A Choice Experiment Assessment of the Impacts of an Invasive Biological Control Agent: the case of the Asian ladybird in France

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PRELIMINARY VERSION

May 25, 2014

Abstract

The Asian ladybird beetle is an introduced biological control agent that has become highly invasive in many regions, including Europe. While biological control is usually considered as an environmentally-friendly alternative to chemical pesticides in controlling pests in crops, there is growing concern that these environmental benefits could be outweighed by the negative consequences of the invasion. These include (i) biodiversity losses as populations of native ladybirds and other aphidophagous insects suffer from intraguild predation and competition for resources ; (ii) human nuisance in houses, including risks of allergy and (iii) potential losses to vine-growers. The aim of this paper is to shed some quantitative light on the valuation of environmental and private characteristics affected by the Asian ladybird's introduction. We conducted a choice experiment among a representative sample of the French population. Our results show that the consequences of the Asian ladybird's introduction do affect significantly the population's utility. Among these, the impact on biodiversity through the threat on native ladybirds seems to be one of the main concerns.

Keywords: Non-market valuation; Choice experiment; Biological Invasion; Biological Control; Biodiversity; Pesticides.

JEL Classification: Q10, Q51, Q57, C35

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We wish to thank Jens Abildtrup, Jeanne Dachary-Bernard, Bérénice Fassote, Marc Kenis, Bénédicte Rulleau, Axel Vandereycken, and all the participants of our focus group for help and useful comments. Financial support from Biofis is gratefully acknowledged.

Contents

1 Introduction

Biological control is usually considered as an efficient and environmentally-friendly method of pest management. Its advocates (van Lenteren, 2012) indicate that biological control outperforms chemical control on many aspects: specificity, success ratio, benefit/cost ratio, and less harmful side effects. In particular, in comparison to chemical insecticides, biological control avoids the release of toxic substances harming non-targeted species (including humans), and avoids the development of resistance in targeted pests. Public concern about chemical pesticides has grown dramatically over the last decades with mounting evidence of their health and ecological effects. Recent studies suggest that citizens in developed countries have a positive willingness to pay (WTP) to avoid exposure to pesticides (see for example Florax et al. (2005) for a meta-analysis of WTP estimates, and Chalak et al. (2008) for a choice experiment disentangling health- and environmental related motivations for a decrease in pesticide use).

However, adverse non-target effects of biological control have been observed in a number of situations. These include the release and spread of exotic species that have become invasive. Invasive species are considered as a major environmental concern, and represent one of the top drivers of global biodiversity loss. Even though there is general agreement that sound risk assessment procedures should precede the release of exotic invertebrate biological control agents, there is no consensus on how to judge the magnitude of non-target effects and whether these effects could outweigh the benefits of biological control (De Clercq et al., 2011).

Our study aims at providing some economic insights in this debate. In particular, we evaluate individual preferences with regard to some of the costs and benefits associated with the release of the multicolored Asian ladybird beetle (*Harmonia axyridis*), a prominent biological control agent that has turned invasive.

Section 2 presents the background, recalling the reasons for the release of the Asian ladybird in Europe (2.1), highlighting the main problems associated with its spread, and discussing the possible options to mitigate these impacts ; it also provides (2.2) a quick survey of the economic non-market valuation literature addressing similar issues, and highlights our original contribution. Section 3 focuses on the methodology we used to conduct our study. Results are presented in section 4 and discussed in section 5.

2 Background and insights from the literature on similar problems

2.1 A tale of a good insect that has become a problem

The Asian ladybird (*Harmonia axyridis*, see Figure 1) is an aphid predator that has been voluntarily released in Europe in the 1990s as a biological control agent because of its voracity. It has been effective at controlling pest insects in a variety of crop systems. However, its populations have spread and established at very fast rates (Brown et al., 2008) in several countries. For France, the following maps (Figure 2) illustrate the progression of the invasion between 2004 and 2011.

Figure 1: The multicolored Asian ladybird beetle (*Harmonia axyridis*)

The Asian ladybird is now considered as one of the world's most invasive insects. The negative consequences of the invasion include:

- *Biodiversity losses* as populations of native ladybirds and other aphidophagous insects suffer from intraguild predation and competition for resources. According to a recent study for England, Belgium and Switzerland (Roy et al., 2012): "The decline in the distribution and abundance of previously widespread and common native ladybirds after the arrival of *Harmonia axyridis* is striking. The dramatic decline of the European ladybeetle species *Adalia bipunctata* (see picture on Figure 3) over the five years following the arrival of *Harmonia axyridis* is of particular note", with a decrease in native populations ranging from 30% (Belgium) to 45% (England) and even 99% (Switzerland);

