QUANTIFYING THE VALUE OF ECOSYSTEM SERVICES: A CASE STUDY OF HONEYBEE POLLINATION IN THE UK

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Abstract

There is concern that insect pollinators, such as honey bees, are currently declining in abundance, and are under serious threat from environmental changes such as habitat loss and climate change; the use of pesticides in intensive agriculture, and emerging diseases. This paper aims to evaluate how much public support there would be in preventing further decline to maintain the current number of bee colonies in the UK. The contingent valuation method (CVM) was used to obtain the willingness to pay (WTP) for a theoretical pollinator protection policy. Respondents were asked whether they would be WTP to support such a policy and how much would they pay? Results show that the mean WTP to support the bee protection policy was £1.37/week/household. Based on there being 24.9 million households in the UK, this is equivalent to £1.77 billion per year. This total value can show the importance of maintaining the overall pollination service to policy makers. We compare this total with estimates obtained using a simple market valuation of pollination for the UK.

Key words: *Valuation, ecosystem services, honeybees, pollination, willingness to pay*.

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1. INTRODUCTION

Natural ecosystems provide a wide range of goods and services to society. An ecosystem function is defined as the ‘capacity of an ecosystem to provide goods and services that satisfy human needs, directly or indirectly’ (De Groot, 1992). The Millennium Ecosystem Assessment (2003) classifies pollination as both a ‘regulatory’ and ‘production’ service. Pollination is a critical link in the functioning of ecosystems and it is essential for the production of a wide range of crops (Mburu *et al*., 2006). It is estimated that the production of 84% of the crop species grown in Europe depends directly on insect pollinators, especially bees (Williams, 1994), and 70% of those that are used directly to feed humans need insect pollination (Klein *et al*., 2007). Without this service, many interconnected processes in an ecosystem would collapse.

There are huge concerns that insect pollinators are declining in number and diversity, and are under serious threat from environmental changes such as habitat loss and climate change; the use of pesticides in intensive agriculture, and emerging diseases (Balmford *et al*., 2002; Biesmeijer *et al*., 2006). In England, populations of bumble bees have declined and by the end of the 20th Century, the number of species decreased from 19 to 16 (Williams, 1982). There is a need to grow the evidence base to help conserve pollinators, and insure against the potential catastrophic loss of the ecosystem services insect pollinators give (Gallai *et al*., 2009). One reason pollinators lack sufficient protection is the lack of understanding of their true economic worth. While the value of insect-pollinated crops is well documented, few studies have properly assessed the economic importance of pollination services to this productivity. Carreck and Williams (1998) estimated the value of pollination to be £202 million per year for the UK. However, their figures are mainly ‘use’ values.

For the US, the honeybee's value to agriculture was estimated to lie between US$6-19 billion per year (Levin, 1984; Morse and Calderone, 2000; Southwick and Southwick, 1992). The range of these numbers shows the lack of common valuation methods for pollination services. Gordon and Davis (2003) examined the value of honeybee pollination in Australian agriculture. The total lost surplus following a loss of honeybee was estimated to be US$1.1 billion. Another standard valuation of pollination service was done by Gallai *et al*. (2009). The total economic value of the pollination service provided by insect pollinators, bees mainly, was €153 billion, which amounts to 9.5% of the total value of global agricultural food production in 2005. A few other global estimates for the value of pollination services are also available (e.g. Richards, 1993; Costanza *et al*., 1997) but do not provide specific and robust quantification of the role of pollination services in the UK.[2]

Research is needed to estimate the full values of pollination ecosystem service, to determine how they relate to conservation priorities, and to understand the benefits, costs or other incentives to compensate providers of pollination services. Taking the total economic value of ecosystem services into account will contribute to better decision-making, providing policy development with new insights. This paper aims to evaluate how much public support there would be in preventing further decline to maintain the current number of bee colonies in the UK. We used the Total Economic Value (TEV) concept as the comprehensive framework to gather information on relevant values (Pearce and Turner, 1990). Pollination mainly has indirect use value

[2] Costanza *et al*. (1997) give a global value estimate of US$120 billion per year for all pollination ecosystem services while Richards (1993) found that the value of pollination in global agriculture is US$200 billion per year.

through its contribution to maintaining agricultural production and natural ecosystems, which provide a flow of goods and services to society.[3]

