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An economic analysis of species conservation and translocation for island communities: the Seychelles paradise flycatchers as a case study

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In this paper we introduce a methodology for assessing the economic justification for translocation–conservation programmes for critically endangered species. We demonstrate our methodology by presenting an economic analysis of the critically endangered Seychelles paradise flycatcher (*Terpsiphone corvina*) (hereafter SPF). To do this we first estimated the critical amenity value of the forest that currently supports the SPF. Results support the maintenance of the forest, which in turn implies that the existing population of SPF needs to be protected so as to achieve species conservation objectives. Next we conducted a benefit–cost analysis of the translocation, showing that the development of a second population yields net economic benefits. By employing the methodology presented we can conclude that our analysis indicates that current conservation and translocation actions to support the SPF are economically justified.

Keywords: species conservation and translocation; benefit–cost analysis; critical amenity value; choice experiment

1. Introduction

The translocation of threatened species to increase their probability of survival is a well-established approach to conservation management (Armstrong and Seddon 2007). Translocations as a conservation tool are employed for many reasons including threats to existing populations from habitat loss as well as limited opportunities for species numbers to increase because of carrying capacity constraints. When undertaking a translocation there are important resource allocation decisions to be made as well as management choices relating to the existing population and habitat. To date the vast majority of the literature only examines the costs of translocation without any consideration for associated benefits (Fischer and Lindenmayer 2000). We add to this literature by employing a novel methodology to assess the economic justification for conservation–translocation activities for threatened species.

We demonstrate our methodology by examining the actual conservation and translocation of the critically endangered Seychelles paradise flycatcher (*Terpsiphone corvina*) (hereafter SPF). The precarious existence of the SPF is such that in 2008 its population was estimated at just 300 individuals, all restricted to the tiny island (16 km^2) of La Digue (Bristol et al. 2009). The SPF is the only endemic bird species in the Seychelles classified

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*Corresponding author. Email: I.M.Fraser@kent.ac.uk on the IUCN Red List as critically endangered. It is evolutionarily distinct from all other *Terpsiphone* paradise flycatchers of the western Indian Ocean (it forms its own monophyletic clade dating back to the early Pleistocene (Bristol et al. 2013)), a characteristic which strengthens an economic case for increased conservation efforts due to evolutionary uniqueness (Weitzman 1998).

The endangered nature of the SPF is a result of various factors. There are extensive pressures for land use change from agriculture, housing development (resulting in the loss of native broad-leaved plateau woodland), the introduction of non-native species and the impact of a vascular wilt disease on the takamaka tree (*Calophyllum inophyllum*) which comprises the preferred habitat of the SPF (Hill, Currie, and Shah 2003). Many of these pressures are unlikely to diminish without significant policy efforts and enforcement of a moratorium on land use change on the remaining habitat on La Digue. Given the threats faced by the SPF, the Government of Seychelles together with international conservation non-governmental organisations (NGOs) concluded that the only viable long-term species recovery plan, to increase population numbers and to reduce the probability of extinction, was to translocate a number of individuals to another suitable island to establish a second free-living population (Currie et al. 2005).[1] This second population provides a form of insurance such that the SPF can be re-introduced to La Digue if there was a sudden collapse in population numbers, whilst also improving genetic variability and overall species numbers.

In this paper we present a new methodology for undertaking the economic analysis of the translocation of the SPF. Unlike the existing literature that is typically only concerned with the translocation process our analysis is composed of two parts. First, we establish that maintenance of the remaining forest habitat supporting the SPF on La Digue is economically justified. There is little point in undertaking a translocation to increase population numbers to achieve the specified conservation objectives unless the original population is protected. The possibility that existing population of the SPF on La Digue could decline in numbers because of inadequate conservation efforts can be considered a form of moral hazard (Varian 1992). Although only a theoretical possibility, it will be interesting to see how the SPFs on La Digue are managed once the second population on Denis Island becomes established. There are constant pressures to reduce the amount of suitable habitat on La Digue in response to the need for extra housing; indeed, the emergence of a second population might provide an argument to undertake this type of action. We undertake this part of the analysis by estimating the critical amenity value (CAV), following Conrad (1997) that the La Digue forest generates for all users including visitors and tourists to the island. Our estimates of CAV are sufficiently large so that they provide support for appropriate forest management that will ensure that the habitat of the SPF is protected.

Second, we undertake a benefit–cost analysis (BCA) of the translocation activity with project-specific information incurred during the actual translocation. These data are complemented by benefit estimates derived by re-estimating choice experiment (CE) data collected in the Seychelles to investigate avian conservation options for rare and endangered species (for details see Veríssimo et al. 2009). Overall our BCA demonstrates that the conservation–translocation of the SPF makes sound economic sense.

