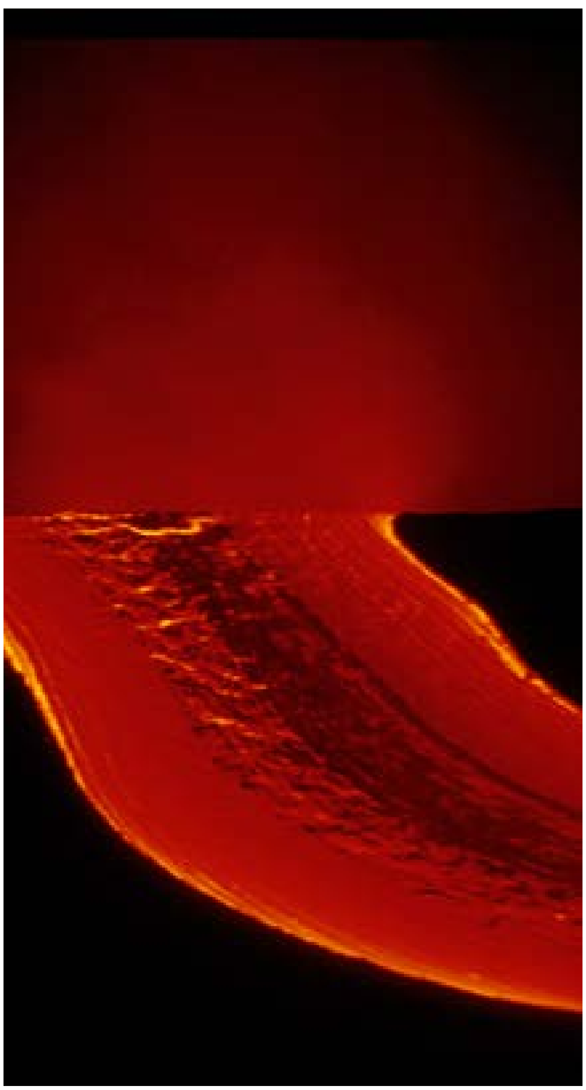



UHERO
THE ECONOMIC RESEARCH ORGANIZATION
AT THE UNIVERSITY OF HAWAI'I

PROJECT ENVIRONMENT

Assessing the Costs of Priority HISC Species in Hawaii

JULY 2016

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Assessing the Costs of Priority HISC Species in Hawaii

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LIST OF ABBREVIATIONS

BIISC	Big Island Invasive Species Council
DLNR	Department of Land and Natural Resources
DOFAW	Division of Forestry and Wildlife
HDOA	Hawaii Department of Agriculture
HISC	Hawaii Invasive Species Council
KISC	Kauai Invasive Species Council
LFA	Little Fire Ant
MISC	Maui Invasive Species Council
OISC	Oahu Invasive Species Council
USFS	United States Forest Service
USFWS	United States Fish and Wildlife Service

LIST OF DEFINITIONS

Expenditures	Dollars spent on management; these are not planned or recommended amounts.
Potential damages	Damages likely to occur in the future as a result of one or more invasive species under a specific set of assumptions.
Present value	Value today of an expected income stream (which may be positive or negative); PV is typically less than the sum of income because future income should be discounted to reflect opportunity costs.
Realized damages	Damages incurred as result of one or more invasive species.

1. OVERVIEW

Over the past decade, funding for the Hawaii Invasive Species Council (HISC) has ranged from less than $2 million per year in the three years following the recent economic downturn, up to almost $6 million in FY2015. The HISC website provides total award amounts for past projects, but it is difficult to attribute exact dollar amounts to specific species for projects that target multiple species. As a starting point, we consider the number of times each invasive species was designated as a target over the period FY2005-2015. While this list does not necessarily represent species that generated the largest economic damages or species for which the most spending has occurred, it is a list of species getting the most attention by HISC. For the most part, the top ten have remained fairly consistent over time, although in recent years, axis deer, albizia, and ivy gourd have received noticeably more attention.

Table 1. Top Invasive Species Mentioned in HISC-Funded Projects (FY2005-2015)[1]

	FY05-10		FY11-15		All Years (FY05-15)	
Rank	**Species**	**Count**	**Species**	**Count**	**Species**	**Count**
1	Miconia	20	Little Fire Ant	29	Miconia	44
2	Coqui Frog	20	Miconia	24	Little Fire Ant	42
3	Pampas Grass	14	Coqui Frog	17	Coqui Frog	37
4	West Nile Virus	14	Axis Deer	11	Pampas Grass	25
5	Little Fire Ant	13	Pampas Grass	11	Fountain Grass	17
6	Fountain Grass	11	Albizia	8	West Nile Virus	16
7	Red Imp. Fire Ant	11	Mongoose	7	Albizia	11
8	Avian Influenza	6	Fountain Grass	6	Axis Deer	11
9	E. Gall Wasp	6	Ivy Gourd	6	Gorilla Ogo	11
10	Gorilla Ogo	6	Others*	5	Ivy Gourd	11

**Others includes the following: barbados gooseberry, brown tree snake, false kava, gorilla ogo, giant reed, long-thorn kiawe, and rubber vine*

The top five most significant threats were identified based on the FY11-15 column in Table 1, with one exception. Because most of the expenditures on pampas grass are for prevention, and fountain grass is already established on multiple islands, we focus on the latter to allow for estimation of realized wildfire damage and fire suppression expenditures.

1 http://dlnr.hawaii.gov/hisc/projects/

2. AXIS DEER REALIZED DAMAGES AND MANAGEMENT EXPENDITURES

As of 2012, the population of axis deer (*Axis* axis) on Hawaii Island was estimated at less than 100, and recent surveys indicate that the population may have been successfully eradicated. In 2014 the Maui Axis Deer Working Group counted 8,000 deer in East Maui (125,000 acres surveyed), the most heavily affected area on the island.[2] Without control, axis deer populations in Hawaii have been known to increase by 20-30% per year. Axis deer browse on native plant species, fruits and vegetables on agricultural lands, and foraging grass on ranches. They have also been known to strip bark from trees to obtain water and also create erosion, which increases the amount of sediment carried to the near shore environment. In addition, fecal material left on farmlands can make crops unsellable under federal regulations.

In a 2012 report to the State of Hawaii Department of Land and Natural Resources (DLNR), Maui County estimated the two-year cost of axis deer damage to farms, ranches, and resorts in the county at over $2 million.[3] Based on the proportional loss of agricultural product on Maui, the potential impact on Hawaii Island is over $8 million annually. In addition, the BIISC estimates that retrofitting fences in watershed conservation areas would cost upwards of $18.7 million.[4] In 2013, damages for Maui Island were reported at $750,000 per year.[5] All of the estimates are likely based on a survey conducted by Kenneth Yamamura, an agricultural specialist in the Maui County Office of Economic Development. The most detailed report was provided in the Maui News.[6] According to the survey of 25 farms, 5 ranches, and 8 resorts, axis deer caused $306,000 in crop damages, $496,000 in damages to the ranches, and $183,000 in damages to resorts, for a total of $985,000 per year over the period 2011-2012.

