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Hawaii and US-Affiliated Pacific Islands

Susan Cordell

Introduction

Hawaii and the US-affiliated Pacific Islands (see Figs. A2.1 and A2.2 for associated map) have high levels of endemic native biodiversity, largely as a function of varied ecosystems and isolation. For example, Hawaii is the most isolated archipelago on Earth where 90% of its 10,000 native species are endemic. This geographic area represents most major forest ecosystem types and includes thousands of oceanic islands, elevational clines from coastal to alpine in temperate and tropical ecosystems, species and communities that occur nowhere else in the world, the tallest mountains on Earth, and a broad range of governments and cultures.

Island ecosystems are particularly vulnerable and susceptible to environmental change from both natural disturbances (wildfire, flood, hurricane, typhoon, and drought) and anthropogenic disturbances (invasive species, deforestation, pollution, and urbanization). Climate change is further exacerbating existing ecological challenges and affecting biological diversity across all biological scales in terrestrial and aquatic ecosystems. This is a global challenge faced around the world, but it is particularly acute in Hawaii and the US-affiliated Pacific Islands, where the loss of biodiversity from extirpations and extinctions is already consequential. An estimated 270 plant and animal species have gone extinct over the past 200 years in Hawaii, with an additional 440 species threatened or endangered (Wagner et al. 1999).

Despite the recognized prominence of invasive species in most of the terrestrial ecosystems in Hawaii and the US-affiliated Pacific Islands, it is unclear if this is a result of more invasive species being introduced or if human disturbance allows greater establishment. In general, Hawaii is considered ground zero for invasive species (Dawson et al. 2017), and with many other ecosystems likely to be impacted, Hawaii can serve as a model system through innovative approaches to both reduce the impacts of invasive species and enhance the resilience of native species assemblages.

Hawaii Overview

Hawaii is considered the most isolated archipelago on Earth with an estimated historic rate of one new species established every 100,000 years (Fosberg 1948). Ultimately, the approximate 1100 native flowering plants now in Hawaii originated from approximately 270 to 280 successful colonization events. Further, those species that not only arrived but successfully colonized harbored traits of long distance travel, endurance, and adaptive flexibility (Wagner et al. 1999). As a result, Hawaii's native flora, fauna, and ecosystems are considered disharmonic with taxa either under- or overrepresented relative to the founder biomes. Currently, there are more endangered species per square mile on these islands than any other place on the planet, and most of these species—and the ecosystems in which they live—are found nowhere else in the world (see https://ecos.fws.gov/ecp0/reports/species-listed-by-state-report?state=HI for more information). Hawaii is home to nearly one third of all Federally listed threatened and endangered species and almost half of all listed plants. The total number of listed plant species in Hawaii has increased by 40% over the last three decades, and over 100 of these have fewer than 20 known individuals (Loope 1998) (also see https://ecos.fws.gov/ecp/species-reports for current statistics).

Invasive species have caused significant ecological and economic damage in Hawaii (see https://dlnr.hawaii.gov/hisc/info/). It is estimated that Hawaii spends $50 million