There are a number of economic approaches available to value ecosystem services (Pearce and Turner, 1990; OECD, 2002; Perman *et al*., 2003). Mburu *et al*. (2006) give a comprehensive methodological framework for the valuation of pollination services, including the economic impacts of a decline in pollinators. The Production function (FP), Replacement Cost (RC) and Contingent Valuation Method (CVM) can be used to determine the economic values of pollination services provided by honeybees. However, these methods measure different aspects of the TEV of pollinators. In the recent years, the CVM has been widely used to value biological resources including rare and endangered species, habitats and landscapes (Mitchell and Carson, 1989; Arrow *et al*., 1993; Hanemann, 1994; Bateman and Langford, 1997; Carson, 2000; Bateman *et al*., 2002; Hanley and Babier, 2009). Theoretically, it should be possible to use the CVM to determine the TEV for insect pollinators. In this paper, we apply the CVM in an attempt to measure a willingness to pay (WTP) for a theoretical pollinator protection policy in the UK. We then compare the results with estimates obtained using a simple market valuation equation used by previous authors.

The remainder of this paper is structured as follows: Section 2 gives the methodology and strategy adopted for implementing the questionnaires. Section 3 presents the results of the CVM exercise. Results from the market valuation method are also reported here. Section 4 gives a discussion and Section 5 concludes the paper.

[3] For example, the benefits from the pollination service are much greater than the value of honey production: the annual value of honey production in the UK was estimated to be US$27 million but the value of pollination service lies in the order of US$240 million (Mburu *et al*., 2006).

2.0 Methods

2.1 Survey design

The CVM was used to value preferences of the British public for a policy to maintain honeybee populations at the current level. The method relied on a well-structured questionnaire that was developed at the Food and Environment Research Agency (Fera) and administered in face-to-face interviews. It was intended to be administered to both the users and non-users of insect pollinators in the UK. The questionnaire was pretested among Fera staff to determine the plausibility and comprehensibility of the contents, including the formulated CVM scenario. Pre-testing was also done to improve the validity of the CVM results, given the fact that estimates generated by CVM can be affected by a number of potential biases. However, Bateman *et al*. (2002) observe that, a well designed CV instrument, backed up by pre-testing of the questionnaire can help reduce some biases associated with the CVM.

The questionnaire was revised accordingly before it was administered in the actual surveys primarily at the Great Yorkshire Show (GYS) in July 2008. The attendees at an agricultural show might not represent a random sample of the public (and hence a selection bias), but these would be users with a sufficient knowledge of pollinating honeybees. Note that Mburu *et al*. (2006) argued that the CVM require respondents to have a sound knowledge of the quantitative contribution that pollination makes to crop production. A number of questionnaires were also administered to non-GYS respondents including those from the Department of Environment, Food and Rural Affairs (Defra), the Plant Health and Seeds Inspectorate (PHSI) and other Fera staff, not involved in pre-testing such as at Woodchester Park (WP), family and friends

(F&F), and students from Reading University (RU). Staff from the National Bee Unit (NBU) based at Fera and other volunteers from Fera administered the surveys.

Members of the public were approached at random and the survey aimed to maximise the number of households interviewed. Surveys were conducted and data collected between July 2008 and February 2009. In the preamble to the questionnaire, respondents were informed that the study was being done for scientific purposes only. This was necessary to reduce possible strategic bias, which would occur if the respondents thought that their answers would influence policy (Bateman *et al*., 2002). It was also explained that the questionnaire should be completed by the person responsible for making expenditure decisions within the household. Data collected include socio-economic characteristics (gender, age, income, education, household size); awareness of declining bee populations; and perceptions of who should pay for a policy to maintain bee populations. A total of 345 households were interviewed, accounting for less than 1% of the total number of households in the UK.

