Journal of Environmental Management (1993) **38**, 133–143

Sample Non-response Bias and Aggregate Benefits in Contingent Valuation: an Examination of Early, Late and Non-respondents

Michael G. Dalecki*, John C. Whitehead†§ and Glenn C. Blomquist‡

**Department of Political Science and Sociology, University of Wisconsin–Platteville, Platteville, Wisconsin 53818, U.S.A., †Department of Economics, East Carolina University, Greenville, North Carolina 27858, U.S.A. and ‡Department of Economics, University of Kentucky, Lexington, Kentucky 40506, U.S.A.*

Received 1 *May* 1992

In this paper we analyze information on contingent valuation mail survey respondents and non-respondents and find non-response bias with respect to several determinants of willingness to pay. We use data from a combination phone/mail sampling and survey approach and find significant differences between early and late respondents, late and non-respondents to the mail survey and all respondents and non-respondents to the mail survey. We fail to find support for the contention that if early and late respondents are similar, respondents and non-respondents are also similar. The range of aggregate benefit estimates narrows as response rates increase and non-response bias decreases. A weighting approach is used to correct for some of the non-response bias in aggregate benefits.

Keywords: contingent valuation, non-response bias, aggregate benefits.

1. Introduction

Contingent valuation (CV) typically involves sampling general populations to estimate the total economic value of environmental resources. Total valuation is necessary if the resource generates significant values which flow to non-users. CV can be implemented using phone interviews, personal interviews and self-administered mail questionnaires, or combinations of all three. Survey methods other than on-site personal interviews must be used to measure total and non-use value. Non-users cannot be surveyed at the resource site or found through sampling lists of hunting and fishing licenses. Because of their relatively low cost, mail surveys are frequently part of CV research designed to measure total economic values. Fortunately, evidence (Randall *et al.*, 1985; Mannesto and Loomis, 1991) suggests that CV responses in mail surveys are of the same quality as personal interviews.

A common problem with mail surveys, however, is sample non-response. Sample non-response bias characterizes (obtained) samples of the population if mail survey

§ Senior authorship is not assigned. Address correspondence to John Whitehead.

0301–4797/93/060133 + 11 $08.00/0

respondents and non-respondents are significantly different with respect to characteristics such as age, education level and income. Generalization of individual willingness to pay (WTP) values to the population will result in biased aggregate benefit estimates if the biased variables are significant determinants of WTP.

In this paper we examine sample non-response bias using a combination of phone/mail sampling and survey approaches. We analyze data which include socio-economic characteristics of non-respondents and which allow tests of non-response bias. We test for differences in characteristics of: (1) early and late respondents; (2) late respondents and non-respondents; and (3) all respondents and non-respondents. We compare individual willingness to pay and aggregate benefit estimates for waves of respondents. A weighting approach is used to illustrate a simple correction procedure for aggregate benefits estimated with biased samples.

2. Background

A low response rate to survey mailouts is often deemed a problem. The fear is that different response rates will bring with them differential response patterns by various segments of the population; some segments will be over-represented and others under-represented. This misrepresentation can introduce bias into estimated population parameters. A representative sample is what is desired. A response rate which is substantially less than 100% is a problem for benefit estimation only if the obtained sample is not representative of the population.

A low response rate does not necessarily mean that benefit estimates will be biased, but great care is warranted in examining sample data to see if such potential biases do occur. Examination is straightforward if population parameters exist with which to compare sample data. Without a population regularly enumerated (such as by the U.S. census), crude parameter comparisons can still be made. General knowledge can guide a search for patterns which should emerge if the sample is adequate. For example, a sample split 70–30 on gender when one would expect 48–52 (as when sampling the general population) is a good indication about the representativeness if theory suggests that gender matters. In a biased sample, the effect is that of a stratified random sample for which corrections have not been used; parameter estimates will be biased.