- *Human nuisance* because the beetle aggregates in buildings when seeking overwintering sites in the autumn (CABI Invasive Species Compendium). Human nuisances that have been reported include aesthetic inconvenience due to aggregates in the housing (see Figure 3). Moreover, reflex

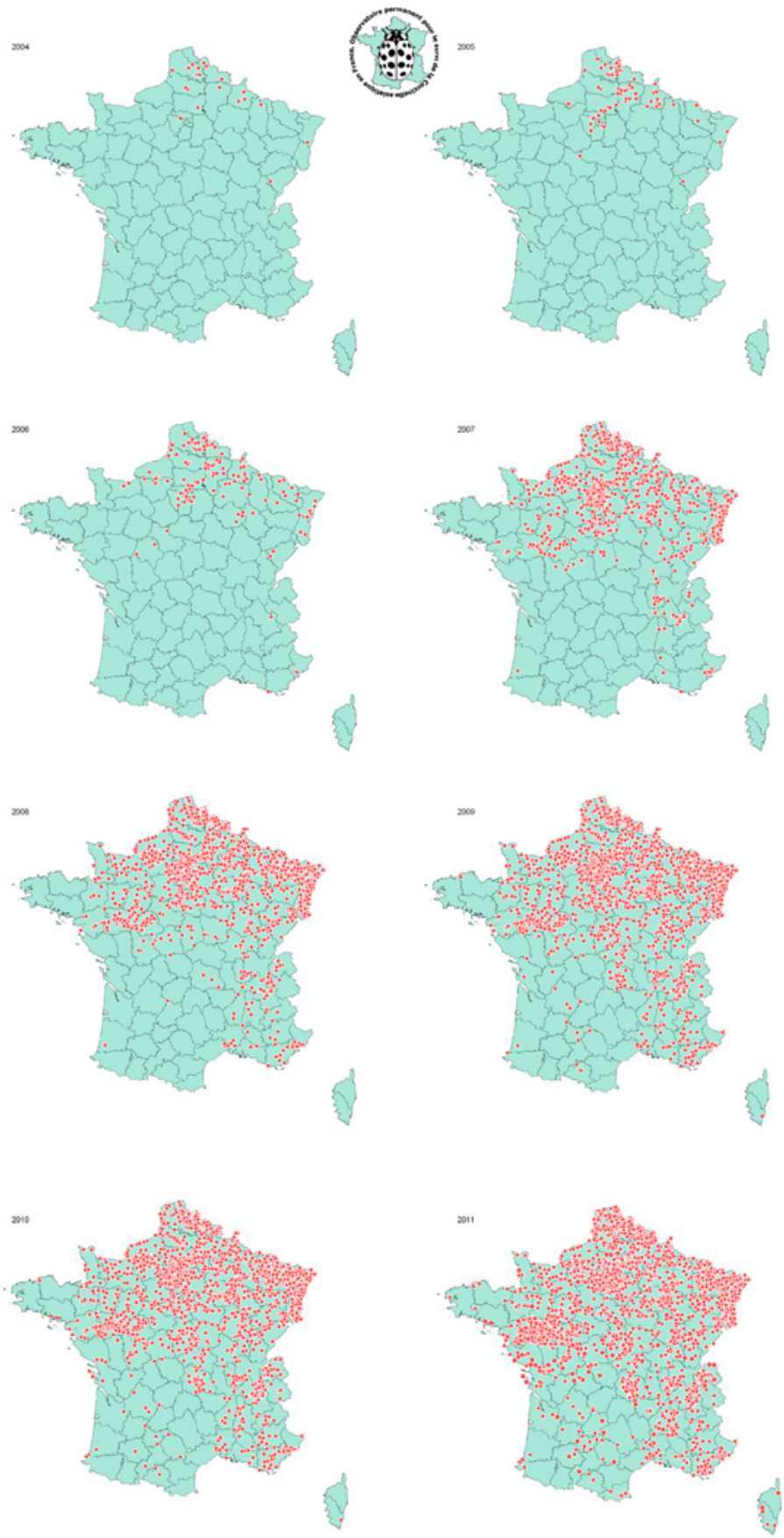

Figure 2: Invasion of the Asian ladybird in France 2004-2011 *(Source: Observatoire Permanent pour le suivi de la coccinelle asiatique en France)*

bleeding ladybeetles may stain furnishings and walls and result in unpleasant odors ; exposure to reflex blood may in a small number of cases trigger allergic reactions in sensitive persons (Majerus et al., 2006; Koch and Galvan, 2008);

- *Potential losses to vine-growers* (Figure 3), because the taste of wine can be spoiled when beetles are crushed with grapes (Pickering et al., 2004). This impact has been reported in North America[1] (where the invasion of *Harmonia axyridis* is also a concern) and to a lesser extent in Europe, including France.

