Economic Impact of IAS in the Caribbean

Case Studies

CABI

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CABI
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Economic Impact of IAS in The Caribbean: Case Studies

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Acknowledgements

CAB International (CABI) has more than a century of global experience in managing pest and diseases in agriculture and the environment with a focus on integrated pest management and biological control. In this context, it's Centre for the Caribbean and Central America (CCA) began more than a decade ago, its efforts at managing invasive species in the Caribbean. This began with a study for the Nature Conservancy (TNC) to determine the 'Invasive Species Threats in the Caribbean Region'. That effort identified a large number Invasive Species in the insular Caribbean and made some recommendations for managing this issue, regionally.

CABI then partnered with the United Nations Environment Programme (UNEP), The Department of Marine Resources in the Bahamas; the Ministry of the Environment and Natural Resources in the Dominican Republic; the National Environment and Planning Agency (NEPA) in Jamaica; the Forestry Department, Ministry of Sustainable Development, Energy, Science and Technology in Saint Lucia; and the Ministry of Food Production in Trinidad and Tobago. To develop a regional project: Mitigating the Threats of Invasive Alien Species in the Insular Caribbean (MTIASIC). The project was funded by the Global Environment Facility (GEF) with co-financing from the various national executing agencies, regional and national collaborators.

The MTIASIC project, informed by the initial CABI TNC study, sought to accomplish the following:

1. Development of National IAS Strategies
2. Establishment of a Caribbean-wide Cooperation mechanism and Strategy.
3. Knowledge Generation, Management and Dissemination
4. Increase Capacity to Strengthen Prevention of new IAS Introductions in Terrestrial, Freshwater and Marine eco-Systems.
5. Increase Capacity to Detect, Respond, Control and Manage IAS Impacts in Terrestrial, Freshwater and Marine Systems.

However, once the project commenced it was soon realized that to accomplish all of the above we needed to describe the problem in economic terms to get recognition, support and funding from the policy makers in order to manage the issue in a sustainable way. This was especially important since this type of data was almost non-existent for the Caribbean with the exception of a few cases of the impact of agricultural crop pest. It was deemed essential to conduct the studies to generate this type of information.

Drs. P. Brown and A. Daigneault of Landcare Research, New Zealand who had considerable experience in conducting this type of analysis were contracted to train teams with a combination of both scientific and economic expertise to measure the cost and benefit of managing IAS in the Caribbean. Twenty participants from the five participating countries (The Bahamas, the Dominican Republic, Jamaica, Saint Lucia, and Trinidad and Tobago) attended a workshop on economic analysis of managing IAS in Port of Spain, Trinidad and Tobago in April 2013. During this workshop, participants developed skills to rigorously perform Cost and Benefits Analysis (CBA) of managing IAS. One year later, participants returned to Port of Spain to present their CBAs of managing IAS in the Caribbean. Five case studies from this programme are included in this document.

CABI will like to acknowledge the funding support from the Global Environment Facility that provided the core funding for the MTIASIC project and the associated activities in hosting the training workshop for the CBA, the ongoing virtual support, and the final workshop in which the results were presented. The oversight of the funding and overall execution of the project by the UNEP was critical to its success. The national executing agencies and, the too numerous to mention, regional and national organisations that contributed significantly to this coordinated effort in executing this initiative is sincerely acknowledged. CABI's CDF contributed direct support for the compilation and editing is duly acknowledged.

Naitram (Bob) Ramnanan (Mr.)
Regional Representative and IAS Coordinator
CABI Caribbean and Central America

CONTENTS

Preface

Invasive Alien Species (IAS) have a negative impact on crop and pasture production, human and animal health, biodiversity and a multitude of other goods and services provided by ecosystems and as such pose one of the biggest threats to economic development on this planet. In fact, it was estimated in 2001 that the impact and cost of managing IAS globally accounted for US$1.4 trillion annually or 5% of annual global GDP (Pimentel *et al*., 2001). Many of these costs, especially losses to biodiversity are difficult to quantify in monetary terms and as such the costs of impacts can be considered to be considerably higher than those estimated. It would not be amiss to assume that the costs of IAS are comparable or even significantly higher than the impacts associated with Climate Change, one of the biggest challenges of our time.

Despite the significant impacts of IAS and benefits of management there has been comparably little investment by donors and governments around the world in IAS control. This can possibly be attributed to the dearth of information on the financial impacts of IAS and the benefits of management. That said, studies which have been undertaken indicate that most investments in management yield positive returns. For example, management of invasive woody alien plants, many of which are consumptive water-users, has been shown to be an excellent investment even when just considering water savings alone (Le Maitre *et al*., 2002; van Wilgen *et al*., 2008; Currie *et al*., 2009). De Wit *et al*. (2001) were able to demonstrate that management of an invasive tree, *Acacia mearnsii*, in South Africa, would yield excellent returns while control of *Miconia calvescens* in Hawaii would yield a net present value benefit of US£34.5 million (Burnett *et al*., 2007).

To date no studies have been undertaken on the costs and benefits of IAS management in the Caribbean. This may partly explain why there has been negligible funding to combat the onslaught of these exotic species in the region. As a result it was decided to provide individuals involved in the UNEP-GEF Project, “Mitigating the Threats of Invasive Alien Species in the Insular Caribbean” with training and an opportunity to undertake Cost-Benefit Analyses (CBAs) on some selected IAS. The CBAs undertaken and reported in this publication clearly demonstrates that the benefits of managing IAS outweigh the costs.

Investing in IAS management is definitely a good investment for any donor or Government to make – it makes financial sense to do so! Wouldn’t you invest in a programme/project with such excellent positive returns? We can turn things around; we can manage IAS and do so cost-effectively for the benefit of people and the environment. I hope that these case studies will go a long way in convincing those in the Caribbean and elsewhere that may believe otherwise.

Arne Witt
Regional Coordinator - IAS
CABI Africa

The Economics of Invasive Alien Species in the Insular Carribean

P. Brown and A. Daigneault
Landcare Research, New Zealand

Invasive Alien Species in the Insular Caribbean

Invasive alien species (IAS) have significant impacts on human wellbeing, animal and plant health, employment, and the environment. These impacts have been clearly documented in the natural science literature and have underpinned calls to prevent entry, to eradicate IAS upon entry, and to manage them after they have become established. However, there has been comparatively little written about the economic feasibility and/or implications of managing IAS, particularly in developing countries where resources are most constrained.

Hence, with the financial support of the United Nations Environmental Programme, a project entitled "Mitigating the Threats of Invasive Alien Species in the Insular Caribbean" was initiated by CABI to increase the capacity of regional practitioners in conducting economic analyses of IAS management. Twenty participants from five Caribbean countries (the Bahamas, the Dominican Republic, Jamaica, Saint Lucia, and Trinidad and Tobago) attended a workshop on economic analysis of managing IAS in Port of Spain, Trinidad and Tobago in April 2013. During this workshop, participants developed skills to rigorously evaluate the management of IAS. One year later, participants returned to Port of Spain to present case studies of managing IAS in the Caribbean using economic analysis in general and cost-benefit analysis (CBA) in particular. Five out of a total of twelve case studies from this programme are included in this document to provide examples of using economic analysis in managing IAS.

Overview of Cost-Benefit Analysis

CBA is a systematic process for identifying, valuating, and comparing costs and benefits of a project, with the primary objective(s) of prioritising projects or selecting among competing options. In this way, CBA helps to inform decisions about whether or not it makes sense to invest in a given project and/or which option to implement.

The CBA process is based on the fundamental principles of welfare economics and was developed in the 1800s in response to a need to assess and prioritise public policy and project alternatives that generate benefits or costs not priced in markets (Fuguitt and Wilcox 1999). Since then, CBA has been intensively developed and debated among economists and is now commonplace in decision-making worldwide.

The key features of CBA are:

- All costs (losses) and benefits (gains) are considered, including potential impacts on human lives and the environment;
- Costs and benefits are valued from a whole-of-society perspective rather than a private perspective;
- To the extent possible, costs and benefits are expressed in monetary terms; and
- Costs and benefits that are realised in the future are discounted to obtain present values.

These features make CBA well suited to analysis of projects in the public sector in particular. CBA can be undertaken while a project is under consideration, i.e., before it is implemented to help inform the design of the project proposal and to appraise whether or not the proposal is feasible. CBA is sometimes also undertaken mid-way through a project to check that it is on track and to inform any adjustments for the remainder of the project period. Finally, CBA can also be undertaken at the end of the project period to evaluate its success, providing transparency in reporting how well public funds have been spent. Because ex-post CBAs are undertaken after a project has been implemented, these analyses can use observed data. For this reason, ex-post CBAs are typically more accurate than ex-ante CBAs.

The first step of CBA is to determine the objectives and the range of options. For invasive alien species, for example, the objective may be prioritise management options. This set of objectives will inform the costs and benefits that must be measured for each option. The analyst should also define what is expected to happen in the absence of any intervention, i.e., the "do nothing" scenario. Next, the analyst values those costs and benefits that may be monetised to facilitate direct comparisons.

Monetary costs and benefits can be estimated using several methods, although values are typically based upon market prices, i.e., the value of inputs and outputs that are readily available in a market setting. Where markets do not exist, it may be difficult to estimate costs and benefits. Still, these values are important, and economists have developed several means of obtaining "non-market values", including cost-based approaches, production-function approaches, surrogate market approaches, and stated preference methods.

Costs and benefits should be valued in real terms (i.e., constant prices) over time as opposed to nominal terms (i.e., prices at the time the goods or services were/are provided). In other words, the impact of inflation should be removed so the costs and benefits are measured in a common money value over time.

Next, the stream of future costs and benefits are discounted to account for values that accrue at different points in time and summed into a single figure that is called the net present value (NPV), which is defined as

$$NPV = \sum_{t=1}^{T} \frac{B_t - C_t}{(1+r)^t}$$

where B_t is value of benefit at time t, C_t is value of cost at time t, T is final time period of project, and r is the real interest rate that is used to discount costs and benefits to the present value.
Only options in which the NPV exceeds zero should be considered economically feasible and preferred to the "do nothing" scenario. If several options are evaluated, that with the highest NPV provides the most net economic benefit to society. That being said, NPV rankings do not account for the distribution of benefits, so a project that is economically feasible may not necessarily be politically feasible.

Sometimes, the benefit-cost ratio (BCR) is reported in addition to the NPV:

This ratio indicates the expected benefits per dollar spent, i.e., it is a measure of the relative efficiency of a project. Unlike the NPV, the BCR does not identify the magnitude of net benefits, although it may be useful in helping to select among projects when budgets are constrained.

Uncertainty arises because it is often difficult to forecast how future costs and benefits will accrue over time. Similarly, stakeholders may discount the future differently. Hence, conducting a sensitivity analysis in which the values of key variables are changed may provide insight into the robustness of the finding. Finally, detailed reports of the CBA are prepared to help decision makers make good choices.

Cost Benefit Analysis for Managing Invasive Alien Species in the Insular Caribbean

To highlight the economic analysis of managing IAS in the insular Caribbean, five analyses presented at the April 2014 workshop are included in this report as follows:

1. Casaurina on Eleuthera Island, Bahamas;
2. Feral donkeys on Cabritos Island, Dominican Republic;
3. Whitetop in Waterloo, Trinidad and Tobago;
4. Giant African Snail in Trinidad, Trinidad and Tobago; and
5. Red Palm Mite in Nariva Swamp, Trinidad and Tobago.

These case studies include two plants, two invertebrates, and one vertebrate animal species. Options range from management through eradication.

Introduced in 1950s as an ornamental plant, casaurina now dominates disturbed lands throughout much of The Bahamas, invading agricultural areas, forest plantations, and natural ecosystems. It is widely considered to be an agricultural pest and is often difficult for landowners to clear using conventional methods. Despite putting effort into managing this IAS, more than 70% of residents surveyed indicated that the population of the tree was increasing.

Four options to manage casuarina were investigated: (i) doing nothing; (ii) public/private partnership to search and destroy; (iii) government-led public education programmes; and (iv) an integrated approach consisting of a public/private programme of removal in combination with the government-led public education programme. The CBA revealed that the search and destroy approach yields the highest net present value and is therefore the most effective of all management options investigated in this study. The benefits of this approach are estimated to $21 per $1 spent on control.

With a small population of feral donkeys in a relatively confined space, eradication is clearly a viable management option for the Cabritos Island and Enriquillo Lake National Park in the Dominican Republic. Moreover, eradication would be a boon for habitat conservation and biodiversity protection, particularly for the Rhinoceros iguana, Ricord iguana, and the American crocodile. Again, four management options were considered: (i) doing nothing; (ii) ground hunting; (iii) live catch; and (iv) an integrated approach that combines the second and third options. The CBA results show that eradication through ground hunting is both effective and inexpensive, yet it prevents an important co-benefit of alternative management options, namely, providing draught animals to local communities. Thus, the integrated approach in which 90% of the donkeys are removed via live capture and the remaining (and most difficult to catch) donkeys are eradicated via ground hunting is recommended. This approach yields at least $4 in benefits for every $1 spent on control, largely through increases in tourism.

Whitetop is a noxious and invasive weed that reduces crop yield and that has been shown to be harmful to humans and animals. It is characterized by its vigorous growth, high fecundity, and allelopathic properties. At the same time, whitetop provides co-benefits that may be valuable to some constituencies, including enhancing the productivity of some crops, providing bioremediation of heavy metals, and being a source of dye. Four management options were considered, namely: (i) doing nothing; (ii) chemical control; (iii) an integrated approach consisting of chemical control combined with manual extraction; (iv) and exploiting whitetop for its potential benefits. A CBA conducted at the Waterloo Research Centre of The University of Trinidad and Tobago demonstrated that the integrated approach produced the greatest benefits overall, although chemical control was more efficient, i.e., it produced greater benefis per dollar spent, at a ratio of 6:1.

In October 2008, the giant African snail was introduced to Trinidad. This IAS threatened the agricultural, health, and environmental sectors as well as international trade. Fortunately, the pest was confined to the Diego Martin Valley in northwestern Trinidad. Concerted efforts by the government led to nearly 35,000 snails being collected and destroyed between 2008 and 2012. However, the giant African snail was subsequently discovered in two towns east of the containment area.

Three options were considered in this case: (i) doing nothing; (ii) managing the giant African snail through moderate chemical control and collection, public awareness, sanitation, surveillance, and legislation; and (iii) eradicating the giant African snail through an intensive campaign of chemical control, collection, public awareness, sanitation, surveillance, and legislation. Results of the CBA reveal that although eradication yields the greatest overall benefits, it comes at high cost. Management yields greater benefits per dollar spent on control, with a ratio of 3.7:1.

Finally, the Nariva Swamp is the largest freshwater wetland in the Caribbean and is marked by its large population of cocnut palms. It provides a wide array of ecosystem services, including habitat for endemic animal species and aesthetic values to Trinidadians. Unfortunately, the cocnut palms have come under serious threat from red palm mite, which colonises the underside of palm leaves, causing leaves to yellow and die, eventually leading to the death of the tree. Extensive surveys revealed that people value the aesthetics of the Nariva Swamp and are willing to pay $US 14 million in total to control red palm mite.

These results thoroughly demontrate that IAS may be managed with concerted effort, that management provides extensive monetary benefits to society, and that management may be undertaken cost effectively. Even without accounting for co-benefits such as protection of biodiversity, management is a good investment. It is our hope that economic studies such as those highlighted here may further justify investment in protecting against the threat of IAS in the insular Caribbean.

In addition to the above five cases, a sixth case that examined the impact of an Invasive Species on the beekeeping industry in Trinidad and Tobago was presented at the workshop and is included in this publication.

Glossary

Benefit: Monetary or non-monetary gain received because of an action taken or a decision made.

Benefit-Cost Ratio (BCR): The ratio of the present value of benefits from an activity, expressed in monetary terms, relative to the present value of its costs.

Cost-Benefit Analysis (CBA): A systematic process for calculating and comparing the advantages (benefits) and disadvantages (costs) of an activity from a social perspective.

Costs: Amounts that must be paid or given up in order to obtain something. In markets, costs usually reflect monetary valuations of the inputs and opportunity forgone to produce and deliver a good or service. In practice, all expenses are costs, but not all costs (such as environmental damaged incurred during production) appear as expenses.

Discounting: A method used to value future benefits and/or costs as present-day values.

Discount Rate: The rate at which future values of benefits and costs are adjusted to remove their time value and to express them in present-day values.

Do Nothing: A measurement or description of a scenario used as a basis for comparison. In CBA, the do nothing scenario represents the best assessment of the world in the absence of the regulation or action proposed for assessment.

Market: An institution in which goods and services are bought and sold.

Non-market Benefits and Costs: Benefits or costs arising from the production or consumption of goods and/or services that either have no monetary price or whose price does not reflect all the benefits and or costs.

Cost Benefit Analysis of Casuarina Species Management on Eleuthera Island, The Bahamas - Governor's Harbour Airport: A Case Study

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Abstract
The purpose of this study is to conduct a benefit cost analysis that estimates economically efficient options to manage the Casuarina species at the settlement level in Governor's Harbour, Eleuthera, The Bahamas. The study site is situated at the Governor's Harbor Airport (~104 hectares). A one hectare plot within the study area was used for the case study and the results extrapolated over the hundred and four (104) hectares. Introduced in the 1950s, Casuarina (Australian pine) (*Casuarina sp*.) species occurs throughout the islands of The Bahamas. The species is considered to be extremely problematic to eradicate, as it is taking over natural systems and out-competing native species creating monotypic stands. Without some form of management intervention, the invasion is expected to continue unabated to the extent that entire beaches along the coastline of affected islands will become eroded and the natural indigenous vegetation will be totally replaced with the Casuarina species.

This case study investigated four management options for Casuarina. The first option was to do nothing. The second management option was a Public/Private Partnership programme of control (removal and replacement with native species followed by annual monitoring). Thirdly, a Government – led Public Education Programme – involving the use of television, radio, social media, town meetings and newspapers to educate and build awareness of the problem). Fourthly, an Integrated Approach that combines options 2 and 3. A sensitivity analysis was also conducted to assess the validity of the results.

Additionally, to investigate the socio-economic impacts of invasive species in Governor's Harbour, two questionnaires were designed. One questionnaire targeted residents of Governors Harbour Eleuthera and the other focused on a small cross section of informed stakeholders on the island. Eighty residents were surveyed out of the total population of the settlement during execution of the first questionnaire. Information on the biophysical growth and effectiveness of various management options to control the invasive were primarily obtained from scientific literature.

The case study concluded that Eleutherans were most willing to support the integrated approach of managing Casuarina. Additionally, residents were deeply divided on whether or not Casuarina could be controlled and whether it could affect a country's economy.

With respect to the economics of controlling Casuarina, the majority of the benefits would accrue from avoided damages to utility and road infrastructure, erosion reduction/beach renourishment costs, increased biodiversity/improved habitat, and profit gained from sale of products. The Cost Benefit Analysis revealed that the Public/Private Partnership Approach (Search & Destroy) yielded the highest net present value and ranked number one out of all the management options investigated in the study. Second and third ranking fell to the Government led Public Education Campaign and Integrated Management Approach options respectively. The highest benefit to cost ratio was achieved with the Government led Public Education Campaign, with the second and third rankings belonging to the Public/

Private Partnership and the Integrated Management Approach. The most cost effective option was the Public/Private Partnership followed by the Government-led Public Education Campaign, with the Integrated Approach placing third.
Keywords: Bahamas, cost benefit analysis, control, invasive alien species, management, Casuarina

Introduction

The purpose of this study is to conduct a Cost Benefit Analysis that estimates economically efficient options to manage Casuarina at the settlement level in Governor's Harbour, Eleuthera. See Figure. 1. The case study project area is situated at the Governor's Harbor Airport (~104 hectares), see Figure. 2.

Casuarina (Casuarina sp.) species occurs throughout the islands of The Bahamas. They produce cone like fruits that are aggregates of follicles, with each follicle producing numerous small seeds. When fully matured, a single tree can produce thousands of seeds, which are dispersed by the wind, and possess prolific natural regeneration tendencies. They are also salt tolerant and can move along shorelines and between islands in seawater. Casuarinas were introduced for the purposes of erosion control, shade trees and as an ornamental in the 1950s. The Bahamas National Invasive Species Strategy (NISS) identified the Casuarina as an invasive species for eradication.

The species is considered extremely problematic to eradicate, as it is taking over natural systems and out-competing native species creating monotypic stands. It shades out the native shrubs and grasses, produces allelopathic compounds that retards growth of other species, and produces a thick ground litter that inhibits seedling germination. *Casuarina sp*. has invaded natural systems including sand dunes, wetlands, rocky shores as well as human disturbed areas, and contributes to beach erosion in every island where it is found. This mass invasion has caused significant ecological damages to the natural ecosystems. The species shallow root system tips over easily during tropical storms and hurricanes, negatively impacting road infrastructure, damaging power lines, which has significant economic implications for the Bahamas, particularly on the more densely populated islands.

Without some form of management intervention, the invasion is expected to continue unabated to the extent that entire beaches along the coastline of affected islands will become eroded and the natural indigenous vegetation will be totally replaced with the *Casuarina sp*. Species biodiversity including fauna will also be negatively impacted. The problem is substantial, such that there have been repeated calls by various environmentalist and other concerned citizen groups for some form of control or eradication programme to be introduced to address the growing problem. To investigate the socio-economic impacts of invasive species in Governor's Harbour, 80 residents were surveyed. Estimated population of Governor's Harbour is approximately 2000-3000 people. Additional information on the impact at the settlement-level was obtained through a community-level focus group. Information on the biophysical growth and effectiveness of various management options to control the invasive were primarily obtained from scientific literature.

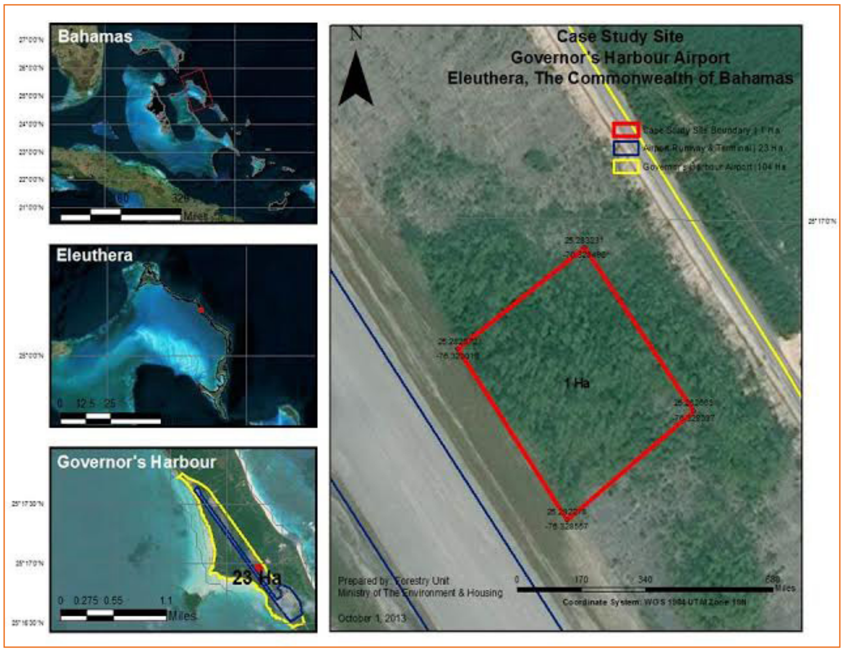


Figure 1: Maps of The Bahamas highlighting Eleuthera, Governors Harbour and the study area

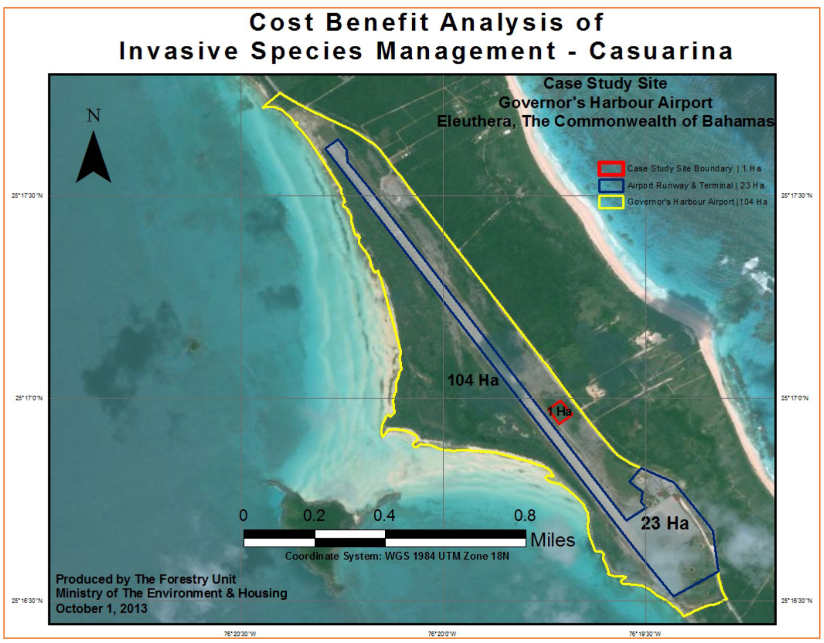


Figure 2: Map of Governors Harbour Airport and entirety of study area

Plant Biology and Ecology

Australian pine is a fast growing (1.5-3m/yr) tree that can be grown to a height of up to 46m (Swearingen 2008). Young seedlings are sensitive to drought, flood and fire. Growth is most rapid during the first ten years. The minimum seed-bearing age is 4 to 5 years. Maximum growth is reached in 20 years with a maximum life span of 40 to 50 years (Elfers 1988, in Snyder 1992). The growth of Casuarina is assumed to follow a logistical biological growth curve; where *Nt* is the population at time *t*, *Nmax* is the carrying capacity, and *b* is the growth parameter. Parameters and carrying capacity were derived from Lugo (2004). Using values of N0 = 1, b = 0.18 and Nmax = 100 produces an s-shaped curve tracing the percentage of population relative to carrying capacity that goes through these two points.

Study Site and Survey Methodology

This pilot study revealed that roughly 6% of the 1ha plot at the Governors Harbour Airport was predominately Casuarina. The study area in the 1ha plot contained 637 stems per hectare. We used this as the initial population at the start of the management regime. Casuarina is usually removed by mechanical clearance with a Bulldozer. This study used chainsaws to remove Casuarina. See Figures 3-5.

Figure 3: Labourers removing recently cut Casuarina

Figure 4: Labourer at study site cutting Casuarina

Figure 5: Cut and stacked Casuarina trees

Herbicides appear to be infrequently used and it is believed that they have no effect on Casuarina.

