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INVASIVE SPECIES ADVISORY COMMITTEE

C/O NATIONAL INVASIVE SPECIES COUNCIL
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Invasive Species Threaten the Success of Climate Change Adaptation Efforts

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Introduction

Across the Nation, climate change must be addressed not only through direct mitigation and adaptation, but also through strategic mitigation of threats to the success of those actions. Invasive species are a significant threat to climate preparedness and resilience[1]—their impacts fundamentally alter natural and built systems, reducing society's ability to adapt to a changing climate. Broad-scale changes to federal priorities and paradigms surrounding climate change actions, from the perspective of invasive species management, are needed to achieve success. Failures to systematically integrate invasive species into these approaches will slow or even prevent meeting climate adaptation goals.

To achieve transformative adaptation to climate change, benefiting all sectors and communities, the National Invasive Species Council (NISC) member agencies must actively integrate invasive species management into climate action planning, funding, and implementation.

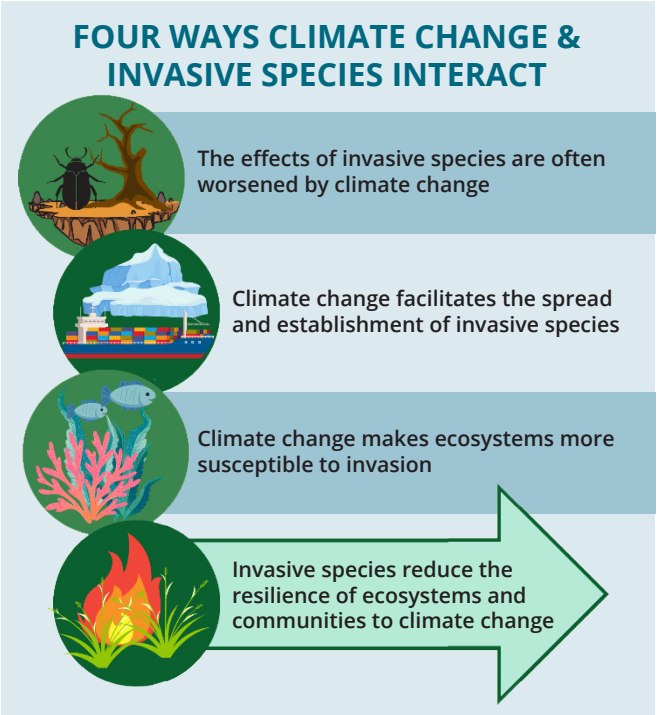
The cumulative effects of invasive species reach every place, every priority, and every agency—economic costs have exceeded $26 billion every year in North America for the last decade (Crystal-Ornelas et al. 2021). Globally, economic impacts are estimated to quadruple every decade with catastrophic repercussions to both society and ecosystems (IPBES 2023). The diversity of invasive plants, animals, bacteria, fungi, and more creates impacts on people and nature that are widespread, severe, and ever increasing. Like climate change, the problems caused by invasive species may be gradual, diffuse, and complex; at other times, they are rapid, localized, and devastating.

Invasive species directly impede efforts to build climate change resilience across a broad spectrum of socio-economic and environmental realms. Climate change is a threat multiplier that is increasing the magnitude of invasive species impacts while simultaneously promoting new biological invasions regionally and globally. Further, climate change facilitates shifts of native species' distributions beyond their historical ranges. In some cases, these species cause negative[2] impacts in their new ranges. The negative effects of both invasive species and climate change are further compounded by complex, often synergistic, interactions. In this paper, we have intentionally focused on one facet of this complexity: the myriad of negative impacts that invasive species have on climate adaptation actions and resilience goals (Figure 1).

The long-lasting and devastating impacts of invasive species reduce climate change resilience by altering ecosystem structure and function while also negatively impacting livelihoods and communities. Every Federal agency and department must act within their strengths and jurisdictions to mitigate these threats. Without mitigating invasive species impacts, the affected lands and waters will lack the ecological integrity needed to provide nature-based solutions, biodiversity targets, or landscape-level resilient systems that are necessary to prevent serious climate change impacts. This in turn affects communities that depend on the services that ecosystems provide. **Federal agencies and departments must integrate invasive species management into climate change adaptation actions to be fully effective across all sectors and increase the likelihood of achieving climate goals.**

1 In this paper, the term "resilience" refers to "the ability to anticipate, prepare for, and adapt to changing conditions and withstand, respond to, and recover rapidly from disruptions," and "adaptation" refers to any "adjustment in natural or human systems in anticipation of or response to a changing environment in a way that effectively uses beneficial opportunities or reduces negative effects" (Executive Order 13653).

2 The Federal definitions are ambiguous with respect to whether native species that disperse and establish out of their natural range in response to human-caused climate change can be defined as invasive (Executive Order No. 13751). The term "neonative" has been proposed to describe range-shifting species; the subset of neonative species with negative impacts are thus termed nuisance neonatives (Essl et al. 2019).



In this paper, the Invasive Species Advisory Committee (ISAC) provides a blueprint for transforming how invasive species are considered within U.S. climate change planning, processes, and policies, structured as follows:

- Five priority recommendations representing practical objectives within existing Federal priorities, strategies, and frameworks;
- Case studies representing threats to 14 climate-related themes for illustration and context; and
- Three success stories to underscore how federal action can yield tangible results.

Figure 1: *Four ways climate change and invasive species interact. All four interactions are important; the Invasive Species Advisory Committee chose to focus on the fourth interaction type in this white paper.*

Recommendations

For a visual summary of the Recommendations, see Figure 2.

RECOMMENDATION 1:
All Federal agencies and departments must explicitly incorporate invasive species into climate change adaptation guidance.

This may include updating and adapting Climate Change Adaptation Plans to incorporate invasive species considerations and mitigations according to agency capabilities and mandates. Executive Order 14008, *Tackling the Climate Crisis at Home and Abroad* directs all U.S. Federal agencies and departments to develop and implement action plans that strengthen the adaptive capacity of the Nation to climate change and build resilience in the coming decades. Twenty-six Climate Change Adaptation Plans have been produced as of 2023, yet only eight directly reference invasive species, and just four (Departments of Agriculture, Commerce, Defense, and the Interior) meaningfully connect invasive species to the Nation's climate preparedness and resilience. Furthermore, these connections are presented as unidirectional; they focus on how a changing climate can influence the spread and impacts of invasive species. Moving forward, Climate Change Adaptation Plans and all similar guidance must reflect that relationship in the other direction; invasive species also negatively impact climate change resilience and adaptation efforts.