Figure 3: a. *Adalia bipunctata*; b. Nuisance in vineyards; c. Asian ladybird aggregate in housing

Could these impacts be mitigated by public intervention or private actions ? Kenis et al. (2008) have surveyed current and potential management strategies against *Harmonia axyridis*. These include mechanical control, trapping, chemical control, the use of deterrents, and even biological control. Although some of the presented methods could eventually solve the problems caused by beetles aggregating in houses and vineyards, the authors acknowledge that "no method is presently available to lower population densities in natural environments and to limit the impact of the Asian ladybird on native species", and that research to date has been very limited. In other words, there is no management strategy that could presently be used to mitigate *all the impacts* of the invasion. Some of them could be addressed efficiently, but to date, checking biodiversity losses -and saving threatened species like the native ladybird *Adalia bipunctata*- can only be considered if substantial efforts are put into research.

Altogether, the negative consequences of the invasion and the lack of solutions have tarnished the image of a species that used to be a symbol of the "good beetle". The result of van Lenteren et al. (2008)'s environmental risk assessment stated that "in the H. axyridis case, current knowledge would

[1] In 2003, over a million litres of Harmonia-tainted wine had to be destroyed in Ontario, Canada (Ejbich, 2003).

lead to the conclusion that, although the predator is capable to effectively control several pest species (a strong benefit), its risks are manifold (...), and it should, thus, not have been released in Northwest Europe". However, this conclusion relies on the assumption that the costs that the invasion has put on our societies outweigh the benefits - while such a conclusion cannot be reached without an economic valuation of these costs and benefits. In particular, if the disappearance of native ladybirds does not matter to the citizens (either because they don't care about ladybirds, or because the Asian ladybird is considered a close substitute), and if the nuisances do not affect their utility significantly, while the use of pesticides does, then the conclusion of a cost-benefit analysis could be in contradiction to that of the environmental risk assessment.

A cost-benefit analysis of the release of the Asian ladybird beetle would also be useful for two other reasons. First, although the invasion in Northern Europe is probably irreversible, weighting the associated costs and benefits may help regulators in other regions making a decision, when considering whether to introduce this insect as a biocontrol agent. For example, Pervez and Omkar (2006) argue that "its field releases in tropical countries like India should be encouraged; however, only after a thorough analysis of the cost and benefit of beneficial and non-target fauna". Second, estimating total costs induced by *Harmonia axyridis* is useful *ex post*, when deciding on the budget dedicated to research on this topic and to the financing of solutions against the negative effects of the invasion.

Our work is a first step in that direction. Because public policy requires tradeoffs, economic analysis is needed. Should public money be spent to limit the decline in native ladybirds populations ? Are nuisances caused by the invasion significant ? How do people weight different environmental characteristics, like biodiversity and pesticides ? How does this translate into policy priorities when improving one environmental characteristic comes at the cost of another one ? By trying to estimate public preferences with regard to some of the consequences of the release of the Asian ladybird in France, our article will provide some answers.

2.2 Insights from the non-market valuation literature

We wish to value, in monetary terms, the weight the French population grants to various impacts of the Asian ladybird. Several non-market valuation methods allow to estimate the monetary value associated to environmental services or damages (stated preference methods and revealed preference methods)

In recent years, there has been an increasing use of choice experiments in non-market valuation (see Hoyos (2010) for a survey). Like other stated preference methods (for instance contingent valuation), this method includes the existence value (or non-use value), which is useful when valuing endangered species or biodiversity. Moreover, it reveals more detailed information than a contingent valuation

by yielding the willingness to pay for different aspects (i.e. attributes) of an environmental good or policy. On the other hand, its main disadvantage is that the survey is generally heavier than for other valuation methods, which may induce some cognitive difficulties (Hanley et al., 2002) and more complex econometric estimations.

Although there are numerous contingent valuations dedicated to endangered species (see Richardson and Loomis (2009) for a meta-analysis of 43 such studies), and several related to the consequences of invasive species (Nunes and van den Bergh, 2004; McIntosh et al., 2010) and the use of pesticides (see Florax et al. (2005) for a meta-analysis), there are only very few choice experiments in these fields. To our knowledge, Travisi and Nijkamp (2008) is the only choice experiment dedicated to chemical pesticides. This contribution analyzes the perception of pesticide risks in Italy, taking into account potential impacts on biodiversity, groundwater quality and human health. According to their results, biodiversity seems to be one of the main concerns related to pesticides. In comparison with our paper, their design does not involve any trade-off between biodiversity and pesticides, as biodiversity losses are a consequence of chemical pesticides use, while in our problem, the decline in native ladybird species is driven by an alternative to chemical pesticides. Hanley et al. (2003, 2010); Bartczak and Meyerhoff (2013) and Wallmo and Lew (2011) use choice experiments to value endangered species and species preservation policies. The species studied in these articles are respectively birds, mammals and fishes. Insect species do not seem to have been the object of choice experiments up to now, when according to Richardson and Loomis (2009) the willingness to pay to preserve an endangered species depends crucially on the species' type.

