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Analysis

Economic valuation of the influence of invasive alien species on the economy of the Seychelles islands

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ABSTRACT

Biodiversity underpins most economic activities in Seychelles, and loss of biodiversity as a result of invasive alien species (IAS) could result in major negative economic impacts for the country. This paper assesses the value of impacts of IAS on biodiversity, natural resources and the national economy, using the principles of total economic value (TEV). The contingent valuation method was used to obtain a willingness to pay (WTP) estimate for a policy to protect important biodiversity from IAS. Tourists indicated a mean WTP of US$52–US $58 on top of their usual expenditures to fund conservation policy. At present approximately US$0.25 million per year is spent on IAS control while the economic damage associated with 4 key IAS is approximately US $21 million per year. Comparing the benefits from eradication with the costs involved gives a benefit-cost ratio greater than unity, indicating that the policy of eradicating IAS is economically justified. However, there is a long way to go before the resources devoted to the problem will be in proportion to the risks.

1. Introduction

Invasive alien species (IAS) are introduced plants, animals and organisms whose establishment and spread threatens ecosystems, habitats and other species (CBD, 2001). IAS cost the Seychelles economy several millions of dollars annually, represent a major threat to the country's unique biological diversity and could have severe negative impacts in the long run if unchecked (Ikin and Dogley, 2005). The potential impacts on global biodiversity are also significant with the islands of Seychelles being part of a 'biodiversity hotspot' (Myers et al., 2000; Mathieu et al., 2003). Additionally, the native biodiversity of Seychelles is one of the most threatened globally. For example, Fregate Island is home to approximately 50% of the world's population of the Seychelles Magpie-Robin (SMR) (*Copsychus sechellarum*), which today is recognised as a critically endangered bird species (Shah, 2001).

IAS primarily gain entry into new geographic areas through human activities, either deliberately or unintentionally (Vitousek *et al.*, 1997; McNeely, 2001; Koo and Mattson, 2004). Economic activity, particularly globalization through trade, is the fundamental human cause of IAS introductions (Perrings *et al.*, 2000, 2002; Pimentel, 2002; Taylor and Irwin, 2004; Koo and Mattson, 2004). It has been argued that the more open economies are, the more vulnerable they are to biological invasions (Dalmazzone, 2000; Vila and Pujadas, 2001; Levine and D'Antonio, 2003). This may be true for Small Island Developing States (SIDS), which are more dependent on imports than continental countries. Dalmazzone (2000) estimated that the average share of imports in the GDP was 43% for island countries compared to 32% for all countries and only 26.8% for continental countries. Island economies also tend to be ecologically more vulnerable to invasions than continental ecosystems (Perrings et al., 2000). The likelihood of invasion by IAS increases as tourism, fisheries, agriculture and forestry become a larger proportion of a countries economy (FAO, 2001).

Over recent decades, the rate of introductions has increased around the world presenting growing environmental and economic threats. IAS are now ranked as the second most serious threat to global biodiversity loss after direct habitat destruction (Pimentel, 2000). However, published figures on the economic costs of IAS are scarce and the few studies available largely focus on the USA. A widely quoted report by the US Congress Office of Technology Assessments (OTA, 1993) estimated monetary costs of about US$5 billion annually. Pimentel et al. (2000, 2002, 2005) revised the OTA estimates and extended the analysis beyond the US context. The second of their papers included estimates for other countries. They calculate that IAS cause damage equal to 53% of agricultural GDP in the US, 31% in the UK and 48% in Australia, but 96%, 78% and 112% of agricultural GDP in South Africa, India and Brazil, respectively. Since these costs represent an externality of trade (and if they are of the correct order of magnitude), they indicate a significant economic problem exists.

Perrings et al. (2002) argue that the primary driver of alien species entry, resulting in some becoming invasive, is economic. Therefore,

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any analysis of the process from potential entry to invasiveness must consider the economic infrastructure to provide long-term solutions. Economic analyses of IAS have the potential to aid decision-making and hence the allocation of scarce resources to the management of IAS. Seychelles has taken impressive measures to eradicate IAS from both small islands and large islands, and to restore island ecosystems where costs permit. However, a major constraint is the lack of economic valuation of the impacts of IAS, mainly because the biodiversity impacted upon by IAS are often not valued. Given the very high financial costs of control and eradication measures associated with IAS (e.g. the cost per hectare of removing invasive plants was about US$16,500 in 2004), with impacts only materialising in the long-term, policy makers often do not see the need to manage IAS (Kueffer and Vos, 2004). More significantly, the lack of economic data on the costs and benefits of IAS control constitutes a major constraint for the effective mainstreaming of prevention and control efforts (Ikin and Dogley, 2005).

There are few economic assessments of biodiversity in Seychelles. A preliminary study by Emerton (1997) to calculate the total biodiversity value of Seychelles considered direct and indirect use values in different sectors. A few other papers have used the contingent valuation method (CVM) and travel-cost method (TCM) to estimate the economic value of marine biodiversity in Seychelles (e.g. Mathieu et al., 2003; Cesar et al., 2004). Veríssimo et al. (2009) used the choice experiment (CE) approach to determine attributes that are important for raising funds for conservation. Murray and Henri (2005), taking into account the direct and indirect use values of biodiversity, placed a total approximate biodiversity value of US $0.434 billion in Seychelles in 2003. Taking the GDP in 2003 (US $0.847 billion from IMF) as the numeraire, their estimates indicate that biodiversity accounted for 51% of the GDP in Seychelles. The study concluded that biodiversity underpins most economic activities in Seychelles, and loss of biodiversity as a result of IAS impacts could result in major negative economic impacts for the country.

The aim of this paper is to provide an estimate of the magnitude of the economic costs associated with the management of IAS in Seychelles. The analysis seeks to provide some indication of the costs and benefits of management of IAS in ecologically important islands, and make recommendations for adopting cost-effective measures in policy and regulatory change. Given the short confines of this study, we focus on alien mammal predators (notably rats and feral cats), which have colonised most of the islands of Seychelles (Hill et al., 2000). Within the granitic islands, only four islands were considered cat and rat free before 1995 (Shah, 2001): Cousin, Cousine, Ile aux Récifs and Aride. Alien mammals can impose a range of impacts. For example, rats act as vectors of serious human diseases (especially *Leptospirosis*) that kill several people every year in Seychelles. They are also responsible for the destruction of crops and all sorts of goods, damage to telephone wires, etc. In addition, rats and cats pose a serious threat to island ecosystems: Norway rat (*Rattus norvegicus*) was accidentally introduced to Fregate Island in 1995 (Shah, 2001), and it quickly became established posing a huge threat to the critically endangered SMR.

