The Nature Conservancy of Hawaii

Invasive Species : The Economics of Prevention, Control and Environmental Impact

Table of Contents

1. Introduction

> "The legislature finds that the silent invasion of Hawaii by alien invasive species is the single greatest threat to Hawaii's economy, natural environment, and the health and lifestyle of Hawaii's people and visitors. "

This is the first sentence in legislation passed by the 2002 Hawaii State Legislature (House Bill 2212) to authorize the creation of a Hawaii Invasive Species Council to lead State efforts on prevention and control of invasive species. This paper supports the above claim, providing economic evidence to illustrate the risk that invasives pose to Hawaii's economy. Three different invasive species are considered: the brown tree snake, the red imported fire ant, and miconia calvescens. Each threatens the Hawaiian economy in its own unique way.

Brown Tree Snake

This snake poses a threat to several sectors of the economy. In addition to the potentially devastating impact it could have on native animal populations, the snake

- poses a public health risk because it bites people and pets,
- threatens poultry farms because it feeds on chickens and eggs
- threatens agriculture in general because it feeds on insectivores that reduce plant pest populations, and
- presents the risk of costly power outages because it climbs electrical power lines causing short circuits in the power supply.

Together, these impacts could add up to $123 million in annual costs to Hawaii.

Red Imported Fire Ant

This pest, already well established in most of the southern mainland U.S., could wreak havoc in Hawaii if it were to become established. If it invades successfully, homeowners can expect to fight the pest much as they now do battle with termites. In addition, the ant poses a threat to the agriculture industry, requiring treatment, reducing yields, and damaging agricultural and electrical equipment.

Costs caused by the fire ant could amount to $46 million annually.

Miconia calvescens

Unlike the brown tree snake and the red imported fire ant, this invasive has already established itself in Hawaii. *Miconia* threatens Hawaii's tropical forests and the watersheds those forests support. By changing the hydrology of tropical forests, Miconia may accelerate the depletion of groundwater supply in Hawaii's watersheds.

Acceleration of water supply depletion in just two of Hawaii's watersheds could amount to additional cost of $13 million annually.

Without intervention, these three species alone could inflict more than $180 million in additional cost to the Hawaiian economy. It would fall to the farmers, homeowners, taxpayers, and businesses of Hawaii to pay for this additional cost.

As an alternative, the Coordinating Group on Alien and Pest Species (CGAPS)[1] has proposed a baseline plan to address the threat posed by potentially invasive species. This plan, summarized in Appendix 1, consists of measures to address prevention, early detection, rapid response, control, enforcement, and public awareness with respect to the most dangerous potential threats to Hawaii. Current estimates for this plan require annual spending of approximately $42 million, with one time investments of $10 million. Compared to the potential cost of allowing invasives to become established, $42 million on a recurring basis is more than justified.

The Coordinating Group on Alien and Pest Species (CGAPS) consists of experts from different agencies and organizations that deal with invasives and related issues in Hawaii.

2. Background

Hawaii is in the midst of invasive alien species crisis affecting the archipelago's highly endemic biota, overall environmental and human health, and the viability of its tourism- and agriculture-based economy. Because of the vulnerability of isolated oceanic islands to invasion, aggressive plant and animal species exploit and modify all but the most resistant native ecosystems in protected areas. The introduction of invasive alien species has been the predominant cause of biodiversity loss in Hawaii for the past century, with more native species eliminated in this state than anywhere else in the United States. Federal, state, and private managers of protected areas are struggling, with some success within their narrow jurisdictions, to reduce the impacts of alien species on native biota so as to prevent further ecosystem degradation and loss of biodiversity, but invasions outpace resources, and successes are only temporary, given continued invasion from beyond their boundaries. (Maui Invasive Species Committee (MISC) 2002 Action Plan)

The problem of invasives in Hawaii today stems from the rate of new species introduction. In recent years, new species have arrived in Hawaii at a rate more than one million times the rate before the arrival of Polynesians. (Roumasset) This acceleration in the rate of introduction puts the state of Hawaii at risk in several ways. As mentioned above, the environmental risk is clear: as alien species arrive in hospitable Hawaiian environments, endemic species can be threatened to the point of extinction. However, the greater risk may be to the economy of Hawaii. Each newly introduced species of vertebrate, invertebrate, or microbe has the potential to affect the Hawaii's isolated environment and economy in unanticipated (and sometimes unpredictable) ways.

Three examples illustrate this important point. First, consider feral ungulates. Scientists have only recently drawn the connection between feral sheep and pigs and Hawaii's watersheds. It is widely accepted these alien species which were introduced hundreds of years ago pose a threat to native wildlife, but a secondary impact of that damage may be to degrade the water supply by accelerating soil erosion. Scientific research has yet to quantify with precision the impact that ungulates have on water quality. However, Roumasset et al. give a basis for estimating that impact, giving their own estimate at more than $28 million annually.

Second, consider the recent outbreak of dengue fever.. In the fall of 2001, an outbreak in East Maui led to many cases of the disease, alarm among public health officials, and an unfortunate downturn in tourist activity. Again, this case illustrates the estimable, but clearly negative impact that an invasive alien species can have on the Hawaiian economy.