2.1. WHAT DETERMINES RESPONSE RATES?

Social exchange theory suggests that respondents balance the benefits and costs of questionnaire return (Blau, 1964; Dillman, 1978; Brown *et al.*, 1989; Mannesto and Loomis, 1991). Benefits can be tangible, such as small monetary payments, or intangible, such as personal influence on environmental policy (Randall *et al.*, 1983). The cost is the time and physical and mental effort required to complete the survey. Survey procedures which increase the benefits and reduce the costs of survey participation increase response rates. Response rates increase when specialized populations, relative to general populations, are surveyed, when the survey topic is salient, when follow-up contacts are used and when small monetary incentives are provided (Heberlein and Baumgartner, 1978; Baumgartner and Heberlein, 1984; Dillman *et al.*, 1984).

Contingent valuation surveys typically follow standard mail survey implementation guidelines, such as Dillman (1978), and it might be expected that obtained response rates would be relatively high. However, the unique nature of CV surveys makes obtaining high response rates difficult. A review of CV mail surveys of general populations published from 1982–1991 reveal that response rates have been as high as 79% and as low as 22% (Loehman and De, 1982; Walsh *et al.*, 1984; Stoll and Johnson, 1984; Bergstrom *et al.*, 1985; Sutherland and Walsh, 1985; Loomis, 1987*a*; Boyle *et al.*, 1987; Edwards, 1988; Reiling *et al.*, 1990; Sanders *et al.*, 1990; Shultz and Lindsay, 1990; Whitehead and Blomquist, 1991; Stevens, 1991).

One difficulty is that everyone in the sampling frame will not be familiar with the subject of the survey. Unfamiliarity drives response rates downward for two reasons. First, potential respondents who are unfamiliar with the topic may feel it is uninteresting and unimportant. The lower the salience of the survey, the lower the response rate. Another reason is the necessary length of text in contingent markets. If the goal of the contingent market is reliable and valid estimates of WTP, individuals who are unfamiliar with the subject must be informed. The education process usually involves a display of maps, photographs and lengthy text which describes the environmental resource. This process lowers response rates (Brown *et al.*, 1989).

2.2. NON-RESPONSE BIAS AND BENEFIT ESTIMATION

An approach that is often used to mitigate non-response bias is to produce a range of aggregate benefits. The upper bound of the range is found by assuming respondents and non-respondents are no different and aggregating over the population. In their examination of *non*-CV recreation surveys, Wellman *et al.* (1980) find that early and late survey respondents are similar in characteristics. This study has been used to justify generalization of survey respondents' WTP to non-respondents (Walsh *et al.*, 1984; Sutherland and Walsh, 1985). Mitchell and Carson (1989) and Carson (1991) question whether this comparison is enough to justify generalizing more demanding CV WTP estimates to the population based on a sample which has a low response rate. The lower bound is found by assuming non-respondents have a WTP of zero dollars. These ranges are usually quite large.

Two CV studies have explicitly examined non-response bias and its effect on aggregate benefits. Edwards and Anderson (1987) interviewed 60% of previous non-respondents and report that non-respondents were less likely to use the natural resource for recreation than respondents, but socio–economic characteristics were similar. Even so, aggregate benefit estimates fell by 17% after accounting for non-respondents. Loomis (1987*b*) finds that respondents have higher education and income levels than the general population. He shows how weighted least squares can be used to correct for non-response bias with open-ended WTP data; aggregate benefit estimates fell by 26% when using the weighted least-squares technique.

3. A sample weighting approach

Assume a population has been sampled, and, in spite of the best efforts within the given limits of time and money, a relatively low response rate, say 20%, is obtained. The sample is compared to known population parameters and is very different, leading the researcher to question the adequacy of the sample data. Rather than discard the data, an attempt to correct for the observed biases can be made. Statistical weighting is used with regularity by those who employ stratified random sampling and can be used to correct some of the non-response bias. In one sense, a biased sample generated from a non-stratified random sampling scheme is little different from a purposely stratified sample. If one can identify strata on which bias exists, one can correct for at least some of this bias by the use of statistical weighting.

