281	0.269
D_t		1.000	0.594	0.626	0.009	-0.149	0.108
P_{A_t}			1.000	0.945	-0.569	-0.687	0.690
Y_t				1.000	-0.652	-0.779	0.516
S_t					1.000	0.736	-0.472
H_t						1.000	-0.496
I_t							1.000

While the coefficients of length of season, price of alternative commodities, and mercury information carry their hypothesized sign, the coefficients of income, success, and hunter pressure do not. The t-values which appear in parentheses below the coefficients

hunting season, number of articles in the year preceding the hunting season, and cumulative number of articles in the two years preceding the hunting season. While information is theoretically important it is difficult to predict the most effective measure of its presence.

The negative effect of information on average days hunted per hunter was found to be primarily due to the volume of information available to the hunter in the year immediately preceding the hunting season measured in column inches.

indicate that only the coefficients of length of the hunting season and the price of alternative goods and activities are significant at conventional α levels.

A high degree of multicollinearity between real per capita income and the price of alternative commodities is indicated by their simple correlation coefficient of 0.945 as shown in Table 3. This high degree of correlation is basically a characteristic of the time series data, thus income will be dropped from the model in an attempt to increase the reliability of the estimated regression coefficients of the remaining variables. Some degree of specification bias may be introduced by the exclusion of income. However, this bias is not expected to be significant. The results of earlier studies on the demand for angler days and big game hunting trips indicate that the effects of differences in family income are insignificant in determination of sportsmen's demand (Brown _et al._, 1964; Stevens, 1966; Nawas, 1972).

The exclusion of real per capita incomes from equation (16) resulted in equation (17):

$$(17) \quad \hat{Q}_t = \underset{(-0.17)}{-0.1733} + \underset{(4.010)}{0.0297}\,(D)_t^{*} + \underset{(3.371)}{0.0287}\,(P_A)_t^{*} + \underset{(0.272)}{0.1727}\,(S)_t + \underset{(1.341)}{0.000008}\,(H)_t - \underset{(-1.431)}{0.000416}\,(I)_t$$

$$*R^2 = 0.914$$
$$\bar{R}^2 = 0.887$$
$$D\text{-}W = 1.21$$
$$n = 22$$

The variables are as defined for equation (16). All coefficients with the exception of hunter pressure are of the hypothesized sign. Again, the coefficients of success, hunter pressure, and information are not significant at conventional α levels.

As in (16) the R^2 and the t-statistics reported for (17) may lead one to put more confidence in the estimated coefficients than is warranted. The Durbin-Watson statistic of 1.21 indicates a high degree of autocorrelation between the disturbances. While the estimated coefficients are unbiased and consistent under autocorrelation their estimated variances will have a negative bias.[10/] Correcting for autocorrelation using the method proposed by Hammonds[11/] resulted in equation (18):

[10/] See Kmenta (1971, p. 278-282) for an elaboration on the properties of estimates with autoregressive disturbances and the limitations imposed on the test statistics.

[11/] T.M. Hammonds (n.a.) in an unpublished paper entitled "The Elimination of Autocorrelated Disturbances in Regression Analysis: A Revised Estimator" suggests a new iterative process to correct for autocorrelation. The new method avoids the errors which Hammonds demonstrates to be intrinsic in some of the textbook recommended corrections for autocorrelation. Three iterations were conducted using $\hat{\rho} = 0.3946$, 0.7589, and 0.7421. The process was discontinued after the third iteration since the regression coefficients had stabilized.

$$(18)\quad \hat{Q}_t = \underset{(2.29)^{12/}}{-0.7272^{**}} + \underset{(3.77)}{0.0238\,(D)_t^{*}} + \underset{(0.83)}{0.0085\,(P_A)_t} + \underset{(1.52)}{0.7549\,(S)_t} - \underset{(-1.25)}{0.000008\,(H)_t} - \underset{(0.29)}{0.00006\,(I)_t}$$

$$^{**}R^2 = 0.572^{12/}$$
$$\bar{R}^2 = 0.438$$
$$D\text{-}W = 1.97$$
$$n = 22$$

With the model corrected for autocorrelation, the sign of hunter pressure becomes negative as hypothesized. However, neither hunter pressure nor information concerning mercury appear to significantly affect the number of pheasant hunting days demanded by hunters who remain in the pheasant hunting population.

Data used to estimate equations 16, 17, and 18 appear in Appendix Table C-1.

Based on equation (18) the hypothesis that knowledge of the presence and dangers of mercury in pheasant will decrease the demand for pheasant hunting days by hunters who remain in the pheasant hunting population is rejected.

12/ Due to the iterative correction process the R^2 and the t-statistics are not reliable, however, they are probably a better indicator than those on the original model.

The Number of Hunters Relationship

The primary effect of mercury on the behavior of pheasant hunters is expected to be reflected in the number of hunters who discontinue hunting entirely in an attempt to avoid exposure to the mercury. To determine the magnitude of this effect, yearly data were used to estimate the number of hunters relationship which was specified in Chapter III.

$$(19) \quad \hat{H}_t = \underset{(3.17)}{69{,}212^*} + \underset{(4.17)}{0.1138}\,(Pop)_t^* - \underset{(-5.32)}{76.6960}\,(Y)_t^*$$

$$+ \underset{(0.81)}{12{,}234}\,(S)_{t-1} - \underset{(-2.44)}{198.22}\,(I_{\#c})_t^{**}$$

$^*\alpha$ = .01

$^{**}\alpha$ = .05

$^*R^2$ = 0.844

$\bar{R}^2$ = 0.807

D-W = 1.59

n = 22

where

H_t = Number of individuals hunting pheasant in Oregon in the t^{th} year.

Pop_t = Oregon's population in t^{th} year.

Y_t = Per capita real income in Oregon in t^{th} year.

$I_{\#c}$ = Cumulative number of The Oregonian articles concerning the presence and danger of mercury in pheasants appearing in the two years preceding the t^{th} hunting season.

S_{t-1} = Expected success of the t^{th} hunting season as measured by the actual success of the $t-1^{th}$ hunting season.[13/]

The t-values for the coefficients appear in parentheses beneath the coefficients. The Durbin-Watson of 1.59 rejects the hypotheses of autocorrelated disturbances at the .05 level.

The correlation matrix associated with equations (19) and (20) appears in Table 4.

Table 4. Simple correlation coefficients between the variables of the number of hunters equations (19) and (20).

	H	Pop	Y	$I_{\#c}$	S_{t-1}	D	%U
H	1.000	-0.669	-0.779	-0.584	0.593	-0.650	-0.524
Pop		1.000	0.974	0.488	-0.486	0.846	0.973
Y			1.000	0.483	-0.526	-0.836	0.912
$I_{\#c}$				1.000	-0.479	0.285	0.381
S_{t-1}					1.000	-0.255	-0.359
D						1.000	0.862
%U							1.000

The coefficient of the important information variable is negative as hypothesized and significantly different from zero at the .01 level. From this specification of the equation it can be inferred that the

[13/] The measure of expected bird population (B_t) was not included in the regression because of the great degree of sampling error present in the raw data. Inventory times varied from year to year as well as cover conditions. Thus variations in the inventory numbers are not believed to be indicative of variations in the actual pheasant population.

knowledge of mercury in the pheasants has resulted in a decrease in the number of pheasant hunters. Seventy-three articles concerning the presence of mercury in pheasants and the environment, and the dangers of mercury consumption to human health appeared in The Oregonian in the two years preceding the 1971 pheasant hunting season. Setting $I_{\#c}$ of equation (19) equal to 73 results in a predicted decrease of 14, 470 hunters from the 1971 pheasant hunter population. This loss of 14, 470 hunters is attributed to the information concerning mercury.

The coefficient of expected success, while positive is not significant at conventional levels.

Population was found to have a significant positive effect on hunter numbers as hypothesized. The effect of income, on the other hand, is estimated to be negative. Due to the high degree of multicollinearity between population and income, $r = 0.974$, the signs of their coefficients and their statistical reliability is questionable. The negative sign on the income coefficient may also be due to a specification bias in the model.

Figure 6 shows a plot of the number of pheasant hunters in Oregon over time. As the plot indicates there is a definite reversal of the upward trend in hunter numbers which occurred sometime from 1959 to 1961. The 1961 season was definitely below any trend line which could be fitted to the 1950-1960 data. Officials of the Oregon