The Maui County survey also included questions on mitigation costs. In 2011-2012, farmers, ranches, and resorts spent $257,000, $610,000, and $81,000 respectively on mitigation, for a total of $948,000. A majority of the mitigation efforts entailed putting up fences. In addition to private mitigation efforts, HISC funds in recent years have been allocated for the control of axis deer on both the Big Island and Maui. For the period spanning FY2011-15, awards specifically targeting axis deer totaled roughly $800,000 (Table 2). Figure 1 plots axis deer management expenditures over time. To avoid double counting, HISC awards were subtracted from individual ISC expenditures on axis deer where applicable. Because we were not able to obtain species-specific expenditure data from the Big Island Invasive Species Council (BIISC), the total should be interpreted as a lower bound.

[2] http://www.washingtontimes.com/news/2014/jan/13/maui-axis-deer-survey-counts-about-8k-animals/

[3] http://files.hawaii.gov/dlnr/meeting/submittals/121026/C-FW-Submittals-C1.pdf

[4] http://www.huffingtonpost.com/barbara-fahs/jungle-beat-invasive-deer_b_4304812.html

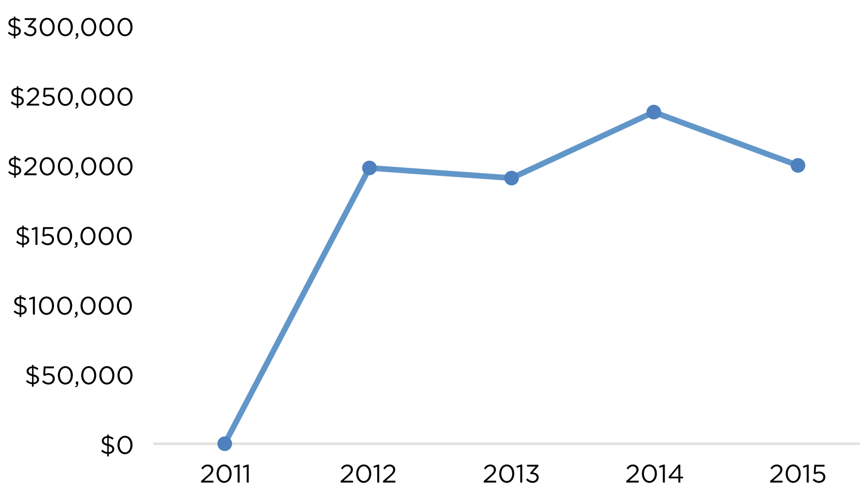
[5] Ibid

[6] http://www.mauinews.com/page/content.detail/id/561027.html

Table 2. Axis Deer Projects, 2011-15[7]

Fiscal Year	Source	Description	Amount	Note
2012	HISC	Big Island Axis Deer Project	$90,000	
2012	DOFAW & USFWS	Big Island Axis Deer Project	$107,772	HISC award leveraged this funding
2013	HISC	Big Island Axis Deer Project	$118,306	
2013	HISC	Management of Axis Deer on Maui Island	$72,790	
2014	HISC	Big Island Invasive Deer Project	$129,526	
2014	HISC	Axis Deer Management: Maui Island	$62,000	
2014	MISC	Additional MISC expenditures allocated to axis deer	$47,424	
2015	HISC	Big Island Axis Deer Early Detection and Response	$150,000	
2015	HISC	Axis Deer Management on Maui Island	$50,000	
		FY2011-15 TOTAL:	**$827,818**	
		AVG ANNUAL MNGT TOTAL:	**$165,564**	

Figure 1. Expenditures on Axis Deer Management, 2011-15



Based on the total in Table 2, the average annual non-private expenditures on management amounted to $165,564. Combining that with estimated private mitigation expenditures and damages results in total annual costs of $2.1 million (Table 3).

[7] Source: http://dlnr.hawaii.gov/hisc

Table 3. Axis Deer Realized Damages and Management Expenditures

Category	Source	Description	Amount
Damage	-	Farms, ranches, resorts	$985,000
Management	Private	Fences	$948,000
Management	HISC, MISC	Planning and removal	$165,564
		AVG ANNUAL TOTAL:	**$2.1M**
		FY2011-15 TOTAL:	**$10.5M**

3. COQUI FROG REALIZED DAMAGES AND MANAGEMENT EXPENDITURES

The coqui frog (*Eleutherodactylus coqui*) disrupts native ecosystems by eating large quantities of insects. Their loud call is a nuisance to both tourists and residents. Disclosure requirements for real estate transactions have resulted in decreased property values, and export plant sales have also declined. Because the frog has no natural predators, populations have reached 55,000 frogs per hectare in some Hawaii locations. Maui hosts thirteen populations of coqui, located around nurseries, hotels, residential areas, and natural areas. On the Big Island, it is estimated that the frogs have infested 60,000 acres.

Although the frogs likely have some effect on the nursery and tourism industries, to date, only the impact on the housing industry has been quantitatively estimated. Using a hedonic pricing model, Kaiser and Burnett (2006) found that on average, properties within 500 meters of a complaint/siting experienced a 0.16% decline in property value. If the number of residential units sold per year in Hawaii County is 2,125, the number used by Motoki et al. (2013) in their analysis of Little Fire Ants, and the median value of owner-occupied housing is $309,800,[8] then the annual damage incurred in the housing sector could reach upwards of $1 million per year, assuming that most sold units on the Big Island are or eventually will be negatively affected by coqui.

The unmeasured impact on nurseries may actually be higher. In 2008, nursery production in Hawaii County was $41.2 million.[9] Thus if coqui infestations reduced exports to neighbor islands and/or out of state by even 10% of the total value, the additional damage per year would be $4.12 million.

Over the past decade, HISC funds have been allocated for research, as well as for control and eradication of coqui statewide. For the period spanning FY2005-15, awards specifically targeting coqui totaled $20.6 million. Recent expenditures over the period FY2011-15 accounted for $4.1 million (Table 4). Figure 2 plots coqui management expenditures over time. Because we were not able to obtain species-specific expenditure data from BIISC (where the coqui problem is most pronounced), total spending on control and eradication should be viewed as a lower bound.