Theoretical support exists for this strategy. Blau (1977) defines the social structure in terms of a network of nominal and graduated parameters. Nominal parameters are those that represent categorical variables which do not reflect order, but rather are exhaustive groupings. Gender and rural/urban residence are examples of nominal parameters of the social structure. Graduated parameters are those variables that vary continuously, such as age, education level and income. These parameters in turn directly influence patterns of interaction, mobility and social status, and indirectly influence attitudes, values, beliefs and statements of behavioral intentions (WTP) made in contingent markets. The extent to which a sample over- or under-represents these structural parameters determines the potential for non-response to influence aggregate benefit estimates.

Blau (1977) also discusses the salience of particular structural parameters which can be applied to the issue of response bias as well. For example, we may find that, on an issue such as wetlands preservation, membership in environmental interest groups is a salient variable. Yet, related to another issue, it may be unimportant. Non-response will tend to bias aggregate benefits in favor of those who find the survey topic more salient. The importance of salience is that it may be used to determine which variables should be used to weight a sample. We cannot know all the relevant strata on which to weight. However, the effort will result in a movement toward a more representative sample than is obtained in the biased situation and to make the sample a better representation of the population.

In a stratified sampling frame, the strata the sample is biased on are predetermined. One can also see what biases exist in a non-stratified sample, except that the strata were generated primarily not as a conscious result of the sampling scheme, but as the interaction of survey topic and demographic characteristics of the initial mailout sample. Weighting is a rather simple exercise if one has access to the relevant population parameters. In essence, weighting a sample is a strategy which forces the sample to conform to the population characteristics which would have been reflected in the sample if it were representative on those characteristics.

Suppose, for example, that one samples from a population known to be 50% male and 50% female. Response patterns, however, result in a sample which is 67% male and 33% female. The way to correct for this bias is to divide the population proportion by the sample proportion, for both males and females. The result is a weight that is multiplied by each individual case. For males the weighting factor would be 0·50/0·67, or 0·75; for females the weighting factor would be 0·50/0·33, or 1·50. Giving males a 0·75 weight and females a 1·50 weight would result in their apparent numbers in the sample being equal. This procedure produces the 50–50 split that would have been achieved with a perfectly representative sample.

Of course, weighting on one simple characteristic is no panacea. It is much more desirable to weight on several salient characteristics simultaneously. This is done by determining what proportion of the population belong to each of the intersections of the variables—such as the proportion of males 36 to 59 years old who have a high-school education. The variables the sample is weighted with must be nominal parameters (categorical variables). Furthermore, the fewer combinations of categories the easier it is to fill them with an adequate number of respondents.

Assuming there are population parameters to compare the sample with, observable biases can be corrected using the same technique used to reconstruct stratified random

TABLE 1. Variable descriptions

Variable names	Description; how data was gathered
Household size	Number of people in the household; phone survey
Tenure	Number of years living at current address; phone survey
Wetland knowledge	Respondent had prior knowledge of wetlands in Kentucky; phone survey (knowledge = 1, no knowledge = 0)
Age	Years of age of respondent; phone survey
Education	Years of education of the respondent; phone survey
Children	Number of children in household; phone survey
Gender	Gender of respondent; phone survey (male = 1, female = 0)
City size	Size of city on respondent mailing address (in '000s); matched from phone survey
Distance	Miles respondent mailing address is from wetlands; matched from phone survey
Conservationist	Respondent is a member or donates money to conservation/environmental organizations; mail survey (member = 1, not a member = 0)
Income	Annual household income; mail survey (1990 dollars)

samples to represent the full population from which they were drawn. Weighting procedures will not produce a perfectly representative sample, but they are likely to produce a more accurate aggregate benefit estimate than the large range which is often produced.

