EERG

DP 95/1

Discussion Paper in Ecological Economics

95/1

Series Editor Dr. Clive L. Spash

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FEBRUARY 1995

Environmental Economics Research Group
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VALUING BIODIVERSITY LOSSES DUE TO ACID DEPOSITION: A CONTINGENT VALUATION STUDY OF UNCERTAIN ENVIRONMENTAL GAINS.

by

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ABSTRACT

Acid deposition is a present and future cause of biodiversity losses in vulnerable upland areas of Scotland important for nature conservation. However, the exact nature of damage under the status quo, and both the timing and extent of recovery of upland ecosystems if deposition is reduced, are subject to uncertainty. This uncertainty complicates damage cost estimation. In this paper, we have explored the use of CVM to measure the willingness to pay (WTP) of the Scottish population for uncertain recovery/damage scenarios from reduced acid rain deposition. An optimally-designed referendum format was used, utilising the distribution of open-ended bids from a pilot study to determine bid amounts and sampling size for each bid amount. Eight explanatory variables, including future damage level were selected in a non-linear step-wise regression analysis. Average household WTP for abatement of acid rain was £247 and £351 per year when faced with low and high future damage levels respectively. Recovery level and recovery time did not significantly influence WTP. When faced with risky outcomes regarding future damage and recovery level respondents were found to be risk averse to both environmental gains and losses.

INTRODUCTION

In the northern hemisphere, acid deposition (acid rain for brevity, from now on) is a major source of environmental degradation. This degradation affects human health (OECD 1981), agricultural and forest crops (Baker et al. 1986), freshwater ecosystems including fish populations (Adriano and Johnson 1989; Muniz and Levestad 1980; Harriman *et al.* 1987) and building materials (Webb et al. 1990). In the United Kingdom a major cause for concern has been damage to the biodiversity of vulnerable mountain areas where some of the most natural and least disturbed sites important for nature conservation occur and which are important spawning waters for the Atlantic salmon *(Salmo salar)* and brown trout *(Salmo trutta)*. Affected areas are characterised by high deposition levels, acidic geology (implying a low buffering capacity) and shallow, organic-rich soils with only a limited capacity for neutralising acid inputs (Wright et al. 1993).

Biodiversity ".. describes the whole range of variation in living organisms: genetic variation, species variation and ecosystem variation" (RSPB, 1993). Biodiversity is valuable for a number of reasons, including the direct utility that individuals derive from animals, plants and ecosystems, and the role that biodiversity plays in maintaining the stability and resilience of the world's ecosystems. Acid deposition adversely impacts on biodiversity in the Scottish Highlands by reducing the variety and population balance of flora and fauna found in this area (Fry and Cooke, 1987).

The United Kingdom, under the Large Combustion Plant Directive of the European Community (EC), is currently committed to cutting sulphur dioxide (SO_2) emissions, the main precursor of acid rain, by 60% compared to 1980 levels. These cuts are to be achieved through fuel switching (coal to natural gas) and flue-gas desulphurisation at an estimated cost of £6 billion (Department of Environment 1990). In 1994 the UK also signed the second UNECE Sulphur Protocol which binds it to a further reduction in SO_2 to 80% of 1980 levels by 2010. However, current scientific projections, based on the Critical Loads approach, suggest that despite these planned reductions continued deterioration in environmental quality can be expected in upland regions of the UK (Critical Loads Advisory Group, 1994). Thus, both inaction and action to enforce the planned reductions in acid rain might result in environmental costs in welfare terms.

Under the Single European Act (Article 130R), environmental policy is required to take account of the costs and benefits of action (or no action). Previous studies have tended to focus on user benefits from recovery in fish stocks (Macmillan and Ferrier 1993, Navrud, 1988), but acid rain abatement can initiate recovery in the ecology of sensitive riverine ecosystems of remote, unfrequented upland areas in Scotland, and thereby generate positive utility from motives related to non-use values for biodiversity preservation. Without a reliable estimate for the non-market benefits of environmental recovery in affected areas, a serious mis-allocation of resources is likely to result[4].

The Contingent Valuation (CV) method currently offers the most promising approach to estimating existence/passive use values. It has been widely applied in the US and increasingly in Europe to air and water quality (Brookshire et al. 1979, Boyle and Bishop 1984), wildlife resources (Brookshire et al. 1983, Randall and Peterson 1984) and wilderness areas (Walsh et al. 1984, Hanley and Craig 1991). Previous attempts to value reductions in biodiversity have also utilised the CV method (Spash and Hanley, 1993; Hanley et al. 1994; Veisten et al, 1993).

[4] Although it would be wrong to suggest that all draft EC environmental regulations are subject to a rigorous cost-benefit analysis: they are not.

Acid rain is a complex phenomenon, where the degree and rate of recovery (perhaps extending to hundreds of years) are, as yet, scientific uncertainties and the suitability of the CV method to produce reliable benefit estimates for long-term, uncertain environmental change has not been determined. This paper describes the application of the CV method to estimate the WTP of the Scottish population for further cuts in acid rain that will prevent long term damage to the ecology of affected areas of the Scottish uplands and initiate long term recovery.

In what follows, we assess the scientific perceptions of the environmental impact of acid rain (section two); present a brief theoretical background from which some propositions over the value of uncertain recovery and damage prospects may be derived (section three); and describe the design of and results from a dichotomous-choice CV study which tests these propositions (sections four and five).