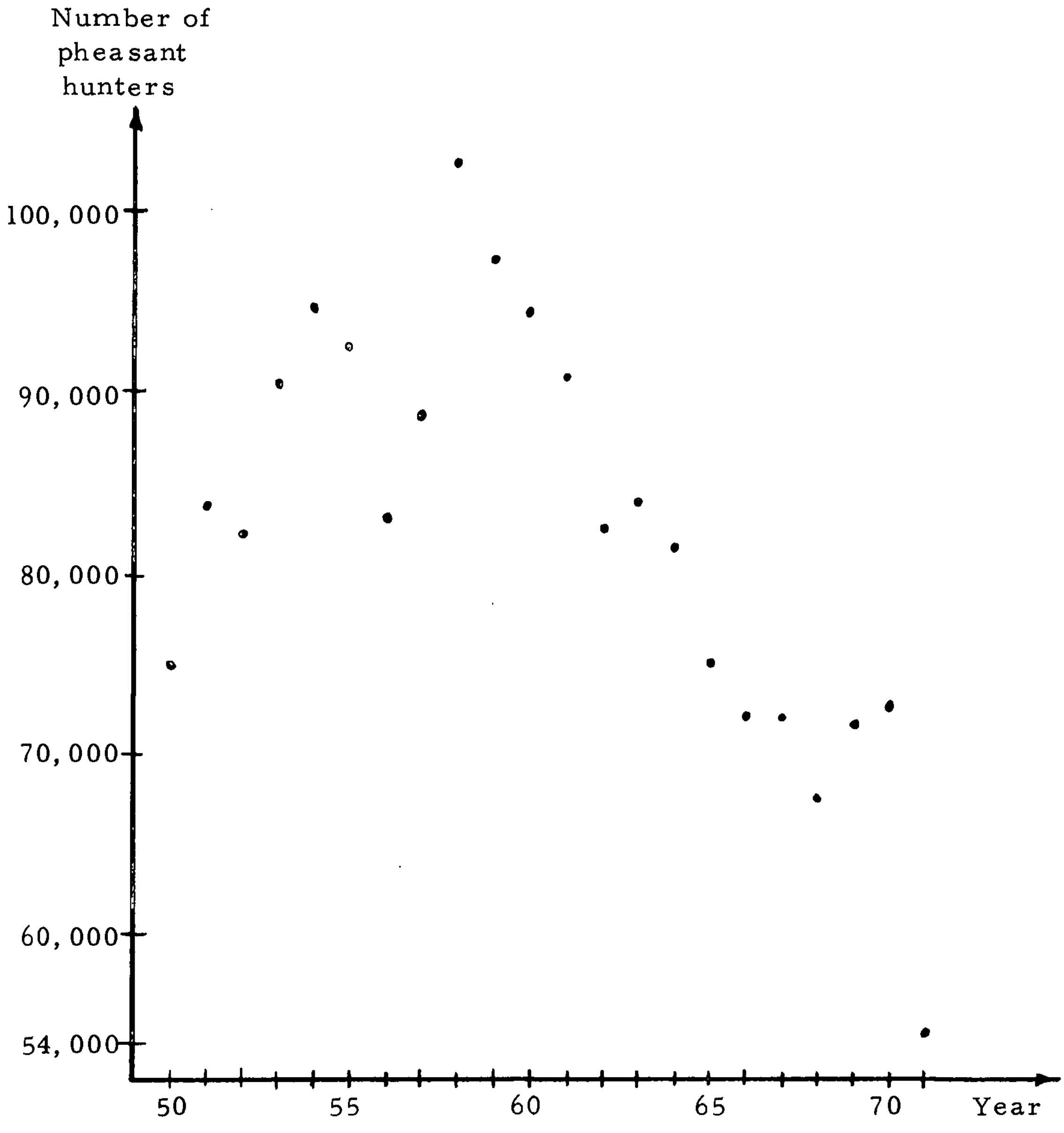

Figure 6. Pheasant hunter numbers over the period 1950 through 1971.

Game Commission attribute the decreasing trend in hunter numbers to a combination of factors. Their records show a continued loss of small game hunters from the primary metropolitan areas of the state.[14/] To determine if the change in recreational opportunities associated with urbanization was a significant factor in the determination of hunter numbers, percent urban residence was added to the model. Neither the predictive ability of the model nor the coefficients of the other independent variables were significantly altered. However, the standard errors of all the coefficients and the degree of autocorrelation in the model were increased. The coefficient of urbanization was positive with a t-value of 0.404. The percent of urbanization (%U) is highly correlated with both population and per capita real income over the period analyzed as documented in Table 4. Given all of these characteristics, the percent of urbanization was omitted from the number of hunters relationship. The hypothesis that urbanization in and of itself is a prime contributor to the decrease in the number of pheasant hunters is also discounted by the fact that the number of big game hunters from urban areas has been continually increasing.[15/]

The primary factor contributing to the decrease in hunter numbers is believed to be the increasing difficulty met by hunters in

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[14/] Phone conversation with Don Wilt, Oregon Game Commission, June 27, 1973.

[15/] Ibid.

gaining access to privately owned lands. Unlike big game hunting in Oregon where federal and state owned lands provide most of the game, small game species are concentrated primarily on private agricultural lands.

Agents of the Oregon State Game Commission began conducting land access surveys in some game districts in 1957. The results of this original survey showed 19 percent of the surveyed lands was posted "No Hunting." By 1961 an average of 29 percent of the farms surveyed over the western counties of Oregon were posted "No Hunting." Game Commission personnel argue that "increased land posting appears to be the inevitable result of mounting hunting pressure" (Oregon State Game Commission, 1961, p. 74). Results of the Game Commission surveys over the period 1957-1970 appear in Table 5.

The Game Commission discontinued the land access survey in 1971 believing the sampling method did not present an accurate measure of general access in the state. The general trend of decreasing hunter access to prime pheasant habitat observed in Table 5 is believed to be correct, however.

Given the variability in both sample size and counties sampled over the 15 year period, it was decided to use a dummy variable to indicate the general decrease in hunter satisfaction. Decreases in accessibility to private lands are believed to be the primary

Table 5. Results of the Oregon Game Commission land access surveys 1957-1970.[1/]

	Miles Sampled[2/]	Percent No Hunting
1970	450	31
1969	608	33
1968	740	24
1967	638	27
1966	765	27
1965	718	29
1964	713	29
1963	454	24
1962	421	22
1961	412	15
1960	423	29
1959	279	21
1958	291	20
1957	291	19

[1/] Source: Oregon State Game Commission, Annual Reports of the Game Division, 1958-1971.

[2/] The counties sampled and the number of miles sampled per county varied from year to year. However, all counties sampled were in Central or Western Oregon.

contributor to that dissatisfaction. The dummy variable was given a value of zero for the years 1950 through 1960 and a value of one for the years 1961 through 1971. Regression of the data which appear in Appendix Table C-2 resulted in the following number of hunters relationship.

$$(20)\quad \hat{H}_t = \underset{(0.63)}{16,677} + \underset{(5.44)}{0.1300}\,(Pop)_t^{*} - \underset{(-5.60)}{69.851}\,(Y)_t^{*}$$

$$- \underset{(-3.33)}{233.73}\,(I_{\#c})_t^{*} + \underset{(1.78)}{23,964}\,(S)_{t-1}^{**}$$

$$- \underset{(-2.76)}{10,386}\,\left(\begin{matrix}\text{Land Access}\\ \text{Dummy}\end{matrix}\right)_t^{*}$$

$^{*}\alpha = .01$ $\qquad$ $^{*}R^2 = 0.8945$

$^{**}\alpha = .05$ $\qquad$ $\bar{R}^2 = 0.861$

D-W = 2.1535

n = 22

The overall explanatory power of equation 20 is not significantly different from that of equation 19. However with the addition of the dummy variable to reflect decreases in land accessibility, the coefficient of expected success becomes significant at the .05 level and approximately doubles in value.[16/] The coefficient of information increases by approximately 18 percent.[17/] Based on equation (20), a

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[16/] The change in the coefficient of expected success is significant at $\alpha = .01$.

[17/] The change in the coefficient of information is not significant at conventional α levels.

loss of 17,602 hunters from the 1971 pheasant hunter population is attributed to the knowledge of the presence and dangers of mercury in pheasants.

Very little change in the coefficient of population or income resulted from the addition of the dummy reflecting the decrease in land accessibility.

While the coefficient of income was originally hypothesized to be positive, an argument can be made for a negative coefficient. Pheasant hunting is primarily an activity for male members of the family 16 years and older. Thus, when the hunting season arrives the men of the family often leave Mom and the children at home. Over time as real incomes increases, the constraint on alternative family recreation activities is relaxed. Thus, a shift may be taking place away from hunting toward alternative forms of family activity.[18/]

The effect of mercury on the behavior of pheasant hunters has been examined through the use of time series models. The effect of mercury on the behavior of hunters who remain in the hunting population after information concerning mercury became available was found

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[18/] Omitting income from equation 20, in an attempt to remove any bias introduced by the multicollinearity resulted in an increase in the coefficients of expected success and the land access dummy. The coefficient of information was 228.90, an insignificant change from the 233.73 of equation 20. A high degree of autocorrelation was also introduced by omitting income. Thus, equation 20 was accepted as the primary hunter numbers relationship.

to be insignificant. A significant reduction in the number of pheasant hunters has been found to be related to the presence and dangers of mercury in pheasants.

To determine the economic value of the effects of mercury on pheasant hunting, cross-sectional demand models for three pheasant hunting areas of Oregon will be estimated.

V. CROSS-SECTIONAL DEMAND MODELS FOR PHEASANT HUNTING IN OREGON, 1971

The effects of mercury on the number of pheasant hunters has been estimated in Chapter IV. An effort will now be made to estimate the economic loss which accompanied the decrease in hunter numbers. The models which appear in this chapter were developed from data typically measured by game management organizations. As such, measurements on the economic variables of expenditures and income were not available. Thus, various assumptions were required to develop the demand models. While the final estimates of economic loss to society rely on the assumptions, the sensitivity of the estimates varies considerably from assumption to assumption. The importance of each of the assumptions in determining the final estimate of social cost will be stated at the time the assumption is made.

Four methods of estimating the demand functions are used. The trade-off method developed in Chapter III is presented first using pheasant hunting days per hunter as the dependent variable.

A distance-based transfer cost model is then developed to serve as a check on the trade-off method. The demand equations are then re-estimated by each of the methods using pheasant hunting trips as the dependent variable.

Cross-sectional demand models for pheasant hunting in each of the three hunting areas will now be presented.

Malheur County Model

Malheur County, located in the southeast corner of Oregon, has a reputation for having the finest pheasant hunting in the state. While it has only 330 square miles of pheasant habitat, pheasant populations are high and hunters have bagged over 175 pheasants per square mile during each of the last four years. Approximately 70 percent of the Malheur County hunters live outside of the area.