4. The data

A CV survey was designed to measure wetland preservation benefits in western Kentucky (Blomquist and Whitehead, 1990). A feature of the survey was a combination of phone interview/mail questionnaire formats which gathered information on every sampled household. The data, therefore, allows measurement of the extent of sample non-response bias in a CV mail survey of the general population.

4.1. THE COMBINATION PHONE/MAIL SURVEY

The target population of the survey was Kentucky households. A random digit dialing procedure, which gives any household with a phone an equal probability of being contacted, was used to draw the sample. A brief phone interview was made and socio-economic characteristics were collected. Phone respondents were then asked if they would complete a mail questionnaire, and, if so, to give their names and addresses for the mail survey list. In May 1990, the University of Kentucky Survey Research Center randomly selected and called 926 households. Of the 926 people called, 730 (79%) completed the phone interview and 641 (69%) gave their names and addresses for the mail survey. We assume that people who did not participate in the phone survey are no different than those who did participate. This assumption may not be unreasonable since the subject of the survey was not revealed until near the end of the phone interview.

Mail survey procedures followed Dillman's (1978) total design method, with three follow-up mailings, two of which included replacement survey instruments. The total number of replies is 487—67% of the households who participated in the phone survey, and 76% of those households mailed a questionnaire. Table 1 contains descriptions of

TABLE 2. Significant differences in socio–economic characteristics of respondents†

Variable	Early respondents	Late respondents	Non-respondents
Household size	2·68‡	3·15	—
	(1·26)	(1·47)	
Tenure	15·51	12·42	14·20
	(14·20)	(12·41)	(15·40)
Wetland knowledge	—	70·07%	58·19%
		(45·95)	(49·43)
Age	50·71	44·17	52·06
	(17·74)	(16·20)	(21·59)
Education	—	12·88	10·88
		(2·52)	(3·03)
Gender	—	41·70	34·91%
		(50·14)	(47·78)
Children	0·61	0·93	—
	(0·95)	(1·27)	
Sample size	214	147	232

† Pairs of variables shown are significantly different at, at least, the 0·05 level.
‡ Standard deviation in parentheses.

variables in the study and when data collection took place (phone or mail). The variables include standard socio–economic characteristics together with knowledge about Kentucky wetlands. Cases with missing data are deleted so that 361 respondents and 232 non-respondents are available for analysis. This number represents 81% of all households who participated in the phone survey.

4.2. TESTING FOR BIAS

We identified four waves of questionnaire returns based on natural breaks in the frequency distribution of responses over time. The first two waves are combined based on natural breaks in returns from the initial mailing and postcard. The third and fourth waves are based on returns from the second and third questionnaire mailings. The breaks allow comparisons of early and late survey respondents. Respondents in the first two (early) waves are combined and compared with the combined third and fourth (late) waves. This early–late comparison can illustrate how the sample differs as response rates increase with time and effort. In addition, late respondents are also compared with mail non-respondents. Finally, all respondents are combined and compared with mail non-respondents to determine the full extent of sample non-response bias.

In the first and second columns of Table 2 comparisons of variables show significant differences between early and late respondents. Compared to early respondents, late respondents have larger households, more children, shorter tenure and are younger. This result contradicts the finding of Wellman *et al.* (1980) and supports the finding of Dolson and Machlis (1991), suggesting that the costs of low mail survey effort and the resulting low response rates are potentially large. A mail survey that only retrieves completed questionnaires from early respondents produces a sample that is almost certainly not representative of the population. Extensive follow-up surveys are required to minimize the potential for early/late response bias (Dalecki *et al.*, 1988).

TABLE 3. Significant differences in socio-economic characteristics of respondents vs. mail non-respondents†

Variable	Respondents	Non-respondents
Wetland knowledge	72·30%‡	58·19%
	(44·81)	(49·43)
Age	48·17	52·06
	(17·38)	(21·59)
Education	12·87	10·88
	(2·60)	(3·03)
Gender	48·20%	34·91%
	(50·00)	(47·78)
Sample size	361	232

† Pairs of variables shown are significantly different at, at least, the 0·05 level.
‡ Standard deviation in parentheses.