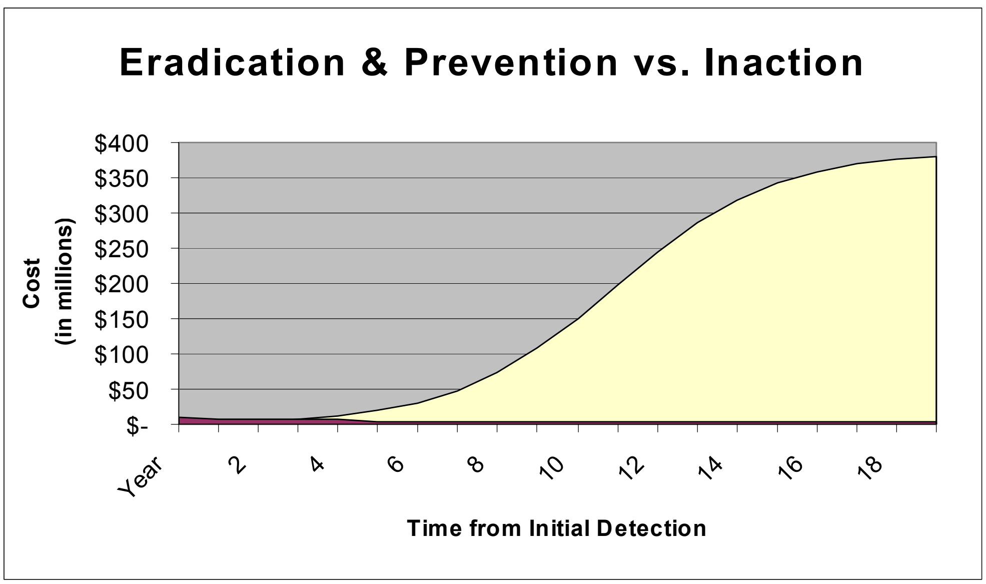
Last, consider the red imported fire ant. This species has not yet become established in Hawaii, but threatens significant damage if it arrives. These ants have already invaded the southern mainland U.S, extending from coast to coast. In South Carolina, where the pest is well established, total cost of the pest (for control, repair, and irreparable damage) amounts to $80 per household per year. Other states report higher costs per household. The state legislature in California recently allocated $40 million to eradicate the pest. This amount may seem extreme, but makes economic sense in light of the expected $250 million *annual* cost to the state if the ant becomes established.

These three examples also illustrate several other important lessons.

- ***The damage caused by an invasion of alien species can escape detection for years or even decades***. This is true in the case of damage to watersheds caused by ungulates. As suggested above, scientists are only now beginning to draw firm connections between ungulate populations and water quality.

- ***Invasive plants, animals, and microbes pose a threat not only to the environment, but also to public health and to the economy.*** In the case of dengue fever, an alien microbe invaded Hawaii, causing a public health crisis, which in turn led to a downturn in economic activity in East Maui.

- ***The ongoing cost of coping with an established invasive can be much greater than the cost of preventing its establishment in the first place***. Said differently, the ongoing costs of prevention are lower than the ongoing costs of damage and control associated with an established invasive species. The case of the red imported fire ant in California demonstrates this point clearly. The state government will spend $40 million to eradicate the pest in order to avoid one quarter of a billion dollars in recurring costs. As shown in the graph below, the total cost of prevention is much less than the cost of inaction that would lead to an established fire ant population.



This graph shows likely expenditures by the state of California to deal with the threatened invasion of the red imported fire ant under two sets of assumptions. The darker region shows eradication expenses of approximately $8 million per year for five years, followed by $5 million per year for prevention. This course of action represents a present value* cost of approximately $600 million to the state of California.

The alternative scenario, taking no action, shown in lighter shade, represents the ongoing costs of spot control and irreparable damage done by the fire ant. This cost grows exponentially at first as the pest spreads uncontrollably. As the pest establishes itself in all suitable habitats, the cost levels off. The present value* cost of this course of action is nearly $2,200 million, more than twenty times the estimated cost of eradication and prevention.

*Computed at a 3% discount rate.

The case of red imported fire ants in California illustrates the themes of this document, namely:

1) Invasive species present a real economic risk whose damage if left unchecked can be substantial, and

2) The cost of preventing and controlling their establishment is significantly less than the expected damage they would cause if established.

The remainder of the document explores the economic case for aggressive measures in the fight against invasives in Hawaii. By looking at the damage and potential damage caused by brown tree snakes, *miconia calvescens*, red imported fire ants and dengue fever, a case is constructed for funding several initiatives. These initiatives encompass preventive measures, early detection and rapid response measures, control and eradication plans in the case of existing populations, and public outreach and enforcement measures. For the initial year, these plans call for total funding of $52.6 million. The spending plans are detailed in Appendix 1, "CGAPS Needs Matrix."

3. Calculating the Cost of Invasives

Roumasset et al. give a useful framework for understanding the costs of invasives. Resources (capital, labor, natural resources) which might be employed elsewhere must be dedicated to:

1) Prevent invasives from becoming established (C_P)
   (e.g. inspections at ports of entry),

2) Control populations of established invasives (C_C)
   (e.g. pesticide applications to control termites),

3) Repair damage caused by established invasives (C_R)
   (e.g. replacing wood structures damaged by termites), and finally

4) Losses incurred when damage caused by invasives cannot be repaired. (C_D)
   (e.g. lower property values or decreased agricultural production).

So, the total cost of invasives can then be thought of as the sum of these four costs, i.e.

Total Cost = $C_P + C_C + C_R + C_D$

From an economic perspective, the objective should be to minimize this total cost. While this may seem to be a straightforward proposition, this equation is much more complex than it appears. Likely solutions for minimizing the total cost will include some elements of each kind of cost.

Notice that the first three of these costs involve choice on the behalf of individuals or policy makers. In the case of preventive measures, it is up to a landowner to determine whether he will install fencing to exclude feral pigs and sheep. Similarly, the state of Hawaii decides how much to spend on port-of-entry inspections to prevent the arrival of invasives. Similar analogies exist for control and repair expenditures.

The only cost that is not subject to human control is the residual damage cost, i.e. the loss incurred when damage cannot be repaired. Given parameters for preventive, control and repair costs, some level of residual damage is likely to occur. Considering the complex interactions of these costs for a particular species, it becomes impossible to determine which combination of prevention, control, and repair costs is ideal. However, as the next sections of this report illustrate, it is generally true that an increase in expenditures for prevention and control results in a decrease in total cost. That is, a dollar spent for prevention and control of invasives yields much more than a dollar in expected benefits.

