

Bateman, Ian et al.

**Working Paper**

## Does phosphate treatment for prevention of eutrophication pass the benefit-cost test?

CSERGE Working Paper EDM, No. 06-13

**Provided in Cooperation with:**

The Centre for Social and Economic Research on the Global Environment (CSERGE), University of East Anglia

*Suggested Citation:* Bateman, Ian et al. (2006) : Does phosphate treatment for prevention of eutrophication pass the benefit-cost test?, CSERGE Working Paper EDM, No. 06-13, University of East Anglia, The Centre for Social and Economic Research on the Global Environment (CSERGE), Norwich

This Version is available at:

<https://hdl.handle.net/10419/80294>

**Standard-Nutzungsbedingungen:**

Die Dokumente auf EconStor dürfen zu eigenen wissenschaftlichen Zwecken und zum Privatgebrauch gespeichert und kopiert werden.

Sie dürfen die Dokumente nicht für öffentliche oder kommerzielle Zwecke vervielfältigen, öffentlich ausstellen, öffentlich zugänglich machen, vertreiben oder anderweitig nutzen.

Sofern die Verfasser die Dokumente unter Open-Content-Lizenzen (insbesondere CC-Lizenzen) zur Verfügung gestellt haben sollten, gelten abweichend von diesen Nutzungsbedingungen die in der dort genannten Lizenz gewährten Nutzungsrechte.

**Terms of use:**

*Documents in EconStor may be saved and copied for your personal and scholarly purposes.*

*You are not to copy documents for public or commercial purposes, to exhibit the documents publicly, to make them publicly available on the internet, or to distribute or otherwise use the documents in public.*

*If the documents have been made available under an Open Content Licence (especially Creative Commons Licences), you may exercise further usage rights as specified in the indicated licence.*

**DOES PHOSPHATE TREATMENT FOR  
PREVENTION OF EUTROPHICATION PASS  
THE BENEFIT-COST TEST?**

**by**

**Ian Bateman, Brett Day, Diane Dupont,  
Stavros Georgiou, Nuno Gonca Noceda Matias,  
Sanae Morimoto, Logakanthi Subramanian**

**CSERGE Working Paper EDM 06-13**

**Does phosphate treatment for prevention of eutrophication  
pass the benefit-cost test?**

**By**

**Ian Bateman<sup>1</sup>, Brett Day<sup>1</sup>, Diane Dupont<sup>2</sup>, Stavros Georgiou<sup>1</sup>, Nuno Gonca Noceda  
Matias<sup>1</sup>, Sanae Morimoto<sup>1</sup>, Logakanthi Subramanian<sup>1</sup>**

**<sup>1</sup>Centre for Social and Economic Research on the Global Environment (CSERGE),  
School of Environmental Sciences, University of East Anglia,  
Norwich, NR4 7TJ, United Kingdom**

**<sup>2</sup>Department of Economics, Brock University,  
St. Catharine's, Ontario, L2S 3A1, Canada**

**Acknowledgements**

Funding for this research was provided by the Commission of the European Community (CEC) through the CLIME project, Framework V Ref. No. EVK1-CT-2002-00121; the PEDM programme which is funded by the UK Economic and Social Research Council (ESRC); and The Economics for the Environment Consultancy (EFTEC).

The support of the Economic and Social Research Council (ESRC) is gratefully acknowledged. This work was part of the interdisciplinary research programme of the ESRC Research Centre for Social and Economic Research on the Global Environment (CSERGE).

**ISSN 0967-8875**

**Abstract:**

Over the past few decades the problem of eutrophication of water bodies has accelerated due to large additions of nutrients from human sources. This paper conducts a contingent valuation of household willingness to pay to reduce eutrophication impacts. The application employs the recently proposed one-and-one-half-bound dichotomous choice method for eliciting willingness to pay responses. It is also novel in that an examination of the rate and determinants of survey participation are analysed allowing superior aggregation of total values by allowing for those who refuse to be interviewed. A simple cost benefit analysis of anti-pollution measures is also reported.

**Keywords:**

Contingent valuation, willingness to pay, one-and-one-half-bound dichotomous choice method, determinants of survey participation, aggregation, cost benefit analysis, eutrophication, pollution.

## **1. INTRODUCTION**

The eutrophication of water bodies is a natural phenomenon, but over the past few decades, this pollution problem has increased significantly due to the large additions of nutrients from human sources. Eutrophication can affect a receiving ecosystem in a number of ways, especially with respect to the quality of water and the uses to which that water can be put. Policy makers are thus increasingly faced with the question of what, if anything should be done about this problem. With respect to any policy analysis of the eutrophication issue, the economic perspective can help policy makers and society more generally to identify allocations of economic resources that maximise social welfare and design policies that achieve these allocations. Social welfare is defined here in terms of individuals' utility or 'preference satisfaction'. Since people value environmental as well as consumer goods, then economic analysis seeks to allocate resources such that welfare is maximised over both types of goods. The economic approach involves trying to balance the opportunity costs of resources used for environmental protection, with the social welfare benefits provided by such protection. A cost benefit analysis of any pollution control policy requires information both on baseline loadings and on the various changes in these loadings and associated costs and benefits.

This chapter undertakes a cost-benefit analysis of eutrophication prevention measures for rivers and lakes in East Anglia. The remainder of the chapter is organised as follows. Section 2 considers the eutrophication problem in more detail, in particular looking at the pressures giving rise to the problem, policies to deal with it, and the costs associated with no change. Section 3 comprises the major analytical focus of this paper; an assessment of the benefits of measures to prevent eutrophication, undertaken using a contingent valuation study that incorporates a novel method of value elicitation. The final section presents the outcome and conclusions from the cost-benefit analysis.

## **2. THE EUTROPHICATION PROBLEM: PRESSURES, POLICY AND COSTS**

One of the most significant problems facing the ecology of freshwater in the UK is eutrophication as caused by the addition of nutrient salts to these water bodies. Eutrophication is defined as the accelerated fertility or ageing of a water body by nutrients<sup>1</sup>. These nutrients are mainly in the form of nitrogen and phosphorus compounds. These critically determine the growth of primary production in water bodies. Nutrients are naturally introduced to water bodies by plant and animal decomposition, excretion, air-sea exchange and oceanic mixing processes. However these inputs are supplemented by human sources of nutrients including domestic wastes, agricultural run-off of excess fertilizer, animal wastes from intensive livestock rearing, aquaculture, industrial effluents and atmospheric deposition of pollutants.

Although both phosphorus and nitrogen contribute to eutrophication, increased loadings of phosphorus are usually considered to have played a central role in accelerated eutrophication of rivers and lakes (Moss, 1996, 1998; Reynolds and Davies, 2001). Generally, phosphorus (as orthophosphate) is the limiting nutrient in freshwater aquatic systems. That is, if all phosphorus is used, plant growth will cease, no matter how much nitrogen is available. Although phosphate is an essential element for plant growth and a fundamental element in the metabolic reactions of plants and animals, excessive inputs will result in changes in primary production and species composition resulting in intense algal blooms and oxygen depletion due to the plant material from the increased blooms and algae

---

<sup>1</sup> From an ecological point of view, large scale eutrophication can be summarised as "oxygen depleted 'dead' bottoms, excessive planktonic and epiphytic algal growth along with a shrinking of the littoral fucus habitat (shift in vegetation and ecosystem)" – Ambio (1990).

decomposition. The lack of oxygen causes the death of organisms requiring high oxygen levels such as fish. Hydrogen sulphide is also produced which is poisonous and can lead to 'dead' water bodies.