In the second and third columns of Table 2 we also compare characteristics of late respondents and non-respondents to the mail survey. Compared to late respondents, non-respondents have longer tenure, less knowledge of wetlands, less education and are older and more likely to be female. This result supports the contention made by Mitchell and Carson (1989) and Carson (1991) that one cannot assume that late respondents and non-respondents are similar.

We find significant differences between all respondents and non-respondents to the mail survey (Table 3). Only variables which were collected in the phone survey are available for comparison, so, unfortunately, income and membership in conservation organizations is not known for non-respondents. Respondents have more knowledge of wetlands, more education, are younger and are more likely to be men.

5. Non-response bias and aggregate benefits

In CV research, the problem created by non-response bias for policy purposes is that biased aggregate benefit estimates result when summing sample WTP values across the population. A strategy that is recommended is to specify a range of aggregate benefits (Mitchell and Carson, 1989). The upper-bound, maximum aggregate benefit is found by summing the sample WTP across the population assuming non-respondents have similar tastes, preferences and characteristics as respondents. The lower-bound, minimum aggregate benefit is found by summing the sample WTP across the portion of the population represented by the sample assuming non-respondents have a WTP of zero dollars for the environmental resource.

The range of aggregate benefits is highly sensitive to the response rate achieved in the mail survey. As the response rate increases the probability of significant non-response bias falls and the sample WTP can be used to represent values held by non-respondents with increasing confidence. With decreasing non-response bias the upper bound becomes a more accurate estimate. The upper bound may also fall if early respondents are those most interested in the topic of the survey and those most likely to value the environmental resource. As more responses are received from those who do not value the resource the sample average WTP will fall. Summing the lower WTP value across the population will yield a lower upper bound. With increased response, the portion of the population assigned a WTP of zero dollars decreases, increasing the lower bound.

TABLE 4. Individual WTP and aggregate benefit estimates by response rate

Response wave	Response rate‡	WTP§ ($)	Aggregate benefits†		
			Minimum ($)	Maximum ($)	Range ($)
1	24%	24·40	5·90	34·16	28·26
2	39%	10·41	4·27	14·57	10·30
3	51%	11·63	6·25	16·28	10·03
4	67%	6·54	4·53	9·16	4·63

† Measured in millions of 1990 dollars.
‡ Calculated as number of returned questionnaires divided by sample size.
§ Median willingness to pay estimate.

In Table 4 we provide an illustration of the effect of response rate, and the underlying non-response bias, on aggregate benefit estimates. The Cameron (1988) technique is used to estimate sample WTP and aggregate benefits for wetlands preservation. For this work we treat each of the four waves separately to emphasize the differences in WTP produced by response waves. For each response wave we estimate logistic regression equations for the dichotomous choice responses and transform the maximum likelihood coefficients into WTP equations. With the full sample, significant determinants of WTP are age, education level and membership of conservation/environmental organizations. These results are available upon request. With these four equations we compute sample median WTP values which are used to find the minimum, maximum and range of aggregate benefit estimates for the population of Kentucky assuming 1·4 million Kentucky households (in this study, the mean WTP is undefined). See Cameron (1988) and Patterson and Duffield (1991) for a discussion of median and mean WTP.

As the response rate increases from wave 1 to wave 4, WTP decreases from $24·40 to $6·54. The decreases indicate early respondents are the types of households that value wetlands the most and later respondents value wetlands less. Marginal differences in WTP are significantly different from zero at the 5% level [Kruskal–Wallis test, $\chi^2 = 8{\cdot}78$ (3 d.f.)]. The combination of increasing response rates and decreasing sample average WTP have opposite effects on the minimum aggregate benefit estimate. The minimum aggregate benefit begins at $5·90 million after wave 1, then decreases, increases and again decreases to $4·53 million after wave 4. The effect of decreasing WTP is to decrease the upper-bound aggregate benefit estimate which falls from $34·16 million after wave 1 to $9·16 million after wave 4. The range of aggregate benefit estimates falls from $28·26 million after wave 1 to $4·63 million after wave 4.