4. Brown Tree Snake

Perhaps no other potential threat to the Hawaiian environment has received as much publicity as the brown tree snake (BTS). The snake presents a particular threat to Hawaii for several reasons.

1) BTS is particularly robust, enduring harsh conditions for long periods, making it well-suited to enter Hawaii by stowing away in wheel-wells of airplanes or in shipboard cargo. At least seven of these snakes have already been caught in Hawaii.

2) Like Guam, where BTS is thriving, Hawaii has a suitable climate, ample prey but no natural predators for BTS.

3) The snake poses a threat not only to Hawaiian wildlife, but also directly to the infrastructure of the Hawaiian economy as evidenced by the damage the snake has caused to the electrical power grid on Guam.

4) The snake creates a public health hazard. In Guam, on average, the snake bites four people per month who require medical treatment.

5) An established BTS population would diminish Hawaii's image in the worldwide tourist industry as a snake-free paradise

To be sure, as many as one thousand other snake species could pose a similar threat. We draw attention to this snake because BTS has been seen in Hawaii, and because Guam provides a clear demonstration of the damage BTS can cause.

Roumasset et al. drew from the experience of Guam to analyze what cost Hawaii could expect to incur if BTS became established in Hawaii. The study also examines what impact preventive and control measures would have on total expected cost. The authors conclude that, unchecked, the total cost of BTS would range from $29 million to $405 million annually. The authors go on to show that spending $16 million for prevention, and $22 million for control (if BTS arrives despite preventive measures) would yield benefits of $194 million annually relative to expected costs.

One possible point of controversy in the Roumasset analysis lies in the value ascribed to native species. The authors use a contingent valuation technique to assign a value of $12.4 million per native bird species. They reason further that BTS would put many species of native birds at risk of extinction, and therefore, this value would be lost. On the other hand, Roumasset et al. excluded the negative impact a snake population would have on Hawaii's image as a tourist destination. Excluding this impact makes sense because determining this cost would have been difficult and the result would likely have been controversial at best.

We have reproduced the analysis done by Roumasset et al. using different assumptions regarding the expected impact of the snake. The potential damage consists of negative impacts to public health, power outages, damages to the poultry industry and damage to agriculture in general. By reproducing their analysis, including only those impacts that have a directly measurable market price, we reach several conclusions. First, we see that in the event a BTS population becomes established, the state should enact control measures. That is, controlling an established snake population is always cost-justified. Second, we see that spending on prevention is also cost-justified in that it will reduce the expected total cost.

Cost to Public Health

In Guam, snakes bite approximately fifty individuals per year, many of them children under the age of five, and many requiring hospitalization. Overall, the average cost for treating snakebite is approximately $70. Extrapolating these figures to the population of Hawaii, leads to an estimate of twenty bites per month, for a total of $16,800 annual cost.

Costs from Power Outages

According to a 1990 report prepared by the Aquatic Nuisance Species Task Force:

> "Brown tree snakes are commonly encountered climbing on manmade structures. Snakes climb guy wires leading to power poles supporting transformers, distribution lines, and high-voltage transmission lines. When the snakes simultaneously touch live and grounded conductors, they create faults, short circuits, and electrical damages. This has resulted in frequent losses of power to parts of the island and even islandwide blackouts. Such power failures, brownouts, and electrical surges in turn damage electrical appliances and interrupt all activities dependent on electrical power, including commerce, banking, air transportation, and medical services. Power outages caused by snakes have been a serious problem on Guam for several years." (http://anstaskforce.gov/BTS%20Control%20Plan.htm)

In 1996, a single eight-hour power outage on Oahu caused an estimated $13 million in damages and lost productivity. Between 1978 and 1997, snakes caused more than 1600 power outages in Guam. In Hawaii outages of this frequency (more than six per month) could cause up to $112 million in damages annually. If outages were less frequent, (say one outage per month), damages would be closer to $15 million annually.

To the extent that Hawaii wishes to attract new businesses such as high technology manufacturing, biotechnology, and telecommunications, a reliable power supply is critical. Companies will not want to invest in high-tech facilities in Hawaii if their supply of electricity may fail periodically due to tree snakes.

Costs to the Poultry Industry

BTS is known to prey on many types of ground nesting birds, including poultry. It is impossible to estimate with any certainty the degree of impact BTS would have on Hawaiian poultry and egg production, so we assume a range of potential damage. According to Hawaii Agricultural Statistics Service (HASS), egg production generates $10.8 million in Hawaii annually. By assuming a decline in production of between 0.2% and 2.0%, we arrive at damage estimates of $21,600 to $216,000 per year.

Costs to Agriculture

Agriculture can expect the same type of impact projected for the poultry industry. BTS preys on natural insectivores, which can lead to a decline in agricultural productivity. According to Hawaii Department of Agriculture figures, agriculture contributes $2.9 billion to the Hawaiian economy. By assuming a decline in agricultural productivity between 0.1% and 1.0%, we arrive at damage estimates of $2.9 million to $29 million annually.

The costs associated with an established population of BTS are summarized in Table 3.1 below.

TABLE 3.1 – COST ASSUMPTIONS FOR BROWN TREE SNAKE

Impact	Basis of estimate	Damage range (annual)
Power outages	Guam experienced 1643 power outages directly attributable to snakes from 1978-1997 (approx. 6.5 per month) During an 8-hour power outage on O'ahu, the island experienced an estimated $13 million loss in productivity.	$15,600,000 (Low) $112,000,000 (High)
Bites requiring medical treatment	In Guam, an average of four people per month is bitten by the snake. On average, treatment costs $70.	$5,600 (Low) $16,800 (High)
Poultry Industry Damage	Snakes are known to prey on poultry	$21,600 (Low) $216,000 (High)
Agricultural productivity	Snakes are known to prey on lizards, birds, and other natural insectivores, leading to a decline in agricultural productivity.	$1,000,000 (Low) $10,000,000 (High)
TOTAL		$16,627,200 (Low) $123,232,800 (High)

Costs of Control and Prevention

Estimating the correct level of preventive expenditure is difficult at best. Instead, we assume a range of expenditure to prevent the invasion of BTS, and look to the expected cost/benefit payoff. In that approach we borrow from Roumasset et al. again, and assume a low-end expenditure of $1.6 million and a high-end expenditure of $16 million annually.