RECOVERY FROM ACID RAIN

Decades of anthropogenic acid inputs have had a marked effect on the biodiversity of riverine ecosystems in the Scottish Highlands. Although historical records are sparse, diatom records from lake sediments and fish records indicate that the process of acidification began between 50 and 100 years ago (Flower et al. 1987, Ferrier et al. 1993). Sharp decreases in ph levels and the episodic release of labile aluminium are the primary causes of damage in acid-sensitive soils and freshwater. These effects have resulted in a major decline in the number and diversity of fish, amphibians, birds and mammals and widespread disruption of the macrophyte, invertebrate and phytoplanktonic communities (English Nature 1992).

The pervasive and complex ecosystem effects of acidification are the subject of much on-going research. At the moment scientific understanding of this long-term environmental change is incomplete and considerable uncertainty surrounds both the ultimate damage likely to be sustained if acid inputs are not reduced below critical levels in affected areas, and the extent and rate of ecosystem recovery if acid inputs are reduced. Long-term projections suggest that recovery in water chemistry is possible within thirty years. The timespan for possible ecosystem recovery is more difficult to predict but is likely to be considerably longer (Ormerod 1990).

THEORETICAL BACKGROUND.

Individuals are likely to value a reduction in acid damages for a number of motives. These include (i) an improvement in the quality of recreational experience for those currently directly using upland areas (walkers, fishermen, ornithologists, etc), (ii) the potential for such use for those not currently using the area, (iii) an increase in satisfaction on the part of those who currently and in the future will only use the area indirectly (eg by reading about the area, or watching TV programmes); and (iv) an altruistic motivation to bequeath a particular level of environmental quality for future generations. Motives (i) and (ii) lead to a direct use value, motive (iii) to a passive use value and motive (iv) to a pure existence value.

Assume that the representative agent has an indirect utility function $V = V(p,z,y)$, where p is a vector of prices of private goods, z is a public good such as environmental quality and y is fixed annual income. Suppose in this case that z represents the state of upland ecosystem, which generates both use and non-use values. Assume that there is certainty as to the level of damages that will occur in the absence of further intervention (the status quo). For a project or policy that reduces losses (acid damages) in z to some specified level such as z^j, **with certainty**, the maximum payment that the individual would offer to secure the project is (following Johansson, 1988):

$$V(p, z^j, y - WTP_j) = V(p, z^i, y)$$

where z^i is the steady state achieved in the status quo and WTP is the compensating surplus (willingness to pay) for this welfare improvement. Clearly, the higher is z^j relative to z^i, the higher will be WTP. In the study reported in the next section, respondents are categorised according to whether they are told that recovery, following action to reduce acid rain, will be to pristine levels (*a*), to moderate, fishable levels (*b*), or that there will be no recovery above current levels (*c*). This enables us to examine:

Proposition 1 : Future Recovery

WTP*a* = WTP*b* = WTP*c* where *a,b* and *c* are, respectively, pristine, fishable,and no improvement levels of recovery.

Similarly, the predicted level of future damage under the status quo may be minimal (x) or high, leading to extinction (*y*). For a fixed, certain level of recovery, we can also therefore examine:

Proposition 2: Future Damage

WTP*x* = WTP*y* where *x, y* are, respectively, minimal and high status quo scenarios.

The timing of recovery from acid damages which might result from reduced deposition is uncertain at present. However, given positive time preference, individuals will prefer a more rapid recovery to a slower recovery, even if they cannot compute the present value of damage streams into the future (as the NOAA report alleges). Given the payment vehicle of an annual increase in costs to the household, we can assess:

Proposition 3: Recovery time

WTPr = WTPt ,where r is a recovery time of 20 years; t is recovery time of 120 years.

It is important to realise that propositions 1, 2 and 3 all involve decisions over certain outcomes from the perspective of respondents in the CV study: each respondent asked to test propositions 1-3 faces only one of the recovery/status quo scenarios.

Finally, we introduce scientific uncertainty to the respondents. As is implicit above, scientific uncertainty exists as to both the level and extent of recovery, and as to the status quo. If respondents are aware of this uncertainty, this will affect their valuation of the proposed programme. Following Johansson (1988), we first test CV estimates when a project with a risky recovery is proposed. In one subsample, respondents are informed that there is a 50% chance that recovery will achieve pristine conditions (level a) and a 50% chance that recovery will be minimal (level c). If individual agents are risk-averse we would expect them to prefer a project with a certain outcome lying midway between a and c: in this case outcome b[5]. Hence:

Proposition 4: WTP*b* = AP where AP is an *ex ante* WTP measure for uncertain recovery.

[5] A problem exists with both Proposition 4 and Proposition 5, in that whilst probabilities over damage/recovery can be numerically quantified for respondents, it is difficult to quantify the 'amount' of biodiversity gain that is achieved in each case (although see Polasky, Solow and Broadus (1993), for one possible approach).

We also estimate WTP when there is uncertainty with respect to the damage level in the absence of further reductions in emissions. In one sub-sample, individuals are informed that there was a 50% chance that minimal damage would occur such that .."once common species such as the dipper and brown trout have become less common but not threatened by extinction...". (damage level x) and that there is a 50% chance that .."Many sensitive species such as the dipper and brown trout have become extinct" (level y). The respondents in the other sub-sample are informed that a median level (w) is certain. In both cases, respondents are told that the proposed reduction in emissions will result in some certain level of improvement.