The structure of our paper is as follows. In Section 2 we explain in detail the translocation process undertaken in this study. This is followed by the presentation of our estimates of the CAV for the forest on La Digue. Section 4 then begins by detailing the costs associated with the translocation of the SPF, followed by our econometric examination of the CE data and associated results. We conclude Section 4 by combining costs and benefit estimates so as to conduct our BCA. Finally, in Section 5 we summarise our results and offer conclusions.

2. Translocation in practice

A multitude of considerations are required before initiating a translocation programme, varying from when to translocate, selection of release sites, the amount and type of genetic diversity that is included in the released population and post-release management, maintenance and monitoring (Engelhardt et al. 2000). Therefore, given the diversity of issues that need to be considered prior to undertaking a translocation, much of the literature is concerned with specific aspects of the translocation process. Studies consider hypothetical examples (e.g., Reynolds et al. 2008) by employing population simulation models to assess a translocation activity. Others report actual examples of species translocations examining legal, socio-economic and policy constraints, plus factors that may contribute to likelihood of translocation success, such as site selection and management, the role of population monitoring and minimising stress to the translocated individuals (Hodder and Bullock 1997; Groombridge et al. 2004).

In the case of the SPF an important issue was obtaining support from the local residents for translocation previously noted for the Rarotonga monarch flycatchers in the Cook Islands (Robertson, Karika, and Saul 2006). For the SPF local support only emerged as the result of a significant and extensive education programme (Vel 2008). Educating the La Digue residents about the need to maintain the current population of the SPF was essential for the translocation to go ahead. Obtaining this support was important because of initial resistance to the translocation by the La Digue population who assumed they had an implicit property right over the SPF as a consequence of the strong association between the bird and La Digue.

Another facet of gaining local support for the translocation of the SPF stemmed from the site selected to receive the birds. The choice of Denis Island as the recipient island for translocated SPF was made following several biological and ecological studies (Hill 2002). Hill (2002) assessed potential rehabilitation and current conservation status with Denis Island ultimately chosen because it has a significant area of existing native plateau forest (27 hectares), a small marsh – a landscape feature considered necessary to support the SPF, plus a further 100 hectares suitable for habitat rehabilitation.

Finally, the issue of economic costs and benefits of translocations has been largely overlooked by scientists and practitioners (Fischer and Lindenmayer 2000). An exception is Baxter et al. (2006), whose study emphasises how changing the balance of activities when undertaking species translocations can impact relative cost effectiveness. They examine different management strategies in relation to species translocation with respect to species fecundity and survival focusing on the Australian helmeted honeyeater (*Lichenostomus melanops cassidix*). They conclude that for the honeyeater management of fecundity is more cost effective than management of survival, illustrating that there are trade-offs with any translocation activity between the effort employed to implement the translocation and the associated likelihood of success (Robert 2009).

3. La Digue forest and critical amenity value

We begin our economic analysis by estimating the CAV of the La Digue forest following Conrad (1997) adding to a small literature that examines the importance of forest amenity values (e.g., Bulte et al. 2002; King and Fraser 2013). The purpose of our analysis is to assess if the possible loss of the La Digue forest that supports the SPF, because of land use changes such as new housing, is justified. If conversion (i.e., loss of forest) cannot be supported then this indicates that every effort should be made to maintain the existing forest that supports the SPF, especially if the objectives of species conservation are to be met.

Calculation of the CAV requires that we assume that the La Digue forest is generating a dividend characterised as an amenity flow (F) over time (t) (where $F = F(t)$) where F captures non-timber benefits from the forest such as those associated with biodiversity. Like Conrad (1997) we employ tourist visitation data as a proxy for unobservable amenity value by assuming that the two are proportional to each other. Thus, assuming that F evolves stochastically via a process of Brownian motion, then F can be characterised as follows:

$$dF = \mu F dt + \sigma F dz \tag{1}$$

where dF is the change in F, μ is the mean drift, dt is an increment of time, σ is the standard deviation and dz is the increment of a standard Wiener process. Then, if the forest is cleared and it is impossible to reverse this outcome it follows that the option value function $V = V(F)$, and its first and second derivatives, must satisfy various conditions if maintaining the forest is to be optimal (Conrad 1997). If δ (the discount rate) is less than or equal to μ (i.e., $\mu \geq \delta$) then it is optimal to clear the forest, but if $\mu < \delta$, then there is a lower bound critical threshold value for the amenity value (F^*) where we will be indifferent between maintaining or clearing the forest. Only when F falls below F^* does it becomes optimal to clear the forest. Following Conrad (1997) the value function equals

$$V(F) \;=\; kF^{-\alpha} + \; F/(\delta - \alpha) \tag{2}$$

where

$$\alpha \;=\; (1/2 - \mu/\,\sigma^2) - \surd((1/2 - \mu/\sigma^2)^2 + 2\delta/\sigma^2) \tag{3}$$

and k is an unknown constant. The value function can be solved for k and F^* using

$$F^* \;=\; \alpha(\delta - \mu)N/(\alpha \;+\; 1) \tag{4}$$

where N is the proposed value of the resource in question, in this case land cleared of forest.