Within the UK, patterns of increasing phosphorus concentrations in freshwater are well documented (e.g. DoE, 1976; Heathwaite et al., 1996; Neal et al., 2000) and suggest that phosphorus concentrations have increased to elevated levels that affect freshwater ecology. The resulting increased fertility through its effect on destabilising the ecosystem, causes the growth of algae, in the form of slime, mats and blooms, certain rooted aquatic plants and weeds. Thus results in various anthropocentric impacts upon the quality of water supplies causing taste and odour problems and clogging industrial water supply filters resulting in large cleanup costs. Eutrophication also causes deleterious effects upon recreation activities, aesthetic quality, and commercial and sport fishing<sup>2</sup> and has been associated with seafood contamination by neurotoxins leading to human health problems. It is immediately apparent then that eutrophication can affect an ecosystem in numerous ways and that there may be substantial economic costs as a result of such pollution.

The Environment Agency's 1998 report on the state of fresh water in the UK identified nutrient enrichment as one of the key issues that needs to be addressed in order to achieve a more sustainable balance between the needs of society and that of freshwater ecosystems. Phosphates are introduced into fresh water from both domestic sewage and agricultural run off. In contrast to agricultural waste and soil run-off, sewage and urban waste waters arise in far greater quantity; and the potential for adverse environmental impact from the phosphates they contain are by far the most serious (Moss, 2001). Estimates for the UK put the annual production of domestic sewage at around 40 million tonnes. These wastes are estimated to contain around 45,000 tonnes of phosphorus, largely derived from human wastes and other household activities, including contributions from household detergents (CEFIC/CEEP, 1998).

The stresses put upon the integrity of freshwater resources are likely to be further exacerbated as a result of pressure from global climate change and population growth. Over the past fifty years or so, there has been an increasing pattern of climate variability in the UK with a trend towards greater extremes, resulting in lower summer baseflow and higher winter flows (Marshe and Sanderson, 1997). The trends reduce the capacity for sewage dilution resulting in elevated nutrient concentrations (Neal et al., 2000)<sup>3</sup>. Consequently there are concerns over nutrient inputs; i.e. lower summer baseflows, higher water residence times and elevated nutrient concentrations may promote the development of algal blooms (Jarvie et al., 2002), with some evidence of regional climate change impact on nutrient cycling in the UK (Osborn et al., 2000). Horne and Goldman (1994) report that alterations to the nutrient cycle through climate change will exacerbate existing water quality problems such as eutrophication. Climate change is also expected to have a secondary effect upon water quality through its role in increasing human demand for water services (Climate Change, 2001), an effect which may well be exacerbated by population growth. For example, the East Anglian case study area considered in this paper has one of the highest population inflows in the UK (Regional Trends, 2002), but is not particularly well prepared for such changes. Of a total of 1200 sewage works in the East Anglian region, only 91 have nutrient treatment facilities for removing phosphates (Environment Agency, 2003).

Given the importance of the water environment to society and the economy, there are statutory obligations and strong political pressure for greater control of phosphorus levels in

---

<sup>2</sup> In fact fish production may increase, though species composition will change, for example trout may decline in favour of fish of lower value.

<sup>3</sup> The impact of these changes is most severe in the south and east of England, which experiences low rainfall and high evapo-transpiration (Jarvie et al., 2002).

freshwater ecosystems. The recently agreed EU Water Framework Directive (WFD) together with the EU Urban Waste Water Treatment Directive (UWWT) provide an important impetus for the general control of phosphorus. The 1991 UWWT Directive (CEC, 1991) is concerned with the collection, treatment and discharge of urban and certain industrial wastewaters, and addresses the waters suffering, or at risk from eutrophication. Various measures have been taken in the UK to achieve compliance, including increasing the number of designated sensitive areas and the increased treatment of urban waste water through phosphate stripping, dredging, etc. Although significant progress has been achieved through the UWWT Directive, it has not achieved all of its stated goals. Given the increasing demand for cleaner water environments, the European Parliament and Council adopted a comprehensive Water Framework Directive that entered into force on 22 December 2000 (CEC, 2000). It requires all member states to adapt the Directive into their National and Regional water laws by December 2003. An important part of compliance with this Directive is the completion by December 2004 of an analysis of the impact and pressures upon states' waters, along with an economic analysis. Such waters need to meet 'good' status by December 2015. For surface waters, the definition of 'good' is based on a new concept of 'ecological quality' taking into account biology, chemistry and their physical features.

Turning now to the costs of preventing eutrophication, a significant problem here in estimating such costs concerns the fact that no absolute definition exists of when nutrient enrichment causes adverse impacts. Rather threshold levels vary such that the nature of the relationship between nutrient enrichment, resulting effects, and costs is uncertain. Accepting this caveat, Pretty *et al.*, (2002) provide some useful cost estimates by carrying out an assessment of the policy response costs of preventing eutrophication of fresh waters for the whole of England and Wales. The costs incurred in responding to eutrophication damage and changing practices to meet legal obligations include compliance control costs and other direct costs incurred by agencies. The compliance costs incorporate sewage treatment costs, the costs of treatment of algal blooms and in-water preventive measures, and the costs of adopting new farm practices that result in lower emissions of nutrients. The direct costs incurred include the costs incurred by statutory agencies for monitoring of water and air, investing in eutrophication control policies and strategies, and enforcing any solutions to eutrophication. With regards to estimating these various costs, the authors note a number of limitations with the economic data on eutrophication. Firstly, there are a number of valuation methodologies and these are not necessarily comparable across cost categories. Second, the limited data for England and Wales necessitated the use of information from elsewhere in the UK and the world. Thirdly, some cost data relate to the wider problem of sewage treatment and hence only a proportion relates specifically to eutrophication. Finally, there is some degree of uncertainty regarding the temporal, spatial and geographic extent of the problem and associated costs. Despite these problems in estimation, Pretty *et al.*, (2002) find that the current annual policy response costs of addressing eutrophication damage in England and Wales amount to £54.8 million. We adapt those figures for use in our subsequent cost-benefit analysis.

### **3. THE BENEFITS OF PREVENTING EUTROPHICATION**

In order to carry out a cost benefit analysis exercise it is obviously necessary to estimate the economic benefits that individuals derive from preventing excess algae (eutrophication) impacts upon open water in rivers and lakes in East Anglia. It is this estimation that forms the major empirical focus of this paper. Given the public goods nature of rivers and lakes in the East Anglia region, estimates of the economic benefits lost through damage to these goods as a result of eutrophication are not available from market price data. In order to obtain the values needed to undertake a cost benefit analysis, a survey questionnaire based on the Contingent Valuation method (Mitchell and Carson, 1989; Bateman *et al.*, 2002) was used to estimate individual's willingness to pay (WTP) for a scheme to prevent excess algae

in the rivers and lakes in order to ensure continued access to the amenity and recreation facilities which each site provides. In the present case, respondents were being asked to pay for a sewage treatment program that would remove phosphorous and reduce eutrophication. As such the study seeks to estimate an equivalent loss welfare measure (Boadway and Bruce, 1984; Bateman et al, 2000)<sup>4</sup>. Furthermore in undertaking the valuation exercise it is necessary to define the accounting stance, or relevant target population, with which to compare the economic benefits and costs. Since the present study was considering the 'rivers and lakes of East Anglia', only the regional population was considered in the valuation and subsequent aggregation exercise, though it is acknowledged that those who benefit may include user households living outside the area as well as a significant population holding non-use values (who may be quite dispersed and difficult to determine).