We contribute to the aforementioned literature and to the policy debate in three ways : first, our framework allows us to evaluate simultaneously the willingness to pay of the French population with regard to the most important impacts of the release of the Asian ladybird: thus, it becomes possible to analyze the underlying preferences with regard to pesticide use, to biodiversity and to nuisances. This is important both to prioritize future action (i.e. highlight the measures that will yield the highest welfare improvements, when tradeoffs are involved), and to shed some quantitative light in the debate whether the negative impacts outweigh the benefits for the society as a whole. Second, we provide estimates and comparisons of the annual willingness to pay / willingness to accept of a representative sample of the French population with regard to a small decrease/increase in pesticide use. Finally, we are able to give a monetary estimate of the value the French population puts on the survival of a threatened insect species, *Adalia bipunctata*, a European native ladybird.

3 Methodology

3.1 Survey design and choice experiment

3.1.1 The choice of the attributes and their levels

In our survey, respondents were asked to chose which situation they would prefer, in a five-years' time, between three options composed of the *Statu-Quo* situation, that is the situation in five years if nothing is done, and two other options. Each option is characterized by different levels of four attributes, including a monetary attribute. Note that the offered options do not necessarily correspond to an applicable and realistic public policy. Each option is just a combination of the different attributes' levels, in order to measure the respondents' value associated to each attribute given their choices. In some existing choice experiments, an option is associated to a policy alternative and the survey informs on which policy to implement. In our case, however, there are presently no available policy to reduce all the negative impacts of *Harmonia axyridis*. Our study is a preliminary step in order to assess the population's willingness to pay to solve this problem, and thus to measure the appropriate budget to be dedicated to this field.

In order to identify the most significative attributes and their levels, discussions were held with experts in ecology and non-market valuation methods. A focus group was also organized allowing informal discussions with non-expert people. The chosen attributes were:

1. The level of pesticides used in the agriculture. Three levels were associated to this attribute: identical to the actual level (*statu-quo*), a 3% increase compared to the actual level, a 3% decrease compared to the actual level.

2. The state of the population of *Adalia bipunctata* (the most threatened European native ladybird), representing the impact of the invasion on biodiversity. Three levels were associated to this attribute: disappeared (*statu-quo*), rare and abundant.

3. The damages caused by the Asian ladybird to human beings, their housing and fruit cultures were grouped in a unique attribute. Three levels were associated to this attribute, in proportion of the affected population: high (*statu-quo*): 15% of the population, moderate: 5% of the population and insignificant: 1% of the population.

4. The cost attribute was chosen as an increase of yearly local taxes, with three possible values: 0 € (*statu-quo*), 5 € and 10 €. Taxation was preferred to voluntary donations to avoid free-riding effects (Whitehead, 2006) and this payment vehicle did not seem to meet major objections during the focus group.

See the table below for a summary of the attributes and their levels. The statu-quo level is indicated by "SQ".

Table 1: Attributes and levels

Attributes	**Description**	**Levels**
Pesticides	Use of chemical pesticides in the agriculture	Actual level (SQ); Reduction (3%); Increase (3%)
Biodiversity	State of *Adalia bipunctata*'s population	Disappeared (SQ); Rare; Abundant
Nuisance	Damages on humans, housing and vine cultures (% of the population affected)	High (15%, SQ); Moderate (5%); Insignificant (1%)
Monetary contribution	Increase in yearly taxes	0 € (SQ); 5 €; 10 €

3.1.2 Experimental design

Once the attributes and their levels were chosen, the next step was to choose which options (i.e. combinations of attributes' levels) to include in the questionnaire. With four attributes and three associated levels each, the full factorial range of combinations (3^4) was too wide to collect the respondents' opinion on all of them. We selected a statistically efficient sub-set of these combinations using a Bayesian D-efficient design. This is the aim of experimental design techniques (see Louviere et al. (2000)) and the associated software[2]. There are different types of experimental designs. The orthogonal design is often used and selects the choice sets that procure the maximal information without any *a priori* information on the population's preferences. The efficient design yields more information for a given number of choice sets but requires *a priori* values (priors) on the population's preferences. These priors can be issued from previous studies in the literature or pilot studies. The efficient design, although less common than the orthogonal given its requirements, is recognized as superior in the literature.