For the final proposition we appeal to Kahneman and Tversky (1979), who present a body of experimental evidence that suggests individuals are risk-seekers when losses are in prospect, but are risk-averse when gains are in prospect (the "reflection effect"). In our case, this suggests that utility will be higher for a programme with an expected loss w but with a possibility that minimal damage might occur (level x), than for a programme with certain losses w. This gives a final proposition:

Proposition 5: AP = WTPw where AP is the ex-ante WTP measure when the status quo level of damage is uncertain.

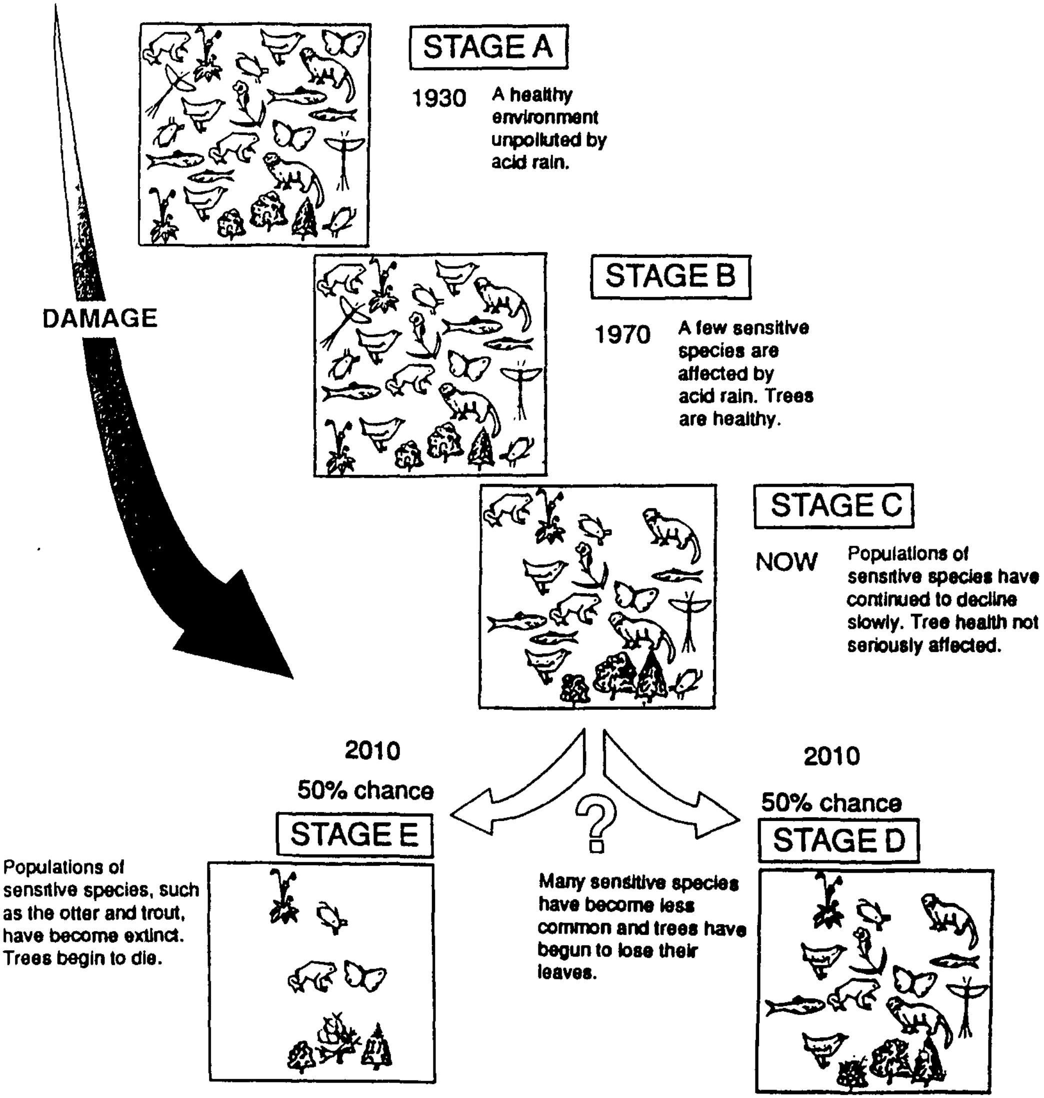
SURVEY DESIGN

Acid rain is a complex phenomenon and describing a suitably clear, understandable and realistic scenario for damage and recovery in the upland ecosystem to respondents presented a significant challenge. In a recent survey less than 10% of scottish residents "knew a great deal" about acid rain and its effects (Government Statistical Service 1991). Considerable effort was spent on pretesting the questionnaire with focus groups with the intention of developing an information set and real-world decision context which would allow respondents, unfamiliar with the commodity and inexperienced at valuation in a hypothetical situation, to formulate their WTP. The intention was to reduce the affective, evaluative and emotional aspects and encourage the respondent to invoke intended behaviour. Thorough pretesting should ensure that the information given to the respondents is comprehensive, easy to understand and presented in such a way that the respondents' cognitive abilities are not strained, nor that they are encouraged to indulge in heuristic behaviour (Fischoff and Furby 1988).