The CVM was used to determine the willingness of households to pay for a policy to protect bee populations. We used the payment card method (which is a form of the open-ended question format as opposed to the closed ended format) to determine if there would be consumer surplus. It has been argued that single and double-bounded dichotomous choice formats do not encourage respondents to think carefully enough about the value they place on an environmental good, since ‘yes’ and ‘no’ are relatively easy answers to give (Hanley and Babier, 2009). Therefore, we used the payment card method because they allow respondents to say the most they are sure that they would pay, and the least they are sure that they would not pay, over a series of amounts presented. We also opted for a face-to-face survey format because it generally yields the highest survey response (Bateman *et al*., 2002). In the questionnaire, respondents were presented with a scenario with regards to bee populations. The scenario was designed to shed light on total values of pollinating honeybees and the welfare measure used reflects the consumer's maximum willingness to pay (WTP). Respondents were asked for their WTP for a policy to maintain bee numbers at current levels. The scenario was formulated as follows:

Scenario: The results of several surveys suggest the number of honey bees in the UK has reduced in recent years, perhaps due to building on green spaces and climate change. We aim to evaluate how much public interest there would be in preventing further declines and maintaining the number of honeybees in the UK indefinitely. Would you be willing to pay to support a policy to maintain bee populations at the current level? If yes, how much would you be willing to pay?

In many CV studies, respondents have a tendency to overstate their true, actual or real WTP because of the hypothetical nature of the scenario (Bateman *et al*., 2002). To reduce hypothetical bias, respondents were reminded of their budget constraint and that they would need to make compensating adjustments to accommodate this additional transaction, as is commonly done with contingent valuation studies. Also, the CVM scenario was followed by follow up questions that were asked to check respondents' understanding and acceptance of the constructed scenario and to identify their motives for giving their answers (Venkatachalam *et al*., 2004).

2.2 Data analysis

Data collected was analysed to check the consistency of responses and to calculate the required valuation estimates. Summary statistics such as means and medians WTP were used to calculate estimates of the total value for the sample population. Valuation frequency distributions were used to estimate the proportion of the sample population that would be WTP a given amount for the theoretical pollinator protection policy. Cross tabulations between WTP and socio-economic and other variables were also performed. Mean WTP bids were calculated for the different groups of respondents, and then checked against the predictions of demand theory. Cross tabulations for dichotomous choice questions (are you WTP £x? yes or no) were also performed to test for differences between respondent groups. Data analysis also involved the use of a *t*-test to test for significant difference between the willingness of the different respondent groups to pay to support a policy to maintain bee populations.

To test the theoretical validity of the CVM results, regression analysis was used to explain the relationship between WTP to support a policy to maintain bee populations and the socio-economic variables of the respondents. The discrete format used in the study provided a qualitative (yes/no) dependent variable that was regressed on the WTP amount the individual was asked to consider plus other explanatory variables such as income, age, environmental attributes etc. We used the Logit model which is most widely used to analyse simple qualitative choice data (Long and Freese, 2006). In the follow up question, the WTP amount was chosen over a series of amounts of between £0.1 and £20 per week, using the payment card method. The upper limit was fixed at £20 per week, as this would represent a high cost to protect honeybees in the

UK. As data are censored with a lower and upper limit, the valuation function could also be estimated using Tobit regression model (Greene, 1987).

3.0 RESULTS

3.1 Socio-economic profile of the sample population

The questionnaire elicited details of the socioeconomic characteristics of the respondents. These questions were used both to answer specific queries and to provide validation data, with specific reference to WTP estimates generated. Most of the respondents were interviewed from the Great Yorkshire Show (GYS) (42.0%), followed by Fera (20.9%), F&F (15.4%) and Reading University (11.0%), while the smallest number of respondents came from Bee keepers (2.3%), Woodchester Park (1.4%), EXT (0.3%) and Defra (0.3%). The gender of the sample population was roughly balanced, with 51% of respondents being female and 49% male. Just under half (48%) of the sample were within the ages 46-60+ years, while 30.1% were between 30-45 years and 22.3% were aged between 18 and 29 years.

The majority of the respondents (84%) interviewed were not a member of a bee-related organisation. A large number of the respondents (89%) had qualifications but only half (51%) possessed a science qualification. About 90% of the respondents had completed school to the age of 16 and 41% had received further education or university degrees. Income categories range up to £70,000 with a large number of respondents (16.9%) falling in the £30,000-£39,000 income level. The maximum number of dependants was 4 persons, with an average of 1 person per household. We can draw two major conclusions from this data. Firstly, the data indicates a sample population that is highly educated, of relatively high income class and middle age. Secondly, the data highlights the question of the representativeness of the sampling population compared to the overall British population?

