ECONOMIC VALUATION OF THE INFLUENCE OF INVASIVE ALIEN SPECIES ON THE NATIONAL ECONOMY OF THE SEYCHELLES

Mwebaze, P[a1]. MacLeod, A[a]. Tomlinson, D[a]. Barois, H.[b] Rijpma, J.[b]

[a]Food and Environment Research Agency (FERA), Sand Hutton, York, YO 41 1LZ, UK
[b]United Nations Development Programme (UNDP), Seychelles, P.O.Box 310, Victoria, Seychelles

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 study assessed the value of impacts of IAS on biodiversity, natural resources and the national economy, using total economic value (TEV) principles, and conducted a Cost-Benefit Analysis of IAS management in Seychelles, taking into account TEV. Using a survey questionnaire, the contingent valuation method was used to obtain a Willingness to Pay (WTP) for a scenario to protect biodiversity at risk from IAS. Seychelles currently spends some US$0.79 per person per year on quarantine measures targeting IAS at the border. We found that economic damage associated with only 4 IAS approximately amount to US$21 million per year while only US$0.25 million per year is spent on their control. This indicates that IAS are causing significant economic impact in Seychelles. Tourists' responses to the questionnaire indicated a mean WTP of US$52-US$58 on top of their usual expenditures to fund conservation policy. 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.**

Key words: *Economic impact, invasive alien species, Seychelles, biodiversity*

1. INTRODUCTION

Invasive alien species (IAS) are introduced plants, animals and organisms whose establishment and spread threatens ecosystems, habitats and other species.[2] IAS cost the economy of Seychelles several millions of dollars annually, represent the main 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 important with the islands of the Seychelles being part of a 'biodiversity hotspot' (Myers *et al*., 2000). Additionally, the native biodiversity of Seychelles is one of the most threatened globally (Shah, 2001).[3] 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; Perrings, *et al*., 2002; Pimentel, 2002; Taylor and Irwin, 2004; Koo and Mattson, 2004). It has been shown 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 especially significant for small island states like Seychelles, which are more

[1] Corresponding author. Current address: The Food and Environment Research Agency (Fera), Sand Hutton, York, YO41 1LZ, UK. Email: p.mwebaze@csl.gov.uk. Tel: +44 (0) 1904463067. Fax: +44 (0) 1904462111.

[2] The Convention on Biological Diversity (CBD, 2001), defines alien species as "species, subspecies or lower taxon, introduced outside its natural past or present distribution, including any part, gametes, seeds, eggs or propagules of such species that might survive and subsequently reproduce". An invasive alien species (IAS) is defined as "alien species whose introduction and or spread threatens biological diversity".

[3] For example Fregate island is home to approximately 50% of the world's population of the Seychelles magpie-robin (*Copsychus sechellarum*), a critically endangered bird species.

dependent on imports than continental countries.[4] Island economies also tend to be ecologically more vulnerable to invasions than continental ecosystems (Perrings, 2000). Invasions are also nationally enhanced by the importance of other sectors such as tourism, fisheries, agriculture and forestry (FAO, 2001).

Over recent decades, the rate of introductions has increased 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. The authors 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. If these costs are of the correct order of magnitude, they suggest that a significant economic problem exists since they represent an externality of trade.

Perrings *et al*. (2002) argue that the primary driver of alien species entry, resulting in some becoming invasive, is economic. Therefore, 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 is taking 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 impact of IAS, mainly because the biological resources impacted upon by IAS are often not valued. Given the very high financial costs of control and eradication measures associated with IAS (e.g. Kueffer and Vos, 2004), with impacts only materialising in the long-term, policy makers do not see the need to manage IAS. 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).

Few studies have been done on economic valuation of biodiversity in the Seychelles. A preliminary study by Emerton (1997) attempted to calculate the total biodiversity value of Seychelles. It considered direct and indirect use values of biodiversity in different sectors. Cesar *et al*. (2004) used the travel-cost model (TCM) and contingent valuation method (CVM) to estimate the value of marine resources and ecosystems in Seychelles. A more recent study by Murray and Henri (2005) took into account the direct and indirect use values of biodiversity. The study placed a total approximate biodiversity value of SR2.4 billion in the Seychelles (equivalent to US$0.434 billion 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 in 2003. The study concluded that biodiversity underpins most economic activities in Seychelles, and loss of biodiversity as a result of IAS 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 selected IAS in Seychelles. The analysis seeks to provide some indication of the costs and benefits of control of IAS, and make recommendations for adopting cost-effective measures in policy and regulatory change. The remainder of

[4] The average percentage of imports as a share of the GDP was 43% for island countries compared to an average of 32% for all countries and only 26.8% for continental countries (see Dalmazzone, 2000).

this paper is structured as follows. The next section outlines some methodological issues. Section 2 describes the general approach, methods used, selection of potential IAS, and data collection. Section 3 gives the general costs associated with all IAS in Seychelles. Section 4 looks at the economic and environmental costs of IAS, focussing on alien mammal predators. The final section provides a multi-species CBA of control and eradication measures, and concludes the paper.

1.1 Measuring damage from IAS

Assessing the impacts of IAS is difficult because the full range of economic costs of biological invasions often goes beyond the immediate impacts to include secondary and tertiary effects such as loss of important biodiversity and other natural resources. It has been suggested that economic impacts of IAS should be categorised into direct and indirect effects, and as market and non-market effects (Evans *et al*., 2002; Bigsby *et al*., 2003).[5] The direct and indirect impacts refer to the way in which the effects of the IAS are manifested, and in turn provide a way in which the effects can be measured. Zadoks and Schein (1979) also separate economic impacts caused by IAS into those correlated with a specific host (direct effects) and impacts not correlated with a host (indirect effects). Examples of indirect effects include public health issues, general market effects, research requirements, market access problems and impacts on tourism. Such impacts were taken into account in this study. Market effects refer to those effects for which the market provides a valuation of the benefits and costs. There is a market price (*P*) and quantities (*Q*) affected can be easily identified and measured, for example in terms of $/ton, acres or volume (Bigsby *et al*., 2003).