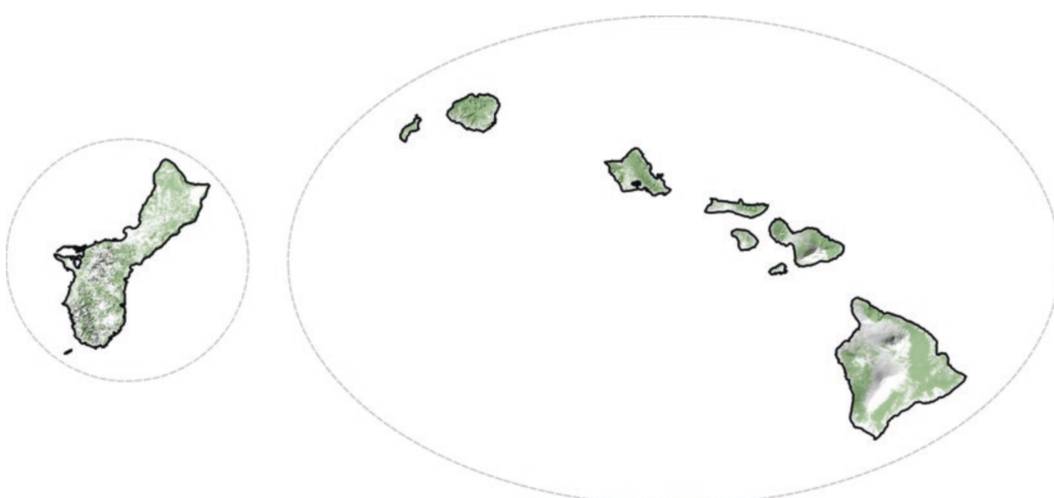

Fig. A2.1 Hawaii and US-affiliated Pacific Islands

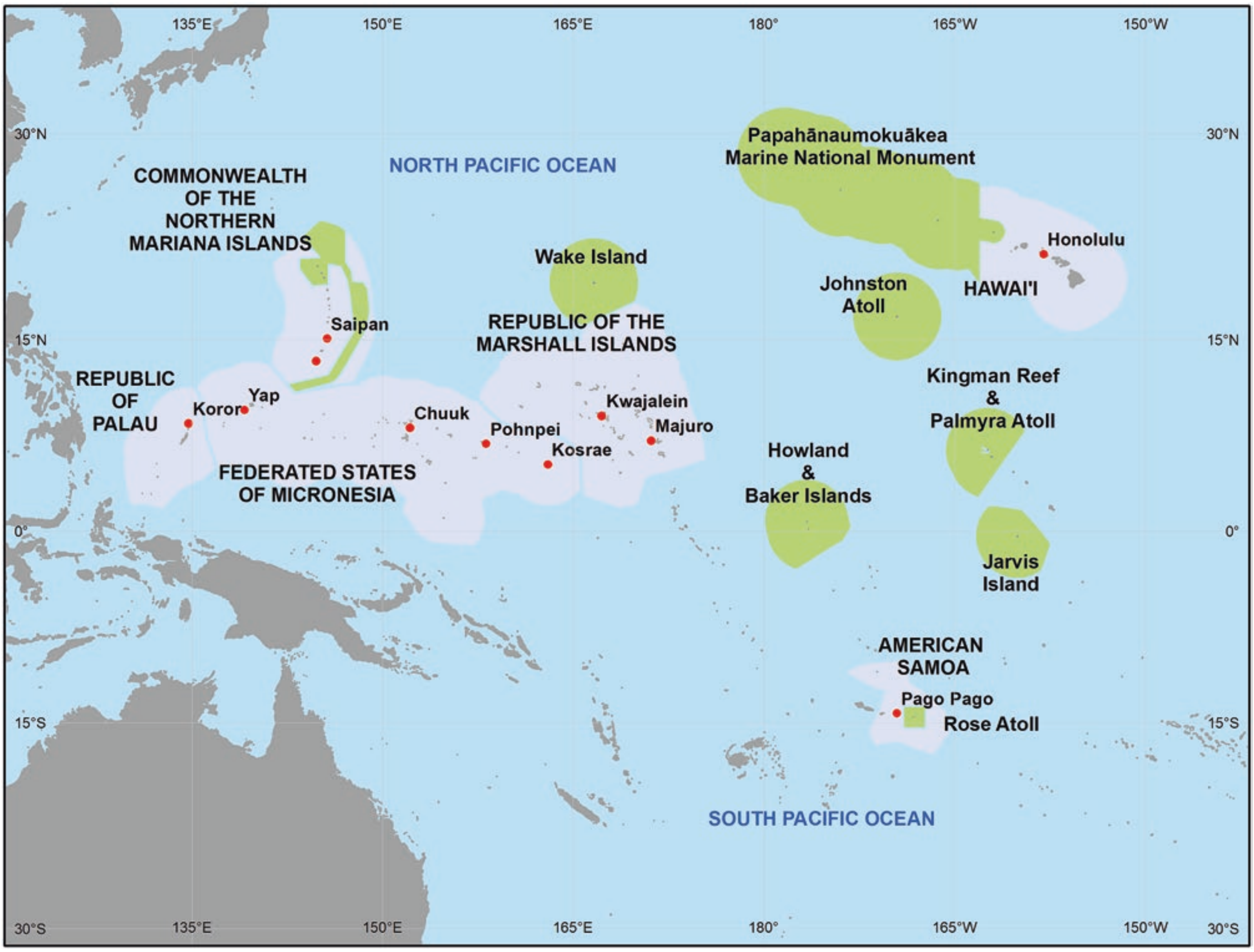

Fig. A2.2 Map of the Hawaii Archipelago and the US-affiliated Pacific Islands

annually to manage invasive species and that costs associated with present and potential invasive species could top $180 million per year. Some important invasive species impacting Hawaii's native and agricultural ecosystems include wild boar (*Sus scrofa*), coconut rhinoceros beetle (*Oryctes rhinoceros*), and the pathogen causing rapid 'ōhi'a death (*Ceratocystis lukuohia and huliohia*). Please see Table A2.1, Fig. A2.3, and https://dlnr.hawaii.gov/hisc/info/ for a list of top invaders. The impacts of invasive species are vast in the Hawaii and Pacific region, especially when considering the diversity of taxa that has established in these susceptible island ecosystems. For example, a newly identified invasive pathogen that causes rapid 'ōhi'a death, *Ceratocystis lukuohia*, has killed hundreds of thousands of 'ōhi'a (*Metrosideros polymorpha*) across more than 50,000 acres of forests and residential areas in east and south districts of Hawaii Island. 'Ōhi'a is a keystone native tree species which occupies 80% of Hawaiian forests across different elevations and habitats and exists in many forms. The tree mortality caused by rapid 'ōhi'a death is anticipated to have widespread impacts to native wildlife and Hawaiian culture.

Protecting the region from the introduction and potential impacts of invasive species is an integral component of land management, and preventing the establishment and spread of invasive plants has continued to be a high priority because these species have been shown to affect all trophic levels of an ecological community (Loope and Mueller-Dombois 1989; Smith 1985). Therefore, the emphasis of this regional study is focused on the impacts, consequences, and mechanisms associated with invasive plants. For reviews on the environmental and economic impacts of other invasive taxa in Hawaii, please see Arcilla et al. (2015), Chynoweth et al. (2013), Day and Winston (2016), Doherty et al. (2016), Marchetti and Engstrom (2016), Pitt et al. (2017), and Spatz et al. (2017).

Invasive Plants

In today's world, Hawaii's combined native and non-native flora is close to 5000 species. Approximately 22 taxa are introduced per year with 869 non-native species becoming established in the last 200 years (Reichard and White 2001; Wagner et al. 1999). In a report by Schmidt and Drake (2011), 7866 ornamental species were brought into the islands from 1840 to 1999. Of