The remainder of the paper is structured as follows. Section 2 describes the general approach used in the study, methods, criteria for selecting IAS/islands, and data collection. Section 3 starts with general costs associated with all IAS in Seychelles and then focuses on alien mammal predators. The final section gives a multi-species CBA of control and eradication measures, and concludes the paper.

2. Methods

2.1. General Approach

This study followed an approach based upon data availability, surveys, stakeholder consultations, questionnaire surveys and economic modelling. The general approach for the valuation of the influence of IAS in Seychelles involved a five-step procedure:

1. Identify the potential IAS that pose a significant threat to important biodiversity in Seychelles.
2. Assess the costs for managing the potential IAS. We followed the approach in Bigsby et al. (2003) and Born et al. (2005), whereby the costs of IAS depends on the stage of the invasion process. The invasion stages are introduction, establishment, colonisation and invasion, according to Born et al. (2005). The CBD requires a hierarchical application of the following three strategies: (i) prevention (ii) eradication and (iii) control. Prevention is defined as any official procedures having the purpose to prevent the introduction and or spread of IAS (FAO, 2006). Control is defined to include suppression, containment or eradication of a population while eradication is the application of measures to eliminate IAS from an area (CBD, 2001; FAO, 2006). Prevention should take place before introduction, eradication can be applied at all stages (especially establishment), and control aims to keep the population below the economically damaging threshold level (Born et al., 2005). In the analysis, costs were assigned to one of the three management strategies.
3. Assess impacts of the selected IAS. As noted, some of these impacts have non-market values. Such impacts can be quantified by applying a range of valuation techniques (Nunes and Van den Bergh, 2004, pp. 519). However, given the wide range of direct and indirect impacts caused by IAS, we were unable to capture the full spectrum of biodiversity impacts. Based on the ecological literature (e.g. Diamond, 1985; Fitzgerald, 1990; Watson et al., 1992; Amarasekare, 1993; Pimentel et al., 2005) and expert consultation with stakeholders in Seychelles, the study focussed on two species that were considered to be at high risk from alien mammal predators; the SMR and the green sea turtle (*Chelonia mydas*). The literature suggests that both species are highly endemic, threatened and cannot coexist with alien mammals on the same islands (e.g. Shah, 2001; Ikin and Dogley, 2005). These two species and the few islands they occupy became the focus of the valuation exercise.
4. Identify monetary values for the selected biological resources impacted upon by the IAS.
5. Apply our findings in a cost-benefit analysis (CBA) to identify the level at which management of IAS is cost-effective. The CBA followed the framework outlined in Nas (1996) and Boardman et al. (2006). The equation to calculate the benefit-cost ratio (BCR) can be simply written as:

$$BCR = \frac{Avoided\ impacts\ by\ IAS(\$)}{Cost\ of\ IAS\ management(\$)}. \quad (1)$$

In addition to calculating the BCRs, the net social benefits (NSB) in terms of the avoided damage by the IAS were also calculated. In order for the protection or conservation policy to be economically justified, the net benefits of the policy must be greater than zero. Net benefits were calculated using the equation:

$$NSB = \sum_t \sum_i \frac{(B_{it} - C_{it})}{(1+r)^t} \quad (2)$$

where: *NSB* is the Net Social Benefit, *B* is a measure of monetary benefits, *C* represents the monetary cost, *r* is the discount rate, and *t* indexes time. When all the market and non-market costs and benefits are measured in monetary values the aggregation is straightforward: the discounted value of the total costs over time is subtracted from the total benefits also discounted over time. If the $NSB \geq 0$ (benefits exceed costs), it indicates that the protection policy is economically justified. But if the$NSB \leq 0$, (costs are larger than benefits) then protection program is not economically justified, unless there are strong non-monetised benefits to consider.

2.2. Data

For the CBA, the selection of IAS largely depended on availability of economic data. There was not an 'official list' of IAS in Seychelles so this work focused on alien mammal predators which are considered as a major problem in Seychelles as identified by Shah (2001) and Ikin and Dogley (2005) and for which there were sufficient data. In order to compare the costs and benefits of managing the selected IAS, data were obtained from a number of primary and secondary sources. We collected background information on a wide range of issues, such as production levels, market prices, pesticide use, quarantine, imports and others from secondary sources. We draw information from published papers but also the 'grey literature', which ranged from government reports and statistics, to reports by NGOs. The literature provided some background information on the costs and potential impacts of IAS in Seychelles. An in depth literature review was carried out, and relevant aspects are used in the analysis. However, it should be stated explicitly that most of the literature reviewed contained only 'ecological' information and little 'economic' data that was required to perform rigorous economic analyses. There were limited calculations of economic costs and benefits in the available literature.

2.3. Survey Design

A tourist survey instrument was developed and used to collect primary data. A draft questionnaire was pre-tested with 10 employees of Fera (UK) who had previously been on holiday to Seychelles. A pilot survey was also done in the Mt Fleuri Botanical Garden (Seychelles) with about 20 respondents. Following these pre-testing rounds, changes were made in the scenario and in the design of many questions that were found to be difficult to comprehend. The questionnaire was intended to be administered at the main tourist sites to target the biodiversity hotspots (e.g. Valleé de Mai, Beau Vallon), on the islands of Mahé, Praslin, Bird, Denis and North Island. However, the problem with on-site surveys is that they are conducted when a trip is still in progress, and respondents may not be able to provide reliable data about costs and other variables. This led to the survey being administered at the departure lounge of Mahé international airport and Praslin airport as this was considered to be the most cost-effective way to tap into a potentially representative sample of tourists with enough experience of Seychelles, as well as the time, convenience and interest to undertake the survey. A total number of 350 questionnaires were administered randomly to tourists at the airport. A local consultant and an assistant from the UNDP administered the survey, both of whom were fluent in both English and French.