A review of the 26 Climate Change Adaptation Plans yielded three common action themes where invasive species considerations should be integrated. ISAC recommends that all agencies and departments task appropriate personnel to ensure that their respective plans incorporate and address invasive species impacts and maximize opportunities for equitable, cross-cutting responses to the climate crisis. These three common action themes include:

1. **Climate literacy, data, tools, information, and communication:** Support research that directly incorporates invasive species impacts at relevant spatial and temporal scales into climate information products and actionable management tools, and ensure that research outcomes and products are accessible by relevant Federal personnel, the general public, and the education community. Invest in better projections for invasive species distributions in the context of a changing climate, including assessments of invasive species impacts to climate change adaptation strategies. Invest in existing climate adaptation datasets and

tools to integrate invasive species information.[3] Increase knowledge sharing and the incorporation of adaptation case studies that include invasive species prevention or management into existing tools, such as the Climate Resilience Toolkit. Formalize best practices to prevent the establishment and spread of invasive species during the response to and recovery from disasters caused by natural hazards using memoranda of understanding, job aids, or other tools.

2. **Infrastructure:** Ensure that all aspects of U.S. infrastructure (including "gray" such as levees and bridges, and "green" or nature-based solutions, such as forests and estuaries) are made more resilient to climate change by actively incorporating the prevention and management of invasive species as part of systems approaches, long-term planning, and disaster response.

3. **Transportation, conveyances, and supply chains:** The unintended transport or ingress of invasive species by air, sea, and land-based pathways disrupts the efficiency, integrity, and effectiveness of supply chains and transportation networks. Agencies must work cooperatively to reduce these invasive species entry events by more effectively defining, predicting, preventing, and detecting introductions before disruptions occur.

RECOMMENDATION 2:
Increase support for national and regional networks and other programs working at the intersection of climate change and invasive species.

Significantly increased support for the Regional Invasive Species and Climate Change (RISCC) Management Networks, collaborative interest networks (such as the National Fish, Wildlife, and Plants Climate Adaptation Network), Tribal climate action and Indigenous Knowledge collectives, National Oceanic and Atmospheric Administration Climate Adaptation Partnerships, U.S. Geological Survey (USGS) Climate Adaptation Science Centers, U.S. Department of Agriculture (USDA) Climate Hubs, innovation grants, research collaboratives, conservation districts, and extension programs is needed to translate science, tools, and technology into practical and actionable management solutions. Expanding these efforts to manage established invasive species will improve climate change adaptation outcomes. Moreover, the tools for effective management of a given established invasive species may exist, but knowledge, resources, capacity, or willingness to act must also be present to effectively mobilize the networks towards their common purposes. The interdisciplinary approaches of professional networks and other expert groups must be elevated to complement and enhance the Federal agencies' responses and needs. This should be reciprocated with higher federal engagement and long-term support.

RECOMMENDATION 3:
Integrate invasive species science and prevention efforts into climate related international treaties, agreements, conventions, practices, and policies.

Preventing the introduction of new invasive species is undeniably the most cost-effective strategy to mitigate the long-term cumulative impacts of biological invasions. Given the high cost of invasive species to the U.S. economy and limited options to successfully eradicate many invasive species once established, more effective and comprehensive prevention measures are urgently needed within and across regional, national, and international borders. ISAC recommends two actions to broaden the reach and increase the effectiveness of both international invasive species prevention and climate action.

1. **Integrate science globally:** Internationally directed federal laws, policies, and regulations seeking to address climate change must integrate the best available biophysical and social science research on invasive species prevention and management, including: geospatial data, technology advancements, and best practices to improve risk-reduction activities. Climate and invasive species baseline data gaps must be addressed, with direct and timely attention to data insufficiencies that have been identified across Pacific and Caribbean Island countries and territories, including the U.S.-Affiliated Islands.

2. **International agreements, treaties, and aid:** Federal departments working internationally (including the Departments of Agriculture, Commerce, Defense, Homeland Security, the Interior, and State, and the U.S. Agency for International Development) must include invasive species considerations in climate change adaptation and response negotiation language and funded initiatives, including: trade and investment agreements, biodiversity and climate agreements, and international aid, research, and funding mechanisms. Ultimately, the globally intertwined nature of both the problems and the solutions to climate change and invasive species must be acknowledged and approached proactively with all trade and diplomatic partners.

3 The White House Climate Mapping for Resilience and Adaptation (CMRA) Tool, Department of the Interior Strategic Hazard Identification and Risk Assessment Project, or the U.S. Geological Survey Flood and Storm Tracker tool could be adapted to include or expand invasive species data where available.

RECOMMENDATION 4:
Ensure early detection, rapid response, and safeguarding strategies account for up-to-date climate data, projections, and models across all geographies.

Early detection, rapid response, and safeguarding are widely recognized as key tenets of effective invasive species management for when an invasive species overcomes existing prevention mechanisms. Detecting newly established invasive species in the earliest stages of establishment enables a more effective rapid response—greatly increasing the chance of successful eradication or containment of the species' spread and impact. Because biological invasions can further exacerbate climate-related stresses on native ecosystems, infrastructure, commerce, and human health, limiting the establishment and spread of new invasive species translates to fewer environmental and economic disruptions and less acute budget challenges as the nation works to mitigate climate change impacts.