Table A2.1 A list of the most impactful invasive species in Hawaii by taxon

Terrestrial plants	Albizia (*Falcataria moluccana*)
Banana poka (*Passiflora tarminiana*)	Tibouchina (*Tibouchina herbacea*)
Fountain grass (*Cenchrus setaceus*)	Glory bush (*Tibouchina urvilleana*)
Gorse (Ulex europaeus)	Hiptage (*Hiptage benghalensis*)
Ivy gourd (*Coccinia grandis*)	Kāhili ginger (*Hedychium gardnerianum*)
Miconia (*Miconia calvescens*)	Prickly blackberry (*Rubus argutus*)
Strawberry guava (*Psidium cattleianum*)	Devil weed (*Chromolaena odorata*)
Fireweed (*Senecio madagascariensis*)	**Marine aquatic plants**
Brown licorice (*Kappaphycus striatus*)	Gorilla ogo (*Gracilaria salicornia*)
Leather mudweed (*Avrainvillea amadelpha*)	[no common name] (*Cladophora sericea*)
Smothering seaweed (*Kappaphycus* and *Eucheuma* spp.)	Hookweed (*Hypnea musciformis*)
Spiny prickly seaweed (*Acanthophora spicifera*)	
Terrestrial vertebrate animals	Axis deer (*Axis axis*)
Coqui frog (*Eleutherodactylus coqui*)	Domestic goat (*Capra hircus*)
Giant marine toad (*Bufo marinus*)	Feral cats (*Felis catus*)
Jackson's chameleon (*Chamaeleo jacksonii*)	Mongoose (*Herpestes javanicus*)
Red-vented bulbul (*Pycnonotus cafer*)	Red-whiskered bulbul (*Pycnonotus jocosus*)
Veiled chameleon (*Chamaeleo calyptratus*)	Wild boar (*Sus scrofa*)
Terrestrial invertebrate species	Apple snail (*Pomacea canaliculata*)
Black twig borer (*Xylosandrus compactus*)	Coconut rhinoceros beetle (*Oryctes rhinoceros*)
Coffee berry borer (*Hypothenemus hampei*)	Erythrina gall wasp (*Quadrastichus erythrinae*)
Giant African snail (*Achatina fulica*)	Little fire ant (*Wasmannia auropunctata*)
Nettle caterpillar (*Darna pallivitta*)	Red imported fire ant (*Solenopsis invicta*)
Rosy wolfsnail (*Euglandina rosea*)	Varroa mite (*Varroa destructor*)
Mosquito (*Culex quinquefasciatus*)	Oriental fruit fly (*Bactrocera dorsalis*)
Freshwater aquatic animals	Apple snail (*Pomacea canaliculata*)
Armored catfish (*Hypostomus watwata*)	Jewel cichlid (*Hemichromis elongatus*)
Freshwater bivalve (*Corbicula fluminea*)	
Infectious organisms	Banana bunchy top virus
Coconut heart rot (*Phytophthora katsurae*)	Papaya ringspot virus
Rat lungworm (*Angiostrongylus cantonensis*)	Rapid 'ōhi'a death (*Ceratocystis fimbriata*)
Marine aquatic animals	Australian mullet (*Osteomugil engeli*)
Blueline snapper or ta'ape (*Lutjanus kasmira*)	Peacock grouper or roi (*Cephalopholis argus*)
Snowflake coral (*Carijoa riisei*)	Orange sponge (*Mycale armata*)