Non-market effects refer to those changes for which there are no direct market valuation. These impacts do not have an existing market that can easily be identified and therefore little or no information on prices, costs, or quantities is available. Loss of biodiversity is a classic example. The problem is how to value such impacts given the absence of a market. Economists are trying to solve this problem by employing methods such as 'contingent valuation' method based on 'willingness to pay to obtain or avoid similar benefits or losses' (see Evans *et al*., 2002; Kaiser, 2006).

Because IAS impose a variety of different direct or indirect impacts, it is important to take all relevant effects into account that are of significance for biodiversity conservation. We used the total economic value (TEV) concept as the comprehensive framework to gather information on all relevant impacts. This concept draws a distinction between 'use' and 'non-use' values (Perman *et al*., 2003). Use values are divided into direct and indirect use values. Option values, which are the values attributed to maintain the option of using services of the ecosystem later, may be attributed to either use values or non-use values. Non-use values refer to willingness to pay (WTP) to maintain the good or ecosystem in existence even though there is no actual, planned or possible use. Nonetheless, its disappearance represents a utility loss to individuals. Distinguishing between use and non-use value is crucial because the latter can be relatively large especially when the commodity in question has few substitutes (Perman *et al*., 2003). Also, non-use values remain highly controversial.

Impacts of IAS can therefore be assessed along TEV principles. Monetary positive (benefits) and negative (costs) impacts of invasive species can be assessed by different methods using both 'business' and 'economic' data (see Born *et al*., 2005). For example, the opportunity cost method calculates the monetary value of an affected

[5] FAO (2001) also identified the following six types of impacts: (i) production, (ii) price and market effects, (iii) trade, (iv) food security and nutrition, (v) human health and the environment, and (vi) financial cost impacts.

good or service by forgone alternative uses. In economics for any use of a good there exists an alternative use and thus opportunity cost. Opportunity cost therefore is not an economic method in itself but we still include it as a category since a large number of studies refer to it. Wit *et al*. (2001) measured the value of fresh water loss, which is an indirect-use value caused by IAS, via the value of alternatively produced crops. Production loss (which is a direct use value) was measured through foregone benefits in the agricultural or forest sector. The production cost approach is a method to measure the effect of an environmental externality on production possibilities, often by measuring the expenditures which individuals are willing to pay to avert damage (Bertram, 1999). Production costs could also simply add the direct costs (e.g. labour, pesticides, equipment etc) and indirect costs (e.g. medical treatment) of measures.

However, with non-market goods, the lack of price transactions necessitates one to estimate individual's WTP. Direct techniques do this by asking individuals 'directly' in some sort of survey. Indirect techniques try to break down composite market goods that include non-market amenities in order to value each of the components. Direct techniques include the contingent valuation method (CVM) and attribute based choice modelling (CM). These methods survey individuals to identify values for amenity goods such as scenic beauty or endangered species. The technique is somewhat problematic because surveying may not reflect the true actions individuals would take if price tags were attached (Perman *et al*., 2003). There are also complications in terms of the information provision requirement necessary to allow respondents to value complex processes, unfamiliar species or ecosystems functions. Some authors have expressed serious doubts about the method's ability to provide valid measures of economic value (Diamond and Hausman, 1994; Portney, 1994). However, direct techniques are the only means available to uncover non-use values (Carson, 2000). In the case of IAS, direct techniques such as CVM are likely to be required for valuation of any loss in biodiversity (Kaiser, 2006). The method is widely used for valuation of biological resources including rare and endangered species, habitats and landscapes (Mitchell and Carson, 1989; Hanemann, 1994; Portney, 1994; Willis *et al*., 1996).

2. METHODS

2.1 General approach

The key issues for this paper were to: (i) assess and value the effects of IAS on biodiversity, natural resources and the national economy, using TEV principles, (ii) assess the costs of IAS management (prevention, control, mitigation, eradication) in the Seychelles, and (iv) perform a Cost-Benefit Analysis (CBA) of IAS management in Seychelles, taking into account total economic values. To adequately address these issues, we followed an approach based upon data availability, surveys, stakeholder consultations, questionnaire surveys and economic modelling. The general approach for the economic valuation of the influence of IAS in Seychelles involved a five-step procedure. The first step was to identify the potential IAS that pose a significant threat to biodiversity in the Seychelles. The second step was to assess the costs for managing the potential IAS. We followed the approach outlined in Bigsby *et al*. (2003) and Born *et al*. (2005), whereby the costs of IAS depends on the stage of the invasion process. According to Bigsby *et al*. (2003), the invasion stages are introduction, establishment, colonisation and invasion. The CBD requires a hierarchical application of the three strategies: (i) prevention, (ii) eradication, and (iii) control. Prevention should take place before introduction, eradication can be applied at all stages especially during establishment, and control aims to keep the population below the economically damaging threshold level. In the analysis, costs were assigned to one of the three conservation strategies.

The third step was to assess impacts from the potential IAS. As already discussed, some of these impacts caused by IAS carry non-market values. These impacts can be quantified by applying a range of valuation techniques. The next logical step therefore, was to identify monetary values for the selected biological resources impacted upon or considered to be at risk from IAS. The final step was to apply this information in a Cost-Benefit Analysis (CBA) to identify the level at which management of IAS is cost-effective. CBA is a procedure whereby for any change in the 'status quo' the benefits of that change must be compared to the costs.[6] 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:

$$BCR = \frac{Benefits}{Costs} \tag{1}$$

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

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 protection or intervention efforts to be economically justified, the net benefits must be greater than zero. Net benefits were calculated using the equation:

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

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≥0, (benefits exceed costs) it indicates that intervention policy is economically justified. But if the NSB≤0, (costs are larger than benefits) then intervention is not economically justified, unless there are strong non-monetised benefits to consider.