3.2 Results from the WTP principle question

In the formulated scenario, respondents were asked for their interest and WTP to support a theoretical policy to maintain bee populations at the current levels. Respondents were also reminded of their budget constraint as the failure to do so could affect their WTP, according to Venkatachalam (2004). The WTP was elicited from respondents who had a positive WTP. About 64% of the sample population interviewed were willing to pay a fee to protect bee populations while 36% were not willing to pay anything to support the theoretical policy to maintain bee populations. The highest percentage of respondents expressing a 'zero' WTP were registered for the respondents from GYS (15.9%). Less than 1% of the respondents protested in that they did not indicate their WTP nor give the reasons for not being willing to pay.

Table 1: What made you limit your contribution to the above amount?

Reasons	**Respondents (%)**
I think bees are not a high priority	32.5
I would be satisfied with the future situation	2.3
I am not interested in this matter	3.5
I need more information/time to answer	26.4
My household cannot afford to pay	28.8
I don't believe bees are important to our environment	0.9
The extra money is insufficient to make any difference	9.0

The rest of the respondents (36%) did not have preferences for a policy to protect bee populations as revealed by their WTP. The reasons for those who expressed unwillingness to pay for a conservation policy to protect bee populations are given in

Table 1. The most commonly stated reasons are that the households could not afford to pay (38.8%), that bees are not a high priority on their agenda (32.5%) or that they needed more information and time to consider (26.4%). Few respondents were either satisfied with the future situation, not interested in the issue or believed that bees are not important to the environment. When asked who they thought should pay for the policy to maintain bee numbers, more than half of the respondents suggested that the government in partnership with industry should pay for pollination services while a large number (27.8%) insisted that the government alone should pay for the policy (Figure 1). This suggests a ‘public good’ perception of pollination, which discourages individual initiatives, intended to conserve insect pollinators (Kasina *et al*., 2003).

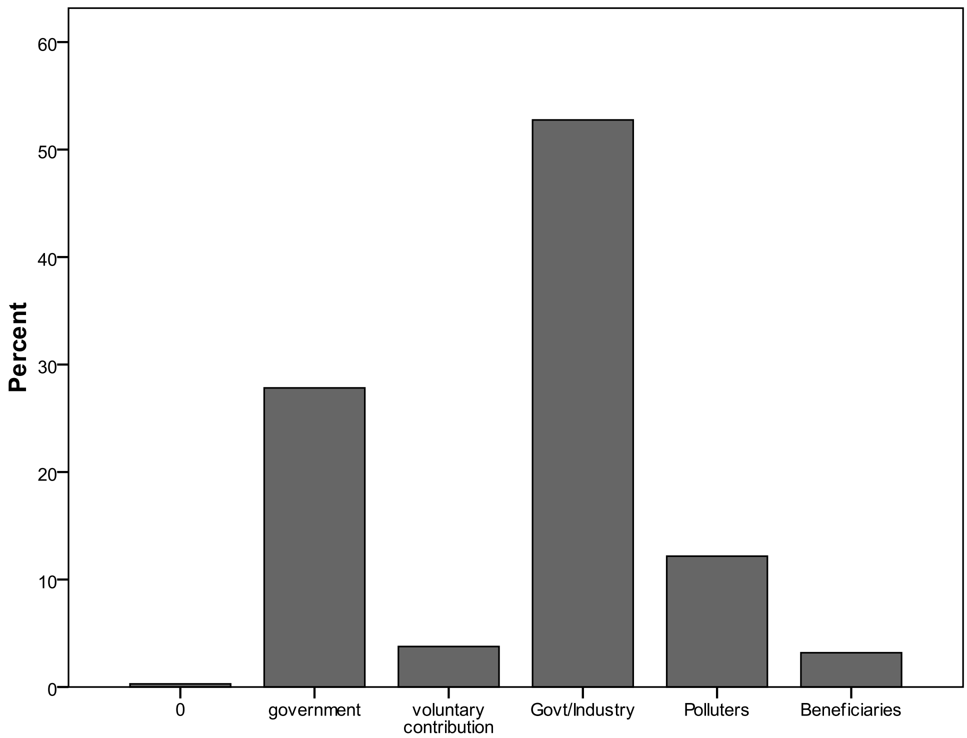

Figure 1: Who should pay to maintain bee populations?