Given the strong interactions between climate change and invasive species, it is important to incorporate climate change considerations into the National Early Detection and Rapid Response Framework build-out that is currently underway. The Framework seeks to integrate surveillance and detection programs, predictive modelling, risk screening, and response measures using a cross-jurisdictional structure. The Framework should include and routinely update climate-informed horizon scanning tools and approaches (e.g., identification of species at high risk of being introduced to new regions), hotspot analyses (e.g., model-based mapping to identify suitable invasive species habitats), pathway-based risk analyses (e.g., determinations of risk based on shared mechanisms of spread), and prioritization strategies to most effectively allocate rapid response resources. As recently as the early 2000s, one quarter of non-native species detected in new locations did not have a record of prior introduction or invasion (Seebens et al. 2018). Therefore, ongoing inspection data must also be used to complement horizon scanning, international cooperation, and historical pest, pathway, and source-region data. Importantly, these efforts must be carried out through strong collaborations and clarity of regulatory authorities, consistent communication of roles and responsibilities, and robust information sharing and cooperative response efforts across Federal, State, Tribal, Territorial, and local governmental partners. These efforts must also include explicit mandates to assess if baseline data and constituent engagement is insufficient in underserved communities and correct those deficiencies to create equity across geographies of risk.

RECOMMENDATION 5:
Increase investments for long-term management of invasive species threatening climate preparedness and resilience.

Reducing the threat that invasive species pose to climate resiliency requires a sustained commitment to management strategies, control efforts, and the development and implementation of new technologies. The protection and active management of existing natural infrastructure (e.g., forests, coral) and related ecosystem services is more effective than the restoration of damaged or destroyed ecosystems. Once invasive species are established, managing their impact often becomes a long-term, costly endeavor. However, a failure to address these impacts has unacceptably higher costs. In many cases, Federal agencies lack sufficient resources to fully address these challenges, resulting in prolonged negative impacts even when control options and social acceptance are present. The ISAC recommends two actions to decrease the long-term impacts of invasive species to climate change preparedness and resilience:

1. **Identify and remedy insufficient investment:** To identify unmet fiscal resource needs and find opportunities to increase cost effectiveness, NISC member agencies should conduct an interagency programmatic gaps analysis. This should focus on long-term investments and be facilitated by NISC through a new process within the annual crosscut budget analysis. In some cases, effective invasive species management tools and strategies are available, but adequate and sustained financial resources to address the problem, especially at large scales, are lacking. In other cases, effective management tools and strategies have not yet been identified, or those that are available are insufficient, leaving agencies with few options to minimize the impacts of an invasive species. Especially in cases of species with limited control options, agencies must be equipped with the resources to effectively prevent human-facilitated dispersal from trade, travel, and natural disaster response.

2. **Support long-term research and innovation:** To meet the significant challenges of invasive species, long-term investment in applied research and technology is vital. As agencies work to update climate adaptation guidance pertaining to invasive species, management-focused research should be identified and adequately resourced. This includes facilitating technology advancements, incentivizing innovations, and minimizing unnecessary or outdated regulatory processes. Key areas for research and technology development include advanced biotechnologies including gene-based technologies (e.g., Trojan Y chromosome strategy, genetic modification for host resistance, genomic screening for natural resistance, gene drive) and RNA interference (e.g., species-specific pesticides and toxicants), biological control (e.g., classical biological control, sterile insect release, induced polyploid functional sterility), improved integrated pest management strategies, and surveillance technology enhancements (e.g., artificial intelligence, high throughput eDNA and eRNA analysis, multispectral remote sensing).

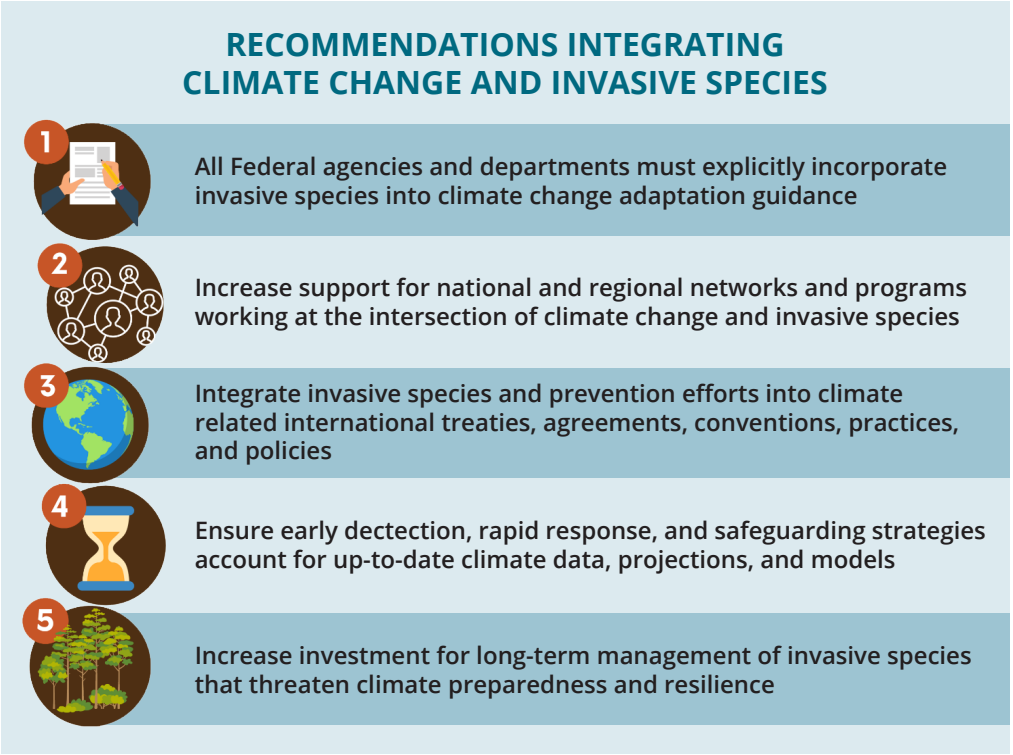


Figure 2. *Five priority recommendations representing practical objectives within existing federal priorities, strategies, and frameworks which integrate climate change and invasive species.*

Case Studies

In support of these recommendations, this section presents a selection of case studies on the impacts that invasive species have on climate change resilience that Federal agencies are encountering in the short- and long-term. The examples demonstrate the challenges faced by agencies and the need for actions mentioned in the above recommendations, emphasizing the ways that invasive species disrupt climate change resilience across a broad scope of geographies and taxa (Figure 3). These cases are intended to resonate across a breadth of experiences, capabilities, and agency mandates, and spark innovation around the cross-cutting solutions required for transformative adaptation to the dual hazards of climate change and invasive species.