2.2 Data

For the CBA, selection of IAS largely depended on availability of economic data. This paper focuses on alien mammal predators for which there were sufficient data. In order to compare the costs and benefits of controlling 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 including the so called 'grey literature', which ranged from government reports and statistics, to reports by NGOs. The literature review provided some background information on the

---

[6] A benefit is any positive change in welfare or utility regardless of who secures that gain, and a cost is any loss of welfare regardless of who suffers that loss (Boardman *et al*., 2006). Measurement of preference is obtained by finding out an individual's maximum willingness to pay (WTP) for a benefit (or to avoid a cost) or their minimum willingness to accept (WTA) compensation for tolerating a cost or foregoing a benefit (Pearce and Turner, 1990).

costs and potential impacts of IAS in the 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 only provided ‘ecological’ information and little economic data that was required to perform rigorous economic analysis. There were limited calculations of economic costs and benefits in the available literature.

2.3 Survey questionnaire

A tourist survey questionnaire was developed and used to collect primary data. A local consultant and an assistant working for the UNDP administered the survey. Respondents to the survey originated from many countries. 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 benefits. The second part includes the CVM exercise. This was designed to shed light on non-market benefits of biodiversity at risk from the alien mammal predators. The welfare measure adopted reflects the consumer’s maximum willingness to pay (WTP). This implies that the present distribution of property rights is respected, so that individuals have to pay for a biodiversity conservation policy. Moreover, such a choice has the advantage that it forces respondents to look forward, which closely mirrors a market situation (NOAA, 1993).

In selecting a payment mechanism we closely 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. Additionally, respondents were reminded of the budget constraint that was insufficient to allow the implementation of biodiversity conservation and monitoring schemes. In view of these conditions, we adopted the use of WTP on top of the entrance fees measure, rejecting alternatives such as the national tax scheme. Before executing the survey, a first draft of the questionnaire was pre-tested in a number of pilot interviews. We opted for a face-to-face survey format because it generally leads to the highest survey response, as well as allowing the use of the double bounded dichotomous WTP elicitation question format (OECD, 2002).

3. ECONOMIC COSTS AND ENVIRONMENTAL IMPACTS OF THE SELECTED IAS IN THE SEYCHELLES

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 (Armstrong, 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 the 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.

3.1 General costs associated with 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. Figure 1 shows real and potential quarantine expenditures for the 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. The figure 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'. These could be charged to users for inspection services (e.g. importers, shippers, travellers, air carriers etc). Fees for services could form a component of the total quarantine budget and are projected to increase from 10% in 2009 to about 30% in 2012 (Fig. 1). Note that these are not 'official' costs but hypothetical ones.

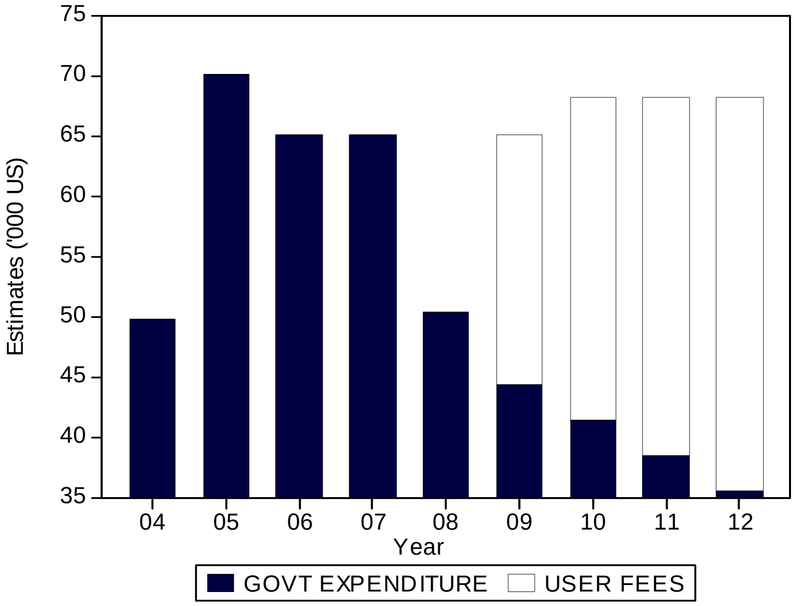

Figure 1: Real and projected quarantine costs for the Seychelles (2004-2012).

Sources: UNDP Project documents, Government of Seychelles expenditure reports

We now consider the significance of these figures. Quarantine costs incurred at the border reflect the intensity of prevention and detection. Taking 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$65,000 and the population of 83,000). This estimate needs to be placed into other contexts. In 1999, the US spent an estimated US$ 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 provided by Congress (USDA, 1999).[7] The US expenditure works out to

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

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), and roughly (US$1.9) equivalent to the US expenditure.[8] New Zealand held a biosecurity budget of US$44 million in 2000-2001. This works out to US$11 per person, which is more than five times the per capita spending in the US and UK. These figures are significantly higher than the ones calculated for Seychelles. The differences are partly due to 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 the 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 the Seychelles from FAOSTAT (2008). These figures can be used as a 'proxy' for the costs of controlling the various pests in agriculture, forestry, health and other sectors. Figure 2 shows volumes of pesticides imported into Seychelles over the 25-year period (1980-2005). 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 is likely to be related to the fruit-fly outbreak and eradication attempts. It is also likely to reflect a major project grant. These costs (adjusted for exports) were used in the analysis as indicative for expenditures incurred in 'controlling' IAS in general.