To investigate the socio-economic impacts of invasive species in Governors Harbour, 80 residents were surveyed. The participants had the option of either filling out the questionnaire themselves or having us complete it based on their answers. Most respondent's opted to have us complete it on their behalf. This method was particularly effective in ensuring that all questions were answered. The questionnaire was divided into two parts. The first part attempted to ascertain general knowledge of the trees from residents. It looked at how residents used the tree, growth, and spread of the tree. The second part looked more at the economics of having such a tree in existence.

A series of questions were asked to elicit willingness to contribute personally to controlling invasive species financially and via volunteer labour. In most developed countries, willingness to pay is identified via questions about tax increases; The Bahamas recently introduced an environmental tax on purchased goods. Currently, no widespread household taxation exists but the need for one has been identified on a number of occasions. The Bahamas is expected to implement a 15% Value Added Tax (VAT) in July 2014. Thirdly, respondents were asked if they believed that this species could affect the country's economy and also whether it could be controlled.

A complementary survey was administered to a focus group in Governor's Harbour. The survey targeted non-governmental organizations (NGOs), utility companies, farmers, etc. The settlement-level questionnaire consisted of open-ended questions regarding the presence of Casuarina and, where applicable, the consequences of its presence (both positive and negative), and community practices for encouraging or limiting its spread.

Survey Results

The individual survey was separated into two categories, namely those who believe Casuarina can be controlled and those who believe that it cannot be controlled. According to the survey of residents who believe that Casuarina can be controlled, the following was revealed:

77% felt the tree served a purpose
66% felt that the existence of this tree could impact the country's economy
57% felt it could negatively impact the economy
79% felt the government should be responsible for controlling the tree
49% felt the integrated approach to managing and controlling Casuarina would work best
50% of residents indicated that they would not support the use of taxpayer's dollars to manage/control Casuarina
63% felt households would not be willing to pay a small fee towards controlling/managing Casuarina
73% felt the Government should provide an incentive for households desirous of assisting in Casuarina control/management
65% said they would assist in the physical removal of the tree

Those respondents who believe that Casuarina cannot be controlled:

63% felt the tree served a purpose
58% felt it could not affect a country's economy
64% felt it could affect a country's economy positively
83% indicated that they would not assist in the physical removal of the tree

Management Options

Different management options can have differential impacts on the growth and spread of the Casuarina. In addition to doing nothing, three other management options are considered in this analysis: A Public/Private Partnership Programme of Eradication (search and destroy) is proposed. The partnership will involve the government in collaboration with the Bahamas National Trust (Leon Levy Native Plant Preserve), One Eleuthera Foundation, and other local stakeholders in the removal of all Casuarina from the site using mechanical tools (chainsaws, backhoes, etc). Thirdly, a Government-led Public Education Programme to teach and educate landowners on methods, ways and means to control the spread of the species (building awareness of the problem). Additionally, identify appropriate ways to use the species for commercial purposes. Fourthly, Integrated Approach (options 2 and 3 combined) which is the Public/Private Programme of removal in combination with Government-led Public Education Programme.

Quantifying Benefits and Costs of Invasive Species Management

The government of The Bahamas typically uses a discount rate of 5% for economic analyses of environmental and biosecurity projects. Several benefits can accrue within the community as a result of managing Casuarina, mostly in terms of avoided damages which equates to money being saved. For the purposes of this case study, possible benefits include avoided damages to utility and road infrastructure, erosion reduction/beach renourishment costs, increased biodiversity/improved habitat, profit gained from sale of products. Unfortunately, these benefits are not easily quantified, either physically or monetarily, however this study attempted to do this.

These specified benefits then need to be expressed in terms of physical units of damage that would likely accrue under the 'do nothing' in the initial time (*t*) period (year 0). See Figure 6 and 7. The Bahamas Electricity Corporation, the only electrical utility company in Governors Harbour estimates that to prevent Casuarina from destroying vital power lines, it expends roughly $5163.84 annually. The daily rate for the work to be completed is $185.27 per hour and on average requires ten (10) days and (forty) 40 hours. This includes a crew of men and a bucket truck with a 35% administrative fee included. Administrative costs include operational costs and equipment. A comparative analysis of Florida data reveals that beach renourishment costs lie in the range of $375,000. The Bahamas Ministry of Tourism arrivals data for 2011 revealed that there were 5.6 million visitors. A Jamaican study revealed tourists were willing to pay $15 for pristine habitat. Bahamas Forestry Unit marketing and product development studies have revealed that forestry products are typically sold at $22 per m3 roundwood. Standard research and monitoring campaigns conducted by various non governmental organizations (NGOs) in The Bahamas estimated a rate of $50 per hour. Whereas ad campaigns inclusive of a newspaper, television and radio packages cost roughly $2,180. NGO's usually do four campaigns per year so this equates to $8,720. Initial capital costs of a search and destroy campaign for Casuarina control estimate costs at about $40,640. This includes equipment and labour costs. After experimenting with various growth curves, the following were finally decided upon because in our estimation they yielded the most realistic graphs:

Do Nothing = 0.3, Search and Destroy = 0.15, Public Awareness Campaign = 0.25 and for the Integrated Approach = 0.10. Tables 6 and 7 illustrate all of these values.

Table 1: Costs and Benefits Analysis of Controlling Casuarina in Governors Harbour, Eleuthera

Cost/Benefit Category	Category	Unit Measurement	Unit Value ($/ units)
Benefits	Avoided damages to utility & road Infrastructure	$/yr	$5,163.04
	Erosion reduction/beach renourishment costs	$/m3	$25.00
	Increased Biodiversity/improved habitat	$/yr	$15
	Profit gained from sale of products	$/m3	$22.00
Costs	Labour	$/man hour	$6.80
	Initial Capital Cost	$/unit	$390.00
	Research and Monitoring	$/hr	$50.00
	Ad Campaign	$/unit	$2,180.00

Table 2: Costs and Benefits Analysis Physical Units of Controlling Casuarina

Cost/Benefit Category	Category	Do Nothing	Public/private (search & destroy)	Gov't Led PR	Integrated Mgt Approach
Benefits	Avoided damages to utility & road Infrastructure	1	1	1	1
	Erosion reduction/beach renourishment costs	600	600	600	600
	Increased Biodiversity/improved habitat	1	1	1	1
	Profit gained from sale of products	19	19	19	19
Costs	Labour	0	200	300	600
	Initial Capital Cost	0	1	0	1
	Research and Monitoring	0	12	8	15
	Ad Campaign	0	4	3	6

Results of Cost Benefit Analysis (in Graph Form)

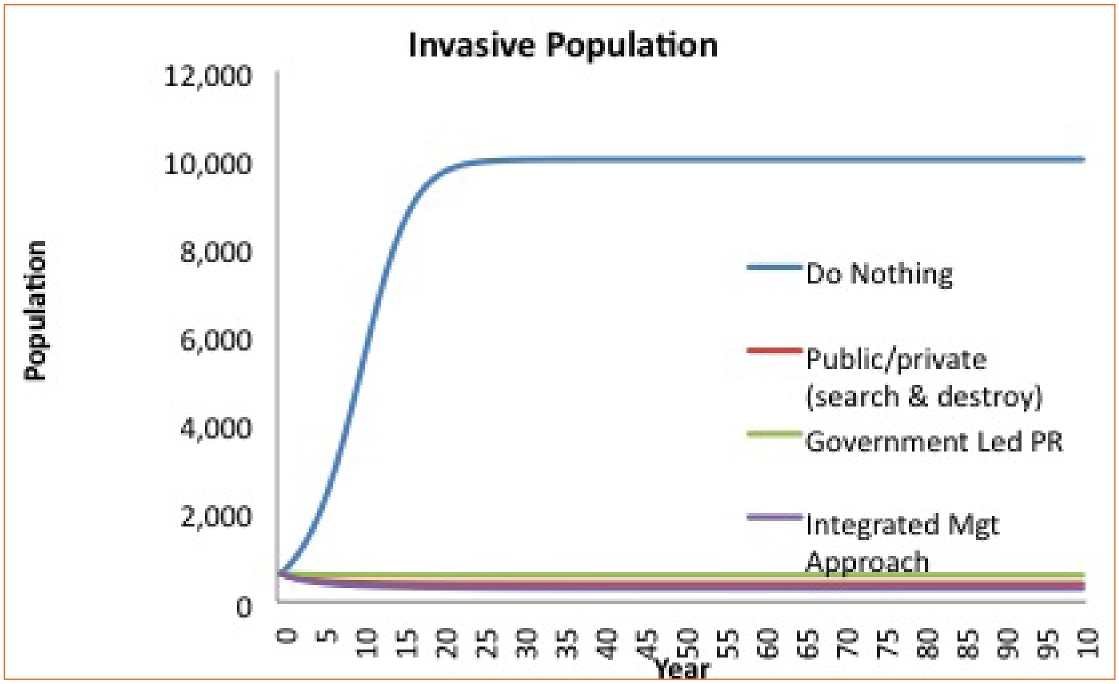


Figure 6: Illustrates the growth curves with the estimated slope values for controlling Casuarina

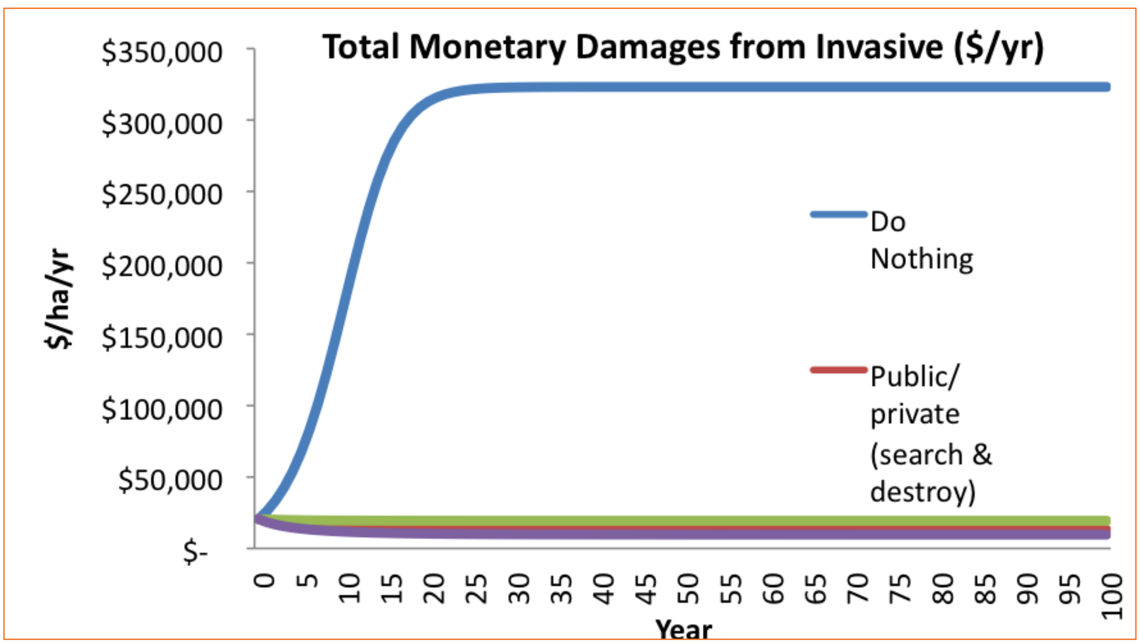
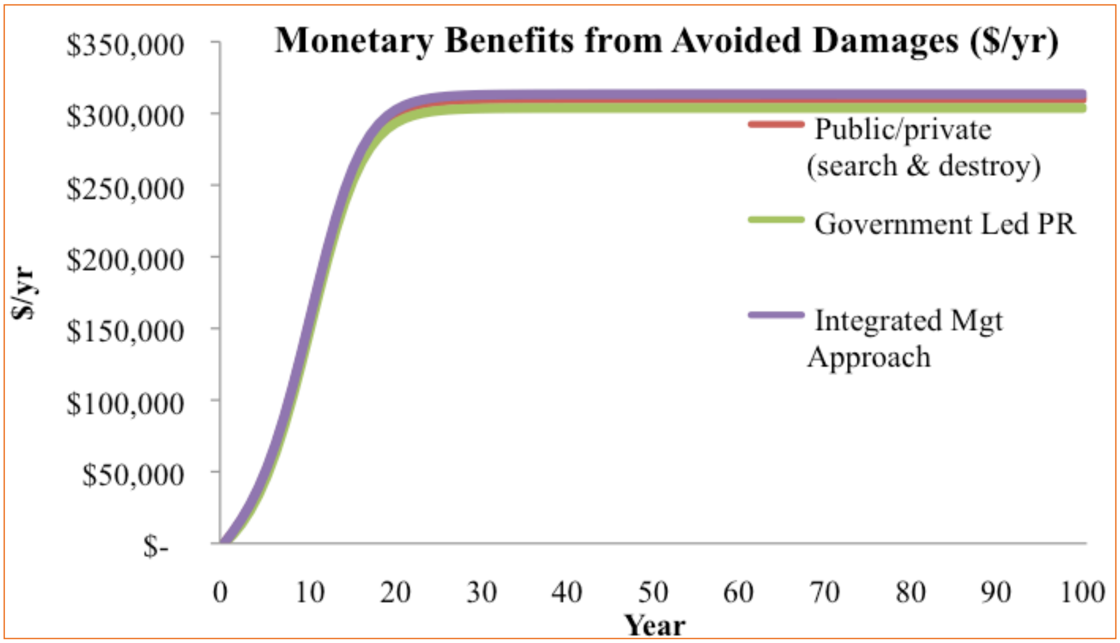


Figure 7: Illustrates Monetary Damages from Invasives



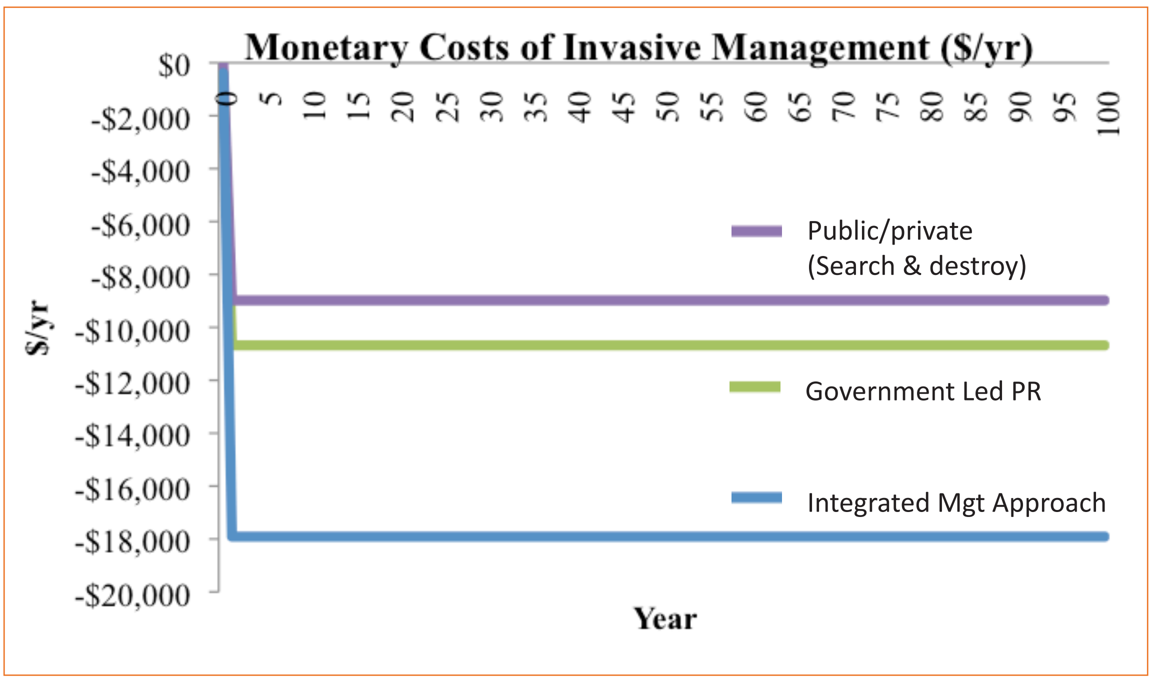


Figure 9: Illustrates Monetary Costs of Invasive Management

Sensitivity Analysis

Cost-benefit analyses of invasive species management typically depend on extensive data and strong assumptions, and this analysis was no different. Analyses often obtain data from an array of sources with varying levels of quality and certainty. Some of the costs and benefits may be difficult to value accurately, and key biophysical data can be difficult to obtain. The population of the invasive species in the initial period can also vary across space. As a result, a sensitivity analysis was undertaken to assess the robustness of our results. Specifically, the results are highlighted with the following variable assumptions**:**

1. Initial population (as % of max) – 25% and 50% base assumption. This changes the initial population of Casuarina from 637 stems per hectare or 6%.

2. Effectiveness of management – 0.5 and 2 times base assumption. This adjusts the pathway of the population growth curves for the three intervention options. An option that is assumed to be twice as effective means that the species is controlled in about half the time as the initial assumption.

3. Discount rate (r) – Rates of 3% and 7%. A summary of the NPV estimates for these sensitivity analyses is presented in the Appendix.

Estimates show that the Public/Private Partnership Programme of Eradication (search and destroy) yields the highest NPV but all of the other options are viable as well.

Sensitivity Analysis	r=5%, T=50 years, study area = 104 ha			
Net Present Value Summary				
Discount Rate =3%				
		Initial Population (relative to max)		
Option	Effectiveness	6%	25%	50%
Search and Destroy	0.5 x base	$4,955,270	$1,344,786	$623,840
	1.0 x base	$5,232,801	$1,451,766	$598,664
	2.0 x base	$5,398,741	$1,426,590	$577,784
	Effectiveness	6%	25%	50%
Government Led PR	0.5 x base	$4,730,135	$1,310,882	$621,802
	1.0 x base	$5,133,396	$1,449,728	$598,879
	2.0 x base	$5,366,151	$1,426,805	$579,142
	Effectiveness	6%	25%	50%
Integrated Approach	0.5 x base	$4,899,222	$1,187,937	$448,689
	1.0 x base	$5,108,461	$1,276,615	$439,184
	2.0 x base	$5,241,268	$1,267,110	$418,448
Discount Rate =5%				
		Initial Population (relative to max)		
Option	Effectiveness	6%	25%	50%
Search and Destroy	0.5 x base	$3,074,425	$884,844	$425,815

	1.0 x base	$3,260,740	$965,476	$398,587
	2.0 x base	$3,378,144	$938,248	$380,662
	Effectiveness	6%	25%	50%
Government Led PR	0.5 x base	$2,927,666	$862,069	$423,532
	1.0 x base	$3,194,836	$963,193	$396,388
	2.0 x base	$3,356,242	$936,049	$379,617
	Effectiveness	6%	25%	50%
Integrated Approach	0.5 x base	$3,028,138	$771,608	$299,739
	1.0 x base	$3,169,312	$839,400	$287,562
	2.0 x base	$3,264,487	$827,223	$269,537
Discount Rate =7%				
		Initial Population (relative to max)		
Option	Effectiveness	6%	25%	50%
Search and Destroy	0.5 x base	$2,014,861	$617,712	$309,232
	1.0 x base	$2,148,009	$682,214	$281,964
	2.0 x base	$2,236,447	$654,947	$266,317
	Effectiveness	6%	25%	50%
Government Led PR	0.5 x base	$1,913,412	$601,418	$306,861
	1.0 x base	$2,101,595	$679,844	$278,738
	2.0 x base	$2,220,769	$651,721	$264,289
	Effectiveness	6%	25%	50%
Integrated Approach	0.5 x base	$1,975,220	$530,764	$212,626
	1.0 x base	$2,076,676	$585,609	$199,536
	2.0 x base	$2,149,196	$572,519	$183,605
NPV Summary				
Discount rate	5%			
Option	Effectiveness	6%	25%	50%
Search and Destroy	0.5 x base	$3,074,425	$884,844	$425,815
	1.0 x base	$3,260,740	$965,476	$398,587
	2.0 x base	$3,378,144	$938,248	$380,662
	Effectiveness	6%	25%	50%
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	1.0 x base	$3,169,312	$839,400	$287,562
	2.0 x base	$3,264,487	$827,223	$269,537

Table 3 illustrates the results of the sensitivity analysis.

Summary and Conclusions

The purpose of this study is to conduct a benefit-cost analysis that estimates the economically efficient options to manage and control Casuarina at the settlement level in Governors Harbour, Eleuthera, Bahamas. Introduced in 1950s as an ornamental plant, it now dominates disturbed lands throughout much of the country, invading agricultural areas, forest plantations, and natural ecosystems. It is often difficult for landowners to clear and control the Casuarina with conventional methods. Although it is generally considered an agricultural pest, some argue that the invasive tree provides benefits such providing wood for grilling, used as Christmas trees, wood for sculpting and furniture production and as good shade trees.

Mostly the NGO communities have sought to control and manage Casuarina along the coastlines by removing large tracts of Casuarina. Most times this is done with a combination of paid labourers and volunteers. The Government of The Bahamas has also removed large tracts of Casuarina in a bid to control the invasive and replant these areas with native trees such as sea grape and sea oats. The Government's efforts have been met with much controversy. In these instances, the uproar from residents has come about because the Casuarina trees along the coastline were used for shade especially on big beach days like holidays and on the weekends. During the survey, it was also revealed that most people over 50 years of age had bonded with the trees over a period of years since most were able to say that they had some activity or another underneath a particular Casuarina tree. Despite putting some effort into managing the invasive, more than 70% of residents surveyed indicated that the population of the tree was increasing.

Under this Cost Benefit Analysis, four options to manage Casuarina were investigated: (i) Do Nothing, (ii) Public/Private Partnership Programme of Eradication (search and destroy), (iii) Government-led Public Education Programme (iv) an Integrated Approach(options 2 and 3 combined) which is a Public/Private Programme of removal in combination with the Government-led Public Education Programme. One thing was made abundantly clear, which is that the population and monetary costs associated with Casuarina will continue to rise if nothing is done. The Cost Benefit Analysis also revealed that the Public/Private (Search & Destroy) approach was estimated to yield the highest net present value and was therefore ranked number one out of all management options investigated in this study. Second and third rankings fell to the Government-led Public Education campaign and Integrated Approach respectively. See Figure 10. The highest benefit to cost ratio was achieved with the Government led Public Education Campaign, with second and third belonging to the Public/Private Partnership and Integrated Approach options respectively. See Figure 11 and Table 4. The most cost effective option was Public/Private (search & destroy) Partnership, followed by the Government-led Public Education option, and the Integrated Approach third. See Figure 12 and Table 5.

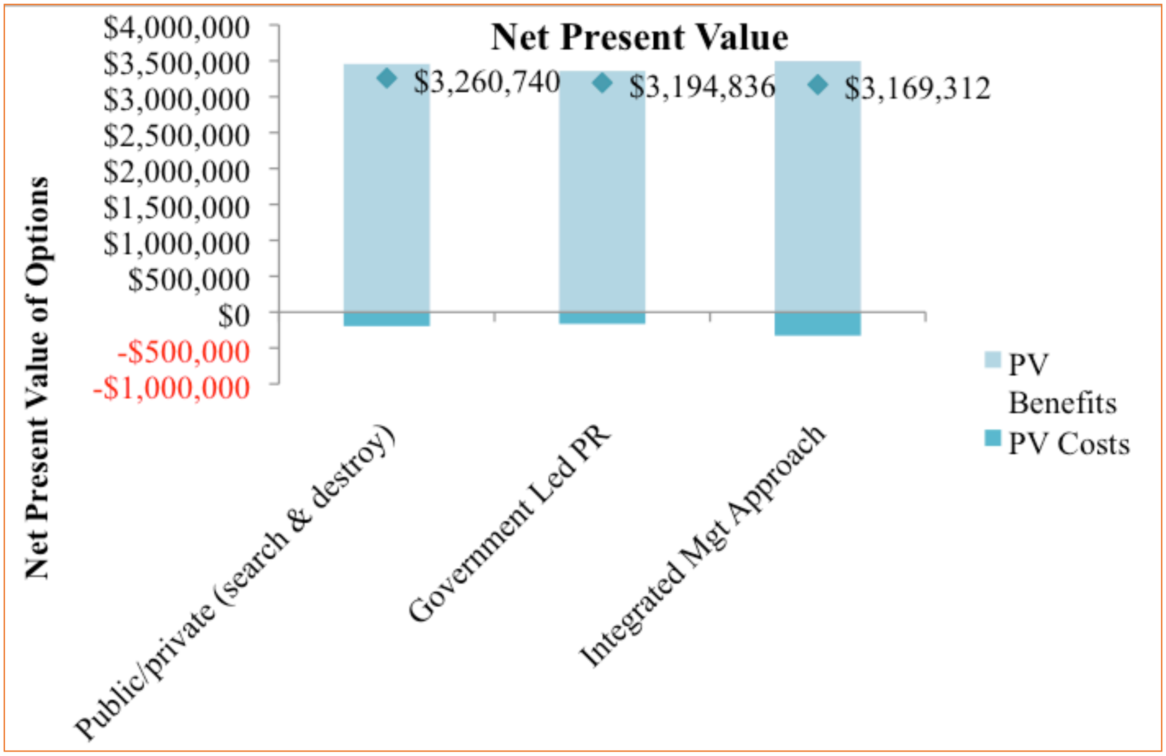

Figure 10: Illustrates Net Present Value of Proposed Management Options

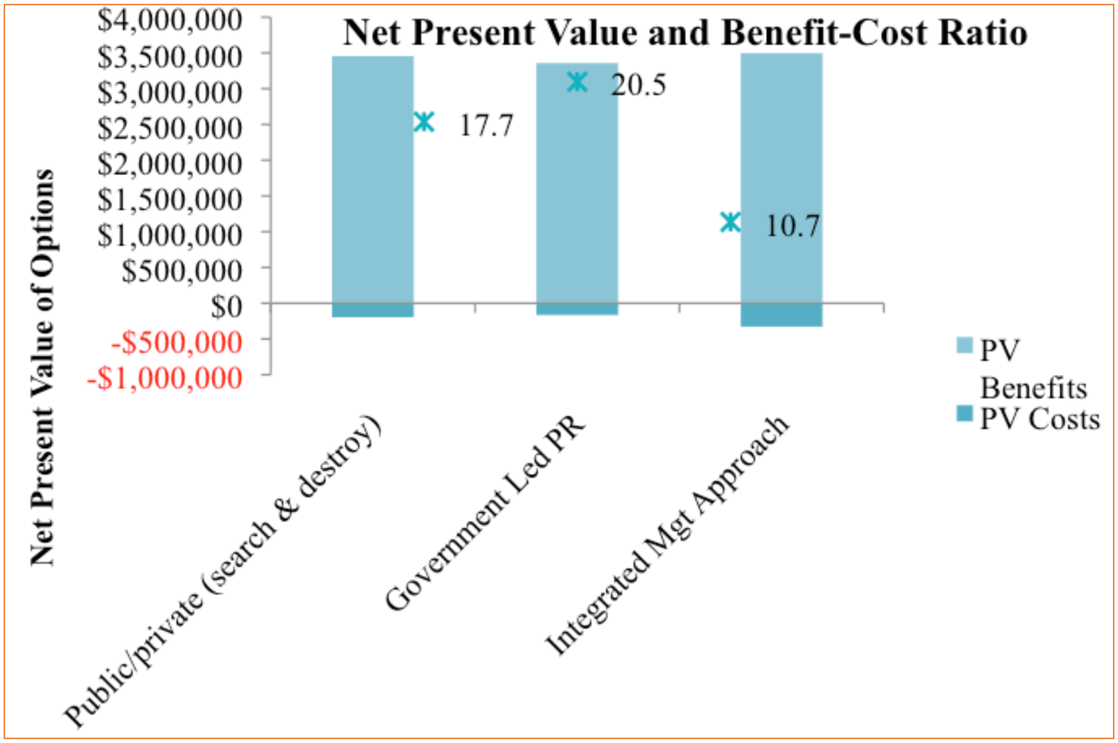

Figure 11: Illustrates Net Present Value and Benefit Cost Ration of Proposed Management Options