Extensive pretesting suggested that respondents would have difficulties with a detailed scientific description of the environmental changes caused by acid rain. Therefore, it was decided to present past damage and future recovery in terms of changes in species diversity using illustrations known as *Species Boxes*. These illustrations were found to give respondents a clear indication of changes in species composition and population levels in an interesting and stimulating style (Figure 1). The scientific veracity of the proposed changes described were also tested with scientists at MLURI working on acid rain.

In accordance with the recommendations of the NOAA report (1993) the questionnaire emphasised the availability of substitute sites and the budget constraint by asking respondents where expenditure might be reduced to allow payment of the bid amount. Care was also taken to remind respondents that acid rain was a social problem for which 'big business' alone could not be blamed. The preferred payment vehicle was higher prices on commonly purchased consumer items (electricity, cars, central heating) caused by stiffer pollution control. This was felt to be a realistic option, and fair in the sense that it reflected the 'polluter-pays' principle.

FIGURE 1


DAMAGE
STAGE A
1930
A healthy environment unpolluted by acid rain.
STAGE B
1970
A few sensitive species are affected by acid rain. Trees are healthy.
STAGE C
NOW
Populations of sensitive species have continued to decline slowly. Tree health not seriously affected.
2010
50% chance
STAGE E
Populations of sensitive species, such as the otter and trout, have become extinct. Trees begin to die.
?
2010
50% chance
STAGE D
Many sensitive species have become less common and trees have begun to lose their leaves.

Pilot Study

Following pre-testing an open-ended pilot study was carried out initially to test for survey design flaws, and to provide a WTP distribution upon which the statistical design of the dichotomous choice format to be used in the main survey was based. In total, 254 respondents were selected from a systematic sample of Scottish households drawn from the telephone directory, each household receiving a mailed questionnaire. The open-ended CV question revealed an average bid of £75 per household. The distribution of these bids was then used to determine the number and value of bid amounts Xi and the number (Ni) of respondents asked each bid amount according to the optimal bid design method described by Cooper (1993). The values for Xi and Ni were chosen to minimize the mean square of error of the WTP measure for a specified sample size.

RESULTS AND DISCUSSION

A dichotomous choice CV survey was then posted to a random sample of 3,000 Scottish households. Each household received a questionnaire corresponding to one of 15 recovery/damage scenarios[6]. Disregarding undelivered questionnaires, a response rate of 67% was achieved (Table 1). The high overall response rate can be directly attributed to the strict implementation of the Total Design Method (Dillman 1979) and the careful pretesting of the survey instrument. Comparison with census information on household characteristics revealed that these respondents were representative of the Scottish population with respect to age and sex. Protest bids were restricted to 6% of respondents. The most common reason for protesting was that industry should be made to pay, not the public (Table 2).

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[6] A copy of the questionnaire is available from the authors.

TABLE 1
SUMMARY OF RESPONSES

Valid	Yes	638
	No	679
	Don't know	352
Protests		118
Incompletes		33
Completed questionnaires		**1820**
Refusals		110
Non-responses		790
Total delivered		2720

TABLE 2
REASONS FOR PROTESTING

	% of respondents
Industry should pay	38
Government responsibility	28
Payment method	7
Don't trust that everyone will pay	5
Disagree with information presented	19
Others	3
Total	100

The distributions of Xi, Ni and the proportions of Yes responses are shown in Table 3. Almost half (47%) of all respondents (excluding those who declined to pay anything even a very

TABLE 3

BID DISTRIBUTION (X_i) NUMBER, (N_i) AND OBSERVED PROBABILITY OF A YES RESPONSE

X_i	N_i	(Yes)
£11	14	.67
£17	33	.75
£21	34	.82
£26	43	.88
£31	51	.79
£37	55	.85
£42	57	.90
£48	69	.87
£55	81	.77
£63	88	.82
£71	99	.69
£81	114	.59
£92	133	.74
£106	155	.72
£122	184	.76
£143	224	.63
£170	285	.68
£209	384	.62
£270	603	.48
£396	294	.47
£798	30	.18

small amount) stated they were willing to pay the highest bid level presented (£396). This was clearly unsatisfactory with respect to identifying the upper tail of the bid curve and a further 30 questionnaires were dispatched with an increased bid price of £798. The observed proportion responding Yes to this bid level was 0.18.

Respondents who answered the WTP bid question were presented with an opportunity to state why they were or were not prepared to pay towards reducing acid rain. For Yes bids the most common reason was concern for future generations, which suggests a strong bequest-related motivation (which might be expected in the case of acid rain damages where recovery will occur some years into the future). Excluding protestors, most respondents unwilling to pay the offered bid price reported that they were unable to afford the yearly payment.

A logistic regression was used to model the bid function for all valid responses from scenarios with certain outcomes. Respondents who reported, prior to answering the bid question, that they were unwilling to pay anything, even a very small amount, were excluded from this analysis. If respondents who were unwilling to pay anything are included the upper asymptote of the logistic curve should correspond to the proportion of respondents willing to pay something, rather than to unity. This raises the issue of how to weight observations to achieve a valid analysis. A simpler approach is to estimate separately the proportion (1-p) of the population willing to pay nothing, and to fit the logistic regression to the remaining data. Overall mean WTP is then estimated as the mean WTP amongst respondents willing to pay something multiplied by p.