Three hundred and fifty-five hunters who returned usable questionnaires to the Game Commission reported that they hunted pheasant in Malheur County. From their questionnaires, data on one-way measured distance from hunter's residence to the nearest border of the hunting area, total success, average success, and days hunted were developed. One hunter was excluded from the Malheur sample for having an extreme number of days given the distance traveled, 18 days and 865 one-way miles. Ordinary least squares regression was applied, using the remaining 354 observations. The following regression was obtained:

$$(21) \quad \hat{Q}_i = \underset{(17.37)}{4.9247^{*}} - \underset{(-1.70)}{0.00114\,(D)_i^{**}} + \underset{(21.42)}{0.5583\,(TS)_i^{*}} - \underset{(-14.82)}{2.3142\,(S)_i^{*}}$$

$$*R^2 = 0.605$$
$$\bar{R}^2 = 0.602$$
$$n = 354$$

* significant at the .01 α level.

** significant at the .05 α level.

Numbers in parentheses below coefficients are their t-values:

$\hat{O}_i$ = Denotes the predicted number of pheasant hunting days taken by the i^{th} hunter during the 1971 season.

D_i = One-way measured distance from the i^{th} hunter's residence to the nearest border of the hunting area.

TS_i = Total success of the i^{th} hunter; the total birds bagged.

S_i = Average success of the i^{th} hunter measured in pheasants bagged per day.

In equation (21) all coefficients are significantly different than zero at the five percent level or above, and all coefficients with the exception of average success, carry the hypothesized sign. Reliability of the coefficients established on the basis of the conventional test statistics can be questioned, however, due to the high degree of heteroskedasticity present in the model.

While the least squares estimators of regression coefficients are both unbiased and consistent under heteroskedasticity, the conventional test statistics and confidence limits developed through the use of the estimators will be biased. Kmenta developed a method to determine the direction of bias introduced by the non-equality of the variance of the error terms.[19/]

Following Kmenta's procedure, the bias was found to be positive for both the coefficients of distance and total success. Thus more confidence can be placed in the estimated coefficients of these variables than is indicated by the calculated t-statistic. In the case of average success, the bias changes from negative to positive with increases in the squared deviations from the mean. With an estimated t-statistic of -14.82 it is believed the estimated coefficient of average success is also significantly different from zero at conventional levels.

A possible rationalization for the negative coefficient on the average success variable may be tied to the variation in the gaminess of the pheasant over the length of the hunting season. Pheasants are an excellent game bird, becoming extremely wary after the hunting season opens. While they will flush easily opening day, a good dog or extensive hunting may be required to flush and retrieve birds for the rest of the season. This being the case, the average success for a given hunter, measured in birds bagged per

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[19/] If $(X_i - \bar{X}_i)^2$ and σ_{μ}^{2} are positively associated, the bias for the i^{th} coefficient will be negative. That is, the calculated standard error will be smaller than the actual standard error. Thus the estimators will be presented as having greater precision than is justified at a given α level.

If $(X_i - \bar{X}_i)^2$ and σ_{μ}^{2} are negatively associated, the bias will be positive. Thus the calculated standard error will be larger than the actual standard error and the estimated coefficients will be more precise than is indicated by the conventional statistical tests. Thus the estimated error terms were plotted against the squared deviations from the mean of each of the independent variables. The distribution of the observed error term was used as a proxy for the variance of the true error term.

day, can be expected to decrease with increases in the number of days hunted.

Looking across individuals, those who have greater success opening day would be expected to have a greater demand the second day, and so forth. However, at the completion of the season, those hunters who did demand more hunting as the result of greater success on any given day will probably have a lower average success per pheasant hunting day than those who stopped hunting after opening weekend.

Examination of the Malheur County data showed the average success to be 1.57 birds bagged per day for all hunters compared with 1.90 birds bagged per day for those who hunted only opening weekend. Thus, the negative coefficient results from the expost aggregate analysis of individual data.

The overall effect of hunting success is measured by the sum of the effects of both total success and average success. Thus, the negative coefficient of average success serves as a correction factor and should not be considered as an indicator of a causal relationship, i.e., that with increases in average success the demand for pheasant hunting days will decrease. The net effect of increases in success is to increase the demand for pheasant hunting days.

Given the predominately positive bias of the standard errors it is believed that the R^2 of 0.605 reported for equation (21) represents a minimum value for the proportion of the variance in days of pheasant hunting demanded per hunter explained by the independent variables.

Calculations of the 1971 Demand Curve for Pheasant Hunting in Malheur County

To determine the relationship between price of a pheasant hunting day and the quantity demanded, a trade-off function developed from the Oregon big game study (Nawas, 1972) will be applied to equation (21) in the manner developed in Chapter III.

The characteristics of pheasant hunting in Malheur County are most similar to big game hunting in the Northeast Region of Oregon. That is, both areas represent the finest hunting areas of the state for their respective game. In addition most hunters who hunted these areas come from outside the hunting region. Thus the trade-off function between transfer costs and one-way measured distance will be developed from the demand curve estimated for big game hunting trips to the Northeast region, equation (22) (Nawas, 1972, p. 103).

(22) Trips/hunter = 1.6939 - 0.006660 (Costs) - 0.007128 (Distance) - 0.4548 (Success) + 0.3783 (Hunters in family)

Following the procedure developed in Chapter III the trade-off coefficient, λ_1 = relative effect of transfer cost = $\hat{\beta}_1/(\hat{\beta}_1+\hat{\beta}_2)$ will equal 0, 4830. The estimated demand equation for pheasant hunting days per hunter for Malheur County (23) is obtained by applying λ_1 to equation (21). Thus $\hat{B}_P^* = \lambda_1\hat{\gamma}_1 = (0.4830)(0.00114) = 0.00055$, and $\hat{B}_{T_1}^* = \lambda_2\hat{\gamma}_1 = (1-\lambda_1)(\hat{\gamma}_1) = (0.5170)(0.00114) = 0.00059$.

$$(23)\quad \hat{Q}_i = 4.9247 - 0.00055\,(P)_i - 0.00059\,(T_1) + 0.5583\,(TS)_i - 2.3142\,(S)_i$$

The average transfer cost per pheasant hunting day can be determined by substituting the mean values of Q, D, TS, and S into equation (23) and solving for $\overline{P}$.

$$(24)\quad 4.4972 = 4.9247 - 0.00055\,(\overline{P}) - 0.00059\,(229.1) + 0.5583\,(6.21) - 2.3142\,(1.57)$$

$$(25)\quad \therefore\ \overline{P} = \$229.24$$

An average transfer cost per day of pheasant hunting equal to \$229. 24 is not an intuitively pleasing estimate. It seems extremely high. Even if a hunter were to return home after each hunting day his travel costs would amount to less than \$50 per day at ten cents per mile.

The implication of this extreme estimate is either that our basic assumption underlying the use of the trade-off function is incorrect; that is, pheasant hunter's trade-off function between transfer costs and travel time is not the same as big game hunter's trade-off function, or there is not a sufficient degree of similarity between the specification of the demand equation for pheasant hunting and the demand equation for big game hunting. In the big game study, demand was estimated using trips per hunter as the dependent variable. Thus λ_1 actually measured the contribution of transfer costs per trip per hunter relative to the total effect of transfer costs per trip per hunter and one-way measured distance per trip. Application of λ_1 to equation (21) therefore assumed that pheasant hunters have the same trade-off function between transfer costs per day per hunter and one-way measured distance as big game hunters have between transfer costs per trip per hunter and one-way measured distance.

Two plausible alternative specifications exist. Demand for pheasant hunting can be expressed in terms of trips, or travel time costs can be expressed in terms of one-way measured distance per day. Both alternatives would result in a demand equation for pheasant hunting which would be more parallel to the demand equation for big game hunting expressed in equation (22), since travel time costs would be per unit of the dependent variable. The use of trips instead of days as the quantity variable has the disadvantage of implying that all trips, whether for one day or two weeks, would be valued equally by the hunter. Thus, the second alternative of expressing travel time costs in terms of one-way measured distance per day was selected. To use either procedure a conversion rule will have to be developed to convert pheasant hunting days into pheasant hunting trips.

It is assumed that hunters living within 100 miles of the hunting area will return home after each day's hunt. Thus, one trip will be allotted for each hunting day. Hunters living from 100 to 200 miles from the hunting area are assumed to stay in the county hunted, if hunting for more than one day. Those who hunted up to three days are assumed to have taken only one trip, opening weekend. A possession limit of nine pheasant or three daily bag limits often encourages Umatilla and Malheur County hunters to return home on Monday after some early morning hunting.[20/] For the rest of the season these hunters are assumed to be making two-day trips; in most cases this would be limited to weekend hunting. Given that there were only five weekends during the 1971 season, hunters who hunted more than 11 days must have taken time off from work, been unemployed, or retired. For hunters who live between 100 miles and 200 miles away from the hunting area but hunted 12 to 30 days, only one trip has been allotted.

[20/] Phone conversation with Robert Mason, Superintendent, Malheur Game Management District.

A tabular presentation of the conversion rule appears in Table 6. Measured one-way distance from the hunter's city of residence to the nearest border of the hunting area served as the allocation criterion.

Table 6. Conversion of pheasant hunting days into pheasant hunting trips. (see footnote 21, p. 80).

