Economic Values of Species Management Options in Human-Wildlife Conflicts: Hen Harriers in Scotland.

Nick Hanley*
Economics Division
University of Stirling

Mikolaj Czajkowski
Warsaw Ecological Economics Center
University of Warsaw

Rose Hanley-Nickolls
Scottish Agricultural College
Edinburgh

Steve Redpath
School of Biological Sciences
University of Aberdeen

*Corresponding author. Phone +44 1786 466410, fax +44 1786 467469, email: n.d.hanley@stir.ac.uk. Mailing address: Economics Division, University of Stirling, Stirling FK9 4LA, Scotland, UK.

We thank Simon Thirgood for help in developing the questionnaire used in this research. Simon passed away before this work was completed. We also thank two referees for useful comments, and seminar participants at DICE, University of Kent.

This project is supported by the European Commission under the 7th Framework Programme for Research and Technological Development. Neither the European Commission nor any person acting on behalf of the Commission is responsible for the use which might be made of the following information. The views expressed in this publication are the sole responsibility of the authors and do not necessarily reflect the views of the European Commission

Second revision August 2010

Abstract

In this paper, we use the choice experiment method to investigate public preferences over alternative management regimes for a top-level predator in UK moorlands, the Hen Harrier. These birds are at the centre of a conflict between moorland managers and conservation organisations. Illegal killing of Hen Harriers on moorland managed for Red Grouse is considered to be one of the main factors limiting harrier population growth in the UK. Incentives for persecution arise due to the impacts of Hen Harriers on populations of Red Grouse, which are managed for commercial shooting. Numerous alternatives have been proposed to manage this system. We considered three which have emerged from stakeholder debates and scientific enquiry: tougher law enforcement, moving "excess" birds from grouse moors, and feeding of harriers. Results showed that respondents, sampled from the Scottish general public, were willing to pay both for avoiding reductions in harrier populations and for increases, but that these values were lower than those associated with equivalent changes for another raptor sharing the same moorland habitat, the Golden Eagle. Respondents valued a move away from current management, but were largely indifferent to which management option was taken up, suggesting that management options should be selected in terms of relative costs, and on who bears these costs. Differences within our sample of respondents in preferences across management options emerge when a latent class model is estimated.

Keywords: human wildlife conflicts; choice experiments; heather moorlands; wildlife management; hen harriers; raptors.

1. Introduction

Single objective land management has historically resulted in the suppression of many plant and animal species. This is most obviously so in the case of agriculture, where the desire to maximise profits from cultivation of particular crops has resulted in the use of herbicides and pesticides to reduce competition for resources and to protect yields. If these changes impact on the goals of other stakeholders, then conflicts over resources often ensue. For example, changing patterns of agricultural land use in parts of Africa have led to increased conflict between farmers and conservationists over crop raiding elephants (Thirgood et al. 2005). Understanding such conflicts requires an appreciation of the economic costs (e.g. crop losses to farmers) and benefits (e.g. non-market benefits of elephant conservation to people living outside elephant habitat) of land management, both in terms of the magnitude of these benefits and costs, and their distribution across stakeholders.

In parts of Europe, a focus on intensive game management for sport has led to changes in the abundance of many species. This is illustrated by the historical impact of managing land for hunting on predators in the UK, through poisoning, shooting or trapping (Lovegrove, 2007). The management of Red Grouse (*Lagopus lagopus scotticus*) in the UK uplands provides a case in point. Management of moorlands for Red Grouse shooting since the mid 19th Century has led to declines in many species of predators, and the extirpation of five species of raptor (Newton 1998). The aim of grouse management is to maximise numbers of birds available for shooting in the autumn. This management involves a mixture of vegetation management (e.g. heather burning) and predator control (Hudson & Newborn, 1998). There is some evidence to suggest that grouse shooting provides economic benefits to rural communities (McGilvary 1995; PACEC 2006), as well as conservation benefits because it retains heather moorland (Robertson et al. 2001) and associated wading birds where well-practised (Thompson et al. 1995; Tharme et al. 2001).

One particular conflict which has arisen in this context concerns the management of Hen Harriers (*Circus cyaneus*) on sporting estates. Hen Harriers are a medium-sized bird of prey which breed on heather moorlands in the uplands. They are Red Listed due to population declines in the last 200 years (Baillie et al., 2009). Most recent data reveals spatial variation in population trends, with a 41% increase in the UK and Isle of Man during 1998–2004, but with decreases on moorland managed for grouse shooting in the Southern Uplands, east Highlands and northern England (Sim et al., 2007). There are roughly 633 pairs in Scotland at present. Hen Harriers have been protected by law since 1954, but illegal killing has occurred due to the economic costs of Hen Harriers to grouse moor managers.