The questionnaire consisted of two parts. The first part was designed to gather information on travel costs, travel time and on-site expenditures. This information was to be used to shed light on recreational use values. The second part included the CVM exercise. This was designed to shed light on non-market benefits of biodiversity at risk from IAS. Following Mathieu et al. (2003), the welfare measure adopted reflects the consumer's maximum WTP, on top of the entrance fees, to support the protection program. This would directly give a measure of the 'consumer surplus', which is the difference between what individual would be willing to pay for a good or service and what they actually pay, an important economic value which is not observed in the market (Boardman et al., 2006). In selecting a payment mechanism we followed the National Oceanic and Atmospheric Administration (NOAA) guidelines to convince respondents that the payment mechanism is appropriate to address the IAS problem and reflects a fair method of payment (Arrow et al., 1993). Additionally, respondents were reminded of the budget constraint that was insufficient to allow the implementation of biodiversity conservation and monitoring programs. The study adopted the use of WTP on top of entrance fees measure, rejecting alternative vehicles such as the national tax scheme. We also opted for a face-to-face survey format because it generally leads to the highest response rate (Hanley and Barbier, 2009).

The questionnaire is provided as an Annex to this paper. The exact text of the WTP question was formulated as follows: are you willing to pay to protect species? Those who responded positively were then asked what amount they would be WTP. The WTP amount was chosen as a payment on top of entry fees and usual expenses of between €20 and €150, using the payment card method (Mitchell and Carson, 1989). The upper limit was fixed at €150 as this would represent a relatively high cost to enter a protected area in Seychelles. At the end of the survey, socio-economic data on age, income, education, and membership of environmental organisations were also collected. The data were coded and entered into a spreadsheet and analysed using SPSS17/STATA 10.0 statistical packages, using multiple regression analyses. The valuation functions were estimated using Tobit regression model as data were censored with lower and upper limits (Greene, 1997; Santagata and Signorello, 2000).

2.4. Descriptive Statistics

The target group was the tourists (users) visiting the selected sites in Seychelles. These are survey respondents who have been consumptive or non-consumptive on-site users of the natural resource, according to Whitehead et al. (1995). A total of 350 tourists were interviewed to investigate their perceptions of the value of biodiversity. The sample size constituted approximately less than 1% of the total tourist population. Table 1 is a summary of the key socio-economic characteristics of the respondents. The tourist population sampled was aged between 17 and 75 years, with an average of 43 years. Gender is not balanced, as a large share of the respondents were male tourists. The majority of the tourists were employed or self-employed. A high percentage of the tourists sampled (80%) were educated with either college/university or advanced degree. Income categories were ranged up to €120,000 with the largest sample ranked above €40,000. A small number (5.6%) of the tourists belonged to an environmental organisation. The information indicates a fairly young, predominantly male, wealthy and highly educated individuals visiting Seychelles, a finding consistent with that of the ecotourism literature (Menkhaus and Lober, 1996).

Respondents to the survey originated from many countries. Table 2 compares the nationalities of respondents in our sample

Table 1
Key socio-economic characteristics of tourists visiting Seychelles ($N = 300$).
Source: Survey questionnaire.

Parameters	Response category	Frequency (%)
Gender	Male	57.0
	Female	39.9
	No response	3.1
Age	<18 years	0.4
	18–29 years	11.2
	30–45 years	44.2
	45–60+ years	42.0
	No response	2.2
Education	I did not finish high school	1.1
	High school	13.3
	College/university	46.5
	Advanced degree	32.8
	Other	3.7
	No response	2.6
Income	€20,000 or less	6.9
	€20,000–€40,000	11.2
	€40,000–€60,000	8.3
	€60,000–€80,000	9.8
	€80,000–€100,000	11.2
	€100,000–€120,000	9.4
	Over €120,000	12.3
	No response	30.8

Table 2
Comparison of survey sample with actual visitor arrivals (%).

	Tourist survey (Jan–Feb. 2009)	Actual visitor arrivals (Jan–Dec 2007)
United Kingdom and Ireland	10.5	10.5
France	31.5	19.8
Germany	9.8	12.0
Italy	7.7	15.8
Switzerland and Austria	6.3	3.4
Other countries in Europe	16.7	17.6
Africa	4.2	10.5
Elsewhere	12.9	10.3

Actual visitor arrivals from disembarkation cards.

nationalities of all visitors in 2007. The ranking of the importance of the various countries is approximately similar. There are of course some minor differences. For example, Africa appears to be under represented (4.2% vs. 10.5%). The reasons for this may be that African tourists often visit Seychelles for business and transit purposes only (Cesar et al., 2004). Italy is also underrepresented (8% vs. 16%). The reason for this was not clear but it may be related to the seasonal differences in the number of tourists, given that our survey was done over the European winter whereas the actual visitor data for 2007 was collected for the whole year. However, the small discrepancies between the sample and the actual data do not warrant any adjustments to the data. This was supported by statistical tests which showed no significant differences in most of the cases.

In the survey, tourists were asked to rank the five most important reasons for their choice of Seychelles as their destination. The results suggest that the most important motivations for the tourists choosing Seychelles is to do with the natural beauty and the scenic view, enjoying the beach and sun, visiting friends and relatives and other reasons not disclosed. The first two reasons highlight the importance of biodiversity protection for the tourism sector in Seychelles. A summary of the responses to the question of appreciation of the whole experience in Seychelles (given the price paid for the experience) indicates that the majority enjoyed the whole experience in Seychelles including viewing endemic species such as birds and sea turtles. The results clearly show that the experience was worth the money spent.

Table 3 gives the average travel costs, duration of visit and total expenditures by country of origin of the respondents. The latter includes hotel costs, entry fees to recreational sites, guide fees and other incidentals. All of these variables can be seen to vary by country of origin of the visitors. The last column provides a simple comparison in terms of the mean expenditure per night per visit.