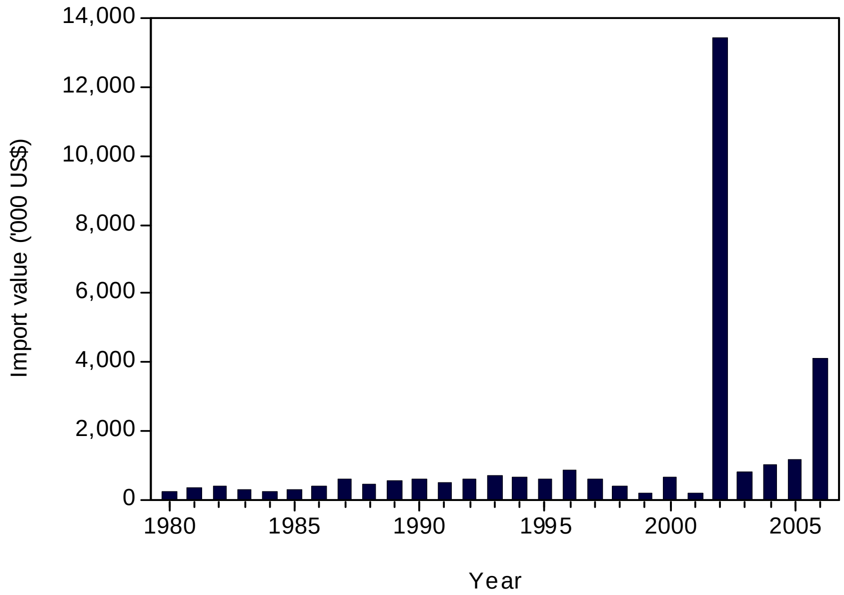

Figure 2: Cost of pesticide imports ('000 US$) to Seychelles (1980-2006).

3.2 Costs of eradication of alien mammal predators in the Seychelles

There were a number of publications, government and NGO reports that 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 that followed. Also,

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

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 1, 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 include the following: 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.

Table 1: Real and potential eradication costs (constant 2004 US$) associated with alien mammal predators on selected islands in the Seychelles (1997-2009).

Islands	Area (ha)	Planning	Eradication	Monitoring	Ant/problem birds	Bird translocation
Anonyme	10	3,100	10,300	75,000	-	-
Petite Soeur	34	5,270	30,900	30,000	22,764	732
Conception	60	9,300	30,900	30,000	27,476	691
Therese	74	11,470	83,110	15,000	30,170	576
Grand 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	1,236
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	3,105	581,715	1,768,510	960,000		

Sources: Based on Henri *et al*. (2004), figures provided by Island Conservation Society (ICS), North Island, etc.

Notes:

1. Figures indicate real and potential costs associated with eradication of alien mammal predators on 17 Islands. They include habitat restoration, monitoring and maintenance.
2. The most significant cost element for planning is the labour for professional time. The average cost across all islands is US$ 55 per hectare. Total planning costs range from US$3,000-117,000, depending on the size of the island. Unit costs vary from US$73-372 per hectare.
3. Eradication: Rat eradication is best achieved by a precision helicopter drop using bait pellets released with a consistent ground distribution. Wild cats are trapped over a short time period by a trained team. Rat/cat eradication range from US$ 10,000-400,000. The average cost across all islands is US$515 per hectare. Unit costs vary from US$1100- US$226 per hectare on smaller islands and the larger islands respectively. As island size increases, unit costs decline to reflect economies of scale.
4. Ant eradication and control of problem birds: all the candidate islands for eradication have varying populations of crazy ants, which can disrupt breeding and kill new chicks. Problem birds include introduced barn owls and mynah birds, which can pose a threat to endemic birds such as the SMR. The total costs increase linearly with island size. Average cost across all islands is US$349 per hectare. Unit costs vary from US$260/ha (large islands) to US$ 670/ha smaller islands.
5. Cost for bird capture and maintenance were included as part of the rat/cat eradication. Total costs for capture and maintenance of 70 birds were US$17,436 for soft release and US$ 136 for hard release birds. Unit costs range from US$249 per bird for soft release to US$ 136 per bird for hard release capture.
6. 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.

Note that costs vary between islands depending on the size. Planning costs range from US$3,100 on Anonyme Island to US$50,220 on Desroches Island. Eradication costs range from US$10,300 on Anonyme Island to just under US$400,000 on Farqhuar Island. 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$100,000. In general, the larger the island, the higher the costs. More details on how the cost parameters were calculated are given in the accompanying notes. Note that long-term monitoring and instituting rigorous prevention measures would be necessary to prevent re-introduction of rats and cats, as well as to control ants and problem birds, to monitor the numbers of translocated birds, and to conduct regular habitat management of the restored islands. These costs were estimated to range from US$ 15,000-40,000 per year depending on island size.

3.3 **Economic and environmental impacts of alien mammal predators**

Alien mammal predators, notably rats and feral cats, have colonized 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. Introduced rodents and feral cats can impose a range of impacts. Rats act as vectors of serious human diseases (especially *Leptospirosis*) that kill several people every year in the Seychelles. They are also responsible for destruction of crops and all sorts of goods, damage to telephone wires, etc. in every country across the globe and the cost of their depredations to human societies is extremely high. In addition, rats and cats pose a serious threat to island ecosystems. For example, the Norway rat (*Rattus norvegicus*) was accidentally introduced to Fregate Island in 1995, and it quickly became established. Fregate Island is home to approximately 50% of the world's population of the Seychelles Magpie-Robin (SMR) (*Copsychus sechellarum*), a critically endangered species (Shah, 2001).