NATURAL CLIMATE SOLUTIONS: CARBON SEQUESTRATION, STORAGE, AND CYCLES

1. **Preventing and reducing invasive forest pests maintains carbon storage and sequestration:** Invasive forest pests and pathogens can reduce a tree's ability to capture and store carbon in many ways, including repeated defoliation, interrupted sap flows, fungal infections, and in many cases, the rapid decline and death of the tree. Affected forests store far less carbon than undisturbed forests each year, with losses estimated at 28–69% of sequestration capacity, equating to an estimated 47 million tons of CO_2, per year (Quirion et al. 2021). Damage to forests from established invasive pests like the emerald ash borer (*Agrilus planipennis*) and hemlock wooly adelgid (*Adelges tsugae*) is ongoing; the introduction of additional invasive pests will decrease carbon sequestration and increase forest management burdens.

2. **Preventing and controlling invasive grasses reduces wildfire risk and increases carbon storage:** Numerous invasive grass species are contributing to increases in wildfire frequency and intensity in ecosystems across the country. For instance, the invasion and disturbance cycle of many invasive grasses leads to a 150% increase in fire frequency (Fusco et al. 2019) often resulting in permanent alterations to native plant communities, wildlife habitats, and ecosystem services such as carbon storage (Germino et al. 2016; Nagy et el. 2021). Ecosystem resilience in regions affected by fire-associated invasive grass species is improved through traditional invasive species management strategies (mechanical, chemical, and biological control) and resilience-enhancing programs (native plant restoration, indigenous-led land stewardship, and active fuel-load management in agricultural and natural areas).

INFRASTRUCTURE RESILIENCE: FLOOD CONTROL, WATER SUPPLY, WATERSHED PROTECTION, AND STRUCTURES

1. **Invasive plant control increases resilience of water infrastructure to climate-linked high-water events and flooding:** Water hyacinth (*Pontederia crassipes*) and invasive giant reed (*Arundo donax*) are two examples of the numerous invasive aquatic plants that aggressively colonize freshwater ecosystems in the United States, negatively impacting water supply, flood control, navigation/transportation, commerce, and human health (Villamagna and Murphy 2010). Water hyacinth's rapid growth and accumulation significantly obstructs waterways, flood control systems, and water supply infrastructure, increasing risks of flood damage during climate-related disasters, such as hurricanes (Vissichelli 2018). Water hyacinth is predicted to expand its range and increase its invasive potential with climate change (You et al. 2013). Densely overgrown invasive giant reed (*Arundo donax*) stands in riparian areas of the southwestern United States can become dislodged during high water events, causing blockages when the thick rafts of vegetation become lodged under bridge pilings, sometimes resulting in bridge damage and collapse.

2. **Control of invasive snakes builds resilience of energy systems to severe storms:** For decades, the brown tree snake (*Boiga irregularis*) has ravaged infrastructure and ecosystems in the U.S. insular territory of Guam, costing millions of dollars in damages and extirpating 12 of 14 native forest birds, four of which are now extinct. Brown tree snakes caused thousands of electrical blackouts per year prior to the modification of the electrical grid. Ongoing electrical disruptions caused by the snakes add stress to Guam's electrical grid that, similar to many other islands and tropical areas, is already under significant pressure from the compounding effects of severe storms, vegetation overgrowth, and corrosion (Fritts 2002).

3. **Invasive plant management can increase water conservation yields:** Invasive species can reduce aquifer recharge rates through high transpiration rates and rainfall interception. For example, salt cedar's (*Tamarix* spp.) high transpiration rate creates net water loss and dense growth disturbs channel flow, resulting in dramatic riparian impacts across the already water-stressed southwestern U.S. rivers. In Hawai'i, the dense monocultures formed by the invasive strawberry guava tree (*Psidium cattleianum*) have severely degraded the islands' native forests. Now the most abundant tree in the state, strawberry guava stands have much higher (53% greater) transpiration rates during dry years than the native 'ōhi'a lehua (*Metrosideros polymorpha*), a species of tree in the myrtle family, and allow less rainfall to reach the forest floor, reducing the groundwater recharge and storage that sustain both ecosystems and human populations (Owen et al. 2022; Takahashi et al. 2011).

4. **Control of invasive animals supports resilience to flooding:** Animal burrows and soil rooting degrade the strength and stability of earthen dams and levees (Bayoumi and Meguid 2011). Numerous invasive animal species are known to damage flood control infrastructure (Harvey et al. 2019) and many are expected to expand their range and abundance with climate change. For example, green iguana (*Iguana iguana*) burrowing causes significant erosion on canal banks and levees in southern Florida, weakening built infrastructure. Although currently limited to parts of Florida and Texas, iguanas are expected to invade farther into the southeastern and Gulf Coast States as the climate changes.

5. **Managing invasive vegetation protects communities and infrastructure from catastrophic wildfire:** Many invasive grasses, including cheatgrass (*Bromus tectorum*), buffelgrass (*Pennisetum ciliare*), and Guinea grass (*Megathyrsus maximus*) are linked to increases in fire frequency in disturbed areas of the United States, such as the southwestern States and areas in the U.S. Pacific Islands (Fusco et al. 2019; Fusco et al. 2021). These invasive grasses can alter fuel structures and create a vicious grass-fire cycle, whereby native species diversity is reduced with each subsequent fire, and ecosystem function can be difficult to recover even when fires are suppressed. The proximity of fire-prone invasive grasses to human infrastructure and activities poses significant social and economic risks, particularly when combined with the impacts of a changing climate. In Hawai'i, declining rainfall combined with increasingly severe and lengthy periods of drought, coupled with high fuel loads from invasive grasses, have amplified fire risk (Frazier et al. 2022), as was the case in the fire that destroyed the town of Lāhainā, Maui, in 2023 (Parsons and Martin 2023).