With the experience of Guam as a reference, it is easy to estimate expected costs for control of BTS. In 1998, Guam spent $450,000 to control the established population of snakes. This amount supported control programs including traps, fumigation, canine detection, hand capture, and other control technique for an established population covering 212 square miles. In Hawaii, BTS could infest approximately 30 times that area, so control costs might be as much as $13.5 million annually.

Table 3.2 shows the total expected cost of BTS under four different scenarios. In the first scenario, the snake arrives without any preventive or control measures. In this case, the snake is expected to cause $105 million in annual damages. In the remaining scenarios control measures are implemented together with varying degrees of preventive measures.

As the table shows, the expected total cost of BTS declines with increasing spending on prevention and control. Recall the "Total Cost" equation discussed in the previous section. If the objective is to minimize the total cost of BTS, then clearly the best course of action is to prevent the establishment of the snake.

Table 3.2 TOTAL COST OF BTS UNDER DIFFERENT SCENARIOS

Scenario	Total Cost	Cost of Prevention (C_P)	Cost of Control (C_C)	Cost of Repair (C_R) plus Residual Damage (C_D)*
No prevention, No control	$91 million	$0	$0	$91 million
No prevention, With control	$66 million	$0	$14 million	$52 million
Low prevention, With control	$47 million	$2 million	$14 million	$31 million
High prevention, With control	$42 million	$16 million	$14 million	$12 million

*The expected cost of damages is reached by assigning probabilities to two factors: 1) the likelihood that BTS arrives and becomes established under scenarios of high, low, or no prevention expenditures, and 2) the likelihood that BTS causes high levels of damage.

Current Situation

In fact, the State of Hawaii, with federal assistance, already supports many measures to prevent the arrival of the BTS. Prevention efforts consist of searching most inbound flights from Guam with canine units, and responding to BTS sightings with search and trapping efforts.

However, as mentioned earlier, hundreds of species of snakes could inflict similar damage, and many of these species are regularly smuggled into Hawaii intentionally. Kraus and Carvalho provide an analysis of the risk to Hawaii from snakes including BTS and snakes smuggled in for use as pets. They conclude that:

> Failure [to reduce the rate of snake introductions] in Hawaii will make successful establishment of ecologically dangerous snakes a virtual certainty.

They also propose a series of measures to improve the detection of snakes and other illicit items at ports of entry, and to improve enforcement of existing laws against importing potential invasives.

5. Red Imported Fire Ant

Like the brown tree snake, there is ample data available on the economic damage threatened by the red imported fire ant (RIFA). This species has existed in the southern U.S for the most of the twentieth century. Originating in Argentina, they entered the U.S. in Mobile, Alabama and have spread as far north as Virginia, and as far west as California. (CRS Report: RL30123). Given its existence in California and Australia, RIFA poses a growing threat to Hawaii with the increasing likelihood that inbound cargo will be infested.

The ants develop large surface-dwelling colonies in disturbed areas such as pastures and lawns. These colonies can be so large and sturdy that they damage farm equipment and disrupt planting and harvesting patterns.

Individually, the ant's sting is less severe than that of many other insects. However, rarely does a person or animal suffer only one sting. When threatened by an individual that has slowed or stopped near its nest, the colony will swarm up the victim's leg, inflicting dozens or hundreds of stings in a matter of seconds. In severe cases, sensitive individuals (human and otherwise) may die from the stings.

In the mainland U.S. some agricultural areas are severely hampered with high levels of infestation. In residential areas, people complain of being unable to use their yards, or allow their pets outside. All these impacts create cost in the economy. Estimated damages to livestock, wildlife and public health in Texas alone are $300 million annually, and $2 billion per year nationally. (CRS Report: RL30123).

California has only recently begun to deal with RIFA, and presents an interesting case for comparison to Hawaii. A study by Jetter, Hamilton and Klotz in California Agriculture gives a valuable insight into the situation Hawaii would face if the red imported fire ant were to gain a foothold on the islands. The study applied knowledge gained from previous studies of infestations in the southern U.S. to estimate the economic impact of an invasion of California. The primary costs of an invasion would be damage to urban households, and to agriculture.

Costs to Urban Households

RIFA can inflict damage on households in several ways. There are potential health problems resulting from bites (both to humans and to pets), especially to individuals who are allergic to the ant's venom. Mounds built by colonies can disrupt the use of recreational facilities, communication and electrical equipment. Households incur costs to control the pest and to repair damaged equipment. A previous study indicated that together, these costs averaged $80 per household per year in South Carolina. The study went on to divide the households into those with a high risk of infestation (due to climate, soil condition, and altitude) and those with a low risk of infestation. The average cost for high-risk households was set at $104, and the average cost for low-risk households at $30.

In 2000, Hawaii's Department of Business, Economic Development, and Tourism (DBEDT) reported that there were approximately 403,000 households in Hawaii. Using three different approaches as outlined in Table 4.1, and using the average costs per household from South Carolina, we can estimate a range for yearly cost to Hawaiian households. The table shows that the red imported fire ant could add between $13.3 million and $41.9 million to the cost of living in Hawaii.

TABLE 4.1 – COST OF RIFA TO URBAN HOUSEHOLDS

Scenario	Description	Cost per Household	Total Annual Cost
Scenario 1	All households low-risk	$33	$13.3 million
Scenario 2	Same distribution of households (low-risk vs. high-risk) as South Carolina	$80	$32.2 million
Scenario 3	All households high-risk	$104	$41.9 million

Costs to Agriculture

Food Crops. In crop fields infested by the red imported fire ant, producers will need to treat the fields with pesticides to control the pest. Applying the logic employed by Jetter et al., producers will treat fields twice annually with methoprene, an insect growth regulator. These applications will create an annual cost of $55 per acre treated.