### ***CV Survey Design and Data***

A contingent valuation survey requires that the change in the provision of the good that respondents are being asked to value is communicated to and understood by them. A procedure to elicit respondent's values is then required (elicitation method), as well as a mechanism by which respondents are told that they will have to pay for the change in provision (payment vehicle). One needs to be confident that respondents are actually valuing the specific change in provision and not some other more general change. These elements are usually contained within an information statement, a valuation scenario and questions, and debriefing questions. In designing the contingent valuation survey questionnaire used in the present study there were a number of stages in its development, including focus group discussions (Morgan, 1993; Krueger, 1994) and a pilot survey of roughly 100 respondents.

The aim of the focus groups was to help determine how much information to present and how to convey it within the specific context of this study, such that the valuation scenario was credible and realistic, as well as to refine the questions used in the valuation exercise survey (e.g. Desvousges and Frey., 1989). Four focus group sessions of between six and seven people were thus organised and conducted during March 2003 with groups of East Anglian residents. The focus group protocol paid particular attention to participants' level of understanding of issues such as: the concept of 'open' waters; the uses given to 'open' water; the frequency of these activities (uses); the characteristics of good rivers and lakes; the concept of 'algae'; the causes of algal growth; the problems caused by excess algae; what defines a 'bad' river or lake; how 'bad' qualities are rated; how both good and bad open water is defined.

The findings from the focus groups were used in the development of a draft contingent valuation survey questionnaire. This comprised a number of sections including: respondents' assessment of their present use of water bodies; reactions, including belief indicators, regarding the process by which water bodies may be affected by eutrophication; assessments of how such changes might impact upon usage of those water bodies; valuation scenario section outlining the proposed scheme (solution to the phosphorus problem); valuation task to determine households willingness to pay to avoid the specified eutrophication impacts; further belief indicators regarding perceived credibility of the proposed phosphorus reduction scheme.

Since the study was concerned with the prevention of eutrophication of rivers and lakes caused by domestic sewage as a result of future climate and population changes, the valuation scenario paid particular attention to the features and uses of rivers and lakes, the problem of phosphates, their sources and impacts in terms of algal blooms, future increases in the population of East Anglia and consequent pressure on sewage treatment works, and

---

<sup>4</sup> For convenience we adopt the term WTP to refer to this value measure, although it should be noted that in so doing we are not referring to the compensating gain measure to which the WTP term more properly applies.



the effects of changing future weather patterns on water quality. Pictograms and photographs were used to explain the scenario, these being detailed in the Appendix to this chapter. These were tested and revised in the focus group discussions. Regarding the constructed market solution to the problem of eutrophication, survey respondents were asked to consider a plausible phosphate removal scheme at sewage works. They were told that such treatment would increase their annual household water bill. Such bills have desirable properties as a payment vehicle since their compulsory payment nature reduces any potential free riding behaviour (Day *et al.*, 1998, Bateman *et al.*, 2002). Water bills are also likely to be the method by which actual payments would be made.

After the presentation of the valuation scenario and payment vehicle, the elicitation question asked respondents how much they would pay to purchase the good, under specified terms and conditions. In particular, the question was based on the application of a novel 'one and one half bound' (OOHB) dichotomous choice (DC) method for the elicitation of WTP values that has recently been developed (Cooper *et al.*, 2002). This differs from a standard single bound DC approach (based on a single yes/no question)<sup>5</sup> or the double bound DC approach (based on a first yes/no question followed by a second yes/no question conditional upon the answer given to the first question), and instead presents survey respondents with upper and lower bound limits of cost per household (or per individual) associated with provision of the good in question. These amounts, which are presented simultaneously as a range, are denoted as £U and £L respectively. Once the range has been defined, a typical treatment might ask a respondent initially if they are prepared to pay the amount £L. A negative response to this question terminates the value elicitation process and is assumed to indicate that the respondent has a WTP less than or equal to £L. However, a positive response to this initial question triggers a second valuation task in which the respondent is asked whether they are prepared to pay £U. Here a further positive response is assumed to indicate that WTP is greater than or equal to £U whereas a negative response denotes WTP lies somewhere between £L and £U. The precise value of £L and £U varies across the sample in order to permit the estimation of survival functions and associated mean and median WTP. The present study is the first to apply this technique within a public goods, non-market valuation context.

The OOHB procedure thus generates a mixture of either single or double bounded responses from individuals. The approach has greater statistical efficiency than the single bound dichotomous choice approach, and whilst not as efficient as the double bounded format, does not suffer from the charge of lacking incentive compatibility regarding the second of the double bounded responses (Carson *et al.*, 2000)<sup>6</sup>.

The elicitation questions were followed by a debriefing question which asked respondents to state their reasons for accepting or refusing the bid amounts. This was followed by questions about the respondent's beliefs regarding the plausibility of the scenario presented. Finally, the survey included questions concerning demographic and socio-economic characteristics of the respondent.

---

<sup>5</sup> Which has been endorsed by the NOAA Blue Ribbon Panel (Arrow *et al.*, 1993) on the grounds that it is an incentive compatible format.

<sup>6</sup> The lack of incentive compatibility arises since respondents are told that the first of the double bounded bids is the cost of the scheme. This is then (conditional upon the first bid response) sequentially changed to a second bid. Arguably this lack of incentive compatibility underpins the observed inconsistency between first and second response distributions in DB exercises (Cameron *et al.*, 1994; Kanninen, 1995; Bateman *et al.*, 2001). The OOHB approach attempts to address this problem by presenting a range of prices at the outset of the valuation exercise so that the plausibility and incentive compatibility of both £U and £L are assumed to hold for both elicited responses.

The draft questionnaire was administered on a sample of around 100 respondents for the purposes of pre-testing and in order to derive information with which to specify a bid vector for use in the main survey. Results from the pilot survey helped to fine-tune the questionnaire, especially in regards the refinement of the valuation scenario budget reminder and the inclusion of 'cheap talk' text. Cheap talk refers to the process of explaining hypothetical bias to individuals prior to asking a valuation questions, and has been found to help in reducing such bias when administered with due care (Cummings and Taylor, 1999; List, 2001; Aadland and Caplan, 2003).