Measured one-way Distance from Hunter's Residence to Nearest Border of Hunting Area in Miles	Number of Days Hunted Pheasant	Number of Pheasant Hunting Trips
D < 100	1-30	Same as days
100 $\leq$ D < 200	1-3	1
	4-5	2
	6-7	3
	8-9	4
	10-11	5
	12-30	1
200 $\leq$ D < 500	1-5	1
	6-7	2
	8-9	3
	10-30	1
500 $\leq$ D	1-30	1

Hunters traveling from 200 to 500 miles are assumed to spend up to five days on their initial trip. Gibbs (1969) has found that recreationists who travel further to a site usually spend a greater length of time recreating at that site. The second and third trips are again assumed to be two-day trips. Hunters residing from 200 to 500 miles from the hunting area, who hunted more than ten days, are assumed to have made only one trip.

Hunters living over 500 miles from the hunting area are assumed to have made only one trip irrespective of the number of days hunted. [21/]

Using the conversion rule, the number of pheasant hunting trips was computed for each of the 355 hunters who reported to have hunted in Malheur County. The travel costs per day expressed in terms of one-way measured distance per day could then be computed by dividing the one-way measured distance per trip by the number of days per trip for each hunter.

The following equation was estimated using the converted questionnaire data for Malheur County.

[21/] To determine how sensitive the estimates of consumer's surplus were to the conversion rule developed, an alternative rule was also examined. This assumed that those individuals who lived within 100 miles of the hunting area would return home each night, i.e., each hunting day would represent a hunting trip. For individuals living more than 100 miles from the hunting area it was assumed that all their hunting days would be taken during one trip. It is believed that this alternative conversion rule represents the extreme and would result in a lower bound for the consumer's surplus estimate, <u>ceteris paribus</u>. Using the distance based transfer cost model which will be discussed later, the average consumer's surplus for Malheur County hunters per season was estimated using each of the conversion rules. The result was $681.04 using the original conversion rule and $651.14 using the extreme rule. Thus, the consumer's surplus estimate is not very sensitive to the conversion rule developed.

(26) $\hat{Q}_i = 5.1317^{*} - 0.005178\,(D/Q)_i^{*} + 0.5429\,(TS)_i^{*}$
(18.28) (-3.40) (20.66)

$-2.2459\,(S)_i^{*}$ 22/

(-14.47)

$*R^2 = 0.626$
$\bar{R}^2 = 0.623$
$n = 355$

where Q_i, TS_i, and S_i are as defined for (21) and $(D/Q)_i$ denotes one-way measured distance per day.

The mean values for each of the variables are:

(27) $\bar{Q} = 4.535$

$\overline{(D/Q)} = 90.94$

$\overline{TS} = 6.26$

$\bar{S} = 1.569$

The λ_1 value of 0.4830 will again be used to separate out that portion of the coefficient of distance which is due to transfer costs per day and that portion which is due to travel time per day. Applying λ_1 to equation (26) results in

(28) $\hat{Q}_i = 5.1317 - 0.0025\,(P)_i - 0.0026\,(T_1)_i$
$+ 0.5429\,(TS)_i - 2.2459\,(S)_i$

22/ The t-values and R^2 presented for equation (26) and all subsequent models represent minimum values as the variance of each coefficient was positively biased due to heteroskedasticity.

Based on equation (28) the average transfer costs per day will equal \$93.80 and the consumer's surplus will equal \$4,113.24 per Malheur County hunter. These exorbitant figures indicate that the correspondence between the pheasant hunting data and the big game hunting data is still not adequate for use of the trade-off function developed from the demand for big game hunting.

A possible explanation for the inflated estimates which resulted through use of the trade-off function is the difference in one-way measured distances between the big game data and the pheasant hunting data. Nawas did not use individual observations of one-way measured distance but instead used distance zone averages.[23/] In the case of the Northeast region, measured distance for the 26 zones outside of the region ranged from 37 miles to 269 miles. This compares with a range of two miles to 1,015miles for individual observations on one-way distance for Malheur County pheasant hunters. The range of the important distance observations is four times greater for the pheasant hunting data.

Given that the distance zones used in the big game study covered the same geographical area as the individual observations for pheasant hunters, the coefficient of the distance variable will be four times smaller using individual observations than it would be

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[23/] Though he suggests "it might have been better to have used the measured distance for each observation" (Nawas, 1972, p. 104).

using distance zone averages.[24/]

To adjust for the variation in distance measurement, the coefficients of one-way measured distance per day in equation (26) should be increased by a magnitude of four and the average one way measured distance per day decreased by a magnitude of four. Applying the trade-off coefficient to the adjusted equation will produce a new estimated demand equation for pheasant hunting in Malheur County.

$$(29)\quad \hat{Q}_i = 5.1317 - 0.0100\,(P)_i - 0.0107\,(T_1)_i + 0.5429\,(TS)_i - 2.2459\,(S)_i$$

[24/] A more accurate measure of the variation in the magnitude of the coefficient of the distance variable would be the ratio of the average zone averaged distance with the average of individual observations. Unfortunately, Nawas reports only the range of the zone averaged distance and does not report the averages for each of the zones nor the overall average for each hunting region.

Comparison of the range of the distance observations will give an unbiased estimate of magnitude of the differences in the distance coefficients only when the hunters are distributed evenly over the same geographical area. If hunters are concentrated close to the hunting area, i. e., only a few at the extreme distances, the correction factor will be overestimated by comparison of the ranges. This will lead to an underestimation of the consumer's surplus.

If hunters are concentrated at the upper end of the distance range the correction factor will be underestimated. In this case the estimated consumer's surplus would provide an upperbound.

The estimate of consumer's surplus using the trade-off method is very sensitive to the correction factor developed; i. e., the estimated consumer's surplus will vary proportionally to changes in the correction factor.

Given the mean values for Q_i, TS_i, and S_i presented in (27) and a mean value of 22.74 for deflated one-way measured distance per day, T_1, the average transfer cost per pheasant hunting day in Malheur County is calculated to be \$22.76. The average consumer's surplus calculated from equation (29) equals \$1,028.31 per hunter per season. This implies that the average Malheur County pheasant hunter would be willing to pay \$1,028.31 more than he actually does pay in order to hunt pheasant in Malheur County. The price elasticity of demand calculated at the means equals -0.0502.

The use of a trade-off function estimated from earlier studies on similar activities could provide a valuable short cut in the estimation of the demand for outdoor recreation. To determine if reasonable estimates of average price and consumer surplus have been developed through use of the trade-off coefficient, the demand for Malheur County pheasant hunting will be re-estimated using distance based transfer costs as a proxy for price. Since this method will consider only the dollar costs of the hunting trip, a negative bias is expected in the resulting consumer surplus estimate (Knetsch, 1963).

Total distance traveled during each hunting trip was calculated by doubling the one-way measured distance from the hunter's home to the hunting area. Total variable transportation costs per trip was then calculated using an average transportation cost of six cents per mile as determined by Guedry (1970).[25/]

Malheur County hunters traveled an average of 181.88 miles per day of pheasant hunting.[26/] This estimate was obtained by dividing the total miles per visit by the average days per visit for each hunter. The average miles per day for each of the hunters were then summed and divided by the number of hunters. An average transportation cost of $10.91 was computed.

Assuming that transportation costs represent 35 percent of total transfer costs,[27/] the average transfer costs per day of pheasant hunting in Malheur County would equal $31.18.

[25/] Guedry computed the average gas, oil, and maintenance cost per mile from data collected on 444 vehicles from recreationists in the Bend Range District of the Deschutes National Forest in Oregon. Average variable transportation costs ranged from $0.0493 per mile for van campers to $0.1081 per mile for trucks pulling trailer campers. The average overall vehicle was $0.06008 per mile. Reported in Table 3, Appendix 2, page 368 of Guedry, the consumer's surplus estimate will vary proportionally to increases or decreases in the transportation cost per mile assumed (Guedry, 1970).

[26/] Using the extreme conversion rule stated in footnote 21 Malheur hunters traveled 174.12 miles per day of pheasant hunting.

[27/] Brown, Singh, and Castle (1964, p. 27) found transportation costs represented 29.32 percent of total current expenditures for salmon and steelhead fishermen in Oregon. Nawas found transportation to represent 31.4 percent of the total variable expenditures of big game hunters in Oregon (Brown, Nawas, Stevens, 1973, p. 25). Neither the salmon-steelhead, nor the big game study attempted to remove at home food expenditures from those occurring while recreating. If no additional food, beverage, and liquor expenses were incurred due to the recreation experience, transportation costs would represent 45 percent and 44 percent of total variable expenditures in the respective studies. If at home food expenditures averaged one half of recreational food, beverage, and liquor expenses, transportation costs would represent 35 percent and 36 percent of total variable expenditures for salmon and steelhead fishing trips and big game hunting trips, respectively.

The demand equation for pheasant hunting days estimated as a function of total success, average success, and transfer costs per day is presented in (30).

$$(30)\quad \hat{Q}_i = \underset{(18.28)}{5.1317^*} + \underset{(20.66)}{0.5429\,(TS)^*} - \underset{(-14.47)}{2.2459\,(S)^*} - \underset{(-3.40)}{0.0151\,(P)^*}$$

$$*R^2 = 0.626$$

$$\bar{R}^2 = 0.623$$

$$n = 355$$

with mean values of $\bar{Q} = 4.535$, $\overline{TS} = 6.259$, $\bar{S} = 1.569$ and $\bar{P} = \$31.18$.

Based on equation (30) the average consumer's surplus of Malheur County hunters will equal $681.04. The price elasticity of demand calculated at the means equals -0.1037.

It was stated earlier that the demand function could also be estimated using trips as the dependent variable. This method was rejected because it would imply that all trips would be valued equally by the hunter.