A bid function was estimated using a linear predictor and a logit link function between the probability of saying Yes and the various explanatory variables for all 'certain' scenarios. Twenty-nine covariates, including ordinal variables for future damage and recovery levels, were considered. *Bid* and either *recovery*, *damage* or *time* were entered first with the remaining covariates selected using a step-wise procedure. Table 4 lists and describes the eight covariates, with a t-value significant at the 5% level, which were included in the final model. In relation to Propositions 1,2 and 3 only future damage level significantly influenced the respondents decision, with high damage at the steady state (y) invoking a higher probability of saying Yes to the payment question. Recovery level and timing did not significantly influence the bid response even when forced into the model first.

TABLE 4
ESTIMATES OF REGRESSION COEFFICIENTS

	Estimate	s.e.	t
Constant	2.31	0.535	4.31
bid	-0.005144	0.00081	-6.36
income	0.412	0.048	8.62
govt	-0.494	0.144	-3.44
return	-0.395	0.121	-3.26
understand	-0.385	0.127	-3.03
member	0.401	0.145	2.77
pollu	-0.194	0.074	-2.62
dam	0.318	0.152	2.09

The other covariates which entered the model influenced the dependent variable in line with *a priori* expectations: the probability of responding Yes decreased with bid but increased with *income*, level of understanding about acid rain (*understand*), and whether the respondent was a member of an environmental charity (*member*). People who ranked pollution (*pollu*) higher in importance among 6 social issues (employment, education etc) and returned their questionnaire earlier (*return*) were also more likely to say Yes. Table 5 describes the effect of each covariate on the residual deviance. Income level exhibited greatest explanatory power, reducing the deviance by 104.6. Bid level, which was forced to enter the model first, reduced deviance less than income, contradicting other studies which conclude that bid is the dominant factor influencing the respondents decision (Bateman et al. 1993).

In order to estimate the mean WTP for the two damage levels it is necessary to integrate under the bid function following the procedure outlined by Hanemann (1984). Conventionally mean WTP is estimated by fitting the logistic regression model by bid level, having averaged over the other covariates. However, this practice can generate a biased estimate of WTP. For example, if many people with an average income were asked to pay £1000, it is likely that all would refuse, whereas if people with a representative range of incomes averaging £1000 were asked to pay the same amount, some of those with very high income might accept. To avoid this bias, we predicted the probability that each individual respondent would accept the bid presented to them using the logistic model. At each bid level, these predictions were averaged to obtain a valid estimate of the probability of a positive response by bid level in the population. A logistic curve was then fitted to the mean probabilities, weighted by the inverse of the variance of the mean (*i.e.* weights = 1/est .var(p(1-p)), where p is the mean of the predicted probabilities for a given bid level). The fitted curve was of the form g(y) = C/(1+exp(-B*(X-M))). The parameter estimates are given in Table 6. In Figure 2 the observed proportions accepting the bid, the predicted proportions, and the fitted logistic curve are plotted by bid level.

Figure 2. Plot of the observed proportions accepting the bid (○), the predicted proportion (●) and the fitted logistic curve (△).