However, a significant number of respondents (12.2%) would like to see the polluters being made responsible for payment of such a policy. Such responses indirectly imply the use of the 'polluter pays principle', whereby firms that pollute the environment or cause damage to biodiversity would be liable to pay to correct the damage, which is in line with OECD principles (Griffiths and Wall, 2004). A small percentage of the respondents (7%) thought that the beneficiaries and voluntary contributors should pay to maintain bee populations (Fig. 1). One of the ways to collect potential payments for the implementation of the proposed pollinator protection policy would be through taxes or establishing trust funds. However, it has been argued that funding such policies through commodity levies has a comparative advantage over the use of taxes in that levies would transfer much of the cost of the policy to the beneficiaries (Sumner, 2003). This might also be relevant in the case of the pollination service.

3.2 WTP Estimation

Table 3 gives the WTP values decomposed for the different respondent groups. From the survey, respondents from bee keepers (BK) category expressed the highest WTP of £4.42 per week, followed by F&F and then Fera (£2.90 and £1.24 per week per household respectively), while respondents from Defra/EXT expressed the smallest WTP of £0.2 per week per household (but low number of respondents). The mean WTP expressed by the total sample is £1.37 per week per household (95% CI: £0.22-£4.62). The test of equality of means confirms that WTP was statistically different between the different respondent groups in the study. This was an expected result as the direct beneficiary from pollination service provided by honeybees would be WTP more than the ones who do not directly benefit from the service (Mburu *et al*., 2006).

Table 2: Summary of WTP per week per household to preserve honeybee populations at current levels, decomposed by respondent categories (£, 2009 prices).

Parameters	BK	FF	Fera	WP	GYS	RU	PHSI	EXT	Defra	Total
Mean WTP	4.42	2.90	1.24	0.98	0.93	0.82	0.78	0.3	0.20	1.37
Median WTP	1.25	1.00	0.6	1.00	0.30	0.60	1.00	0.3	0.20	0.60
Std deviation	7.64	5.86	2.33	0.64	2.30	0.71	0.64	-	-	3.26
Std error	3.12	1.00		0.29	0.24	0.17	0.16	-	-	0.22
Minimum	1.00	0.1	0.1	0.3	0.1	0.1	0.1	0.3	0.20	0.1
Maximum	20	20	10	2.0	20	2.0	2.0	0.3	0.20	20
% of zero bids	1.00	5.50	6.7	0.00	15.9	5.8	1.44	0	0	35.9
% Dont know	0	0	4.5	0	0.3	0	0	0	0	0.3
Sample size	8	53	72	5	145	38	5	1	1	345

Notes: BK=Bee Keepers; F&F=Friends & Family; WP=Woodchester Park; RU=Reading University; GYS=Great Yorkshire Show; Fera=Food & Environment Research Agency; PHSI=Plant Health and Seeds Inspectorate.

The variation in WTP is explained by the wide range in the amounts which the surveyed groups were WTP yielding high standard deviations. Figure 2 gives the distribution of WTP for a policy to protect pollinators. It can be seen that the WTP decline as the prices asked of respondents' increase, in accordance with economic theory (Hanley and Barbier, 2009).