8 http://quickfacts.census.gov/qfd/states/15/15001.html

9 http://www.nass.usda.gov/Statistics_by_State/Hawaii/Publications/Annual_Statistical_Bulletin/index.asp

Table 4. Coqui Frog Projects, 2011-15

Fiscal Year	Source	Description	Amount	Note
2011	KISC	Total KISC expenditures allocated to coqui	$40,160	
2011	OISC	Total OISC expenditures allocated to coqui	$34,122	
2011	MISC	Total MISC expenditures allocated to coqui	$488,141	
2011	State, HDOA, County	Costs of Eradicating Coqui on Maui	$725,000	Proposed spending
2012	KISC	Total KISC expenditures allocated to coqui	$30,410	
2012	OISC	Total OISC expenditures allocated to coqui	$36,623	
2012	MISC	Total MISC expenditures allocated to coqui	$627,529	
2012	State, HDOA, County	Costs of Eradicating Coqui on Maui	$200,000	Proposed spending
2013	KISC	Total KISC expenditures allocated to coqui	$27,790	
2013	OISC	Total OISC expenditures allocated to coqui	$32,456	
2013	MISC	Total MISC expenditures allocated to coqui	461,047	
2013	State, HDOA, County	Costs of Eradicating Coqui on Maui	$200,000	Proposed spending
2014	KISC	Total KISC expenditures allocated to coqui	$28,690	
2014	OISC	Total OISC expenditures allocated to coqui	$16,992	
2014	MISC	Total MISC expenditures allocated to coqui	475,806	
2015	KISC	Total KISC expenditures allocated to coqui	$27,530	
2015	OISC	Total OISC expenditures allocated to coqui	$17,972	
2015	MISC	Total MISC expenditures allocated to coqui	$606,454	
		FY2011-15 TOTAL:	**$4.1M**	
		AVG ANNUAL MNGT TOTAL:	**$815,290**	

Source: http://dlnr.hawaii.gov/hisc and http://dlnr.hawaii.gov/hisc/files/2013/02/20071217coquiplandraft.pdf

Based on the total in Table 4, the average annual expenditures on prevention, control, and eradication total $815,290. Combining that with estimated damages to the housing and nursery industries results in total annual costs of $6.0 million (Table 5).

Figure 2. Expenditures on Coqui Frog Management, 2011-15

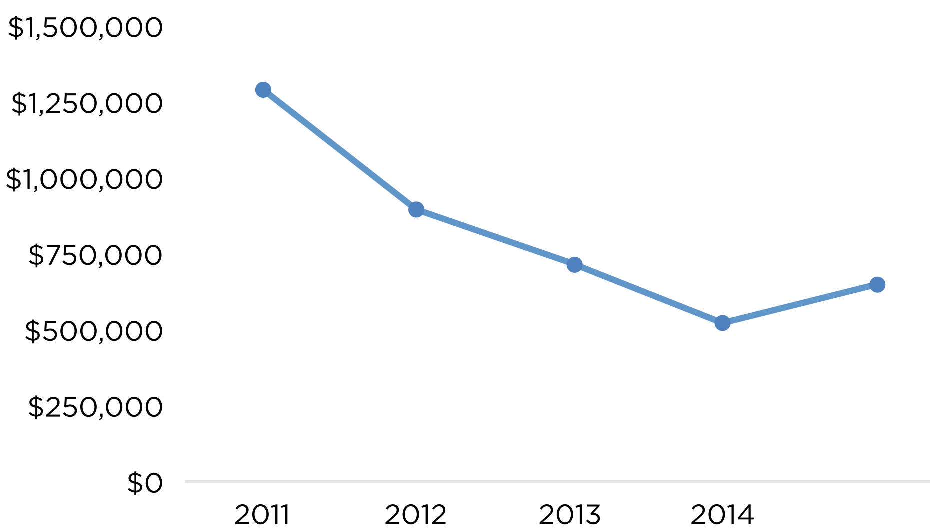


Table 5. Coqui Frog Realized Damages and Management Expenditures

Category	Source	Description	Amount
Damage	-	Housing	$1,050,000
Damage	-	Nurseries	$4,120,000
Management	HISC, OISC, KISC, MISC, State, HDOA, County	Prevention, control, eradication	$815,290
		AVG ANNUAL TOTAL:	**$6.0M**
		FY2011-15 TOTAL:	**$29.9M**

4. FOUNTAIN GRASS REALIZED DAMAGES AND MANAGEMENT EXPENDITURES

Fountain grass (*Pennisetum setaceum*) grows quickly and outcompetes native plants. It is a poor pasture grass and degrades the quality of pasturelands. The grass is both fire-promoting and fire-adapted, which means that it serves as fuel for brush fires but also can survive those fires, where native plants cannot. Populations of fountain grass can be found on all islands, but the largest infestation exists on the Big Island; the invasion spans 200,000 acres on the Kona side. Statewide, nonnative grasslands and mixed grass-shrublands currently comprise >400,000 ha or 24% of the state's total land area.

In Hawaii Volcanoes National Park, alien grass invasion in the late 1960s increased fire occurrences notably; in the 48 years prior to the invasion, 27 fires burned an average of 4 ha/fire, whereas 58 fires burned an average of 205 ha/fire in the 20 years following the invasion (D'Antonio and Vitousek 1992; Smith and Tunison 1992). On the leeward side of Hawaii Island, where fountain grass occupies over 80,000 ha, five Class-G fires (up to 4,000 ha) have occurred since the 1980s (Castillo et al. 2007). Syntheses of the recently available statewide wildfire history dataset (HWMO 2013) demonstrate that non-native, grass-dominated ecosystems account for the majority (a little more than half) of the more than 7,000 ha that now burn on average each year in Hawaii (C. Trauernicht, personal communication). This is a 17-fold increase in annual area burned from the early 1900s.

To our knowledge, no study has yet estimated the exact relationship between fountain grass presence and increased risk of fire. Nevertheless, we attempt to roughly quantify wildfire suppression expenditures incurred as a result of fountain grass invasion in Hawaii. In 2014, the federal government spent $1.5 billion to suppress 63,212 wildfires, covering 3.6 million acres nationwide.[10] This amounts to an average of $417 per acre. However, that number is likely an overestimate for our study because the data used to calculate it includes large scale fires, some of which are much bigger than those typically observed in Hawaii. For comparison, we obtained data from DOFAW on wildfire suppression costs over the past half-century. When the entire dataset is considered, suppression costs averaged $62 per acre. When the data is limited to occurrences where the fuel description includes at least one type of non-native grass, the per-acre suppression cost falls to $37. Focusing only on fountain grass related incidents further reduces the average suppression cost to $31 per acre. However, because more than half of the observations fail to identify a specific fuel source, it is not clear that controlling fountain grass fires is necessarily less costly than suppressing fires fueled by other types of landcover. Therefore, we conservatively assume a per-acre suppression cost of $60.

While we do not know for certain that an alternative land cover would not have burned in the absence of fountain grass, we use the burned acreage estimates as a starting point. Over the period 2004-2012, ignitions data suggests that roughly 66,000 acres were burned in fountain grass related fires, or 44% of the 150,000 acres burned statewide. That amounts to 7,300 acres per year, on average. Over the period FY2011-2013, however, fountain grass related fires accounted for a little over 3,000 acres burned or 1,012 acres per year. Because the number of acres burned in a given year is driven by many factors other than land cover (e.g. climate, ignition source), it is difficult to extrapolate acres burned for FY2014-15. For the purposes of our cost calculations, we assume that the FY2011-13 average of 1,012 acres per year extends to the present, i.e. over the 5-year period 5,060 burned acres are attributed to fountain grass. This implies annual expenditures of $60,720 on the suppression of wildfires linked to fountain grass.