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 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. Figure 3 shows production trends for fruit, vegetables and root crops in Seychelles during the period 2000-2007. Comparing the total volumes for the last few years we can clearly see an increase in the domestic production. This rise in total production can be attributed to factors such as larger shade houses being used, more intensive and commercial farms and possibly better collection of data. Using the current production volumes, prices and values, 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 2).

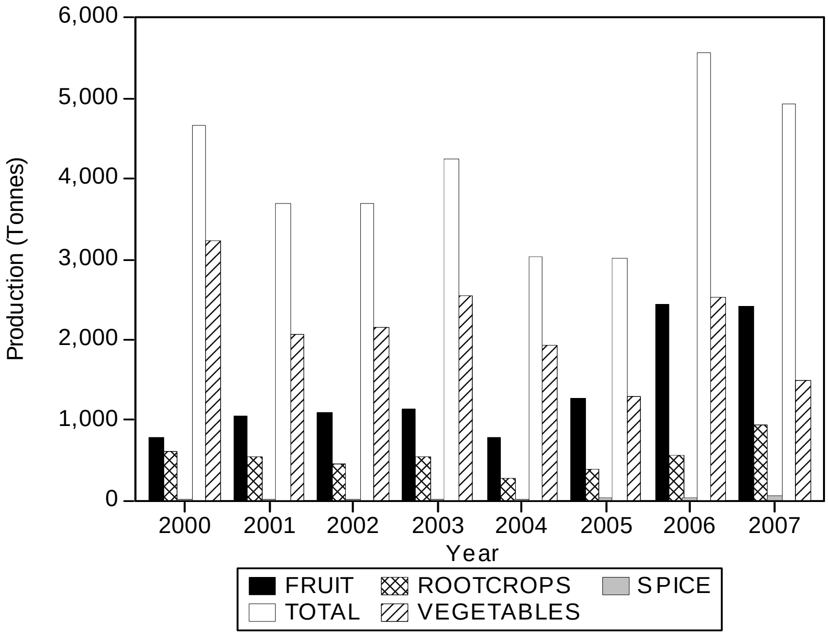

Figure 3: Production of fruit, vegetables and root crops in Seychelles (2000-2008).

Source: Ministry of Environment and Natural Resources, Seychelles

The other approach used by Pimentel *et al*. (2005) would be to assume that there is at least 1 rat per person in the country. With the current population of about 0.083 million persons gives an estimated 0.083 million rats in urban and peri-urban areas of the Seychelles. The method then assumes that each adult rat consumes stored produce valued at US$15 per year (Chopra, 1992; Ahmed *et al*., 1995). Based on these figures, the total cost of destruction to crops by introduced rats in the Seychelles works out to US$15*0.083 million, which is approximately US$1.245 million. Note this figure is close to the one calculated using the direct production impact (Table 2).

Table 2: Estimated production losses to introduced rodents in the Seychelles.

Year	Production volume (Tonnes)	Estimated value (US$'000)	Potential damage (%)	Value of potential losses (US$'000)
2008	5,170	4,347	30	1,304

Source: Figures from the Ministry of Environment and Natural Resources, Seychelles.

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 the Seychelles. An estimated 36 persons were reported to have been infected in 2008, with 32 cases requiring medical treatment and 4 reported deaths (Figure 4). More than 80% of the victims are male. 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 3).

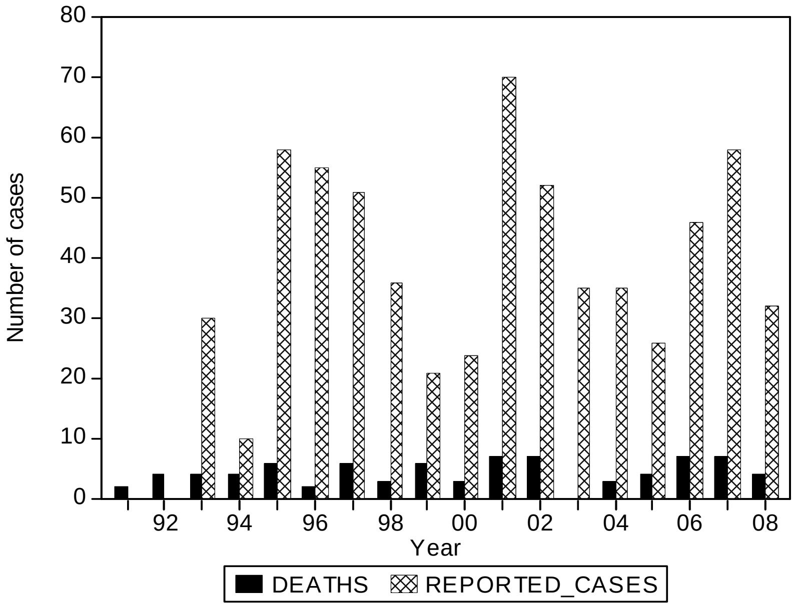

Figure 4: Number of reported cases and human deaths due to *Leptospirosis* (1991-2008).

Source: Data from the Ministry of Health, Seychelles.

In addition to health impacts, rats can cause fires by gnawing electric wires, and damage to telephone wires, cables etc. It was hard to find reliable estimates to use to quantify some of these impacts. Infrastructure damage by introduced rodents in the Seychelles was estimated to cost over US$0.1 million in 1994 (Table 3).

Table 3: Real and potential impacts of alien mammal predators in Seychelles (nominal US$).