To determine what the differences in the resulting consumer's surplus estimate would be, equations (29) and (30) were rerun using trips as the dependent variable and expressing transfer cost and average success on a per trip basis. The resulting equations, (31) and (32), using the trade-off method and the transfer cost method, respectively, and their consumer's surplus estimates appear in Table 7.

Table 7. Summary of the four methods of estimating the demand for pheasant hunting in Malheur County, 1971.

Equ. #	Method of Estimation	Constant	$\hat{B}_P$	$\hat{B}_{T_1}$	$\hat{B}_{TS}$	$\hat{B}_S$	R^2	Consumer's Surplus per Hunter per Season	Consumer's Surplus per Hunter Day	e
(29)	Trade-off Method $\hat{Q}$ Days	5.1317 (18.28)	-.0100	-.0107	.5429 (20.66)	-2.2459 (-14.47)	.626	$1,028.31	$226.75	-.0502
(30)	Distance-based Transfer Cost Method $\hat{Q}$ Days	5.1317 (18.28)	-.0151 (-3.40)		.5429 (20.66)	-2.2459 (-14.47)	.626	$681.04	$150.17	-.1037
(31)	Trade-off Method $\hat{T}$ Trips	3.1271 (11.92)	-.0065	-.0069	.4692 (16.91)	-.6082 (-11.47)	.585	$668.06	$93.47	-.1285
(32)	Distance-based Transfer cost Method $\hat{T}$ Trips	3.1271 (11.92)	-.0098 (-4.03)		.4692 (16.91)	-.6082 (-11.47)	.585	$443.38	$62.04	-.2632

The distance based transfer cost models (30) and (32) assume that the disutility of overcoming distance is only a function of money costs. Following the argument of Knetsch (1963) the estimated recreational benefits per hunter per season would contain a serious conservative bias.

Using the trade-off coefficient method both the money costs and the travel time costs are considered in estimation of the recreational benefits. This resulted in estimates of consumer's surplus which were 50 percent higher than those developed using the transfer cost method.

Using the trade-off method the magnitude of the consumer's surplus estimates is inversely related to the magnitude of the assumed trade-off coefficient, λ_1. If pheasant hunters' trade-off function between transfer costs and travel time were such that λ_1, the relative effect of transfer costs, was 0.75 instead of the 0.4830 estimated from the big game method, then the estimate of consumer's surplus would be reduced. Specifically, a value of \$434.62 would be generated using trips as the dependent variable.

Likewise, the estimates derived from the transfer cost models are directly dependent on the estimated transportation cost per mile and inversely related to the proportion of transfer costs made up by transportation costs. If on the average two hunters shared all transportation costs, the average transportation cost per hunter per mile would drop to $0.03 and the estimated consumer's surplus derived from the distance-based transfer cost model would be halved.

Cross-sectional demand models for pheasant hunting days in Umatilla County and the Willamette Valley will now be estimated using both the trade-off function method and the distance derived transfer cost method. These will provide further tests of the trade-off function method of estimating the demand for recreation as well as providing estimates of the net willingness to pay of pheasant hunters in each of the two hunting areas.

Umatilla County Model

Umatilla County is part of the Columbia Basin habitat area which includes 1,999 square miles of habitat and provides some of the best pheasant hunting in the state. Being a more populated area than Malheur County, approximately 70 percent of the hunters reside within the Umatilla County boundaries.

Two hundred and twenty-two of the returned questionnaires were from individuals who hunted pheasant in Umatilla County. One-way distance to the hunting area ranged from 18 miles to 1,018 miles for hunters residing outside of the county.

The demand for pheasant hunting days will first be estimated using the trade-off function method. λ_1, the trade-off coefficient, will be set equal to 0.4830, the value derived from the big game hunting demand model for the Northeast region. It is believed that the geographic dispersion of Umatilla County pheasant hunters is most similar to that of the Northeast region big game hunters.

A deflation factor of four will again be used so that the coefficient of the important distance variable will be comparable between the two studies.[28/]

Ordinary least squares was used to estimate the following days per hunter relationship.

$$(33)\quad \hat{Q}_i = \underset{(15.92)}{6.6074^{*}} + \underset{(8.66)}{0.7668}\,(TS)_i^{*}$$

$$- \underset{(-9.14)}{4.0584}\,(S)_i^{*} - \underset{(-1.69)}{0.0300}\,(D/Q)_i^{**}\ \text{29/}$$

$$^{*}R^2 = 0.340$$

$$\bar{R}^2 = 0.331$$

$$n = 222$$

where Q_i, TS_i, S_i, and (D/Q_i) are as defined for equation (26).

28/Since hunters are concentrated close to the hunting area the correction factor of four based on comparison of the ranges will lead to an underestimation of the consumer's surplus, ceteris paribus.

29/The t-values and R^2 represent minimum values as the variance of each coefficient was positively biased due to heteroskedasticity.

The mean values of each of the variables are:

$$(34) \quad \bar{Q} = 5.667$$

$$(\overline{D/Q}) = 7.77$$

$$(\overline{TS}) = 3.81$$

$$(\bar{S}) = 0.894$$

Using $\lambda_1 = 0.4830$ as a measure of the relative effect of transfer cost to the total effect of transfer cost and travel time cost, the demand equation for pheasant hunting days in Umatilla County during the 1971 pheasant hunting season is estimated.

$$(35) \quad \hat{Q}_i = 6.6074 - 0.0145\,(P)_i - 0.0155\,(T_1)_i + 0.7668\,(TS)_i - 4.0584\,(S)_i$$

The average transfer cost per hunting day can be computed using the mean values (34) and equals \$7.60. Based on equation (35) the average consumer's surplus per Umatilla pheasant hunter will equal \$1,107.42 per season. The demand elasticity calculated at the mean equals -0.0194.

Estimating the demand for pheasant hunting days as a function of transfer costs per day, total success and average success using the transfer cost method developed earlier results in equation (36).

$$(36)\ \hat{Q}_i = 6.6074^{*} + 0.7668\ (TS)^{*} - 4.0584\ (S)^{*} - 0.0219\ (P)^{**}$$
$$(15.92) \quad (8.66) \quad (-9.14) \quad (-1.69)$$

$$^{*}R^2 = 0.340$$

$$\bar{R}^2 = 0.331$$

$$n = 222$$

with mean values of $\bar{Q} = 5.667$, $\overline{TS} = 3.81$, $\bar{S} = 0.894$ and $\bar{P} = \$10.67$ and demand elasticity = -0.0407.

Based on equation (36) the average consumer's surplus of Umatilla County pheasant hunters will equal $733.22. Again this estimate will contain a serious conservative bias. As in the case of the Malheur County models the distance based transfer cost model estimates net recreational benefits to be approximately two-thirds of the benefits estimated by use of the more comprehensive trade-off function method.

Using trips as the dependent variable and expressing transfer costs and average success on a per trip basis resulted in equations (37) and (38) which are reported in Table 8.

Willamette Valley Model

The Willamette Valley contains 2,434 square miles of pheasant habitat, the majority of which is in private ownership. In 1970, 31,680 individuals hunted and bagged 60,370 pheasant within the valley; this compared to 65,420 pheasants bagged by 8,800 Malheur

Table 8. Summary of the four methods of estimating the demand for pheasant hunting in Umatilla County, 1971.

Equ. #	Method of Estimation	Constant	$\hat{B}_P$	$\hat{B}_{T_1}$	$\hat{B}_{TS}$	$\hat{B}_S$	R^2	Consumer's Surplus per Hunter per Season	Consumer's Surplus per Hunter Day	e
(35)	Trade-off Method	6.6074	-.0145	-.0155	.7668	-4.0581	.340	$1,107.42	$195.42	-.0194
	$\hat{Q}$ Days	(15.92)			(8.66)	(-9.14)				
(36)	Distance-based transfer cost Method	6.6074	-.0219		.7668	-4.0581	.340	$733.22	$129.38	-.0407
	$\hat{Q}$ Days	(15.92)	(1.69)		(8.66)					
(37)	Trade-off Method	5.3704	-.0064	-.0072	.5009	-1.4744	.248	$1,953.12	$260.07	-.0221
	$\hat{T}$ Trips				(5.52)	(-6.05)				
(38)	Distance-based transfer cost Method	5.3704	-.0098		.5009	-1.4744	.248	$1,275.50	$169.84	-.0282
	$\hat{T}$ Trips	(12.46)	(-1.39)		(5.52)	(-6.05)				

County hunters. Thus the valley, while it provides an opportunity for pheasant hunting, is not presently considered to be an excellent pheasant hunting area.

The Willamette Valley also contains the major population centers of the state: Portland, Salem, and Eugene. Due to these heavy population concentrations, the valley receives the greatest number of pheasant hunters of any hunting area in the state.

There were 512 hunters in the sample who hunted in the Willamette Valley. Only 89 hunters hunted outside of their county of residence. Distance was measured from the city of residence to the nearest border of the county in which they reported hunting; either Benton, Lane, Linn, Marion, Polk or Yamhill County. One hunter whose residence was in Paso Robles, California, was excluded from the sample for having extreme mileage. It is believed that his trip was not primarily for pheasant hunting.

Pheasant hunting in the Willamette Valley and the geographical dispersion of Willamette Valley pheasant hunters is most similar to big game hunting in the Northwest Region and the geographic dispersion of Northwest Region big game hunters. Thus, the trade-off function will be developed from the demand equation estimated for big game hunting in the Northwest Region (39) (Nawas, 1970, p. 109).