3.1. CAV estimation

To undertake the CAV estimation we assume that the forest area in question is the remaining area of indigenous woodland on the western plateau of La Digue. The western plateau is 161 hectares in size and only 25% (approximately 40 hectares) remains as indigenous woodland. Of this 21 hectares are situated in the La Veuve special nature reserve (which was initially established in 1991). Based on current (2013) real estate prices undeveloped land on La Digue is estimated to be worth in the range of €70,000–€100,000 per hectare.[2] Thus, if we assume a worst case scenario, and the remaining 40 hectares is cleared and used for other activities such as housing, tourism or farming, then the value of N is at least €4 million (i.e., 40 × 100,000). Given this estimate for N and provided we also have values for μ and σ, and an acceptable value for δ exists, F^* for the forest can be calculated.

First, μ and σ are estimated using time-series data on visitation rates. We began by collecting annual tourist visitation data for the Seychelles. We know that the majority of tourist visitors to La Digue are day visitors and a high percentage of visitors to the Seychelles do visit La Digue. For example, Payet (2007) reported that day visits to La Digue can number at least 200 per day (if not significantly more). So assuming 200 visits per day for 365 days yields an estimate of 73,000 per annum. Also, those visitors staying on La Digue for more than one night in 2007 was 8544. Given that in 2007 the Seychelles had 161,273 visitors; this indicates that at least 50% of all visitors to the Seychelles visited La Digue. Therefore, we employ the data on visitors to the Seychelles as a proxy to derive our key parameters. Data on visitor numbers are freely available on the Seychelles National Bureau of Statistics website (www.nsb.gov.sc). We collected annual visitor data for the period 1971 until 2012.

To ensure that the data on annual visitors to the Seychelles can be used to estimate μ and σ we need to test if the data are stationary or not. We follow Conrad (1997) who employed the augmented Dickey–Fuller (ADF) test statistic assuming only one lagged differences. Let Y_t be the annual number of visits in year t made and let $y_t = \ln(Y_t)$. To undertake the test we estimate the following model:

$$(y_t - y_{t-1}) = \beta_0 + \beta_1 t + \beta_2 y_{t-1} + \beta_3 (y_{t-1} - y_{t-2}) + \varepsilon_t \tag{5}$$

and test the null hypothesis H$_0$: $\beta_0 = \beta_1 = \beta_2 = 0$, employing the ADF test. Regression results and ADF test statistics are reported in Table 1.

These results mean that we do not reject the null hypothesis and that visitor data can be characterised as showing Brownian motion.[3] As such μ and σ are estimated using the visitor data taking the natural logarithm of the ratio of visitor numbers between successive

Table 1. Dickey–Fuller regression results and critical amenity value estimates.

Unrestricted model (u)	Coefficients	SEs	P-value
β_0	5.03	1.54	0.00
β_1	0.26	0.15	0.10
β_2	−0.46	0.14	0.00
β_3	0.02	0.01	0.00
RSS(u)	0.30		
Restricted model (r)	**Coefficients**	**SEs**	**P-value**
β_1	0.19	0.15	0.23
RSS(r)	0.44		
DF test statistic Decision: unable to reject H_0	3.35	Critical values: 4.16 (90%), 4.88 (95%) and 6.50 (99%)	
Critical amenity value estimates ($\mu = 0.53$, $\sigma = 0.114$, $\delta = 0.07$)			
F^* ($N = €4$ million)	€110,000		
F^* ($N = €40$ million)	€660,000		

Note: $n = 36$. SEs = standard errors; RSS = residual sum of squares.
DF test = $(T - k)(\text{RSS(r)} - \text{RSS(u)})/(q\text{RSS(u)})$, where RSS is the residual sum of squares, T is the length of the time series, k is the number parameters estimated in the unrestricted model and q is the number of restrictions imposed.

years (i.e., $\ln(Y_{t+1}/Y_t)$). These results, shown at the bottom of Table 1, are $\mu = 0.053$ and $\sigma = 0.114$. Based on these estimates and assuming δ equal to 7%, if the value of the forest is €4 million then F^*, which is estimated using Equations (2)–(4) is approximately €61,000 per annum. In contrast, if we think that the value of the forest is much higher (i.e., assume land is valued at €1 million per hectare), for example, €40 million, then F^* equals €600,000 per annum.