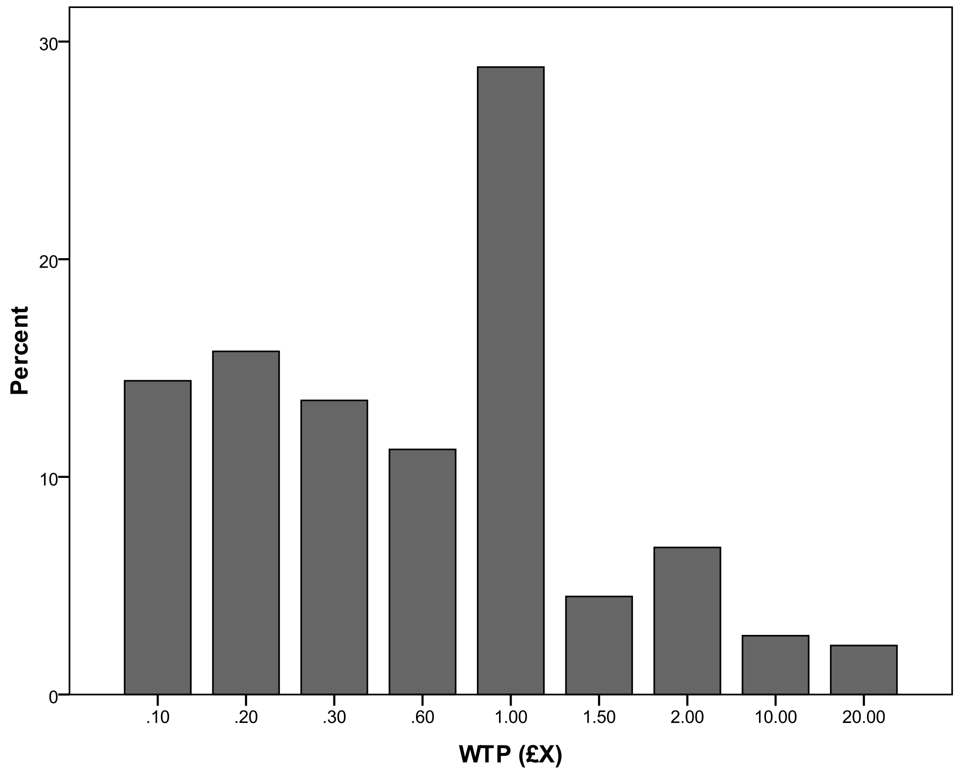

Figure 2: Distribution of WTP amounts (£) to maintain bee populations at current level.

Table 3: Logit valuation function for WTP to maintain honeybee population

Parameters	**Coefficient (se)**	**t-statistics**
Constant	0.0376 (1.9040)	0.02
WTP (£)	-0.0021 (0.0121)**	-2.05
Income	0.4413 (0.2498)**	-2.45
λ^2- value	7.10	
Log likelihood	-7.7651	
Pseudo R^2	0.3139	
No. of obs	212	

Legend: Coefficient/(standard error), ***, **, * indicates significance at the 1%, 5% and 10% levels, respectively.

In the logistic regression analysis of the WTP to support a policy to maintain bee populations and the socio-economic variables of respondents shows that the WTP was significantly correlated to the price asked and income of the respondents (Table 2). The analysis indicates that priced and income alone were able to explain 31.4% of the variation in the WTP. No other socio-economic variables significantly contributed to WTP variance. The coefficient of –0.0021 means that a £100 increase in the price asked would reduce the odds by 0.21 (that is would reduce the relative probability of saying yes by 1.2337). Similarly, a £1 increase in income would increase the odds by 0.4413, which means it increases the relative probability of a yes by 1.5547.

Table 4 gives the results of the best-fitting Tobit regression model. Tobit models largely confirm the signs and significance already observed in the logit function. The correlation between the predicted and observed values of WTP is 0.3647. If we square this value, we get the multiple squared correlation, this indicates predicted values share about 13% (0.3647^2 = 0.133) of their variance with WTP. The variables age, gender, aware and member of organisation are marginally significant but have the correct signs. On the other hand, income shows a significant positive impact on WTP amount, consistent with economic theory. These results suggest construct and theoretical validity claim of the instrument used and are consistent with the predictions of economic theory (Perman *et al*., 2003; McIntosh *et al*., 2009).

Table 4: Tobit valuation function for WTP to maintain honeybee population

Parameters	Coefficient (se)	t-statistics
Constant	2.66 (1.59)**	1.96
Gender	0.42 (0.03)	1.08
Age	-0.69 (0.24)	-1.24
Income	1.50 (1.01)**	2.49
Aware	0.72 (0.29)*	1.92
Member of bee organisation	0.77 (0.55)	1.39
λ^2- value	30.35	
Log likelihood	-521.81	
R^2	0.13	
No. of obs	212	

Legend: Coefficient/(standard error), ***, **, * indicates significance at the 1%, 5% and 10% levels, respectively.

We can then estimate the aggregate WTP to maintain bee numbers over the total UK population. For simplicity, if we take the estimated mean WTP of £1.37 per household per week as the relevant average value and factor in the total number of households in the UK in 2009 (24.9 million from the UK Office of National Statistics), we would obtain a total WTP for insect pollinators of about £1.77 billion per year. This figure can be broadly interpreted as representing an estimate of the lower bound on the WTP-based valuation of the potential value of insect pollinators that could be lost if bees are not protected from environmental threats (i.e. diseases, invasive species, pesticide use, climate change).