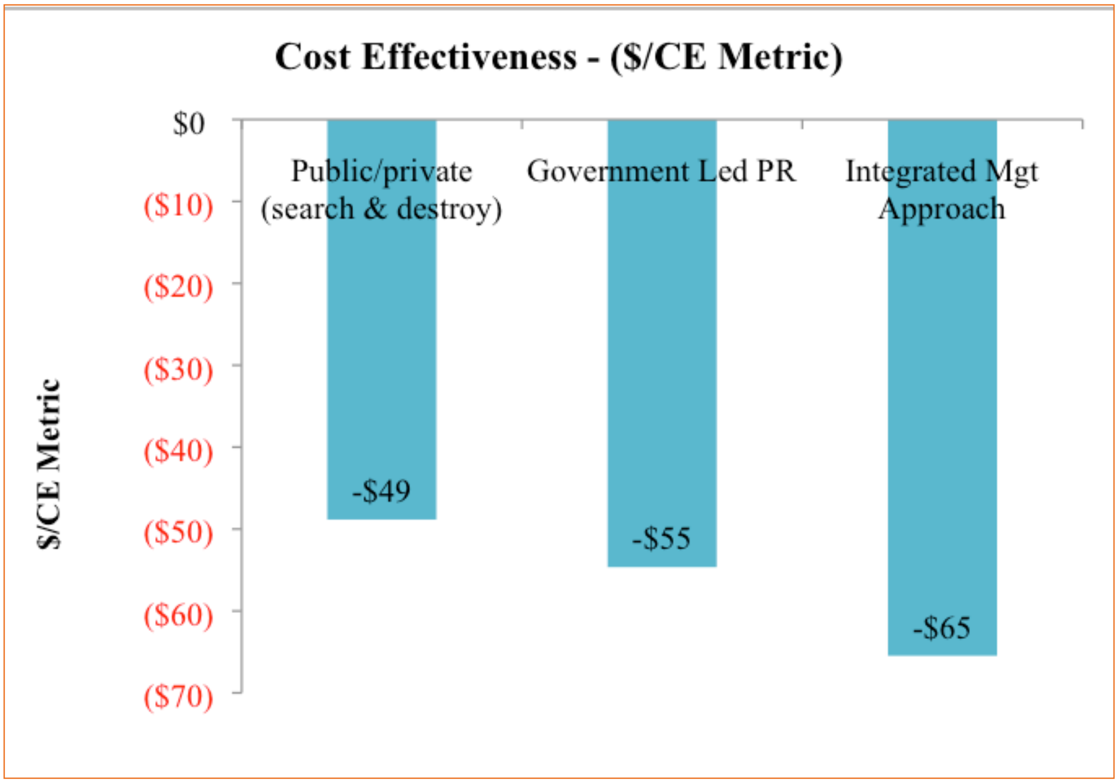

Figure 12: Illustrates Cost Effectiveness of Proposed Management Options

Table 4: Summary of Benefit-Cost Analysis (r = X%, t= Y years)

Option	PV Costs	PV Benefits	Total NPV	Benefit-Cost Ratio
Do Nothing	$-	$-	$-	1.00
Public/private (search & destroy)	-$195,363	$3,456,103	$3,260,740	17.69
Government Led PR	-$163,938	$3,358,774	$3,194,836	20.49
Integrated Mgt Approach	-$327,354	$3,496,666	$3,169,312	10.68

Table 5: Summary of Cost-Effectiveness Analysis (r = X%, t= Y years)

Option	CE Metric	CE ($/Metric)
Do Nothing	**0**	**0**
Public/private (search & destroy)		-49
Government Led PR		-55
Integrated Mgt Approach		-65

Recommendations

The cost benefit analysis reveals that the Government led PR campaign is the most efficient use of funds out of the three other management options. However, the most cost effective option was the Public/Private Partnership (search and destroy). This is most appropriate as it ensures the sustainability of the effort in the long term since the government led PR would most likely be short lived. This Cost Benefit Analysis will be submitted to the Government of The Bahamas and the Public/Private Partnership will be recommended for immediate implementation as part of the Bahamas National Invasive Species Strategy.

References

Anderson, H. J., D. C. Le Maitre, I. M. Kotze, S. Ndala, B. Brown, and M. B. Rapholo. 2004. Costs and benefits of biological control of invasive alien plants: case studies from South Africa. *South African Journal of Science* 10:113–122.

Convention on Biological Diversity 2002. Decision VI/23. Alien species that threaten ecosystems, habitat or species Available at: http://www.biodiv.org/decisions/default.asp?lg=0&dec=VI/23.

Duever, L. 2004. Casuarina equisetifolia. Available online <http://www.floridata.com/ref/c/casu_equ.cfm>.

Elfers, S. 1988. Element stewardship abstract for *Casuarina equisetifolia*: Casuarinas. The Nature Conservancy. Available online <http://tncweeds.ucdavis.edu/esadocs/documnts/casuequ.html>.

Epanchin-Niell, R., and A. Hastings. 2010. Controlling established invaders; integrating economics and spread dynamics to determine optimal management. *Ecological Letters* 13:528–541. CrossRef

Global Invasive Species Database. 2010. *Casuarina equisetifolia* (tree). Available online <http://www.issg.org/database/species/ecology.asp?si=365&fr=1&sts=&lang=EN>.

Hammerton, J. 2001. Casuarinas in The Bahamas: a clear and present danger. *Bahamas Journal of Science*9:2–14.

Higgins, S., D. Richardson, R. Cowling, and T. Trinder-Smith. 1999. Predicting the landscape-scale distribution of alien plants and their threat to plant diversity. *Conservation Biology* 13:303–313. CrossRef

Jacobs, J. 2007. Invasive plant management: options and actions. Chapter 8, in Invasive Plant Management: CIPM Online Textbook. Center for Invasive Plant Management, Bozeman, Mont. Available online <http://www.weedcenter.org/textbook/index.html>.

Leung, B., D. M. Lodge, D. Finnoff, J. F. Shogren, M. Lewis, and G. Lamberti. 2002. An ounce of prevention or a pound of cure: bioeconomic risk analysis of invasive species. *Proceedings of the Royal Society of London* 269:2407–2413. CrossRef

Lugo, A.E 2004. Alien tree invasions in Puerto Rico. Frontiers in Ecology and Environment. 2(5): 265-273.

Masterson, J. 2007. Smithsonian Marine Station at Fort Pierce: *Casuarina equisetifolia*. Available online <http://www.sms.si.edu/irlspec/casuarina_equisetifolia.htm>.

Morton, J. 1980. The Australian pine or beefwood (*Casuarina equisetifolia* L.), an invasive “weed” in Florida. *Proceedings of the Florida State Horticultural Society* 93:87–95.

Parrotta, J. 1993. *Casuarina equisetifolia* L. ex J.R. & G. Forst. Pp. 107–117 *in Institute Internacional de Dasonomía Tropical, Departamento de Agricultura de los Estados Unidos.* U. S. Department of Agriculture, Forest Service, Southern Forest Experiment Station, New Orleans, La.

Pimentel, D., L. Lach, R. Zuniga, and D. Morrison. 2000. Environmental and economic costs of nonindigenous species in the United States. *BioScience* 50:53–65. BioOne

Ramula, S., T. Knight, J. Burns, and J. Buckley. 2008. General guidelines for invasive plant management based on comparative demography of invasive and native plant populations. *Journal of Applied Ecology* 45:1124–1133. CrossRef

Rodgers, J. 2005. The Distribution of Casuarinas on San Salvador Island, The Bahamas. *Southeastern Geographer* 45:222–238. CrossRef

Rodgers, J. Ambinakudige, S. 2012. Distribution Patterns of Invasive Casuarinas (*Casuarina equisetifolia* L.) Within Beach Environments on San Salvador, The Bahamas. Natural *Areas Journal* 32(4):386-390.

Sealy, N. 1985. Bahamian Landscapes: an Introduction to the Geography of the Bahamas. Collins Caribbean, London.

Sealy, N. 2006. The cycle of Casuarinas-induced beach erosion; a case study from Andros, Bahamas. Pp.222–230 *in* R. Davis and D. Gamble, eds., Proceedings of the 12th Symposium on the Geology of the Bahamas and other Carbonate Regions. Gerace Research Center, San Salvador Island, The Bahamas.

Swearingen, J. 2008. Casuarinas; *Casuarina equisetifolia* L. Plant Conservation Alliance's Alien Plant Working Group, U.S. National Parks Service. Available online <http://nps.gov/plants/alien/fact/caeq1.htm?>.

The Bahamas Environment, Science and Technology Commission. 2003. *The National Invasive Species Strategy for The Bahamas, Nassau, The Bahamas.* The Bahamas Environment, Science and Technology (BEST) Commission, Ministry of Health and Environment in conjunction with the British High Commission, Nassau, The Bahamas.

The Southwest Regional Working Group –

http://www.floridainvasives.org/workinggroups/InvasivePlants_Uplands_03-04_southwest.pdf

U.S. Fish and Wildlife Service. 2010. Managing invasive plants, concepts, principles, and practices.Available online <http://www.fws.gov/invasives/staffTrainingModule/assessing/inventory.html>.

Wittenberg, R., and M. Cooke. 2001. Invasive Alien Species: a Toolkit of Best Prevention and Management Practices. CAB International, Wallingford, Oxon, U.K. CrossRef

Zavaleta, E. 2000. The economic value of controlling an invasive shrub. *Ambio* 29:462–467. BioOne

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Central Bank of The Bahamas

Bahamas Ministry of Tourism

One Eleuthera Foundation

Water and Sewerage Corporation

Residents of Governors Harbour, Eleuthera

Appendix: Summary of Net Present Value Sensitivity Analysis Preferred Rankings

Rank Summary (#1 = most preferred, #3 = least preferred)				
Discount Rate =3%				
		Initial Population (relative to max)		
Option	Effectiveness	6%	25%	50%
Search and Destroy	0.5 x base	1	1	1
	1.0 x base	1	1	2
	2.0 x base	1	2	2
	Effectiveness	6%	25%	50%
Government Led PR	0.5 x base	3	2	2
	1.0 x base	2	2	1
	2.0 x base	2	1	1
	Effectiveness	6%	25%	50%
Integrated Approach	0.5 x base	2	3	3
	1.0 x base	3	3	3
	2.0 x base	3	3	3
discount rate	5%			
	Initial Population (relative to max)			
Option	Effectiveness	6%	25%	50%
Search and Destroy	0.5 x base	1	1	1
	1.0 x base	1	1	1
	2.0 x base	1	1	1
	Effectiveness	6%	25%	50%
Government Led PR	0.5 x base	3	2	2
	1.0 x base	2	2	2
	2.0 x base	2	2	2

	Effectiveness	6%	25%	50%
Integrated Approach	0.5 x base	2	3	3
	1.0 x base	3	3	3
	2.0 x base	3	3	3
Discount Rate =7%				
		Initial Population (relative to max)		
Option	Effectiveness	6%	25%	50%
Search and Destroy	0.5 x base	1	1	1
	1.0 x base	1	1	1
	2.0 x base	1	1	1
	Effectiveness	6%	25%	50%
Government Led PR	0.5 x base	3	2	2
	1.0 x base	2	2	2
	2.0 x base	2	2	2
	Effectiveness	6%	25%	50%
Integrated Approach	0.5 x base	2	3	3
	1.0 x base	3	3	3
	2.0 x base	3	3	3
Rank Summary (#1 = most preferred, #3 = least preferred)				
Discount rate	5%			
Option	Effectiveness	6%	25%	50%
Search and Destroy	0.5 x base	1	1	1
	1.0 x base	1	1	1
	2.0 x base	1	1	1
	Effectiveness	6%	25%	50%
Government Led PR	0.5 x base	3	2	2
	1.0 x base	2	2	2
	2.0 x base	2	2	2
	Effectiveness	6%	25%	50%
Integrated Approach	0.5 x base	2	3	3
	1.0 x base	3	3	3

Benefits to Biodiversity outweigh cost of Vertebrate Eradication on Cabritos Island: Costs Benefits Analysis of Donkeys Eradication

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Abstract: Invasive mammals on Cabritos Island have degraded a fragile ecosystem in which native Ricord iguana (*Cyclura ricordi*), Rhinoceros iguana (*Cyclura cornuta*), and American crocodiles (*Crocodylus acutus*) live; these species are especially threatened by donkeys that have settled on the island. This paper reports the results of a cost-benefit analysis to evaluate different managemet options for Cabritos Island.

Keywords: Cabritos Island, Dominican Republic, Invasive alien species, *Cyclura ricordi, Cyclura cornuta,* donkeys, cost-benefit analysis.

Introduction

Cabritos Island is located 40 meters below sea level in the middle of Enriquillo Lake in the southwest region of the Dominican Republic. It's total area is approximately 24 km^2. Enriquillo Lake was the first Ramsar site in the Dominican Republic, and as a national Park, Cabritos Island and Enriquillo Lake are included in the Biosphere Reserve Jaragua-Bahoruco-Enriquillo.

Cabritos Island and Enriquillo Lake National Park was created in 1974 to maintain the natural resources of the island and in general and to conserve the habitat of the two rock iguana species, Rhinoceros iguana (*Cyclura cornuta*) and Ricord iguana (*Cyclura ricordii*), in particular. Enriquillo Lake is important to the American crocodile (*Crocodylus acutus)*.

Cabritos Island is a globally important site for biodiversity conservation in protecting those species, both from economic and from ecological points of view. Still, while the biological advantages of protecting the island are well studied and well understood, the economic implications – which are crucial for decision makers – are poorly understood.

Cabritos Island has long been occupied by invasive alien species. While donkeys (*Equus africanus asinus*) and feral cats are especially problematic, other invasive species such as cows and rats are also present. These species impact the ecosystem, threaten the iguana species by eating hatchlings, and disturb nesting sites for the crocodile.

Pilot Project for Donkey Eradication on Cabritos Island

The donkey is a domesticated member of the *Equidae* or horse family. The wild ancestor of the donkey is the African wild ass, *E. africanus*. The donkey has been used as a working animal for at least 5,000 years. There are more than 40 million donkeys in the world, mostly in underdeveloped countries, where they are used principally as draught or pack animals. Working donkeys are often associated with those living at or below subsistence levels. Small numbers of donkeys are kept for breeding or as pets in developed countries.

In the Dominican Republic, donkeys are used as work and transportation animal, particularly among the rural poor. In the poor communities near Cabritos Island and Enriquillo Lake National Park (e.g., Los Ríos, Villa Jaragua, Postrer Rio, Las Clavellinas, La Descubierta, Bartolomé and Boca de Cachón), donkeys are especially relied upon for transportation. Donkeys that were removed from Cabritos Island and distributed to these communities could thus improve the social welfare of local people.

In 2011, the population of donkeys on Cabritos Island was estimated to be 127 individuals. Although, the surface of the island was once approximately 24 km^2, the island shrank to 19 km^2 after the lake level rose.

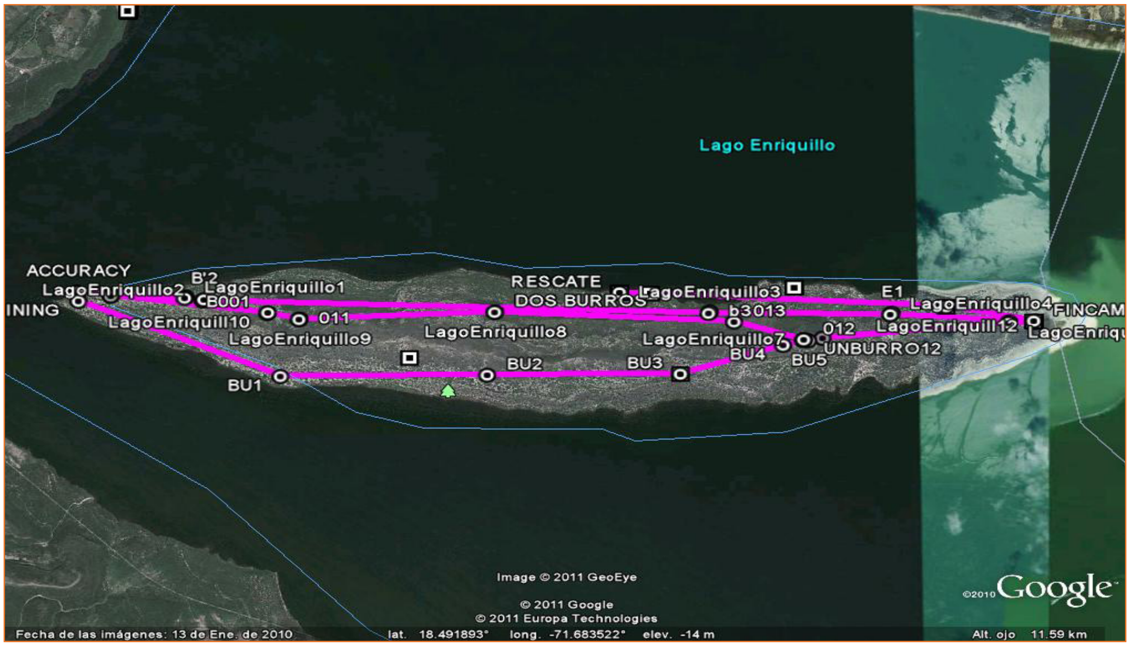

Figure 1. Model used to assess the donkeys population in 2011.

When a species is introduced into a new habitat that it finds suitable, it may experience exponential growth. No research has yet been conducted on Cabritos Island to determine the population growth rate of donkeys, but Choquenot (1990) reports that the growth rate in the population of wild donkeys in Northern Australia ranged from from 21% to 25%. However, age at maturity and juvenile mortality displayed some density dependence (Choquenot 1991), confirming that at high density, juvenile mortality was three times as great as at low density and was associated with poorer juvenile body condition and slower growth. Because food availability on Cabritos Island is poor, I assume that 25% annual growth is the upper bound for population growth on Cabritos Island.

The formula used to calculate the donkey's population grown is as follow: $g(n) = bn[1-(n/N_{max})]$,
where $g(n)$ is the annual change in the donkey population, b is the intrinsic growth rate, n is the population of donkeys, and N_{max} is the total carrying capacity of the donkeys. If there is no intervention, we use a b of 0.25 to estimate the growth rate of the population: $g(n) = 0.25*127*[1-(127/200)] = 11.6$

Thus, after 20 years, applying this formula, in a time period of 20 years, if no action is undertaken to eradicate the donkeys, the population occupying the island will be 200. If this happens iguana species, both Ricord and Rhinoceros iguana and important flora wildlife will disappear. On the other hand, ecotourism on the island will diminish, or even also disappear.

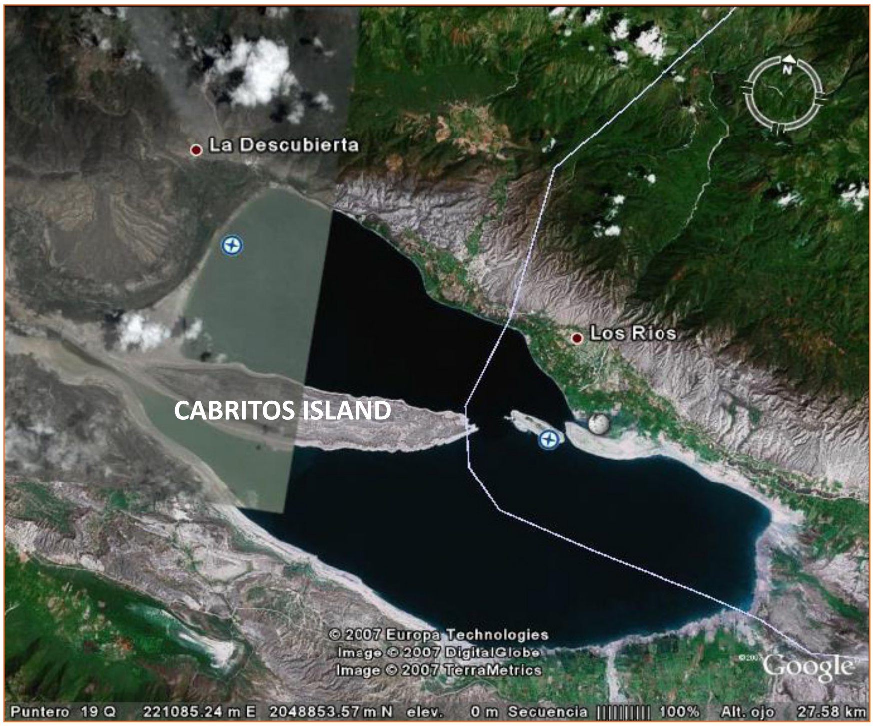

Fig. 2 Project area

The key benefits of donkey eradication include saving the Ricord iguana from extinction, increasing the population of crocodiles, and potentially increasing the number of tourists that visit the island from its current level of approximately 600 per month.

Management Options

Five options were initially considered to manage the donkeys on Cabritos Island: 1) do nothing; 2) live capture and transport to the main land; 3) hunting on the ground; 4) a combination of live capture and ground hunting; and 5) hunting by helicopter. Since helicopter hunting is not viable from a societal standpoint, it was eliminated from the analysis. The combination option assumed that live capture was used to remove 90% of the donkeys and ground hunting was used to remove 10% of the donkeys.

Costs of eradication are directly related to the scale of eradication (i.e., to the size of the island), to the distance of the protected area from population centres, and to the nature of the species that will be managed (Martins et al, 2006; Carrion et al, 2007; Cruz et al, 2009). For example, Martins et al. (2006) found that 72 % percent of the eradication cost could be explained by the island area.

Data sources are shown in Table 1.

Table 1. Data Source for CBA on mammal eradication in Cabritos Island.

Data	Source
Social and economic data for communities; ecotourism potential; programs undertaken by community leaders; and the potential for social marketing.	Local NGO´s (AGELE, CIEPO, FLORESTA)
Animal health; population estimation methods.	National Zoological Park
Natural conditions of the ecosystem before the donkeys were established on Cabritos Island.	The Nature Conservancy
Ecosystem impacts of invasive species.	Ministry of Environment
Trapping techniques	Ornithological Society of Hispaniola

Physical Costs

Labor for trapping and transporting the donkeys may be hired for $10 per hour. Specialised labour for surveying and monitoring is $25 per hour, as is specialized labour for hunting. Other capital costs include items such as boats, rifles, and bullets. A summary of these costs is listed in Table 2.

Table 2. Physical units of costs by management option

Costs	Do nothing	Live capture	Ground hunting	Combination
Capital costs ($)	$0	$17,000	$8,000	$16,100
Trapping and transporting (hours)	0	4,000	350	3,635
Survey and monitoring (hours)	0	300	100	280
Specialized hunter (hours)	0	0	200	20

The break down by cost and benefits categories is shown below, considering biodiversity protection and ecotourism as the main economic values for Cabritos island and Enriquillo Lake (see Table 3). The reptile's species were considered included in the ecotourism benefits, due their significance for the visitors.

Table 3. Physical units of benefits by management option

Category	Do Nothing	Live Capture	Ground hunting	Combination
Ecotourism	913	913	913	913
Crocodiles	1	1	1	1
Iguanas	1	1	1	1
Biodiversity protected	1	1	1	1

Costs were monetized and categorized for the analysis using the unit values, shown in the Table 4.

Table 4. Monetized benefits and costs

Cost/Benefit Category	Category	Unit Measurement	Unit Value ($/units)
Benefits	Ecotourism	Visitors	$100.00
	Crocodiles	Population	$ -
	Iguanas	Population	$ -
	Biodiversity protected	$	$2,273.00
Costs	Labour	Hours	$10.00
	Initial Capital	Dollars	$1.00
	Specialised Hunting	Hours	$25.00
	Monitoring	Hours	$25.00

Figure 3 shows the changes in population under the different management options. If do nothing option is choice option, donkeys continue growth at a rate of approximately 25% and in a period time of Twenty (20) year, population can arise the amount of 200 individuals. The live catch, ground hunting, and combination options all assume that a majority of the donkeys would be removed in the first 3 years of the intervention, and that the last donkey would likely be removed within 7 years.