(39) Trips/hunter = 0.0307 - 0.007172 (Costs) - 0.009720 (Distance)

- 0.2898 (Success) + 0.4880 (Hunters in Family)

$$\lambda_1 = \frac{0.007172}{0.016892} = 0.4246$$

The demand equation for pheasant hunting days in the Willamette Valley during the 1971 season (40) was calculated using 511 observations and a λ_1 value of 0.4246. A correction factor of 6.7 was used to adjust individual observations to zone averaged observations.

$$(40)\ \hat{Q}_i = \underset{(25.18)}{3.9609^*} - \underset{(-2.86)}{0.0536\,(P)_i^*} - \underset{(-2.86)}{0.0724\,(T_1)_i^*}$$

$$+ \underset{(18.78)}{1.2115\,(TS)_i^*} - \underset{(-13.84)}{4.0207\,(S)_i^*}$$

$$*R^2 = 0.419$$

$$\bar{R}^2 = 0.416$$

$$n = 511$$

Using mean values of $\bar{Q} = 3.920$, $\bar{T}_1 = 1.04$, $\overline{TS} = 1.354$ and $\bar{S} = 0.386$ the mean transfer cost per day is calculated to be $1.01. The average consumer's surplus of Willamette Valley hunters calculated from the trade-off function method is $143.34. The elasticity of demand calculated at the means equals -0.0138.

Using the distance based transfer cost method the estimated demand equation is

$$(41)\quad \hat{Q}_i = \underset{(25.18)}{3.9609^{*}} + \underset{(18.78)}{1.2115\,(T\$)_i^{*}} - \underset{(-13.84)}{4.0207\,(S)_i^{*}} - \underset{(-2.86)}{0.0551\,(P)^{*}}$$

$$^{*}R^2 = 0.419$$

$$\bar{R}^2 = 0.416$$

$$n = 511$$

where the average transfer cost per day equals \$2.38. Based on equation (41) the average consumer's surplus is computed to equal \$139.44. The elasticity of demand equals -0.0330.

The demand equation which resulted from each of the two methods using trips as the dependent variable appears in Table 9, equations (42) and (43).

In the case of the Willamette Valley both the transfer cost method and the trade-off function method yield similar results. The transfer cost method still results in a smaller value as expected. The average distance traveled per day of pheasant hunting is only 13.89 miles, thus the negative bias introduced by ignoring the travel time costs would not be expected to be great.

In general the trade-off function method has been found to be an effective method of estimating the demand for recreation in cases where the geographic dispersion of recreationists is similar to that of the recreationists in the original sample.

Table 9. Summary of the four methods of estimating the demand for pheasant hunting in the Willamette Valley, 1971.

Equ. #	Method of Estimation	Constant	$\hat{B}_P$	$\hat{B}_{T_1}$	$\hat{B}_{TS}$	$\hat{B}_S$	R^2	Consumer's Surplus per Hunter per Season	Consumer's Surplus per Hunter Day	e
(40)	Trade-off Method $\hat{Q}$ Days	3.9609	-.0536	-.0724	1.2115	-4.0207	.419	$143.34	$36.57	-.0138
		(25.18)			(18.78)	(-13.84)				
(41)	Distance-based Transfer cost Method $\hat{Q}$ Days	3.9609	-.0551		1.2115	-4.0207	.419	$139.44	$35.57	-.0330
		(25.18)	(-2.86)		(18.78)	(-13.84)				
(42)	Trade-off Method $\hat{T}$ Trips	3.9876	-.0640	-.0868	1.2040	-4.0067	.416	$118.58	$30.25	-.1889
		(25.75)			(18.57)	(-13.76)				
(43)	Distance-based Transfer cost Method $\hat{T}$ Trips	3.9876	-.0657		1.2040	-4.0067	.416	$115.48	$29.29	-.0454
		(25.75)	(-4.38)		(18.57)	(-13.76)				

The actual estimates of consumer's surplus estimated through use of the trade-off function are believed to be positively biased because this method has not discounted for food, beverage, and liquor expenditures which would have occurred at home. Thus, the consumer's surplus estimated by the trade-off function method can be considered an upper bound on the net willingness to pay of pheasant hunters. The consumer's surplus estimated through use of the transfer cost method can be considered a lower bound, since the effects of travel time were not considered.

These consumer's surplus estimates can now be used to estimate the net loss in the value of Oregon pheasant hunting which accompanied the use of mercury fungicides in Oregon.

VI. CONCLUSIONS

Through use of the time series models developed in Chapter IV a loss of 17,062 hunters from the 1971 pheasant hunter population has been attributed to the knowledge of the presence and dangers of mercury in Oregon's pheasants. This represents 92 percent of the actual decrease in hunter numbers from the 1970 season to the 1971 season.

The demand for pheasant hunting days of those hunters who remained in the hunter population was found to be unaffected by the knowledge of mercury or by associated changes in hunter numbers and success.

An estimate of the loss of consumer's surplus to those hunters who discontinued hunting is developed using the weighted average of the consumer's surplus estimates developed in Chapter V. If the loss in hunters was proportional to the number of hunters in each area, the weights for each area would equal the percent of the total hunters in all three areas represented by the hunters in a given area. However the loss of hunters was not proportionate to the number in each area. Estimates of the number of pheasant hunters in each area during the 1970 and 1971 hunting seasons developed by the game commission show no decrease in the number of Malheur County hunters (Oregon State Game Commission, 1970, 1971). A decrease of 13,380 hunters is reported for the Willamette Valley, and a loss of 2,150 hunters from the Northeast region. The Southwest and Central regions reported decreases of 790 and 1,890 hunters, respectively, while in the Great Basin area of the Southeast region, hunter numbers were down by 550.

The weights for each area will be the number of hunters lost from that area divided by the number of hunters lost from both the Willamette Valley and the Northeast region. Thus, a weight of .86 will be attached to the consumer's surplus of Willamette Valley hunters and .14 for Umatilla County hunters, since they represent hunters of the Northeast region. The consumer's surplus estimates are those which were developed using pheasant hunting days as the dependent variable. The estimate generated by use of the trade-off model will serve as an upper bound and the estimate generated by the distance based transfer cost model will serve as a lower bound. The weighted upper bound of the loss of consumer's surplus per hunter is estimated to be equal to $278.31 per season. The weighted lower bound equals $222.57 per hunter per season. On a daily basis the loss in net economic value per hunter has an upper bound of $58.81 and a lower bound of $48.70. Thus, the net loss in the value of Oregon pheasant hunting which can be attributed to the use of mercury fungicides in Oregon will have an upper bound of 4.7 million dollars and a lower bound of 3.8 million dollars.

All consumer's surplus estimates are derived from the average demand function of those hunters who hunted during the 1971 pheasant hunting season. Their demand was found to be unaffected by the knowledge of mercury contamination. The use of these consumer's surplus estimates assumes that the average demand function of those hunters who discontinued hunting would be identical to the average demand function of the 1971 pheasant hunters, in the absence of any knowledge of the mercury contamination.

The actual loss of revenues to the merchants who provide goods and services to Oregon pheasant hunters, which resulted from these hunters discontinuing their pheasant hunting, was equal to $16.48 per hunter per season using the average transfer cost estimates developed from the trade-off method or $9.43 per hunter per season using the average transfer cost estimates developed from the distance-based transfer cost method. This implies an actual loss of revenues to these merchants in the range of $160,894.66 to $281,181.76 as the result of the knowledge of the presences and dangers of mercury in Oregon's pheasants. Neither of these estimates includes the multiplier effect nor do they include any investment expenditures for durable equipment such as shotguns, campers, special clothing, or other equipment.

To the extent that hunters substitute other goods and activities for their pheasant hunting experience, these funds would be spent and could result in either increased or decreased revenues within the state depending on the relative multiplier effects.

Limitations on the Trade-off Method Estimates of Average Transfer Costs and Average Consumer's Surplus

The trade-off method was used to allow for the non-monetary costs of travel to the hunting area. An explicit assumption was that pheasant hunters would have the same trade-off function between transfer costs and travel time costs as those exhibited by big game hunters. Implicit in this assumption, was that the trade-off of big game hunters was in fact measured correctly in estimates of the demand for big game hunting developed by Nawas (1972).

Initial runs on the raw data of the big game study resulted in inefficient estimates of the important variable cost coefficient due to the high degree of multicollinearity between transfer costs and distance. Distance made up approximately 31 percent of total variable expenditures for big game hunting trips. Thus, Nawas' raw data provided the same problem observed in earlier studies by Brown, Castle, and Singh (1964) and Stevens (1966). That is, the inclusion of distance to reduce specification bias resulted in reduced efficiency of the coefficients due to multicollinearity.

However, in Nawas' case instead of discarding distance entirely, he simply broke it up into more discrete units. By reducing the continuous nature of the variable, naturally the degree of multicollinearity decreased. If this procedure is to be theoretically accepted an implicit assumption must be made; that hunters view the disutility of travel time as a discrete step function, i.e., a relatively long distance must be added to a trip before the disutility of travel is increased. In terms of time this may represent one to two hours. This assumption is intuitively acceptable to this writer. Thus it is the nature of Nawas' travel time measure, zone averaged one-way distance from zone of residence to the nearest border of the hunting area, which allows for increased stability on the price variable when distance is also included in the model.

Nawas argues that the use of individual observations on his distance variable as opposed to zone averaged distance would have improved his model since other variables were based on individual trip observations. In light of the preceding discussion, an improvement would have resulted only if the decreased difference in the distance measure between individuals more nearly represented the unit by which the disutility of time is measured by the hunter.

Having accepted the method used by Nawas for developing the demand curves which I have reported in equations (22) and (39), the trade-off coefficient could be estimated. This coefficient was then applied to the more continuous individual observations of distance obtained from the pheasant hunter questionnaires. Given that the trade-off coefficient was the average trade-off, its appropriateness at the extreme observations can be questioned.