Estimates (US$'000)	**1994**	**1996**	**1997**	**2000**	**2004**	**2008**
Health costs	474					1,482
Infrastructure damage	118					
Entry fees						
Cousin island special reserve				60	93	
Aride island special reserve		9			17	
Sooty tern eggs			51	51	51	

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

3.3.3 Biodiversity impacts

Alien mammal predators pose a significant threat to island biodiversity. Rats prey on some native invertebrate and vertebrate species such as birds and bird eggs (Amarasekare, 1993). In Seychelles, the black rat (*Rattus rattus*) causes considerable destruction to bird nests, and eating eggs and chicks, while the Norway rat (*Rattus norvegicus*) is largely terrestrial and causes more damage to soil invertebrates (e.g. insects, snails etc) and ground feeding sea birds. Feral cats prey on native species including birds, mammals, amphibians and reptiles (Fitzgerald, 1990). Alien predators are reported as being responsible for the extinction of several island species. Watson *et al*. (1992) reported that feral cat was the cause of the SMR extinction on Aride and

Alphonse islands as well as a serious decline on Fregate. As a result, some endemic species are restricted to the few islands that have remained rat and cat free. This is the case with some endemic bird species such as the SMR, Seychelles Warbler, and Foddy etc. Reports also indicate that alien predators are causing significant damage to populations of marine species such as the Sea turtle.

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 3. 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.

The other approach taken was to estimate visitor's WTP for the assets by using the CVM. Table 4 gives a summary of the main economic results from the CVM survey. Respondents were asked for their interest in funding conservation policy with regard to two endemic species at risk from IAS. As well as inquiring about their expenditures for various activities, the survey asked tourists about the maximum amount they would be WTP per experience, in addition to usual expenses, to fund a conservation policy to protect the SMR and sea turtle in Seychelles. Table 4 shows potential payments for turtles and the critically endangered SMR. Results indicate a mean WTP of €40-44 more than they had already spent on their usual trips. The mean WTP for turtles and the SMR are €44 and €40, respectively. The next step was to estimate the aggregate WTP over the total tourist population. We followed the procedure outlined in Perman *et al*. (2003). Taking the estimated mean WTP of €40(US$52) for the SMR and €44 (US$58) for the turtle as the relevant averages and factoring in the number of tourists (161,273) visiting Seychelles in 2008 gives a total WTP for both species of approximately €13.55 million (US$17.7 millions). 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.

Table 4: Summary of WTP per visit per year in € (2009) for all tourists.

Parameters	Seychelles Magpie Robin	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

Source: CVM survey

These WTP figures must be compared with those obtained from other related studies, as part of CVM validation. Cesar *et al*. (2004) evaluated the socio-economic impacts of marine ecosystem degradation in the Seychelles. The study used TCM and

CVM to derive economic values for selected marine biodiversity. The main results from this survey are reproduced in Table 5, indicating a WTP of around US$ 5 more than they had already spent on their snorkelling and diving trips. The average WTP for turtle tours was about US$50, which is not too far to the value obtained in this paper. Table 5 also indicates that the WTP level was positively correlated with the activity level of the respondent. The WTP declines in the order of the users and non-users. The WTP value was also lower than the average entrance fee of about US$10 that most users would have to pay to enter Marine Protected Areas in Seychelles.

Table 5: Cost and benefit estimates for a marine experience for different user groups in 2004 (US$ per dive/snorkel trip)

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

Source: From Cesar *et al*. (2004).

Expenditure figures also appear to support the WTP estimates obtained. Table 6 gives expenditure information recently collected by the National Statistics Bureau (NSB) from four surveys involving 4,575 persons in 2007. The data relates mainly to travel costs, entry fees, guide fees, souvenirs, handicrafts etc but exclude hotel bill. The 'all' figure in Table 6 are a weighted average by the country of origin figures.

Table 6: Expenditure per visitor night by country of origin for 4 aggregated surveys, 2007 (US$)

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

Source: Special survey report by the National Statistics Bureau (NSB).
Note: total excludes hotel bill. It includes car hire, taxis, bus fares, excursions, boat tickets, sports etc.

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 the Seychelles had to 'live with' the species. Between 1997-2009, the total cost of eradication of alien mammal predators from 16 islands in Seychelles amounted to over US$3.3 million (Table 7). 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 is close to US$21 million. Comparing the benefits and costs gives a simple BCR of 6:1 (Table 7).

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 7). 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. We can use this information to identify critical success factors for the model, to create an improvement strategy and identify variables for further data collection.

Table 7: Benefit-cost ratios of eradicating alien mammal predators in the Seychelles.

Parameters	Cumulative (1997-2007)	Annualised projections (2009-2013)
Eradication costs (US$’000)	3,310	255
Potential benefits (US$’000)	20,768	20,768
Discount factor (%)	1	6
Time (years)	-	5
Annuity factor	-	4.2124
Present value eradication costs (US$’000)	3,310	1,072
Present value potential benefits (US$’000)	20,768	87,487
Net present benefits (US$’000)	17,459	86,415
Benefit-cost ratio	6.3	82

Notes: Cumulative figures include real and potential costs. Future projections based on annualised estimates.

4. 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 alien mammal predators (rat, feral cat, goat, etc) 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. Results from this study indicate 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. However, there are other factors such as technical feasibility and institutional capability to consider. The precise economic costs of some of the most damaging IAS are not available since many of these impacts have non-market values. Identifying and capturing such values using stated or revealed preference methods is somewhat problematic because IAS often cause changes in the population or health of a biological resource, rather than its complete destruction (Cook and Proctor, 2007). Eliciting marginal values is yet to be done.

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 there is a long way to go before the resources devoted to the problem are sufficient and in proportion to the risks involved. For example, quarantine expenditure against IAS in Seychelles is significantly lower than some other countries. There is also a 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 research.