Wildfire damages depend on how the land was being used prior to the fire. In 1978, a table of damage costs was constructed as a guide for estimating fire damage statewide. Inflation-adjusted values are reported in Table 6.

[10] https://www.nifc.gov/fireInfo/fireInfo_documents/SuppCosts.pdf

Table 6. Guide for Estimating Fire Damage

Land Use		1978	2015
TIMBER			
	COMMERCIAL MATURE TIMBER STAND	$3,000	$10,980
	PLANTATION (POTENTIALLY SALEABLE)	$1,500	$5,490
RANGELAND			
	ALL GRAZEABLE GRASS LANDS	$100	$366
WILDLIFE HABITAT			
	RARE & ENDANGERED SPP HABITAT	$3,000	$10,980
	WILDLIFE REFUGE	$1,000	$3,660
	ALL OTHER AREAS	$200	$732
RECREATION			
	DEVELOPED CAMPGROUND	$5,000	$18,300
	ALL OTHER AREAS	$500	$1,830
WATERSHED			
	ABOVE POPULATED SITES	$2,500	$9,150
	ABOVE IRRIGATION RESERVOIRS	$1,000	$3,660
	ALL OTHER AREAS	$500	$1,830
EXPERIMENTAL FORESTS		$2,000	$7,320
SCENIC AREAS		$3,000	$10,980
HISTORICAL AREAS		$3,000	$10,980
RARE & ENDANGERED PLANTS		$3,000	$10,980
ERODIBLE SOIL (WIND OR WATER)		$2,000	$7,320

Although the fountain grass itself has little value, it may serve as habitat for some wildlife, and other types of land cover interspersed between the fountain grass patches have some value as well. We estimate fire damages at $740,784 per year by multiplying 1,012 acres by the $732/acre value assigned to “all other wildlife habitat”.

Over the period FY2011-15, awards specifically targeting fountain grass totaled $584,245 (Table 7). Figure 3 plots fountain grass management expenditures over time. Because we were not able to obtain species-specific expenditure data from BIISC (where the fountain grass issue is most pronounced), total spending on control should be interpreted as a lower bound.

Table 7. Fountain Grass Projects

Fiscal Year	Source	Description	Amount
2011	KISC	Total KISC expenditures allocated to fountain grass	$25,230
2011	HISC	Foreign Exploration for Biocontrol Agents	$55,000
2011	OISC	Total OISC expenditures allocated to fountain grass	$13,482
2011	MISC	Total MISC expenditures allocated to fountain grass	$141,761
2012	HISC	HDOA Biocontrol Foreign Exploration	$40,000
2012	OISC	Total OISC expenditures allocated to fountain grass	$30,925
2012	MISC	Total MISC expenditures allocated to fountain grass	$109,424
2013	OISC	Total OISC expenditures allocated to fountain grass	$32,589
2013	MISC	Total MISC expenditures allocated to fountain grass	$51,370
2014	OISC	Total OISC expenditures allocated to fountain grass	$24,713
2014	MISC	Total MISC expenditures allocated to fountain grass	$14,098
2015	OISC	Total OISC expenditures allocated to fountain grass	$28,416
2015	MISC	Total MISC expenditures allocated to fountain grass	$17,237
		FY2011-15 TOTAL:	**$584,245**
		AVG ANNUAL MNGT TOTAL:	**$116,849**

Source: http://dlnr.hawaii.gov/hisc

Based on the total in Table 7, the average annual expenditures on control over the period FY2011-15 total $116,849. Combining that with estimated wildfire damage and suppression expenditures results in total annual costs of $0.9 million (Table 8).

Figure 3. Expenditures on Fountain Grass Management, 2011-15

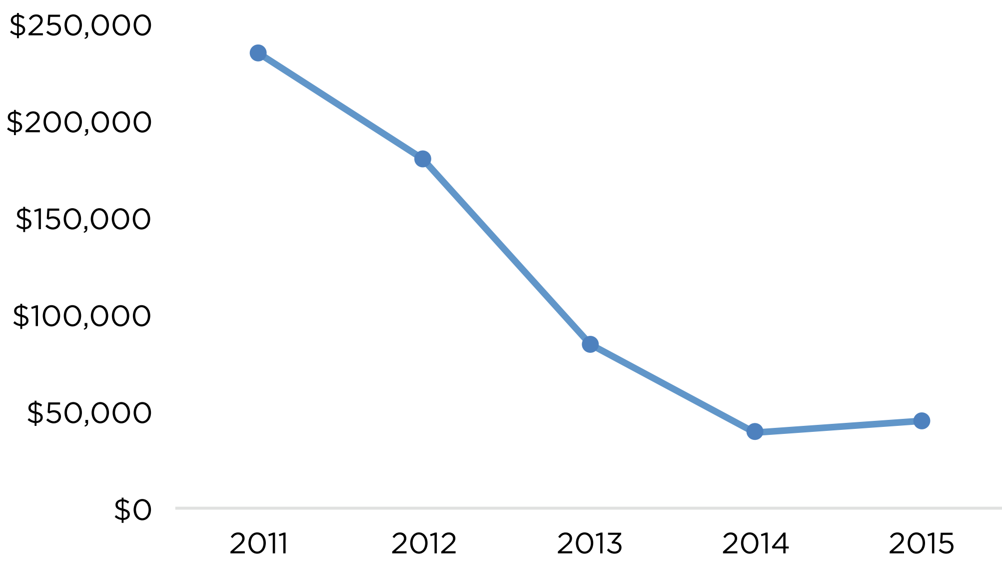


Table 8. Fountain Grass Realized Damages and Management Expenditures

Category	Source	Description	Amount
Damage	-	Lost land use value	$740,784
Management	-	Wildfire Suppression	$60,720
Management	HISC, KISC, MISC, OISC	Biocontrol research, prevention, control	$116,849
		AVG ANNUAL TOTAL:	**$0.9M**
		FY2011-15 TOTAL:	**$4.6M**

5. LITTLE FIRE ANT REALIZED DAMAGES AND MANAGEMENT EXPENDITURES

The little fire ant (*Wasmannia auropunctata*) damages agricultural crops, nursery products, and native plants; delivers a painful sting to humans, which impedes tourism; promotes pest plants, which reduce agricultural productivity; can infest buildings; and may be a danger to pets and native animal species. One infestation is under active control on Kauai and another was eradicated on Maui in 2013. Little fire ants (LFA) have spread to an estimated 6,000 sites on the Big Island: 4,000 homes, 186 farms, 6 parks, 1 school, 1 hotel, and 568 other sites.[11] 23 percent of plant nurseries on Hawaii Island are infested and a number of landscapers on Maui have stopped importing from the Big Island. Visitors at affected beaches have reported stings.