3. Results: Economic and Environmental Costs of IAS

Estimating the full extent of the environmental damage caused by IAS and the number of species extinctions they have caused is 'mission impossible'. Nonetheless, there are a number of species listed as threatened or endangered that are considered to be at risk primarily because of competition with or predation by IAS. Globally, it is estimated that as many as 80% of the endangered species are threatened and at risk due to the pressures of non-indigenous species (Amstrong, 1995). Estimating the economic impacts associated with IAS in Seychelles proved difficult. Nonetheless, there are some data available to quantify some of the impacts on agriculture, forestry, biodiversity, infrastructure and public health. In this section, as much as possible, we attempt to assess the magnitude of the economic costs and environmental impacts associated with selected IAS that have become established in Seychelles. In doing so, we used real costs for species where the impacts have been well documented but also included potential costs in cases where the impacts were less certain.

Table 3
Expenditure per visitor night by country of origin for 4 aggregated surveys, 2007 (US$).
Source: Special survey report by the National Statistics Bureau (NSB).

	UK	France	Germany	Italy	Switzerland	Other EU	Africa	Others	All
Total	28.9	21.7	19.0	17.5	27.6	29.6	23.6	42.3	25.0

Note: total excludes hotel bill. It includes car hire, taxis, bus fares, excursions, boat tickets, sports etc.

3.1. General Costs Associated with All IAS

These are costs that are incurred in preventing, controlling and eradicating IAS in general. They are not specific to any particular species. They include quarantine expenditures at the border and pesticide costs. Fig. 1 shows real and potential quarantine expenditures for Seychelles. It depicts government budgets for specific quarantine and IAS related control measures. Real costs are indicated for the period 2004–2006 while hypothetical projections are for the period 2007–2012. Fig. 1 indicates government expenditures, which reflect costs for a number of agencies for performing specific quarantine and IAS control activities, such as the Department of Natural Resources (DONR), Department of Environment (DOE), Transport, Immigration and Customs etc. The other cost depicted in Fig. 1 relate to 'user fees'. It was assumed that these charges would be introduced incrementally to the users for inspection services (importers, shippers, travellers, air carriers, etc.). Fees for services could form a component of the total biosecurity budget and are projected to increase from 10% in 2009 to about 30% in 2012 (Fig. 1). Note that these are hypothetical costs based on assuming the introduction of a new biosecurity policy.

Quarantine costs incurred at the border reflect the intensity of prevention and detection measures. Taking the national population in 2006 as the numeraire, the estimates reported in Fig. 1 indicate that preventative quarantine measures at the border against IAS cost the Seychelles economy about US$0.79 per person (based on total spend of US$65,000 and the population of 83,000). This estimate needs to be placed into other contexts. We could not find reliable estimates for other SIDS for comparison. The following examples were therefore drawn from developed countries for which data were available. In 1999, the US spent an estimated US$ 590 million to prevent and control IAS, raised partly from fees (US$141 million or about 24%) charged to users for inspections, with additional public funds

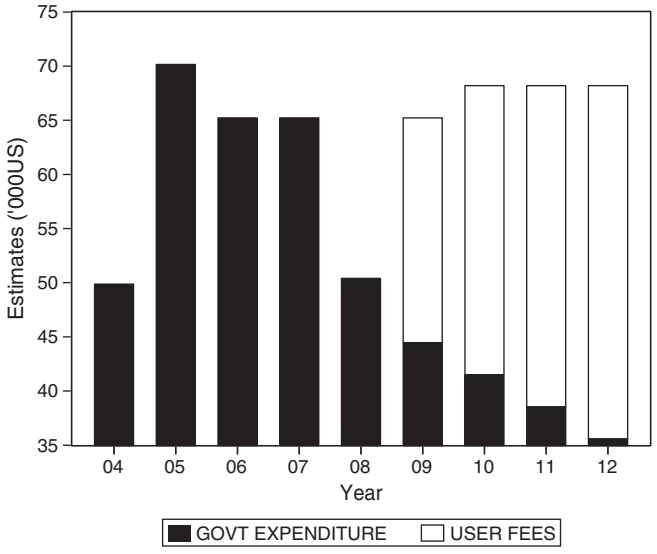

Fig. 1. Real and projected biosecurity costs for Seychelles (2004–2012).

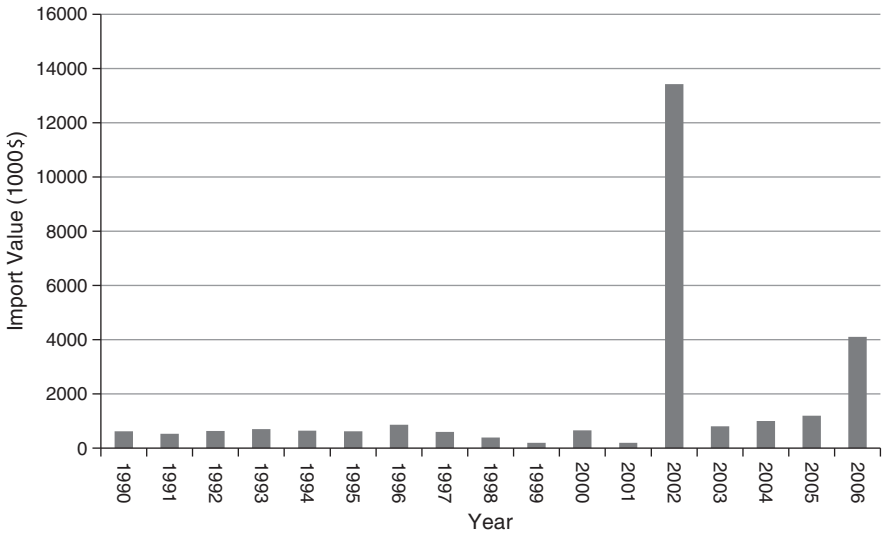

Fig. 2. Cost of pesticide imports to Seychelles (1990–2006) ('000 US$).

provided by Congress (USDA, 1999).[2] The US expenditure is equivalent to US$2.1 per person. The UK spent nearly US $111 million on animal and plant pest quarantine in 2000, with about 90% of this going to animal health (Defra, 2001), [3] and roughly (US$1.9 per person?) equivalent to the US expenditure. New Zealand held a biosecurity budget of US$44 million in 2000–2001. This is equivalent to US$11 per person, which is more than five times the per capita quarantine spending in the US and UK. These figures are significantly higher than the ones calculated for Seychelles. The differences arise from a number of factors including, the different risks as a result of climate, relative value of agriculture and agricultural trade, different approaches to prevention and detection, public and political attitudes to risk and ability to pay (Mumford, 2002).