A final question is how conservation efforts will 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 the GOS. An example is the USA where about 30% of the biosecurity budget is raised from fees. Our WTP analysis found tourists were WTP US$52-55 on top of their usual expenditures to fund conservation policy. But there are caveats. CVM studies are subject to a number of potential biases that affect the validity and reliability of the results. One of these is 'strategic bias', whereby the true WTP is not revealed because of the problem of 'free-riding' etc (Perman *et al*., 2003). Expenditure figures (including entry fees, guide fees, souvenirs etc) support the WTP estimates obtained, however. Tourism expenditure data recently collected by the NSB from a survey of 4,575 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.

While this is a simple economic analysis, we hope it will help advance the argument that investments made now to prevent future introductions will be returned many times more in the conservation of biodiversity and natural ecosystems. 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 Seychelles economy. There are also some limitations to acknowledge. This paper is one of a few efforts to compile environmental and economic data for Seychelles, and is a preliminary attempt to gauge the economic costs and benefits associated with IAS and biodiversity. A degree of caution should be exercised in interpreting and using the results from this work. The results should be taken as a lower bound estimate of the total impacts associated with the selected IAS.

References

Ahmed, E., Hussain, I. and Brooks, J.E. (1995). Losses of stored foods due to rats at grain at grain markets in Pakistan. *International Biodeterioration and Biodegradation*, 36 (1-2): 125-133.

Amarasekare, P. (1993). Potential impact of mammalian nest predators on endemic forest birds of western Mauna Kea, Hawaii. *Conservation Biology*, 7(2): 316-324.

Amstrong, S. (1995). Rare plants protect Cape's water supplies. *New Scientist*, February 11, 8.

Bertram, G. (1999). The impact of introduced pests on the New Zealand Economy, Wellington, pp. 45-71.

Bigsby, H., Evans, E., Lee, D. and Alavalapati, J. (2003). Economics of managing invasive species in tropical and sub-tropical areas of the USA: Case study development. Working Paper Series, Institute of Food and Agricultural Sciences, University of Florida, pp. 1-24.

Boardman, A.E., Greenberg, D.H., Vining, A.R. and Weimer, D.L. (2006). Cost-Benefit Analysis: Concepts and Practice. Prentice Hall, Upper Saddle River, NJ, pp. 187-205.

Born, W., Rauschmayer, F. and Brauer, I. (2005). Economic evaluation of biological invasions-a survey. *Ecological Economics*, 55:321-336.

Carson, R.T. (2000). Contingent valuation: a user's guide. *Environment, Science and Technology*, 34(8): 1413-1418.

Cesar, H., Van Beukering, P., Payet, R. and Grandcourt (2004). Evaluation of the socio-economic impacts of marine ecosystem degradation in the Seychelles. Annex 4: in Seychelles marine ecosystem management project (GEF/SEYMEMP): Final report.

Chopra, G. (1992). Poultry farms. In: Prakash, I., Ghosh, P.K. (Eds.), Rodents in Indian agriculture. Scientific Publishers, Jodhpur, India, pp. 309-330.

Convention on Biological Diversity (CBD) (2001). Alien species that threaten ecosystems, habitats or species, annex: interim guiding principles for the prevention introduction and mitigation of impacts of alien species. Available at: http://www.biodiv.org.

Cook, D. and Proctor, W. (2007). Assessing the threat of exotic plant pests. *Ecological Economics*, 63:594-604.

Dalmazzone, S. (2000). Economic factors affecting vulnerability to biological invasions. In: Perrings, C., Williamson, M. and Dalmazzone, S. (Eds), *the economics of biological invasions*, Cheltenham, Edward Elgar, pp. 17-30.

Diamond, A.W. (1985). The conservation of landbirds on islands in the tropical Indian Ocean. In: P.J. Moors (ed.) pp.85-100, conservation of island birds. Case studies for the management of threatened island species. ICBP Technical Publication Number 3.

Diamond, P.A. and Hausman, J.A. (1994). Contingent valuation: Is some number better than no number? *Journal of Economic Perspectives*, 8(4): 45-64.

Emerton, L. (1997). Seychelles Biodiversity: Economic Assessment, IUCN.

Evans, E., Spreen, T. and Knapp, J. (2002). Economic issues of invasive pests and diseases and food safety. Paper presented at the 2nd International Agricultural Trade and Policy Conference, Gainesville, Florida, USA (November 14-15).

FAO, 2001. The State of Food & Agriculture, 2001. Economic impacts of transboundary plant pests and animal diseases, FAO Agriculture Series No. 33, FAO Rome, 296pp.

Fitzgerald, B.M. (1990). Diet of domestic cats and their impact on prey populations. In: turner, D.C., Bateson, P. (Eds.), The domestic cat: The biology of its behaviour. Cambridge University Press, Cambridge, pp. 123-150.

Freeman, A.M. (1994). The measurement of environmental and resource values: theory and methods, Washington D.C: Resources for the future.

Hanemann, W.M. (1994). Valuing the environment through contingent valuation. *Journal of Economic Perspectives*, 8(4): 19-43.

Henri, K., Milne, G.R. and Shah, N.J. (2004). Costs of ecosystem restoration on islands in the Seychelles. *Ocean and Coastal Management* 47: 409-428.

Herriges, J. and C. Kling (eds) (1999). Valuing recreation and the environment: revealed preference methods in theory and practice, Cheltenham: Edward Elgar.

Hill, M.J., Merton, D.V. and Shah, N.J. (2000). Eradication of introduced mammals in Seychelles. Unpublished Manuscript, Nature Seychelles, Victoria.

Ikin, R. and Dogley, D. (2005). Invasive alien specie review for the UNDP-GEF PDF-B project, mainstreaming biodiversity in the Seychelles. Final Report

Kaiser, B.A. (2006). Economic impacts of non-indigenous species: Miconia and the Hawaiian economy. *Euphytica*, 148: 135-150.

Koo, W. and Mattson, W. (Eds.) 2004. Economics of detection and control of invasive species: Workshop Highlights. Centre for Agricultural Policy and Trade Studies: Department of Agribusiness and Applied Economics.