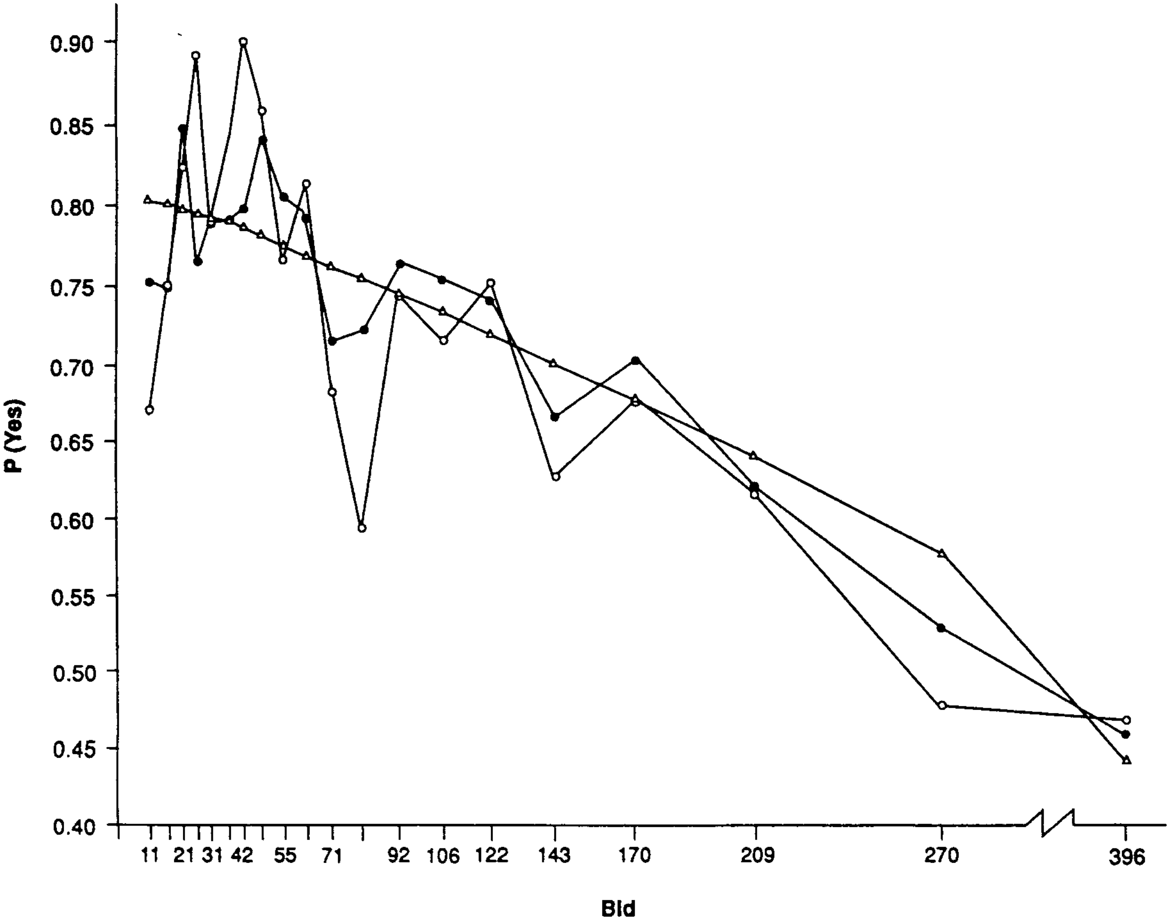

TABLE 5

ACCUMULATED ANALYSIS OF DEVIANCE

Change	d.f.	deviance
+bid	1	44.1049
+income	1	104.5878
+govt	1	23.7530
+return	1	14.3275
+understand	1	11.0545
+member	1	8.0560
+pollu	1	6.2256
+dam	1	4.4163
Residual	731	720.3504
Total	739	936.8759

presented in Table 7.

TABLE 6

ESTIMATES OF PARAMETERS

	estimate	s.e.
B	-0.00294	0.00108
M	153.	288.
C	1.395	0.578

Willingness to Pay Results With No Uncertainty on the Part of Respondents

We turn initially to our first proposition that WTPa > WTPb > WTPc, where a,b, and c are declining levels of recovery. While WTPa and WTPb are broadly equivalent, the 'no recovery' scenario (c) generates the highest WTP values (Table 7). This trend is apparent under both damage levels and clearly contradicts our a priori expectations. Although the means are not significantly different, this result seems difficult to explain. One possibility, which requires further investigation with focus groups, is that respondents faced with Scenario c (which stated that recovery was not possible) may have viewed future acid rain losses as irreversible. Concern about irreversibility, therefore, may have underpinned the high WTP values. However, the wide confidence intervals around the mean estimates suggests caution with any interpretation of the results.

With regard to proposition two (senstivity to level of damages in the absence of further action), the calculated mean household WTP per annum are again shown in Table 7. As may be seen, for low damage values were lower (WTPx= £247) than for the high damage scenario (WTPy= £351). Aggregated to the Scottish population this is equivalent to £484 and £688 million respectively. Finally, with regard to proposition three, we note from the bid curve results (Table 4) that recovery time does not significantly influence WTP. Indifference to the recovery time period is consistent with the bequest-related motive for paying which was expressed strongly by the majority of respondents. However, it may be, as the NOAA report (1993) suggests, that respondents generally have difficulty accounting for time preference in their valuation. Knetsch (1993) argues that people are less sensitive to time-frame when considering the avoidance of 'dreaded events'. Evidence from this study suggest that this insensitivity may also extend to potential environmental gains.

TABLE 7

MEAN WTP (£) MEASURES FOR ALTERNATIVE SCENARIOS[1]

	Recovery			
	Pristine(a)	Fishable(b)	None(c)	Mean
Damage				
minimal (X)	239	241	272	247
	(195-344)	(181-592)	(201-676)	(213-308)
	n = 106	n = 118	n = 113	
high (y)	299	339	503	351
	(237-465)	(248-678)	(283-2959)	(280-500)
	n = 122	n = 125	n = 107	
Mean	272	298	351	308
	(232-345)	(230-512)	(257-761)	(265-365)

[1] Averaged over both recovery times

Willingness to Pay Under Uncertainty

Turning now to Proposition 4 regarding uncertainty in recovery level. The mean value for WTPb was £241 (90%CI:181-592) and for the AP measure was £187 (90%CI: £73-£1013). This supports the earlier empirical work of Johansson (1988) which indicated that respondents were risk averse with respect to environmental gains. Under Proposition 5 respondents were presented with uncertainty regarding losses (but with recovery to pristine conditions assured) and WTPw = £328 (90%CI: £217-£1174) and AP = £184 (90%CI: £153-£248). This result does not suggest risk-seeking behaviour as described by Kahneman and Tversky (1979) for respondents faced with financial losses. When faced with future environmental damage respondents appear to be risk-averse.

Cautious interpretation of the results from the final two Hypotheses is necessary for the following reasons. Firstly, it was not possible to precisely identify the median damage level using the described presentation format (ie species boxes). Hence AP and WTPb/WTPw measures may not be expressing equivalent biodiversity losses to respondents. Secondly, respondents were presented with one scenario only and were not aware of the alternative recovery and damage levels; therefore, their decision depended entirely on their response to the information presented rather than on a comparison of alternative scenarios.