As a first step, we implemented a pilot study on a sample of students based on an orthogonal design. This allowed us to obtain priors in order to implement an efficient design on a representative sample of the population (see below). The pilot study was administered to 204 French students on an engineering school campus in Paris's suburbs (AgroParisTech) in December 2013.

The efficient design was then obtained resulting in 9 choice sets. Each choice set is composed of the *statu-quo* and two alternative scenarios, as shown in the example presented below (Figure 4, in French), in which the pesticide attribute is labeled "Pesticides", the state of *Adalia bipunctata*'s

[2]We used the NGene software which is a reference in this field.

population attribute is labeled ”Biodiversité”, the attribute related to damages on humans is labeled ”Nuisances” and the cost attribute is labeled ”Participation financière”.

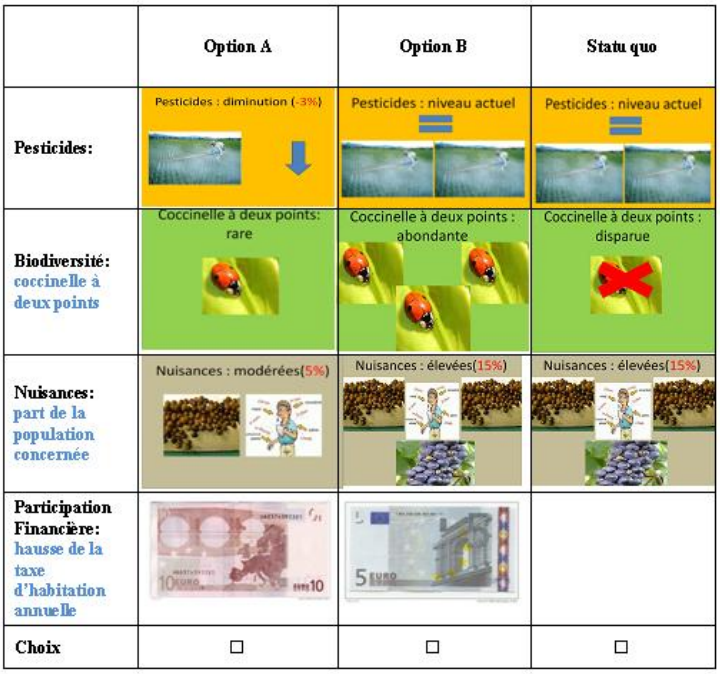

Figure 4: Example of a Choice Set

3.1.3 Data collection and presentation of the questionnaire

The survey was administered on line on May 2014 by a survey institute, yielding 503 answers from a representative sample of the French population. The questionnaire was designed to last less than 15 minutes. After a short introduction on the context of the survey, some general questions where asked related to the respondent's environmental attitudes (consumption of organic products, passed voluntary donations, etc.). A summary of our problematic was then presented through a video and slides. Then came the nine choice sets, composed of three options each. Respondents were asked to carefully consider their current budget and expenditures in making their choices. The order of the choice sets was randomized so that potential reduction of the concentration for the last questions would not always affect the same choice sets. In one of the choice sets, there was one dominated option (same monetary contribution but better levels for all other attributes) in order to check the respondent's coherence. At the end of the nine choice sets, interviewees were asked whether they were satisfied with their answers. Socio-economic information on the interviewee such as income level, gender, age and level of education were collected at the end of the questionnaire, as they do not require a high level of

concentration.

The socio-demographic characteristics of the sample were very close from the French population's characteristics, as shown in Table 2.

Table 2: Socio-demographic characteristic

	France	Sample
Age	44.86	44.77
18-34	26%	25%
35-49	36%	37%
50+	38%	38%
CSP		
CSP+	26%	35%
CSP-	40%	37%
Inactifs	21%	24%
Sexe		
Hommes	49%	47%
Femmes	51%	53%

Among the respondents, 38 individuals (7.5% of the sample) selected a dominated option in one of the choice sets. This choice was potentially consistent only if the person had a preference for an *increase* in pesticides. Therefore we checked in their responses along the other choice sets whether they were consistent with a positive willingness to pay for an increase in pesticides: they were not, so these 38 answers were excluded from our analysis.

Moreover, 70 individuals (14% of the sample) indicated there were not entirely satisfied with their answers. We chose not to systematically exclude them from the sample as most of them seemed to have understood the questions quite well and were simply frustrated by the trade-offs they had to make, for instance having to choose between less pesticides or more biodiversity[3]. An issue was whether to exclude or not those who had chosen the *statu-quo* in all choice sets (17 respondents), given it could express a protest answer. We chose not to exclude them as we could not differentiate with certainty between those having a zero willingness to pay and those expressing protestation.