[11] http://www.civilbeat.com/2013/09/19850-big-damages-from-little-fire-ant-could-be-170m-a-year-on-big-island-alone/

Motoki et al. (2013) estimate that expected economic damages from LFA under current management are upward of $140 million and mitigation costs would exceed $1.2 billion over the period 2012-2022. These damages are based on an analysis of six sectors: nurseries, agriculture, residential, lodging, parks, and schools. The total damages do not include threats to native species or effects on domestic pets. In the long run, LFA is expected to reduce agricultural yields by 0-50%, which translates to damages equal to 20-30% of sales or $33-50 million per year (livestock and crop sales on the Big Island were $165 million in 2008). Based on industry observations, export sales in the nursery industry are expected to fall by 50%, a loss of $7 million per year (nursery export sales were $13.8 million in 2008). Survey of the lodging industry revealed that the sector is "moderately sensitive" to biting and stinging insects. A 20% reduction in revenue due to LFA infestation is equal to $183,259 per property. The study assumes that the residential sector is also "moderately sensitive" to stinging and biting insects. Because home sellers are legally required to declare LFA infestations prior to sale, LFA reduces property value. Including the loss in backyard recreational value, the cost of LFA is $1,023-1,058 per household per year. The estimated impact on parks is based on benefit transfer. The study assumes that ecosystem services provided by the parks (pollination services, genetic diversity, and recreational opportunities) are valued at $2,523 per acre per year. If the annual service loss falls in the range of 1-30%, then total damages are $25-757 per acre per year. Other expected damages include reduction in revenue of $533 per business.

Table 9. Little Fire Ant Estimated Damages

Fiscal Year	Source	Description	Amount
2011	Extrapolated	Agriculture, Lodging, Nurseries, Parks, Residential, Schools, Other	$0.15M
2012	Extrapolated	Agriculture, Lodging, Nurseries, Parks, Residential, Schools, Other	$0.89M
2013	Extrapolated	Agriculture, Lodging, Nurseries, Parks, Residential, Schools, Other	$3.93M
2014	D. Lee	Agriculture, Lodging, Nurseries, Parks, Residential, Schools, Other	$11.48M
2015	D. Lee	Agriculture, Lodging, Nurseries, Parks, Residential, Schools, Other	$14.05M
		FY2011-15 TOTAL:	**$30.5M**

The average annual total costs of LFA over the ten-year period is $136 million, but this number is largely influenced by high projected damage and mitigation costs starting in 2016. Since the current study aims to estimate historical realized damages rather than uncertain future or potential damages, we fit a generalized logistic function[12]

[12] We assume the following functional form: $a/(1+e^{-bt})$, where the parameters a and b are chosen to generate a curve that best fits the data. In addition to the 2012-14 values, we assume a starting value of 0 for 2006, the year the Hawaii Ant Coordinator position was established.

to the 2012-2014 annual values generated by the model (D. Lee, personal communication) to extrapolate damages in 2010 and 2011. Damages over the period FY2011-15 totaled $30.5 million, an average of $6.1 million per year (Table 9).

Over the period FY2005-15, awards specifically targeting LFA totaled $2.7 million. Recent expenditures over the period FY2011-15 accounted for $2.9 million (Table 10). Figure 4 plots little fire ant management expenditures over time. Because we were not able to obtain species-specific expenditure data from BIISC, total spending on control should be viewed as a lower bound.

Table 10. Little Fire Ant Projects

Fiscal Year	Source	Description	Amount	Note
2011	HISC	Hawaii Ant Lab	$58,000	
2011	US Senate	Development of Nursery Pest Ant Management Programs	$28,000	HISC award leveraged this funding
2011	USFS	Regional Approach to Invasive Ant Prevention	$200,000	HISC award leveraged this funding
2011	T-STAR	Economic Impact Analysis of LFA in Hawaii	$117,000	HISC award leveraged this funding
2011	DOFAW	Planning Workship for Response and Management of New Ant Incursions	$25,000	HISC award leveraged this funding
2011	KISC	Total KISC expenditures allocated to LFA	$29,370	
2011	OISC	Total OISC expenditures allocated to LFA	$3,155	
2011	MISC	Total MISC expenditures allocated to LFA	$42,523	
2012	HISC	Control of Little Fire and Emerging Pest Ant Species in Hawaii	$72,783	
2012	Other	Total HAL Funding (other than HISC)	$210,217	
2012	KISC	Total KISC expenditures allocated to LFA	$31,630	
2012	OISC	Total OISC expenditures allocated to LFA	$25,042	
2012	MISC	Total MISC expenditures allocated to LFA	$17,483	
2013	HISC	Hawaii Ant Lab Core Funding	$34,851	
2013	HISC	Hawaii Ant Lab Core Funding	$50,475	
2013	HDOA	HAL funding by HDOA	$99,795	
2013	HDOA	Total HAL Funding (other than HISC and HDOA)	$133,060	HISC award leveraged this funding
2013	HISC	Kauai Little Fire Ant Eradication	$14,469	

2013	KISC	Total KISC expenditures allocated to LFA	$38,650
2013	OISC	Total OISC expenditures allocated to LFA	$34,023
2013	MISC	Total MISC expenditures allocated to LFA	$67,416
2014	HISC	Statewide Harmonization of Invasive Ant Detection and Response	$4,972
2014	HISC	Hawaii Ant Lab Core Funding	$55,802
2014	HISC	Eradication of Little Fire Ants on Kauai	$17,420
2014	HISC	Hawaii Ant Lab Core Funding	$65,257
2014	KISC	Total KISC expenditures allocated to LFA	$48,050
2014	OISC	Total OISC expenditures allocated to LFA	$42,608
2014	MISC	Total MISC expenditures allocated to LFA	$218,266
2015	HISC	Core Support for the Hawaii Ant Lab	$239,177
2015	HISC	Development of a Little Fire Ant Detector Dog Program	$158,000
2015	HISC	Applied Research for Control of Little Fire Ants	$30,000
2015	HISC	Community Based Education Regarding Little Fire Ant	$18,217
2015	HISC	County of Hawaii Little Fire Ant Control Program	$175,000
2015	KISC	Total KISC expenditures allocated to LFA	$41,530
2015	OISC	Total OISC expenditures allocated to LFA	$85,240
2015	MISC	Total MISC expenditures allocated to LFA	320,377
		FY2011-15 TOTAL:	**$2.9M**
		AVG ANNUAL MNGT TOTAL:	**$570,572**

Source: http://dlnr.hawaii.gov/hisc

Based on the total in Table 10, the average annual expenditures on management total $570,572. Combining that with estimated economic damages in Table 9 results in total annual costs of $6.7 million (Table 11).