Following on from the pilot testing of the questionnaire, the main survey was carried out for a period of five weeks in and around the city of Norwich, centrally located in the East Anglia region. The survey was carried out using a face-to-face interview approach in accordance with the NOAA Panel recommendation (Arrow *et al.*, 1993). Randomly selected starting bid levels were administered to the sample. Information gleaned from the focus group and pilot survey exercises suggested a bid vector ranging from £10 to £200. Each respondent was randomly allocated to one of nine possible bid pairs: £10-£50; £25-£100; £50-£100; £75-£100; £100-£150; £100-£200; £48.50-£98.50. With the exception of the latter pair (£48.50 to £98.50 which was only offered in a 'lower to upper', ascending order), all bid pairs were offered either in an ascending or descending order generating a total of 13 different bid treatments. Although households were randomly allocated to bid pairs care was taken to ensure that roughly similar proportions were allocated to each pairing of bid amounts.

## **Results**

The results of the contingent valuation survey are presented under four headings. The first section provides information on the general characteristics of the sample; the second section considers respondents' perceptions and level of awareness of the issue, while the third section presents the results of the valuation exercise to assess the benefits of reducing eutrophication. The fourth section aggregates these benefit estimate values for the relevant population to obtain total benefits from reducing the damage caused by eutrophication to rivers and lakes in East Anglia.

### *Survey participation and refusal*

Although most contingent valuation studies undertake extensive analysis of WTP responses, relatively few consider the important issue of sample self selection. In total, 2321 households were approached for interview at their place of residence. Of this, 1067 refused to participate in the survey, thus giving a response rate of 54%. Analysis of the decision to participate in the survey was undertaken in order to examine whether there was any systematic bias in the survey sample collected. This analysis was naturally limited to those variables passively observable by interviewers for those who were approached for interview (since it was not possible to collect more extensive information on those who refused to participate in the survey). These variables included: the approximate age of the person approached; their gender; and the type of housing they lived in. It was found that, as expected, there was a high degree of correlation between the type of housing a person lived in and their age. Further multivariate logistic regression analysis examined the influence of the available variables, including the gender of the interviewer, on the decision to participate in the survey. Given the correlation between house type and age, as well as the ease of interpreting the age variable, the former variable was excluded from this analysis. Table 1 shows the coefficients from the estimated model that explains respondent participation in the survey. All the coefficients were highly significant and indicate that: the probability of participating in the survey is a parabolic function of age; female respondents are less likely to participate in the survey compared with men; and respondents of either sex are more likely to participate in the survey when questioned by a female rather than a male.

**Table 1: Multivariate Logistic Analysis of Decision to Participate in Survey**

Variable	Coefficients	s.e.
Respondent age	-0.9491 **	0.1627
(Respondent age) <sup>2</sup>	0.0818 **	0.0138
Female respondent	-0.1933 *	0.0859
Female interviewer	0.3514 **	0.0877
Constant	2.7065 **	0.4527
LLF	-1572.9364	

Figures in parentheses are standard errors. Confidence levels are: \*\* 99 % ; \* 95 %

Figure 1 illustrates these findings more clearly by showing the probability of participating in the survey according to age, the gender of the respondent and the gender of the interviewer. We observe a U shaped relationship between age and participation. This relationship contrasts with the inverted U relationship between WTP and age sometimes observed in CV studies<sup>7</sup>. Taken together one might argue that these results suggest that those most likely to participate in CV studies are those with lower values for the good in question. This need not be considered a paradox if we consider that those with lower values may be participating so as to ensure that their values are not over-ridden in the decision process resulting in an overcharging for services relative to the value they generate for such respondents.

<sup>7</sup> Aldy and Viscusi, 2004; Arnould and Nichols, 1983; Johannesson et al., 1997; Jones-Lee et al., 1985; Thaler and Rosen, 1975; and Viscusi, 1979 report such an inverted U for WTP for risk reduction. Alberini et al. (2004) find a somewhat weaker relationship, revealing a reduction in WTP measures of the value of statistical life after age 70.

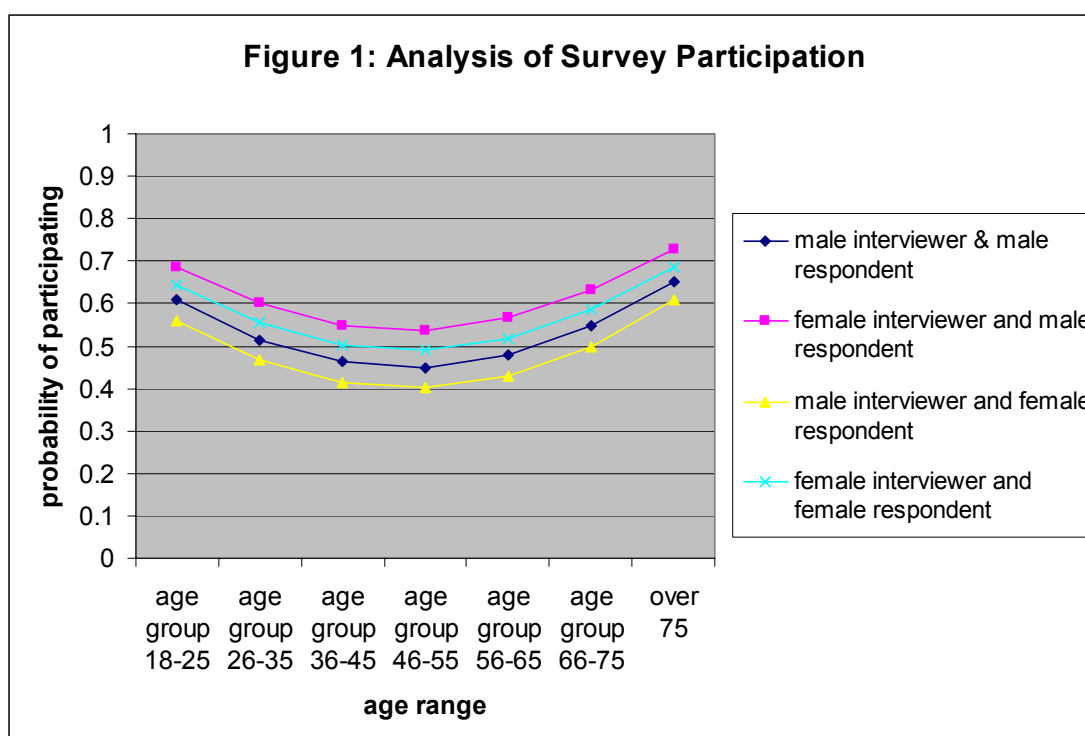


Figure 1 also illustrates the interactions between age and the gender of both the (potential) respondent and the interviewer. Those most likely to participate in the survey are male respondents being interviewed by female interviewers, whilst those least likely to participate are female respondents being interviewed by male respondents. In summary these findings suggest that there is significant self-selection within our sample, a result which we suspect may apply to many other CV studies which typically do not test for this problem. We return to this issue subsequently.

### *Respondents characteristics*

If we now consider the sample that actually completed the survey, their general socio-economic characteristics are shown in Table 2 along with the population demographics of the East Anglia target population (Regional Trends, 2001). There were significant differences in gender ( $p < 0.05$ ) and employment ( $p < 0.05$ ) between the study sample and the target population. However, no significant differences were found in the distribution of income between the study sample and the target population.