How can we make use of this estimate to support continued forest management for the SPF? We can compare it with an annualised estimate of consumer surplus for use of the forest on La Digue, or alternatively the willingness to pay (WTP) associated with preserving the SPF. If the estimated consumer surplus exceeds F^*, then ongoing forest management is optimal. To estimate WTP we need to know the number of annual visitors. The average annual number of visitors to La Digue who stay for at least one night between 2010 and 2012 is approximately 11,000. If we assume that only half of them have a positive WTP for the SPF (based on the latent class model (LCM) results, see Section 4 for details) of €20 per annum then this yields an estimate of €20 × 5500 = €110,000. In contrast, if we now consider all tourists who visit La Digue for less than 24 hours, then based on numbers arriving by boat from Mahé this at least 50,000 per annum if we extrapolate following Payet (2007). So again assuming only half have a positive WTP we arrive at an estimate of 25,000 × €20 = €500,000. This estimate is clearly very much larger than that based on a land value of €100,000 per hectare but slightly smaller than if we assume €1 million per hectare.

Finally, if we examine the existing literature on non-market valuation studies for the Seychelles (summarised in Mwebaze and Macleod 2013) we find annual estimates of WTP to fund conservation policy of at least €44 per individual. We note that these estimates are for a range of policy activities, not a single policy option. However, taking this as an upper bound in our analysis then would yield an estimate of €44 × 5500 = €242,000 and €44 × 25,000 = €1,100,000, the latter being far larger than either estimate of F^*.

So in summary, our analysis yields results that support ongoing policy efforts to maintain the La Digue forest in its current state because of the associated amenity values. This is important as maintaining the viability of the forest and at the same time the SPF depends not only on the success of the translocation, but also on the continued existence of the required habitat on La Digue for the existing population.

4. BCA of translocation

The translocation of the SPF to Denis Island occurred in November 2008 (Bristol et al. 2009). Denis Island had already experienced and been subject to significant ecosystem restoration to support translocations of other species, for example, the Seychelles warbler (*Acrocephalus sechellensis*) and the Seychelles fody (*Foudia sechellarum*). Although this meant that many of the translocation costs of the SPF (e.g., island restoration including eradication of rats and mice and extensive habitat management) had already been made, we include all costs in the BCA given the illustrative nature of the case study.

4.1. The costs of translocation[4]

To calculate the costs associated with the translocation we draw on our own field data. These data relate to the costs of the translocation of the SPF which was partly funded by a UK Government Darwin Initiative project grant (www.darwin.defra.gov.uk/project/15009). In addition, Henri, Milne, and Shah (2004) provide a valuable source of cost data associated with ecosystem restoration and species translocation in the Seychelles. Taking these sources together, we have identified the following set of costs:

- Island identification: there is a cost in identifying a site for the translocation. Denis Island was identified as suitable for the SPF. The search is estimated to have cost €25,000 (Henri, Milne, and Shah 2004).
- Island restoration: Henri, Milne, and Shah (2004) provides detailed data for Denis Island. Ecological restoration began in 1999, including efforts to eradicate rats and mice, and habitat management to promote regeneration of native high-canopy forest, which provides the SPF its required invertebrate food. Coconut palms had been cleared from 30 hectares and a plant nursery established providing saplings to create additional habitat. Total costs of island restoration are €50,000.
- Education of La Digue population: the education programme on La Digue takes data from the education project budget (Vel 2008). These activities incurred labour costs of €33,000 (a field officer) and €6500 (assistants). All costs were incurred over three years. The total costs (including administration) are €55,000 per annum for three years.
- Preparatory research and species transportation: monitoring existing population numbers to identify suitable candidate birds to move required field data collected by a field officer and two field workers employed for three years. Based on the actual SPF translocation these costs are €30,000 per annum for the field officer and €13,000 per annum for the field workers. From budgetary data the cost of an avian veterinarian specialist to undertake health screening (€7000), the cost of transit by helicopter (€3500) plus other associated labour and equipment costs resulted in transportation costs of €25,000.
- Monitoring and maintenance costs: no activities, such as supplementary feeding or clutch manipulations have been employed to increase productivity of the SPF. Once on Denis Island SPF management required a trained and experienced conservation officer. Based on data from Henri, Milne, and Shah (2004) and the actual translocation of the SPF, monitoring and maintenance costs are €30,000 per annum. These costs are ongoing for as long as it is necessary to ensure success of the translocation.
- Non-market valuation study: a non-market valuation of the translocation activity is an integral part of the overall evaluation of a project. Based on previous experience of conducting non-market valuation, fieldwork costs are estimated to be €10,000.

A summary of our cost data is provided in Table 2.

4.2. The benefits of translocation

To estimate the benefits associated with the SPF translocation we re-examine and re-estimate the CE data-set collected on La Digue and Cousin islands during 2007, and reported by Veríssimo et al. (2009). This CE was designed to examine consumer preferences for avian conservation on remote islands such as La Digue for species under threat. Veríssimo et al. (2009) examined the data using a mixed logit econometric specification. In this paper we re-examine the data employing an LCM specification so as to reveal different information about preferences for avian conservation in the Seychelles.