Figure 4. Expenditures on Little Fire Ant Management, 2011-15

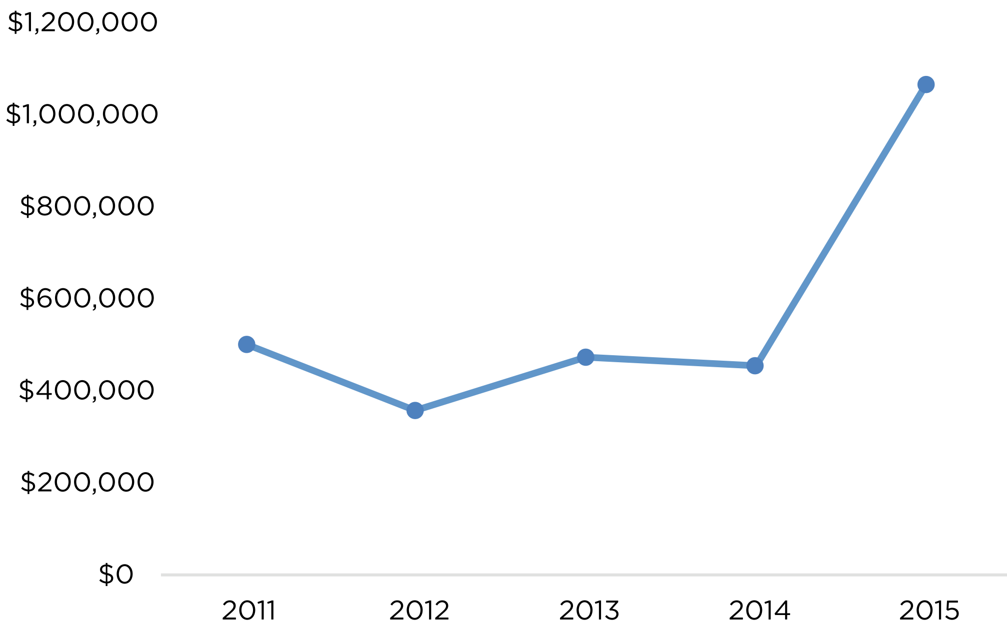


Table 11. Little Fire Ant Realized Damages and Management Expenditures

Category	Source	Description	Amount
Damage	-	Agriculture, Lodging, Nurseries, Parks, Residential, Schools, Other	$6.1M
Management	HISC, MISC, OISC	Control, Prevention, Outreach, Planning	$570,572
		AVG ANNUAL TOTAL:	**$6.7M**
		FY2011-15 TOTAL:	**$33.4M**

6. MICONIA REALIZED DAMAGES AND MANAGEMENT EXPENDITURES

Miconia (*Miconia calvescens*) forms dense monotypic stands that shade out native plants and reduce the amount of rainwater that is able to recharge underlying groundwater aquifers. Its shallow root system also promotes erosion. Miconia is or has been present on Kauai, Oahu, Maui, and the Big Island.

Chock et al. (2010) estimate average and total annual expenditures on miconia control on Maui and the Big Island using GIS data and MISC/BIISC budgets for FY 2008-2009 (Table 12). If expenditures have remained roughly constant since 2008, then miconia control expenditures for Hawaii County total approximately $340,000 per year.

Table 12. Miconia Control Expenditures on the Big Island and Maui

	Big Island	Maui core (Hana and Nahiku)	Rest of Maui
Managed acres	13,325	1,817	26,242
Annual control cost	$25.34/acre	$70.50/acre	$15.73/acre
Total control cost	$337,655/year	$138,099/year	$413,092/year

Source: Chock et al. (2010)

Burnett et al. (2007) calculate damages from miconia by compiling the assets at risk for each island in terms of threatened or endangered bird species and groundwater recharge to aquifers. Dollar values are then assigned based on a study of willingness to pay to protect endangered bird species (Loomis and White 1996), a study on the expected economic losses from a reduction of recharge on Oahu (Kaiser and Roumasset 2002), and a study on sedimentation costs due to increased surface runoff (Kaiser and Roumasset 2000). Total *maximum* annual damages for "complete accommodation of the invasion", calculated using estimated damage functions for each island, range from $61 million on Oahu to $169 million on the Big Island (Burnett et al., 2007). Applying those damage functions to existing miconia populations generates estimates for current annual damages equal to $107,350, $38,376, and $330,410 on Oahu, Big Island, and Maui respectively. Over the past decade, awards specifically targeting miconia totaled $8.4 million (including the $340,000 per year extrapolated from Table 12). Recent expenditures over the period FY2011-15 amounted to $8.1 million (Table 13). Combining expenditure data from Table 13 with estimated management costs from Table 12 and damage costs from results in total annual costs of $2.1 million (Table 14).

Table 13. Miconia Projects, 2011-15

Fiscal Year	Source	Description	Amount	Note
2011	HISC	Foreign Exploration for Biocontrol Agents	$55,000	
2011	KISC	Total KISC expenditures allocated to miconia	$46,070	
2011	OISC	Total OISC expenditures allocated to miconia	$257,756	
2011	MISC	Total MISC expenditures allocated to miconia	$744,369	
2011	BIISC	Total BIISC expenditures allocated to miconia	$340,000	Extrapolated
2012	HISC	HDOA Biocontrol Foreign Exploration	$40,000	
2012	KISC	Total KISC expenditures allocated to miconia	$38,200	
2012	OISC	Total OISC expenditures allocated to miconia	$357,267	
2012	MISC	Total MISC expenditures allocated to miconia	$996,881	
2012	BIISC	Total BIISC expenditures allocated to miconia	$340,000	Extrapolated
2013	HISC	Technical Support of Weed Biocontrol Research in Volcano, Hawaii	$22,750	
2013	KISC	Total KISC expenditures allocated to miconia	$34,210	
2013	OISC	Total OISC expenditures allocated to miconia	$253,800	
2013	MISC	Total MISC expenditures allocated to miconia	$987,033	
2013	BIISC	Total BIISC expenditures allocated to miconia	$340,000	Extrapolated
2014	HISC	Targeting High-Priority Miconia Patch Populations with an Accelerated Intervention Schedule Utilizing HBT	$87,000	
2014	KISC	Total KISC expenditures allocated to miconia	$39,370	
2014	OISC	Total OISC expenditures allocated to miconia	$316,473	
2014	MISC	Total MISC expenditures allocated to miconia	$855,402	
2014	BIISC	Total BIISC expenditures allocated to miconia	$340,000	Extrapolated
2015	HISC	Quantifying Outcomes of Miconia Management Projects Through Advancements in HBT	$65,000	
2015	HISC	Technical Support of Miconia Biocontrol Research	$46,000	
2015	KISC	Total KISC expenditures allocated to miconia	$38,850	
2015	OISC	Total OISC expenditures allocated to miconia	$332,634	
2015	MISC	Total MISC expenditures allocated to miconia	$771,538	
2015	BIISC	Total BIISC expenditures allocated to miconia	$340,000	Extrapolated
		FY2011-15 TOTAL:	**$8.1M**	
		AVG ANNUAL MNGT TOTAL:	**$1.6M**	