Drawing on data from DBEDT, we can estimate the incremental cost for treatment of Hawaii's various crop fields. We show the estimated cost impact for three different levels of field infestation, a low level of 10% of acreage infested, a medium level of 25% and a high level of 40%. Table 4.2 shows the additional cost producers could expect to incur to combat infestations of RIFA. If only 10% of acreage in crop fields becomes infested, treatment will cost $0.7 million, but if infestation reaches 40% of crop fields, treatment expense will rise to $2.7 million.

Table 4.2 shows only the cost associated with treatment to control infestations of RIFA. Other studies have shown that RIFA can cause additional damage by consuming developing fruit, seeds, roots, or tubers, thereby diminishing crop yields. In one documented case, eggplant yield in Florida decreased by 50% because of an infestation of RIFA. While this type of damage can be severe, there is insufficient evidence to estimate the impact of crop yield reduction in Hawaii.

Nursery. According to the Jetter study, treatments at nurseries for RIFA would cost about $650 annually per acre. The treatment includes applications of fenoxycarb, hydramethylnon, and bifenthrin. DBEDT reports that there were approximately 2,300 acres of open field nurseries in Hawaii in 1999, meaning that treatment costs for the nursery industry would total approximately $1.5 million annually.

Livestock. Red imported fire ants attack livestock in rangelands where the pest is established. Attacks can produce skin inflammations, infections, and blindness (the ant is attracted to the mucous membranes around the eyes and nose). When the ants infest food and water supplies, livestock will not eat or drink from those supplies. Without constant monitoring, this type of infestation can lead to livestock malnourishment or dehydration.

As in the case of reduced crop yields, there is insufficient evidence to estimate the impact of RIFA infestations on livestock. (Jetter)

TABLE 4.2 ESTIMATED ANNUAL COST OF RED IMPORTED FIRE ANTS TO HAWAII CROPS

		Farm	Additional Costs to industry ($000s)			% Farm receipts		
	Acres	Receipts	Acreage Affected			Acreage Affected		
Crop	(000s)	($000s)	10%	25%	40%	10%	25%	40%
Sugarcane	60.0	62,600	330.0	825.0	1,320.0	0.53%	1.32%	2.11%
Pineapples	20.7	101,530	113.9	284.6	455.4	0.11%	0.28%	0.45%
Vegetables and melons								
Beans, Snap	0.2	1,092	1.2	2.9	4.6	0.11%	0.26%	0.42%
Cabbage, Chinese	0.3	1,512	1.8	4.4	7.0	0.12%	0.29%	0.47%
Cabbage, head	0.5	2,774	3.0	7.4	11.9	0.11%	0.27%	0.43%
Corn, sweet	0.4	1,320	2.4	6.1	9.7	0.18%	0.46%	0.73%
Cucumbers	0.4	2,508	2.2	5.5	8.8	0.09%	0.22%	0.35%
Onions, dry	0.3	3,053	1.9	4.7	7.5	0.06%	0.15%	0.25%
Onions, green	0.2	1,290	0.8	2.1	3.3	0.06%	0.16%	0.26%
Peppers, green	0.2	1,540	1.1	2.8	4.4	0.07%	0.18%	0.29%
Potatoes, sweet	0.3	1,500	1.4	3.6	5.7	0.10%	0.24%	0.38%
Squash, Italian	0.2	1,033	1.0	2.5	4.0	0.10%	0.24%	0.38%
Taro	0.5	3,710	2.6	6.5	10.3	0.07%	0.17%	0.28%
Tomatoes	0.5	8,580	2.8	6.9	11.0	0.03%	0.08%	0.13%
Watercress	0.1	1,067	0.3	0.7	1.1	0.03%	0.06%	0.10%
Watermelons	0.6	3,150	3.1	7.7	12.3	0.10%	0.24%	0.39%
Herbs	0.1	5,380	0.6	1.4	2.2	0.01%	0.03%	0.04%
Ginger Root	0.3	8,910	1.5	3.7	5.9	0.02%	0.04%	0.07%
Other	1.4	11,342	7.7	19.3	30.8	0.07%	0.17%	0.27%
Fruits								
Bananas	1.6	10,440	8.5	21.3	34.1	0.08%	0.20%	0.33%
Guavas	0.7	2,051	3.7	9.4	15.0	0.18%	0.46%	0.73%
Papayas	1.7	16,007	9.1	22.7	36.3	0.06%	0.14%	0.23%
Other	3.2	2,866	17.7	44.3	70.8	0.62%	1.54%	2.47%
Coffee	7.9	23,055	43.5	108.6	173.8	0.19%	0.47%	0.75%
Macadamia nuts	18.4	29,500	101.2	253.0	404.8	0.34%	0.86%	1.37%
Seed Crops	2.8	35,400	15.4	38.5	61.6	0.04%	0.11%	0.17%
TOTAL	**123.3**	**343,210**	**678.1**	**1,695.2**	**2,712.4**	**0.20%**	**0.49%**	**0.79%**

Threat to Wildlife

Much like the brown tree snake, the red imported fire ant poses a threat to biodiversity in Hawaii. Strong evidence from infestations in Texas indicates that the ant affects bird and reptile populations by destroying the eggs and young. One such study found a 92% reduction of waterbird offspring when natural habitats were not treated for ant infestations. Again, it is difficult to quantify the value of this threat, but the potential biodiversity loss caused by the red imported fire ant cannot be ignored.

Total Cost

Table 4.3 summarizes the estimated total annual cost to Hawaii's economy if the red imported fire ant were to become established. This cost ranges from $15.5 million at the low end to $46.1 million at the high end.