The economic costs to grouse moor owners arise because harriers prey on grouse (Thirgood et al., 2000). Arguments between the conservation lobby and the sporting estate community have become polarised over time (Redpath et al, 2004; Thirgood and Redpath, 2008). Evidence shows that (i) Hen Harrier densities can increase to the extent that they make management for grouse shooting economically unviable; (ii) illegal killing has resulted in a suppression of harrier populations in both England and Scotland (Etheridge et al., 1997; Sim et al., 2007); and (iii) that enforcement of current laws prohibiting lethal control has been ineffective (Thirgood and Redpath, 2008, Redpath et al., 2010). It is clear that sustainable management options should be considered more broadly (Thompson et al., 2009).

In this paper, we employ the choice experiment method to investigate public preferences for alternative management strategies for Hen Harriers on grouse moors. We view public preferences as important to the success of conflict management, since solutions are only likely to be effective in the long term if they command majority support. Non-hunting members of the public may well feel that

they also have a stake in the future management of heather moorlands managed for grouse, since a legal right of recreational access to all such areas exists in Scotland, and since non-use values for wildlife and landscape associated with heather moorlands are also likely to be important. As noted by Redpath et al. (2010), a number of alternative management options have been proposed to help manage this stakeholder conflict. Three of these alternatives are dealt with here: the establishment of feeding stations, providing harriers with alternative food sources to grouse; the establishment of quotas for Hen Harrier densities on sporting estates maintained by physically moving eggs or chicks away from grouse moors to alternative locations with lower or zero harrier populations; and increasing the probability of detection of illegal persecution, by increasing police surveillance on grouse moors. These are the alternatives most under discussion by stakeholders and scientists at the present time.

Estimating people's willingness to pay for environmental goods has been in focus of mainstream ecological economics for over 30 years now, as in some cases it remains the only way of providing economic value of many environmental goods. Estimating these values is necessary for conducting cost-benefit analyses, which may provide economic arguments for conservation. In particular, there have been numerous valuation studies of improvements in the condition of endangered species. A recent meta-analysis of 43 such studies is provided by Richardson and Loomis (2009a). The authors review 67 willingness-to-pay estimates for threatened, endangered or rare species and identify major drivers of these values. The reported WTP for avoiding loses or ensuring survival of bird species are within the range or 11.38 to 130.19 USD^{2006} with a mean close to 40 USD (Richardson and Loomis, 2009b).

Similarly, Martín-López et al. (2008) and Jacobsen and Hanley (2009) review a large number of studies on economic valuation of biodiversity and perform metaanalyses of these studies to

determine what factors affect willingness to pay. Among other things, they find that anthropomorphic and anthropocentric characteristics, resulting from the public's attitude toward species, remain highly significant even when respondents are sufficiently informed about 'scientific factors' that need to be taken into consideration.

A similar consideration for valuing animal species is provided by Jacobsen et al. (2008). The authors aim at valuing environmental improvements (preserving natural habitats) using number of species as an indicator of biodiversity. In one of the two treatments of their experiment they used quantitative description of changes in the number of species, while in the other they named a few species and observed substantially higher WTP values. Since economic values are by definition anthropogenic it is understandable that so called 'flagship species' or 'charismatic species' (usually top predators or species associated with national identity or culture) will receive more attention and higher WTP values (May, 1995; Noss, 1990).

The aims of this work were to estimate public preferences and willingness to pay for the three management alternatives of Scottish moorlands outlined above. To accomplish this, a Choice Experiment was implemented using members of the Scottish general public as the sampling frame, allowing us to investigate preference heterogeneity of different groups of the public – in particular hunters and people living in rural vs. urban communities. In our choice experiment, in addition to the description of management alternatives we have included descriptions of possible population changes of Hen Harriers. To avoid a focussing bias (Kahneman, 2010) on Hen Harriers, a second raptor population – Golden Eagles (*Aquila chrysaetos*) – was included in the experimental design. Golden Eagles are often found in Hen Harrier habitat, and are also top predators which have been subject to illegal persecution, particularly in managed grouse moors (Watson et al., 1989; Whitfield

et al., 2007; RSPB, 2006). However, note that feeding stations established for Hen Harriers are not likely to benefit Golden Eagles due to differences in feeding behaviour.

In what follows, Section 2 describes the questionnaire design and sampling methods; Section 3 provides some results, whilst a discussion and conclusion follow in Section 4.