RESILIENT COASTAL COMMUNITIES: CORAL REEFS, SALTWATER MARSHES

1. **Preventing invasive coral disease increases coastal protection from extreme storms:** Stony coral tissue loss disease (SCTLD) is a highly contagious, white plague-like disease afflicting almost 30 species of coral, including reef-building species. SCTLD threatens reef habitat structure, complexity, and functionality and has triggered an unprecedented loss of corals in the Caribbean region (Alvarez-Filip et al. 2022). Given its rapid appearance in places that are geographically distant and distinct, it is likely that ballast water and hull fouling are contributing to the spread of SCTLD, which puts the Indo-Pacific at high risk through domestic and international maritime transport (Rosenau et al. 2021). In addition to their importance for livelihoods and food security, healthy reefs are critical to withstanding climate change impacts such as through storm surge and sea level rise in states like Hawai'i and Florida, other U.S. insular areas, and the Freely Associated States of Micronesia.

2. **Control of invasive species supports coastal wetland resilience:** Nutria (*Myocastor coypus*), a large invasive rodent, has been reported in over 40 states. Across the southeastern United States, nutria destructively burrow and feed at high densities along the coastal plain, resulting in widespread degradation and conversion of coastal wetlands to open water habitat—this in turn greatly decreases protection of communities from storm surge and high tide events. The Roseau cane scale (*Nipponaclerda biwakoensis*), an invasive insect, is destroying stands of the native common reed (both native and invasive common reed are subspecies of *Phragmites australis*) stands along the brackish waters of the Gulf of Mexico, destabilizing marshy habitats and thereby decreasing coastal resilience in hurricane- and flood-prone areas.

CULTURAL PRACTICES: FIRST FOODS, MEDICINAL PLANTS, TRADITIONAL ARTS

1. **Preventing agricultural diseases boosts food security in island communities that are impacted by climate change:** In the mid-1990s, an epidemic of an invasive taro blight (*Phytophthora colocasiae*) struck the U.S. insular territory of American Sāmoa, decimating taro production. Chemical treatments are not effective against this fungus-like pathogen, and manual control is only advantageous during mild infections. Taro is a culturally important subsistence and staple food crop in the Pacific Islands, where taro food-production systems (i.e., taro patches) can be resilient to climate events- sequestering freshwater during flooding while providing a sustainable food source. Blight-resistant cultivars were identified elsewhere in the U.S. Pacific Islands and have been widely accepted in American Sāmoa, where taro cultivation and consumption have resumed (Brooks 2000).

2. **Managing the impacts of forest pests on culturally important tree species protects imperiled Indigenous cultural practices:** In the southeastern United States, invasive redbay ambrosia beetles (*Xyleborus glabratus*) are spreading an invasive tree-killing fungal disease, laurel wilt (*Harringtonia lauricola*), to swamp bays, redbays, and sassafras trees (Olatinwo et al. 2021). Redbay and swamp bay trees are culturally important to Indigenous peoples, including roles in traditional Tribal medicine and funeral practices. In Hawai‘i, two species of invasive *Ceratocystis* fungus cause rapid ‘ōhi‘a death, leading to rapid decline and death of ‘ōhi‘a lehua (*Metrosideros polymorpha*) across four islands. The ‘ōhi‘a lehua is a keystone species of indigenous Hawaiian culture and an intrinsic part of many cultural traditions including the construction of temples from its wood to the stringing of ‘ōhi‘a blossom leis for ceremonies. The invasive emerald ash borer’s (*Agrilus planipennis*) rapid and complete destruction of ash (*Fraxinus* spp.) trees across the eastern United States and Canada directly imperils ecosystem health and the landscape-level viability of all affected tree species. The many Tribes and First Nations across this region hold relationships with ash trees for traditional art forms such as basketmaking, as well as strong cultural ties to the trees themselves. The loss of culturally important natural resources caused by these invasive pathogens and insects add to the cumulative burden to Indigenous groups that are already losing access to cultural resources due to climate changes’ roles in changing land use, shifting ecological relationships, and altered phenology.

ISLAND SUSTAINABILITY: HUMAN HEALTH, FOOD SYSTEMS, TRADITIONAL PRACTICES

1. **Preventing the spread of invasive beetles protects food security, shorelines, and cultural practices:** The invasive coconut rhinoceros beetle (*Oryctes rhinoceros*) infests and destroys coconut palms, costing the United States millions of dollars a year in economic losses, particularly in Guam and Hawai‘i where they may be capable of causing up to 50% tree mortality (Moore 2009; Manley et al. 2018). The coconut palm is called the “Tree of Life” in the Pacific Islands region, providing food, durable materials, shelter, shoreline stability, wind breaks during heavy storms, and, in some atolls, the only source of drinking water during times of drought. The Pacific Islands region is a particular point of vulnerability for continued spread of this beetle as well as other invasive species, due to the near total lack of adequate inspection and sanitation capabilities, as well as increasing commercial, military, and tourism traffic between Asia, the U.S.-Affiliated Pacific Islands, and the continental United States (Hao et al. 2022).

2. **Controlling invasive disease vectors decreases disease transmission in areas already highly vulnerable to the negative impacts of climate change:** Invasive disease vectors, particularly the mosquitoes *Aedes aegypti* and *Aedes albopictus*, have contributed to major and regular outbreaks of dengue, Zika, and chikungunya virus, affecting hundreds of thousands of people throughout the Pacific Islands region, including all U.S. and affiliated jurisdictions (Filho et al. 2019; Seok et al. 2023). Vector-borne disease compounds the strain on already limited public health resources and can worsen the health-related effects of climate change, such as heat impacts or a lack of clean water. These burdens are expected to be further exacerbated by climate change. Addressing invasive vectors like *Aedes* mosquitoes is a well-recognized component of OneHealth and builds climate resilience for both people and wildlife.

