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.

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 Casuarinas species. 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.

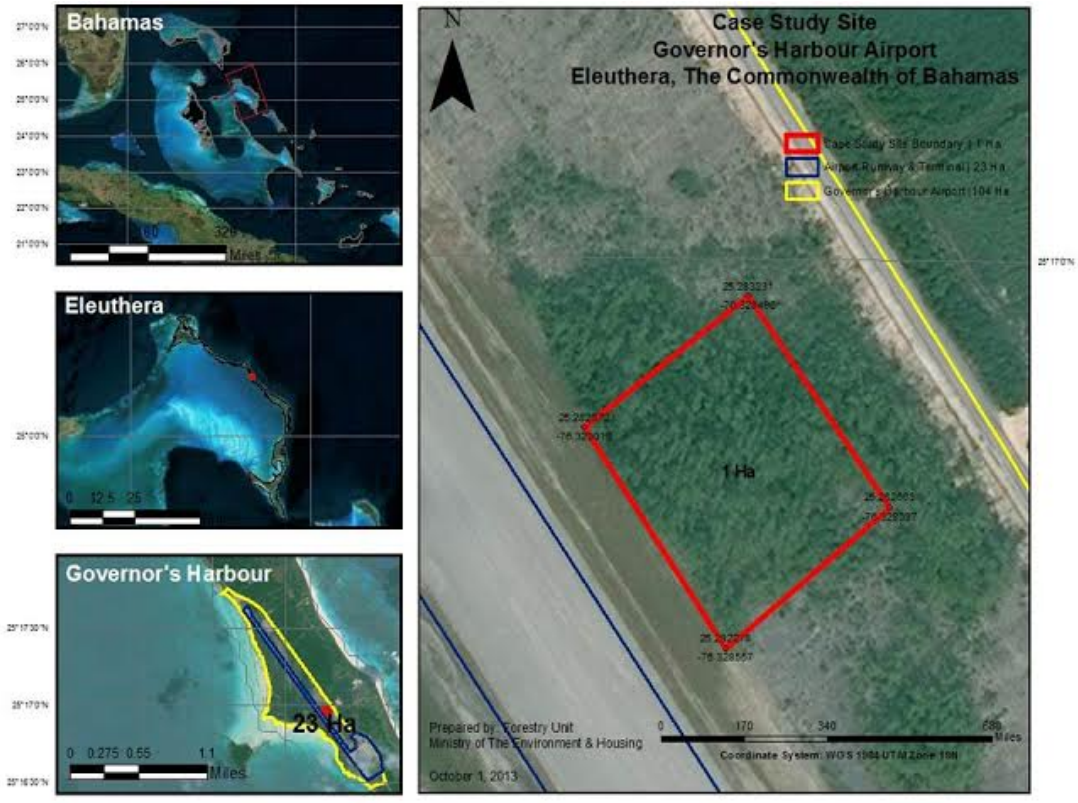

Figure 1: Maps of The Bahamas highlighting Eleuthera, Governors Harbour and the study area