2. Questionnaire design and sampling methods

In order to elicit WTP values we constructed a postal survey questionnaire containing choice experiments. The survey instrument can be obtained from the authors on request. The survey begins by introducing respondents to the location of "the uplands" in the UK, and asking whether they have visited this area and for what reasons. The questionnaire then describes how some uplands areas are managed as grouse moors:

"*About half of the heather moorlands found in the uplands are managed for grouse shooting. As well as using heather burning to keep the heather in good condition, many landowners employ game keepers to look after the grouse, for example by protecting them from predators. Red grouse shooting provides many economic, social and ecological benefits to an area. If there are enough grouse, shooting is the primary source of income in many upland estates. In Scotland, grouse shooting contributes £5 million to the rural economy a year and supports about 1,240 jobs.* "

Respondents were also told about the contribution of grouse management to maintaining heather moorlands. *"In areas where there are no longer enough grouse to maintain a shoot, land owners are using moorland for forestry or sheep grazing. This is thought to have contributed in part to the decline in heather moorland in the U.K.. Since 1950 over 30% of grouse moorland has become unmanaged, and between 1940 and 1970, 20% of heather moorland was lost."*

The text then introduces the Hen Harrier, describing their conservation status and threats from illegal persecution. Respondents are asked whether they think any action should be taken with regard to the current situation. Next, the survey introduces Golden Eagles, and again describes their conservation status and current threats to the species. The three alternatives for moorland management aimed at Hen Harriers are then described: setting up feeding stations, moving eggs and chicks to ensure local populations stay within prescribed quotas, and stricter law enforcement. Respondents were told that each of these alternatives would impose costs on society, for example in terms of extra policing, or labour costs for movement of birds, and that these costs would need to be paid for out of increased taxes.

The choice sets were then presented to individuals. The choice experiment design consisted of four attributes. These were:

- Changes in the population of Hen Harriers on heather moorlands in Scotland. The levels here were a 20% decline (used as the status quo), maintaining current populations, and a 20% increase in the current population.
- Changes in the population of Golden Eagles on heather moorlands in Scotland. The levels here were a 20% decline (used as the status quo), maintaining current populations, and a 20% increase in the current population.
- Management options. These included the current situation, moving Hen Harriers ("MOVE"), diversionary feeding ("FEED") and tougher law enforcement ("LAW"). These levels were included as labelled choices. That is, in each choice card, 4 options were available. One represented the status quo, and then 3 choice columns showed variations in other attribute levels given a particular, labelled management strategy.

- Cost of the policy. We told respondents that "*the **cost** level indicated is the amount of extra tax which a household like yours might have to pay if the government went ahead with that option."* The levels used were £0 (the status quo), £10, £20, £25, and £50. These costs are not linearly associated with any management option, since actual costs are unknown, and since this would create difficulties for estimating the choice model. Cost levels were chosen based on the results of a pilot survey.

Figure 1 gives an example of a choice card. Respondents were asked to carefully consider their budgets and current expenditures in making their choices, and that they should not worry if they did not feel that they had expert knowledge on the issues, but that their opinion was important to government policy making. Six choice cards were given to each respondent. Those respondents who chose the status quo, zero cost option in each choice card were asked why this was, in order to separate out protest bidders from people who did not value Hen Harrier or Golden Eagle conservation in moorlands. Having completed their choices, respondents were asked to read back carefully through these to make sure they were happy with how they had completed these tasks. Finally, a series of socio-economic and behavioural questions were asked, for example including household income, and whether the respondent was a hunter or had ever been hunting.

The choice experiment was designed to minimize the determinant of the AVC matrix of the parameters (*D-error*) given the priors on the parameters of a representative respondent's utility function (Scarpa and Rose, 2008). We have accounted for uncertainty with respect to parameters' priors by allowing these priors to be random variables following a probability distribution (*Bayesian efficient design*; Sándor and Wedel, 2001). The parameters of this distribution were derived from a preliminary model estimated on data available from a pilot study. Pilot surveys were undertaken

using in-person surveys of a random sample of Edinburgh households.[1] The final design consisted of 8 questionnaire versions, each with 6 choice cards per respondent.

This final version of the questionnaire was mailed to a random sample of 1,000 addresses in Scotland during 2009. Addresses were extracted from the database 192.com, which is based on the electoral register and telephone records. Rural areas were deliberately over-sampled, and the sample was stratified by region to ensure adequate regional coverage. Two weeks after mailing the first copy of the questionnaire to a respondent, a reminder letter was sent to those who had not responded. Two weeks after this, a second reminder and copy of the questionnaire was sent out to those who still had not responded.

We have received 223 surveys which were usable for future analysis, i.e. the respondents answered the most vital questions of the survey (in particular marked their choices in the choice experiment section). Comparing the representativeness of our sample with the characteristics of the general adult population of Scotland we must note that our sample suffered from some over-representation of respondents aged 41-65 and under-representation of younger adults (aged 15-25 and 26-40), and over-represented higher income groups.[2] The ratio of male and female respondents was very close to the national average. In addition, 24% (54) of the respondents in our sample turned out to be hunters or have ever been hunting, 70% (149) were currently living in the countryside, while 51% (109) stated that they grew up in the rural communities. Those living in rural areas were therefore more likely to return their questionnaires than those living in urban areas.

Protesting respondents were identified as those who at the same time: (1) stated that hen harriers should be protected, (2) picked the 'do nothing' option in every choice set and (3) as a reason for

[1] The design for the pilot study was also generated for D-efficiency, using expert judgment priors.
[2] 17.5% of the respondents refused to provide their income what might further contribute to the high income bias.

picking 'do nothing' option stated that either they did not believe other options would work, that the money would be wasted and not used appropriately or that others should pay for conservation. In total there were only 3 respondents (1%) who were thus classified as 'protesters'.