3. **Controlling invasive ants protects multiple aspects of island sustainability while building resilience to climate change:** Invasive ants represent a significant threat to climate resilience and sustainability in the U.S. Pacific Islands, exerting profound impacts on food security, livelihoods, and ecosystems, and compounding the challenges faced by communities already grappling with the impacts of climate change. The economic implications of ant invasions in the Pacific are enormous: Lee et al. (2015) estimated that increasing Hawai'i's little fire ant (*Wasmannia auropunctata*) management expenditures by just $8 million would yield $1.2 billion in reduced control costs over 10 years. Gutrich et al. (2007) estimated if the red imported fire ant (*Solenopsis invicta*) were to establish and spread in Hawai'i, it would cost $2.5 billion over 20 years. Furthermore, invasive ants perpetuate a cycle of ecological degradation that exacerbates climate vulnerabilities by damaging crop yields, disrupting soil structure, reducing nutrient cycling, and changing root structures in native forests. Despite growing public and political awareness of the risks, agencies responsible for detection and response across the U.S. Pacific Islands region are understaffed and under-resourced, and at a 2022 regional conference on invasive species threats, none of the U.S. Pacific Island countries and territories had developed emergency response plans for priority invasive ants (PESC 2022).

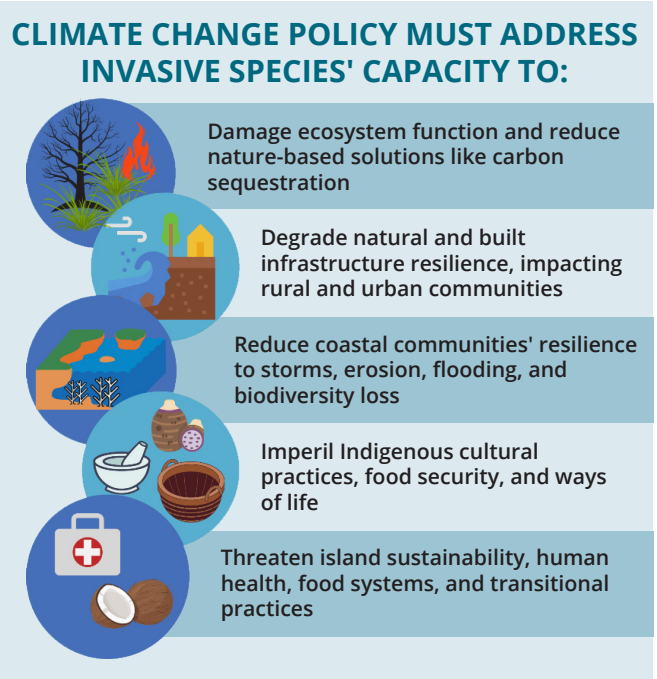


Figure 3. *Five concept groupings showing how policy must address invasive species capacity to negatively impact different facets of climate change resilience.*

Success Stories

Invasive species prevention and management can yield successful outcomes. In many cases, there is wide overlap between invasive species management and the protection of climate change resilient systems. The three examples below illustrate where an invasive species response currently is seeing success, how that success will build climate change resilience and support adaptation efforts, and what key federal actions have contributed to those successes.

- **Protecting carbon storage, maintaining carbon sequestration, and mitigating urban heat islands through sustained commitment and cooperation.** The repeated successes of early detection and rapid response to Asian longhorned beetle infestations has led to a history of successful eradications of this beetle across North America. Dedicated substantial and sustained funding to cooperative eradication programs has prevented widespread losses of forest carbon sequestration and storage, as well as protected urban tree canopies across the Nation. The success of this program supports one of the most important nature-based solutions to the impacts of climate change on people-resilient urban forests as critical green infrastructure.
- **Preventing the destabilization of infrastructure and commerce by implementing a cross-agency regulatory framework alongside research programs.** The containment of the brown tree snake on Guam has prevented potentially billions in damages and other enormous risks to other islands within the U.S. insular Pacific, namely the Commonwealth of the Northern Mariana Islands (CNMI) and the State of Hawai'i. The USDA Animal and Plant Health Inspection Service (APHIS) initiated commercial cargo controls in 1992 to prevent the transport of the snake off of Guam (Shwiff et al. 2010; Hall 1996) and in 2002, the USGS established a multi-agency Brown Tree Snake Rapid Response Team for training, logistics, and outreach. In 2023, the U.S. Department of the Interior allocated $4 million in grant funding toward suppression and control in Guam and prevention, detection, and rapid response efforts in the CNMI and Hawai'i. Each year that efforts to prevent the spread of brown tree snake from Guam succeed is an economic victory for the rest of the Pacific.

- **Protecting agriculture and human health through coordinated, sustained rapid response.** The giant African land snail (*Lissachatina fulica*) is considered one of the most damaging pests worldwide. Native to East Africa, the invasive snail has a global distribution and is likely to expand its range and densities as climate changes (Patiño-Montoya et al. 2022). The giant African land snail is known to feed on over 500 economically important plant species. It is also an intermediate host of the rat lungworm (*Angiostrongylus cantonensis*), which can infect humans and cause meningitis (Cowie 2013). There have been multiple documented introductions of this invasive snail in Florida since 1966, and each of these introductions have been the subject of intensive interagency eradication efforts by USDA APHIS and the Florida Department of Agriculture and Consumer Services. While the repeated introductions of the giant African land snail reflect the challenges and complexities of prevention programs, the successful eradication of small populations through coordinated rapid response demonstrate the potential for success when prevention measures fail. The successes of Florida's giant African land snail response efforts are attributed to strong Federal and State coordination and dedicated fiscal and staffing resources. These elements enable rapid and sustained control, regulatory authority to access private lands, effective public education and outreach, development of effective control tools, and adoption of integrated pest management strategies. These containment and eradication efforts are significantly minimizing impacts to Florida's horticultural and agronomic crop industries and curtailing the potential spread of meningitis to human populations.

The successes in invasive species prevention and management illustrated here are defined not only by benefits conferred to ecosystems, economies, and human health, but also by how they support community well-being and our Nation's resilience to the effects of climate change. Federal actions addressing invasive species—such as the examples seen in these success stories—will have the best possible outcomes when coupled with clear communication of the value that invasive species prevention and management brings to climate change adaptation, mitigation, and action.