Kueffer, C. and Vos, P. (2004). Case studies on the status of invasive woody plant species in the western Indian Ocean; 5. Seychelles. FAO Forest Health & Biosecurity Working Papers. FAO, Rome, Italy.

Levine, J.M. and D'Antonio, C.M. (2003). Forecasting biological invasions with increasing international trade. *Conservation Biology*, 17 (1): 322-326.

Maille, P. and Mendelsohn, R. (1993). Valuing ecotourism in Madagascar. *Journal of Environmental Management*, 38:213-218.

McNeely, J.A. 2001. An introduction to human dimensions of invasive alien species The Great Reshuffling: Human Dimensions of Invasive Alien Species. pp. 5-20.

Menkhaus, S. and Lober, D.J. (1996). International ecotourism and the valuation of tropical rainforests in Costa Rica. *Journal of Environmental Management*, 47, 1-10.

Mitchell, R. and Carson, R. (1989). Using surveys to value public goods: the contingent valuation method. Resources for the future, Washington, DC.

Mumford, J.D. (2002). Economic issues related to quarantine in international trade. *European Review of Agricultural Economics*, 29 (3): 329-348.

Murray, M. and Henri, K. (2005). An economic assessment of Seychelles biodiversity. Consultancy report for the UNDP-GEF PDF-B Mainstreaming Biodiversity.

Myers, N.R., Mitteremeier, R., Mitteremeier, C., da Fonseca, G. and Kent, J. (2000. biodiversity hotspots for conservation priorities. Nature, 403, 24 February, 853-859.

Nas, T.F. (1996). Cost-benefit analysis: Theory and application. Sage Publications, California, pp. 57-66.

National Oceanic and Atmospheric Administration (NOAA) (1993). Report of the NOAA panel on contingent valuation. *Federal Register*, US, 58:4601-4614.

OECD (2002). Biodiversity valuation handbook, OECD, Paris.

Office of Technology Assessment, US. Congress (OTA) (1993). Harmful non-indigenous species in the United States. OTA publication OTA-F-565. US government printing office, Washington D.C.

Pearce, D.W. and Turner, R.K. (1990). Economics of Natural Resources and the Environment. New York: Harvester Wheatsheaf.

Perman, R., Ma, Y., McGilvray, J. and M. Common (2003). *Natural Resource and Environmental Economics*, Third Edition, Harlow: Pearson Education Limited.

Perrings, C., Williamson, M. & Dalmazzone, S. (2000) The economics of biological invasions. Cheltenham, UK, Edward Elgar Publishing Ltd., Northampton, MA.

Perrings, C., Williamson, M., Barbier, E.B., Delfino, D., Dalmazzone, S., Shogren, J., Simmons, P. & Watkinson, A. 2002. Biological invasion risks and the public good: an economic perspective. *Conservation Ecology* 6 (1): 1.

Pimentel, D. 2000. Environmental and economic costs of non-indigenous species in the US. *Bioscience*, 50:53-65.

Pimentel, D., Lach, L., Zuniga, R and Morrison, D. (2005). Update on the Environmental and economic costs associated with alien-invasive species in the United States. *Ecological Economics*, 52 (3): 273-288.

Pimentel, D.S. 2002. Biological Invasions: Economic and Environmental Costs of Alien Plant, Animals and Microbial Species. CRC Press, Boca Raton.

Portney, P.R. (1994). The contingent valuation debate: why economists should care. *Journal of Economic Perspectives*, 8(4): 3-17.

Richards, C.G.J. (1989). The pest status of rodents in the United Kingdom. In: Putman, R.J. (Ed.), Mammals as pests. Chapman and hall, London, pp. 21-33.

Shah, N.J. (2001). Eradication of alien predators in the Seychelles: an example of conservation action on tropical islands. *Biodiversity and Conservation*, 10: 1219-1220.

Taylor, B.W. and Irwin, R.E. 2004. Linking Economic Activities to the Distribution of Exotic Plants. Proceedings of the National Academy of Sciences Published online on December 9, 2004, 10.1073/pnas.

Vila, M. and Pujadas, J. (2001). Land use and socio-economic correlates of plant invasions in European and North African countries. *Biological Conservation*, 100 (3): 397-401.

Vitousek, P. M., D'Antonio, C. M., Loope, L. L., Rejmanek, M. and Westbrooks, R. (1997). Introduced species: A significant component of human caused global change. *New Zealand Journal of Ecology* 21(1): 1-16.

Watson, J., Warman, C., Todd, D. and Laboudallon, V. (1992). The Seychelles magpie robin *Copsychus sechellarum*: ecology and conservation of an endangered species. *Biological Conservation*, 62:93-106.

Wilgen, B.W., Richardson, D.M., La Maitre, D.C., Marais, C. and Magadlela, D. (2001). The economic consequences of alien plant invasions: examples of impacts and approaches to sustainable management in south Africa. *Environment, Development and Sustainability*, 3:145-168.

Williamson, M. (1996). *Biological Invasions*. Chapman and hall, London.

Willis, K. and C. Garrod (1992). An individual travel cost method of evaluating forest recreation. *Journal of Agricultural Economics* 41, 33-42.

Willis, K., Garrod, G., Benson, J. and Carter, M. (1996). Benefits and costs of the wildlife enhancement scheme: a case study of the Pevensey levels. *Journal of Environmental Planning and Management*, 39(3): 387-401.

Wit, W.P., Crookes, D.J., Wilgen, B.W. (2001). Conflicts of interests in environmental management: estimating the costs and benefits of a tree invasion. *Biological Invasions*, 3:167-178.

Zadoks, J.C. and Schein, R.D. (1979). Epidemiology and plant disease management. Oxford University Press, Oxford.