Chemical pesticides are widely used in Seychelles in their efforts to eradicate insect pests and endemic diseases. The exact volume of pesticides consumed in many developing countries is not often known. However, we obtained the volumes of pesticides imported into Seychelles from FAOSTAT. These figures can be used as a 'proxy' for the costs of controlling the various pests in agriculture, forestry, health and other sectors. Fig. 2 shows volumes of pesticides imported into Seychelles over a 25-year period (1990–2005). There is a general trend of increasing pesticide costs. The volume of pesticides imported in 2002 (over US$13 million) stands out as a clear outlier. The reason for this sharp increase in pesticide costs is likely to be related to an outbreak of the serious melon fruit-fly pest (*Bactrocera cucurbitae*) that damages cucurbit crops such as cucumber, pumpkin, watermelon, squash, bitter gourd and snake gourd. *B. cucurbitae* was accidentally introduced into Seychelles in November 1999 (Stonehouse et al., 2000). Lack of resources severely limited eradication efforts and the pest established on Mahé Island. The spread of this pest in Seychelles could result in losses of up to 60% of production of cucurbit crops, and force the country to import vegetables. Annual losses for the country were estimated to be US $4.3 million (Dogley, 2000). The sharp increase is also likely to reflect a major project grant to fight the pest. These costs (adjusted for re-exports) were used in the analysis as indicative for expenditures incurred in 'controlling' IAS in general.

[2] The USDA budget estimate for 1999: http://www.usda.gov/agency/obpa/budget-summary/2000/text.htm/.

[3] DEFRA departmental budget from: http://www.defra.gov.uk/corporate/deprep/2001/default.htm/.

3.2. Costs of Eradication of Alien Mammal Predators

Government, NGO reports and journal publications provided good data on the costs associated with eradication of alien mammal predators (e.g. Henri et al., 2004). However, it should be noted that some of the costs are not directly related to the IAS problem and therefore not included in the CBA. Also, there are a number of islands which were not included in the Henri et al. analysis but for which eradication attempts have since been implemented. We collected additional data from the Island Conservation Society (ICS) and North Island Hotel in order to fill the gaps. The estimated costs are given in Table 4, showing planning, actual eradication, monitoring and associated costs after the eradication was completed. These costs were derived based on extensive consultations with forestry and agriculture specialists and island managers in Seychelles. The main cost components included: planning; rat and cat eradication; control of ants and problem bird species; bird capture, maintenance and translocation; and monitoring and maintenance. It was not clear whether the associated restoration costs should have been included as the costs of IAS eradication. We counted them as indirect costs.

These costs vary between islands depending on the size. Planning costs range from US$3100 on Anonyme Island (10 ha) to US$50,220 on Desroches Island (324 ha). Eradication costs range from US$10,300 on Anonyme Island to just under US$400,000 on Farqhuar Island (760 ha). Eradication was done twice on some islands such as Denis (2000, 2003), North (2003, 2005) and Anonyme (2003, 2005). Fregate, Denis, North, Felicite, Curieuse, Farqhuar and Desroches have eradication costs in excess of US$100,000. More details on how the costs parameters were calculated are given in the table notes. Long-term monitoring and instituting rigorous prevention measures would be necessary to prevent re-introduction of rats and cats, to control ants and problem birds, to monitor the numbers of translocated birds, and to conduct regular habitat management of the restored islands. These costs were estimated to range from US $15,000–40,000 per year depending on island size. In general, the larger the island, the higher the costs, as is indicated in Table 4.

3.3. Economic and Environmental Impacts of Alien Mammal Predators

3.3.1. Agriculture (Crop Related) Impacts

Introduced rodents have become serious pests on farms and industries in Seychelles. On farms, rats and mice are particularly destructive. Following Evans et al. (2002), production impacts from introduced species are considered to be the most direct economic

Table 4
Real and potential eradication costs (constant 2004 US$) associated with alien mammal predators on selected islands in Seychelles (1997–2009).
Sources: Based on Henri *et al.* (2004), figures provided by Island Conservation Society (ICS), North Island, etc.

Islands	Area (ha)	Planning	Eradication	Monitoring	Ant/ problem birds	Bird translocation
Anonyme	10	3100	10,300	75,000	–	–
P. Soeur	34	5270	30,900	30,000	22,764	732
Conception	60	9300	30,900	30,000	27,476	691
Therese	74	11,470	83,110	15,000	30,170	576
Gr. Soeur	84	13,020	43,260	15,000	32,714	742
Marianne	95	14,725	48,925	15,000	35,009	692
Bird	101	15,655	52,015	180,000	13,270	1,467
Alphonse	140	21,700	72,100	15,000	–	–
Denis	143	44,330	147,290	105,000	44,187	806
D'Arros	150	23,250	77,250	90,000	–	–
Cosmoledo	165	25,575	84,975	30,000	–	–
Fregate	202	31,310	104,030	135,000	58,827	775
North	210	65,100	216,300	75,000	59,799	1236
Felicite	268	41,540	138,020	15,000	70,973	721
Curieuse	285	88,350	146,775	135,000	74,067	651
Desroches	324	50,220	166,860	15,000	–	–
Farqhuar	760	117,800	391,400	15,000	–	–
Total	3105	581,715	1,768,510	960,000		

Figures indicate real and potential costs associated with eradication of alien mammal predators on 17 Islands. They include habitat restoration, monitoring and maintenance. Monitoring/maintenance: Annual costs will be incurred after the eradication operation. Annual costs are estimated in the range of US$35,000–40,000/year.

impacts and are fairly straightforward to estimate. It is estimated that rats cause pre and post-harvest losses of about 30% to fruit, vegetable and root crop production in Seychelles. We obtained data on the production of fruit, vegetables and root crops during 2000–2007. Comparing the total volumes for the last few years, there was an increase in domestic production, which can be attributed to the use of larger shade houses, more intensive and commercial farms and also better data collection methods. Using the current production volumes and prices, and factoring in the potential losses of 30% of the value of production per year, gives an estimated value of approximately US $1.3 million in losses to introduced rats (Table 5).