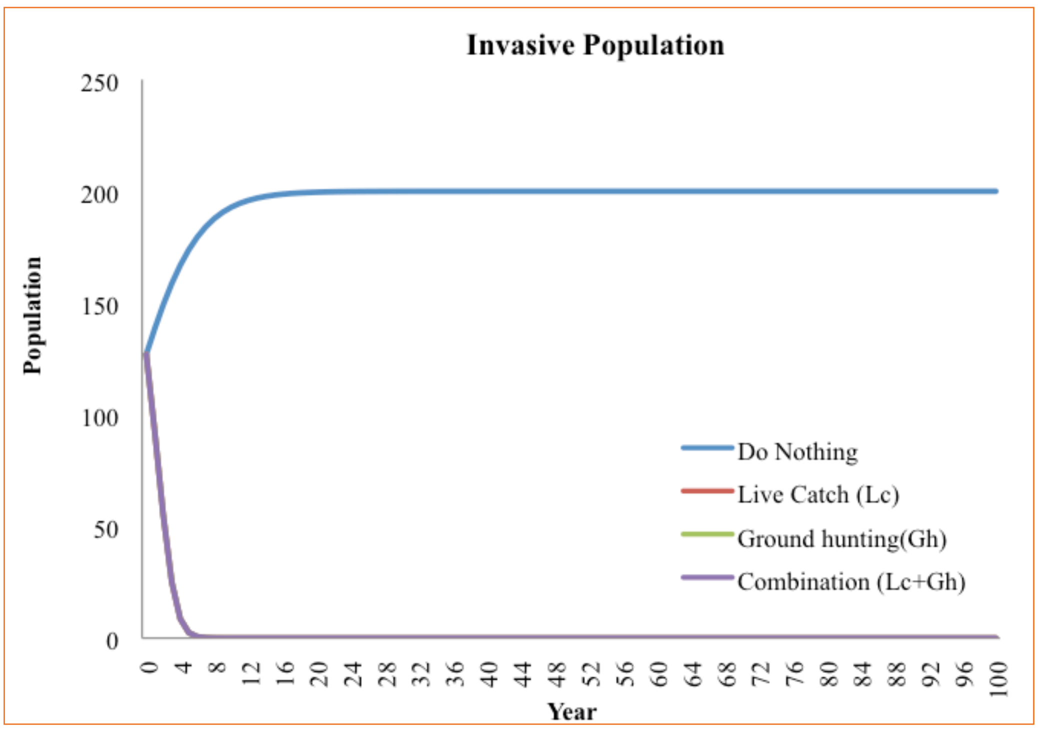

Figure 3. Population of donkeys under alternative management scenarios

With this situation, biodiversity will be unprotected and the main species of the fauna in the island could disappear and loss all the incomes from the ecotourism, as show Figure 4. By using the change in population under the various options, we can estimate the avoided damages, or benefits, from managing the donkey relative to the do nothing case.

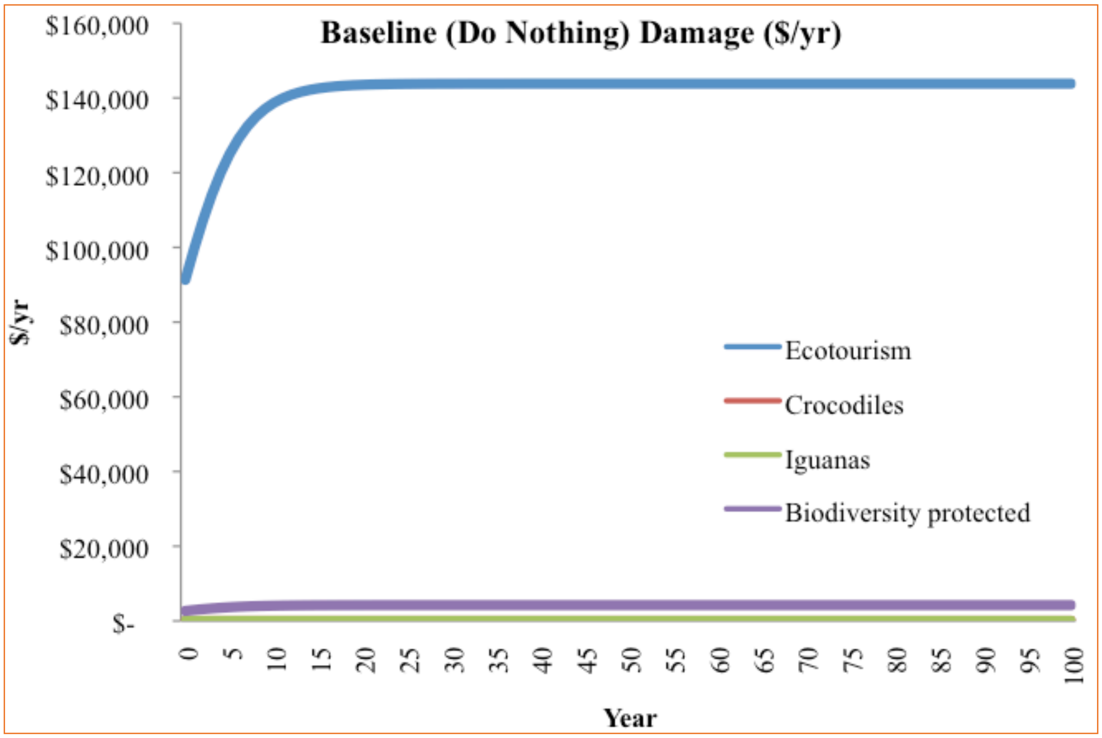

Figure 4 Monetary loss in USD under 'do nothing' case.

The monetary cost for each of the option is depicted in Figure 5. As one can see in the Figure 5, the most expensive option in the short term is helicopter hunting due to the high cost of helicopter rental. However, ongoing costs are lower in the long run as live capture and ground hunter require monitoring activities.

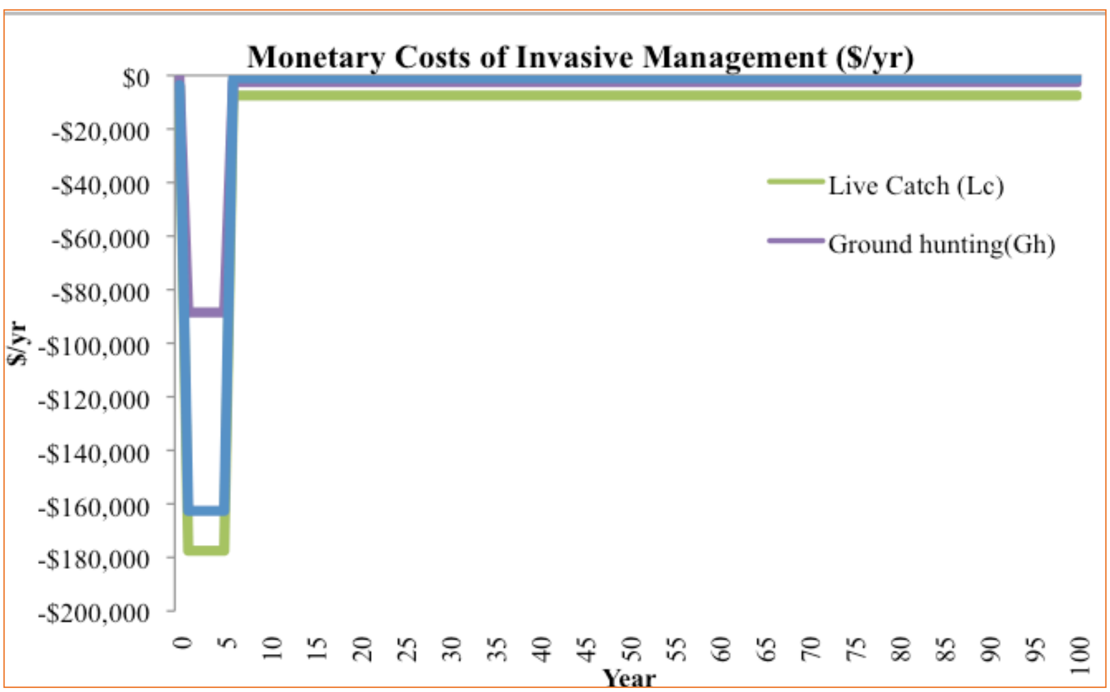

Figure 5. Cost of donkeys eradication on Cabritos Island.

Cost Benefits Analysis

The cost benefits analysis assumes a project period of 100 years and a discount rate of 8%. Estimates are listed in Table 5. The results indicate that the most suitable option for the eradication for the Cabritos Island invasive mammals is the ground hunter, as this option has the highest net present value (NPV), at $1.2 million, as well as the highest benefit-cost ratio, at $4.20 for each $1 spent. The live catch and combination options also have positive NPVs and BCRs greater than 1, indicating that they are also preferred over the 'do nothing' scenario. However, benefits to local communities are not explicitly considered in these calculations. If the benefits of having draught animals are significant, or if the benefits of local employment exceed the wages that are paid in capturing and transporting the animals, then the live capture option may be an appropriate alternative.

Table 5. Cost benefits analysis

Option	PV Costs	PV Benefits	Total NPV	Benefit-Cost Ratio
Do Nothing	$0	$0	$0	1.00
Live Catch (Lc)	$776,468	$1,567,988	$791,520	2.0
Ground hunting(Gh)	$374,959	$1,567,988	$1,193,029	4.2
Combination (Lc+Gh)	$661,366	$1,567,988	$906,622	2.4

Conclusions

With a small population of donkeys in a relatively confined space, eradication is clearly a viable management option for the Cabritos Island and Enriquillo Lake National Park. Eradication would be a boon for habitat conservation and biodiversity protection, particularly for the Rhinoceros iguana, Ricord iguana, and the American crocodile.

Eradication through ground hunting is both cost effective and efficient, yet it prevents an important co-benefit of alternative management options, namely, providing draught animals to local communities. Thus, we advocate the combination method in which 90% of the donkeys are removed via live capture and the remaining (and most difficult to catch) donkeys are eradicated via ground hunting.

As a result, activities to capture and remove donkeys during 2012 included using tie-ropes to catch the animals alive, transporting them to the main land, and giving them to community members to use as working animals. After one year of effort, a total of 99 animals were captured. Tie ropes were not effective in capturing the remaining animals, so it became necessary to begin ground hunting. Between August 31, 2013 and September 13, 2014, 11 donkeys were eradicated via hunting.

These activities were implemented under the project "Mitigating the Threats of Invasive Alien Species in the Insular Caribbean", with funding provided by UNEP/GEF and planning supported by CABI at the regional level and by the Dominican Republic's Ministry of Environment and Natural Resources. The non-governmental organizations Island Conservation and Sociedad Ornitológica de la Hispaniola were involved directly in the eradication field activities during the campaign of 2013 and 2014.

We strongly advocate for additional effort in eliminating the last remaining donkeys to ensure that the work undertaken to date has not been in vain.

Cited Literature

Bullock, D., S. North; E. Dulloo and M. Thorsen. 2004. The impact of rabbit and goat eradication on the ecology Round Island, Mauritius. (in) Turning the Tie: The Eradication of Invasive Species. Proceedings of the International Conference on Eradication of Island Invasives. Veitch C. and Clout, M. Editors.

Carrion, V., C. Donland; K.Campbell; C. Lavoie and F. Cruz. 2007. Feral Donkey (***Equus asinus***) eradication in the Galapagos. Biodiversity and conservation (2007) 16: 437-445 pp.

Chuquenot, D. 1990. Rate of increase for population of feral donkeys in Northern Australia. Applied Ecological Research Group, Canberra College of Advanced Education 71(2): 151-155.

Chuquenot, D. 1991. Density-dependent growth, body conditions and graphy in feral donkeys. Testing the food hypothesis. Ecology 27(3): 805-813 pp.

Cruz, F., V. Carrion; K. Campbell; C. Lavoie and J. Donland. 2009. Bio-economic of Large-Scale Eradication of feral Goats from Sntiago Island, Galapagos. Wildlife Management 73(2): 191-200 pp.

Klinger, R., Shuyler, P. and Sterner, J. 2004. The response of herbaceous vegetation and endemic plant species to the removel of feral sheep from Santa Cruz Island, California. (in) Turning the Tie: The Eradication of Invasive Species. Proceedings of the International Conference on Eradication of Island Invasives. Veitch C. and Clout, M. Editors.

Appendix: Capturing Donkeys on Cabritos Island

Typical tie-ropes used to capture donkeys

Community member receiving a donkey removed from Cabritos island

An Economic Analysis of the Management of the Invasive Weed, Whitetop, on the UTT Waterloo Research Centre

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March 2014

ABSTRACT
Whitetop (*Parthenium hysterophorus)* is a noxious and invasive weed that reduces crop yield and quality and has shown to be harmful to humans and animals. The weed is characterized by its vigorous growth, high fecundity and allelopathic properties. This study reviews several management options which set out to prevent and/or control the spread of this invasive weed species in order to mitigate its adverse effects. A cost-benefit analysis of the four management options was conducted at Waterloo Research Centre of The University of Trinidad and Tobago over a one-year period beginning March 2013. It evaluated several variables including benefit and cost values of agricultural crops, human health, labour, herbicides and research amongst others, using the logistic curve toolkit developed by Landcare Research, New Zealand. The ranking function within the toolkit suggested that an 'Integrated Management Approach' attributed the highest Net Present Value whereas the 'Current Management' option ranked highest as the option with the greatest Benefit-Cost Ratio, displaying the most benefits expected for each dollar of costs. The 'Current Management' option also ranked first in terms of cost-effectiveness. The success of this preliminary model will now be extended to several industrial and agricultural locations in Trinidad where the weed is persistent and difficult to manage.

Introduction
Parthenium hysterophorus L. (family *Asteraceae*) commonly referred to as Whitetop, is an aggressive and obnoxious annual herbaceous weed that has spread from tropical America to various tropical and subtropical parts of the world. Whitetop is presumed to be native to Central America, the West Indies and the Gulf of Mexico. It is included in the IUCN Global Invasive Species database and is rated one of the most serious weeds of the 20th century. This may be attributed mainly due to its vigorous growth and high fecundity in habitats varying from hot and arid, semi-arid to humid and from low- to middle- to high-altitude regions.

Parthenium hysterophorus is an annual herb with a tendency to be perennial, growing erect up to 2m in height. It has a deeply penetrating root system with a stem that is branched and covered with hairy structures or trichomes bearing dissected pale green leaves that are lobbed and hairy. Leaves vary from 6 to 55 per plant and irregularly dissected and bipinnate, having small hairs on both sides. Trichomes are considered storehouses for toxic chemicals found in the weed known as parthenin (Batish *et al*, 2012). Flower heads are creamy white, about 4mm across, arising from the leaf fork and forming a capitula. Flowering usually occurs one month after germination with each flower containing five seeds which are small (2mm), wedge-shaped, brown to black in color and bears two thin white scales. Pollen grains are produced in clusters and are pollinated by wind. According to Haseler (1976), a single plant can produce around 15 000 seeds or even up to 100 000. Seeds are mainly dispersed through water currents, animals and the movement of vehicles, machinery, livestock and stock feed, and to a lesser extent by wind. Seeds can remain viable for long periods and are capable of germinating as long as moisture is available.

The ideal conditions for growth are high moisture content, high humidity and a temperature around 25^{o}C. However, it can grow under a wide range of environmental conditions with soil moisture being the only limiting factor for germination and growth. According to Challa (1987), it can grow under a wide range of soil pH, varying from 2.5 to 10.0, though the optimum pH for growth is 5.5 – 7.0. Additionally, Whitetop grows well in areas where annual rainfall is higher than 500mm. In Trinidad, this weed grows on abandoned lands, along highways, roadsides, drains, gardens, plantations and vegetable crop plots. It colonizes disturbed sites very aggressively, possesses allelopathic properties and has no natural enemies like insects or diseases.

Whitetop has been known to have major economic, social and ecological impacts and is commonly referred to as the most troublesome and noxious weed in rural and even urban areas in many countries around the globe, including Trinidad.

The main impacts of Whitetop include:

- Health hazards to humans and livestock – The pollen and dust of this weed tends to elicit allergic contact dermatitis in humans. With exposure over prolonged periods, persons manifest symptoms of skin inflammation, eczema, asthma, allergic rhinitis, allergic bronchitis and burning and blistering of the eyes. Whitetop can cause toxicity in livestock, loss of pigmentation, dermatitis and diarrhoea. Studies have reported degenerative changes in the liver and kidneys of buffalo and sheep and reduced meat and milk quality of these animals.
- Reduction of agricultural and livestock grazing productivity – Whitetop exhibits phytotoxic effects and allelopathic interference on crops and other surrounding plants, inhibiting germination and radicle growth, causes poor fruiting, reduces contents of chlorophyll, hosts crop pests and changes above-ground vegetation and below-ground soil nutrient contents. Additionally, it reduces grazing land productivity by outcompeting grasses and plants naturally present on these fields.
- Biodiversity loss – The invasive capacity and allelopathic properties have rendered Whitetop with the potential to disrupt natural ecosystems. It has been known to cause total habitat changes and to rapidly invade new surroundings by replacing native species.

Growth strategies of Whitetop including fast growth rate, short life-cycle, great reproductive potential, high competitive ability and allelopathy make it successful invaders of native habitats. Through management, the chief objective is to prevent and/or control the spread of this invasive weed species in order to mitigate its adverse effects. However, management efforts will begin in and around The University of Trinidad and Tobago (UTT) Waterloo Research Centre (WRC) compound within the initial year (Year 1). The intention in subsequent years (Years 2 - 10) is to extend management of Whitetop to major agricultural and industrial areas nationwide which are plagued with this weed.

Objectives

1. To conduct a cost-benefit analysis on several management options for the invasive weed, *Parthenium hysterophorus*
2. To determine the economically efficient option for managing *Parthenium hysterophorus* at the UTT Waterloo Research Centre
3. To prevent and/or control the spread of *Parthenium hysterophorus* in order to mitigate its adverse effects.

Methods and Materials

Intensive research was conducted on the biology, distribution and impacts of the invasive weed, *Parthenium hysterophorus* (Whitetop). Data collection was confined to the UTT Waterloo Research Center (WRC), its environs and staff members and was estimated for the initial period of one (1) year. Approximately 10 surveys on Whitetop, its impacts and effects were conducted with the staff of the WRC. This was done in an attempt to collect essential information on different variables required for completing a toolkit developed by Landcare Research, New Zealand. The toolkit was developed in an attempt to assign monetary values, where possible, to specific variables in order to conduct cost-benefit analyses on different management options for the control of Whitetop. Data included costs of agricultural and research crops, human health bills, biodiversity, initial capital, labour, supplies and research. As far as possible, values obtained were based upon market prices. In the case of this project, four management options were proposed and utilized; "Do Nothing", "Current Management', "Integrated Management Approach' and "Exploitation of Benefits". The outcome of the toolkit ranked the management options in terms of Net Present Value (NPV), Benefit-Cost Ratio (BCR) and Cost Effectiveness (CE).

Results and Discussion

For this study, an economic analysis was performed on *Parthenium hysterophorus* (Whitetop) involving a cost-benefit analysis where several variables were inputted into a toolkit developed by Landcare Research, New Zealand. The analysis was done on four proposed management options in order to determine the best suitable one for the control of this invasive weed. Table 1 below gives a short description of each of the management options that were considered.

Table 1: Description of the proposed management options for the control of Whitetop

Management Option	Description
Do Nothing (DN)	This refers to employing no management options at all and simply leaving the invasive to grow and spread at its natural rate without intervention. The initial population density is assumed to be 6% of the carrying capacity.
Current Management (CM)	This option leaves the situation in its existing state or maintains the status quo of the Whitetop population. At the WRC, the current management being employed is mainly chemical control of the weeds through the use of several chemicals and herbicides namely SunquatTM and SwiperTM. The application of chemical herbicides is timed and plants are treated before flowering and seed setting to ensure effective application. With the CM option, the population density still increases but at a slower rate than the DN option.
Integrated Management Approach (IMA)	This option entails combining chemical control (SunquatTM and SwiperTM herbicides – active ingredient Paraquat) with manual and mechanical control methods. Manual and mechanical methods involve use of a hoe and plough, cutting and hand weeding or uprooting of weeds. However proper safety gear needs to be utilized when handling this weed directly due to allergic reactions. Additionally, handling of the weed should be planned to the time before plants reach the flowering stage in order to avoid dispersal and spread of seeds. An IMA requires accurate and precise development and standardization of each combination of control being used. It has been proven to be effective but sometimes entail greater effort than other management options in terms of time, resources, skills and money. With IMA, more effort is required but there is greater effectiveness (reduces carrying capacity). The initial costs are greater as well but more benefits are manifested.
Exploitation of Benefits (EB)	This management option involves investments in research and development to determine the possible benefits that Whitetop has to offer and an exploitation of these positive uses which will attempt to control the spread of the invasive weed. Potential benefits of Whitetop include medicinal value, enhancement of crop productivity, bioremediation of heavy metals and dyes and through the eradication of weeds. With this option, caution must be taken to avoid adverse effects from the use of the weed. EB requires the largest investments in research and initial costs but shows fewer benefits than DN and IMA.

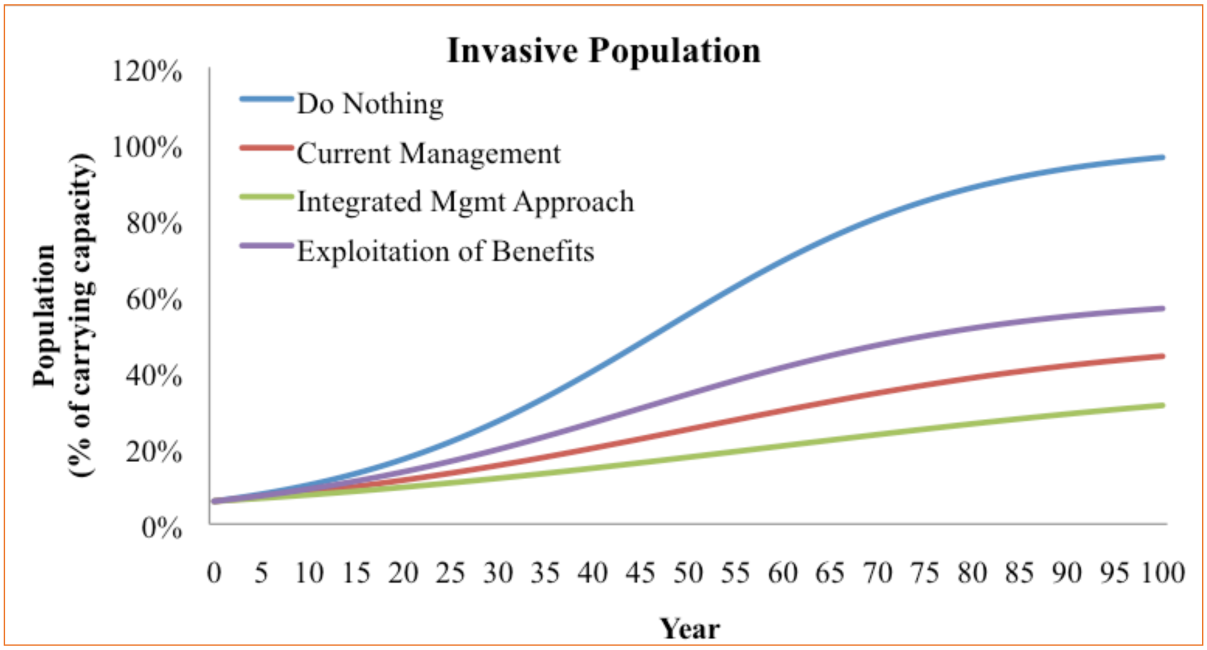


Figure 1: Graph showing the trend of the Invasive Population for each Management Option

It can be seen in Figure 1 that as time goes by from year 0 to 100, the fastest population increase can be observed in the DN option, followed by the EB and then by CM. The IMA displayed the slowest increase in the invasive population for the time period. This graph was generated using the toolkit and imputing an estimate of the population at Year 0 and an annual population growth parameter for each management option.

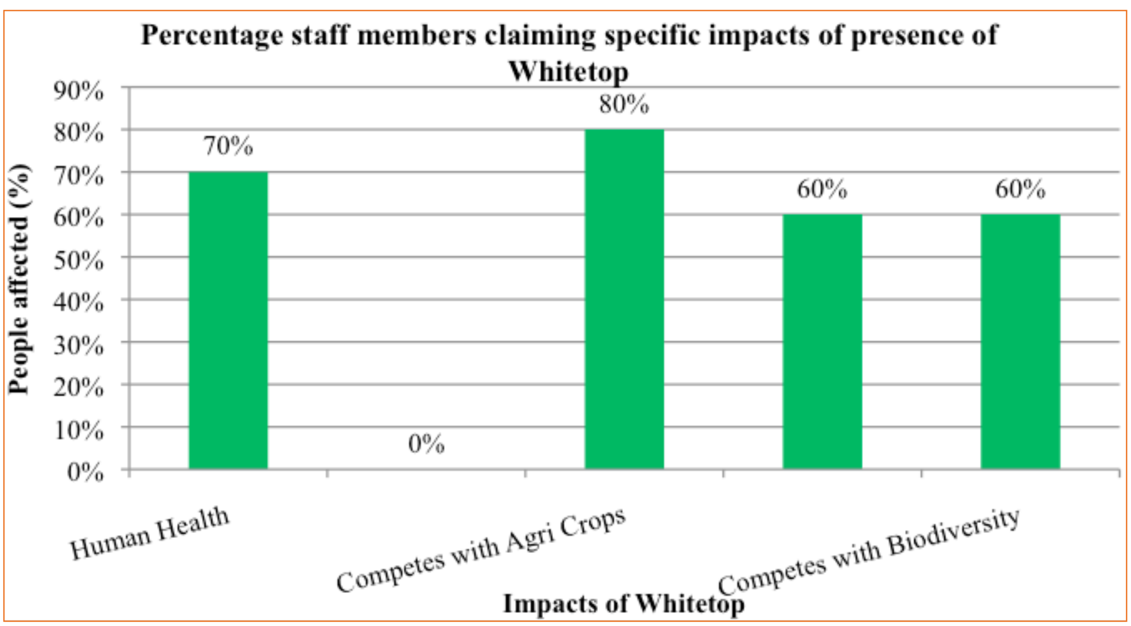


Figure 2: Bar Graph showing the percentage of WRC staff affected by the impacts of Whitetop

A total of 10 staff members were surveyed comprising 3 field assistants and 7 research technicians. The survey used can be viewed in Appendix 1. Figure 2 above shows that 70% of those surveyed were impacted health-wise, mainly though skin irritations, sneezing, runny nose and itching and 80% responded that the weed competes with agricultural crops. Six out of ten of the respondents said that Whitetop competes with both research crops and biodiversity on the WRC. The WRC houses no livestock and thus none of the respondents answered this question.

Table 2 describes the qualifying costs and benefits for each management option proposed for the control of Whitetop. It takes into consideration the value per unit for several categories for benefits and costs of each management option. Benefits are described as the monetary or non-monetary gain received because of an action taken or a decision made. Benefits regarding this project include agricultural and research crops, human health and biodiversity. Agricultural crops are those crops which are grown for domestic uses including daily consumption, medical or traditional uses whereas research crops are those used by WRC for research purposes by staff and graduate students for respective projects and not necessarily for domestic uses. Both of these variables are measured in $/kg and values were obtained from the National Agricultural Marketing and Development Corporation (NAMDEVCO), Wholesale Prices and Volumes of Agricultural Commodities, Northern Wholesale Market, Macoya for January 2014. Biodiversity in this case refers to the field museums located on the field plots of the Campus such as the sugarcane museum and herbal germplasm. These museums are simply utilized as germplasms for exhibit and illustrative purposes and do not necessarily serve as sources for domestic or research uses. Biodiversity was measured in $/m^3 and values were also obtained from NAMDEVCO as well as The Forestry Division. The human health variable accounts for visits to the doctor for conditions related to the effect of Whitetop such as skin inflammation, eczema, asthma, allergic rhinitis, allergic bronchitis and burning and blistering of the eyes.