Source: http://dlnr.hawaii.gov/hisc

Figure 5. Expenditures on Miconia Management, 2011-15

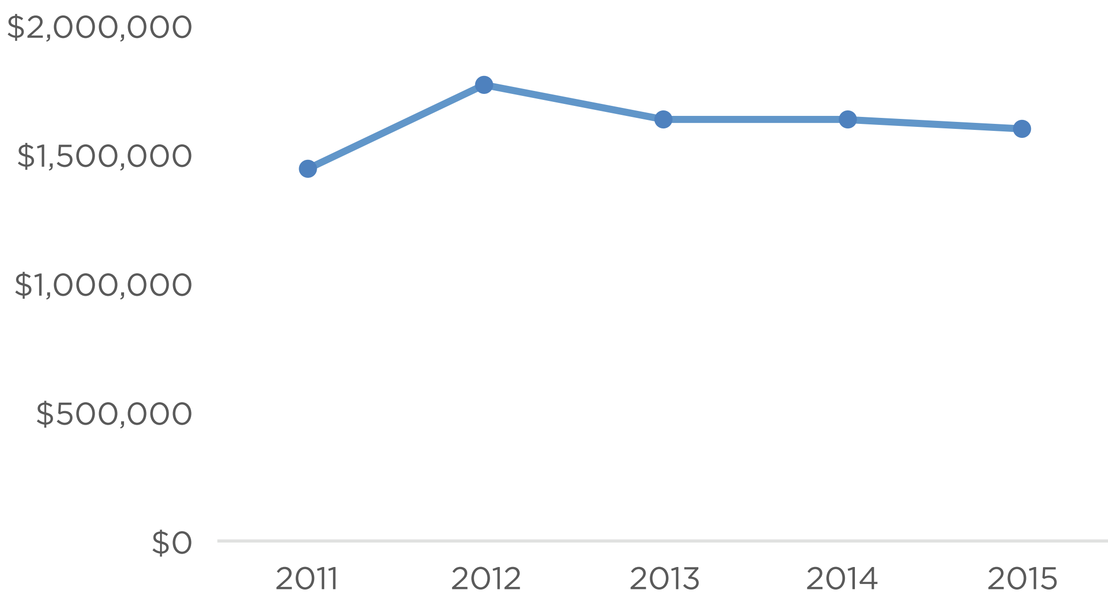


Table 14. Miconia Realized Damages and Management Expenditures

Category	Source	Description	Amount
Damage	-	Bird habitat loss, recharge loss, sedimentation (Oahu)	$107,350
Damage	-	Bird habitat loss, recharge loss, sedimentation (Big Island)	$38,376
Damage	-	Bird habitat loss, recharge loss, sedimentation (Maui)	$330,410
Management	HISC, OISC, KISC, MISC, BIISC	Biocontrol research, HBT, prevention, control	$1.6M
		AVG ANNUAL TOTAL:	**$2.1M**
		FY2011-15 TOTAL:	**$10.5M**

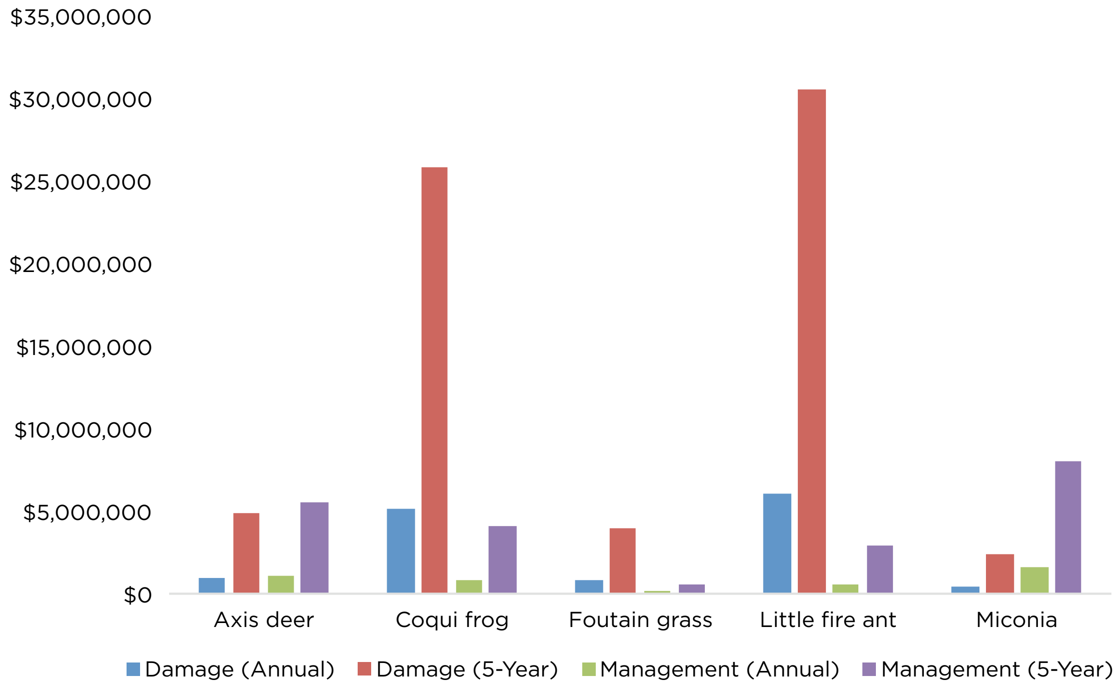
7. COMPARISON OF DAMAGES AND EXPENDITURES ACROSS SPECIES

Table 15 and Figure 6 aggregate damage and management expenditure data for the top-five priority HISC species. Combined, damages and spending amount to roughly $18 million annually over the period 2011-15, with damages accounting for over 75% of the total. It is clear from Figure 6 that realized damages largely exceed expenditures for coqui and LFA, but lower damage-to-spending ratios for the other priority species are not necessarily an indication that managing those species is less worthwhile. As we discuss in the following section, potential future damages should also be accounted for (to the extent possible) when allocating effort across multiple invasive species.

Table 15. Realized Damages and Management Expenditures for Priority HISC Species

	Damage		Management	
Species	**Annual Damages (millions)**	**FY2011-15 Total Damages (millions)**	**Annual Expenditures (millions)**	**FY2011-15 Total Expenditures (millions)**
Axis deer	$1.0	$4.9	$1.1	$5.5
Coqui frog	$5.2	$25.9	$0.8	$4.1
Fountain grass	$0.8	$4.0	$0.1	$0.6
Little fire ant	$6.1	$30.5	$0.6	$2.9
Miconia	$0.5	$2.4	$1.6	$8.1
TOTAL:	**$13.5**	**$67.7**	**$4.2**	**$21.2**