The CE survey instrument was composed of five attributes; these are summarised in Table 3.

Table 2. Summary of cost data for BCA (all in €s).

Activity	Cost (min, max) (€'000)	Duration (years)
Island identification	25 (15, 40)	1
Island restoration	50 (25, 150)	3
Education on La Digue	55 (25, 85)	3
Bird translocation	25 (10, 40)	1
Staff costs on La Digue	43 (30, 55)	3
Monitoring/maintenance	30 (10, 70)	10
Non-market valuation survey	10 (5, 15)	1

Source: Own calculations and Henri, Milne, and Shah (2004).

Each choice card was composed of two unlabelled options plus a neither option, the latter acting as the status quo option. The CE employed a main effects orthogonal design with the options paired together to ensure balance in terms of the attribute levels. Each respondent was asked to complete eight choice sets. Prior to answering the choice sets it was explained that for all options presented on all choice cards the option they selected would lead to an increase in population size of 50% over the next 10 years. The CE framed the issue as a one-off donation that they would be willing to make to ensure the implementation of a bird conservation project over a 10-year period that aimed at increasing a species' probability of survival.[5] The CE did provide explicit information on population levels but no specific mention was made of species extinction.

The respondents were English-speaking tourists over 18 years of age visiting the islands of La Digue and Cousin. The sampling technique employed was opportunistic sampling with all surveys conducted face-to-face. In total 198 useable surveys were collected with La Digue supplying 55% of respondents, and Cousin 45%. The socio-economic mix of respondents reflected the fact that they were tourists being drawn from 21 different nations, mostly in Europe. The sample composition was 56% male and 44% female, with an average age of 37 years. Educational attainment was high with more than 50% having attained a university degree. Finally, reported income was high with average income of €45,000 per annum.

4.2.1. Statistical analysis

As noted, in this paper we employ a latent class (logit) model (LCM) that allows us to capture respondent heterogeneity (Boxall and Adamowicz 2002). The LCM is based on the basic multinomial (conditional) logit (MNL) and is composed of two parts: an

Table 3. Attributes and levels used in choice experiment and model estimation.

Attribute	Description
Appearance (App)	Perceived species attractiveness: attractive (1) and unattractive (0)
Endemism (End)	Geographic distribution Seychelles only (1) or beyond (0)
Population size (Pop)	Number of a given species: 150 (low = 0) and 3000 (high = 1)
Special characteristics (Specch)	Presence (1) or absence (0) of unusual or unique ecological or behavioural characteristics
Days to see (Days)	Number of days needed to see a species: one, three and seven days
Payment (Pay)	Payment to support project, €10, €20, €60, €100 and €200

observable deterministic component and an unobservable random component. In this model a respondent *n* has to make one choice from a finite set *C*. The utility respondent *n* obtains from selecting an alternative *I* ($I \neq k$, for all $k \in C$) is

$$U_{ni} = \beta X_{ni} + e_{ni} \tag{6}$$

where *U* is the utility obtained by individual, β is a vector of parameters to be estimated, *X* is a vector of attributes from the CE and ε is a random component assumed to be a type 1 extreme value distribution. We now assume that within the population there are a finite number of segments *S* such that individual *n* belongs to segment *s* ($s = 1, \ldots, S$). Given this we can re-express the utility that respondent *n* obtains from selecting an alternative *I* as

$$U_{ni|s} = \beta_s X_{ni} + \varepsilon_{ni|s} \tag{7}$$

such that the utility parameters are segment specific. The deterministic part of Equation (7) can be divided into two: (1) the specific attributes of the choice made and (2) individual-specific characteristics (i.e., the socio-economic variables). It can be shown that the choice probability for individual *n*, given that they belong to segment *s*, will select an alternative *I* is

$$\mathrm{Pr}_{ni|s} = \left(\frac{e^{\beta_s' X_{ni}}}{\sum_{k=1}^{C} e^{\beta_s' X_{nk}}} \right) \tag{8}$$

Next we use a MNL to place individual *n* into a specific segment *s* as follows:

$$\mathrm{Pr}_{ns} = \left(\frac{e^{\alpha_s' Z_n}}{\sum_{s=1}^{S} e^{\alpha_s' Z_n}} \right) \tag{9}$$

where Z_n is a vector of individual-specific variables and α_s a vector of segment-specific parameters to be estimated. Thus, conditional on a specific segment membership, the probability that respondent *n* selects an alternative *I* is $Pr_{ni} = Pr_{ns}Pr_{ni|s}$. Thus, to estimate the LCM we combine Equations (8) and (9) as follows:

$$\mathrm{Pr}_{ni} = \sum_{s=1}^{S} \left[\frac{e^{\alpha_s' Z_n}}{\sum_{s=1}^{S} e^{\alpha_s' Z_n}} \right] \left[\frac{e^{\beta_s' X_{ni}}}{\sum_{k=1}^{C} e^{\beta_s' X_{nk}}} \right] \tag{10}$$

Note that if $\alpha_s = 0$ then the LCM collapses to the standard MNL. Various statistical criteria can be used to select the optimal number of segments including model log-likelihood estimates and the Akaike information criterion (AIC). Finally, and most importantly, we also decided upon the number of segments based on the economic plausibility of parameter estimates.