In estimating rat impacts, Pimentel et al. (2005) assumed at least one adult rat per person in a country and assumed each adult rat consumes stored produce valued at US$15 per year (Chopra, 1992; Ahmed et al., 1995). Following such an approach, with 0.083 million Seychellois, we estimate that introduced rats consume approximately US$1.245 million stored produce each year. This figure is close to the one calculated using the direct production impact (Table 5). However, since there is likely to be more than one rat per person in any given country, the agricultural losses reported in this paper are probably underestimated.

3.3.2. Human Health and Infrastructure Impacts

Rats act as vectors of several human diseases including *Salmonellosis*, *Leptospirosis* and *Hepatitis*, and to some extent plagues and *Murine typhus* (Richards, 1989). These diseases cause several deaths annually in Seychelles. An estimated 36 persons were reported to have been infected in 2008, with 32 cases requiring medical treatment and 4 reported deaths (Fig. 3). More than 80% of the victims are male.

Table 5
Estimated production losses to introduced rodents in Seychelles.
Source: Figures from the Ministry of Environment and Natural Resources, Seychelles.

Year	Production (tonnes)	Estimated value (US$'000)	Potential damage (%)	Value of losses (US$'000)
2008	5170	4347	30	1304

The Ministry of Health estimated medical treatment cost nearly US $0.5 million in 1994, excluding indirect costs such as lost productivity etc. More recent data indicates health costs have tripled reaching nearly US$1.5 million in 2008 (Table 6). In addition to health impacts, rats can cause fires by gnawing electric wires, and damage to telephone wires, cables etc. Infrastructure damage by introduced rodents in Seychelles was estimated to cost over US$0.1 million in 1994 (Table 6).

3.3.3. Biodiversity Impacts

There are no estimates of the total number of species killed by rats and feral cats in Seychelles per year. Therefore it is very difficult to estimate the total damage to populations of endemic species. A more significant problem is how to attach economic values to these biodiversity related impacts. One approach suggested in Menkhaus and Lober (1996) involves measuring direct costs such as entrance fees to parks, which might not reflect the full extent to which these resources are valued. There are four islands that support both globally important endemic bird species; Cousin, Cousine, Denis and Aride remain cat and rat free (Hill et al., 2000). Revenues generated through entry fees to these sites are presented in Table 6. These values can be counted as representing an estimate of the lower limit of the potential values of endemic bird species that could be lost as a result of alien mammal predators.

From the CV exercise, a large proportion of tourists (40%) who expressed an unwillingness to pay to protect biodiversity did so because of their individual economic situations as revealed through the direct question addressed to them. Although the theoretical biodiversity protection policy was approved by the majority of the tourists, nearly 50% of those respondents who were unwilling to pay thought that conservation was the responsibility of the government and NGOs. This result is similar to that reported by Nunes and Van den Bergh (2004). It reflects zero protests, implying that it does not reflect a zero valuation of the protection program but rather a disapproval of the proposed payment mechanism (Nunes and Van den Bergh, 2004). Based on this argument, these respondents were excluded from the CVM analysis.

Table 7 gives a summary of the main economic results from the CVM survey. The results indicate a mean WTP of €40–44. The mean WTP for turtles and the SMR are €44 (US$52) and €40 (US$58), respectively, on top of what they had already spent on their usual trips. Note that for both species, the WTP values are higher than the average entrance fee of US$10 that most users would have to pay to enter protected areas in Seychelles. The difference between the WTP and the entry fee is the consumer surplus (CS), measuring the portion of the value of the visits that is over and above the market price (Mathieu et al. (2003). Hence the average consumer surplus per tourist is US$48 and US$42 for turtles and the SMR, respectively. The total consumer surplus is approximately US$14.51 million (€10.97 million), given that 161,273 tourists visited the protected areas in 2008. This figure can be crudely interpreted as representing an estimate of the lower limit on the WTP-based valuation of the potential value of the SMR and turtle that could be lost as a result of IAS.

Valuation frequency distributions showed that, as the WTP amounts increase, the proportion of the sample willing to pay the amount declines, consistent with the literature. Table 8 gives the results of the best-fitting Tobit regression model containing the explanatory variables measured in the study. Tobit models predicting WTP confirm the signs and statistical significance of the explanatory variables ($\chi^2 = 316.87–321.73$, d.f. = 17). The squared correlation between the observed WTP and predicted WTP values was in the range 0.43–0.44, indicating that the explanatory variables accounted for 43–44% of the variability in the WTP model. However, the variables age and gender are marginally significant ($p<0.1$) although they do have the expected signs. On the other hand, expenditure (used as a

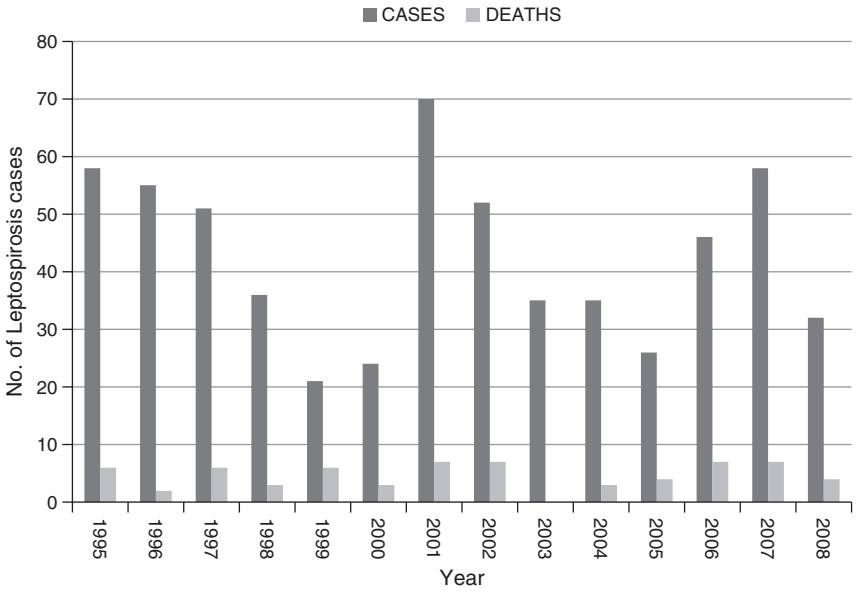

Fig. 3. Number of reported cases and human deaths due to *Leptospirosis* (1991–2008).

proxy for income) shows a significant positive impact ($p<0.05$) on WTP amount, consistent with economic theory (Pearce and Turner, 1990; Perman et al., 2003; Hanley and Barbier, 2009). Another interesting finding was that the country of origin was significantly correlated with the WTP, with tourists from the UK, Ireland, Italy, Scandinavia, Spain and the Netherlands being willing to pay more, and those from other EU countries willing to pay less, on average. The valuation results are similar to those reported by Mathieu et al. (2003) for Seychelles. They suggest construct and theoretical validity claim of the instrument used and are consistent with the predictions of economic theory (Hanley and Barbier, 2009; McIntosh et al., 2009).