[3]We tested the robustness of our econometric results when excluding these 14% and the results remained very close.

3.2 Econometric model

The choice experiment technique is an application of the characteristics theory of value (Lancaster, 1966), combined with random utility theory (McFadden, 1974). As suggested by this literature, we assume here that the utility for each individual i and for each alternative a in each choice set s can be decomposed into a linear-in-parameters part, that depends on observable variables V_{ias}, and an error term ε_{ia}. Then, the utility function of individual i $(i = 1, ..., N)$ with the alternative a $(a = 1, ..., A)$ in choice set s $(i = 1, ..., S)$ can be denoted as:

$$U_{ias} = \beta' x_{ias} + \gamma_i' z_{ias} + \varepsilon_{ias} \tag{1}$$

where x_{ias} and z_{ias} are the observed variables associated to alternative a in choice set s, β is the vector of fixed coefficients, γ is a vector of random terms with mean zero and ε_{ias} is a vector of error terms. The alternative a will be chosen over some other option a' if and only if $U_{ias} > U_{ia's}$.

The econometric model depends on the assumption on the distribution of error terms. If the ε_{ias} are independent identically distributed (IID) type I extreme value, we have a random parameter logit (or mixed logit model) (Train, 2009). The standard logit is a special case of this model where γ has a zero variance. Random parameter logit is a highly flexible model that can approximate any random utility model (McFadden and Train, 2000). It enables to avoid the three limitations of standard logit by allowing for random taste variation, unrestricted substitution patterns, and correlation in unobserved factors over time (Train, 2003).

In the random logit model, it is also necessary to make an assumption regarding the distribution of each of the random coefficients. In principle any distribution could be applied. However, the choice is often limited by difficulty of model estimation and availability in econometric software. We assume here that the random parameters are normally distributed. The normal is the most easily applied distribution and allows for both negative and positive preferences that could be expected. As it is usually the case in the literature, we assume here that the parameter representing the marginal utility of income is constant (Hensher and Greene, 2003).

For a given value of γ, the conditional choice probability is a standard logit:

$$L_{ia}(\gamma) = \frac{e^{\beta' x_{ia} + \gamma_i' z_{ia}}}{\sum_{a' \in A} e^{\beta' x_{ia'} + \gamma_i' z_{ia'}}} \tag{2}$$

and the unconditionnal choice probability, in the random parameter logit model is the logit formula in equation 2 integrated over all values of γ weighted by the density of γ:

$$P_{ia} = \int L_{ia}(\gamma) f(L_{ia}(\gamma)/\Omega) d\gamma, \tag{3}$$

where $f(L_{ia}(\gamma)$ is the density of γ and Ω is the fixed parameter of the distribution. The choice probability in equation 3 cannot be calculated exactly because the integral does not have a closed form in general. This integral is approximated through simulations. For a given value of the parameters Ω, a value of γ is drawn from its distribution. Using this draw, the logit formula in (2) is calculated. This process is repeated for many draws, and the mean of the resulting $L_{ia}(\gamma)$ is taken as the approximate choice probability giving equation 3.

$$SP_{ia}(\gamma) = \frac{1}{R}\sum_{r=1}^{R} L_{ia}(\gamma_r), \tag{4}$$

where, R is the number of draws of γ, and SP is the simulated probability that an individual i chooses alternative a.

In our experiment, the participants were asked to make $S = 9$ choices between $A = 3$ alternatives. The utility function in our case is:

$$\begin{aligned} U_i &= cte_{SQ} + \gamma_1 biodiv_2 + \gamma_2 biodiv_3 + \gamma_3 nuisance_2 + \gamma_4 nuisance_3 \\ &\quad + \gamma_5 pesticide_2 + \gamma_6 pesticide_3 + \beta cost \end{aligned} \tag{5}$$

where $biodiv_2$ and $biodiv_3$ respectively correspond to a "rare" and "abundant" level of population for the attribute labeled biodiversity; $nuisance_2$ and $nuisance_3$ respectively correspond to "insignificant" (1%) and "moderate" (5%) levels for the attribute regarding damages on humans; $pesticide_2$ and $pesticide_3$ are respectively the "increase" (+3%) and "decrease" (−3%) for the pesticides attribute and *cost* is the level of the monetary attribute. The term cte_{SQ} refers to the alternative specific constant (ASC) associated to the *statu-quo* which represents the role of unobserved sources of utility. As we have unlabeled experiments[4], we only include an ASC for the *statu-quo* alternative (Hoyos, 2010). β, and γ_k $(k = 1, ...6)$ are the parameters to be estimated. They measure the marginal utility associated with a change in the level of the corresponding explanatory variable (i.e. attribute) with regard to the *statu-quo*. In our model, the utility coefficients vary among individuals, but are constant among the choice situations for each individual. This reflects an underlying assumption of stable preference structures for all individuals (Train, 1999).