To analyse the choice data, the Hen Harrier and Golden Eagle attributes were dummy coded as levels, to allow for non-constant marginal utility of the improvements. Price was entered in pounds sterling. The management alternatives FEED, LAW and MOVE enter as labelled Alternative Specific Constants. We ran a variety of Random Parameter Logit (RPL)[3] models on the data (Hensher and Greene, 2003, Hensher et al., 2005). For the RPL, we ran models with various distributions of parameters (normal, lognormal, triangular), including heterogeneity in means and variances of these distributions with respect to individual-specific socio-economic data. In addition we tested models with error components included (with and without heteroscedascity in random error components). Finally, we estimated models both with correlated and un-correlated parameters. Since each respondent faced six choice-sets, a panel data specification of errors was used throughout.

3. Results

In the best performing model all the attributes were specified as random parameters of a normal distribution. We allowed for correlations between random parameters (which proved to be highly significant) and accounted for panel structure of our dataset (each respondent faced 6 choice-sets) by introducing a random effects type of treatment – an additional random term for all observations from the same individual. In addition, we have introduced individual heterogeneity in all random parameters' distributions means using individual-specific explanatory variables. This allowed us to observe how preferences systematically differ between groups of respondents. In our case, the two most interesting variables *a priori* were (1) being a hunter vs. not being a hunter, and (2) living in

[3] The Random Parameters Logit model allows for a very wide range of model specifications in terms of underlying choice processes and preference structures (McFadden and Train, 2000).

rural vs. urban community. Our results showed, however, that living (or growing up) in rural vs. urban areas did not allow to account for any unobserved heterogeneity. This leaded to the first conclusion that there were no systematic differences in preferences between respondents living in rural vs. urban communities. Therefore, in the final model we have included only being a hunter as an explanatory variable of random parameters means.

Table 1 shows the results for our Random Parameters Logit model. Taking the results in column A, we can see that all of the attributes are significant determinants of choice: people prefer either no decline or an increase in Hen Harriers relative to a decline, and the same holds for Golden Eagles. For the management alternatives, LAW, FEED and MOVE, their signs suggest that they are all preferred to the current situation. Price is a negative and significant determinant of choice. Column B provides strong evidence of unobserved preference heterogeneity in terms of significant standard deviation coefficients for all attributes. This is especially apparent in the case of alternative specific constants – standard deviations of their distributions suggest that at least for some respondents this coefficient might be close to 0 or negative (and hence they might prefer the status quo).

Finally, in column C of the table we present the estimates of covariates of means or random parameters – i.e. how being a hunter influences the mean of each random parameter. The coefficients suggest that hunters have significantly lower willingness-to-pay for any improvement in Hen Harrier populations. Similar pattern emerges for improvements for golden eagles, however this result is not statistically significant. Finally, the means of ASCs for implementing each of the management options are substantially higher for hunters.[4]

[4] Should the reader be interested in inspecting correlation between the parameters, we report the estimates of the elements of lower triangular of Cholesky matrix (i.e. products of Cholesky decomposition of the variance-covariance matrix of coefficients) in Annex 1.

Table 2 shows implicit prices (willingness to pay values) for the whole sample, and also implicit prices derived for hunters and non-hunters, along with associated standard deviations.[5] These were generated using parametric bootstrapping following Krinsky and Robb (1986). Since our price parameter was also random we have followed the simulation method proposed by Hu et al. (2005): in order to avoid "exploding" implicit prices when random price parameter was very close to zero we averaged over 10^4 draws of each parameter, for each round of Krinsky and Robb draws from parameter distributions. Our results show that for our sample the mean willingness to pay for maintaining current populations of the Hen Harriers and Golden Eagles are around £36 and £52 per household per year respectively. A 20% increase in the population of each species would be worth £44 and £61 respectively. These results are in line with other valuation studies focusing on birds of prey species (Richardson and Loomis, 2009ab). WTPs for improvements in the population of Golden Eagles exceeds WTPs for improvements in population of Hen Harriers. This finding confirms earlier results that respondents are generally willing to pay more for species with higher charisma – in this case larger and more culturally-dominant eagles than smaller harriers (e.g. Martín-López et al., 2008; Jacobsen and Hanley, 2009). Comparing willingness toy pay for stabilising the population relative to a decline with willingness to pay for a 20% population increase suggests decreasing marginal utility from these improvements over the status quo.

WTPs for all management options relative to the status quo is in the order of £100/household/year, a surprisingly large amount. The WTPs for management options LAW, FEED and MOVE are very similar, and not significantly different from each other at the 95% level. The general message seems to be that people are willing to pay for a change in the current management situation, but are rather

[5] Implicit prices were calculated for a model without the covariate in the mean of the distribution of the random price coefficient which was found insignificant (see Table 1).

indifferent as to *which* policy option is implemented or *how* increases in populations of the birds are achieved.