TABLE 4.3 - ESTIMATED TOTAL COST OF ESTABLISHED RIFA POPULATION

	Impact ($000s)		
Category	**Low**	**Medium**	**High**
Food Crops	678	1,695	2,712
Nursery	1,516	1,516	1,516
Households	13,299	32,240	41,912
TOTAL	15,493	35,451	46,140

Costs and Benefits of Prevention

CGAPS assembled a list of preventive measures deemed necessary to prevent the arrival and establishment of RIFA. Among others, proposed measures include:

1) Improving knowledge of invasion pathways,
2) Passing a state law giving HDOA authority to inspect non-agricultural. Items,
3) Implementing a "No ants allowed" policy for goods/persons entering Hawaii,
4) Securing assistance from USDA under federal domestic quarantine law,
5) Inspecting first class mail from the mainland,
6) Implementing regulations requiring special handling of goods from RIFA-infested areas, and
7) Making available emergency funds for eradication.

CGAPS estimates that measures to prevent the arrival of RIFA and to control it if it does arrive will cost approximately $12 million annually. Of this amount, only $0.5 million would be targeted exclusively to ants. The remaining $11.5 million consists of inspection and enforcement resources that would address multiple invasive species threats.

Here again, as is the case of the brown tree snake, we see that the cost of prevention and control is much less than the expected cost of inaction. Table 4.4 summarizes this result.

Table 4.4 TOTAL ANNUAL COST OF RIFA UNDER DIFFERENT SCENARIOS

Scenario	Total Cost	Cost of Prevention (C_P)	Cost of Control (C_C)	Cost of Repair (C_R) plus Residual Damage (C_D)*
No prevention, No control	$40.9 million	$0	$0	$40.9 million
No prevention, With control	$30.0 million	$0	$9.4 million	$20.5 million
Low prevention, With control	$25.8 million	$1.2 million	$9.4 million	$15.1 million
High prevention, With control	$19.8 million	$5.0 million	$9.4 million	$5.4 million

*The expected cost of damages is reached by assigning probabilities to two factors: 1) the likelihood that RIFA arrives and becomes established under scenarios of high, low, or no prevention expenditures, and 2) the likelihood that RIFA causes high levels of damage.

6. Miconia calvescens

Miconia (aka Velvet Purple Leaf) has received a great deal of attention it has already established populations on Hawaii and on Maui due to its ability to outcompete native Hawaiian vegetation. In east Maui, the Maui Invasive Species Committee (MISC) has identified a 2,500-acre core area of infestation in Hana adjacent to Haleakala National Park. In that core infestation, *Miconia* has crowded out existing vegetation, destroying the understory and establishing a monotypical stand.

In Tahiti, with a climate and environment similar to those in Hawaii, *Miconia* has taken over sixty-five to seventy percent of existing tropical forests. If the plant were to spread so pervasively in Hawaii, *Miconia* would do irreversible damage to native ecosystems. *Miconia* would almost certainly cause the extinction or endangerment of several native plant species. More to the point, some of this potential damage would have a direct impact on the Hawaii's economy. Specifically, infestations of *Miconia* could alter the water supply provided by Hawaii's aquifers.

Estimates of Economic Impact to Watersheds

Much like the impact that ungulates have on watersheds, the effect of *Miconia* on water supply has not been quantified scientifically. However, there is anecdotal evidence to suggest that the kind of damage caused by *Miconia* (formation of monotypical stands, destruction of the understory) will lead to diminishing recharge rates in tropical forest watersheds. As a case in point, studies of the fynbos watershed in South Africa indicated that invasion of alien woody species into the watershed led to decreases in recharge rates of 30 to 80 percent (Gutrich).

Given the uncertainty of *Miconia's* impact on watershed recharge rates, Gutrich and Donovan performed a contingent analysis of management practices in the Hawaii's watersheds. They conclude as follows:

> If watershed management activities in the Ko'olaus can prevent a mere 5 percent reduction in groundwater recharge due to damage caused by feral ungulates and invasive plants, the partnership efforts will sustain annual groundwater benefits worth approximately $561,457. Partnership efforts that prevent even larger levels of degradation will provide a bigger return to watershed management, maintaining benefits of $1.3 million annually (based on prevention of a 10 percent decrease)…

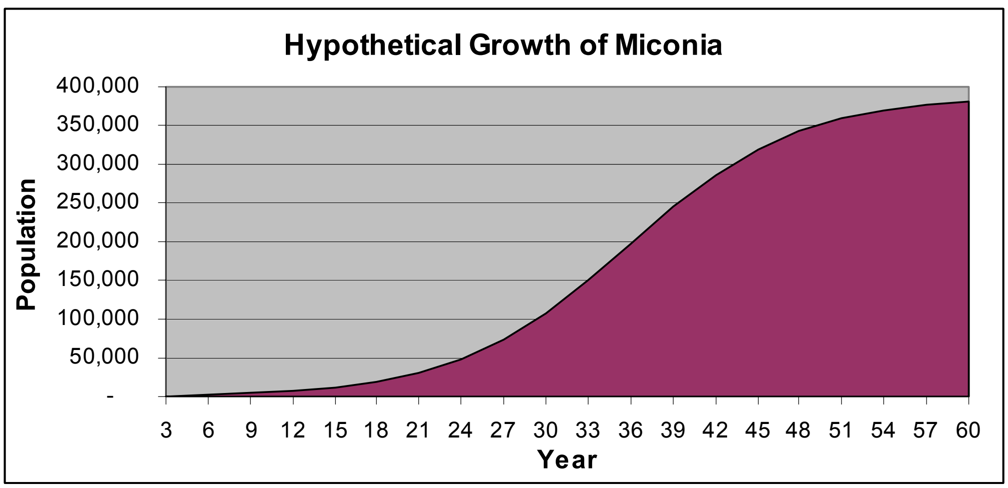
Addressing Miconia specifically, Gutrich and Donovan studied the control measures undertaken by the East Maui Watershed Partnership.