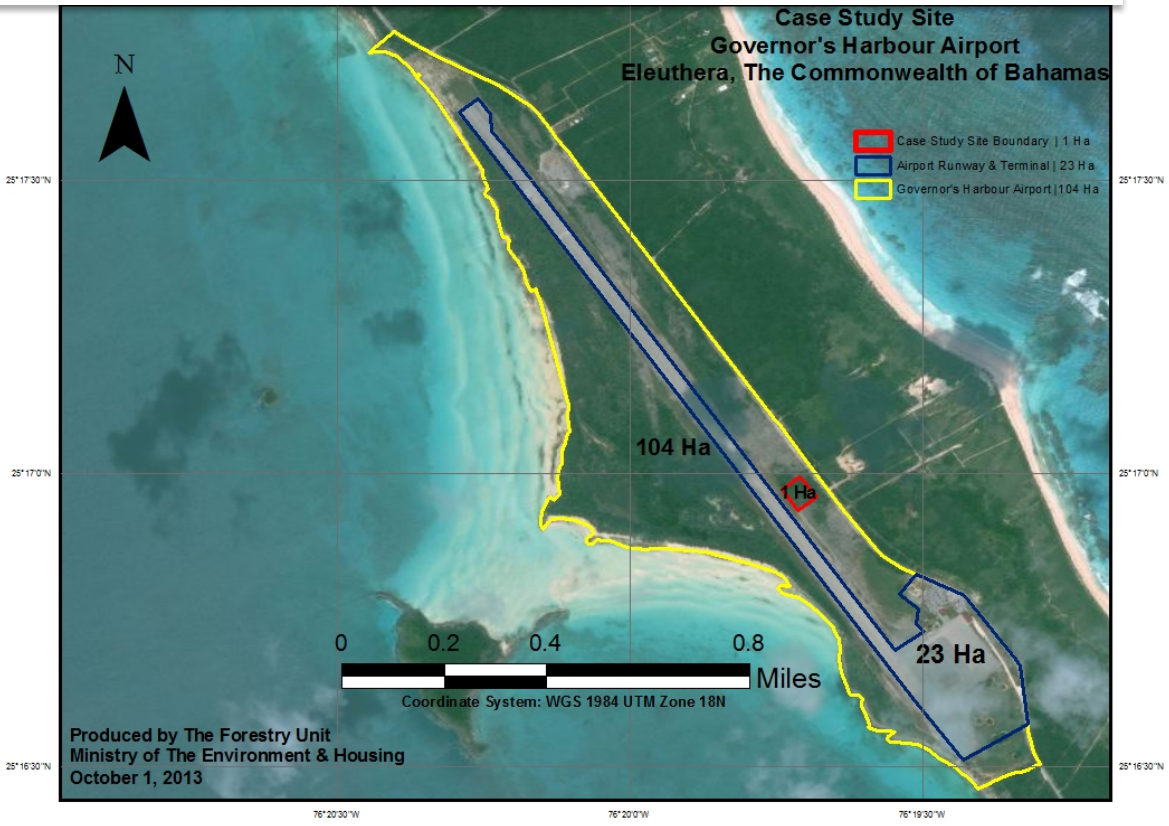

Figure 2: Map of Governors Harbour Airport and entirety of study area

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 1997). 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 1hectare 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 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, 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% felt 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 (to 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.

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

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

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

Results of Cost Benefit Analysis (in Graph Form)

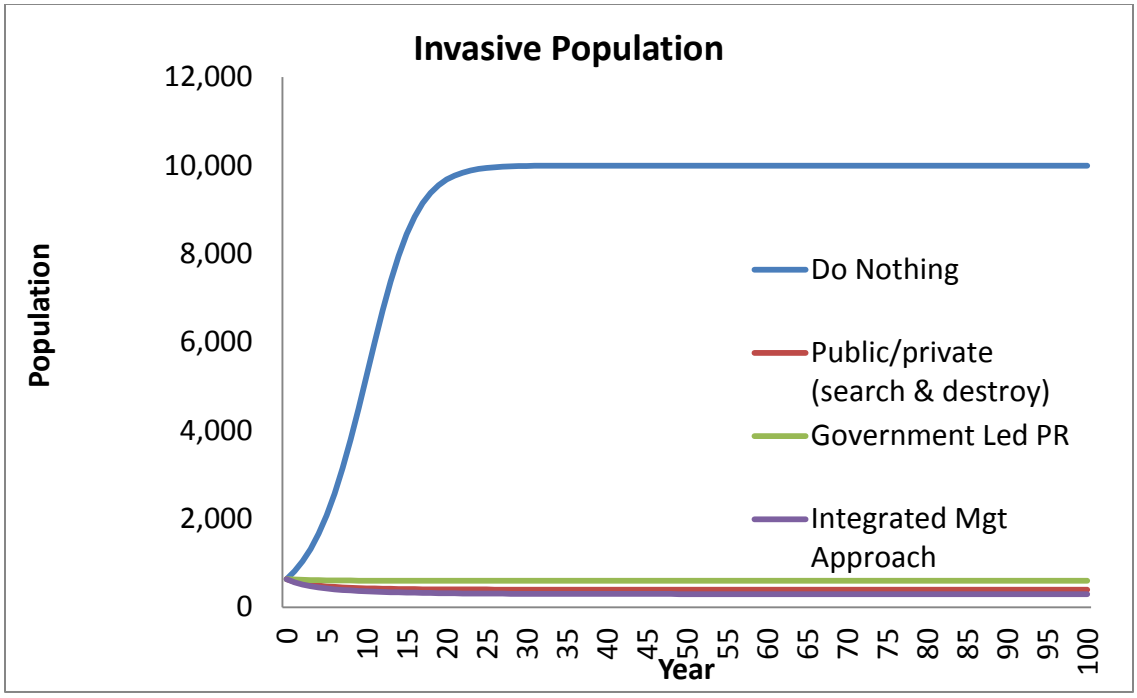

Figure 6: Illustrates the growth curves with the estimated slope values for controlling Casuarina