these, 420 were considered naturalized, and 141 were listed as weeds with 39 of those listed as noxious. A more recent report by Dawson et al. (2017) which captured native and non-native naturalized flora and fauna in Hawaii lists 1586 native plant species and 1488 non-native plant species (Table A2.2). This list includes dicots, monocots, gymnosperms, and ferns.

The welcome mat for non-native plant species in Hawaii was laid out as the first humans arrived from Polynesia more than 1500 years ago. These Polynesian plant introductions—better known as "canoe plants"—were somewhat benign compared with what was to come as the exponential rise in transport to and from the islands provided numerous opportunities for alien colonizers (Loope et al. 1988). The combination of advances in agricultural technology, increases in population density, and the introduction of alien animals (ungulates, rodents, etc.) led to a multipronged induced decline of Hawaii's native biota (Denslow 2003; Loope et al. 1988). Further, in the 1930s, State and Federal foresters deemed that many of the native tree species in Hawaii lacked "utility" which resulted in the planting of 1026 non-native species into forest reserves, many of which became invasive (Woodcock 2003). Correspondingly, the seed banks of most Hawaiian systems—even those that are native-dominated—are now saturated with non-native species, indicating that these forests will likely be heavily impacted and influenced by non-native and perhaps invasive species when disturbed (Cordell et al. 2009; Drake 1998; Nonner 2005). The extreme habitat complexity of the islands due to large gradients of elevation, productivity, and climate (ranging from dry desert to subalpine climates) has offered comfortable homes for a broad suite of temperate and tropical species. Almost every traveler can find a familiar plant from home while visiting Hawaii.

Why Are Invasive Plant Species So Successful in Hawaii?

Attempts to define unified themes and/or hypotheses about the success of invasive species are as difficult in Hawaii as it is