> Our analysis concludes that from the year 2001 to 2021, a $1 million annual expenditure is warranted to stop the spread of Miconia in the East Maui watershed because annual economic damages to natural systems from inaction will far exceed this cost.. Yet, if policymakers had acted sooner, when the spread of Miconia could have been isolated, management (or eradication) costs may have been substantially lower.

Impending Threat

The lesson to be learned from the experience of Miconia in Hawaii is that it is best to act early. As Gutrich observed with the benefit of hindsight, the most cost-effective approach to controlling *Miconia* probably would have been when the invasive population was still small and vulnerable. However, we do not suggest that because the best opportunity has been missed, we should now do nothing.

To the contrary, the real risk of Miconia spread may still be a few years away. Data compiled by Gutrich from other Tahiti and other Polynesian islands suggests the typical growth pattern for Miconia includes a "lag phase" of twenty to thirty years. During this time, when a small population entrenches itself in the new environment spreading just enough to acquire critical mass. At some point, growth explodes and the plant takes over as much suitable land as it can reach. The chart below gives an indication of what a projected growth curve for Miconia in Hawaii might look like. Miconia probably arrived about twenty years ago, suggesting that Hawaii is approaching a critical point in the growth curve, when costs to eradicate the infestation are still relatively low. To wait another five or ten years may allow the population to grow sufficiently that eradication costs double or triple, or that control becomes impossible.



7. Dengue Fever Outbreak

In the fall of 2001, Hawaii and in particular Maui experienced an outbreak of dengue fever. By the time the outbreak was declared to have ended in May, 2002, there had been 119 confirmed cases of the disease. In response to the outbreak, the state and local governments in Hawaii spent a good deal of money on containment, prevention, and public awareness. Final numbers for spending related to the outbreak are not yet available, but Hawaii Department of Health indicates that it spent on the order of $1 million combating the outbreak.

The U.S. Centers for Disease Control (CDC) plans to study the total cost of the outbreak. This study should incorporate the amounts spent by local governments as well as costs to treat the infected victims, imputed costs of volunteers who assisted government efforts, lost productivity, and foregone commerce.

None of the measures proposed by CGAPS could have prevented the outbreak of dengue. However, the outbreak of dengue draws attention to a different risk. Officials at Hawaii Department of Health observed that the dengue fever outbreak would have been much worse had a more effective vector been involved.

Dengue fever is spread by either of two mosquitos form the genus *Aedes* -- most commonly by *A. aegypti* (a night biting mosquito that is also an effective yellow fever vector) and by *A. albopictus* (the common day biting mosquito in Hawaii). As it turns out, *A. aegypti* is not commonly found in Hawaii and *A albopictus* is not a very effective vector for dengue. Consequently, the recent dengue outbreak did not reach epidemic proportions. One official speculated that as many as one in five residents of Hawaii could have been infected if the vector had been *A aegypti* rather than *a albopictus*. That could have spelled disaster for the public health system in Hawaii, which would have been overwhelmed with dengue victims.

As bad as the recent dengue scenario sounds, matters would be worse still if, rather than dengue, the outbreak had been malaria, yellow fever, rabies, or even bubonic plague. Each of these diseases requires a specific vector for transmission, and as of yet, most suitable vectors are not established in Hawaii.

The bottom line on infectious diseases as they relate to invasive species is that by preventing invasions of suitable vectors, and eradicating existing ones, the risk of disease outbreak is significantly reduced. This reduced risk leads to a reduced expected cost of treating and containing disease. So, while hard cost data are not available to build a sound business case for measures to prevent the invasion of mosquitoes and other vectors, the qualitative case is clear.

8. Conclusions

The foregoing sections shed light on the potential damage that could result from three of the more widely known invasives threatening Hawaii. In fact, the list of potentially harmful alien species is much longer, and the scope of damage threatened by these species is much greater. Table 7.1 gives a small sampling of some of the other species that could cause significant harm to the economy and welfare of Hawaii.

Table 7.1 – OTHER POTENTIAL INVASIVES TO HAWAII

Species	**Risks**
Biting Sand Flies	Can inflict thousands of bites per human per day. Have had detrimental effect on visitor resorts in Tahiti, Caribbean and the Marquesas. (*A potential infestation of this insect was averted because of the sensitivity of the crew of the voyaging canoe Hokuleia returning from the South Pacific and the rapid response of the Hawaii Department of Agriculture.*)
Malaria-carrying mosqitoes	Transmits malaria and other diseases to humans. If established, residents and visitors to Hawaii would require malaria shots or pills.
Queensland fruit fly	Breeds in a variety of crops, limiting their export to major markets.
Piranha	Attacks humans and other large animals
Banana bunchy-top disease	Attacks banana and other tropical plants (This disease is already established in several locations in Hawaii.)
Asian Long-horn Beetle	Infests forests, destroying trees, leading to disruption of the water cycle

As with the species studied in detail in this document, each of these (and others) will inflict harm to the environment of Hawaii, and much of that harm will have a directly measurable economic impact. However, the greatest threat may be to Hawaii's tourism industry. Hospitality is the dominant industry in the state, and therefore any risk to tourism should be taken seriously. Other resort islands, (the Marquesas, Tahiti, and in the Caribbean) have already experienced the impact that new pests such as biting sand flies can have on tourism. How would tourism to Hawaii be affected if all visitors required malaria shots? How would the recreation industry change if there were piranha in the waters of Hawaii?

These and other questions must be addressed when considering how to address the threat of invasives. The species discussed in this document could cause quantifiable damage exceeding $180 million annually in the absence preventive or control measures.

To be sure, the state and federal governments already spend a great deal to combat the spread of invasives. Hard data are not available for U.S. government spending on invasives, but according to Hawaii's Legislative Research Bureau, the State of Hawaii spends approximately $7 million annually. However, a recent intensive inspection period at Kahului airport on Maui demonstrated that existing measures are woefully inadequate. During a ten-week period in autumn 2000, airport inspectors increased their level of inspection, and intercepted nearly one thousand pests, nearly ten times the normal rate of detection (Honolulu Advertiser).