Finally, we turn to analyzing systematic differences in preferences of hunters vs. non-hunters. Our results indicate that hunters are willing to pay substantially less for the proposed population increases of Hen Harriers and Golden Eagles than non-hunters. In the case of Hen Harriers the hunters' WTPs are around £11 and £16, while for non-hunters the implicit prices are £44 and £53 respectively. This is understandable, as increased populations of birds of prey might be associated with lower populations of red grouse, and hence lower bag limits. The same holds for Golden Eagles – £28 and £49 for hunters vs. £49 and £65 for non-hunters. Despite this, hunters are willing to pay substantially more for implementing one of the proposed management programs – their willingness to pay for feeding and relocating program is roughly £50-£57 higher, and for tougher law enforcement it is almost £75 higher than non-hunters' WTP. This may reflect a willingness to suppress illegal activity which brings a bad public reputation to law-abiding estate owners.

Overall WTPs for all management programs (controlling for Hen Harriers and Golden Eagles population changes) are surprisingly high. We find this result interesting and provide the following interpretation. The respondents expected the proposed management options to solve management-conservation conflict in managed moorlands in Scotland. Reconciling the interests of hunters, conservationists and managers seems to be worth a lot, even if it does not cause populations of the birds of prey to increase. In other words, our respondents might have associated implementing the programs with other improvements (not accounted for by our attributes). For instance they could have considered feeding program to eliminate the pressure on red grouse populations, and be willing to pay for it even if it would not increase Hen Harrier and Golden Eagle populations. If this was the case, it is not surprising that the hunters were willing to pay even more for such a improvement, as it

could provide economic benefits not only to adjacent communities, but also to hunters directly, as there would be more game for shooting.

4. Discussion and Conclusions

In this paper, we have used choice modelling to investigate public preferences for the management of the Hen Harrier. Public preferences matter if governments wish to partly base policy decisions over species protection and land management on an assessment of relative costs and benefits (Hanley and Barbier, 2009). Here, we show that the public is willing to pay to prevent further declines in harrier populations in Scotland, and to increase these populations. To avoid a potential bias from asking respondents to focus on a single environmental "good", the experimental design used here allowed to trade-offs between the protection of Hen Harriers and another charismatic raptor, the Golden Eagle. This showed that Golden Eagle conservation was valued more highly than Hen Harrier conservation. Due to sample selection effects, we are unable to aggregate our sample willingness to pay measures to the general population: we cannot also draw inferences about the preferences of those who self-selected into not responding to the survey.

For the sample as a whole, the Random Parameters Logit models showed that respondents were willing to pay to achieve more raptor conservation on moorlands, but were largely indifferent to how a given population was achieved. That is, there were no statistically significant differences in the utility attached to either of the three labelled management alternatives – stricter law enforcement, feeding stations and moving eggs and chicks (this implies that replacing the three labelled Alternative Specific Constants with one ASC for the status quo choice would yield qualitatively similar results). No evidence emerged that any of the options was viewed as being different on ethical or conservation effectiveness grounds by respondents. This indifference to *how* conservation objectives are achieved implies that benefits are roughly equal across management alternatives if the

same outcome is achieved. In turn, this implies that economic efficiency would require the management action with the lowest costs to be chosen.

Our results, in terms of WTP for increasing population levels are in the range of £35-£60 per year per household, depending on whether Hen Harrier or Golden Eagle population will increase and whether the increase will allow to maintain current population or increase the population a further 20%. These results seem to be similar to those observed in the other studies (see Richardson and Loomis, 2009a and 2009b for a comprehensive review). In addition, we observe that WTP for a larger, more charismatic species (Golden Eagle) is higher than for a less charismatic species. This is in line with earlier findings of other studies (Martín-López et al., 2008; Jacobsen and Hanley, 2009; Jacobsen et al., 2008, May, 1995; Noss, 1990). Furthermore, we observe a surprisingly high WTPs for implementing any of the management programs, irrespectively of the changes in populations of birds of pray they incorporate.

We ran a number of RPL models to allow for preference heterogeneity, and included socio-demographic explanatory variables for random parameter distributions means. Our results show that although there was large preference heterogeneity, many individual characteristics (such as whether people lived in a rural or urban area; whether they were born in an urban area; or visit the uplands for recreation) did not account for significant systematic differences in preferences. However, being a hunter turned out to significantly explain respondents' preferences. Overall, hunters were willing to pay substantially less for increases in the populations of birds of prey, however, they were willing to pay substantially more for implementing management programs independently of the impact on raptor populations.