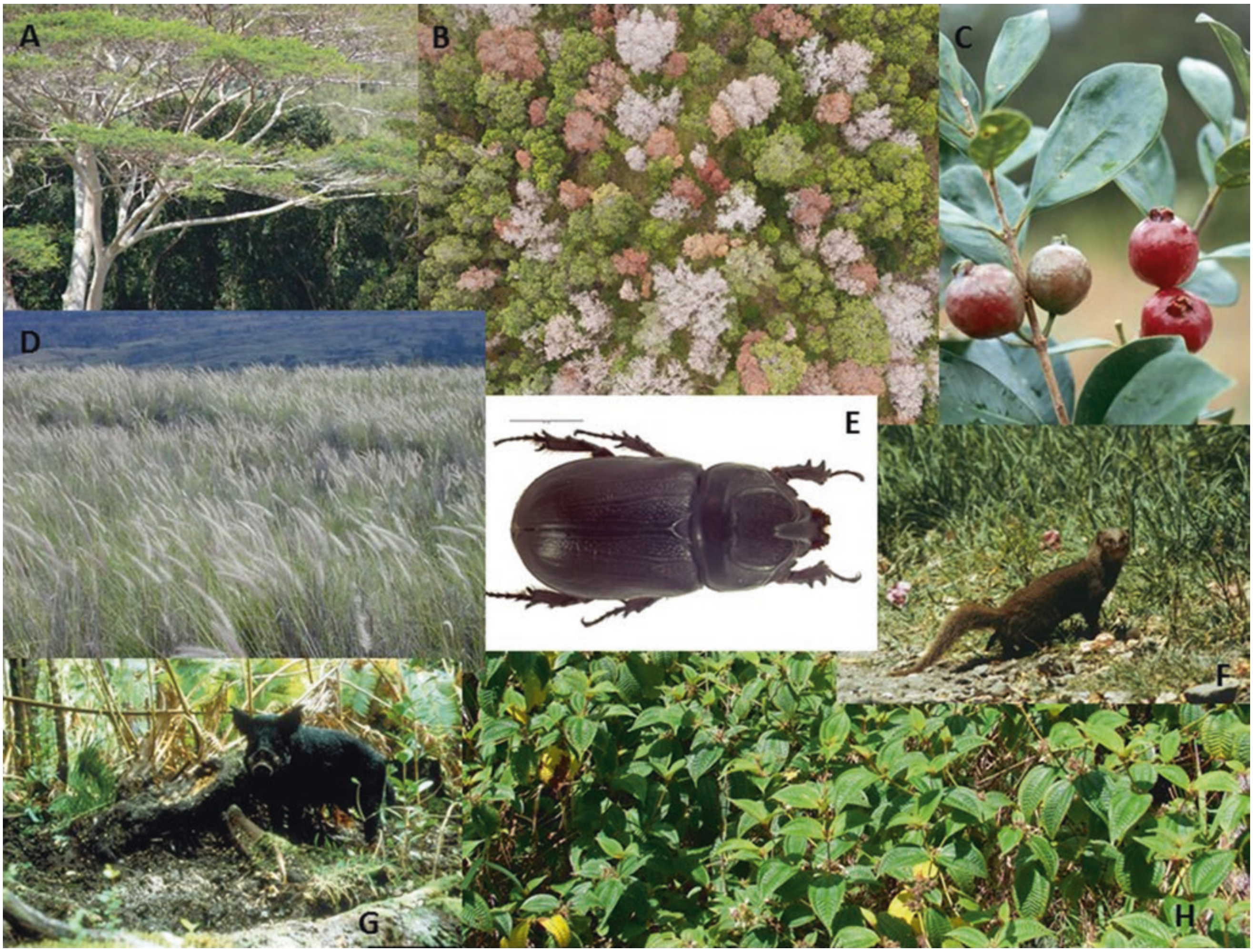

Fig. A2.3 A pictorial view of some of Hawaii's most problematic invasive species. See Table A2.1 for scientific names. (**a**) albizia; (**b**) rapid 'ōhi'a death; (**c**) strawberry guava; (**d**) fountain grass; (**e**) rhinoceros beetle; (**f**) mongoose; (**g**) wild boar; (**h**) clidemia

Table A2.2 Estimates of the number of introduced and native species in Hawaii grouped by taxon (data are from Zeigler (2002) and Dawson et al. 2017)

Taxon	Total	Introduced and naturalized	Native
Plants	3074	1488	1586
Insects	7982	2592	5390
Spiders	205	77	128
Snails	804	34	770
Fishes	51	45	6
Amphibians	7	7	0
Reptiles	25	25	0
Birds	158	54	104
Mammals	22	20	2

anywhere (Catford et al. 2009). While classic success pathways related to plant invasion are evident and perhaps even predominant in Hawaii (Denslow 2003), Daehler (2003) argues that "outside of super-invaders, increased resource availability and altered disturbance regimes associated with human activities often differentially increase the performance of invaders over natives." Others add that, once disturbed, other classic hypotheses such as superior traits (reproductive output, growth rates) and competitive abilities (resource acquisition) of invasive species over natives as well as the enemy release hypothesis (Keane and Crawley 2002; Kellner et al. 2011), non-native herbivores, and loss of frugivores and pollinators (Carlquist 1980) directly interact and shape a trajectory from native to invaded communities. In a recent paper, where Hawaii leads the globe as the number one hotspot for non-native species, Dawson et al. (2017) show that invasion success correlates with a region's wealth, population density, and climate. They further argue that wealthier islands are more vulnerable because these areas have more points of entry.

Impacts and Effects of Invasive Species

Disturbance Regimes At the ecosystem level, invasive species in Hawaii have introduced a number of severe positive feedback level disturbance regimes that have overwhelmed the natural resource management community. In tropical wet habitats, fast-growing and often nitrogen (N)-fixing invasive tree species have substantially increased nutrient cycling which facilitates further invasion (Hughes and Denslow 2005; Ostertag et al. 2009). Many times, the native species adapted to these ecosystems are often outcompeted and slowly eliminated from the mix. In separate but similar studies, Allison et al. (2004) and Hughes and Denslow (2005) convey evidence of noticeable increases in litter nutrients, decomposition rates, and nutrient availability following invasion in lowland wet forests. Both argue that these shifts facilitate further invasion and alternative stable states.