**Table 2: Economic and socio-demographic characteristics of the sample and target population**

Respondent's characteristics	Total sample	East Anglia population
Mean household income per annum (£)	£ 22,732	£ 26, 520
Mean age (years)	47.2	N/A
University degree (%)	26.8	N/A
Upper secondary (%)	57.2	N/A
Female (%)	57.0	51.0
Mean size of the household	2.6	2.4

Employment (% of sample with some type of employment)	52.6	79.2
Membership to Green peace/National trust/RSPB (%)	24.1	N/A

*Awareness, perceptions and beliefs regarding eutrophication and the valuation scenario*

Prior to the valuation questions, respondents awareness of the algae problem was sought, as well as their perceptions of how algae might affect their enjoyment of any visit made. The responses to these questions are presented in Table 3. It can be seen that 82.5% of the sample surveyed had previously seen algae in the water bodies, whilst 69.1% considered it would considerably reduce their enjoyment of a visit.

**Table 3: Awareness and perceptions regarding eutrophication**

<b>Awareness</b>	Have you ever seen algae before in any lake or river you have visited?	Response (%)
	No (%)	16.3
	Yes (%)	82.5
	Unsure (%)	1.2
<b>Perception</b>	How will seeing algae in the water affect your enjoyment of the visit?	Response (%)
	No change in enjoyment	4.9
	Slight reduction in enjoyment	25.9
	Considerable reduction in enjoyment	69.1

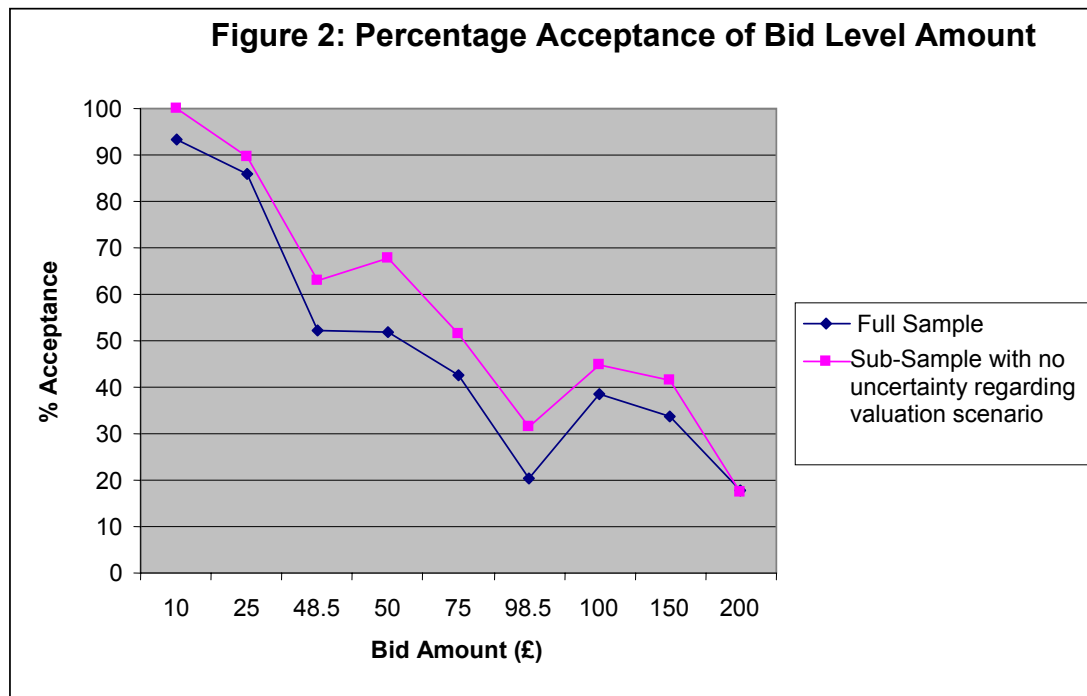
Respondents were also asked some questions concerning the plausibility of the constructed CV scenario. These included questions about whether they believed the information that was presented to them regarding: population growth in East Anglia; the change in weather patterns in recent decades, the possibility of excess algae occurring in the future; and the success of the proposed scheme to prevent algal growth. Responses to these questions are shown in Table 4. In all cases, the majority of respondents believed the information that was provided. However a substantial minority expressed uncertainty regarding the effectiveness of the proposed scheme. We return to this issue subsequently.

**Table 4: Belief in the Valuation Scenario**

<b>Statement on valuation scenario considered</b>	<b>Don't Believe (%)</b>	<b>Unsure (%)</b>	<b>Believe (%)</b>
<b>Population of East Anglia is increasing</b>	0.8	5.0	94.2
<b>Weather patterns are changing</b>	3.5	17.5	78.9
<b>Possibility of excess algae occurring in the future</b>	0.6	14.8	84.6
<b>The scheme would prevent excess algae from occurring</b>	1.4	33.0	65.6

### *Economic valuation results*

A total of 1254 households completed the survey questions containing one of the 13 bid treatments, selected randomly so as to ensure equal sample sizes for each bid level. The percentages of respondents agreeing to accept payment of the bid level amount offered to them are presented in Figure 2 and Table 5 for each of the nine possible bid amounts used. It can be seen that, as expected, the rate of acceptance falls from 93.2% of the sample when the bid amount is £10 to 17.8% acceptance when respondents face a £200 bid level amount. Acceptance rates are also shown for the sub-sample of respondents who answered positively to the questions on the plausibility of the valuation scenario (see previous section). Once again the proposed bid amount had a negative relationship on acceptance of the bid level. Comparing acceptance rates across the two samples, it can be seen that, as expected, higher acceptance rates were found at all bid levels (with the exception of the highest bid level of £200) for the sub sample who expressed no uncertainty regarding the plausibility of the valuation scenario.



**Table 5: Response to bid levels**

<b>Bid Amount (£/household/year)</b>	<b>Total sample</b>			<b>Believers in scenario<sup>a</sup></b>		
	Total asked <sup>b</sup>	Acceptance of bid amount	Percentage	Total asked <sup>b</sup>	Acceptance of bid amount	Percentage
10	178	166	93.2	93	93	100
25	169	145	85.8	76	68	89.5
48.50	46	88	52.3	35	22	62.9
50	341	177	52.0	174	118	67.8
75	167	71	42.5	78	40	51.3
98.50	88	18	20.5	35	11	31.4
100	836	323	38.6	409	183	44.7
150	163	55	33.7	82	34	41.5
200	174	31	17.8	92	16	17.4

<sup>a</sup> Believers in scenario represent the subgroup of the sample who responded positively to the questions used to test the plausibility of the valuation scenarios.

<sup>b</sup> Total asked numbers include responses to the initial value presented and when it was presented as a follow-up value. Hence, we do not have equal numbers of responses for each bid value.