If the purpose of these data is to supply policy makers with information about the benefits of wetlands preservation for use in benefit–cost analysis, the effect of increasing response rates can be dramatic. As the response rate increases from 24 to 67%, the range of aggregate benefits falls from 83% of the upper-bound estimate to 51%. This range at 67% response rate is only 16% of the range at a 24% response rate.

To mitigate the non-response bias we weight the sample on intersections of three variables. These three variables were significantly different for respondents and non-respondents and were important in the WTP equations: age, education level and gender. Respondents are grouped by age (18–35, 36–59 and over 59), education (less than high school graduate, high school graduate and beyond high school) and gender (male, female). Combined groupings generate 18 categories of respondents. The proportion of the population in each category is divided by the proportion of the respondent in each

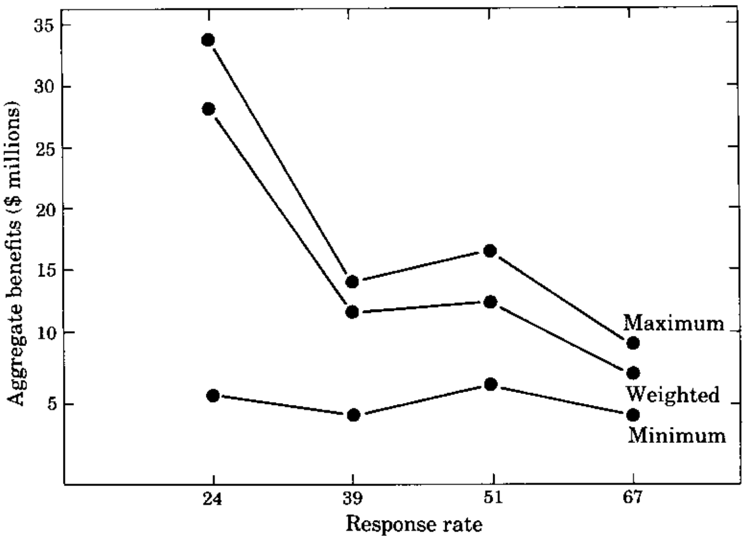

Figure 1. Weighted, minimum and maximum aggregate benefits.

category to generate 18 weights. Different weights are calculated at each response rate. Individual WTP values are then multiplied by the resulting weight to find weighted WTP and weighted aggregate benefits.

Results of weighting are summarized by Figure 1 where aggregate benefits are plotted by survey response rate. Weighted aggregate benefits are between the minimum and maximum, as expected, and display the same pattern as the maximum benefit estimate. The weighted benefit estimate falls from 83 to 70% of maximum benefits as the response rate increases from 24 to 67%. At the highest response rate, the weighted estimate almost splits the range of the minimum and maximum benefit estimates.

6. Discussion and implications

In this paper we analyze information on contingent valuation mail survey respondents and non-respondents and find non-response bias with respect to several determinants of WTP. We find significant differences between early and late respondents, late and non-respondents to the mail survey, and all respondents and non-respondents to the mail survey. We fail to find support for the contention that if early and late respondents are similar, respondents and non-respondents are also similar. Non-response bias cannot be assumed small.

Non-response bias reduces the confidence that policy makers can place on aggregate benefit estimates found from the biased sample. Policy makers can be presented with ranges of aggregate benefits, but these ranges may be large, especially at low response rates. The only way to reduce these ranges is to increase the time, money and effort spent on the mail survey in order to increase response rates.

If additional time, money and effort is constrained to be zero, an alternative research strategy is to weight the sample to obtain an estimate within the range of aggregate benefits. Using data on non-respondents, we illustrate the weighting technique and find that weighted aggregate benefits falls within the postulated range. Weighted aggregate benefits are a considerable distance from both the minimum and maximum aggregate benefit estimates, suggesting that if either of these estimates are used for policy analysis, the chances of inefficiencies are large.