In the analysis of the collected data, we estimate three types of models: the standard logit (SL), the conditional logit (CL) and the random parameter logit (RPL). The latter is the most flexible as it has the advantage of assuming that the alternatives are not independent and it takes into account unobserved heterogeneity as well as random taste variations among individuals (Train, 2009).

[4]Each option in the choice sets does not necessarily correspond to a precise policy alternative which could be labeled, it is just a random combination of attributes' levels.

We use the estimated parameters to calculate the willingness to pay (WTP) associated with each attribute and each level ($biodiv_2$, $biodiv_3$, $nuisance_2$ $nuisance_3$,$pesticide_2$,$pesticide_3$) as follows:

$$WTP_j = -\frac{\gamma_j}{\beta} \tag{6}$$

In calculating a measure of WTP, it is important that both attributes to be used in the calculation are found to be statistically significant, otherwise no meaningful WTP measure can be established.

4 Results and interpretation

The estimation results of the random parameter logit model are shown in Table 3. All the parameters are highly statistically significant and have the expected sign. Unsurprisingly, the sign of *cost* as well as the sign of $pesticide_2$ are negative. This means that any increase in the pesticides level and costs from the *statu-quo* reduces the respondents' utility. Results also show that the standard deviations of the coefficients enter significantly, indicating that a random parameter model provides a significantly better representation of the choice situation than a standard logit, which assumes that coefficients are the same for all respondents. This allows us to observe how preferences systematically differ between respondents. For this reason, we focus on the results of the random parameter logit model.

The choice experiment approach then allows us to estimate the willingness to pay (WTP) associated to each level of each attribute. Using equation (6), results of WTP are presented in Table 4. Results in the RPL case show that respondents are ready to pay in average 10€ per year to increase European native ladybird population from the *statu-quo* level ("disappeared") to a level "abundant". Respondents seem also concerned by pesticides' use in agriculture as they are able to pay in average 2.8€ per year to decrease their level by 3% compared to their actual level. The WTP associated with an increasing level of pesticides in agriculture are negative which means that the respondents need to receive in average 6.5€ to compensate the loss of welfare associated with a 3% increase of pesticides used in the agriculture. Concerning the human damages caused by the Asian ladybird, respondents have an average WTP of 5€ and 7€ per year to reduce these damages from their actual "high" (15% of the population concerned) level to a "moderate" level (5% of the population) and "insignificant" level (1% of the population) respectively.

As shown in our results, there is a significative willingness to pay to preserve the endangered native ladybird, *Adalia bipunctata*. The annual willingness to pay for the preservation of this native ladybird does not seem extremely high compared to the value obtained in the literature on choice experiments valuing endangered species[5]. However, as explained above, these studies are dedicated to mammals, birds and fishes rather than insect, which may explain the variation in the obtained values.

[5]Ranging approximately from 10€ to 70€, depending on the species' type, whether the payment prevents extinction,

Table 3: Estimation results

	SL	CL	RPL	
	Param	Param	Param	SD
constante	-1.185***	0.0130	-1.386***	3.304***
	(-32.42)	(0.14)	(-6.51)	(16.99)
pesticide2	0.813***	1.001***	0.521***	0.527***
	(9.39)	(11.04)	(4.96)	(3.44)
pesticide3	-0.695***	-0.262**	-1.182***	1.820***
	(-7.97)	(-2.81)	(-6.59)	(12.26)
biodiv2	0.460***	0.913***	1.510***	0.0833
	(4.53)	(8.60)	(10.58)	(0.51)
biodiv3	1.022***	1.317***	1.815***	0.708***
	(16.27)	(19.77)	(15.52)	(4.93)
nuisance2	-0.138	0.388***	0.928***	0.588***
	(-1.83)	(4.61)	(8.02)	(4.94)
nuisance3	0.705***	1.023***	1.313***	1.018***
	(6.99)	(9.75)	(9.75)	(9.72)
cout	-0.178***	-0.124***	-0.181***	
	(-22.50)	(-14.56)	(-14.03)	
χ^2	2053.24***	1465.81***	1176.23***	
$N \times A \times S$	12528	12528	12528	

t statistics in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

One could have expected a higher willingness to pay for a reduction of the use of pesticides, given the potential effects of these chemicals on health and fertility, which can easily alarm respondents. Moreover, the pesticides' impacts have a partly private nature whereas biodiversity is a typical public good. Due to free-riding behaviors, one might have expected a larger willingness to pay for (partly) private attributes than for purely public ones. Travisi and Nijkamp (2008) obtain much higher annual values in the Italian population for pesticides' reductions (approximately 7 € in total per month taking the form of higher food expenditures). However, this value includes the willingness to pay for biodiversity (which is one of the three attributes selected by these authors) whereas in our case,

on the extent of the variation of the population induced by the payment, whether it is a one time or annual payment, whether the concerned species is emblematic.