It is believed that as distance increases the importance of travel time costs relative to the total effect of travel time costs and money costs may be greater than at the average. Likewise on short trips the travel time costs would probably have less of a relative effect than for the average trip. In fact, the effects of travel time may even be positive for short trips with anticipation of the hunt. The joint effect of these variations from the average trade-off coefficient would be to rotate the estimated demand curve so that its intercept with the price axis would be a higher value and its intercept with the quantity axis would be at a smaller value. Given the inelastic nature of the demand curve in the area of the means the average transfer costs would be expected to decrease and the average consumer's surplus estimates expected to increase.

As stated in Chapter V, the consumer's surplus estimates derived from the trade-off method are highly dependent on the correction factor developed to adjust the individual distance observations to the zone averaged distances used in the big game study. Because the averages of the distance zones were not reported for the big game study, the ratio of the ranges for distance observations were used. For the Willamette Valley where most hunters live in the county hunted, use of the range as the correction factor would result in underestimating the consumer's surplus per hunter. For Malheur County hunters the consumer's surplus per hunter would be positively biased as most hunters were concentrated at the far end of the distance range. Estimated consumer's surplus for Umatilla hunters is probably not biased by use of the range as their distribution was bi-modal with concentrations on each end of the range.

The overall implication of comparing the range of individual distance values and zone averaged distance values is that the average consumer's surplus of those hunters who discontinued hunting is probably underestimated using the trade-off method since it represents the weighted averages of Willamette Valley and Umatilla County hunters.

Limitations on the Estimates of Consumer's Surplus Derived from the Distance-based Transfer Cost Method

Throughout the demand analyses a constant linear relationship was assumed between transportation costs and transfer costs. This assumption was required because of the lack of actual measurements on the variable expenditures of the pheasant hunters.

The assumption that transportation costs represent 35 percent of all transfer costs is probably a very good estimate for the average individual, but as with the use of any average, its appropriateness at the extremes can be questioned.

For the case of hunters who live within their hunting area, distance traveled was set equal to one mile. This implies transportation costs of $.12 per trip and transfer costs of $.34 per trip. Given that shotgun shells usually cost about $.20 apiece, transfer costs per day are unquestionably underestimated for in county hunters. This underestimation would have the affect, *ceteris paribus*, of decreasing the average transfer cost and increasing the absolute slope of the demand curve, which may or may not affect the measure of consumer's surplus.

For hunters who are assumed to return home each evening transfer costs are probably overestimated. That is, transportation costs may be as high as 70 to 75 percent of their transfer costs per day.

Over the range of the average number of trips and the average distance traveled the estimate of 35 percent is considered to be accurate. This would also be true of individuals who traveled over the average distance but stayed over the average number of days per trip.

An overestimation of transfer costs and thus consumer's surplus may result for individuals who travel a great distance but stay fewer than the average number of days per trip, ceteris paribus.

Perhaps a superior method would have been to assume a different relationship between transfer cost and transportation costs for each major distance group. However, given the great variability in the expenditure patterns of hunters and recreationists in general, it becomes very difficult to estimate the appropriate relationship.

Bias can also be introduced by the use of a constant transportation cost of $.06 per mile. This assumes that only one hunter is traveling in the average vehicle. Thus, if two or more hunters travel together their transportation costs per hunter will be overestimated. This would imply a positive bias of the consumer's surplus estimate, ceteris paribus.

In some cases the bias introduced through use of the constant transportation cost-transfer cost relationship may be offset by the use of the average transportation cost of $.06 per mile. Individuals who travel long distances to hunt but hunt only opening weekend are likely to be using a truck and camper, or perhaps fly to the hunting area in the case of California hunters. For these hunters $.06 per mile would underestimate their transportation costs which would counter balance the overestimation of transfer costs resulting from the assumed transportation cost-transfer cost relationship.

Biases could also be introduced into the estimates derived from both estimation methods due to the limitations on the cross sectional data available. Development of both the number of hunting days and the number of hunting trips required the use of many limiting assumptions which could cause biases in the results. Specification bias may also be present due to the exclusion of observations on the number of hunters in the party, the number of total individuals, their level of income, and other socio-economic characteristics. The characteristics of the land hunted, whether it is privately or publicly owned, and whether it has stocked or native birds may also be important variables in estimating the demand for upland game hunting.

Limitations of the Time-Series Models

The use of time-series models to determine the effect of information concerning mercury was undertaken to avoid the biases which would certainly result through use of a questionnaire. The time-series models have biases of their own, however. The use of aggregate data, obtained primarily through secondary sources, removes a great deal of variability from the observations.

In the case of the days per hunter model this lack of variability in the dependent variable may have been a primary contributor to the insignificant coefficients estimated for hunter pressure, hunting success, and information concerning mercury.

The assumptions required in developing the information variable could also introduce bias into the results. While The Oregonian is a state-wide paper not all Oregonians read it, and those that do surely do not read every article. Thus, the use of column inches of articles and the cumulative number of articles as proxies for information and making inferences about the knowledge of pheasant hunters from these proxies can only be considered a first approximation.

The Mercury Problem

The decrease in the number of pheasant hunters and the associated loss of revenues to the state can be reversed due to the restrictions which have been placed on the use of mercury fungicide. On Friday, March 24, 1972, the Environmental Protection Agency ordered the suspension of federal registrations for all alkyl mercury pesticides. It also gave notice of its intent to cancel the federal registration of all other mercury pesticide products (Environmental Protection Agency, 1972).

No attempt was made by the government to recall suspended mercury products already in the hands of the distributors or on the dealer's shelves because of the serious problems related to the disposal and storage that a massive recall would create (Environmental Protection Agency, 1972).

At the request of this writer, a second sampling of Oregon's pheasants was conducted in December of 1972 and January of 1973 to determine the effects of the mercury restrictions. The Oregon State Game Commission collected a total of 43 birds from the three test areas, and Dr. Buhler and the staff of the Environmental Health Sciences Center again performed the analysis for mercury. Pheasants from Malheur County, Umatilla County, and the Willamette Valley contained average mercury concentrations in their breast muscle of .283, .006, and .085 ppm, respectively, with an average value of .011 ppm for all birds examined. The muscle of 3 out of 13 birds tested from Malheur County and 2 out of 13 birds tested from the Willamette Valley showed mercury levels in excess of the .05 ppm U.S. Food and Drug Administration guideline value. None of the Umatilla County birds exceeded the guideline. These figures indicate that mercury contamination of the pheasants is decreasing but that some "hot spots" still exist as farmers use up their remaining stock of the mercury pesticides.

If the pheasants of Oregon can be given a clean bill of health and that fact publicized, a return of the pheasant hunters can be expected.

Contributions

The results of this study must be viewed in light of the limiting assumptions which were required in their development. Recognizing the many limitations of the study, three contributions are believed to have been made:

1. The use of a trade-off function developed through the results of earlier studies appears to be an effective means of allowing for consideration of both money costs and travel time costs in the estimation of the demand for recreational activities.
2. The use of data commonly collected by recreational management organizations in combination with the results of previous detailed demand studies can provide a base for economic estimates if the assumptions required are acceptable.
3. The measurement of information flows concerning environmental contaminants may be as important as measurements of actual contaminant flows in estimating the effects of contaminants on a society.

A normative implication of this third conclusion is that public institutions should be providing information obtained through research to the public. This information would enable society's members to make their own value judgments and decrease the necessity of value judgments for the public decision maker.

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APPENDICES

APPENDIX A

World Background of the Mercury Problem

Mercury compounds are effective killers of fungi, and farmers have used them for that purpose for many years. Cereal grain seeds are particularly subject to fungus attack and mercury compounds, both powders and liquids, have been used almost universally to provide a protective coating for seeds during storage. The first mercury seed dressings were developed in Germany about 1914 and quickly spread into use. About the time of World War II, liquid preparations of a new kind of mercury compound - alkylmercury - were introduced, and became nearly the universal treatment for wheat and barley seed because of the ease of application and effectiveness of the liquid (Novick, 1969). The cereal diseases of bunt, smut, and leaf stripe have been successfully controlled by mercury treatment of the cereal seed (Study Group, 1970). The compounds were used not only to treat fungus infected seed, but also to prevent the growth of fungus in healthy seed. The use of the alkylmercury compounds became as routine in cereal production as plowing (Löfroth, 1969).

While the dangers of direct consumption of mercury or inhalation of mercury vapors have been known for centuries, it was not until the 1950's that mercury was recognized as an environmental pollutant.

During 1953-1970, 121 persons were killed or severely disabled in Minamata, Japan, as the result of eating fish which had been contaminated by mercury discharged from a plastics manufacturing plant into Minamata Bay. Of the 121, 23 were congenitally defective babies born to mothers who had eaten the contaminated fish, but who themselves had not shown signs of mercury poisoning (Study Group, 1970).

A second poisoning accident occurred in 1965 in Niigata, Japan. Studies at the Kumamoto University and the University of Niigata identified the cause of the Minamata disease as heavy consumption of fish contaminated with an organic form of mercury. This was later identified as methylmercury (Study Group, 1970).

Wildlife served its traditional role as an early warning system for man when problems with mercury arose in Sweden. Deaths, reproductive failures, and population declines of both seed-eating and raptorial birds were reported in the mid 1950's (Otterlind, Lennerstedt, 1964). Toxicity from mercury used in seed dressing was suspected. Experimental and pathological work demonstrated that the suspicions were correct. The Swedish researchers concluded that lethal and sublethal mercury poisoning appeared to be very widespread in Swedish wildlife. The heavy use of methyl and ethyl mercury compounds as a liquid seed dressing was determined to be the primary source.