No data exists on the relative costs of the management options presented here to allow for a comparison, with the exception of one study on diversionary feeding (Redpath et al, 2001). An important distinction from a policy perspective is to think about on whom these costs would fall. For each management option, costs might be divided into private costs to estate owners and workers, and costs to the public purse. Costs to estate owners and workers would be highest when populations of Hen Harrier reach levels on a particular moor that result in management for grouse shooting becoming un-economic. This seems most likely under the stricter law enforcement scenario. Costs to the public purse include those involved in monitoring harrier populations, setting up feeding stations, and moving eggs and chicks. If government wanted to introduce alternatives which minimised costs to estate owners it would therefore be likely to select either the "FEED" or "MOVE" alternatives, if the ecological effectiveness of these schemes could be assured. Currently, there is considerable uncertainty over how effective such schemes could be, and over the economic, social and ecological implications of adhering to one of those policies (Redpath et al. 2010). Alternatively, government could issue lump sum compensation to estate owners and workers where harrier numbers reach levels which make management for grouse shooting un-profitable, seeing this as a payment for the production of a public good (raptor conservation). However, such approaches are often viewed unfavourably by both sides of the debate (Redpath et al. 2010).

It may also be the case that preferences for Hen Harrier management are sensitive to the way information is presented to respondents. For example, how information on illegal killing or on the local economic benefits of grouse moor management is presented may affect individual preferences. Individuals might revise their preferences over or willingness to pay for management options and changes in Hen Harrier populations depending on what they understand about who benefits from grouse moor management (for example, the relative impacts on owners of land compared to estate workers). This is a question which we intend to explore in future work. Additionally, it would be

interesting to investigate other management options which impact on a wider range of public goods than raptor populations. Moorlands are known to be important for producing a wide range of ecosystem services, such as water purification and carbon sequestration, whilst they provide habitats for a range of flora and fauna (Holden et al, 2007; Evans et al, 2005). Knowing how alternative (perhaps less intensive) management options impact on these ecosystem services and on biodiversity, and how people value these impacts, is another interesting question for future research. Finally, we note that whilst information on the costs and benefits of management options can cast considerable light on the best choice of management option in human-wildlife conflicts, such an approach will not find favour with all stakeholders, and will in the vast majority of cases be supplemented with other forms of information on the relative merits and social acceptability of management alternatives.

References

Baillie, S.R., Marchant, J.H., Leech, D.I., Joys, A.C., Noble, D.G., Barimore, C., Grantham, M.J., Risely, K. & Robinson, R.A. (2009). *Breeding Birds in the Wider Countryside: their conservation status 2008.* BTO Research Report No. 516. BTO, Thetford.

Etheridge, B., Summers, R.W. & Green, R. (1997) The effects of illegal killing and destruction of nests on the population dynamics of Hen Harriers in Scotland. *Journal of Applied Ecology* 34, 1081–1106.

Evans, C., Monteith, D.T., Cooper, D.M., 2005. Long-term increases in surface water dissolved organic carbon: observations, possible causes and environmental impacts. *Environmental Pollution* 137, 55–71.

Hanley N. and Barbier E. (2009) *Pricing Nature: Cost-Benefit Analysis and Environmental Policy-Making*. Cheltenham: Edward Elgar.

Hensher D, Greene W (2003) The Mixed Logit model: The state of practice. *Transportation* 30(2): 133-176

Hensher DA, Rose JM, Greene WH (2005) *Applied Choice Analysis: A Primer*. Cambridge University Press, Cambridge

Holden, J. Shotbolt, L., Bonn, A., Burt, T.P., Chapman, P.J., Dougill, A.D., Fraser, E.D.G., Hubacek, K., Irvine, B. Kirkby, M.J., Reed, M., Prell, C., Stagl, S., Stringer, L.C., Turner, A., Worrall, F. (2007) Environmental change in moorland landscapes. *Earth Science Reviews* 82: 75-100

Hu W, Veeman MM, Adamowicz WL (2005) Labelling Genetically Modified Food: Heterogeneous Consumer Preferences and the Value of Information. *Canadian Journal of Agricultural Economics* 53(1): 83-102

Hudson P. and Newborn D. (1995) *A Manual of Red Grouse Management*. Fordingbridge: The Game Conservancy.

Jacobsen, J. B., Boiesen, J. H., Thorsen, B. J., and Strange, N., 2008. What's in a Name? The Use of Quantitative Measures Versus 'Iconised' Species when Valuing Biodiversity. *Environmental and Resource Economics*, 39(3):247-263.

Jacobsen, J. B., and Hanley, N., 2009. Are There Income Effects on Global Willingness to Pay for Biodiversity Conservation? *Environmental and Resource Economics*, 43(2):137-160.

Kahneman, D. (2010) "The riddle of experience versus memory" Internet Lecture: TED lecture series, uploaded February 2010. www.ted.com/talks. Accessed April 5th 2010.

Krinsky I, Robb AL (1986) On Approximating the Statistical Properties of Elasticities. *The Review of Economics and Statistics* 68(4): 715-719.

Lovegrove R. (2007) *Silent fields: the long decline of a nation's wildlife.* Oxford: Oxford University Press.