4.2.2. CE results

Our MNL and LCM results are reported in Table 4.

Based on model selection criteria and economic interpretation our preferred LCM specification has two classes. The top part of Table 4 shows there is significant improvement in model performance in moving from the MNL to the LCM2.[6] Based on the LCM2 our respondents can be divided into two groups with almost equal probability (i.e., .499 and .501, respectively). If we compare the MNL and the LCM2 parameter estimates for each attribute they are of the same sign in all cases. Thus, Price is negative, whereas all other parameter estimates are positive, indicating that respondents are WTP for these attributes. The only exception is Population which is negative which indicates that respondents preferred projects with an initially low population level.

Next consider the segment membership equation in the middle of Table 4. We have only included whether or not a respondent is an existing member or not of an environmental organisation as this is the only significant variable. Table 4 shows that segment 1 yields a positive estimate for environmental membership. This then means that for segment 2 this is more likely to contain individuals who are not members of an environmental organisation.

Finally, the lower part of Table 4 provides WTP estimates.[7] They reveal an interesting story. First, the WTP estimates for the MNL are significantly bigger than the LCM results. Second, segment 1 of the LCM does not have a statistically significant Price coefficient such that the resulting WTP estimates are not statistically different from zero. Only for

Table 4. Choice experiment model results.

	MNL		LCM class 1		LCM class 2	
Parameters	Coefficients	SEs	Coefficients	SEs	Coefficients	SEs
Price	-0.150^{**}	0.067	-0.061	0.1432	-0.251^{**}	0.125
Spec	0.336^{***}	0.088	0.462^{**}	0.227	0.276^{*}	0.161
Days	0.038^{**}	0.016	0.077^{**}	0.036	0.007	0.031
Endemic	1.176^{***}	0.091	2.061^{***}	0.596	0.589^{***}	0.196
Population	-1.430^{***}	0.094	-2.070^{***}	0.384	-1.156^{***}	0.168
Picture	0.920^{***}	0.092	1.001^{***}	0.208	0.964^{***}	0.157
Alternative specific constant	-1.563^{***}	0.157	-4.417	3.123	-1.252^{***}	0.318
Segment per cent			49.9		50.1	
Segment equation						
Constant			-0.192	0.483		
Env org			1.103^{*}	0.586		
Log-likelihood	-1130.12		-1102.05			
AIC	2274.2		2236.1			

WTP estimates	MNL	SEs	Class 1	SEs	Class 2	SEs
Spec	-2.230^{**}	0.941	-7.478	17.619	-1.099	0.831
Days	-0.253^{**}	0.101	-1.260	3.107	-0.031	0.128
Endemic	-7.798^{***}	2.345	-33.31	76.817	-2.346^{*}	1.277
Population	9.478^{**}	3.894	33.47	77.592	4.601^{*}	2.364
Picture	-6.099^{***}	1.889	-16.18	37.539	-3.837^{*}	2.001

Note: SEs = standard errors.
***Significant at 1% level.
**Significant at 5% level.
*Significant at 10% level.

segment 2 are the WTP estimates statistically significant and these are much smaller than for the MNL. As would be expected our WTP estimates are similar in magnitude to those in Veríssimo et al. (2009) (i.e., approximately €20 per annum for 10 years) although we now observe that these estimates of WTP only apply to approximately 50% of respondents. Interestingly, the segment with a statistically significant WTP estimate did not typically include existing members of environmental organisations. Therefore, we assume that annual WTP is €20 per annum and this is employed in our BCA. However, given uncertainty surrounding this estimate we also consider a minimum value of €1.

4.3. BCA assumptions

To undertake our BCA of the translocation, we broke down the process into its constituent parts in terms of when activities happened. We identified five key stages that incur costs and benefits:

1. Identification of a suitable recipient island for translocation
2. Restoration, La Digue population education activities and preparatory fieldwork
3. Translocation activity
4. Benefits from the translocation
5. Annual monitoring and maintenance of the new population

Consequently, we constructed a timeline for our analysis, allowing us to identify when costs and benefits associated with activity contributed to the BCA. A summary of the timeline is presented in Table 5.