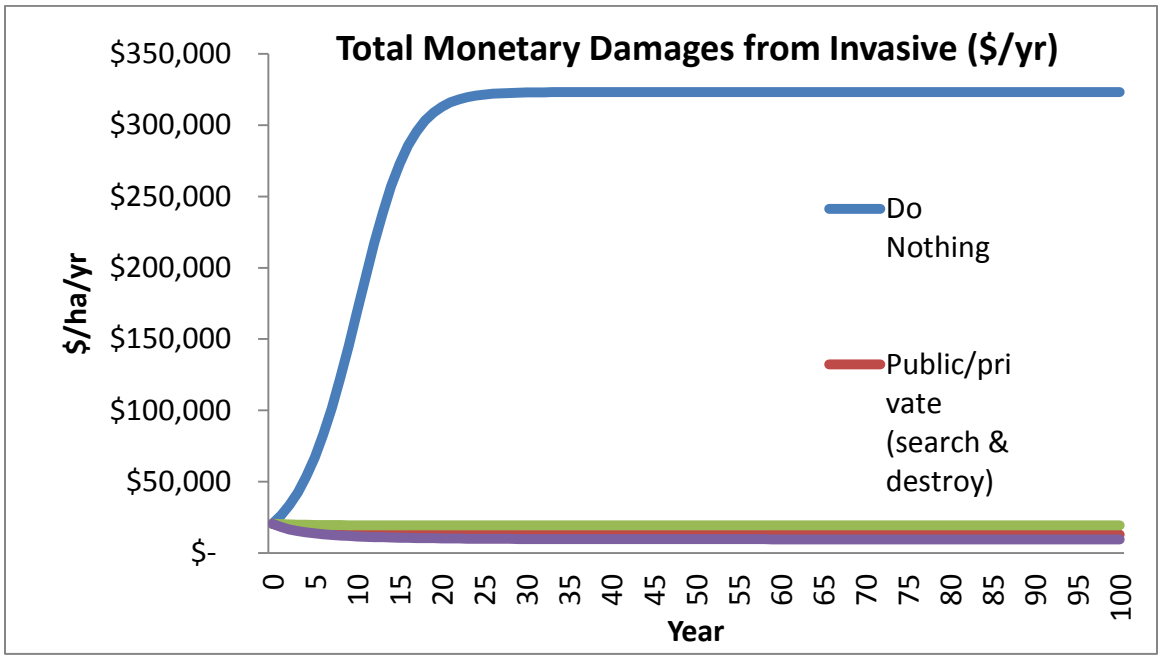

Figure 7: Illustrates Monetary Damages from Invasives

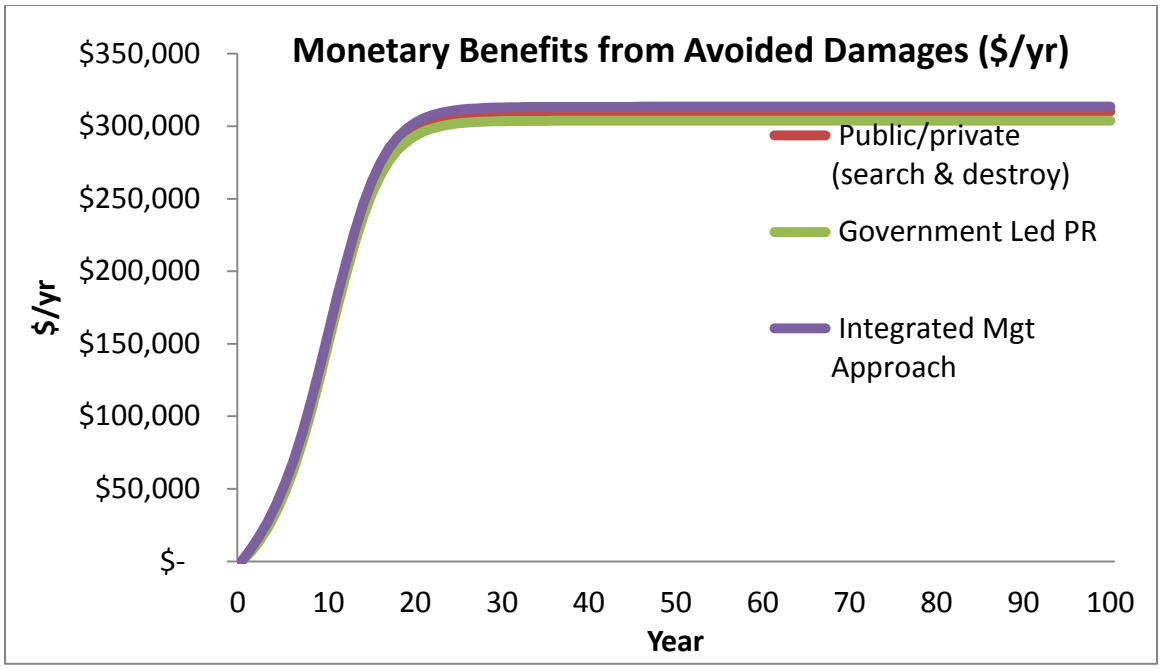

Figure 8: Monetized benefits of avoided damages from management of Casuarina

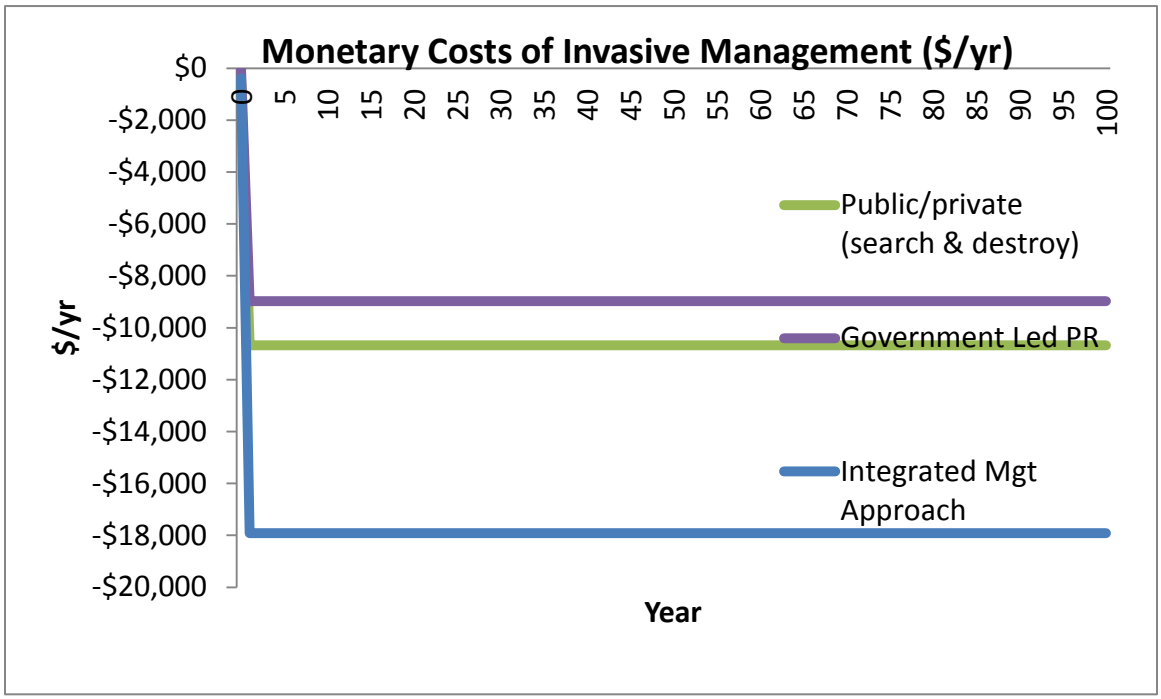

Figure 9: Illustrates Monetary Costs of Invasive Management

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
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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.