Additional time, money and effort which might be spent to increase response rates should be weighed against the value of the information produced by reducing non-response bias. This allocation rule for CV surveys fits Freeman's (1984) framework for tactical decision making about research to support benefit–cost analysis. The cost should be weighed against the value of reducing uncertainty about project or regulatory benefits. Several implications of this framework apply. No additional cost should be incurred if the reduction in bias would not potentially change the decision. The value of less-biased WTP estimates is higher if, say, expected net benefits are positive but there is a good chance actual net benefits are negative. This may occur if true benefits are closer to the sample minimum. The value of less-biased WTP estimates is higher the lower is the cost of transferring benefit estimates for other regulatory decisions. These aspects should be considered by decision makers who deal with sample non-response bias in mail CV surveys which are used for aggregate benefit estimation.

References

Baumgartner, R. M. and Heberlein, T. A. (1984). Recent research on mailed questionnaire response rates. In *Making Effective Use of Mailed Questionnaires* (D. G. Lockhart, ed.), pp. 65–76. San Francisco: Jossey-Bass.

Bergstrom, J. C., Dillman, B. L. and Stoll, J. R. (1985). Public environmental amenity benefits of private land: the case of prime agricultural land. *Southern Journal of Agricultural Economics* **17**, 139–149.

Blau, P. M. (1964). *Exchange and Power in Social Life*. New York: Wiley.

Blau, P. M. (1977). *Inequality and Heterogeneity: A Primative Theory of Social Structure*. New York: The Free Press.

Blomquist, G. C. and Whitehead, J. C. (1990). *The Effect of Alternative and Reclaimed Areas on the Value of Wetlands*. Final Report. U.S. Department of the Interior, Office of Surface Mining Reclamation and Enforcement.

Boyle, K. J. (1990). Dichotomous-choice, contingent-valuation questions: functional form is important. *Northeastern Journal of Agricultural and Resource Economics*, 125–131.

Boyle, K. J., Bishop, R. C. and Welsh, M. P. (1987). Toward total economic valuation of Great Lakes fishery resources. *Transactions of the American Fisheries Society* **116**, 339–345.

Brown, T. L., Decker, D. J. and Connelly, N. A. (1989). Response to mail surveys on resource-based recreation topics: a behavioral model and an empirical analysis. *Leisure Sciences* **11**, 88–110.

Cameron, T. A. (1988). A new paradigm for valuing non-market goods using referendum data: maximum likelihood estimation by censored logistic regression. *Journal of Environmental Economics and Management* **15**, 355–379.

Carson, R. T. (1991). Constructed markets. In *Measuring the Demand for Environmental Quality* (J. B. Braden and C. D. Kolstad, eds), pp. 121–162. Amsterdam, The Netherlands: Elsevier.

Dalecki, M. G., Ilvento, T. W. and Moore, D. E. (1988). The effects of multi-wave mailings on the external validity of mail surveys. *Journal of the Community Development Society* **19**, 51–70.

Dillman, D. A. (1978). *Mail and Telephone Surveys: The Total Design Method*. New York: John Wiley.

Dillman, D. A., Dillman, J. J. and Makela, C. J. (1984). The importance of adhering to details of the total design method (TDM) for mail surveys. In *Making Effective Use of Mailed Questionnaires*, pp. 49–63. San Francisco: Josey-Bass.

Dolson, D. E. and Machlis, G. E. (1991). Response rates and mail recreation survey results: how much is enough? *Journal of Leisure Research* **23**, 272–277.

Edwards, S. F. (1988). Option prices for groundwater protection. *Journal of Environmental Economics and Management* **15**, 475–487.

Edwards, S. F. and Anderson, G. D. (1987). Overlooked biases in contingent valuation surveys: some considerations. *Land Economics* **63**, 168–178.