In tropical dry and subalpine systems, fire-promoting tropical grasses from Africa have introduced a positive-feedback grass-fire cycle resulting in the almost complete loss of native forest. In Hawaii, for example, fires were generally infrequent and limited in size prior to human-induced changes in native ecosystems (Loope and Mueller-Dombois 1989). Over the past century, however, wildfire frequency and size have increased dramatically as a result of invasion by fire-promoting alien grasses (Hughes et al. 1991; Smith and Tunison 1992; Trauernicht et al. 2015). These grasses increase fine fuel loads and alter fuel structure in ways that increase the likelihood of fire ignition and spread. Furthermore, fire effects and post-fire environmental conditions promote recruitment of non-native grasses and inhibit recruitment of native woody species. These changes in community structure and composition result in fuel and microclimate conditions that increase the likelihood of subsequent fire (Freifelder et al. 1998). In this way, non-native grass invasion initiates a grass-fire cycle that converts native forest to non-native-dominated grassland (D'Antonio and Vitousek 1992). This cycle is now considered the primary agent of forest-to-grassland conversion in dry and mesic plant communities in Hawaii and elsewhere in the tropics (Mack and D'Antonio 1998). While the total area burned annually in Hawaii may be small relative to that of fire-prone areas of the US mainland, the proportion of land burned in Hawaii is greater (0.48% area burned in Hawaii relative to 0.30% in the continental United States) indicating that the potential damage to natural resources posed by fires in Hawaii is profound (Trauernicht et al. 2015). Over 90% of the original Hawaiian dry forests have been destroyed (Bruegmann 1996; Mehrhoff 1993), and over 25% of the officially listed endangered plant taxa in the Hawaiian flora are from dry forest or dry-scrub ecosystems (Sakai and Wagner, unpublished data).

Carbon and Nutrient Cycling In Hawaii, changes in carbon and nutrient dynamics as a result of invasive species are ecosystem-dependent especially when they possess plant functional traits not represented in the native flora (Vitousek 1986). For example, introduced grass species in Hawaii result in the transformation of a forest to a grassland yielding a massive loss of aboveground carbon and large impacts on nutrient cycling (Mack 2003). In a tropical dry ecosystem in Hawaii, total aboveground biomass was 93% lower within a grass-converted site relative to forested plots (Litton et al. 2006). In wet ecosystems, the highly invasive firetree (*Morella faya*) also reduced carbon stocks, although not through a state transition as described above, but rather through shading out light-dependent native understory and midstory species (Asner et al. 2008). In a lowland wet forest experiment in which all alien species were removed, productivity as measured by litterfall decreased by 40% when compared with the invaded site (Ostertag et al. 2009). Further, in N-limited Hawaiian substrates, invasive N-fixing tree species have the greatest impact on ecosystem function through strong increases in carbon and nutrient cycling and carbon storage (Allison and Vitousek 2004; Hughes and Denslow 2005; Hughes et al. 2014; Mascaro et al. 2012). Even the invasive coqui frog (*Eleutherodactylus coqui*) was shown to increase invasive plant growth and increase litter decomposition rates by reducing herbivores and increasing new leaf production in a nutrient-poor site thereby conferring a competitive advantage to invasive plants in an ecosystem where native species have evolved in nutrient-poor conditions (Sin et al. 2008). Other studies have linked these altered biogeochemical cycles to facilitation of additional problematic invasive species (Hughes and Denslow 2005; Vitousek 1986), ultimately shifting these systems to entirely novel ecosystems (Mascaro et al. 2012). Nutrient additions from invasive species via litterfall inputs are also positively correlated with non-native earthworm (*Eisenia* spp.) density leading to increases in feral pig activity (Aplet et al. 1991; Zou 1993) which in turn disperses non-native fruits. This positive-feedback cycle links invasive species both by altering the nutrient cycle and facilitating the density and spread of additional invaders.

Competition for Resources Invasive species in Hawaii often outcompete native species because they have superior traits and use resources more efficiently (Baruch and Goldstein 1999). In addition, some invaders have the ability to utilize limiting resources by maximizing performance during times of abundance and avoiding stressful conditions during times of scarcity (Stratton and Goldstein 2001; Vitousek 1986). Pattison et al. (1998) showed definitively that invasive species in a wet tropical forest in Hawaii had higher growth rates than natives, particularly when compared in low-light environments. In a similar system, Cordell et al. (2016) indicated a parallel trend in wet forest seedlings where introduced and invasive pioneer species from Central America and Asia grow significantly faster than the highly conservative and slow-growing dominant native forest species. To further the impact, many Hawaiian species in these systems are shade-intolerant so are quickly displaced by shade-tolerant invaders once there is canopy closure (McDaniel and Ostertag 2010; Schulten et al. 2014). High-resolution remote sensing imagery confirms this transition by showing alteration of the three-dimensional structure of a Hawaiian rainforest following invasion through the loss of midstory and understory native species (Asner et al. 2008). Hawaiian forests are typically characterized by more open canopies than their continental tropical counterparts, and most native Hawaiian forest species require high-light environments for germination and survival (Burton and Mueller-Dombois 1984; Drake 1993; Drake and Mueller-Dombois 1993). Unfortunately, the high-light conditions in Hawaiian lowland wet forests are also conducive to the establishment and growth of invasive species. For example, Pattison et al. (1998) found that invasive species in Hawaii were able to capture and utilize light more efficiently than the natives, and their photosynthesis rates were significantly higher in high-light environments.