3.3 Importance of well informed citizens

Awareness of the threat facing bee populations and their importance as a source of a unique ecosystem service was important in helping respondents to value insect pollinators. In the Tobit regression, the variable aware has a positive coefficient although it is only marginally significant (Table 4). This assertion is supported by the fact that the majority (84%) of the total population sampled were informed of the status of bee populations and the decline that they face if not protected, prior to participating in this survey. Only 16% of the respondents were not aware that bee populations are in decline. It is also noteworthy that only 16% of the sample respondents were a member of a bee-related organisation while most of the respondents were not associated with any bee organisations. This implies that information on bee populations and their importance would have been obtained from other sources. The majority of the total population sampled expressed some concern about losing bee populations and the ecosystems services they provide.

Additionally, those aware of declining bee populations and after the proposed conservation policy was introduced, expressed a mean WTP of £1.45 per week per household compared to £0.56 per week per household for those who were not aware of declining bee populations. The difference in the mean WTP between those with information and those without information of declining bee numbers is statistically significant ($p<0.05$). This shows that information about bees and their importance as a source of unique ecosystem service was instrumental in helping respondents to reveal their preferences for pollination services. It highlights the need to spread knowledge on the 'positive externalities' of honeybees for pollination (Kasina *et al*., 2009).

3.4 Valuing pollination service using simple market value method

We acknowledge that it is somewhat difficult to use CVM to value services that include a strong use-value component because of the problem of separating use value from non-use value. Carreck and Williams (1998) estimate the value of pollination service on the basis of the crop value of the pollinated crops. Gallai *et al*. (2009) extended this simple bioeconomic approach to determine the global economic value of insect pollination and the vulnerability to pollinator loss. The approach gives an order of magnitude estimate of the value of pollination service. In this section, we apply the same equation with more recent data to provide updated estimates of the value of pollination by honeybees to the UK economy. Following Gallai *et al*. (2009), the economic value of insect pollination (EV) can be calculated using equation (1).

$$EV = \sum_{I=1}^{i} \sum_{j=1}^{J} (P_{ij}.Q_{ij}.D_i) \qquad (1)$$

where: Q_{ij} is the quantity of crop *i* produced in country *j*, P_{ij} is the price of crop *i* per unit produced in country *j*, and D_{ij} is the dependence ratio of the crop *i* on insect pollination. For comparability, we restricted the scope of the analysis to the crops reported in the original study by Carreck and Williams (1998). Data on crop production was taken from Defra statistics (2010) while the dependence ratio of crops on honeybees came from Carreck and Williams (1998) and ADAS (2001).

Table 4 gives the estimates of the value of pollination by honeybees to the UK economy calculated using the market price valuation. The best estimate of the value of pollination by honeybees to agricultural and horticultural crops in the UK is approximately £230 million in 2008 prices. This figure is much smaller compared to the CVM estimates but it represents only use values in agriculture.

Table 5: Value of insect pollination in UK crops (£'million in 2008 prices)

Crop	Role of honeybees in pollination (%)	Market value (£ million)	Value of insect pollination (£ million)
Apple	90	120	108
Field beans	8	73	6
Mixed orchard	40	15	6
Oilseed rape	8	609	49
Other soft fruit	15	42	6
Pear	30	10	3
Raspberry	30	104	31
Strawberry	10	213	21
Total			230

Notes: Estimates calculated using market price method in Carreck and Williams (1998), and Gallai *et al*. (2009).

4. DISCUSSION

There are a number of methods that can be used to estimate the value of the pollination service. But no single method adequately captures the entire value of the pollination service. Using the market valuation equation of Gallai *et al*. (2009), the total value of pollination for UK agriculture amounted to £230 million per year in 2008. This figure is about 8 times less than the estimate obtained using the CVM. However, this figure refer to only the 'direct use' value of the pollination service while the CVM estimates refer to total values including non-use values of honeybees. These values tend to be important when the good in question has few substitutes. Since most biological resources such as honeybees are unique by definition, their non-use values are likely to be significant (OECD, 2002). But we did not find any other papers using the CVM to value insect pollinators or similar species that could be used to compare the magnitude of the estimates reported in this paper.