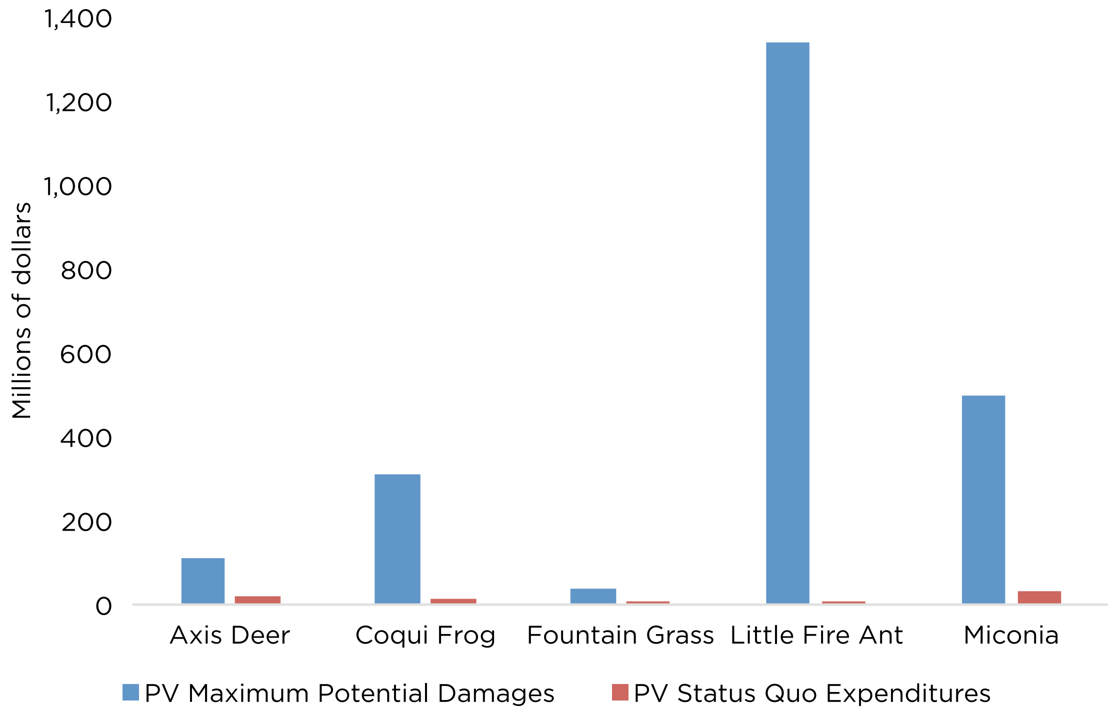
Figure 6. Realized Damages and Management Expenditures by Species



8. POTENTIAL DAMAGES

The data suggests that when aggregated across species, total realized damages exceed total management expenditures (Figure 6). Thus, there appears to be an opportunity to further reduce damages by increasing spending on management. This type of comparison does not, however, tell us how exactly current management is preventing future damages, which may be many orders of magnitude higher than current realized damages. Although building a fully dynamic bio-economic management model for each of the priority species is beyond the scope of this project, we use publicly available data to provide a rough estimate of the present value of potential future damages (Figure 7).

Figure 7. PV Maximum Potential Future Damages and Status Quo Expenditures by Species



Assumes a 50-year time horizon and 5% discount rate, with the exception of potential damages for LFA, which are based on Motoki et al. (2013).

Annual status quo management expenditures are determined by the amounts summarized in Table 15 for each species. A stream of spending is then constructed by extending (constant) average annual expenditures over 50 years, and the present value is determined for a discount rate of 5%. Calculation of potential damages are detailed in the remainder of this section for each species. Generally, potential maximum damage for a particular species is approximated using available information from other studies. The rate of damage growth is taken as proportional to an assumed rate of spread. Potential damage is then allowed to grow according to that rate from the current (status quo) level up until its maximum level over time, where it remains until the end of the 50-year planning period. Finally, the present value of the stream of damages is calculated assuming a 5% discount rate.[13] For all priority species, the present value of maximum potential damages far exceeds the present value of status quo expenditures.

[13] Avoided damages for status quo management can be calculated by subtracting PV realized damages from PV potential damages if we are comfortable assuming that status quo management is maintaining invasive species populations at levels that ensure realized damages remain approximately constant over time.

Recall that based on the proportional loss of agricultural product on Maui due to axis deer, the potential impact on Hawaii Island is estimated by experts to be near $8 million annually. A lower bound for potential damages to the agricultural industry in Maui and Hawaii Island is therefore $9 million per year. Absent management and assuming that damages grow at the same rate as the axis deer population (20% per year), the $1 million dollars in current damages would reach $9 million by year 13. For a discount rate of 5%, the present value cost of potential damages over a 50-year horizon amount to $111.2 million.

Given current coqui populations, we calculated that a 10% reduction in the total value of nursery production in Hawaii County would result in damages of $4.12 million per year. In the absence of management, the impact on the nursery industry is likely to be even larger. If the value of statewide nursery production were reduced by 20% in the worst-case-scenario, then annual damages could potentially be upwards of $16 million. The impact of coqui presence on property values can similarly be estimated for the worst-case-scenario. In 2014, 6,696 single family homes and 7,083 condominiums were sold statewide[14] at average prices of $575,000 and $351,000 respectively.[15] Based on the 0.16% decline in property value estimated by Kaiser and Burnett (2006), the potential annual effect on the housing industry is $10.1 million. Maximum annual potential damages, including impacts to both nursery production and housing sales, amount to $26.1 million. In the absence of management, current annual realized damages of $5.2 million would increase to $26.1 million by year 17 assuming a 10% rate of coqui spread. The PV cost of potential damages for a discount rate of 5% exceeds $310 million.

To our knowledge, there have not been any attempts to monetize potential fountain grass damage. Ideally, a model would be developed that could map fountain grass spread over time and overlay probabilities of fire ignitions, which could then be linked to potential fire damages. Without such a model, we assume that potential burned acreage would increase by 5% on average per year in the absence of management. Current damage of roughly $0.8 million would increase to $9.2 million by year 50, generating a PV cost of $38.9 million at a 5% discount rate.

Motoki et al. (2013) project huge damages from LFA over a relatively short time horizon. Under current management, expected economic damages total $140 million and mitigation costs exceed $1.2 billion over the period 2012-2022. Over a longer (e.g. 50-year) time horizon, potential damages are even larger. Because management adapts to LFA spread in the model as damages increase, we include management costs as part of total potential damages (presumably the benefits of management outweigh the costs). However, the outcome cannot be interpreted as a "worst-case scenario". The $1.34 billion can be interpreted as a lower bound for potential LFA damages.

[14] http://files.hawaii.gov/dbedt/economic/databook/2014-individual/21/213414.pdf

[15] http://files.hawaii.gov/dbedt/economic/databook/2014-individual/21/213514.pdf

Assuming that the damages generated by miconia grow at the same rate as the plant's population, carrying capacity and maximum damages would be reached in just under 50 years, given a 15% rate of spread in the absence of management. The present value damage costs over a 50-year time horizon is $500.8 million at a discount rate of 5% for the "low damage" scenario in Burnett et al. (2007).

The gap between PV maximum potential damages and PV status quo expenditures is largely dependent on the underlying assumptions of the analysis. For example, less aggressive growth rates for the invasive species would result in smaller damages over time. The general result that potential damages exceed current management expenditures is unlikely to change, however, even with very conservative assumptions. Therefore, opportunities likely exist to increase investment in management techniques that are effective at slowing or preventing further spread of invasive threats to avoid larger potential damages in the future.

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