Table 2: Table showing the Qualifying Costs and Benefits for each Management Option

				Units For Initial Period			
	Category	Units	Unit Value ($/units)	Do Nothing	Current Management	Integrated Mgmt Approach	Exploitation of Benefits
Benefits	Agricultural Crops	$/kg	$10.00	335	335	335	335
	Research Crops	$/kg	$25	8,087	8,087	8,087	8,087
	Human Health	$/report	$200	24	24	24	24
	Biodiversity	$/m^3	$50	5,280	5,280	5,280	5,280
Costs	Labour	$/day	$200	0	36	72	270
	Initial Capital Cost	$/unit	$1	0	1,775	8,670	9,000
	Herbicides	$/liter	$20	0	16	16	0
	Machine service	$/service	$200	0	0	3	0
	Research	$/hour	$30	0	0	0	600

Also depicted in table 2 are costs associated with the project which are different for each management option. Labour is measured in $/day and the value quoted is based on the salary paid by UTT for a field officer. Initial capital costs are fixed, one-time expenses for the project which include the purchase of tools (shovels, forks, spray cans, hoes), gear (boots, safety glasses, gloves, coveralls) and machinery (weed whacker). Herbicides include the purchase of chemicals, mainly Sunquat and Swiper and values are based on market prices. Machine service is the servicing of the whacker on a per service basis. Research costs including the hourly rate for the analysis of data as well as laboratory services involved in the project were obtained for UTT.

The Net Present Value (NPV) is intended to represent the overall net benefit of a project to society. The Benefit Cost Ratio (BCR) is the ratio of the NPV of benefits associated with an activity, relative to the NPV of the costs of the same activity. It indicates the benefits expected for each dollar of costs. For this study, we discounted future costs and benefits to present value using a discount rate of 5%, and the project length is assumed to be 10 years. Cost-effective (CE) analysis is an approach often used to rank intervention options when monetary benefits cannot be derived from key categories in a given project. CE is the NPV of the monetized costs of the intervention divided by the effectiveness of the project option measured in physical units. The smaller the CE ratio, the greater is the cost-effectiveness of an intervention.

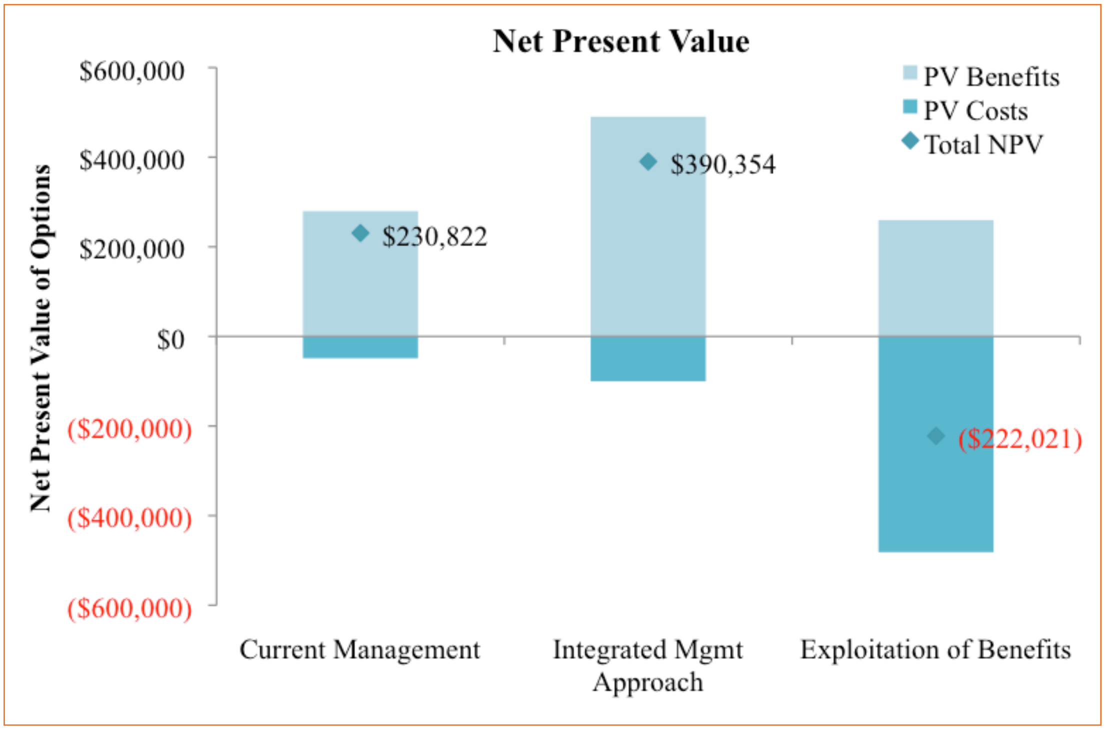


Figure 3: Bar graph showing the Net Present Value for the Management Options

Table 3: A summary of the Net Present Value, Cost Benefit Ratio and Cost Effectiveness rankings for the four management options

Scenario	Total NPV	NPV Rank	BC Ratio	BCR Rank	CE ($/Metric)	CE Rank
Do Nothing	$0	3	1.0	3	$0	-
Current Management	$230,822	2	5.7	1	-1,218	1
Integrated Management Approach	$390,354	1	4.9	2	-1,668	2
Exploitation of Benefits	-$222,021	4	0.5	4	-24,079	3

*NPV – Net Present Value; BCR – Benefit Cost Ratio; CE – Cost Effectiveness

The cost-benefit analysis for the four different management options disclosed that the CM option yielded the greatest benefit for each dollar of costs and thus was most efficient on funds. This can be seen in Table 3 and is also graphically represented in Figure 3 above. The CM option also ranked first in cost effectiveness being the option with the least cost per physical unit of benefit. The "Integrated Management Approach" (IMA) ranked first in NPV. Therefore, this option yielded the most benefit to society in terms of managing the spread of Whitetop, without considering the costs associated. Both approaches appear to be better than the DN option. The EB option however proved to require the largest investment, yield the least benefits per dollar spent and be the least cost effective management option compared to the other options.

CONCLUSION

After conducting the economic analysis for the management of *Parthenium hysterophorus* (Whitetop), it was revealed that the "Current Management" option was the option yielding the greatest benefits per dollar spent as well as the most efficient option. The "Integrated Management Approach" displayed the greatest overall benefit to society, but also incurred larger costs and may be more difficult to implement on a limited budget. The WRC is managed with a fixed budget and thus directors and decision makers must consider the cost associated with projects when deciding which option to choose. Considering this, the option with the highest benefit to cost ratio (5.7) i.e. the "Current Management" option, would be the best option for managing the spread of Whitetop at the UTT WRC. Since the CM option is also ranked as the most cost-effective selection this adds to the confidence in selecting this management technique. The success of this preliminary model will now be extended to several industrial and agricultural locations in Trinidad where the weed is persistent and difficult to manage.

REFERENCES

Ahmed, M.N., P.R. Rao, and M. Mahendar, 1988. Experimental induction of acute toxicity in buffalo calves by feeding *Parthenium hyterophorus. Indian Journal of Animal Science* 58:731-734.

Ayele.S, 2007. The Impact of Parthenium (*Parthenium hysterophorus L.*) on the range ecosystem dynamics of the Jijiga Rangeland, Ethiopia. MSc. Thesis. Haramaya University. April 2007.

Batish DR; Kohli RK; Singh HP; Kaur G. (2012) Biology, Ecology and Spread of the Invasive Weed *Parthenium hysterophorus* in India. Panjab University, Chandigarh, India.

Bridgemohan. P. (1987). A survey of the incidence of *Parthenium hysterophorus* L. in vegetable crops in Trinidad. Department of Crop Science, The University of the West Indies, St. Augustine, Trinidad and Tobago. 104 pp

Bridgemohan. P and Brathwaite, R.A.I (1987). A review of Whitetop (*Parthenium hysterophorus* L.), its biology and control. Department of Crop Science, The University of the West Indies, St. Augustine, Trinidad and Tobago. 71 pp

Bridgemohan. P. (2012). Emergence of Parthenium [*Parthenium hysterophorus L. (f)*] as a trans-border invasive weed in the Caribbean. Biosciences, Agriculture and Food Technology, Waterloo Research Campus. The University of Trinidad and Tobago.

Challa, C. (1987) Chemical control of weeds in grape (*Vitis vinifera* L.) nurseries. *Pesticides* 21, 27-29

Eiswerth, M, Johnson. W, Lewis. S, Hughes. L. The Economic Costs of Delaying Invasive Weed Control: An Illustration based on Nevada's Tall Whitetop Initiative. The University of Nevada, Reno. Special Publication -01 -08. Retrieved from http://www.unce.unr.edu/publications/files/nr/2001/SP0108.pdf

Evans. HC, Seier. M, HAvery. J, Djeddour. D, Aneja KR, Doraiswamy. S, Kauraw. LP, Singh. SP, Sreerama Kumar. P. Developing strategies for the control of Parthenium weed in India using fungal pathogens. Crop Protection Programme. Final Technical Report. ZA0007/87; R6695. CABI, UK. Retrieved from http://researchintouse.com/nrk/RIUinfo/outputs/R6695_FTR.pdf

Gupta, O.P and J.J Sharma, 1977. Parthenium menace in India and possible control measure. *FAO, Plant Protection Bulletin*, 25: 112-117.

Hanif Z; Adkins S; Prentis P; Navie S; O'Donnell C, 2011. Characterization of the Reproductive Behavior and Invasive Potential of Parthenium weed in Australia. 23rd Asian-Pacific Science Society Conference. The Sebel Cairns, 26-29 September 2011.

Haseler, W.H. (1976) *Parthenium hysterophorus* L. in Australia. *Pest Articles and News Summaries* 22, 515-517

Jayachandra, J. (1971). Parthenium weed in Mysore State and its control. Current Science 40, 568-569.

Karki. D, 2009. Ecological and Socio-economic impacts of *Parthenium hysterophorus* L. Invasion in Two Urban Areas in Nepal. Central Department of Botany, Tribhuvan University, Kirtipur, Kathmandu, Nepal. Retrieved from http://www.forestrynepal.org/images/thesis/2009_Karki%20D_Socioeconomic%20and%20ecological%20impact%20of%20parthenium%20invasion.pdf

Lalitha. P, Shivani. K, Rama Rao. R, 2012. *Parthnium hysterophorus* – An Economical Tool to Increase the Agricultural Productivity. International Journal of Life Sciences Biotechnology and Pharma Research Hyderabad, India. ISSN 2250-3137 Vol. I, No. 1, January 2012. Retrieved from http://ijlbpr.com/jlbpradmin/upload/ijlbpr_4f0b1cb6f1278.pdf

McConnachie AJ; Strathie LW; Mersie W; Gebrehiwet L; Zewdies K; Abdurehim A; Abrha A: Araya T; Nigetu L; Tadesse B; Tana T, 2010. Current and potential geographical distribution of the invasive plant *Parthenium hysterophorus* in eastern and southern Africa. Weed Research; An international Journal of Weed Biology, Ecology and Vegetation Management. 20 July 2010. DOI:10.1111/j.1365-3180.2010.00820.x

Motooka, Philip/Castro, Luisa/Nelson, Duane/Nagai, Guy/Ching, Lincoln. 2003. Weeds of Hawaii's Pastures and Natural Areas; An Identification and Management Guide. College of Tropical Agriculture and Human Resources, University of Hawaii at Manoa. 184 pp.

Pandy D.K., L.M.S. Palni S.C. Joshi, 2003.Growth production and photosynthesis of ragweed parthenium *(Parthenium hysterophorus L.). Weed Sci*.51 :191-201.

Patel. S, 2011. Harmful and beneficial aspects of *Parthenium hysterophorus*: an update. 3 Biotech (2011) 1:1-9. Springerlink.com

Sankaran, K.V. (n.d). Invasive Pest Fact Sheet – *Parthenium hysterophorus*. Asia-Pacific Forest Invasive Species Network. Kerala Forest Research Institute, Peechi, Kerala, India.

Seo. M; Yang D; Kays S; Lee G; Park K, 2009. Sesquiterpene Lactones and Bitterness in Korean Leaf Lettuce Cultivars. HortScience 44 (2):246-249. April 2009.

Swaminathan, C., R.S Vinaya Rai, K.K. Suresh, 1990. Allelopathic effect of *parthenium hysterophorus* on germination and seedling growth of a few multi purpose trees and arable crops. *J of the International Tree Crops*, 6:143-150.

Weed Management Guide. Weeds of National Importance. Parthenium Weed – *Parthenium hysterophorus*. 2003. ISBN 1-920932-12-7

APPENDICES

Appendix 1: Survey developed to elicit knowledge of presence, impacts and management of the invasive weed, *Parthenium hysterophorus* (Whitetop).

SURVEY

Target Group - Farmers/Researchers/Homeowners

Q1. Age: [ ] 20 [ ] 20-29 [ ] 30-39 [ ] 40-49 [ ] > 50

Q2. Sex: [ ] Male[ ] Female

Q3. Which category do you fall in?

[ ] Farmer [ ] Researcher [ ] Homeowner [ ] Other ______________

Q4. Is your garden plot or yard plagued by weeds?

[ ] Yes [ ] No

Q5. What weeds are currently present in your garden/research plot or area/yard? Please list.

____

____

Q6. Do you recognize this weed? [ ] Yes [ ] No

Q7. What is the name of the weed?

[ ] *Parthenium hysterophorus* [ ] Whitetop [ ] Other ______________

Q8. Is this weed present in your garden/research plot or area/yard? [ ] Yes [ ] No

Q9. Are you [ ] Positively [ ] Negatively [ ] Not impacted by this weed?

Q10. Which groups are impacted by this weed? Please tick all that apply.

Group	
People in direct contact with the weed	
People in surrounding areas	
Livestock/animals in direct contact	
Livestock/animals in surrounding areas	
Agricultural lands in surrounding areas	
Agricultural lands a distance away	
Biodiversity	
Soil	
Other	

Q11. How are humans affected?

____
____
____
____

Q12. How is livestock/animals affected by this weed?

____
____
____
____

Q13. How are agricultural or other lands affected by this weed?

____
____
____
____

Q14. What percentage of the land is impacted by this weed?

[ ] < 10%   [ ] 10-25%   [ ] 26-50%   [ ] 51-75%   [ ] > 10%   [ ] Not sure

Q15. Please list any other positive or negative impacts/effects of this weed.

____
____
____
____

Q16. What is the average cost incurred for the implementation of measures for the prevention/elimination/migration of this weed?

Q17. What is the average cost incurred for medical bills associated with human impacts due to this weed?

Q18. What is the average cost incurred for loss of agricultural produce due to impacts of this weed?

Q19. What is the average cost incurred for loss of livestock or livestock products due to impacts of this weed?

Q20. Have you taken any measures to prevent/eliminate/mitigate the impacts of this weed?

[ ] Yes [ ] No

Q21. What are some of these measures?

Q22. How effective are these measures at preventing impacts of this weed?

THANK YOU FOR YOUR PARTICIPATION

An Economic Analysis of Three Management Options of the Giant African Snail (*Achatina fulica*) in Trinidad and Tobago

Allan Balfour and Nazia Ali

Abstract

In October 2008, the giant African snail (*Achatina fulica*) was introduced to Trinidad. The highly invasive pest had a potential to cause serious damage in the agricultural, health and environmental sectors and also threatened international trade. The pest was confined to the Diego Martin Valley, north western Trinidad. These factors initiated a highly intensive eradication programme led by the Research Division in association other divisions and external agencies. The programme was multifaceted and comprised of weekly baiting and monitoring operations, a public awareness programme, field sanitation, surveillance and the development of legislation. By the end of 2012 a total number of 34,747 snails were collected and an average annual cost of TT$ 1,520,000.00 incurred. After successful containment of the giant African snail (GAS) for 5 years within the Diego Martin Valley (the Eradication Zone), the pest was discovered in two towns east of the containment. Hence the management programme was considered to address the new dynamics of the pest outbreak.

The cost benefit analysis of the giant African snails management included the collation of data from several agricultural agencies and a survey of residents. Most preliminary results reflected that the public was in favour of some control over the GAS and that it was damaging to aspects of the local environment. The data for the cost benefit analysis of the management option was 40% less than that of the eradication option. The results from the analysis highlighted the eradication programme as favourable using the Net Present Value, whereas the management option was preferred using the Cost Benefit Ratio. Both options were preferred over no management.

1.0 Introduction

The giant African snail *Achatina fulica,* Bowdich (Mollusca: Achatinidae) is native to East Africa but is now widely distributed in the Indo-Pacific region. It is an invasive alien species (IAS) which was reported to be one of the world's worst 100 IAS (AQIS, 2008). Since the 1980s the pest has been present in the Caribbean region, with a wide distribution among the Lesser Antilles.

Although it had been marked as a regulated pest for Trinidad and Tobago, the pest was introduced into Trinidad in the Diego Martin Valley in October 2008. The isolation of the pest within in a single residential area created a potential for the eradication. Hence, an eradication programme was developed by the Research Division of the Ministry of Food Production, using USDA's "New Pest Guidelines: Giant African Snails" as a guide.

The giant African snail (GAS) Eradication Programme adopted an integrated approach based on the location and biology of the snail, environmental and ecological factors and topography. The components of the progrmme included baiting, monitoring and removal of snails which directly impacted on population levels, employed with public awareness, surveillance, field sanitation and legislation.

By 2012 the pest was well distributed throughout the highest populated districts of the Diego Martin Valley. The eradication activities by 2013 targeted four (4) core zones and twenty- eight (28) satellite areas. *A. fulica* continued to be successfully confined to the Diego Martin Valley, with the rest of the island and Tobago remaining pest free, by the end of 2013.

The total number of snails collected was 34,747 from October 2008 to December 2012. By 2013, due to the GAS Eradication Programme, data on GAS population levels showed a marked reduction of 40% between 2011 and 2013.

The total expenditure of the GAS Eradication Programme from 2009 to 2012 amounted to TT$6,080,000. The total average annual expense for that period was $1,520,000.

In early 2013, approximately five (5) years after successful containment of the snail in the Diego Martin Valley, the GAS was discovered outside of the Diego Martin Valley. Snails collected amounted to 20,146 snails in Mt. Lambert and in Maraval areas, which were farming and residential respectively.

The spread of the pest to other areas had seriously placed a strain on the resources required to maintain the programme. The movement of soil and landfill was suspected to be the carrier of this pest. This weakness in the containment of the pest continued to be a challenge, especially in the absence of completed legislation and television advertisement.

The introduction of the GAS to Florida USA in 1966 instigated an eradication programme costing US $1,000,000. The mitigating efforts were said to have saved the country US 11,000,000 annually (USDA 2011). The economic analysis of three management options (eradication, management and no action) should serve to inform on the validity of choosing one of these to implement, based on the best economic value and potential for efficiency.

2.0 Objectives

2.1 General Objective - To compare the economic viability of the giant African snail Eradication Programme against the options of a management programme and without mitigation efforts, using a cost-benefit analysis

2.2 Specific Objectives –

- Collate data of costs and benefits of three options
- Plug information into the Cost Benefit Analysis Toolkit provided in IAS Workshop
- Analyze the results of the data generated from the Toolkit
- Evaluate the performance of the GAS Eradication Programme and compare via cost benefit analysis to a management programme and no management
- Use information to inform on strategies towards validating an approach

3.0 Biological and Ecological Factors

The average life span of *A. fulica* is 3-5 years with a maximum of 9 years. Adults are hermaphrodite, but reciprocal copulation is required to produce viable eggs. The snails reach sexual maturity in less than 1 year. Fertilized eggs can be laid repeatedly after a single mating (Robinson 2002).

Adult snails can begin laying eggs at 5-6 months. Laying can begin 8 - 20 days after copulation. Eggs are laid in batches of 10 – 400 and hatch by 11 days. The juveniles feed on their own shell and then search for other food sources. They then burrow and remain underground for a 5 – 15 days. Juveniles remain close to the nesting area for a few weeks. They feed on plant material primarily and tend to explore feeding on decaying material as they mature.

Species within the family *Acatinidae* need significant amounts of calcium for shell formation and successful reproduction. Many sources are found in their habitats such as calcium rich soils, cement structures and even other snails within large populations.

Aestivation can occur in conditions deficient of moisture. However it is believed that aestivation can also be cyclical. During harsh conditions snails burrow 10 – 15 cm deep in soil; and can become inactive for 1 year. During this period it can lose up to 60% of body weight (USDA 2007). High infestations are known to develop due to condition with high moisture. The snail is active mostly at night, GAS can disperse at an estimated rate of 125 meters per month (Tomiyama and Nakane 1993).

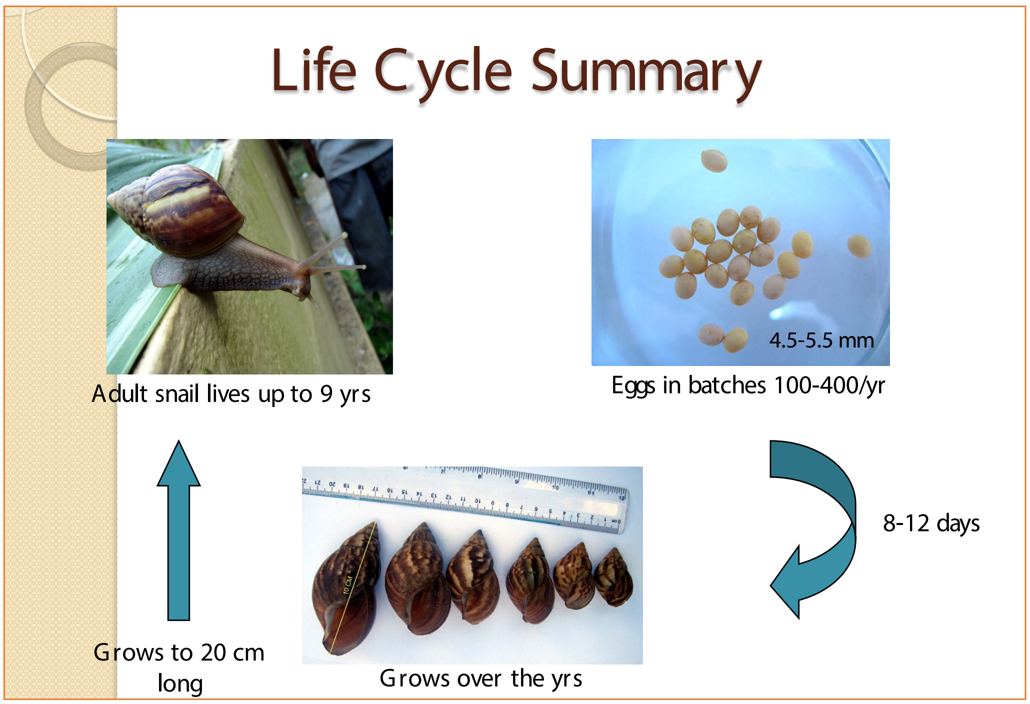


Figure 1 – Life cycle of *A. fulica*

4.0 Potential Treats/ Problems

The GAS has shown the potential to cause serious damage and induce high costs to the country. Due to its highly invasive, populations can increase rapidly as one fertilized adult can lay up to 1200 eggs annually. Passive dispersal is easily facilitated by human movement and the movement of soil, plant material and debris.

The various sectors can be affected in the following ways:-

- Agricultural and horticultural production - It can feed on over 500 plant species including for breadfruit (*Artocarpus sp*.), cassava (*Manihot esculenta*), cocoa (*Theobroma cocao*) and most species of legumes and curcubits (Lambert, 1999).
- Public Health - It is a potential host for the rat lung worm (*Angiostrongylus cantonensis)* which can spread eosinophilic meningitis to humans. This poses as one of the main concerns for the public as the pest has infested residential areas and subsequently farming areas.
- Environmental – It defaces public and private areas by feeding on concrete and limestone based structures and defecation trails on properties.

- International Trade –The International Plant Protection Convention (IPPC) dictates that member states conform to International Sanitary and Phytosanitary Measures. Eradication or containment of the GAS would have placed Trinidad and Tobago in a position to implement ISPM #4 (Requirements for the Establishment of Pest Free Areas), thereby strengthening its position in international trade.

5.0 Methodology

The potential problems, potential pest pathway, cost and benefits associated with the introduction of the GAS to Trinidad and Tobago were listed and used to define the options according to Table 1. Three (3) options to address this pest infestation were identified as follows:

1) No management
2) Management
3) Eradication

Table 1: Management Options for the GAS Infestation

Option #1 - Without Any Management
Management : No management applied Invasive Pathway: The snail quickly establishes high populations due to high level of proliferation. Ecological habitats include residential areas, abandoned lots, fresh water estuaries, and agricultural plots. Infestation of entire country due to flooding, rivers, movement of material and well developed roadways Key Stakeholders: Government, Private Sector and The Public Costs: No management costs Benefits: No benefits are produced from this option due to damages incurred Impacts: Adverse impact on agriculture, the environment, human health. Competition with local mollosc and polyphagous activity could impact negatively
Option # 2 - Management
Management : Moderate use of chemical application and collection, public awareness, field Sanitation, surveillance and legislation Invasive Pathway: The population of the snail is outside of the initial containment are, but is reduced to 50% - 75% of that under option #1. Incidence of dispersal is reduced by 75%. Key Stakeholders: Government and The Public Costs: 1 vehicle, Spraying equipment, computers, GIS Equipment (initial year); labour, chemicals, safety gear and material, equipment, Public Awareness, testing of Rat lungworm, research activities, surveys Benefits: Providing some reduction of damages in the related sectors below a perceived economic threshold and reduce spread of the pest countrywide
Option # 3 - Eradication
Management: Intensive use of chemical application and collection, public awareness, field Sanitation, surveillance and legislation Invasive Pathway: The population of the snail is limited to the containment area and subsequently reduced to zero of that under option #1. Dispersal is mitigated Key Stakeholders: Government and The Public Costs: More regularity and amounts than option #2; 1 vehicle, Spraying equipment, computers, GIS Equipment (initial year); labour, chemicals, safety gear and material, equipment, Public Awareness, testing of Rat lungworm, research activities, surveys Benefits: Prevention of any damages from infestations pest countrywide, reducing health risks, and trade embargos.

The procedure for the Cost Benefit Analysis (CBA) was derived from the "Training Course on Economic Analyses of Invasive Alien Species in the Caribbean" which was held 18th to 21st March 2013, facilitate by CABI. A schedule of activities guided the outputs to be produced. These activities took place for eight months which climaxed with the production of the Cost Benefit Analyses. The benefits and costs items were first submitted to the facilitating team and online conference sessions were conducted between the participants and the analytical experts to ensure that the information solicited was correct.