Martín-López, B., Montes, C., and Benayas, J., 2008. Economic Valuation of Biodiversity Conservation: the Meaning of Numbers. *Conservation Biology*, 22(3):624-635.

May, R. M., 1995. Conceptual Aspects of the Quantification of the Extent of Biological Diversity. In: *Biodiversity: measurement and estimation*., D. L. Hawksworth, ed., Chapman and Hall, London, 13-20.

McFadden D, Train K (2000) Mixed MNL Models for Discrete Response. *Journal of Applied Econometrics* 15(5): 447-470

McGilvary J. (1995) *An Economic Study of Grouse Moors.* University of Strathclyde and the Game Conservancy Trust, Fordingbridge.

Newton I. (1998) *Population limitation in birds.* London: Academic Press.

Noss, R. F., 1990. Can we Maintain Biological and Ecological Integrity. *Conservation Biology*, 4(3):241-243.

PACEC (2006) *The Economic and Environmental Impacts of Sporting Shooting*. Public and Corporate Economic Consultants, Cambridge.

Redpath, S.M., Thirgood, S.J. & Leckie, F.M. (2001) Does supplementary feeding reduce harrier predation on red grouse? *Journal of Applied Ecology,* 38, 1157–1168.

Redpath, S., Arroyo, B., Leckie, F., Bacon, P., Bayfield, N., Gutierrez, R. & Thirgood, S. (2004) Using decision modelling to resolve human–wildlife conflicts: a case study with raptors and grouse. *Conservation Biology,* 18, 350–359.

Redpath, S.M., Amar, A., Smith, A., Thompson, D.B.A. & Thirgood, S.J. (2010).People and nature in conflict: can we reconcile hen harrier conservation and game management? In: *Species management: challenges and solutions for the 21st Century.* Ed. D.B.A. Thompson. Stationery Office.

Richardson, L., and Loomis, J., 2009a. The total economic value of threatened, endangered and rare species: An updated meta-analysis. *Ecological Economics*, 68(5):1535-1548.

Richardson, L., and Loomis, J., 2009b. Total Economic Valuation of Endangered Species: A Summary and Comparison of United States and Rest of the World Estimates. In: *Conserving and Valuing Ecosystem Services and Biodiversity: Economic, Institutional and Social Challenges*, K. N. Ninan, ed., Earthscan, London, UK, 25-46.

Robertson, P.A., Park, K.J. & Barton, A.F. (2001) Loss of heather moorland in the Scottish uplands: the role of red grouse management. *Wildlife Biology* 7:11-16.

RSPB (2006) *A review of bird persecution in Scotland 2006.* Royal Society for the Protection of Birds, Sandy, Beds.

Sándor Z, Wedel M (2001) Designing Conjoint Choice Experiments Using Managers' Prior Beliefs. *Journal of Marketing Research* 38(4): 430-444

Scarpa R, Rose JM (2008) Design Efficiency for Non-Market Valuation with Choice Modelling: How to Measure it, What to Report and Why. *Australian Journal of Agricultural and Resource Economics* 52(3): 253-282

Sim, I., Dillon, I., Eaton, M., Etheridge, B., Linley, P., Riley, H., Saunders, R., Sharpe, C. & Tickner, R. (2007) Status of the Hen Harrier in the UK and Isle of Man in 2004 and a comparison with the 1988 and 1998 surveys. *Bird Study,* 54, 256–267.

Tharme, A.P., R.E. Green, D. Baines, I.P. Bainbridge and M. O'Brien (2001). The effect of management for red grouse shooting on the population density of breeding birds on heather-dominated moorland. *Journal of Applied Ecology* 38: 439-457.

Thirgood, S.J., Redpath, S., Rothery, P. & Aebischer, N. (2000) Raptor predation and population limitation in red grouse. *Journal of Animal Ecology* 69 , 504–516.

Thirgood, S., Woodroffe, R. & Rabinowitz, A. (2005) The impact of human– wildlife conflict on human lives and livelihoods. *People and Wildlife: Conflict or Coexistence?*(eds R. Woodroffe, S. Thirgood & A. Rabinowitz), pp. 13– 26. Cambridge University Press, Cambridge, UK.

Thirgood S. and Redpath S. (2008) "Hen Harriers and red grouse: science, politics and human-wildlife confliect" *Jnl Applied Ecology*, 45, 1550-1554.

Thompson, D.B.A., MacDonald, A.J., Marsden, J.H. & Galbraith, C.A. (1995). Upland heather moorland in the UK: a review of international importance, vegetation change and some objectives for conservation. *Biological Conservation* 71:163-178.

Thompson, P. S., Amar, A., Hoccom, D. G., Knott, J., and Wilson, J. D., 2009. Resolving the conflict between driven-grouse shooting and conservation of hen harriers. *Journal of Applied Ecology*, 46(5):950-954.