In tropical dry systems in Hawaii—and even in wet systems to a certain extent—water is a predominant limiting resource. Rainfall in these systems is episodic and somewhat aseasonal, and the flora that evolved and adapted to these conditions tend to have conservative growth strategies. As a result, drought-tolerant and drought-adapted invasive species that exhibit plasticity in morphological and physiological traits when resources are abundant or scarce can quickly outcompete native species. In the leeward (dry) sides of the islands, drought-tolerant grasses from Africa have been highly successful based on their ability to quickly utilize water resources when they are abundant and retreat to dormancy during times of drought (Williams et al. 1995). Experimental invasive grass removal in a tropical dry system on Hawaii Island resulted in a 40% increase in growth rates of native tree species relative to the grass-invaded plots (Cordell and Sandquist 2008). Oxygen isotope data from this study further revealed that the grasses were able to access water from low-rainfall (<10 mm) events more effectively than native species through their shallow root systems. In contrast, invasive mesquite trees (*Prosopis* spp.) in a similar system are able to dominate by accessing groundwater resources though deep-rooted taproots (Miyazawa et al. 2015). In wet systems periodic droughts are also common (Michaud et al. 2015). In an invasive species removal experiment in a lowland wet forest in Hawaii where non-native and invasive species are known to utilize more water resources than natives, Cavaleri et al. (2014) revealed an increase in water use by native species, and stand-level water use within the removal plots was half that of the invaded plots.

Climate Change and Plant Invasion Recent advances in climate modeling in Hawaii using the Coupled Model Intercomparison Project Phase 5 (Timm et al. 2015) indicate warmer-wetter scenarios for the windward slopes of the high islands and warmer-drier conditions for the remainder of the State. Other expected changes include seasonal and interannual variability accentuation (Lauer et al. 2013). These modeling efforts have been used to further predict the fate of Hawaii's plant and animal populations, including invasive species. Dramatic declines in native birds are predicted as warmer temperatures increase the prevalence of avian malaria in suitable bird habitat (Liao et al. 2015), and extinction is projected for some native plant populations when habitat area as defined by climatic envelopes is impinged by sea level rise on the lower end and elevation at the upper end (Fortini et al. 2013). An invasibility metric defined by Vorsino et al. (2014) used current knowledge of invasions from species distribution models and expected climate-driven reductions of native ecosystems to project plant invasion onto a 2100 Hawaii regional climate change scenario. While most of the area occupied by invasive species increased in size, the area of two highly invasive species occupying upper elevation wet forest decreased dramatically.

Management All land management agencies in Hawaii are tasked with managing invasive species because of their detrimental effects on native biodiversity. Numerous strategies have been attempted with efforts primarily invested in chemical and manual control (including exclusion via fences) methodologies; however, many of these efforts are challenging due in part to Hawaii's often inaccessible steep and rugged terrain. Most argue that an integrated pest management approach is required, including programs to exclude and screen new species, strategies to reduce or eradicate species, public education, and a biological control program for the most problematic species (Medeiros et al. 2013). The Hawaii Pacific Weed Risk Assessment (Daehler et al. 2004), a cost-efficient tool that uses a modified version of the Australia and New Zealand tool, has been useful for educating the public and the horticulture industry about the potential effects of species introductions. Beginning in the early 2000s, the State of Hawaii invested in interdepartmental island-specific Invasive Species Councils "for the special purpose of providing policy level direction, coordination, and planning among State departments, Federal agencies, and international and local initiatives for the control and eradication of harmful invasive species infestations throughout the State and for preventing the introduction of other invasive species that may be potentially harmful."

Other Approaches The use of forest plantations and restoration to reduce problematic invaders and promote native biodiversity has been an effective strategy in many parts of the tropics (Holl et al. 2011; Lugo 1997). Unfortunately this is not the case in Hawaii, where forest plantations have been shown to facilitate other weedy and invasive species, rather than increasing native species recruitment (Ostertag et al.