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References

Alvarez-Filip, L., González-Barrios, F. J., Pérez-Cervantes, E., Molina-Hernández, A., & Estrada-Saldívar, N. (2022). Stony coral tissue loss disease decimated Caribbean coral populations and reshaped reef functionality. Communications Biology, 5(1), 440. https://doi.org/10.1038/s42003-022-03398-6

Bayoumi, A., & Meguid, M. A. (2011). Wildlife and safety of earthen structures: a review. Journal of Failure Analysis and Prevention, 11, 295-319. https://doi.org/10.1007/s11668-011-9439-y

Brooks, F.E. (2000). Taro Leaf Blight: Pests and Diseases of American Samoa, Number 3. American Samoa Community College Agriculture, Human & Natural Resources Cooperative Research & Extension. https://www.ctahr.hawaii.edu/adap/ASCC_LandGrant/Dr_Brooks/BrochureNo3.pdf

Cowie, R. H. (2013). Pathways for transmission of angiostrongyliasis and the risk of disease associated with them. Hawai'i Journal of Medicine & Public Health, 72(6 Suppl 2), 70.

Crystal-Ornelas R., Hudgins E.J., Cuthbert R.N., Haubrock P.J., Fantle-Lepczyk J., Angulo E., Kramer A.M., Ballesteros-Mejia L., Leroy B., Leung B., López-López E., Diagne C., Courchamp F. (2021) Economic costs of biological invasions within North America. The economic costs of biological invasions around the world. NeoBiota 67: 485-510. https://doi.org/10.3897/neobiota.67.58038

Essl, F., Dullinger, S., Genovesi, P., Hulme, P. E., Jeschke, J. M., Katsanevakis, S., Kühn, I., Lenzner, B., Pauchard, A., Pyšek, P., Rabitsch, W., Richardson, D.M., Seebens, H., van Kleunen, M., van der Putten, W.H., Vilà, M. & Bacher, S. (2019). A conceptual framework for range-expanding species that track human-induced environmental change. BioScience, 69(11), 908–919. https://doi.org/10.1093/biosci/biz101

Executive Office of the President. (2016). Executive Order 13751: Safeguarding the Nation from the Impacts of Invasive Species (Dec. 8, 2016), 81 Federal Register 88609. https://www.federalregister.gov/d/2016-29519

Executive Office of the President. (2013). Executive Order 13653: Preparing the United States for the Impacts of Climate Change (Nov. 1, 2013), 78 Federal Register 66817. https://www.federalregister.gov/d/2013-26785

Executive Office of the President (2021). Executive Order 14008: Tackling the Climate Crisis at Home and Abroad (Jan. 27, 2021), 86 Federal Register 7619. https://www.federalregister.gov/d/2021-02177

Frazier, A.G., Giardina, C.P., Giambelluca, T.W., Brewington, L., Chen, Y-L., Chu, P-S., Fortini, L.B., Hall, D., Helweg, D.A., Keener, V.W., Longman, R.J., Lucas, M.P., Mair, A., Oki, D.S., Reyes, J.J., Yelenik, S.G., & Trauernict, C. (2022). A century of spatial and temporal patterns of drought in Hawai'i across hydrological, ecological, and socioeconomic scales. Sustainability, 14(19): 12023. https://doi.org/10.3390/su141912023

Filho, W. L., Scheday, S., Boenecke, J., Gogoi, A., Maharaj, A., & Korovou, S. (2019). Climate change, health and mosquito-borne diseases: Trends and implications to the pacific region. International Journal of Environmental Research and Public Health, 16(24), 5114. https://doi.org/10.3390/ijerph16245114

Fritts, T. H. (2002). Economic costs of electrical system instability and power outages caused by snakes on the island of Guam. International Biodeterioration & Biodegradation, 49, 93–100. https://doi.org/10.1016/S0964-8305(01)00108-1

Fusco, E. J., Finn, J. T., Balch, J. K., Nagy, R. C., & Bradley, B. A. (2019). Invasive grasses increase fire occurrence and frequency across U.S. ecoregions. Proceedings of the National Academy of Sciences, 116(47), 23594–23599. https://doi.org/10.1073/pnas.1908253116

Fusco E.J., J.K. Balch, A.L. Mahood, R.C. Nagy, A.D Syphard, B.A. Bradley (2021). The human–grass–fire cycle: how people and invasives co-occur to drive fire regimes. Frontiers in Ecology and the Environment, 20(2): 117–126. https://doi.org/10.1002/fee.2432

Germino, M. J., Belnap, J., Stark, J. M., Allen, E. B., & Rau, B. M. (2016). Ecosystem impacts of exotic annual invaders in the genus Bromus. In Germino M. J., Chambers J. C., and Brown C. S. (Eds.), *Exotic bromegrasses in arid and semiarid ecosystems of the western U.S.* (pp. 61–95). Springer International Publishing, Switzerland Springer International Publishing.

Gutrich, J. J., VanGelder, E., & Loope, L. (2007). Potential economic impact of introduction and spread of the red imported fire ant, *Solenopsis invicta*, in Hawaii. Environmental Science & Policy, 10(7–8), 685–696. https://doi.org/10.1016/j.envsci.2007.03.007

Hall, T. C., (1996). Operational Control of the Brown Tree Snake on Guam. Proceedings of the Seventeenth Vertebrate Pest Conference 1996. 23. Accessed 2 November 2023. https://digitalcommons.unl.edu/vpc17/23

Hao, M., Aidoo, O. F., Qian, Y., Wang, D., Ding, F., Ma, T., Tettey, E., Ninsin, K. D., Osabutey, A. F. & Borgemeister, C. (2022). Global potential distribution of *Oryctes rhinoceros*, as predicted by Boosted Regression Tree model. Global Ecology and Conservation, 37, e02175. https://doi.org/10.1016/j.gecco.2022.e02175

Harvey, G. L., Henshaw, A. J., Brasington, J., & England, J. (2019). Burrowing invasive species: An unquantified erosion risk at the aquatic-terrestrial interface. Reviews of Geophysics. 57, 1018–1036. https://doi.org/10.1029/2018RG000635

IPBES – Intergovernmental Science-Policy Platform on Biodiversity and Ecosystems Services (2023). Summary for Policymakers of the Thematic Assessment Report on Invasive Alien Species and their Control of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services. Roy, H. E., Pauchard, A., Stoett, P., Renard Truong, T., Bacher, S., Galil, B. S., Hulme, P. E., Ikeda, T., Sankaran, K. V., McGeoch, M. A., Meyerson, L. A., Nuñez, M. A., Ordonez, A., Rahlao, S. J., Schwindt, E., Seebens, H., Sheppard, A. W., and Vandvik, V. (eds.). IPBES Secretariat, Bonn, Germany. https://doi.org/10.5281/zenodo.7430692