Watson, A., Payne, S., and Rae, R., 1989. Golden Eagles *Aquila chrysætos*: Land Use and Food in North-east Scotland. *Ibis* 131: 336–348.

Whitfield, D. P., Fielding, A. H., McLeod, D.R.A, Morton, K.M., Sirling-Aird, P., Eaton, M. 2007. Factors constraining the distribution of Golden Eagles *Aquila chrysaetos* in Scotland. *Bird Study* 54, No. 2, 199–211.

Figure One – example choice card

	DO NOTHING Maintain current management.	LAW Stricter law enforcement.	FEED Feeding stations away from grouse.	MOVE Move eggs and chicks to new sites.
HEN HARRIER	20% population decline.	Maintain current population.	Maintain current population.	Maintain current population.
GOLDEN EAGLE	20% population decline.	20% population increase.	Maintain current population.	20% population decline.
COST	£0	£50	£50	£10
YOUR CHOICE (please tick one only)	□	□	□	□

Table 1 – the results of the RPL models

	Means of normally distributed parameters		Standard deviations of normally distributed parameters		Covariate of means of random parameters (being a hunter)	
	coefficient	s.e.	coefficient	s.e.	coefficient	s.e.
HH1 – maintaining current populations	3.1112***	0.5005	2.3347***	0.4811	-1.9225**	0.9016
HH2 – 20% increase in populations	3.6114***	0.4248	1.9138***	0.2817	-2.2369***	0.6007
GE1 – maintaining current populations	4.5658***	0.6574	3.6520***	0.5027	-1.3374	0.9761
GE2 – 20% increase in populations	4.8116***	0.6019	2.9145***	0.4104	-0.5768	0.7979
LAW – alternative specific constant	4.2940***	1.1878	10.2201***	0.6687	4.7938***	1.1683
FEED – alternative specific constant	4.0083***	1.1951	11.2235***	0.5751	4.7247***	1.1948
MOVE – alternative specific constant	3.5152***	1.2053	11.4516***	0.5570	4.5486***	1.1676
COST – monetary attribute	-0.0860***	0.0146	0.1811***	0.0082	0.0370	0.0254
	Log likelihood function		-1012.6131			
	Pseudo R^2		0.4441			
	AIC		1.6204			
	BIC		1.8254			

***, **, * Significance at 1%, 5%, 10% level

Table 2 – the implicit prices based on the RPL models [£ /household/year]

	All sample		Hunters		Others	
	implicit price	standard error	implicit price	standard error	implicit price	standard error
HH1 – maintaining current populations	35.98***	5.1355	10.70	9.2351	44.05***	6.4356
HH2 – 20% increase in populations	44.40***	6.2125	16.47**	6.8377	53.31***	7.9123
GE1 – maintaining current populations	51.80***	6.5345	27.96***	9.4326	59.42***	8.1766
GE2 – 20% increase in populations	61.24***	7.7825	48.54***	9.7525	65.30***	8.9929
LAW – alternative specific constant	103.40***	29.9435	159.96***	42.1290	85.34***	27.9055
FEED – alternative specific constant	101.22***	29.9852	144.25***	39.1485	87.48***	28.5799
MOVE – alternative specific constant	97.98***	29.3582	136.10***	38.2710	85.81***	27.9631

***, **, * Significance at 1%, 5%, 10% level

Annex 1 – Lower triangular of Cholesky matrix for the RPL model with random price parameter (standard errors given in parentheses)

	HH1	HH2	GE1	GE2	LAW	FEED	MOVE	COST
HH1	2.3347*** (0.4810)	–	–	–	–	–	–	–
HH2	-0.8520** (0.3476)	0.7137*** (0.2887)	–	–	–	–	–	–
GE1	-3.4839*** (0.5577)	-1.0656* (0.5560)	0.2533 (0.3676)	–	–	–	–	–
GE2	-1.8386*** (0.4478)	-2.0772*** (0.4367)	-0.5242* (0.3113)	0.7243*** (0.1843)	–	–	–	–
LAW	8.9989*** (1.1548)	-4.0036*** (1.0161)	-1.6430*** (0.6289)	-2.1285*** (0.4388)	0.4584 (0.5210)	–	–	–
FEED	8.8351*** (1.1407)	-4.4241*** (0.9934)	-3.3678*** (0.6548)	-1.8889*** (0.4630)	3.6486*** (0.6178)	0.3350* (0.2018)	–	–
MOVE	8.6098*** (1.1785)	-4.6650*** (1.0500)	-3.7047*** (0.6385)	-2.8039*** (0.4491)	3.3484*** (0.6197)	1.5544*** (0.2555)	0.1796 (0.2100)	–
COST	0.1126*** (0.0135)	-0.0923*** (0.0114)	-0.0312*** (0.0078)	0.0377*** (0.0086)	0.0011 (0.0088)	0.0557*** (0.0074)	0.0174** (0.0077)	0.0762*** (0.0088)