Data were sourced according to the costs and benefits of three options of management to address the problem of the GAS Infestation in Trinidad. Primary and secondary data were solicited (Table 3) and a questionnaire developed used to generate information from sixty-three (63) affected residents (Appendix I).

The costs and benefits were valued. Table 3 list the values for the costs and benefits of the three management options. The number of units within the Management Programme is based on a 40% reduction of the Eradication programme. Data was inserted into the Toolkit developed by Landcare Research of New Zealand and facilitated by Dr. Adam Daigneault. The analysis generated a full economic analysis with indicators such as the Net Present Value (NPV) and Cost Benefit Ratio (CBR). The management options were compared and ranked using Benefit-Cost Ratio. Recommendations were stated based on results of the economic analysis, the status and distribution of the pest and the resource capacity of the implementing agency.

A sensitivity analysis was conducted. This served to test the robustness of estimates with changes to variable assumptions conducted. Three (3) ranges of effectiveness were used as displayed in Table 5. An initial assumption of 20% of carrying capacity was examined and a discounted rate of 8%.

Table 2: Overview of Economic Analysis

Project/Invasive:	Giant African Snail
Duration of Project (years)	25
Project Area	5128 km2
Discount Rate	8%

Table 2 above displays the project area used for this CBA was 5128 sq. km (area of Trinidad and Tobago) with special attention to the Diego Martin Valley. The project period was assessed up to 25 years at 8% discounted rate.

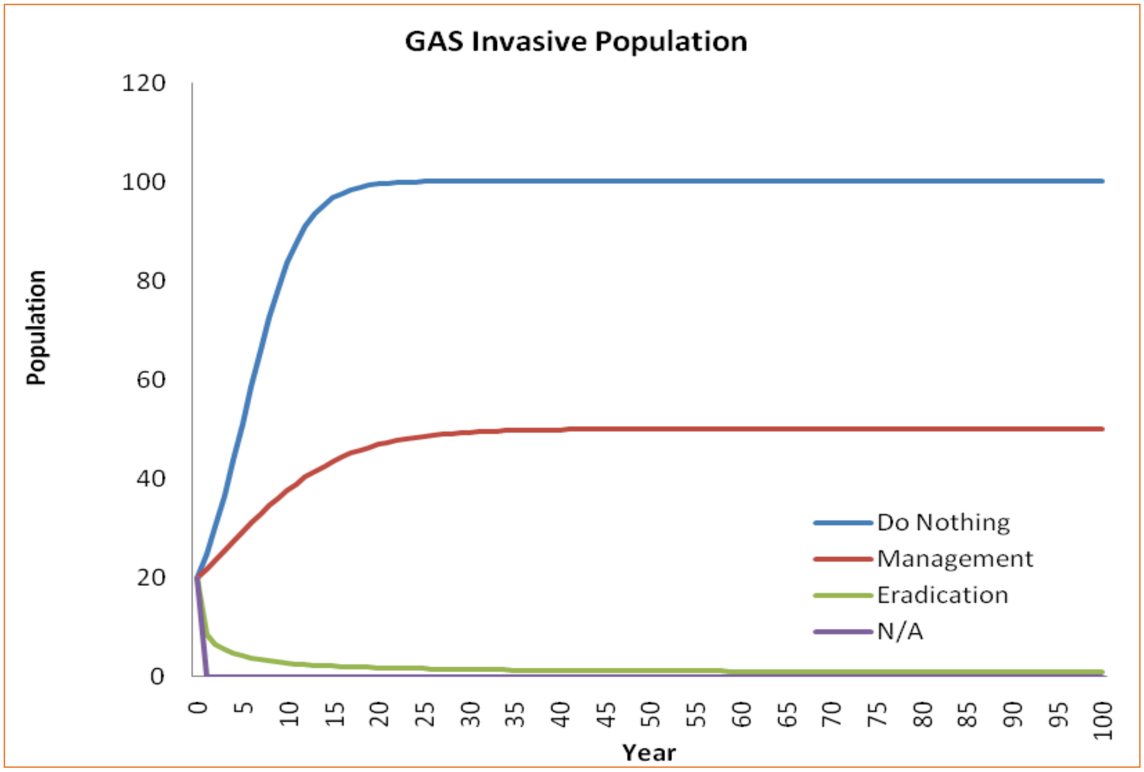


Figure 2: Projection of GAS Populations among 3 option

The invasive potential of the GAS was represented in Figure 2. The projection of the population for the GAS showed a steady increase with management and with no management. The results indicated that the increase to maximum capacity will take approximately 15 years with no management and 20 years with management. The eradication option shows a decrease in population to achieve effectual zero population at approximately 25 -30 years.

Table 3 – Annual Costs and Benefits for three options

				Units For Initial Period			
	Category	**Units**	**Unit Value ($/units)**	**Do Nothing**	**Management**	**Eradication**	**N/A**
Benefits	Crops and ornamentals	plant	$9.80	500	500	500	500
	Native plants	plant	$106	18	18	18	18
	Native snails	snail	$65	35	35	35	35
	Health	meningitis test	$323	200	200	200	200
	Property value	square ft	$25	25,000	25,000	25,000	25,000
Costs	Annual Labour	man days	$208	0	753	1883	0
	Initial Capital Costs	units	$1	0	165313	316962	0
	Annual Chemicals	litres	$73	0	672	1680	0
	Annual Marketing	campaigns	$828,256	0	0.40	1	0
	Other Annual Costs	units	$1	0	52880	104640	0

7.0 Results

The results generated by the Toolkit (Landcare Research) revealed that the eradication option displayed a higher total net benefits and total net costs, than the management option (Table 4). In addition, the Net Present Value was higher for the eradication option at $13,739,733 than the management option at $8,655,589.

However, management yielded the highest Benefit-Cost Ratio 3.4. Both are preferred over the no management option.

Table 4 Summary of Benefit-Cost Analysis (r = 8%, t= 25 years)

Option	PV Costs	PV Benefits	Total NPV	Benefit-Cost Ratio
Do Nothing	$0	$0	$0	1.0
Management	$3,570,879	$12,226,468	$ 8,655,589	3.4
Eradication	$9,880,890	$ 23,620,623	$13,739,733	2.4

The sensitivity analysis yielded results which indicated that the eradication option had the highest ranking throughout, with the except at the highest carrying capacity and at 2.0 x effectiveness rating, where the management option was highest (Table 5).

Table 5: Sensitivity Analysis at 8% Discounted Rate

Rank Summary (#1 = most preferred, #3 = least preferred)				
Option	Effectiveness	10%	20%	40%
Management	0.5 x base	2	2	2
	1.0 x base	2	2	2
	2.0 x base	2	2	1
	Effectiveness	10%	20%	40%
Eradication	0.5 x base	1	1	1
	1.0 x base	1	1	1
	2.0 x base	1	1	2

The assessment of the monatry damge incurred as a result of the three options revealed a great difference in values among the options. At the 20 year mark, the no managemenr option incurred the approximated $2,000,000 more in damges than the manamgenmet option. The eradication option incurred the least cost. By year 20, the pest would be eradicated and hence would incurr no cost.

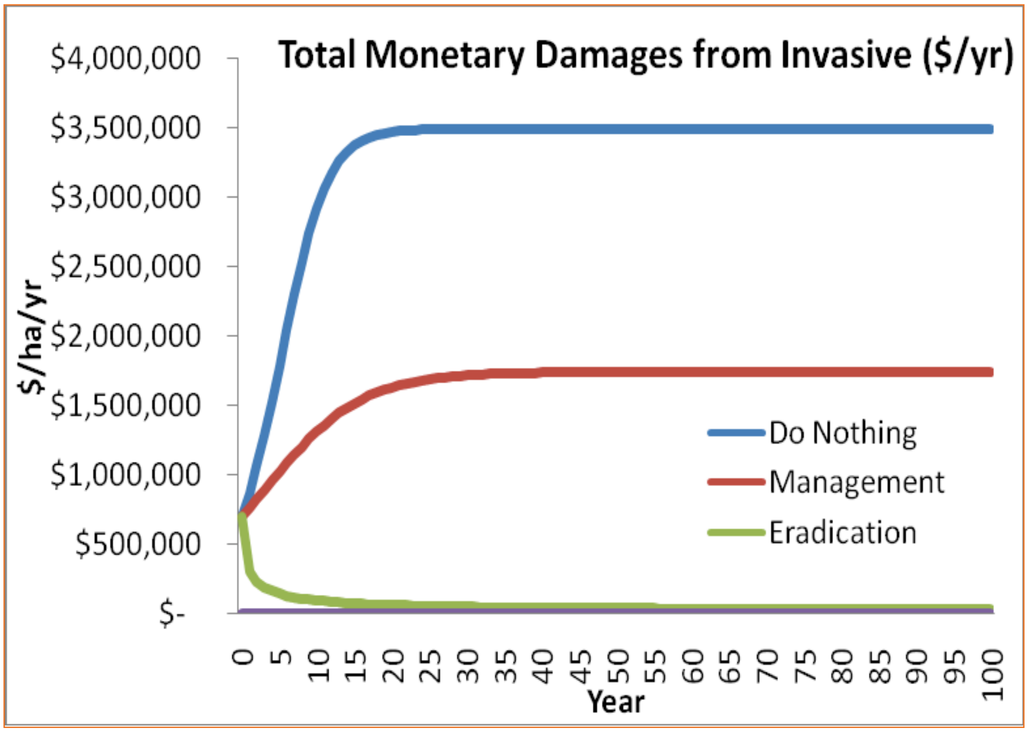


Figure 3: Total monetary damages from the three options

8.0 Discussion

The summary of the Cost Benefit Analysis gave a clear indication that the eradication and management options were preferred over the no management option. Using the Net Present Value the eradication option generated a more favourable value, whereas the management option had a higher benefit cost ratio. While this indicated that the latter option would generate the highest value of benefits for each dollar spent, the eradication programme had a faster resolution of the pest problem and incurred less damage in monetary values.

According to figure 4, the do nothing option will create a potentially damaging repercussions based on the highly prolific nature of the pest and the hazard it can manifest.

Both options on the Sensitivity Analysis yielded a positive Net Present Value, which is preferred over no management. In addition, eradication is preferred over management with the exception of the scenario that assumed high initial population, high effectiveness, and a high discount rate.

The high NPV yielded from the eradication option of $13,739,733 was largely due to the high PV Benefits. The difference between the PV Benefits of the eradication and management options is higher than the same comparative value between the PV Cost. This comparative difference led to the NPV of eradication generating a higher value than the management option.

The Cost Benefit Ratio was higher in the management option. Both management and eradication options yielded a CBA greater than 1, which inferred that they were both were viable. The higher investment of the eradication programme not only yields comparatively a higher benefit than the management option but brought a faster a more permanent solution to the pest problem.

9.0 Conclusion

The Economic Analysis is a sound avenue to evaluate the potential and feasibility of a project. The Landcare Toolkit which conducted the Cost Benefit Analyses of the three management options generated useful results and indicators which allowed for effective comparisons among the options.

The values of the Cost Benefit Ratio showed that both the eradication and management options are viable, with the latter yielding a more favourable value. Management also can be a preferred option based on the lower cost incurred to operate the project compared to eradication (Table 2). This option may favour with some policy makers if resources are limited.

Using the Net Present Value, eradication was the preferred option. This option is recommended in view of a potentially shorter period of operation and the eventual removal of the pest within the country. According to the qualitative results of the survey (Appendix I), eradication was a preferred end-point and also maybe more appealing to the crop protection and environmental personnel, based on high values of monetary damages incurred with no management and management options (Figure 4). The eradication project can be selected as the recommended option to address the GAS infestation present in Trinidad, if resources are not a limiting factor and based on the results generated from the economic analysis.

10.0 References

AQIS 2008, Bulletin May / June

APHIS / USDA 2011, "Giant African Snails Invade Florida", www.APHIS.USDA.gov

Lambert M. 1999. The Giant African Snail Plant Protection Service Secretariat of the Pacific Community, Pest Advisory Leaflet No. 6

Robinson, D.G. 2002. Introduction to Giant African Snail. Presentation to Giant African Snail Workshop. Inter–American Institute for Cooperation Agriculture and Ministry of Agriculture. Forestry and Fisheries, Rodney Bay, St Lucia, December 4-5 2002

Tomiyama, K. and M. Nakane. 1993. Dispersal patterns of the giant African snail, *Achatina fulica* (Ferussac) (Stypommatophora: Achatinidae), equipped with a radio transmitter. Journal of Molluscan Studies 59: 315-322

USDA, APHIS. 2007. New Pest Response Guidelines. Giant African Snails: Snail Pests on the Family Achatinidae

Appendices

Appendix I - Total for Responses for Qualitative Questions re Survey on Giant African Snail Cost/Benefit Analysis

No.	Question 5	Question 6	Question 7	Question 9
	If you had to control the snail with pesticides, physical collection/ hiring an expert etc., how much would you spend a month	What is the average cost of a plant that may be eaten by the snail?	If you had to test for the Rat Lungworm or meningitis, how much would you spend per visit?	What value do you place on a local snail to preserve it?
1	200.00	150.00	200.00	100.00
2	300.00	200.00	500.00	0.25
3	250.00	400.00	1,000.00	-
4	200.00	200.00	300.00	300.00
5	-	5.00	200.00	-
6	200.00	300.00	250.00	-
7	200.00	50.00	300.00	2.00
8	200.00	20.00	250.00	-
9	-	250.00	150.00	-
10	-	100.00	300.00	-
11	-	150.00	-	-
12	-	-	400.00	-
13	-	300.00	-	-
14	-	-	-	-
15	100.00	100.00	100.00	50.00
16	200.00	6.00	350.00	200.00
17	600.00	150.00	200.00	-
18	-	40.00	-	-
19	50.00	-	100.00	-
20	300.00	200.00	200.00	-
No.	Question 5	Question 6	Question 7	Question 9
	If you had to control the snail with pesticides, physical collection/hiring an expert etc., how much would you spend a month	**What is the average cost of a plant that may be eaten by the snail?**	**If you had to test for the Rat Lungworm or meningitis, how much would you spend per visit**	**What value do you place on a local snail to preserve it?**
21	100.00	50.00	100.00	-
22	100.00	50.00	400.00	-
23	-	20.00	300.00	-
24	100.00	50.00	300.00	-
25	200.00	150.00	300.00	-

26	200.00	70.00	200.00	-
27	200.00	150.00	400.00	-
28	-	50.00	-	-
29	-	150.00	200.00	-
30	100.00	50.00	200.00	-
31	-	20.00	-	-
32	100.00	50.00	100.00	-
33	200.00	50.00	200.00	50.00
34	100.00	25.00	200.00	1.00
35	100.00	-	200.00	-
36	-	100.00	-	-
37	-	200.00	500.00	-
38	100.00	70.00	200.00	-
39	-	30.00	-	-
40	200.00	75.00	250.00	-
41	200.00	-	300.00	1.00
42	300.00	50.00	500.00	5.00
No.	**Question 5**	**Question 6**	**Question 7**	**Question 9**
	If you had to control the snail with pesticides, physical collection/hiring an expert etc., how much would you spend a month	**What is the average cost of a plant that may be eaten by the snail?**	**If you had to test for the Rat Lungworm or meningitis, how much would you spend per visit**	**What value do you place on a local snail to preserve it?**
43	100.00	20.00	2,000.00	-
44	100.00	50.00	200.00	-
45	200.00	25.00	200.00	0.50
46	500.00	300.00	250.00	-
47	-	50.00	500.00	-
48	400.00	-	300.00	-
49	300.00	-	150.00	-
50	-	-	-	-
51	-	20.00	-	-
52	300.00	-	-	-
53	-	-	-	-
54	200.00	-	-	-
55	-	-	-	-
56	-	-	-	-

57	200.00	-	-	-
58	-	-	-	-
59	-	-	-	-
No.	**Question 5**	**Question 6**	**Question 7**	**Question 9**
	If you had to control the snail with pesticides, physical collection/hiring an expert etc., how much would you spend a month	**What is the average cost of a plant that may be eaten by the snail?**	**If you had to test for the Rat Lungworm or meningitis, how much would you spend per visit**	**What value do you place on a local snail to preserve it?**
62	-	-	-	-
63	100.00	-	300.00	-
Totals	**7500**	**4546**	**13550**	**709.75**
Ave.	202.70	105.72	322.62	64.53

Appendix II

Values for Annual Costs and Benefits – Eradication Programme

Cost/Benefit Category	Physical Unit	Monetary Unit	Estimation Approach	Source
Benefits				
Reduced losses to crops and ornamentals (Ave cost of 3 vegetable crops)	Kg/ha	$/kg 9.8	Farmers and market survey	Agricultural agencies, Ministry of Food Production, Agri- Census
Protection of native plant species	Unit /plant (each)	$105.72/plant	Market surveys	Agricultural agencies, Forestry Division, Valuation Unit
Protection of native snail species	Unit/ snail	$64.53/snail	Household survey, biologists	
Reduced expenses related to meningitis problems	Per test	$322.62/test	surveys	Health testing units
Reduce damages and devaluation of property	Sq feet	$/damaged sq ft 25	Market surveys	Valuation Unit
Costs				
Labour	Man days/yr 1883	$/day/worker 208	Market Ave	Ministry of Food Prod'n
Chemicals -Bait -Liquid pesticide	Litres/unit 1440 240	$/litre 60 150	Market Ave.	Input suppliers
 Safety Gear Materials	Units 64 222	$/item 598.2 54.73	Market Ave.	Input suppliers
Equipment Computers *Vehicles –purchase Vehicles -maintenance	6 1 1 2	1921.25 5000 250,000 50,000		

Cost/Benefit Category	Physical Unit	Monetary Unit	Estimation Approach	Source
Public awareness Tv Ads Radio Ads Fliers, posters	units/ spots 1170 744 1000	$/spots 636.54 103.5 6.5	Markets Ave.	Publishing & media houses
Testing parasites (Shipping)	Lbs 72	$/lbs 40	market interviews	Veterinary laboratory & Fed Ex
Research /surveys	Per project 1	$/project 1760.2	surveys	Ministry of Food Production

*Initial cost in year 1 alone

Management Programme - Value for Annual Costs and Benefits

Cost/Benefit Category	Physical Unit	Monetary Unit	Estimation Approach	Source
Benefits				
Reduced losses to crops and ornamentals (Ave cost of 3 vegetable crops)	Kg/ha	$/kg 9.8	Farmers and market survey	Agricultural agencies, Ministry of Food Production, Agri- Census
Protection of native plant species	Unit /plant (each)	$105.72/plant	Market surveys	Agricultural agencies, Forestry Division, Valuation Unit
Protection of native snail species	Unit/ snail	$64.53/snil	Household survey, biologists	
Reduced expenses related to meningitis problems	Per test	$322.62/test	surveys	Health testing units
Reduce damages and devaluation of property	Sq feet	$/damaged sq ft 25	Market surveys	Valuation Unit
Costs				

Cost/Benefit Category	Physical Unit	Monetary Unit	Estimation Approach	Source
Labour	Man days/yr	$/day/worker	Market Ave	Ministry of Food Prod'n
	753	208		
Chemicals	Litres/unit	$/litre	Market Ave.	Input suppliers
-Bait	576	60		
-Liquid pesticide	96	150		
	Units	$/item	Market Ave.	Input suppliers
Safety Gear	256	598.2		
Materials	89	54.73		
Equipment	2.5	1921.25		
Computers	0.5	5000		
Vehicles –purchase	0			
Vehicles -maintenance	1	50,000.00		
Public awareness	units/ spots	$/spots	Markets Ave.	Publishing & media houses
TV Ads	468	636.54		
Radio Ads	298	103.5		
Fliers, posters	400	6.5		
Testing parasites (Shipping)	Lbs	$/lbs	market interviews	Veterinary laboratory & Fed Ex
	28	40		
Research /surveys	Per project	$/project	surveys	Ministry of Food Production
	1	1760.2		

Appendix III

Net Present Value (TTD) of Giant African Snail management in Trinidad and Tobago for all sensitivity analyses

Discount Rate =4%				
		Initial Population (relative to max)		
Option	Effectiveness	10%	20%	40%
Management	0.5 x base	$ 26,224,676	$ 9,902,036	$ 1,744,499
	1.0 x base	$ 32,811,701	$ 15,250,427	$ 5,695,637
	2.0 x base	$ 42,432,579	$ 9,902,036	$ 10,774,054
Eradication	0.5 x base	$ 48,938,854	$ 22,915,676	$ 7,873,519
	1.0 x base	$ 50,978,060	$ 25,455,627	$ 9,419,147
	2.0 x base	$ 52,637,778	$ 21,300,655	$ 9,502,168
Discount Rate =8%				
		Initial Population (relative to max)		
Option	Effectiveness	10%	20%	40%
Management	0.5 x base	$ 14,986,822	$ 5,676,560	$ 711,219
	1.0 x base	$ 18,425,906	$ 8,655,589	$ 3,072,943
	2.0 x base	$ 23,706,768	$ 5,676,560	$ 6,282,288
Eradication	0.5 x base	$ 26,122,327	$ 11,853,939	$ 3,283,918
	1.0 x base	$ 27,545,237	$ 13,739,733	$ 4,491,953
	2.0 x base	$ 28,790,911	$ 10,739,958	$ 4,549,714
Discount Rate =12%				
		Initial Population (relative to max)		
Option	Effectiveness	10%	20%	40%
Management	0.5 x base	$ 8,987,085	$ 3,367,801	$ 162,503
	1.0 x base	$ 10,905,945	$ 5,147,594	$ 1,680,009
	2.0 x base	$ 14,013,588	$ 3,367,801	$ 3,861,483
Eradication	0.5 x base	$ 14,470,956	$ 6,171,424	$ 991,193
	1.0 x base	$ 15,530,872	$ 7,655,099	$ 1,984,066
	2.0 x base	$ 16,521,093	$ 5,351,985	$ 2,027,278

Appendix IV

Management Options Evaluated for Economic Analysis

Management Option	Name
Do Nothing	Do Nothing
Option 1	Management
Option 2	Eradication
Option 3	N/A

Qualitative Description of Project Benefits and Costs

Category	Units	
Crops and ornamentals	plant	
Native plants	plant	
Native snails	snail	
Health	meningitis test	
Property value	square ft	
Initial Capital Costs	units	safety gear, computers, vehicles and other 'one time' purchases
Annual Labour	man days	
Annual Chemicals	litres	
Annual Marketing	campaigns	
Other Annual Costs	units	

Monetary Unit Values of Project Benefits and Costs

Category	Unit Value ($/units)	
Crops and ornamentals	9.80	
Native plants	105.72	
Native snails	64.53	
Health	322.62	
Property value	25.00	
Annual Labour	208.00	
Initial Capital Costs	1.00	
Annual Chemicals	72.86	Weighted Average ($60/l) of Bait and liquid pesticide ($150/l)
Annual Marketing	828,256	
Other Annual Costs	1.00	

Physical Units of Damages Created by Invasive in Initial Project Period

Category	Physical Units
Crops and ornamentals	500
Native plants	18
Native snails	35
Health	200
Property value	25000

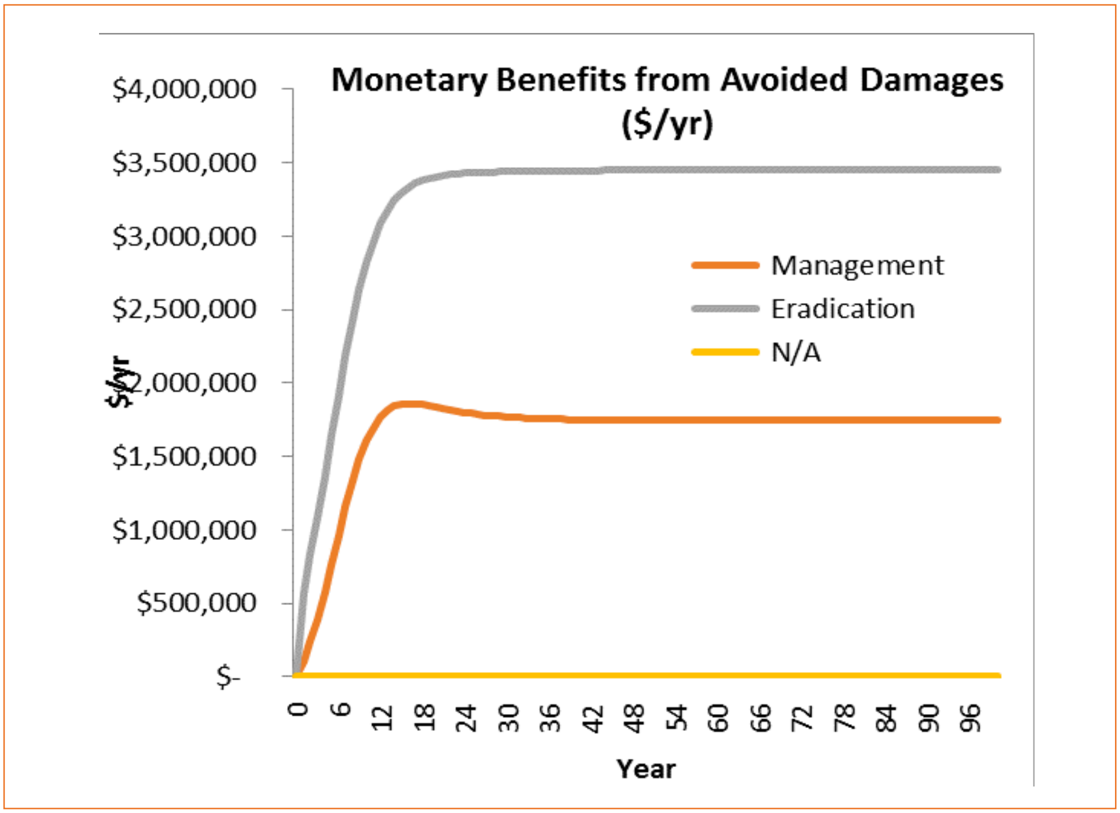
Physical Units of Costs Incurred by Managing the Invasive Species

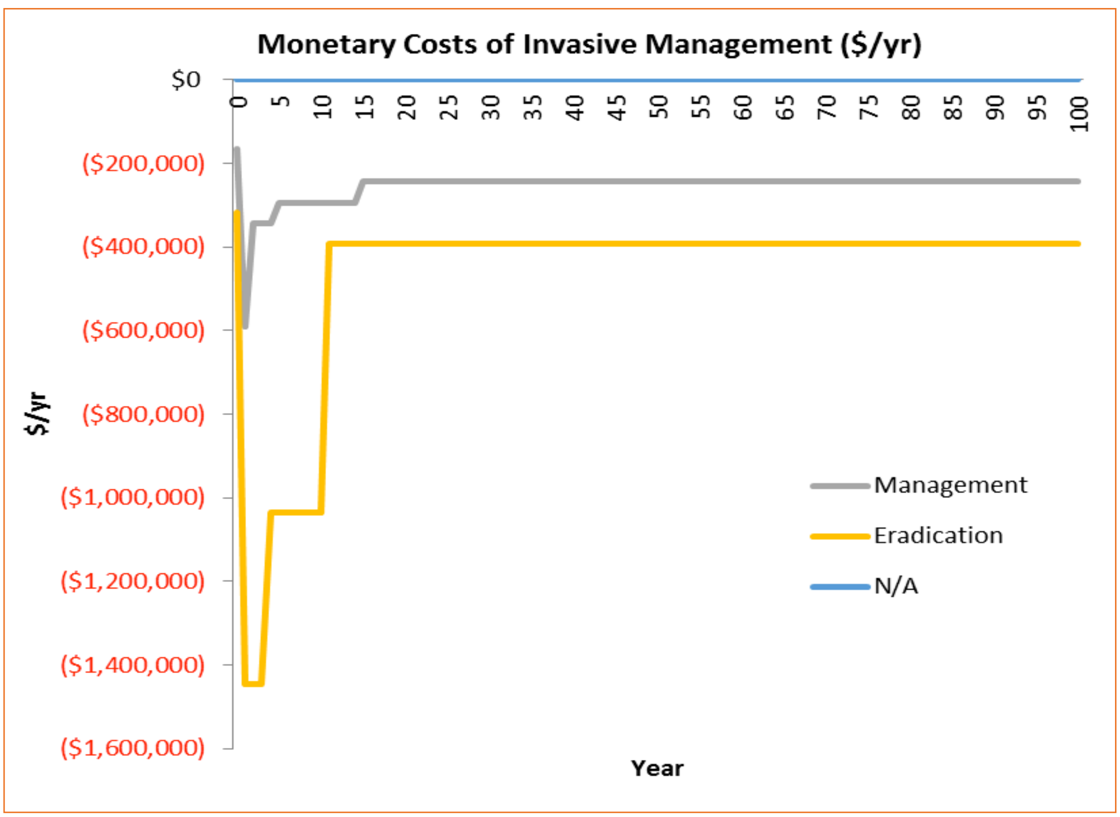
Category	Management Option			
	Do Nothing	Management	Eradication	N/A
Annual Labour	0	753	1883	
Initial Capital Costs	0	165313	316962	
Annual Chemicals	0	672	1680	
Annual Marketing	0	0.4	1	
Other Annual Costs	0	52880	104640	

Invasive Population Growth Function (Logistic Growth Curve)

Management Option	n_0	b	C	N_Max
Do Nothing	20.00	0.3		100.00
Management	20.00	0.15		50.00
Eradication	20.00	0.03		1.00
N/A				

Appendix V


Monetary Benefits from Avoided Damages ($/yr)
$4,000,000
$3,500,000
$3,000,000
$2,500,000
$2,000,000
$1,500,000
$1,000,000
$500,000
$-
$/yr
0 6 12 18 24 30 36 42 48 54 60 66 72 78 84 90 96
Year
Management
Eradication
N/A


Monetary Costs of Invasive Management ($/yr)
$0
($200,000)
($400,000)
($600,000)
($800,000)
($1,000,000)
($1,200,000)
($1,400,000)
($1,600,000)
$/yr
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
Year
Management
Eradication
N/A

An Economic Assessment of the Impact of *Raoiella Indica* on the Nariva Swamp, Trinidad and Tobago

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Introduction

The Nariva Swamp is the largest freshwater wetland in the Caribbean. It is one of two local wetlands that are of international importance under the Ramsar Convention and has been deemed as an environmentally sensitive area. This wetland is located in central Trinidad on its east coast. It is a truly diverse ecosystem that supports a wide array of flora and fauna, some of these rare and endangered.