CONCLUSIONS

The results of this survey have implications for government policy on acid rain abatement. The Scottish public, despite the planned reductions in acid rain, remain very concerned about sensitive upland areas where acidification is continuing and long term damage is in prospect. Abatement policy should therefore focus on protecting these areas rather than by SO_2 reductions which stimulate recovery in sites where acidification is no longer proceeding. This might be achieved through targeting spatial groups of sources for SO_2 reductions. Scientific research which reduces the uncertainty associated with the environmental response to acid rain abatement should be encouraged since our results show that people prefer lower levels of environmental uncertainty.

Two final comments regarding methodological issues. Firstly, the open-ended approach employed in the pilot revealed a mean WTP of only £75 per household. The equivalent mean using the discrete-choice format resulted in a WTP some four times greater. Similar findings have been widely reported elsewhere (Sellar 1985, Walsh et al 1989) and have been linked to a number of possible effects. The tendency to 'yea-say' (that is, to respond yes to an offer price of Lx even though true WTP is less than Lx) has been identified as a source of upward bias in DC results

(Kanninen, 1995). This may be a result of upward rounding by respondents reluctant to say 'No' since this would result in their positive preference for the good being ignored (Loomis 1987) or of an anchoring effect, where respondents, unfamiliar with the good being valued or are highly uncertain of their valuation, may anchor their WTP to the bid level (Harris *et al.* 1989). Linear logit models have also been shown to generate mean estimates up to 50% greater than equivalent measures obtained from log logistic forms (Bateman *et al.* 1993).

Secondly, the very high response rate (67%) together with high construct validity suggest that well-executed mail surveys, particularly when dealing with environmental issues where passive use and existence values are likely to feature prominently, have few serious drawbacks.

ACKNOWLEDGEMENTS

This work was funded by the Scottish Office Agriculture and Fisheries Department, Edinburgh, Scotland. The authors would like to thank Prof. K. Thompson, University of Aberdeen, and Dr. J. Kay, Scottish Agricultural Statistics Service for helpful comments on the paper

REFERENCES

Adriano, D.C., and Johnson, A.H. (eds) 1989. *Acidic Precipitation (Vol. 2): Biological and Ecological Effects.* Springer-Verlag, New York.

Baker, C.K., Colls, J.J., Fullwood, A.E. and Seaton, G.G.R. 1986 Depression of growth and yield in winter barley exposed to sulphur dioxide in the field. *New Phytologist* 104, 233-241.

Bateman, I.J., Langford, I.H., Willis, K.G., Turner, R.K and Garrod, G.D. 1993. The impacts of changing willingness to pay format in contingent valuation studies: An analysis of open-ended, iterative bidding, and dichotomous choice formats. *Paper presented at the IVth EAERE Conference, Fontainableu, France,1993*

Boyle, K.J. and Bishop, R.C. 1984 Economic Benefits Associated With Boating and Canoeing on the Lower Wisconsin River. *Economic Issues no. 84, Dept. of Agricultural Economics, University of Wisconsin, Madison.*

Brookshire, D.S., d'Arge, R.C. and Schulze, W.D. 1979 Experiments in Valuing Non-Marketed Goods: A Case Study of Alternative Benefit Measures of Air Pollution Control in the South Coast Air Basin of Southern California, In *Methods Development for Assessing Tradeoffs in Environmental Management, Vol* 2, EPA-60076-79-0016, Washington DC.

Brookshire, D.S., Eubanks, L.S. and Randall, A. 1983 Estimating Option Price and Existence Values for Wildlife Resources. *Land Economics* 59(1), 1-15.

Cooper, J.C. 1993. Optimal bid selection for discrete choice contingent valuation surveys. *Journal of Environmental Economics and Management* 24(1):25-40.

Critical Loads Advisory Group. 1994. *Critical Loads of Acidity in the United Kingdom. Summary Report.* ITE, Penicuik.

Department of the Environment 1990. *This Common Inheritance.* HMSO, London.

Dillman, D.A. 1979 *Mail and Telephone Surveys:The Total Design Method.* John Wiley and Sons, New York.

English Nature 1992. *Freshwater acidification of SSSIs in Great Britain I: Overview.* English Nature, Peterborough.

Fischhoff, B and Furby, L. 1988 Measuring values: A Conceptual Framework for Interpreting Transactions with Special Reference to Contingent Valuation of Visibility. *Journal of Risk and Uncertainty* 1, 147-184.

Ferrier, R.C., Wright, R.F., Bulger, A.J., Cosby, B.J. and Jenkins, A. 1994. Changes in acidification of lochs in Galloway, southwestern Scotland: application of a fish population status model. *Journal of Hydrology* (in press).

Flower, R.J., Battarbee, R.W. and Appleby, P.G. 1987. The recent palaolimnology of acid lakes in Galloway, south-west Scotland: diatom analysis, pH trends, and the role of afforestation. *Journal of Ecology* 75:797-824.

Fry, G.L.A. and Cooke, A.S. 1987 *Acid Deposition and Its Implications for Nature Conservation in Britain.* Focus on Nature Conservation 7, Nature Conservancy Council, Peterborough.