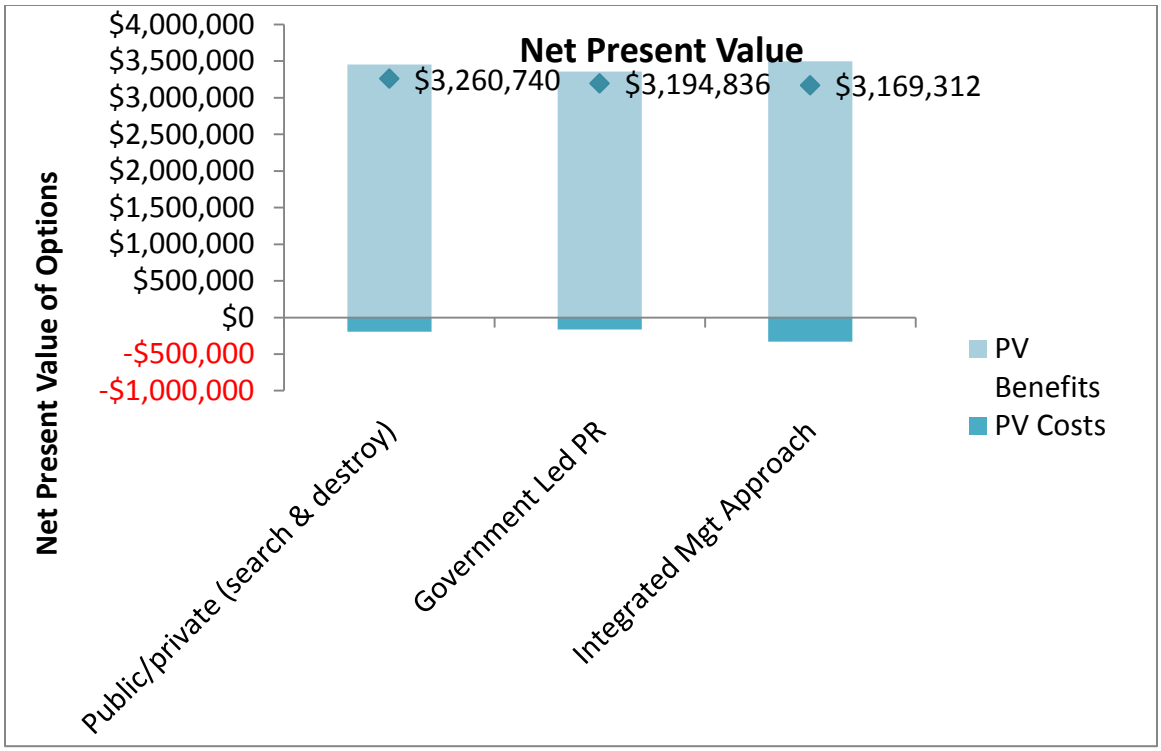

Figure 10: Illustrates Net Present Value of Proposed Management Options

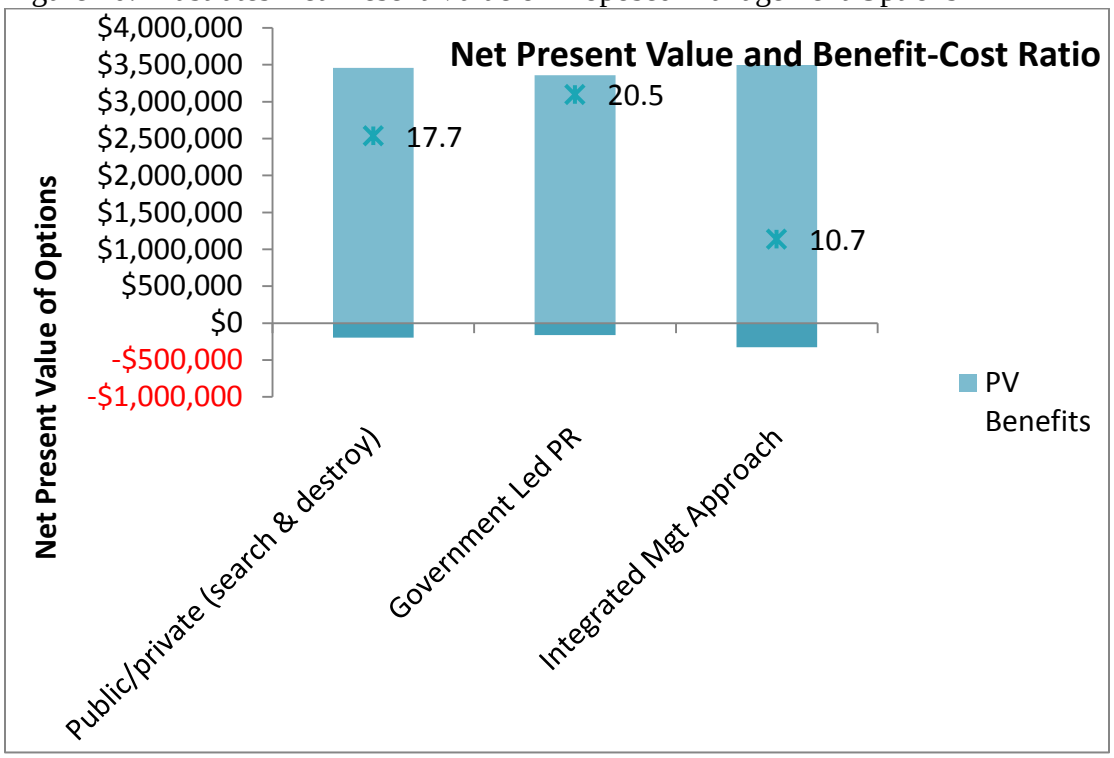

Figure 11: Illustrates Net Present Value and Benefit Cost Ration of Proposed Management Options

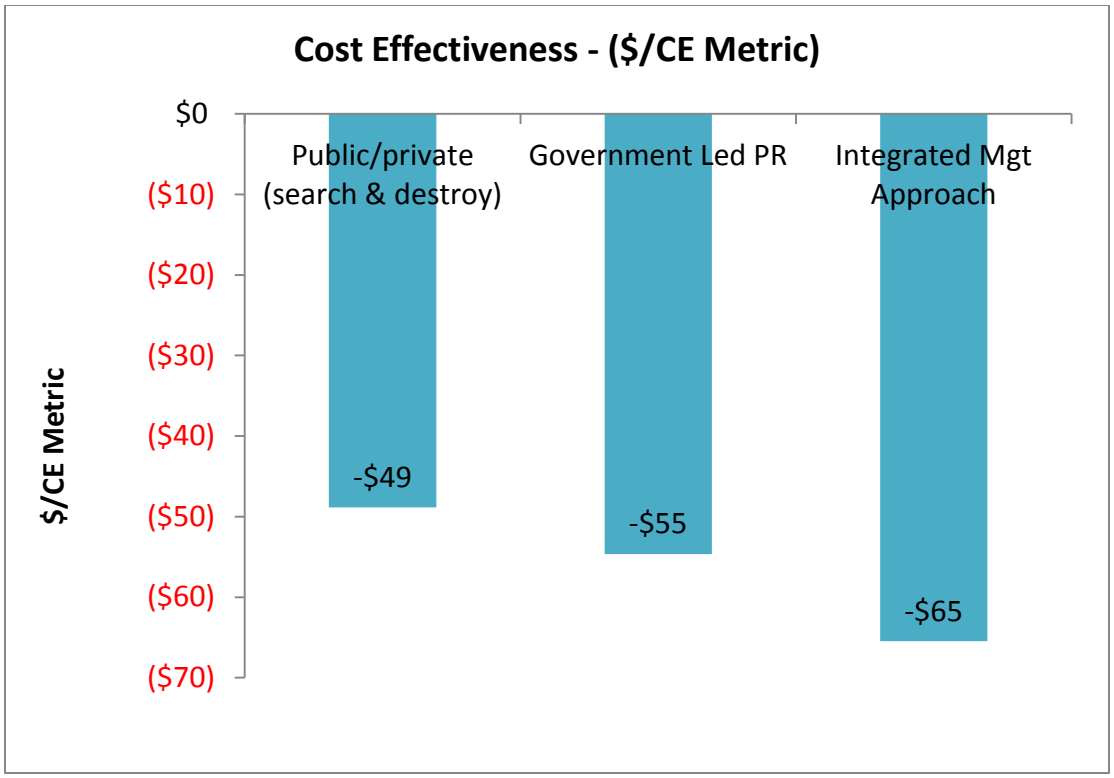

Figure 12: Illustrates Cost Effectiveness of Proposed Management Options

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 4: Summary of Benefit-Cost 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**

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

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.

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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