3.4. Cost-benefit Analysis of Eradication Measures

The estimated costs of eradication of alien mammal predators need to be balanced against the biodiversity values. It can be considered that the benefits resulting from excluding the IAS represent the costs that would be avoided if Seychelles had to 'live with' the species. Between 1997 and 2009, the total cost of eradication of alien mammal predators from 16 islands in Seychelles amounted to over US$3.3 million (Table 9). Annualised costs work out to some US $255,000 per year. The estimated annual impacts (including real and potential impacts) in agriculture, human health, infrastructure and biodiversity and conservation sectors are close to US$21 million. Comparing the benefits and costs gives a simple BCR of 6:1.

Conservatively, if we assume that eradication costs remain constant over the next five years (2009–2013) and apply a discount factor of 6% over 5 years, we get an annuity factor of 4.2124 (Table 9). Comparing the benefits from eradication with the costs involved in achieving eradication gives a BCR greater than unity. This indicates that the policy of eradication is economically justified. If we include full biodiversity impacts in the calculations, then the benefits of eradication is likely to be even higher. The important question that arises is the ability of individual islands to generate revenues to offset the costs of eradication and justify the longer-term investment in conserving endemic species. The management of the islands needs to weigh the costs of IAS eradication against potential incomes generated through various means including tourism benefits. This paper suggests that the avoided impacts from IAS offset all the investment and longer-term operation costs. Sensitivity analysis showed that the exchange rate, tourist population, crop damage, eradication costs, and WTP to protect SMR/turtle are the major factors contributing to uncertainty (Table 10).

4. Discussion

There are a number of questions that arise from the results presented. The first is whether the CVM estimates are expected to be of this relative magnitude? An earlier study by Mathieu et al. (2003) used the CVM to determine tourists' WTP for visits to marine national parks in Seychelles and yielded an average WTP of US$12.2. Their figure is much smaller compared to the one reported in this paper but is based on surveys done in 1997, over 20 years ago. A more recent paper by Cesar et al. (2004) used a combined TCM–CVM to derive

Table 6
Real and potential impacts of alien mammal predators in Seychelles (nominal US$).

Estimates (US$'000)	1994	1996	1997	2000	2004	2008
Health costs	474					1482
Infrastructure damage	118					
Entry fees						
Cousin island special reserve				60	93	
Aride island special reserve		9			17	
Sooty tern eggs			51	51	51	

Health impacts are real costs provided by the Ministry of Health. Infrastructure damage obtained from the literature. Entry fees accruing to special reserves, which implement strict rat and cat free policy, were taken from Murray and Henri (2005).

Table 7
Summary of WTP per visit per year in € (2009) for all tourists.
Source: CV survey.

Parameters	SMR	Sea turtle
Mean WTP (€)	40	44
Median WTP (€)	20	30
Standard deviation (€)	31	43
Minimum (€)	1	20
Maximum (€)	150	150
% of zero bidders	40.2	40.2
% Do not know	4.5	4.5
Sample size	286	286
Total sample	300	300

Table 8
Multivariate tobit valuation functions, by species.

Variables	SMR		Green sea turtle	
	Coefficient (s.e)	t-ratio	Coefficient (s.e)	t-ratio
Expenditure	1.44 (0.72)**	2.00	1.15 (0.78)**	1.98
Age	−9.01 (8.31)	−1.08	−10.62 (8.79)	1.21
Gender	6.12 (5.35)	1.14	3.96 (5.81)	0.68
Country of origin				
France	64.22 (29.99)**	2.14	58.77 (33.19)*	1.77
UK and Ireland	73.08 (30.79)**	2.37	67.72 (33.93)**	2.00
Germany	58.48 (30.66)*	1.91	49.81 (33.91)	1.47
Italy	73.16 (31.18)**	2.35	64.40 (34.50)*	1.87
Scandinavia	83.51 (36.51)**	2.29	37.30 (40.38)	0.92
Spain/Portugal	72.48 (36.63)**	1.98	73.20 (40.50)*	1.81
The Netherlands/ Belgium	69.84 (31.62)**	2.21	68.83 (34.99)**	1.97
Other countries in Europe	58.25 (30.63)*	1.90	62.54 (33.78)*	1.85
USA and Canada	62.78 (30.85)**	2.03	65.43 (34.13)*	1.92
Asia	83.04 (36.26)**	2.29	68.46 (40.11)*	1.71
South Africa	59.31 (31.65)*	1.87	69.60 (35.02)**	1.99
Other countries	69.49 (32.62)**	2.13	10.79 (38.17)	0.28
Constant	126.75 (42.45)***	2.99	55.10 (46.01)	1.20
Standard error of estimate	29.44		32.58	
Log-likelihood	−722.05		−741.52	
Chi-squared	316.87		321.73	
Pseudo R^2	0.45		0.43	
Number of Obs.	264		267	

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

economic values for selected marine biodiversity in Seychelles. The key results from this study are reproduced in Table 11. The mean WTP for turtle tours was estimated to be US$50, which is somewhat closer to our own estimates. The practice of benefits transfer means existing WTP values for specific environmental changes may be transferred across time, space, people and sometimes biological resources (Navrud and Ready, 2007). Based on results of these three papers, the obvious question is the effect of time on WTP values? The effect is not conclusive but from a practical point of view, time may play a significant part in benefits transfer (Brouwer, 2006). The NOAA panel report on CV raised some concern about the temporal stability of CV estimates (Arrow et al., 1993). Another closely related paper by Nunes and Van den Bergh (2004) used a combined TCM–CVM to value protection against invasive marine species in the Netherlands. They estimated average values of non-market benefits (associated with beach recreation, human health and marine ecosystem impacts) of about US$62 per year to prevent invasions. McIntosh et al. (2009) estimated the value of delaying the inevitable risks posed by aquatic invaders in fresh water lakes in the USA. The mean WTP per year from all species was US$108 for one year of protection from low impacts, US $146 from high impacts, and US$213/year for 10 years of protection from high impacts. We can therefore conclude that our estimates fall within the range of these published WTP values (US$12.2–US$146) and so are believable values. Moreover, the expenditure figures obtained support the WTP estimates.