The Coordinating Group on Alien and Pest Species (CGAPS) consists of experts from different agencies and organizations that deal with invasives. The group assembled a list of measures and associated costs they believe will not only address the gaps in current inspection, but will also prepare Hawaii to deal with the threat of invasives through early detection, response and control. Appendix 1 gives the summary section of the CGAPS list.

The list requests $42 million in recurring spending plus $10 million in one-time expenditures. The measures proposed by CGAPS would address a wide range of potentially invasive alien species. Considering that quantifiable damage from just three of the best known invasives could amount to $180 million annually, incremental spending of $42 million in prevention is more than justifiable.

9. Appendix 1 – CGAPS Needs Matrix

The figures below summarize expected needs to address the problem of invasive species in Hawaii. For detailed spending plans by species, please see "CGAPS Needs Matrix".

CGAPS "Box Exercise" Statewide Additional Needs Matrix

Species: Summary of All

	#FTE's	FTE $	Funding	Subtotal
Prevention	144	$8,640,000	$820,000	$9,460,000
Early Detection	31.5	$1,890,000	$789,000	$2,679,000
Rapid Response	68.25	$4,095,000	$539,000	$4,634,000
Control	292	$17,520,000	$12,732,000	$30,252,000
Enforcement	6	$360,000	$410,000	$770,000
Public Outreach	50.25	$3,015,000	$1,787,000	$4,802,000
Totals	515	**$35,520,000**	$14,003,000	**$52,597,000**

Assumptions:
FTE $= projected at $60,000 per position to cover salary, fringe and support
Helicopter time= $640/hr

10. Appendix 2 – Bibliography

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Interviews

Bruce Anderson, Director, Hawaii Department of Health

Alexa Biggs, Consultant, Carter Burgess

Paul Brewbaker, Chief Economist, Bank of Hawaii

Suzanne Case, Acting Executive Director, The Nature Conservancy of Hawaii

Paul Effler, Chief, Communicable Disease Division, Hawaii Department of Health

Mark Fox, Director of External Affairs, The Nature Conservancy of Hawaii

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Grady Timmons, Communications Director, The Nature Conservancy of Hawaii

Mark White, Director of Conservation Programs, The Nature Conservancy of Hawaii

11. Appendix 3 – Next Steps

In this section, we identify weaknesses in this study which should be strengthened as The Nature Conservancy and others pursue additional funding for the fight against invasives.

Needs Matrix

One of the first steps in strengthening this case should be to revisit the "Needs Matrix" created by CGAPS. This iteration of the needs assessment is now nearly one year old, and according to Mark White, is a good starting point, but probably not as accurate as it needs to be. The matrix as it exists now is an excellent "stake in the ground". The format is easy to understand, and probably the right way to assemble the information. Going forward, in addition to segregating requests by "shared" vs. "species-specific", it will likely be necessary to segregate by responsible agency and potential funding source as well.

As the case for additional funding to combat invasive species progresses, it will be critical to know exactly what is being requested, why it is needed, who should provide it, and how much it will cost. That is, convincing policymakers to fund a program may depend on the quality of the planning exercise, particularly with respect to cost. Nobody wants to agree to fund a $42 million plan, only to find out later that the real need is for $100 million.

Actions: **Reassess needs matrix.**
Categorize needs by species, responsible agency and funding source.
Develop action plans for each request.

Impact Estimates

The case will be much stronger if it contains expected damage assessments for each of the species addressed by the proposed preventive measures. People who allocate funding typically like to match expenditures to benefits. For example, if one requests $14 million in funding for general prevention, and an additional $0.5 million is targeted against ants, somebody will ask, "Why is the incremental $0.5 million necessary? What do I get for that extra $0.5 million?" In order to have an answer to that question, TNC needs to understand the economic impact of each invasive it hopes to fight. At the least, a broad understanding of the types of impacts, with detailed projections for ten or twelve species might suffice.

Action: **Develop impact assessments for more species.**

Include "Softer" Costs

Paul Brewbaker suggested including information in the cost of invasives for costs which are less tangible. Such information might include "willingness-to-pay", or contingent valuation figures. Roumasset and Gutrich both give examples of "revealed-willingness-to-pay" costs for endangered species. The reasoning goes that when a species becomes endangered, the government spends some amount of money to protect the species. In the case of snakes which if established would threaten native birds, the business case might include costs for adding bird species to the endangered species list and associated protective measures.

Other "softer" costs might include:

- Extinction of plant and animal species,
- Reduction in desirability of Hawaii as a tourist destination,
- Reduciton in desirability of Hawaii to bring in new businesses.
- Reduction in desirability of recreational areas.

Actions: **Revisit Roumasset and Gutrich for information on softer costs.**
Work with representatives of tourist industry to determine "willingness-to-pay" costs of preventing invasives like biting sand flies.

Determining Costs to Watersheds

This area of cost estimation is fairly weak, mostly because science does not yet understand all of the details surrounding the water cycle. The scientific community continues to refine its understanding of how changes in soil and forest conditions affect groundwater recharge rates. As this understanding improves, so will our ability to assign costs to damage done by invasives such as ungulates and *Miconia*.

Actions: **Stay current on water cycle research. Integrate as appropriate.**

Dengue Fever Outbreak

Dr. Paul Effler of Hawaii Department of Health indicated that the Centers for Disease Control planned to perform a cost study of the recent outbreak on Maui. When that cost study becomes available, it should be included in this report as a point of interest.

None of the measures proposed by CGAPS could have prevented the outbreak of dengue. However, the CGAPS measures do address the threat of invasion by new species of mosquito, many of which may be vectors for other tropical diseases. That is, if a different species of mosquito, a new invasive, had been available, the outbreak could have affected many more people, and therefore cost more. So, the cost information for the dengue outbreak can serve as a lower bound for the cost of future outbreaks.

Actions: **Integrate findings from CDC cost study into this report.**
Extrapolate these into cost of invasion by new mosquito species.