We present our analysis over 30 years. We assumed that the non-market valuation exercise is conducted in year 3, that translocation occurs in year 3 and that we monitor the translocated population from year 4 to year 29. Thus, we are assuming that benefits are then realised over 26 years from the point at which the birds are initially translocated. We consider this an appropriate time frame as Towns and Ferreira (2001) argue that 20 years is the minimum duration required before success of a translocation can be pronounced. Note that we also examine what happens to our results if we delay the onset of the stream of benefits to reflect the idea that benefits only start to accrue once the translocated population has become established.[8] Another important choice parameter for our analysis is the discount rate, for which we employed a range of values (i.e., 1%, 5% and 10%) to assess the sensitivity of our results to the choice of this parameter.

Table 5. Timeline of BCA.

Year	Activity
Year 0	Identification of recipient island (i.e., Denis Island)
Year 1	Gain approval for project (Govt. and funders)
Years 1, 2 and 3	Island restoration, SPF fieldwork on La Digue and education of La Digue population
Year 3	Translocation
Year 3	Non-market evaluation
Years 4–29	Establishment of SPF population on Denis Island, monitoring of population dynamics
Years 4–29	Non-market benefits begin to accrue

The final parameter we needed to select was the appropriate size of the human population required to make the payments to pay for the translocation activity. To deal with the uncertainty regarding which number to employ we take the following approach. We multiply the non-use WTP estimates by a specific population size so as to yield a BCA ratio of 1 in all scenarios examined. This allows us to examine how sensitive our results are to the choice of this key parameter. Having identified the required population size we then consider this relative to potentially relevant populations.

4.4. BCA results

Our results are presented in Table 6.

Given the assumptions made in the benchmark case the number of contributing individuals necessary to finance the translocation is 3350 if the translocated population takes 30 years to be successfully established. If we then modify the discount rate from 5% to

Table 6. BCA: base case and sensitivity analysis.

Base case			
	Discount rate	BCA ratio	Population size
Base case	5%	1	3350
High	10%	1	4550
Low	1%	1	2625
Sensitivity analysis Benefit = €1			
	Discount rate	BCA ratio	Population size
Base case	5%	1	67,200
High	10%	1	91,000
Low	1%	1	52,500
Restoration = €150,000			
	Discount rate	BCA ratio	Population size
Base case	5%	1	4450
High	10%	1	6350
Low	1%	1	3275
Restoration = €150,000 and monitoring = €70,000			
	Discount rate	BCA ratio	Population size
Base case	5%	1	6450
High	10%	1	8350
Low	1%	1	5300
Delay benefits = start in year 9			
	Discount rate	BCA ratio	Population size
Base case	5%	1	4750
High	10%	1	7750
Low	1%	1	3350

Note: Base case parameters: benefit = €20; restoration = €50,000; and monitoring = €30,000.

1% and 10%, the required population size changes to 2625 and 4550, respectively. Table 6 also shows the results if we significantly reduce the size of the benefit estimate, in this case from €20 to €1. Obviously, the size of the human population required to yield a cost–benefit ratio of 1 is now 20 times larger. Clearly, the magnitude of the benefit estimate has a huge effect on the necessary population size to ensure that the translocation is economically justified.

In contrast, if we examine the sensitivity of these results to changes in other key parameters such as restoration costs, monitoring costs and staff costs or a delay in when benefits start to occur, they do not change the magnitude of the population size required to yield a cost–benefit ratio equal to 1 in any way close to that from changing the size of the benefit estimate. There is nothing inherently unusual about this finding, but it does have important ramifications for actual funding of translocation or other conservation projects such as the one being examined here.

Finally, what is the appropriate human population that should be considered in this case? If we assume that it is the current Seychelles population then this was 88,000 in 2012. This figure is only marginally smaller than the population size reported in Table 6 assuming a benefit estimate of €1 and a discount rate of 10%. However, the non-market benefits being considered are almost all based on existence value of the SPF. Therefore, we might include all visitors to the Seychelles who were approximately 200,000 in 2013. But if we are going to correctly account for existence values then maybe we need to consider who has actually funded the translocation project – in the case of the SPF, the UK Government and associated conservation organisations such as the Royal Society for the Protection of Birds (RSPB). In 2013 the RSPB had an annual membership of in excess of one million. Alternatively, we could consider Birdlife International, whose mission statement confirms that the 2.5 million members worldwide wish to prevent the extinction of any bird species. Indeed, Birdlife International has previously supported nature conservation in the Seychelles by purchasing Cousin Island in 1968 to provide a reserve so as to save the Seychelles warbler (*Acrocephalus sechellensis*).

Almost all of the appropriate human population options considered support the translocation of the SPF in terms of the BCA. Thus, they confirm that the BCA shows that the translocation and ongoing conservation of the SPF make sound economic sense.