2008). However, forest restoration in dry systems in Hawaii does hold promise as a tool to shade out light-dependent invasive grasses (Cordell et al. 2004; McDaniel and Ostertag 2010), including attempts to reduce the highly invasive gorse (*Ulex europaeus*) using the native koa tree (*Acacia koa*). Girdling and thinning of highly invasive tree species in Hawaii Volcanoes National Park were both effective treatments in reducing new invasion and facilitating native species recruitment (Loh and Daehler 2007), while a new approach that uses functional traits to select species combinations of native and non-native (but noninvasive) to reduce invasion in lowland wet ecosystems in Hawaii holds promise as an effective tool (Cordell et al. 2016; Ostertag et al. 2015).

US-Affiliated Pacific Islands Overview

The state of the science of the impact of invasive plant species in the US-affiliated Pacific Islands is sparse largely due to the remote setting and lack of resources such as trained specialists. These areas include American Samoa, Guam, the Marshall Islands, the Northern Mariana Islands, Palau, and the Federated States of Micronesia (see Fig. A2.2). Moreover, the pronounced diversity of types of island or groups of islands (atolls to volcanic high mountains, isolated to archipelagos) and variation in land-use history makes it challenging to set priorities or find unifying themes. In the late 1990s, the islands of Micronesia and American Samoa were extensively surveyed for invasive plant species at the request of the Pacific Islands Forestry Committee, Council of Western State Foresters (Space and Falanruw 1999). The survey resulted in comprehensive lists of invasive plant species throughout the region grouped in the following five categories:

1. Species that are invasive elsewhere in similar ecosystems but were not listed in the literature during the time of this survey as being present in Micronesia (82 species)
2. Species that are invasive elsewhere and are also invasive in Micronesia (13 species)
3. Species that are not known to be particularly invasive elsewhere but are invasive in Micronesia (3 species)
4. Species that are invasive or weedy elsewhere and are common or weedy but not yet invasive in Micronesia (117 species)
5. Native species that exhibit aggressive behavior following disturbance (16 species)

As a result of these surveys, local forestry departments now prioritize their activities to keep the worst invasives at bay and educate communities about the economic and biological impacts of invasive species. In 2009, Denslow et al. surveyed Pacific Islands extensively to address the roles of biogeographic, environmental, and socioeconomic impacts on the distribution and spread of exotic species. Across the Pacific Islands, size, elevation, and the presence of an airport with a paved runway all correlated with exotic species richness, whereas analysis by country revealed that exotic species richness was associated with size, gross domestic product, and population density (Denslow et al. 2009). A broader survey across tropical oceanic islands (Kueffer et al. 2010) found that the best predictor of invasive species across all islands sampled was human development and habitat diversity. Further, the number of dominant invaders decreased with increasing age of the island. When comparing flora across islands, they conclude that invasive species found in an island group are also almost always present in other groups where they may not yet be considered invasive. This finding clarifies the need for early detection monitoring programs on oceanic islands (Kueffer et al. 2010). In 2017, Pysek et al. looked at many factors associated with naturalized non-native flora of the world. In their analysis, they included information from Hawaii, Guam, American Samoa, and the Northern Mariana Islands. What really stands out in their report is that islands, and in particular tropical islands, have a much higher percentage of alien flora than other systems. For example 66% of Guam's, 48% of Hawaii's, 41% of the Northern Mariana Islands', and 33% of American Samoa's total flora are non-native, whereas 23% of California's and 30% of Florida's flora are represented by non-native species.

Aside from island-wide surveys, weed risk assessments, and comparative studies, very little work has been done in this region on the impacts and consequences of invasive species. However, promising results from two studies indicate that invasive species removal in American Samoa (Hughes et al. 2012) and the cessation of anthropogenic disturbance regimes (primarily fire) in Palau (Costion et al. 2012) have resulted in the recovery of native forest.

Conclusions

The historical and continued degradation of Hawaiian and Pacific Island ecosystems has opened the door to species invasions that have, in turn, transformed entire ecosystems and altered historic disturbance regimes. Together with the unique character of Hawaii and the US-affiliated Pacific Islands' plant and animal species (isolation, biogeography, endemic flora), invasive species are leading many of these ecosystems to a crossroad in which all native systems are no longer sustainable. In essence, Hawaii is ground zero for invasive species. Scientists estimate that more than 10,000 non-native plant and animal species have been brought to Hawaii with more than 100 of those causing extreme damage to Hawaii's native ecosystems. If we are to save these ecosystems and the associated native species from extinction, innovative approaches are needed to both reduce impacts of invasive species and enhance the resilience of native species assemblages.

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Northwest Region

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Introduction

The Northwest region (Idaho, Oregon, and Washington; Figs. A3.1 and A3.2) contains major coastal and inland ports (Coos Bay, Lewiston, Pasco, Portland, Seattle-Tacoma, and The Dalles), waterways (Puget Sound, Columbia River Basin, and Willamette Valley), and major