The swamp is comprised of a wide array of vegetation too. Some of these are palm forest, herbaceous swamp and freshwater marsh which provide habitats for various monkeys, reptiles, amphibians and birds. It is common to see and hear flocks of parrots and macaws flying in and out of the swamp. These birds are heavily dependent on the palm population of the swamp for food and habitat. Particularly the Moriche and Palmiste palms are sought by these native birds. Coconut palms are also extremely prevalent throughout this wetland. These are often harvested by villagers from nearby communities and are either consumed or sold in markets. These palms have influenced the appearance of the Nariva Swamp and its environs for many years, as they often line roadways through the swamp and along the east coast which is a boundary for this wetland. To combat further destruction of the Nariva Swamp, many government-assisted projects have been launched, targeted to conserve its biodiversity. One such project was the Nariva Restoration Initiative of 2007, which focused on increasing understanding of hydrology within the swamp and recommending improvements to existing conditions to facilitate sustainable use of the Nariva Swamp (Carbonell et al. 2007; NSRI 2008). The economic assessment performed in this study will add to the pool of information on the swamp and is also aimed at highlighting and valuing damages to the swamp, to promote conservation efforts.

Importance of Wetlands

Wetlands are bodies of water that can include mangroves, rivers, lakes and flooded forests. These areas are generally home to large plant and animal populations. Wetlands such as the Nariva Swamp are some of the most dynamic and intricate ecosystems. These bodies of water are often a mix of freshwater and sea water, as they are generally estuaries (Barbier, Acreman, and Knowler 1997). This blend of conditions increases the intrinsic value of wetlands and the role they play in regulating ecology. As development occurs though, wetlands are often marginalised in favour of other economic activities (Stuip, Baker, and Oosterberg 2002).

Wetlands have a major function in controlling water flow, which is often received via runoff water and flooding. When these bodies of water are inundated by floodwaters, mangrove wetlands also serve as filtration systems for debris, chemicals and other pollutants. Pesticides and fertilizers carried with floodwater are removed by the existing bacteria in the soil and vegetation of the mangroves. Wetlands also play a role in carbon sequestration. When new water enters the ecosystem, the resulting accumulation of sediment deposits and buried biomasses is stored in the mangroves (NOAA 2013).

Wetlands are also important cultural sites for various groups. Some wetlands provide resources used in many cultural and religious practices. For example in Australia, wetlands are spiritually significant to the Aboriginal people (Streever et al. 1998). In recent years, wetlands have been described as a contributor to ecotourism. Many visit wetlands for research purposes and other educational activities. Others too visit to engage in different services offered as hiking, fishing, kayaking and wildlife watching. Wetlands are very important to the protection of biodiversity and offer a range of goods and services.

Palm Population of the Nariva Swamp

Comeau, Comeau, and Johnson (2003) suggest that there are approximately 10 species of palm trees that make up the palm forest of the Nariva Swamp. Many of these palms provide food for various birds as the Green Parrots and the Red Bellied Macaws (Bonadie and Bacon 1998). Of these palms, three species are of economic interest and these are the Palmiste palm, the Moriche palm and the Coconut palm.

Introduced by the Amerindians, the Palmiste palm stands at forty (40) metres tall with a large, spreading crown. They provide food for the fauna of the swamp inclusive of bats and macaws. This palm is now heavily threatened due to habitat destruction and unsustainable harvesting. The meristems are gathered for use in local cuisine, while other parts of the palm are used for ornamental decoration and as building materials (Comeau, Comeau, and Johnson 2003). The Nariva Swamp is one of few communities that support the Moriche palm. This palm is of particular interest due to its economic significance. According to Comeau, Comeau, and Johnson (2003), the outer part of the petiole is stripped and used for the weaving of baskets, hats, mats and other decorations.

The Coconut palm which usually stands at about 20m tall features clusters of fruit numbering between ten and thirty (Comeau, Comeau, and Johnson 2003). It has been described as one of the most important tropical crops. Locally, fruits are used in the raw form for drinking water and consumption of the pulp or jelly. The kernel of the coconut or the copra is also edible and is used in the production of coconut oil, which is used in cooking and in soaps and margarine. Fibre from dried coconuts is used in rope making and in weaving of mats, hats and other similar articles while the midribs of the leaves are mainly used in making brooms. All of these products are in high demand, not only locally but across geographic borders.

The Nariva Swamp is also known for its large population of coconut trees, especially along the roadways on its boundaries. Many use this site for photo-shoots and artwork as they are largely attracted to the site because of its great scenic beauty. Visitors often describe a trip to the site as 'driving through the coconuts.' Thus, the introduction of invasive alien species (IAS) as the Red Palm Mite spells serious ramifications for these palms.

Invasive Alien Species

IAS are plants, animals, pathogens and other organisms that are non-native to an ecosystem. They are characterized by their rapid reproduction rates, potential for dispersal and their ability to survive, adapt and thrive in various new conditions (Masters and Norgrove 2010). IAS are foreign organisms that become established and pose a threat to its new environment. They have the potential to cause economic or environmental harm or adversely affect human health. In particular, they impact adversely upon biodiversity, including decline or elimination of native species (CBD 2009).

IAS have the ability to enter new habitats and adapt to the present conditions. To survive in new environments, these species usually out-compete the endemic flora, fauna and even humans for food and habitat (CBD 2009). Increasing problems are caused when these IAS begin to multiply and expand their territory.

The Red Palm Mite is a new invasive pest in the Western Hemisphere. *Raoiella indica* is a major pest of the palm plant family. It is often referred to as the Coconut Red Mite, Red Date Palm Mite, Leaflet False Spider Mite, Frond Crimson Mite or Scarlet Mite (Pena et al. 2006).

The Red Palm Mite originated in the Eastern Hemisphere. It was first described by Stanley Hirst on coconut leaves in Coimbatore, South India in 1924 (Hirst 1924). Subsequently, the mite spread to the near east Mauritius, Reunion and Russia (Etienne and Flechtmann 2006). It was also observed in parts of the Philippines, Malaysia, Israel, Egypt, Sri Lanka, Pakistan, Sudan and Iran (Pena et al. 2006; Kane and Ochoa 2006).

The year 2004 marked the official arrival of *Raoiella indica* into the New World. It was first reported on 4 March 2004 on coconut and ornamental palm leaves on the French speaking island of Martinique (Flechtmann and Etienne 2004). In the following year, it was found just north, on the island of Dominica (Pena et al. 2006). Once established in the Caribbean, it spread on great proportions.

Subsequently in 2006, the Red Palm Mite was confirmed as established in other Caribbean islands such as Saint Martin, Saint Lucia, Guadeloupe, the Dominican Republic, Puerto Rico and the twin island republic of Trinidad and Tobago (Etienne and Flechtmann 2006; Flechtmann and Etienne 2006; Welbourn 2009; Rodrigues, Ochoa, and Kane 2007). The literature shows that in 2003, symptoms on coconut palms in St. Lucia were found to be similar to the Lethal Yellowing Disease. Further surveys were conducted but the bacteria that causes Lethal Yellowing was found to be absent. It was in the next year that tiny herbivores, mites, were observed. These were later identified by the United States Department of Agriculture (USDA) as *Raoiella indica* (Kane et al. 2004).

Raoiella indica continued its traverse through the Caribbean islands. In April 2007, it was first identified in Jamaica (Ministry of Agriculture, Jamaica 2007?). Also in that year, other Caribbean nations that reported its presence included the US Virgin Islands, Grenada and Haiti (Welbourn 2009).

Later, the Red Palm Mite was discovered in other parts of the New World, on the continents of North and South America. According to Vasquez et al., it was the discovery of the mite in Trinidad and Tobago that raised suspicions of its spread to Venezuela, just a few miles east (Vasquez et al. 2008). Throughout 2010, high populations of Red Palm Mite were also discovered on coconut palms in Colombia, west of Venezuela (Carrillo et al. 2011).

Although it is difficult to observe the Red Palm Mite with the naked eye, its effects can be seen from miles away. Upon close physical examination, this invertebrate is known by its bright red colour. Generally, the mite forms colonies on the underside of the leaves of its chief host, palm trees. Extended feeding of these mites causes the yellowing of leaves and this is often confused with the symptoms of the disease Lethal Yellowing. As the leaves become yellow and die, entire branches die. Then any fruit that is on the tree falls off due to a lack of nutrients. Eventually the whole plant or tree dies, changing landscapes and vistas.

As yet there are no identified benefits of the Red Palm Mite. If left uncontrolled, this organism can further decimate the palm population, reducing the scenic beauty and the use of the swamp's resources by future generations.

Objective

Very often, the typical methods of assessing the negative impacts of introduced pests are based on physical damage estimation, with focus on decreased yields and resulting losses of income. The negative changes to the Nariva Swamp cannot all be measured through physical examination and direct market valuation. If such an evaluation is performed, then all damages to intangible benefits will be overlooked, leading to an inaccurate evaluation exercise. Often it is the intangible changes that can result in reduced visits to such ecosystems. This in turn can be followed by a loss of income to the region and surrounding communities, with small businesses usually being the most affected. These losses can only be accounted for through the use of non-market valuation.

According to Mwebaze, MacLeod and Barois (2010) economic assessment of IAS' impacts has the potential to aid in decision making, policy formulation and resource allocation. To formulate an argument in support of raising IAS awareness to facilitate control and eradication, the effects of IAS must be quantified.

This can be an intricate task because market prices are not directly attached to goods and services that may be impacted, such as the aesthetic values of recreational sites. Since market prices are not always available to illustrate the direct effect of IAS on an ecosystem, studies such as this one have become necessary and are now popular. To adequately estimate the losses or costs incurred by IAS, monetary values must be placed on affected goods and services, as far as possible. The lack of information on impacted aspects can lead to inaccurate impact assessment and inadequate resource allocation for policy implementation.

Since Trinidad and Tobago is an island country, ecosystems are highly sensitive and crucial to the welfare of the economy. Many people rely on the swamp for their livelihoods. Some depend on the swamp for agriculture, fishing, recreation and others for income earned by small business from visitors to this wetland. This study is therefore necessary to provide quantification and better understanding of stakeholders' value and perception of this wetland. The overall objective of this study is to establish the mean willingness to pay for the protection of the swamp and aggregate that value across the population. This value can then be used in determining the socio-economic impact of the Red Palm Mite on the Nariva Swamp.

Methodology

Questionnaires were distributed to the study sample over a period of three months. From the population, a sample comprising 216 respondents was surveyed. This sample was then divided into two groups of equal members, with each population numbering 108. These two strata consisted of one group of respondents who were interviewed face to face at the study site; the other group was sampled using a web-based questionnaire. Both were presented with the identical survey instrument.

Both the web-based and in-person survey selection processes were performed randomly. On visits to the study site, one member of every other family or group was interviewed. This respondent was most times volunteered by other member of the group. The snowballing technique was applied to the online survey distribution to reduce the chances of any bias in the case of the researcher disseminating all questionnaires.

The main feature of the survey instrument was the contingent question that was key to obtaining willingness to pay. For this, the dichotomous choice format was used to elicit a yes or no response to bid amounts presented to respondents. This closed-ended approach results in a binary response or qualitative response regression model as explained by Gujarati (2003). Generally, the aim of most Contingent Valuation studies is to produce a mean WTP. This WTP is the amount that a respondent is willing to pay for a change to the status quo. In calculating WTP, we assume that the parameters are given and we look for measures of central tendency over the distribution of preference uncertainty.

Photos as presented before and after scenarios to survey respondents.

The hypothetical scenario was designed to assist in valuing the Nariva Swamp, through its aesthetic values, recreational services and flora and fauna. By providing the contingent market, respondents were able to state how their behaviour toward the study site will respond to the change in status quo. Two photographs of the swamp were used in the contingent valuation process. One illustrated the status quo or current aesthetics of the wetland and the other was edited to depict the possible negative effects of the mite if left uncontrolled. This was done to improve the respondent's understanding of the threat posed by this invasive alien.

Respondents were then presented with the bid question and were asked if they were willing to make a one-off contribution to a fund that will be used to maintain the aesthetics of the Swamp by removing the Red Palm Mite. Various bids or amounts were presented randomly to respondents, then determining their willingness to pay the one off contribution to remove the Red Palm Mite from the Nariva Swamp.

There were 6 different bid amounts that were presented to respondents. These amounts of \$50, \$100, \$150, \$200, \$250 and \$300 (TTD) were presented randomly to each household surveyed. As a follow-up to the contingent question, participants were asked to state the largest one-off contribution they were willing to make. Thus, one could have chosen to contribute more than \$300 or in the event of a refusal to contribute, a lower amount (even \$0) could have been indicated by the respondent.

During the survey process, debriefing questions were used to obtain reasons for acceptance or refusal of the offered bid. Respondents were also asked about their knowledge of the study site and their attitudes toward it. Other data points asked individuals about their awareness of the Red Palm Mite and their preferred methods of receiving information about it and other pests. The data collected along with personal information as income were used in explaining the probability of the respondent being willing to pay, through Logistic Regression.

Findings

The results show that 23% of the total population was willing to pay to remove the mite because they cherished the Swamp's flora and fauna. These results coincide with Carson (2000) who stated that contingent valuation is necessary to obtain estimates for passive values. In the case of this study, it was observed that approximately 76% of the population that were willing to pay did so because of an appreciation for non-use values such as the swamp's continued existence, use by future generations and the opportunity to enjoy the ecosystem services in the future.

More than half of the sample population never heard of the mite before this study. This was expected since in the pre-testing phase of the survey instrument, only three of 20 respondents had any knowledge of the Red Palm Mite. More than half of the study population accepted the presented bid and were willing to pay.

Participants were asked to give reasons for rejecting the presented bid for the removal of the Red Palm Mite. The largest group that objected did so because they found it unfair to pay a cost that should be borne by the government. According to the results of the logistic regression, a positive rating of the swamp's importance increased the probability of the respondent being willing to pay for the removal of the Red Palm Mite. In both survey formats more than 90% of the sample rated the swamp as important to them.

Approximately 86% of the sample population displayed positive attitudes towards environmentally degrading activities such as dumping, illegal hunting and illegal farming. This characteristic was found to be statistically significant and was included in the model to explain the log odds ratio of a yes response to the contingent question.

WTP Results

In performing the logistic regression, variables included were the rating of the swamp's importance, the randomly presented bid, attitudes to swamp degradation and income. Likert scales were used for ratings of swamp importance, attitudes toward degrading activities and income (TTD '000). Additionally, a variable was created to define the survey format used whether a web based survey was employed (web-based=1) or a face to face survey (face to face=0). This data was used to determine the effect on the probability of a 'yes' response as the dependent variable was coded as yes=1 and no=0.

Table 1: Variables in the Equation

	B	S.E.	Wald	df	Sig.	Exp(B)
Bid Amount	-0.008	0.002	16.086	1	0.000	0.992
Attitudes	1.196	0.461	6.715	1	0.010	3.305
Swamp Importance	0.612	0.180	11.507	1	0.001	1.844
Income	0.187	0.138	1.827	1	0.177	1.205
Survey Mode	0.707	0.379	3.485	1	0.062	2.027
Constant	-2.400	1.085	4.892	1	0.027	0.091

The analysis estimated the log odds ratio of a yes response. The results show that along with the bid variable, respondents' attitudes to swamp degradation and their rating of the wetland's importance were significant at the 5% level by having a p-value less than 0.05.

All of the coefficients of the independent variables except the bid variable are positive. This means that as increasing bid amounts were presented to respondents, the probability of a yes response decreased. This shows internal validity of this contingent study performed on the Nariva Swamp.
The parameter estimates of the predictor variables illustrate the change to the log odds of a yes response to the bid question in relation to a change in the predictor, while holding all other independent variables constant. A positive sign of the coefficient explains an increase in the log odds due to an increase in the independent variable while a negative coefficient explains decreases in the log odds ratio with respect to increases in the predictor. Thus for the purposes of this study, the regression equation is:

Equation 1

$$Log\left[\frac{\Pr(yes)}{1{=}\Pr(yes)}\right] -2.4 -.008Bid + 1.196Attitude + .612Importance + .187Income$$

$$+.707Survey\ Mode + \varepsilon_i$$

The positive signs of the other variables demonstrate a direct relationship between the odds of a yes response and the predictors. Therefore the higher the respondent rated the importance of the swamp and once he/she cared about swamp degradation, the chance of a yes response to the bid question increased.

From equation 1 for every unit change to the bid, the log odds of a yes response is expected to be reduced by 0.008. When respondents cared about degrading activities occurring at the study site, there was an expected 1.196 increase in the log odds of the respondent accepting the presented bid. For increasing ratings on the swamp's importance, the log odds ratio was expected to increase by 0.612. It must be noted that these changes to the log odds ratio in response to a change in any of the independent variables are interpreted when all other predictors are held constant. These predictors were statistically significant.

In the tabular presentation of the logistic regression, the parameter estimates can be transformed to explain the odds ratio of the predictors. This transformation is performed by determining the exponential of the coefficients of the independent variables.

Mean Willingness to Pay
The mean willingness to pay (WTP) is calculated as:

$$E(WTP) = \frac{a\,z_j}{b}$$

This can be defined where E(WTP) represents the mean willingness to pay, a corresponds to the vector of parameter estimates of the non-bid variables, z_j represents the means of the vector of non-bid variables and b refers to the coefficient of the bid variable, where b is positive. The table presented below defines the parameter estimates and their respective means used in calculating mean WTP.

Table 2: Calculation of Mean WTP

Variables	Parameter Estimates (a)	Mean Value of Parameter Estimate (zj)	a zj
Attitude	1.196	0.86	1.02856
Importance Rating	0.612	3.95	2.4174
Income	0.187	2.67	0.49929
Survey Mode	0.707	0.50	0.3535
Constant	-2.400	1.00	-2.400
		$\sum \alpha z_j$	1.89875

Using $\beta = -0.008$ as given in the regression output in table 1:

$$E(WTP) = \frac{\alpha z_j}{\beta} = \frac{1.89875}{-(-0.008)} = 237.34375$$

= \$237.34 (TTD) or \$37(US)

The above amount of \$237.34 signifies the mean willingness to pay for the removal of the Red Palm Mite from the Nariva Swamp. This can also be referred to as the average individual's willingness to pay, whether sampled online or in-person.

The mean value of WTP calculated above was aggregated to the total number of households in Trinidad and Tobago. This value was given as 401,382 and was obtained from the local Central Statistical Office (CSO 2012, 32). Therefore:

Total Number of Households x Mean WTP = Total WTP

i.e.,

401,382 x \$237.34 = \$95,264,003.88 (TTD) or \$14,792,547.19 (USD)

The above aggregated willingness to pay of \$95,264,003.88 represents the total willingness to pay for protection of the Nariva Swamp or total social value of the swamp to the country of Trinidad and Tobago.

Discussion

It can be derived that the attitude respondents held to any activities that may further degrade the swamp exerted the greatest influence on the log odds ratio of a yes response to the bid question. This variable was shown to have the largest coefficient that was also positive. The attitude variable was shown to be statistically significant at the 5% level with a probability value of 0.010. This finding was consistent with the a-priori expectation that positive attitudes towards the ecosystem will increase the probability of an individual being willing to pay for protection from the Red Palm Mite.

The findings of Shultis (1999) further demonstrate the validity of the positively significant relationship between the log odds ratio and attitudes toward degrading activities. In observing New Zealand's wilderness regions, he found that public attitudes to these areas were highly positive. He explained that attitudes towards wilderness and natural resources have great repercussions for future government support and management strategies. Shultis describes this as useful in the case of New Zealand Wilderness Policy. Similarly, the positive attitudes toward stopping environmentally degrading activities at the Nariva Swamp reveal an appreciation of the intrinsic value and overall desire for the wetland's protection. This is also supported by Streever et al. (1998) when examining the conservation of wetlands in New South Wales, Australia.

The rating of importance can be included among the vector of individual characteristics or attitudes that generally define consumer willingness to pay. This finding is in unison with the work of Mill et al. (2007, 11). When obtaining willingness to pay for the protection of forests, respondents who considered the ecosystem and its attributes as important were more likely to be willing to pay for forest conservation.

Socio-demographic variables such as gender, age, education, occupation and income are generally included in willingness to pay models presented in the literature. Adams and Lee (2007) provide support for the lack of statistical significance of socio-demographic variables. That study sought to examine the relationship between invasive weeds and recreational activities in Florida's parks. This involved determining the park users' willingness to pay to prevent the establishment and/or subsequent control of such invasives. While other characteristics as site knowledge and species awareness proved significant to the model, none of the socio-demographic variables were significant. In the case of the Nariva Swamp, formal education, age, sex and income had no significant impact on willingness to pay.

Income was not found to be significant in explaining the log odds of a yes response to the bid question. Evidence in favor of this study's findings with respect to income can be drawn from the work of Jensen and Jakus (2003). In the case of the Nariva Swamp, income effects are also not present. As incomes increased, willingness to pay for mite removal was not significantly affected. This violated the a-priori expectation that income was significant in explaining willingness to pay. This was suspected to be the result of differences in recreational choice behaviour between lower and higher income households in Trinidad and Tobago. The majority of households with higher income do not frequent the Nariva Swamp probably due to a more frequent choice of urban settings for recreation. This reduces their emotional attachment to the study site.

Through further investigation, it was found that few site users who were unwilling to pay cited inability to pay as their reason for objection. This variable, though not significant, was left in the model to explain that higher income households did not necessarily value the ecosystem services of the Nariva Swamp more than persons with lower income households.

It was also found that the majority of respondents were willing to pay for the mite's removal to ensure use of the ecosystem services by future generations. Thus, the contingent study also captured the existence value of the Nariva Swamp. The results showed that approximately 19% of respondents who gave 'yes' responses cited the future existence of the swamp as their main reason for paying, even if active use of the ecosystem services is disallowed.

Conclusion

The Nariva Swamp, like all other such sites provide a wide range of ecosystem services to consumers. Of such services, aesthetic values have been shown to be integral in recent contingent studies. This warranted the need for this study to apply contingent valuation to determine how much value persons place on these services or benefits of the swamp. Therefore, this study further illustrates the use of valuation of non-market goods and services for inclusion in impact assessments and resulting policy formation.

Although persons were found to be willing to pay for the removal of the mite from the Nariva Swamp, many remain unaware that the Nariva Swamp is an ecologically sensitive Ramsar site. Similarly, most of the population is unaware of the Red Palm Mite's presence and its potential for destruction; therefore, it is felt that an educational campaign is necessary to raise awareness of these issues. It is suspected that there will be greater appreciation for the swamp and a stronger desire for protection, once a better understanding of the fragile nature of this wetland, its economic importance and the potential threat due to the Red Palm Mite is given to the public.