The number of studies reporting non-use values are as yet few in the literature but increasing (e.g. Bateman and Langford, 1997; Sattout *et al*., 2007). Our results should be best interpreted as indicating individual total economic value, an assessment encompassing use, option and existence values. Hargrove (1989) argued that non-use values can be anthropocentric, for example natural beauty, or ecocentric, where it is based upon the notion that animal and plant species have a right to exist. In the pollination context, we can distinguish three types of non-use values (Kolstad, 2000): existence value (based on the utility derived from knowing that insect pollinators exist), altruistic value (based on utility derived from knowing that somebody else benefits from insect pollinators), and bequest value (based on utility gained from future improvements in the welfare of one's descendants). It would have been impossible to try to measure empirically these different categories of non-use values.

An alternative method to value pollination service is the replacement cost (RC). However, since cost-based methods use 'costs' as a proxy to estimate 'benefits', they do not provide a correct measure of economic value (McIntosh *et al*., 2009). Costs as a measure of benefits will always yield a benefit-cost ratio of unity, and so the method cannot give guidance on the efficiency of investing in the replacement. Nonetheless, replacement costs are widely used to estimate values of ecosystem services (e.g. Costanza *et al*., 1997; Pimentel *et al*., 1997; Allsop *et al*., 2008). A recent study by Marris *et al*. (2009) used RC to value the role of pollinating honeybees in UK apple orchards. If bees did not pollinate apples and we had to rely on hand pollination, then to maintain production at existing levels the price of each individual dessert apple would need to rise by about 120%. Their paper captures the value of the pollination service provided by honeybees from a different perspective of replacement costs.

For the management of the pollination service, the important economic measure is the 'marginal' value of pollination service. While total values are most useful to communicate the overall economic importance of pollination to policy makers, the marginal values can provide guidance on the 'optimal protection' of the pollinators. For this, the production function (FP) approach must be applied to estimate the marginal value of the pollination service. The FP approach has been used to value many different ecosystem goods and services (Freeman, 1993). As most authors are interested in the value of pollination service at the aggregate scale, the FP approach has been the valuation method of choice in recent papers (Southwick and Southwick, 1992; Gordon and Davis, 2003; Kasina *et al*., 2009). We are not aware of any papers using the FP approach to value pollination service in the UK. To summarise, these various methods place different economic values on honeybee pollinators, and it should always be remembered that these methods are based on different assumptions.

5. **CONCLUSIONS**

The approach used in measuring the value of honeybees was different from that used in other papers. It has been argued that stated preference methods are not suitable to value pollination service (e.g. Mburu *et al*., 2006). It is asserted that these valuation methods require respondents to have a sound knowledge of the quantitative contribution that pollination makes to crop production but our results show that it is possible to value insect pollinators using the CVM. The survey sample used is relatively small and might not entirely capture the full profile of the British population but it provides information that is ‘useful’ on the value of honeybees in the UK. The data generated represents a tangible set of information pointing to potential values that exists in honeybees. The main advantage of using the CVM is the ability to determine the total willingness of the public to pay to support insect pollinators, comprising use and non-use values. The results from the CVM defining a WTP for a theoretical protection policy indicates a real value of honey bees for the population.

The importance of awareness campaigns to provide information about the value of honeybees and the ecological importance of their unique ecosystem service could potentially increase the number of individuals that would be WTP for their protection, as revealed in this paper. The findings from this survey could provide a convincing argument for policy makers and other stakeholders in agriculture and conservation to consider policies required to protect insect pollinators. Without such a policy, future generations may not enjoy this service if we do not conserve honeybees given the continued threat from emerging diseases, habitat loss, pesticide use, and climate change. Given the importance of awareness on WTP values, there is an urgent need to spread knowledge about the positive externalities of bees for pollination.

There are limitations to this paper. The main one to acknowledge relates to contingent valuation of pollination. In general, it is difficult to separate use value from non-use value in CV of honeybees. And so it was not clear in the survey whether individuals have a high non-use value for honeybees (given that the WTP is relatively higher than the estimates of the market value of pollination service) or whether individuals hold small non-use values and are simply giving high estimates of pollination use values. Therefore, we recommend that the estimates from this valuation exercise be best viewed from a relative perspective, and not an absolute perspective (i.e the relative value of option A vs option B). Further, we recommend more work to validate our results as well as to examine other covariates not accounted for in this survey. This would mean covering a clearly larger and more representative sample of the British profile. Limitations notwithstanding, the data from this survey point to some concern of the population for the future conservation of honeybees and that action must be taken if the biodiversity position of honeybees is not to decline further.

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