Together with the Japanese, the Swedish investigators have also shown that alkylmercury compounds (methyl and ethyl) are several times more toxic than the other forms of mercury and have different effects. Alkylmercury is more readily absorbed, more firmly attached to tissue proteins, and most slowly excreted. It accumulates in the brain, destroying cells and causing neurotoxicity and death in men and animals. It passes through the placenta readily and can damage the fetus or migrate through the oviduct into the eggs. There is also some evidence that methylmercury can cause chromosome disjuncture. Unlike other forms of mercury poisoning the brain damage caused by alkylmercury compounds is irreversible (Löfroth, 1969).

In 1964 the Plant Protection Institute recommended that the amount of mercury in seed dressing be cut in half and only infected seed be treated. In October, 1965, they made the recommendation compulsory after a September 1965 scientific conference on mercury clearly implicated the agricultural use of mercury to the drastic decrease in bird populations (Löfroth, 1969).

Investigation also revealed Swedish fish contained large amounts of mercury compounds attributed to pulp and paper factories, certain chlor-alkali manufacturing plants, and a number of miscellaneous activities. Fish from certain waters were declared unfit for human consumption in November 1967.

The Swedish program of biological, ecological, and toxicological research discovered that microorganisms in the sediment of rivers, lakes, and bays will convert mercury deposited there in any form to **methylmercury** within their cell structures. The process is not well understood and requires much more study to determine the conditions that permit methylation and the rate at which it occurs in nature. However, studies show that methylmercury predominates in animals and fish even where other mercury compounds have been released, thus the process of methylation is a common and powerful natural force (Study Group, 1970).

In 1967, Norvald Fimreite, a Norwegian, came to the University of Western Ontario with a proposal to work on the effects of mercury on Canadian wildlife. During 1968-69, mercury contents of wildlife and fish were analyzed. The mercury levels found in the livers of pheasants and partridge averaged well above 1 part per million. All of the adult pheasants and Hungarian partridge collected in Southern Alberta in June and July of 1969 showed levels of mercury in their tissue above the 0. 1 parts per million tolerance level established by the Canadian Federal Food and Drug Directorate for food products (Fimreite et al., 1969). Therefore, Alberta's 1969 hunting season for pheasant and partridge was closed.

As the result of the findings in Alberta backed up by the poisoning in Japan and Sweden, various states began tests on their fish and wildlife populations early in 1970. Their action was also spurred by tragedy in Alamogordo, New Mexico where the Huckleby family was poisoned as the result of eating meat from a hog which had been fed methylmercury-treated seed.

The mercury problem can be divided into two broad parts: One relates to the toxicity of unmodified mercury pesticides and the other to the accumulations in aquatic systems of alkylated mercury from a variety of sources. The second involves a complicated and ill-defined process by which sediment can convert inorganic mercury to methylmercury by the action of microbial systems. This methylmercury can then be concentrated in the food chain of the aquatic system and present a great hazard to man if he ingests contaminated fish. The mercury contaminate in the bottom sediments represent a potential hazard for man for years to come as the methylating process continues. The mercury pesticides represent a more straight-forward threat in their toxicity to wildlife, domestic animals, and man.

APPENDIX B

MONTANA STATE DEPARTMENT OF HEALTH
Division of Environmental Sanitation

NEWS RELEASE
October 24, 1969

"Dr. John S. Anderson, Executive Officer, State Department of Health, clarifies concern regarding mercury in Montana game birds. Residuals of mercury have been found in the recent sample birds collected by the Montana Fish and Game Department.

It is believed that the mercury found in these birds is due to the consumption of grain treated with fungicides containing mercury. The birds very likely acquire the treated grain as food by digging up the treated seed or by picking up treated seed which may have been spilled in the process of sowing.

The U. S. Food and Drug Administration is not conducting research or regularly monitoring for mercury at present. A zero tolerance has been set by the Food and Drug Administration for all foods. In 1963 the Food and Agriculture Organization of the United Nations and the World Health Organization suggested a tolerance of .05 parts per million for any food. The WHO also set a maximum safe daily intake for mercury of .003 milligrams per day for an adult man which would amount to 1.1 milligrams for one year.

The mercury found in the Montana birds range from .05 to .47 parts per million.

If a man consumes a two-pound pheasant having .47 parts per million of mercury, this individual has used up his recommended intake for approximately 3 to 4 months. This is using World Health Organization recommended figures.

The pressing question is "Are upland game birds in Montana that have mercury residues in their muscle tissues a danger to man if consumed?" At the present levels of mercury no deaths or acute effects are likely to occur; however, in terms of chronic effects, research is not complete enough to determine what levels will begin to cause acute symptoms.

The analyses were performed on muscle tissue; however, the residuals in liver and kidney tissue are usually higher.

The State Department of Health recommends that an individual should not regularly consume game birds. The daily intake of foods should be varied, and if game bird liver is consumed in any form the diet should be restricted because of the possibility of higher mercury residuals being present.

There are several other sources of mercury in our diet so that it is difficult to determine the exact or even approximate yearly mercury intake.

At present levels, and if the diet is restricted, or in other words if only a few birds were consumed a year, it is unlikely that acute or long term chronic effects will occur."

APPENDIX C

Appendix Table C-1. Values of variables for time-series days per hunter per season model, 1950-1971.

Year	Q_t 1/	D_t 1/	PA_t 2/	Y_t 3/	S_t 1/	H_t 1/	I_t 4/
1971	4.5 5/	30	121.3	3264	0.7 5/	54400	655.3
1970	4.5	37	116.3	3197	0.7	72880	815.5
1969	4.5	37	109.8	3213	0.7	71840	0
1968	4.5	37	104.2	3176	0.7	67590	0
1967	4.7	37	100.0	3081	0.8	72135	0
1966	4.4	37	97.2	3009	0.8	72133	0
1965	4.3	37	94.5	2913	0.8	75373	0
1964	4.5	44	92.9	2789	0.9	81722	0
1963	4.6	44	91.7	2679	1.0	84024	0
1962	4.5	37	90.6	2603	0.9	82430	0
1961	4.4	37	89.6	2527	0.9	91117	0
1960	4.2	30	88.7	2506	0.9	94599	0
1959	4.4	37	87.3	2496	0.9	97474	0
1958	4.4	37	86.6	2390	1.0	102789	0
1957	3.9	17	84.3	2368	0.9	88691	0
1956	3.8	24	81.4	2477	0.7	83206	0
1955	3.8	23	80.2	2403	0.8	92741	0
1954	3.5	23	80.5	2262	0.9	94699	0
1953	3.4	23	80.1	2331	0.9	90441	0
1952	3.3	17	79.5	2358	0.9	82145	0
1951	3.2	17	77.8	2299	0.9	83920	0
1950	3.1	16	72.1	2247	0.8	74968	0

1/ Source Annual Reports - Oregon Game Commission.

2/ Consumer Price Index U.S. (1967=100). Economic Report of the President January, 1972

3/ Per capital personal income for Oregon - U.S. Office of Business Economics - Survey of current business, August 1972, deflated by Consumer price index.

4/ Number of columninches of articles in The Oregonian.

5/ 1971 data on average days per hunter was calculated through use of the allotment rule developed in Chapter III and weighing each area average by the number of hunters in that area.

6/ Average birds per day for 1971 calculated by multiplying calculated average days/hunter time 54,400 the number of hunters in 1971 and dividing by 167,910 birds harvested. The number hunters and the harvest were obtained from Oregon Game Commission.

Appendix Table C-2. Values of variables for time series number of hunters per season model, 1950-1971.

Year	H_t 1/	Pop_t 2/	Y_t 3/	$I_{\#c}$ 4/	S_{t-1} 1/	D	%U 2/
1971	54,400	2,143,010	3264	73	0.7	1	95.5
1970	72,880	2,102,000	3197	27	0.7	1	95.3
1969	71,840	2,075,640	3213	0	0.7	1	94.9
1968	67,590	2,050,900	3176	0	0.8	1	94.8
1967	72,135	2,006,360	3081	0	0.8	1	94.5
1966	72,133	1,999,780	3009	0	0.8	1	94.1
1965	75,373	1,972,150	2913	0	0.9	1	93.6
1964	81,722	1,906,000	2789	0	1.0	1	93.2
1963	84,024	1,856,190	2679	0	0.9	1	92.9
1962	82,430	1,825,138	2603	0	0.9	1	92.3
1961	91,117	1,816,345	2525	0	0.9	1	91.9
1960	94,599	1,772,000	2506	0	0.9	0	91.3
1959	97,474	1,777,000	2496	0	1.0	0	90.6
1958	102,789	1,728,550	2390	0	0.9	0	90.2
1957	88,691	1,737,470	2368	0	0.7	0	89.7
1956	83,206	1,734,650	2477	0	0.8	0	88.9
1955	92,741	1,690,840	2403	0	0.9	0	88.5
1954	94,699	1,662,680	2262	0	0.9	0	88.3
1953	90,441	1,636,800	2331	0	0.9	0	87.5
1952	82,145	1,602,100	2358	0	0.9	0	86.1
1951	83,920	1,568,000	2299	0	0.8	0	85.8
1950	74,968	1,532,000	2247	0	0.9	0	84.8

1/ Annual Reports - Oregon Game Commission.

2/ Oregon Economic Statistics, 1972, p. 2.

3/ U. S. Office of Business Economics - Survey of Current Business, August, 1972 deflated by Consumer's price index.

4/ Cumulative number of articles concerning the presence and danger of mercury in pheasant and the environment which appeared in The Oregonian.