Lee, D. J., Motoki, M., Vanderwoude, C., Nakamoto, S. T., & Leung, P. (2015). Taking the sting out of Little Fire Ant in Hawaii. Ecological Economics, 111, 100–110. https://doi.org/10.1016/j.ecolecon.2015.01.010

Manley, M., Melzer, M. J., & Spafford, H. (2018). Oviposition preferences and behavior of wild-caught and laboratory-reared coconut rhinoceros beetle, *Oryctes rhinoceros* (Coleoptera: Scarabaeidae), in relation to substrate particle size. Insects, 9,4: 141. https://doi.org/10.3390/insects9040141

Moore, A. (2009). Guam Coconut Rhinoceros Beetle (CRB) Eradication Program Semi-annual Progress Report. University of Guam Cooperative Extension Service, p. 13. Accessed 3 November 2023. https://guaminsects.net/doc/tech/CRB_Prog20090511.pdf.

Nagy, R. C., Fusco, E. J., Balch, J. K., Finn, J. T., Mahood, A., Allen, J. M., & Bradley, B. A. (2021). A synthesis of the effects of cheatgrass invasion on U.S. Great Basin carbon storage. Journal of Applied Ecology, 58(2), 327–337. https://doi.org/10.1111/1365-2664.13770

Olatinwo, R. O., Fraedrich, S. W., & Mayfield III, A. E. (2021). Laurel wilt: Current and potential impacts and possibilities for prevention and management. Forests, 12(2), 181. https://doi.org/10.3390/f12020181

Owen, S. M., Kuegler, O., Lehman, A. D., Hughes, R. F., Terzibashian, J., Sprecher, I., Thompson, T., Ayotte, S., Yatskov, M., & Silva, M. (2022). Hawai'i's Forest Resources: Forest Inventory and Analysis, 2010-2015. Gen. Tech. Rep. PNW-GTR-1008. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 104 p. https://doi.org/10.2737/PNW-GTR-1008

Parsons, E. & C. Martin (2023). The tragedy in Lahaina: How invasive grasses and shrubs are fueling the wildfire crisis in Hawai'i. Accessed 3 November 2023. https://naisma.org/2023/10/10/the-tragedy-in-lahaina-how-invasive-grasses-and-shrubs-are-fueling-the-wildfire-crisis-in-hawai'i/

PESC – Pacific Ecological Security Conference (2022).3-5 October 2022, Biosecurity Plan for Invasive Ants in the Pacific. Koror, Palau. Accessed 2 November 2023. https://doi.org/10.5281/zenodo.7683199

Patiño-Montoya, A, Giraldo A., Tidon R. (2022). Variation in the population density of the Giant African Snail (*Lissachatina fulica*) in the Neotropical region. Caldasia 44:627–635. https://www.jstor.org/stable/48731912

Quirion, B. R., Domke, G. M., Walters, B. F., Lovett, G. M., Fargione, J. E., Greenwood, L., Serbesoff-King, K., Randall, J.M., & Fei, S. (2021). Insect and disease disturbances correlate with reduced carbon sequestration in forests of the contiguous United States. Frontiers in Forests and Global Change, 4, 716582. https://doi.org/10.3389/ffgc.2021.716582

Rosenau, N. A., Gignoux-Wolfsohn, S., Everett, R. A., Miller, A. W., Minton, M. S., & Ruiz, G. M. (2021). Considering commercial vessels as potential vectors of stony coral tissue loss disease. Frontiers in Marine Science, 8, 709764. https://doi.org/10.3389/fmars.2021.709764

Seebens, H., Blackburn, T. M., Dyer, E. E., Genovesi, P., Hulme, P. E., Jeschke, J. M., ... & Essl, F. (2018). Global rise in emerging alien species results from increased accessibility of new source pools. Proceedings of the National Academy of Sciences, 115(10), E2264-E2273. https://doi.org/10.1073/pnas.1719429115

Seok, S., Raz, C. D., Miller, J. H., Malcolm, A. N., Eason, M. D., Romero-Weaver, A. L., Giordano, B. V., Jacobsen, C. M., Wang, X., Akbari, O. S., Raban, R. Mathis, D. K., Caragata, E. P., Vorsino, A. E., Chiu, J. C. & Lee, Y. (2023). Arboviral disease outbreaks, *Aedes* mosquitoes, and vector control efforts in the Pacific. Frontiers in Tropical Diseases, 4, 1035273. https://doi.org/10.3389/fitd.2023.1035273

Shwiff, S. A., Gebhardt, K., Kirkpatrick, K. N., & Shwiff, S. S. (2010). Potential economic damage from introduction of brown tree snakes, *Boiga irregularis* (Reptilia: Colubridae), to the Islands of Hawai'i. Pacific Science, 64, 1–10. https://doi.org/10.2984/64.1.001

Takahashi, M., Giambelluca, T.W., Mudd, R.G., DeLay, J.K., Nullet, M.A., & Asner, G.P. (2011). Rainfall partitioning and cloud water interception in native forest and invaded forest in Hawai'i Volcanoes National Park. Hydrological Processes, 25: 448–464. https://doi.org/10.1002/hyp.7797

Vissichelli, M. (2018). Invasive species impacts on federal infrastructure. National Invasive Species Council Secretariat, Washington, DC. https://www.doi.gov/sites/doi.gov/files/uploads/invasive_species_impacts_on_federal_infrastructure.pdf

Villamagna, A. M., & Murphy, B. R. (2010). Ecological and socio-economic impacts of invasive water hyacinth (*Eichhornia crassipes*): a review. Freshwater Biology, 55(2), 282–298. https://doi.org/10.1111/j.1365-2427.2009.02294.x

You, W., Yu, D., Xie, D., & Yu, L. (2013). Overwintering survival and regrowth of the invasive plant *Eichhornia crassipes* are enhanced by experimental warming in winter. Aquatic Biology, 19(1), 45–53. https://doi.org/10.3354/ab00519