Government Statistical Office 1991. *The Scottish Environment - statistics.* The Scottish Office, Edinburgh.

Hanemann, W.M. 1984. Welfare evaluations in contingent valuation experiments with discrete responses. *American Journal of Agricultural Economics,* 66:332-341.

Hanley, N and Craig, S. 1991. Wilderness Development Decisions and the Krutilla-Fisher Model: The Case of Scotland's 'Flow Country'. *Ecological Economics* 4, 145-164.

Hanley N, Walker L and Spash C (1995) Problems in valuing the benefits of biodiversity protection. Forthcoming, *Environmental and Natural Resource Economics.*

Harriman, R., Morrison, B.R.S., Caines, L.A., Collen, P. and Watt, A.W. 1987 Long Term Changes in Fish Populations of Acid Streams and Lochs in Galloway, South-West Scotland. *Water, Soil and Air Pollution* 32, 89-112.

Harris, C.C., Driver, B.L. and McLaughlin, M.J. 1989. Improving the contingent valuation method: A psychological approach. *Journal of Environmental Economics and Management* 17, 213-229.

Johansson, P-O 1988, Valuing public goods in a risky world: an experiment in Folmer, H. and van Ierland, E. (eds). *Valuation methods and Policy Making in Environmental Economics.* Studies in Environmental Science 36. Elsevier, Amsterdam.

Kahneman D and Tversky A 1979. Prospect theory: an analysis of decision under risk *Econometrica*, 47 (2), 263-291.

Kanninen, B. J. 1995. Bias in discrete response contingent valuation. *Journal of Environmental Economics and Management* 28(1), 114-125.

Knetsch, J.L. 1993. Environmental valuation: some practical problems of wrong questions and misleading answers. *Resource Assessment Commission, Occasional Paper No. 5.* Australian Government Publishing Service, Canberra.

Loomis, J.B. 1987. Expanding contingent value estimates to aggregate benefit estimate: current practices and proposed solutions. *Land Economics* 63, 396-402.

Macmillan, D.C. and Ferrier, R.C. 1993. Modelling the economic benefits of recovery in salmon fisheries from acidification: A case study in south-west Scotland. In *Proc. Environmental Pollution,* ICEP, Barcelona.

Muniz, I.P. and Leivestad, H. 1980. Acidification - effects on freshwater fish. In: *Ecological impacts of acid precipitation*, ed D.Drablos and A.Tollan, 84-92. Oslo: SNSF.

Navrud, S. 1988. Estimating social benefits of environmental improvements from reduced acid depositions: A contingent valuation survey. In Folmer, H. and van Ierland, E. (eds). *Valuation methods and Policy Making in Environmental Economics.* Studies in Environmental Science 36. Elsivier, Amsterdam.

NOAA 1993. Report of the NOAA Panel on Contingent Valuation. *Federal Register* 58(10), 4602-4614, USA.

OECD 1981 *The Costs and Benefits of Sulphur Oxide Control.* OECD, Paris.

Ormerod, S.J, Weatherly, N.S. and Whitehead, P.G. 1990. Temporal patterns of ecological change during the acidification and recovery of streams throughout Wales according to a hydrochemical model. In Kamari, J. Brakke, D.F. Brakke, Jenkins, A. Norton, S.A. and Wright, R.F. (eds) *Regional acidification models: Geographic extent and time development.* Springer-Verlag, Berlin.

Polasky S, Solow A and Broadus J (1993) "Searching for uncertain benefits and the conservation of biological diversity" *Environmental and Resource Economics*, 3 (2), 171-182.

RSPB 1993 *Biodiversity challenge: An agenda for conservation in the UK.* Sandy, Bedfordshire.

Randall, A. and Peterson, G.L. 1984 The Value of Wildlife Benefits: An Overview. In Peterson, G.L. and Randall, A (eds), *Valuation of Wildland Resource Benefits*, Westview Press, Boulder.

Sellar, C., Stoll, J.R. and Chavas, J.P. 1985. Validation of empirical measures of welfare change: A comparison of nonmarket techniques. *Land Economics* 61, 156-175.

Spash C and Hanley N (1994) *"Preferences, Information and Biodiversity Preservation".* Discussion papers in Ecological Economics no.94/1, University of Stirling.

Veisten K, Hoen H, Navrud S and Strand J (1993) "Valuing biodiversity in Norweigan forests". *Paper to the EAERE conference, Fontainebleau*, June 1993.

Walsh, R.G., Loomis, J.B. and Gillman, R.A. 1984 Valuing Option, Existence, and Bequest Demands for Wilderness. *Land Economics* 60(1), 14-29.

Walsh, R.G. Johnston, D.M. and McKean, J.R. 1989. Issues in nonmarket valuation and policy application: A retrospective glance. *Western Journal of Agricultural Economics* 14, 178-188.

Webb, A.H., Bawden, R.J., Busby, A.K. and Hopkins, J.N. 1990. Studies on the effects of air pollution on limestone degradation in Great Britain. In *Acidic Deposition: Its nature and impacts*. The Royal Society of Edinburgh Conf. Abstracts.

Wright, R.F., Cosby, R, Ferrier, R, Jenkins, A. and Harriman, R. 1994. Regional surveys in 1979 and 1988 and evaluation of the MAGIC model. *Journal of Hydrology* (in press)

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