In order to obtain estimates of the mean and median WTP values for the phosphorous removal scheme, parametric modelling of the OOHb responses is undertaken. The OOHb model begins by assuming that the an individual's WTP is a random variable with a cumulative distribution function (CDF) denoted  $G(C_i; \theta)$ , where  $C_i$  is the individual's true maximum WTP and  $\theta$  represents the parameters of the distribution, which are to be estimated on the basis of the responses to the CV survey. As outlined earlier, the OOHb format presents respondents with an initial range of bids  $[L, U]$  such that  $L < U$ . One of the two bids ( $L, U$ ) is selected at random and the respondent is asked if they would be willing to pay this amount. A follow-up question is asked only if it is compatible to the response to the initial bid. Thus, if the lower bid amount  $L$ , is drawn randomly as the initial bid, a respondent would only be asked a second question about willingness to pay the higher bid amount ( $U$ ) if they have said yes to the initial lower bid. If the lower bid amount ( $U$ ) is offered as the starting bid, then there are three possible response outcomes. These are (no), (yes, no to the second higher bid amount) and (yes, yes to the second higher bid amount). Following Cooper *et al.*, (2002) the corresponding response probabilities are denoted by  $\pi_i^N$ ,  $\pi_i^{YN}$ ,  $\pi_i^{YY}$ . Conversely, if the higher bid amount ( $U$ ) is offered as the initial bid, the possible response outcomes are (yes), (no, yes to the second lower bid amount) and (no, no to the second lower bid amount). Again, the response probabilities can be denoted as  $\pi_i^Y$ ,  $\pi_i^{NY}$ ,  $\pi_i^{NN}$ . As these probabilities are such that  $\pi_i^N = \pi_i^{NN}$  and so forth, then:

$$\pi_i^N = \pi_i^{NN} = \Pr\{C_i \leq L\} = G(L; \theta),$$

$$\pi_i^{YN} = \pi_i^{NY} = \Pr\{L \leq C_i \leq U\} = G(U; \theta) - G(L; \theta),$$

$$\pi_i^{YY} = \pi_i^Y = \Pr\{C_i \geq U\} = 1 - G(U; \theta).$$

The log likelihood function for responses using the OOHb format is given by:

$$\ln L^{\text{OOHB}}(\theta) = \sum_{i=1}^N \{d_i^Y \ln [1 - G(U; \theta)] + d_i^{YN} \ln [G(U; \theta) - G(L; \theta)] + d_i^N \ln [G(L; \theta)]\}$$

where,

- $d_i^N = 1$  if either the starting bid is  $L$  and the response is (no) or the starting bid is  $U$  and the response is (no, no), and 0 otherwise;
- $d_i^{YN} = 1$  if either the starting bid is  $L$  and the response is (yes, no) or the starting bid is  $U$  and the response is (no, yes), and 0 otherwise; and
- $d_i^{YY} = 1$  if either the starting bid is  $L$  and the response is (yes, yes) or the starting bid is  $U$  and the response as (yes), and 0 otherwise.

The parameters of the WTP distribution are estimated by maximising the above log-likelihood function using maximum likelihood techniques programmed in GAUSS®. In the empirical application described below, we assume that the distribution of WTP,  $G(\cdot)$ , is log normal. Accordingly, values for mean and median WTP can be simply recovered by plugging the parameter estimates into well-known closed-form formulas that describe the mean and median of a log-normal distribution (Bateman *et al.* 2002). Moreover, 95% confidence intervals for mean and median WTP can be estimated using a bootstrap procedure (Efron and Tibshirani, 1993). In our application, the 95% confidence interval is taken as the 2.5th and 97.5th percentiles of the distribution of mean (or median) WTP values calculated from 1000 bootstrap samples of the original data.

In order to assess the theoretical validity (Mitchell and Carson, 1989; Bateman *et al.*, 2002) of our findings, statistical analysis procedures, as set out above, were employed to estimate a bid function in which the mean of the distribution was able to be shifted by the



socioeconomic characteristics of respondents<sup>8</sup>. The variables included in the model were respondents' sex, age, income and their annual frequency of visits to lakes and rivers in East Anglia. The estimated model, which is described in Table 6, makes the conventional assumption that the WTP distributions underpinning responses to the first and second bound are identical (irrespective of the order in which amounts were presented)<sup>9</sup>. Results from the estimation process show the expected negative relationship between a positive response and the cost of the scheme, with the latter providing a superior fit when specified as a natural logarithm (lnPRICE). Expected positive relationships are also with respondents' household income and the annual number of visits to lakes and rivers. WTP also declines significantly with age, but is not significantly determined by the sex of the respondent. These findings accord with prior economic-theoretic expectations and thereby support the theoretical consistency of our results. The degree of correlation that exists between the two responses from the same individuals is captured by the parameter RHO which here is positive and significantly different from zero, implying that there is positive correlation between individuals' responses<sup>10</sup>.

**Table 6: Coefficients from constrained model**

Variable	Coefficients (s.e.)
Ln BID	-0.7783 (0.0584) *
INCOME	0.0133 (0.0024) *
AGE	-0.0040 (0.0019) **
FEMALE	0.0652 (0.0680)
VISITOR	0.0009 (0.0004) **
CONSTANT	3.0917 (0.2777) *
RHO	0.4263 (0.1134) *
LLF	-1092.157

Figures in parentheses are standard errors. Confidence levels are: \* 99 % ; \*\* 95 % ; \*\*\* 90 %

The coefficients from the above model were used to produce estimates of the mean and median WTP as shown in Table 7. The mean household annual WTP for the total sample (n=1112) was found to be £75.41. Although analysis of protest responses was undertaken, this did not have any impact on the valuation estimates<sup>11</sup>. Further analysis was also

<sup>8</sup> While Table 1 is compiled from responses from the full set of 1254 households, the regression models are restricted to a smaller set of some 1112 households who provided responses in terms of the socioeconomic and demographic covariates considered. The extent of this change is dictated by item non-response to the income question for which 142 households (11.3% of those interviewed) failed to provide a response.

<sup>9</sup> In further work we examine the implications of relaxing this assumption (see Bateman et al., 2004).

<sup>10</sup> More intriguingly, the correlation is far from perfect; RHO is highly significantly different from a value of 1 (t-stat 8.38). Again this is investigated further in Bateman et al., (2004).

<sup>11</sup> A total of 232 protest bids were identified based on the answers to question regarding the reasons for acceptance/refusal of a bid amount. These were identified as proposed by Bateman *et al.*, (2002).

undertaken on the sub-sample of users (according to whether respondents visited the rivers and lakes in the East Anglia region). Thus 1013 users were identified. It was found that the users did have a slightly higher WTP than the total sample, though the difference was not statistically significant. These results are in line with the consistent finding of somewhat elevated WTP amongst user groups (Desvousges et al, 1987; Dupont, 2003) showing that users have higher WTP than non-users. Estimation of WTP for non-users was not possible due to insufficient sample size.

WTP estimates were also estimated for the sample of respondents who 'believed' (see Table 4 for definition) in the plausibility of the valuation scenario'. These results are also presented in Table 7. For the sample of 'believers', the mean annual household WTP was now £66.39. Once again when only users of rivers and lakes were included for the 'believers' sample mean household WTP was £67.06 per year. Again the mean WTP of the non-users was not estimated due to insufficient sample size.

**Table 7: Mean and median WTP for the total sample and 'scenario believers' sub-sample**

<b>Total sample</b>	<b>Total (N=1112)</b>	<b>Users(N=1013)</b>
<b>Mean WTP (£)</b>	75.41	77.75
<b>Median WTP (£)</b>	69.07	71.87
<b>95% C.I.</b>	69.41-84.36	70.43-86.96
<b>Believers only</b>	<b>Total (N=537)</b>	<b>Users (N=497)</b>
<b>Mean WTP (£)</b>	66.39	67.06
<b>Median WTP (£)</b>	63.86	64.66
<b>95% C.I.</b>	58.98-74.97	58.93-76.89

#### *Aggregation of Benefit Estimates*

In aggregating the benefits estimates for application within a Cost Benefit Analysis only the population of the East Anglian region was included as the relevant population that benefits from the prevention of eutrophication. However, as already discussed, such values exclude those held by others living outside the region and so can be considered lower bound benefit estimates.