Table 4: WTP estimates

	SL	CL	RPL
WTPpesticides2	4.576***	8.080***	2.877***
	[3.505,5.648]	[6.148,10.01]	[1.573,4.181]
WTPpesticides3	-3.911***	-2.113**	-6.525***
	[-4.754,-3.068]	[-3.455,-0.771]	[-8.017,-5.032]
WTPbiodiv2	2.592***	7.366***	8.339***
	[1.590,3.593]	[5.794,8.939]	[7.133,9.544]
WTPbiodiv3	5.752***	10.63***	10.02***
	[5.203,6.302]	[9.210,12.05]	[8.655,11.39]
WTPnuisance2	-0.775	3.134***	5.125***
	[-1.643,0.0919]	[1.828,4.440]	[4.009,6.241]
WTPnuisance3	3.968***	8.259***	7.252***
	[3.053,4.884]	[6.795,9.723]	[6.153,8.351]
$N \times A \times S$	12528	12528	12528

95% confidence intervals in brackets

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

biodiversity appears as separate to the pesticides' attribute. Our relative small willingness to pay for reducing pesticides might be due to the small reduction of pesticides considered (3% in five years may not seem significant for a portion of the population) or to a lack of knowledge on risks associated to pesticides[6].

Furthermore, one may note the strong dissymmetry between the willingness to pay for a reduction of pesticides and the willingness to accept for a same extend increase of pesticides. This confirms a well-known result in the literature according to which a willingness to accept is higher than a willingness to pay for a same variation of the environmental quality.

Last, the willingness to pay for a reduction of human nuisances due to the Asian ladybird are not insignificant at all. For instance, based on a household's average willingness to pay to reduce these nuisances from a high level (15% of the population) to an insignificant level (1% of the population) equal to 7.25€ per year, the total budget that should be dedicated in France to solve *Harmonia*'s effects in housings and vineyards exceeds 200 millions euros.

[6]In our will to stay as neutral as possible regarding the information delivered before the choice sets, we did not detail the potential negative effects of chemical pesticides. Instead a short sentence mentioned potential effects on the environment and health without detailing.

5 Conclusion and discussion

The objective of this paper was to evaluate individual preferences with regard to some of the costs and benefits associated with the release of the Asian ladybird beetle. We conducted a choice experiment on a representative sample of the French population to quantify these various impacts: effects on local biodiversity, use of chemical pesticides, and nuisance to humans and fruit cultures.

Our preliminary results show that all the attributes considered to measure the impacts of the Asian ladybird have a significant effect on the utility of respondents. Our estimates show that respondents have a positive willingness to pay to preserve native species of ladybirds, to decrease the nuisances caused by the invasion, and to reduce the use of chemical pesticides. In particular, respondents are ready to pay 10€ per year in average to increase European native ladybird's population from the *statu-quo* level ("disappeared") to a level "abundant". Conversely, any increase in pesticides has a strong negative impact on respondents' utility. Thus respondents would need to receive a payment of 6.5€ per year in average to compensate the loss of welfare associated with a 3% increase of pesticides' use in agriculture.

This article contributes to the literature in three ways. First, it is a first estimation of the willingness to pay of the French population for reductions of the use of chemical pesticides, whereas their use has become controversial in this country. Second, we obtain some first choice experiment estimates of the monetary value for an endangered species of the insect type, namely the emblematic two-spot ladybird (*Adalia bipunctata*). Third, our work is a first step towards a cost-benefit analysis of the introduction of the Asian ladybird, which was crucially lacking according to the ecological literature on the topic (Pervez and Omkar, 2006). Our results suggest the costs associated to the invasion of this beetle are far from insignificant and caution should prevail when considering further introductions of this biocontrol agent. Moreover, our results argue in favor of dedicating significant budgets - several hundreds millions euros in France - to solve the problems associated to this ladybird beetle.

Our work can be improved in many directions. The effect of socio-economic variables on the obtained willingness to pay should be further analyzed. Among these, we wish to explore the impact of the type of place of residence (urban / rural zone) on the respondents' value for the various attributes. In some further work, we would also like to develop other surveys in order to test the robustness of our results regarding the attributes' levels. These include the extent of the pesticides variation (3%) and the amount chosen for the increase of yearly local taxes (5€ and 10€).

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