The total monetary value of more than 14 million (USD) represents the present value of benefits from any efforts aimed at removing the Red Palm Mite from the Nariva Swamp. This imputed value can be used in a cost benefit analysis of a control or eradication programme with respect to the mite. If no action plan is instituted however, this value will represent the opportunity cost of such an endeavour.

This study has provided a basis for further contingent valuation exercises in Trinidad and Tobago. Overall, this study shows that conservation of the Nariva Swamp is crucial to the local population. The benefits derived/reported by respondents prove that the swamp should be maintained, the Red Palm Mite should be removed and the existing quality of ecosystem services be improved. These benefits must be considered in conservation policy formation.

References

Barbier, Edward B., Mike Acreman, and Duncan Knowler. 1997. Economic Valuation of Wetlands A Guide for Policy Makers and Planners. Ramsar Convention Bureau, Gland, Switzerland. http://liveassets.iucn.getunik.net/downloads.

Bonadie, Wayne A., and Peter R. Bacon. 1998. "Year-round utilisation of fragmented palm swamp forest by Red-bellied macaws (*Ara manilata*) and Orange-winged parrots (*Amazona amazonica*) in the Nariva Swamp (Trinidad)." In *Biological Conservation* 95: 1-5.

Carbonell, Montserrat, Dawn Browne, Gerard Alleng, and Bobby Massey. 2007. Nariva Swamp Restoration Initiative, Trinidad and Tobago. Ducks Unlimited, Inc. Memphis, TN, USA. http://www.ducks.org/lac/homepage.

Carrillo, Daniel, Denise Navia, Francisco Ferragut, and Jorge E. Pena. 2011. "First Report of Raoiella Indica (Acari: Tenuipalpidae) in Colombia." In *Florida Entomologist* 94 (2): 370 - 371.

Carson, Richard T. 2000. "Contingent Valuation: A User's Guide." In *Environmental Science and Technology* 34 (8): 1413-1418. doi: 10.1021/es990728j.

CBD (Convention on Biological Diversity). 2009. What Are Invasive Alien Species? http://www.cbd.int/idb/2009/about/what/.

Comeau, Paul L., Yasmin S. Comeau, and Winston Johnson. 2003. *The Palm Book of Trinidad and Tobago Including the Lesser Antilles*. S. l.: International Palm Society.

CSO (Central Statistical Office). 2011. Trinidad and Tobago 2011 Population and Housing Census Demographic Report. http://www.cso.gov.tt/sites/default/files/content/images/census/TRINIDAD%20AND%20TOBAGO%20 2011%20Demographic%20.

Etienne, Jean, and Carlos H. W. Flechtmann. 2006. "First Record of Raoiella indica (Hirst, 1924) (Acari: Tenuipalpidae) in Guadeloupe and Saint Martin, West Indies." In *International Journal of Acarology* 32 (3): 331 - 332. Accessed January 22, 2011. doi: 10.1080/01647950608684476.

Flechtmann, Carlos H. W., and Jean Etienne. 2004. "The Red Palm Mite: Raoiella indica Hirst, A Threat to Palms in the Americas (Acari: Prostigmata: Tenuipalpidae)." In *Systematic & Applied Acarology* 9: 109 - 110.

______. 2006. "Further Notes on Plant Associated Mites (Acari) From Guadeloupe and Les Saintes, Lesser Antilles." In *International Journal of Acarology* 32 (4): 377 -382.

Gujarati, Damodar, N. 2003. *Basic Econometrics.* 4th ed. New York: McGraw-Hill.

Hirst, Stanley. 1924. "On Some New Species of Red Spider." In *The Annals and Magazine of Natural History* 14 (9): 522-527.

Kane, Ethan C., and Ronald Ochoa. 2006. "Detection & Identification of the Red Palm Mite Raoiella indica Hirst (Acari: Tenuipalpidae). USDA Research, Education and Economics Agricultural Research Service. http://www.sel.barc.us.

Kane, Ethan. C, Ronald Ochoa, Guy Mathurin, and Eric F. Erbe. 2004. "Raoiella indica Hirst (Acari: Tenuipalpidae): An island-hopping mite pest in the Caribbean." USDA Research, Education and Economics Agricultural Research Service. http://www.researchgate.net/publication/242147478_Raoiella_indica_Hirst_(Acari_Tenuipalpidae)_An_island-hopping_mite_pest_in_the_Caribbean.

Masters, Greg, and Lindsey Norgrove. "Climate Change and Invasive Alien Species." CABI Working Paper 1 (2010): 1-30. http://www.prod.sgk.cabiorg.cab.semcs.net.

Mill, Greig A., Thomas van Rensburg, Stephen Hynes and Conor Dooley. 2007. "Willingness to Pay and Consumer Versus Citizen Values: Evidence From Ireland." Working Paper No. 114, Department of Economics, National University of Ireland, Galway.

Ministry of Agriculture, Jamaica. 2007? "The Red Palm Mite in Jamaica." http://www.moa.gov.jm/PlantHealth/data/THE%20RED%20PALM%20MITE%20IN%20JAMAICA.pdf.

Mwebaze, Paul, Alan MacLeod, and Herve Barois. 2009. Economic Valuation of the Influence of Invasive Alien Species on the National Economy. Final Report for the Government of Seychelles (GOS)-UNDP-GEF project 'Mainstreaming Prevention and Control Measures for Invasive Alien Species into Trade, Transport and Travel Across the Production Landscape.

NOAA (National Oceanic and Atmospheric Administration). "Coastal Blue Carbon." 2013. NOAA Habitat Conservation National Marine Fisheries Service. http://www.habitat.noaa.gov/coastalbluecarbon.html.

(NSRI) Nariva Swamp Restoration Initiative Development of a Reforestation Scheme and assessment of its Social Impact on Communities of the Nariva Swamp. 2008. The Tropical Re-Leaf Foundation, Trinidad and Tobago.

Pena, J. E., C. M. Mannion, F. W. Howard, and M. A. Hoy. 2006. "Raoiella indica (Prostigmata: Tenuipalpidae): The Red Palm Mite: A Potential Invasive Pest of Palms and Bananas and Other Tropical Crops of Florida." University of Florida IFAS Extension. http://www.edis.ifas.ufl.edu/pdffiles/IN/IN68100.pdf.

Rodrigues, Jose C. V., Ronald Ochoa, and Ethan C. Kane. 2007. "First Report of Raoiella Indica Hirst (Acari: Tenuipalpidae) and Its Damage to Coconut Palms in Puerto Rico and Culebra Island." In *International Journal of Acarology* 33 (1): 3 - 5.

Shultis, John. 1999. "The Duality of Wilderness: Comparing Popular and Political Conceptions of Wilderness in New Zealand." In *Society and Natural Resources* 12 (5): 1 - 16. http://www.doc.govt.nz/Documents/science-and-technical/Wil.

Streever, W. J., M. Callaghan-Perry, A. Searles, T. Stevens, and P. Svoboda. 1998. "Public Attitudes and Values for Wetland Conservation in New South Wales, Australia." In *Journal of Environmental Management* 54 (1): 1 - 14.

Stuip, M. A. M., Baker, C. J. and Oosterberg, W. 2002. "The Socio-economics of Wetlands." Wetlands International and RIZA, The Netherlands. http://www.wetlands.org/LinkClick.aspx?fileticket=OQzbLZJdKcU%3D&tabid=56.

Vasquez, Carlos, Magally Quiros De G., Orlando Aponte, and D. MariaF. Sandoval. 2008. "First Report of Raoiella indica Hirst (Acari: Tenuipalpidae) in South America." In *Neotropical Entomology* 37 (6): 739 - 740. http://dx.doi.org/10.1590/S1519-566X2008000600019.

Welbourn, Cal. 2009. "Pest Alert Red palm mite Raoiella indica Hirst (Acari: Tenuipalpidae)." Florida Department of Agriculture & Consumer Services, Division of Plant Industry. http://www.freshfromflorida.com/pi/enpp/ento/r.ind.

Socioeconomic Assessment of the Impact of an Invasive Alien Species on the Beekeeping Industry in Trinidad and Tobago: The Case of *Varroa Jacobsoni or Varroa Mite.*

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Abstract
Varroa Jacobsoni, also referred to as the Varroa Mite, was first sighted in July 1996 in Maraval in the island of Trinidad. The invasive alien species (IAS) is believed to have reached Trinidad on swarms that migrated from the Venezuelan mainland into the country. The mite attacks all stages of the life cycle from pupa to adult. Early reporting indicated that hives were completely destroyed within three months after invasion. Soon after the sightings, beekeepers began to use Apistan strip to treat their hives and this continued to this date.

This study seeks to access the Socioeconomic Impact of Varroa Jacobsoni on the Beekeeping Industry in Trinidad and Tobago. More specifically, the study assesses:
(i) Producers' perception of the IAS (*Varroa Jacobsoni)* as an indicator of "level of threat" on their business. The IAS was rated against other threat factors such as the Africanized honey bee, vandalism and colony migration. This was done through producer surveys in Trinidad using the five point Likert scale and point score analysis.
(ii) The cost of the IAS to beekeepers in Trinidad and Tobago.

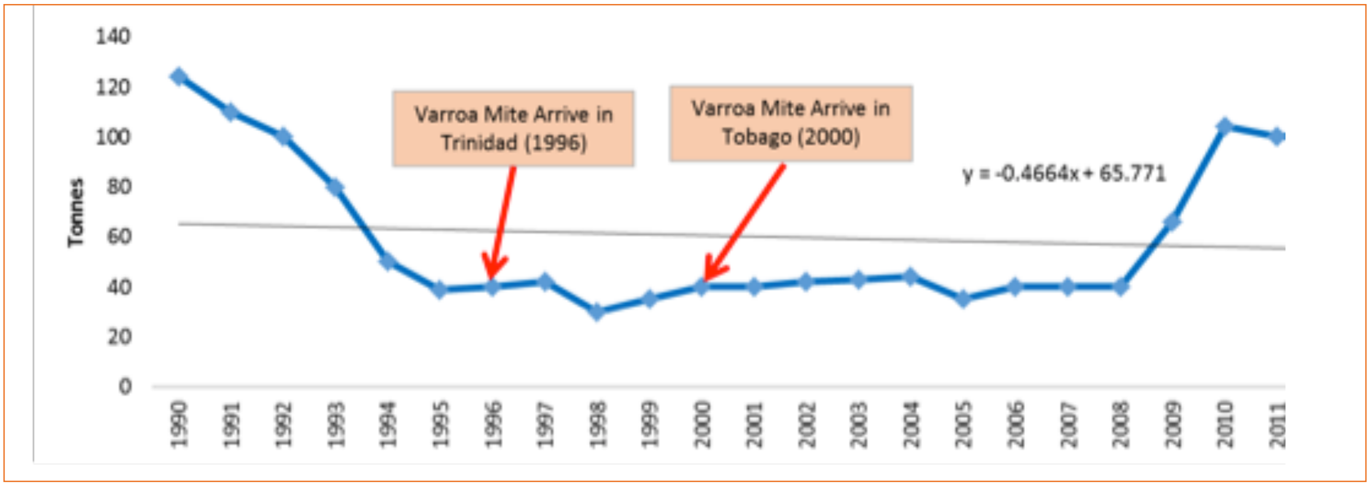
The results of the study showed that producers ranked the Varroa mite as having the greatest impact on their operations while the Africanized bee on the other hand was considered to have little to no impact on the industry. The findings suggest that the use of the Apistan strip might have been effective in control of the mite and prevented the decline of the industry. In 1996, the production of honey in Trinidad and Tobago was recorded at 40 tons. However, by 2012 honey production increased to about 100 tons, which represents a 150% increase over 1996 levels.

Keywords: *Varroa Jacobsoni*, Invasive Alien Species, Point Score Analysis.

Introduction

Apiculture in Trinidad and Tobago has been a major contributor to small farmers' earnings over years. Following the arrival of the Africanized Bees, honey production continued a declining trend between 1990 and 2012, as illustrated in Figure 1. The *Varroa Jacobsoni* (Varroa Mite) was first observed during the year 1996 in Trinidad and 2000 in Tobago. However, as is illustrated in the graph, from 2008 there was a marked increase in honey production possibly due to beekeepers management of the two invasive alien species (IAS).

Figure 1: Honey Production in Trinidad and Tobago, 1990 - 2012 (Tonnes)



Data Source: FAOStat Database

As stated by Anderson and Trueman (2000), the Varroa Mite is the world's most devastating pest of Western Honey bees. It was also shown that, "Although the Varroa complex includes multiple species, *V. destructor* is the species responsible for the vast majority of the damage attributed to mites from this genus". Further, the University of Florida (2012) has published a paper suggesting that the effect of these mites are hard to find but these mites have killed thousands of colonies worldwide and have increased the cost of production to beekeepers reducing their margin. Hence, there is a need to assess the Socioeconomic Impact on the Beekeeping Industry in Trinidad and Tobago. Therefore, the general objective of this study is to assess beekeepers perception of the Varroa Mite relative to other adverse factors, such as vandalism and pesticide use.

Methodology

Data was collected to identify the demographic and technical features of the honey industry in the twin island state of Trinidad and Tobago by use of a structured questionnaire. The survey tool utilized the Likert scale to ascertain respondents' perception of the Varroa mite and other negative factors to their operations. Likert scales use fixed choice response and are designed to measure attitudes or opinions (McLeod, 2008). The five point scale was used in this study since Garland (1991, 4) showed evidence that the exclusion of the midpoint value resulted in distortion of results.

Chi-Square (Cross Tabulation): To test the significance of the relationships, the Chi Square (X^2) test was used. This allows for the examination of the differences between two groups. If the difference was found to be significant, the differences between the two populations were not due to chance.

The Chi Square (X^2) statistic was used to investigate whether distributions of categorical variables differ from one another[1], by testing the difference between the actual sample and another hypothetical distribution.

The Chi Square test statistic is shown below:

$$X^2 = \Sigma\, [(o\text{-}e)^2 {}_* e^{-1}] \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where,

o = observed values

e = expected values

Point Score Analysis: Ilbery (1977, 69) used Point Score analysis to compute the overall ranking of decision making factors in order of its importance. Given the relative homogeneity of the issue; that is, the "threat", it is possible to hypothesize that some overlap may exist rather than distinct spatial variations because many of the factors can be interpreted as having personal connotations to the respondents and there may also be some interrelationship between certain factors. However, they can still be classified into economic, social or physical groups. Despite the relative subjectivity of the method, the main advantage of categorizing the degree of importance of each factor is that the answers can be coded into one of a number of groups, enabling further statistical analysis. The importance of these carefully selected factors can be analyzed in conjunction with each other and a ranking of their importance can be obtained.

The factors selected for ranking based on previous research and expert opinion were: Africanized Bees as an IAS, the Varroa mite (IAS), other pests, vandalism, lack of genetic material, pesticide use and migration of colonies, amongst others. Numerical values, or point scores, were allocated to the various categories of importance (Table 1) with 5 having the greatest impact and 1 the least impact.

Table 1: Likert Scale ranking used in the study

Label (level of importance)	Value used for analysis
Very Serious threat	5
Threat	4
Moderate threat	3
Mild threat	2
No threat	1

The overall importance of each factor was measured by totaling the point scores for all the beekeepers interviewed for the factor in question. An alternative approach would be to ask the farmers to allocate a score to each factor. Nonetheless, the qualitative factors can still be ranked in order of importance to the decision-making process with the assigned scores.

1 http://math.hws.edu/javamath/ryan/ChiSquare.html

The point score of each variable is calculated by the sum of the values selected by the number of respondents that choose the respective value.

The formula is:

Point Score = *n*i*w......(2)

Where,

i = perceived threat level…………………i = 1, 2, 3, 4 or 5

w = number of respondents that choose the respective 'i'

n = sample size

Results

Demographics of the Bee Industry in Trinidad

There were 23 respondents to the questionnaires distributed of which the majority were males (96%), with very little difference between part time (52%) and full time (48%) beekeepers. Almost 75% of the respondents were over 50 years of age with no respondent under 20 years (Table 2).

Table 2: Age of Beekeepers'

Age categories (years)	Percentage of Respondents (%)
Under 20	0
21-30	4.3
31-40	4.3
41-50	17.4
Over 50	73.9

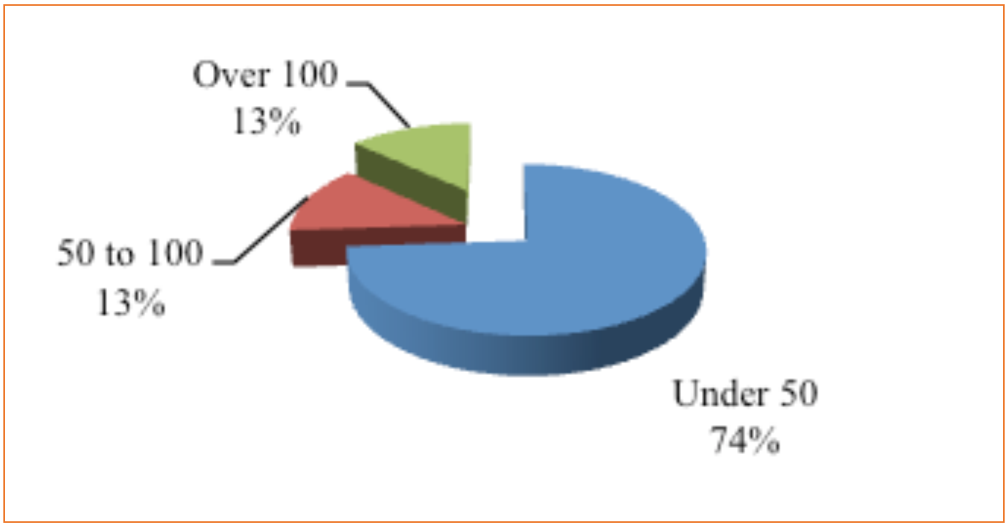
The majority of respondents in the sample (47.8%) were operating for more than 20 years and none were in the industry for less than five years. However, one can conclude from this table that 34.8% of the sample joined the industry after the presence of the Varroa mite entry into Trinidad and Tobago. Cross tabulating the age of the respondents and the number of years in the beekeeping industry, showed a positive and significant (Chi = 26.64, p=0.017) correlation between the variables.

Table 3: Length of time in the beekeeping industry

Years	Percentage of Respondents (%)
Less than 5	0
5-10	17.4
11-15	17.4
16-20	13
Over 20	47.8

Figure 2, provides the indication of the size of beekeeping operations for the respondents of the study. As can be seen from this figure, 74% of the sample can be considered to be small, managing 50 or less hives at the time of the interview. Only 13% of the respondents managed more than 100 hives.

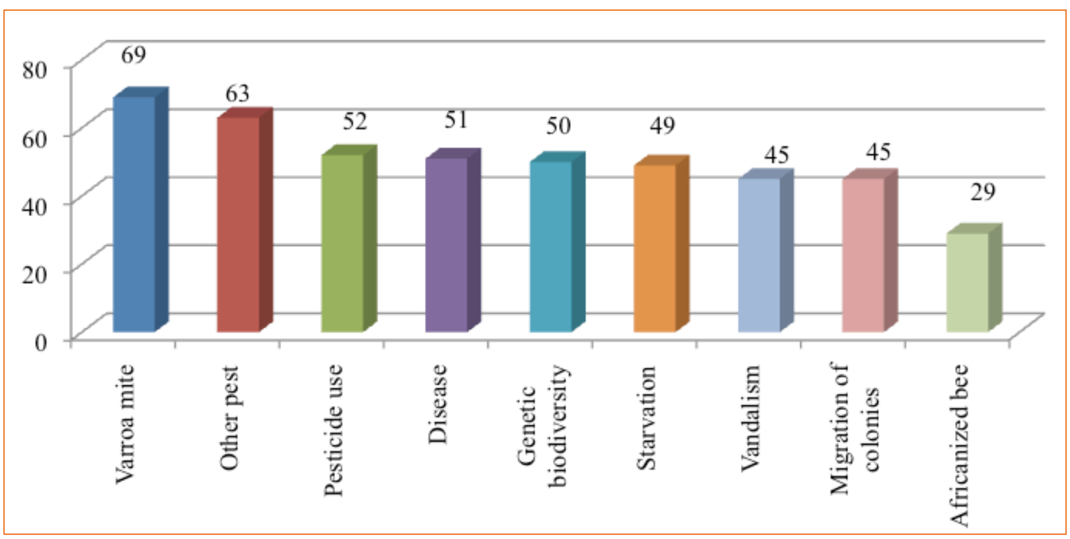
Figure 2: Hive Ownership Structure of Beekeepers in Trinidad and Tobago - Sample Population



Determination of the Varroa Mite as a Threat in the Beekeeping Industry

For this analysis, the point score can range from a low of 23 (no impact) to a high of 115 (very serious threat). Among the respondents, the Varroa Mite was considered to have the greatest impact on their operations with a score of 69, followed by the threat of "Other pests" (63) while Africanized Bees received the lowest point score suggesting that it had little or no threat to the beekeepers operations (Figure 3).

Figure 3: Ranking of Threats to Beekeeping Operations in Trinidad and Tobago (2014)



Further analysis revealed that beekeepers who had exclusively European honey bee populations, that is, those in Tobago, perceived that the Varroa Mite had the greatest threat on their operations (Chi = 14.19, p value =0.07). On the other hand mixed, those with the Africanized bee operations considered this pest to have a mild or no threat.

Economic Implications of the Varroa Mite

In order to control the IAS, beekeepers applied the Apistan strips twice annually before the honey flow periods. The data showed that 86% of the beekeepers had a problem with the Varroa Mite and 80% of the sample used the Apistan strips in their colonies, *ceteris paribus*. This data was used as a proxy of beekeepers that apply the Apistan strip in Trinidad and Tobago to estimate the annual cost for control for the Varroa mite. According to the Central Statistical Office (CSO), Trinidad and Tobago had an estimated 236 apiaries and approximately 4,069 colonies in 2009. Using the proxy estimator of Apistan application, then approximately 3, 256 colonies are controlled with the Apistan strips twice bi-annually. The unit cost for an Apistan strip is US$ 3.97. A colony typically uses two strips per application and often is re-used. Therefore, the annual cost of purchasing Apistan strips for the colonies in Trinidad and Tobago is estimated at US$25,852.64. Based on the interviews conducted with beekeepers, it normally takes approximately 20 minutes per colony to apply and remove the Apistan strip. Using this as an estimator of the labour requirements, then an estimated cost of labour can be determined. The beekeepers surveyed indicated that the cost of labour is normally US$31.75 per day for an 8 hour day or the equivalent of US$ 1.20/application. Using the estimated number of colonies applying Apistan strips, it will cost US$3,907.20 annually to apply and remove Apistan strips.

Indirectly, the Varroa mite will also place other economic costs on the industry. Farmers with low input-low output systems stand the chance of easily losing their hives. Further, the IAS will destroy feral hives unnoticed and unrecorded. It is well known that these bees also offer pollination services to farmers, florist and forestry. There is also the added cost of losing the "organically-produced" and possibly "Geographic Indications" labels along with the possibility of low levels of pesticide residues in the honey. Assignment of costs to these will require contingent valuation methods.

Conclusion

The Varroa Mite was considered to have the greatest impact on beekeepers operations in the twin island state of Trinidad and Tobago.

When the sample population was disaggregated, Tobago beekeepers perceived that the Varroa Mite had the greatest threat on their operations while some farmers with the Africanized bee operations considered this pest to have a mild or no threat.

The direct cost to manage the IAS through the application of the Apistan Strips bi-annually before the honey flow periods was estimated at US$29,759.84.

Indirectly, the Varroa mite will place other costs on the beekeeping and honey industry. These include increasing the probability of losing the hives, the negative impact on pollination services, losing the "organically-produced" and possibly "Geographic Indications" labels and possibilities of pesticide contamination.

References

Anderson, D.L., Trueman J. W. H. 2000. "*Varroa jacobsoni* (Acari: Varroidae) is more than one species." *Experimental and Applied Acarology* 24: 165-189.

Central Statistical Office of Trinidad and Tobago (CSO). 2009. "Apiculture and Aquaculture Statistics 2009." CSO Report: Trinidad and Tobago.

De Jong, D. 1997. Mites: Varroa and other parasites of brood. pp 278-327. *In* Honey Bee Pests, Predators, and Diseases (Third Edition). The A.I. Root Company, Medina, Ohio.

Garland, Ron. 1991. "The Mid-Point on a Rating Scale: Is It Desirable?" *Marketing*

Bulletin (2): 66-70.

Ilbery, B.W. 1977. "Point Score Analysis: A Methodological Framework for Analyzing the Decision Making Process in Agriculture." *Tijdschrift voor Economische en Sociale Geografie* 68: 66-71.

McLeod, S. A. (2008). Likert Scale. Retrieved from http://www.simplypsychology.org/likert-scale.html.

University of Florida. 2012. Featured Creatures: Varroa Mite. Retrieved from http://entnemdept.ufl.edu/creatures/misc/bees/varroa_mite.htm.

Appendix

Table A1: Cross tabulation: Operator Age and Years in Beekeeping

Age * Years In Beekeeping Cross tabulation

Count **less than 5 years**		**Years In Beekeeping**					**Total**
		5-10	**10-15**	**16-20**	**over 20**		
Age	21-30	0	1	0	0	0	1
	31-40	0	0	0	1	0	1
	41-50	0	0	3	1	1	5
	over 50	1	1	2	1	11	16
Total		1	2	5	3	12	23

Chi-Square Tests

	Value	**df**	**Asymp. Sig. (2-sided)**
Pearson Chi-Square	24.644[a]	12	.017
Likelihood Ratio	16.437	12	.172
Linear-by-Linear Association	3.033	1	.082
N of Valid Cases	23		

a. 19 cells (95.0%) have expected count less than 5. The minimum expected count is .04.

Table A2: Ranking of Threats to beekeeping operations in Trinidad (2014)

Threats	Point Score	Rank
Varroa Mite	69	1
Other Pest	63	2
Pesticide Use	52	3
Disease	51	4
Genetic Biodiversity	50	5
Starvation	49	6
Vandalism	45	7
Migration Of Colonies	45	7
Africanized Bee	29	8

Table A3: Cross tabulation between impact of Varroa Mite and Bee species

Bee Species * Varroa Mite Cross tabulation

Count no threat		Varroa Mite					Total
		mild threat	moderate threat	threat	Very serious threat		
Bee Species	African-ized	3	1	0	1	2	7
	Italian	0	0	0	4	4	8
	mixed	5	1	1	1	0	8
Total		8	2	1	6	6	23

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	
Pearson Chi-Square	14.187[a]	8	.077	
Likelihood Ratio	19.041	8	.015	
Linear-by-Linear Association	1.471	1	.225	
N of Valid Cases	23			

a. 15 cells (100.0%) have expected count less than 5. The minimum expected count is .30.