5. Summary and conclusions

In this paper we employed a new methodology for assessing the economic justification for translocation–conservation programmes for critically endangered species. We have illustrated the methodology by examining the translocation of the SPF from La Digue to Denis Island. We have found that there appears to be economic support for the translocation of the SPF to a second island. In addition, our estimates of the CAV associated with the existing forest habitat support continued conservation efforts for SPF on La Digue. This means that ongoing efforts to maintain the forest are economically rational from a conservation perspective. Thus, as we have argued, the success of any conservation strategy to support the SPF requires not only increasing the habitat available, but also the maintenance of that which already exists.

Although we consider the results we present to be robust, there are a number of important limitations that need to be acknowledged. We note that our analysis does not address issues of risk relating to how the population of SPF on Denis Island will perform. We have assumed that the translocation is successful and there is a history of successful species translocation in the Seychelles, including the Seychelles magpie-robin (*Copsychus* *sechellarum*), Seychelles warbler (*Acrocephalus sechellensis*), Seychelles white-eye (*Zosterops modestus*) and Seychelles fody (*Foudia sechellarum*) (Henri, Milne, and Shah 2004). Also, since the translocation of the SPF to Denis Island in 2008, the new population there has not only become established, but also started to breed and produce first- and second-generation individuals (Bristol et al. 2009). But, there is no guarantee that the creation of any population by translocation will be successful. In practice, success may require additional translocation efforts (and associated costs) such as those advocated by Engelhardt et al. (2000). However, future applications of the methodology introduced can accommodate risk of success following the approach of Joseph, Maloney, and Possingham (2008) and the adjustments to the BCA explained by Pearce, Atkinson, and Mourato (2006).

Another limitation of our analysis is the establishment of the value resulting from forest clearance on La Digue. We have estimated a value based on existing residential land values as advertise to overseas buyers. The prices being asked are not necessarily the same as those being paid. However, we would argue that the final price paid will be less than the asking price as is common with this type of transaction in the Seychelles.

Finally, the establishment of a second population of SPF can be considered a form of insurance against extinction. The current circumstances facing the SPF indicate there is a chance that species will become extinct within the next 30 years. As such, species translocation can be regarded here as an insurance against extinction by attempting to increase population numbers. But, the act of taking out insurance might lead the population of La Digue to treat the existing population of SPF with less care. It will be interesting to see how the SPFs on La Digue are managed going forward. As we have noted there may well be pressure to reduce the amount of suitable habitat on La Digue for the SPF in response to pressures for extra housing; indeed, the emergence of a second population might provide an argument to undertake this type of action. But as we have demonstrated, the CAV associated with the existing forest on La Digue is such that it should remain intact.

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Notes

1. Captive breeding was not a realistic option for the SPF which is an insectivorous passerine bird that requires highly specialised and intensive avicultural techniques (Bristol et al. 2009). However, there are also reasons to be critical of the use of translocation (see Ricciardi and Simberloff 2009), but in some circumstances it is the only remaining option for managing a species if it is to be saved from extinction.
2. Details of real estate prices obtained from various online sources such as http://www.seychelles-properties.com/listings/La_Digue.
3. In addition to the ADF test there are many other statistical tests that can be used to examine if data are stationary or not (Gujarati and Porter 2009). To assess the robustness of our result we implemented the ADF allowing lag length to be determined using information criteria, for example, AIC. We also conducted the Phillips–Perron (PP) and the KPSS tests. The more general ADF test was in agreement with the test results reported. However, both the PP and KPSS tests yielded much weaker results, only yielding results in support of the ADF results at the 10% level of significance. As such these results suggest the need to treat with some caution the assumption that the visitation data satisfy Brownian motion.

4. All financial estimates are presented as euros. We have assumed one euro buys US $1.25 and we have also converted 2004 data on prices into 2010 estimates using a Seychelles price deflator from the Central Bank of Seychelles (www.cbs.sc).
5. We note that the form of payment employed in the CE may not satisfy consequentiality (Vossler and Watson 2013). However, as observed by Haab et al. (2013) research on this issue to date has yielded mixed results in relation to impact on WTP estimates.
6. We also estimated 3 and 4 segment specifications. Although these models converged they yielded economically implausible results and as a result we report the LCM2.
7. Note that all estimates need to be multiplied by 100 as Price is divided by 100.
8. An alternative way to examine risks associated with the translocation activity could be to follow Joseph, Maloney, and Possingham (2008) who explicitly include an estimate of the likelihood of success of a conservation project in an evaluation framework. A related approach could be to conduct the BCA assuming that the probability of success is known (Pearce, Atkinson, and Mourato 2006). This type of approach was not adopted as the SPF has been translocated successfully.

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