The results of the benefits aggregation exercise are shown in Table 8. The estimates found differ according to the precise WTP values assumed to apply at the population level. In this respect, two possible alternatives were identified. For our first estimate, no adjustment is made to the sample mean WTP to take account of those respondents who refused to be interviewed (i.e., the sample mean WTP is applied to the target population). In this case, the population aggregate WTP was estimated by multiplying the sample mean WTP (£75.41) by the number of households in East Anglia (2.253 million) to obtain annual benefits of £170 million. Our second estimate assigns a zero WTP to those who refused to be interviewed (as per Bateman *et al.*, 1997). As such, the inclusion of the 1067 respondents who refused to be interviewed results in a lower sample mean household WTP per year of £38.48 giving an aggregate annual benefits estimate of £87 million.

**Table 8: Aggregate Benefits of the phosphate removal scheme for East Anglia region**

<b>Aggregation approach</b>	<b>WTP per household (1) (£/year)</b>	<b>Aggregate Benefits (£) [(1) x 2.253million]</b>
Aggregation with sample mean WTP (excluding non-response) and East Anglian population- total sample	75.41	169.89 million
Aggregation with sample mean WTP (including non-response) and East Anglian population - total sample	38.48	86.70 million

#### **4. COMPARISON OF COSTS AND BENEFITS AND CONCLUSION**

Comparing the annual aggregate benefits of preventing eutrophication by a phosphate removal scheme for the East Anglian Region (shown in Table 8) with the current annual policy response costs of addressing eutrophication damage for the whole of England and Wales (reported in section 2 at £54.8 million), it is clear that net benefits are positive. Even for the lower bound benefit estimate value of £86.7 million/annum, the costs of addressing eutrophication for the whole of England and Wales are still less than the benefits of preventing eutrophication just for the East Anglian region.

One source of uncertainty in our analysis is the self-selection bias noted at the start of our discussion of results. This issue, commonly ignored in many CV studies, proved significant with participation in the survey being linked to age and the interplay between interviewer and potential respondent. However, our analysis provides admittedly circumstantial evidence to suggest that, if anything, it may be those with lower WTP values who are self-selecting into the sample of respondents at a greater rate than others. This would tend to deflate aggregate values and lower benefit-cost ratios. Certainly we have no evidence here to suggest that total values have been inflated by the self-selection process. Consequently the above conclusions remain valid in our opinion.

Although there are still uncertainties associated with both the cost and benefit estimates, fresh water resources would appear to be highly valued, and policies and schemes to protect them can be considered to be worthwhile investments. This point is driven home by the fact that the benefit estimated in this study was only for prevention of eutrophication by a phosphate removal scheme. Other benefits linked to the protection of rivers and lakes, such as, the value of water bodies for commercial and other uses, make the investment in phosphate removal equipment an even more compelling project.

To conclude, CBA has been previously used in number of water resources management schemes (Eisen-Hecht *et al.*, 2002, Whittington *et al.*, 1994, Bateman *et al.*, 1995). In terms of project analysis, no method other than CBA enjoys as widespread application or analytical power. The analysis of the relative costs and benefits of preventing eutrophication undertaken in this study has shown how even a 'crude' cost benefit analysis can play an important role in environmental decision making. In the wake of the new EU Water Framework Directive and the increasing pressure on public finances, it becomes even more important to correctly allocate resources with respect to fresh water resource protection. Such investments would certainly appear to be worthwhile since these resources provide positive net benefits for people in the United Kingdom.

Finally, recall that the benefit values estimated in this study were based on the novel one and one half bound elicitation method proposed by Cooper *et al.*, (2002). This approach is designed to address some of the problems associated with single bound and conventional double bounded elicitation approaches. Nevertheless, more rigorous testing of the methodological robustness of this technique is warranted and further investigation is ongoing (see Bateman et al, 2004).

## References

- Aadland, D., Caplan, A.J. (2003), 'Cheap talk reconsidered: New evidence from CVM', Department of Economics, Utah State University.
- Alberini, A., Cropper, M., Krupnick, and Simon, N.B. (2004) Does the value of a statistical life vary with age and health status? Evidence from the US and Canada, *Journal of Environmental Economics and Management*, 48: 769–792.
- Aldy, J. and W. K. Viscusi. (2004). Age Variations in Workers' Value of Statistical Life, *mimeo*, Harvard University.
- Ambio, (1990), Special Report No. 7, Sept 1990, Royal Swedish Academy of Sciences.
- Arnould, R., and L. Nichols. (1983). "Wage-Risk Premiums and Workers' Compensation: A Refinement of Estimates of Compensating Wage Differential", *Journal of Political Economy*, 91(2):332-340.
- Arrow, K.R., Solow, P.R., Portney, E.E., Radner, L.R., and Schuman, H, (1993), 'Report of the NOAA panel on contingent valuation', Washington DC: Resources for the Future.
- Bateman, I.J., Carson, R.T., Day, B., Hanemann, W.M., Hett, T., Jones- Lee, M., Loomes, G., Mourato, S., Ozdemiroglu, E., Pearce, D.W., Sudgen, R., and Swanson, R., (2002), *Economic valuation with stated preference techniques: a manual*, Cheltenham: Edward Elgar publications.
- Bateman, I.J., Day, B.H., Dupont, D. and Georgiou, S. (2004) 'OOH la la: Testing the one-and-one-half bound dichotomous choice elicitation method for robustness to anomalies'. *CSERGE Working Paper EDM 04-6*, Centre for Social and Economic Research on the Global Environment, University of East Anglia.
- Bateman, I.J., and Langford, I.H. (1997), 'Budget constraint, temporal and ordering effects in contingent valuation studies', *Environmental and Planning A*, 29(7): 1215-1228.
- Bateman, I.J., Langford, I.H., Jones, A.P. and Kerr, G.N. (2001), 'Bound and path effects in double and triple bounded dichotomous choice contingent valuation', *Resources and Energy Economics*, 23: 191-213.
- Bateman, I.J., Langford, I.H., Munro, A., Starmer, C. and Sugden, R. (2000) 'Estimating the four Hicksian measures for a public good: a contingent valuation investigation', *Land Economics*, 76(3): 355-373.
- Bateman, I.J., Langford, I.H., Turner, R.K., Willis, K.G. and Garrod, G.D. (1995) Elicitation and truncation effects in contingent valuation studies, *Ecological Economics*, 12(2):161-179.
- Boadway, R.W., and Bruce, N. (1984) *Welfare Economics*, Basil Blackwell, Oxford.
- Cameron, T.A. and J. Quiggin, (1994) 'Estimation Using Contingent Valuation Data from a Dichotomous Choice with Follow-Up Questionnaire', *Journal of Environmental Economics and Management* 27(3): 218-234.
- Carson, R.T. and Mitchell, R.C. (1995), 'Sequencing and nesting in contingent valuation surveys' *Journal of Environmental Economics and Management*, 28: 155-173.