Another question is how the conservation program would be funded? It could be raised partly from fees charged to users (importers, shippers, travellers, air carriers, etc.) for inspections, with additional public funds allocated by government. An example is the USA where about 30% of the biosecurity budget is raised from user fees. Our WTP analysis found tourists were willing to pay US$52–55 on top of their usual expenditures to fund the protection program. But there are caveats. CVM studies are subject to a number of potential biases that affect the validity and reliability of the results. Therefore a degree of caution should be taken in interpreting and using CVM results. Expenditure figures (e.g. entry fees, guide fees, souvenirs) support the WTP estimates obtained, however. Tourism expenditure data collected by the National Statistics Bureau (NSB) from a survey of 4575 persons found an average of US$25 per visitor night. Hence a levy of about one-half of the WTP estimate (US$25 per tourist per year) seems reasonable and would raise US$4 million per year (based on 150,000 visitors per year) in conservation funds. Sumner (2003) argued that funding IAS programs through such levies may have an advantage over the use of general tax revenue in that levies transfer much of the cost of the IAS prevention policy to the beneficiaries. Sumner's findings may be relevant for future biosecurity policies in Seychelles. For effective IAS management, Olson (2006) argued that policies such as 'border control' and 'eradication' have attributes of public goods for the affected producers and consumers. In terms of IAS management, it was not expected that the SMR and sea turtle would become distinct programs but rather part of a larger national biosecurity policy. This strategy would help to achieve substantial economies of scale and reductions in the total projected costs (Fig. 1).

Table 9
Benefit-cost ratios of eradicating alien mammal predators in Seychelles.

Parameters	Cumulative (1997–2007)	Annualised (2009–2013)
Eradication costs (US$'000)	3310	255
Potential benefits (US$'000)	20,768	20,768
Discount factor (%)	1	6
Time (years)	–	5
Annuity factor	–	4.2124
Present value eradication costs (US$'000)	3310	1072
Present value potential benefits (US$'000)	20,768	87,487
Net present benefits (US$'000)	17,459	86,415
Benefit-cost ratio	6.3	82

Cumulative figures include real costs. Annualised projections include potential costs.

Table 10
Contribution of variables to uncertainty in the CBA ratio.

Variables	Uncertainty (%)
Exchange rate (US$)	44.5
Tourist population	20.6
Estimated crop damage (%)	10.2
Unit eradication costs (US$)	6.0
WTP for green turtle (US$)	4.8
WTP for SMR (US$)	4.5
Island area (ha)	2.1

Sensitivity analysis done using Crystal Ball Simulation Software (version 7.2).

5. Conclusions

With so many IAS becoming established in Seychelles, the fraction that is harmful does not have to be large to inflict significant damage to biodiversity and natural ecosystems. This study suggests that economic damage associated with only four alien mammal predators (rat, feral cat, goat, and pigs) amount to approximately US$21 million per year, with costs of management of US$0.255 million per year spent on efforts to limit damage. Our results show that the policy of prevention, eradication and control pass the cost-benefit test. It would appear that prevention would be the most cost-effective strategy.

Table 11
Cost and benefit estimates for a marine experience for different user groups in 2004 (US$ per dive/snorkel trip).
Source: Cesar et al. (2004).

Benefit parameters	Total sample	Divers	Snorkelers	Non-users
Expenditure	–	65.00	45.00	–
WTP conservation	4.87	5.17	4.86	4.37
WTP turtle tour	47.70	48.14	47.26	47.02

However, there are other factors such as technical feasibility and institutional capability to consider. The precise economic costs of the most damaging IAS are not available since many of these impacts have non-market values.

However, the real problem of IAS lies in preventing further damage to biodiversity and natural ecosystems in Seychelles. Development of robust prevention policies need to take into account the pathways through which IAS gain access and become established in Seychelles. Similarly, the spread of already established IAS to other areas and islands with potentially important biodiversity or other economic value needs to be prevented and or controlled. This paper suggests that there is still a long way to go before the resources devoted to the problem will be sufficient and in proportion to the risks involved. For example, we found that quarantine expenditure against IAS in Seychelles is significantly lower than some other countries. There is also an important question of what future spending level might be necessary for effective IAS management in Seychelles. There was insufficient data to calculate the 'optimal' spending levels using the traditional economic approach. This is left as a subject for further work. There were also other limitations to this study. The paper set out to provide an order of magnitude estimate of the economic costs associated with IAS in Seychelles. It remains one of a few studies to compile environmental and economic data for Seychelles, meaning a degree of caution should be taken in interpreting and using the results. The reality is that economic valuation of the impact of IAS on biodiversity can only ever be partial because many of the impacts have non-market values. It would be 'mission impossible' to capture the full range of non-market impacts. Identifying and measuring these values using either stated or revealed preference methods also remains somewhat problematic because IAS often cause changes in the population or health of a biological resource, rather than its complete destruction (e.g. Kaiser, 2006; Cook and Proctor, 2007). Eliciting marginal values for IAS impacts is left as a subject for further work. Because of the short confines of this study, the valuation exercise focused on a limited number of species and this is not the same as valuing the benefits of biodiversity protection in Seychelles islands.

The results reported in this paper should be taken as a lower bound estimate of the total impacts associated with the selected IAS in Seychelles. Nonetheless, we hope this study will help advance the argument that investments made now to prevent future introductions will be returned many times more in the protection of biodiversity in Seychelles. Based on our analysis, investments to prevent the introductions of potentially harmful IAS should be focussed on inspections at all airports, seaports and other entry points concerning the threat of IAS to the Seychellois economy.

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