Freeman, A. M., III (1984). On the tactics of benefit estimation under Executive Order 12291. In *Environmental Policy under Reagan's Executive Order: The Role of Benefit–Cost Analysis* (V. K. Smith, ed.), pp. 167–186. The University of North Carolina Press: Chapel Hill.

Heberlein, T. A. and Baumgartner, R. M. (1978). Factors affecting response rates to mailed questionnaires: a quantitative analysis of the published literature. *American Sociological Review* **43**, 447–462.

Loehman, E. and Vo, H. D. (1982). Application of stochastic choice modeling to policy analysis of public goods: a case study of air quality improvements. *Review of Economics and Statistics* **64**, 474–480.

Loomis, J. B. (1987*a*). Balancing public trust resources of Mono Lake and Los Angeles' water right: an economic approach. *Water Resources Research* **23**, 1449–1456.

Loomis, J. B. (1987*b*). Expanding contingent value sample estimates to aggregate benefit estimates: current practices and proposed solutions. *Land Economics* **63**, 396–402.

Loomis, J., Updike, D. and Unkel, W. (1989). Consumptive and nonconsumptive values of a game animal: the case of California deer. *Transactions of the 54th North American Wildlife and Natural Resources Conference* **54**, 640–650.

Mannesto, G. and Loomis, J. B. (1991). Evaluation of mail and in-person contingent value surveys: results of a study of recreational boaters. *Journal of Environmental Management* **32**, 177–190.

Mitchell, R. C. and Carson, R. T. (1989). *Using Surveys to Value Public Goods: The Contingent Valuation Method*. Washington, D.C.: Resources for the Future.

Patterson, D. A. and Duffield, J. W. (1991). Comment on Cameron's censored logistic regression model for referendum data. *Journal of Environmental Economics and Management* **20**, 275–283.

Randall, A., Hoehn, J. P. and Brookshire, D. S. (1983). Contingent valuation surveys for evaluating environmental assets. *Natural Resources Journal* **23**, 635–648.

Randall, A., Blomquist, G. C., Hoehn, J. P. and Stoll, J. R. (1985). *National Aggregate Benefits of Air and Water Pollution Control*. Interim Report to the U.S. Environmental Protection Agency. Washington, D.C.

Reiling, S. D., Boyle, K. J., Cheng, H.-T. and Phillips, M. L. (1990). Contingent valuation of a public program to control black flies. *Northeastern Journal of Agricultural and Resource Economics*, 126–134.

Sanders, L. D., Walsh, R. G. and Loomis, J. B. (1990). Toward empirical estimation of the total value of protecting rivers. *Water Resources Research* **26**, 1345–1357.

Shultz, S. D. and Lindsay, B. E. (1990). The willingness to pay for ground water protection. *Water Resources Research* **26**, 1869–1875.

Stevens, T. H., Glass, R., More, T. and Echeverria, J. (1991). Wildlife recovery: is benefit–cost analysis appropriate? *Journal of Environmental Management* **33**, 327–334.

Stoll, J. R. and Johnson, L. A. (1984). Concepts of value, nonmarket valuation, and the case of the whooping crane. *Transactions of the 49th North American Wildlife and Natural Resources Conference* **49**, 382–393.

Sutherland, R. J. and Walsh, R. G. (1985). Effect of distance on the preservation value of water quality. *Land Economics* **61**, 282–291.

Walsh, R. G., Loomis, J. B. and Gillman, R. A. (1984). Valuing option, existence, and bequest demands for wilderness. *Land Economics* **60**, 14–29.

Wellman, J. D., Hawk, E. G., Roggenbuck, J. W. and Buhyoff, G. J. (1980). Mailed questionnaire surveys and the reluctant respondent: an empirical examination of differences between early and late respondents. *Journal of Leisure Research* **12**, 164–172.

Whitehead, J. C. and Blomquist, G. C. (1991). Measuring contingent values for wetlands: effects of information about related environmental goods. *Water Resources Research* **27**, 2523–2531.