Carson, R., Groves, T. and Machina, M. (2000) "Incentive and Informational Properties of Preference Questions", Mimeo. University of California San Diego, February.

CEC (1991). Directive 1991/271/EEC of the European council 21 May, 1991, concerning urban wastewater treatment, Luxembourg: Official Journal of the European Communities, L 327, 1-73.

CEC (2000), Directive 2000/60/CE of the European Parliament and of the Council 23<sup>rd</sup> October 2000 establishing a framework for community action in the field of water policy, Luxembourg: Official Journal of the European Communities, L327, 1-73.

CEFIC/CEEP. 1998. International conference on Recovery of phosphates for recycling from sewage and animal wastes; summary of conclusions and discussions. CEFIC, Belgium.

Climate Change (2001) Impacts, adaptation and vulnerability, contribution of Working Group II to the third assessment report of Intergovernmental Panel on Climate Change, McCarthy, J., Canziani, O.F., Leary, N.A, David, D.J. and White, K.S., (Eds.), Cambridge University Press: 295-303.

Cooper, J.C., Hanemann, M. and Signorello, G. (2002), 'One-and-one-half-bound dichotomous choice contingent valuation', *Review of Economics and Statistics*, 84(4): 742-750.

Cummings, R.G and Taylor, L.O. (1999), 'Unbiased value estimates for environmental goods: A cheap talk design for contingent valuation method', *American Economic Review*, 89(3): 649-666.

Day, B., and Mourato, S. (1998), 'Willingness to pay for water quality maintenance in Chinese rivers', CSERGE working paper WM 98-02, Centre for Social and Economic Research on Global environment, University of East Anglia, and University College of London.

Desvousges, W.H., Smith, V.K. and Fisher, A. (1987), "Option Price Estimates for Water Quality Improvements: A Contingent Valuation Study for the Monongahela River", *Journal of Environmental Economics and Management*, 14: 248-267.

Desvousges, W.H. and Frey, J.H. (1989), "Integrating Focus Groups and Surveys: Examples from Environmental Risk Studies", *Journal of Official Statistics*, 5(4): 349-363.

DoE, Department of the Environment, (1976), *Digest of Environmental Statistics*, HMSO, London.

Dupont, D. P. (2003), 'CVM Embedding Effects When There Are Active, Potentially Active and Passive Users of Environmental Goods', *Environmental & Resource Economics*, 25(3): 319-341.

Efron, B. and Tibshirani, R.J. (1993), *An Introduction to the Bootstrap*, Chapman and Hall, London.

Eisen-Hecht, J.I. and Kramer, R.A. (2002), 'A Cost-Benefit Analysis of water quality protection in the Catawba basin', *Journal of the American Water Resources Association*, 38(2): 453-465.

Heathwaite, A.L. Johnes, P.J. and Peters, N.E. (1996), 'Trends in nutrients', *Hydrological Processes*, 10: 263-293.

Horne, A.J. and Goldman, C.R. (1994), *Limnology*, McGraw-Hill, New York, NY, USA, 2<sup>nd</sup> ed..

Jarvie, H.P., Lycett, E., Neal, C. and Love, A. (2002), 'Patterns in nutrient concentrations and biological quality indices across the upper Thames river basin, UK', *The Science of the Total Environment*, 282-283: 263-294.

Johannesson, M., P-O. Johansson, and K-G., Löfgren. (1997). On the Value of Changes in Life Expectancy: Blips versus Parametric Changes. *Journal of Risk and Uncertainty* 15, 221-239.

Jones-Lee, M.W., M. Hammerton, and P. Philips. (1985). The Value of Safety: Results of a National Sample Survey. *The Economic Journal*, Vol. 95, No. 377, p49-72.

Krueger, R.A. (1994), *Focus Groups: A Practical Guide for Applied Research*, Sage, Thousand Oaks, Ca.

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

List, J.A. (2001), 'Do explicit warnings eliminate the hypothetical bias in elicitation procedures? Evidence from field auction experiment', *American Economic Review*, 91(5): 1498-1507

Marshe, T.J. and Sanderson, F.J. (1997), 'A review of hydrological conditions throughout the period of the LOIS monitoring programme – considered within the context of the recent UK climatic volatility', *The Science of the Total Environment*, 210-211: 59-70.

Mitchell, R.C. and Carson, R.T. (1989), 'Using surveys to value public goods: the contingent valuation method', Resources for Future, Washington, D.C.

Morgan, D.L. (1993), *Successful Focus Groups: Advancing the State of the Art*, Sage, Newbury Park, Ca.

Moss, B. (1996), 'A land awash with Nutrients – the problem of eutrophication', *Chem. Ind.* 3, June.

Moss, B. (1998), *Ecology of freshwaters – Man and medium, past to future*, Blackwell Science, London.

Moss, B. (2001), *The Broads: The people's wetland*, London: Harper Collins Publishers.

Neal, C., Williams, R.J., Neal, M., Bhardwaj, C.L. Wickham, H., Harrow, M. and Hill, L.K. (2000), 'The water quality of the River Thames at a rural site downstream of Oxford', *The Science of the Total Environment*, 251-252: 441-458.

Osborn, T.J., Hulme, M., Jones, P.D. and Basnet, T.A. (2000), 'Observed trends in the daily intensity of United Kingdom precipitations', *International journal of Climatology*, 20: 347-364.

Pretty, J.N., Mason, C.F., Nedwell, D.B. and Hine, R.E. (2002), 'A preliminary assessment of the environmental costs of the eutrophication of fresh waters in England and Wales', University of Essex, U.K.

Regional Trends (2001), National Statistics, UK, No. 36.

Reynolds, C.S. and Davies, P.S. (2001), 'Sources and bioavailability of phosphorus fractions in freshwaters: A British perspective'. *Biol. Rev.* 76: 27-64.

Thaler, R., and S. Rosen. (1975). "The Value of Saving a Life: Evidence from the Labour Market". In N. Terleckyj, (ed.) *Household Production and Consumption*. Columbia University Press; New York. P 265-298.

Viscusi, K. (1979) *Employment Hazards: An Investigation of Market Performance*. Harvard University Press; Cambridge, MA.

Whittington, D.G., Amaral, C.D., McClelland, Wang, H. and Poulos, C. (1994), 'The economic value of improving the environmental quality of Galveston Bay, department of environmental sciences and engineering, University of North Carolina at Chapel Hill and Galveston Bay, national estuary program, publication, GBNEP – 38.



**Appendix: Information used to convey certain of the scenarios presented to survey respondents.**

**Excess algae can change rivers and lakes from this ...**



**To this....**



- **Excess algae forms a scum in and on top of the water**
- **This cuts out light and reduces the amount of oxygen in the water**
- **This can kill larger water plants and the fish and wildlife that depend on them.**
- **It creates an unpleasant odour (a musty or mouldy smell).**

**Algae prevents swimming and may affect other recreation, such as enjoying the view.**

Appendix (continued)

THE WATER ENVIRONMENT IN EAST ANGLIA IS FACING TWO PRESSURES

