White Paper for Review at Invasive Species Advisory Council in-person meeting to be held 11/13/2023-11/15/2023. This draft completed 11/3/2023

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Invasive Species Threaten the Success of Climate Change Adaptation Efforts

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 risk 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 considerations 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 nation must actively integrate invasive species management into climate action planning, funding, and implementation.

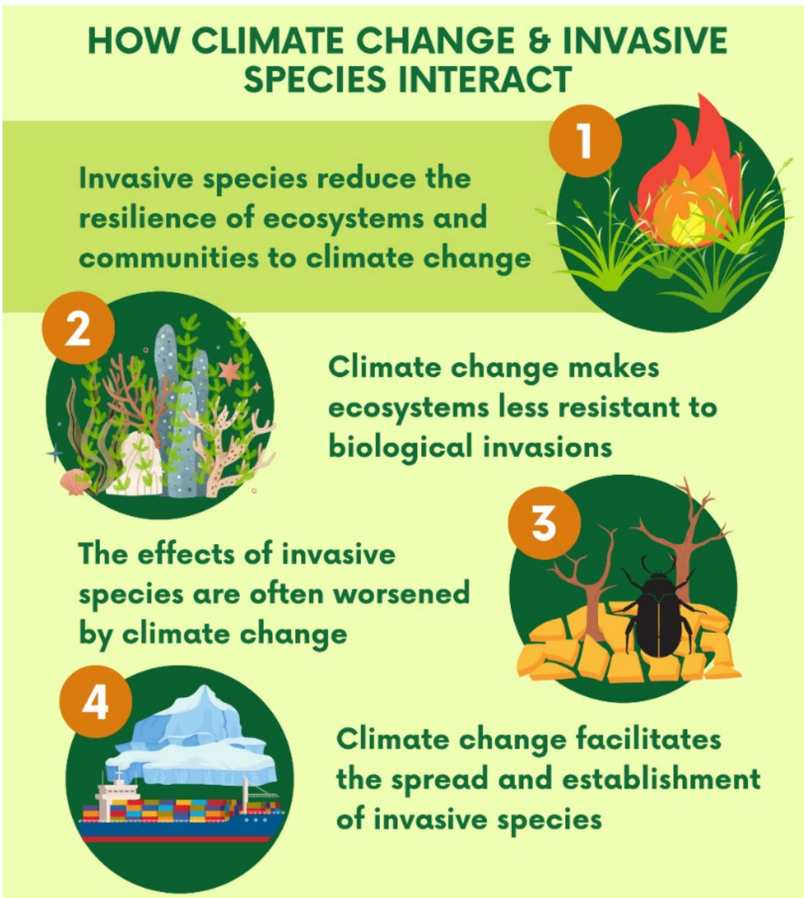
The cumulative effects of invasive species reach every place, every priority, and every agency—economic costs have exceeded US$26 billion every year in North America for the last decade (Crystal-Ornelas et al., 2021). Globally, economic impacts are estimated to quadruple every decade with devastating repercussions to both society and ecosystems (IPBES 2023). While any given invasive species has a distinct range and niche, the inherent diversity of these 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 is facilitating shifts of native species' distributions

[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 No. 13653).

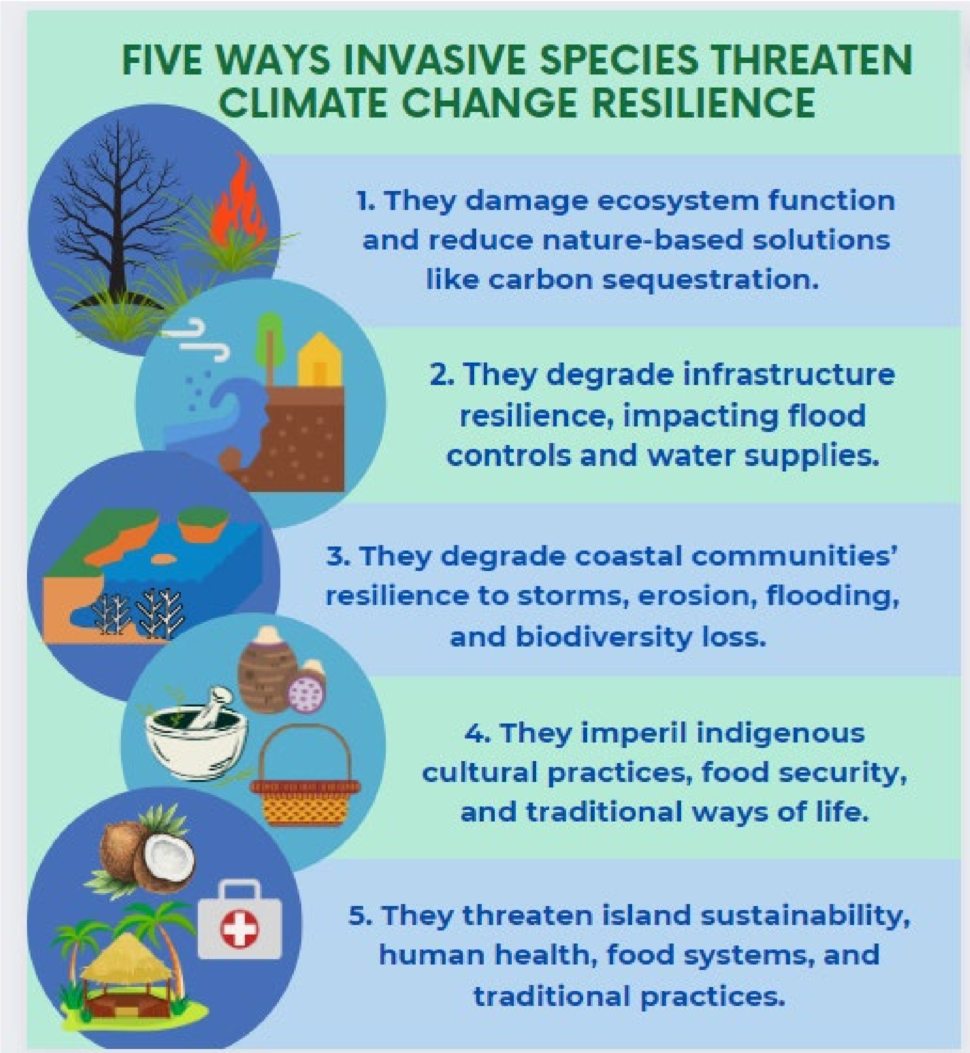
beyond their historical ranges. In some cases, these species cause negative[2] impacts in their new ranges. The negative effects of both invasive species and climate change are further compounded by complex, often synergistic, interactions. In this paper, we have intentionally focused on one facet of this complexity: the myriad of negative impacts that invasive species have on climate adaptation actions and resilience goals.

Figure 1. (Draft art and concept) How Climate Change & Invasive Species Interact



[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).

Figure 2. (Draft art and concept) Five Ways Invasive Species Threaten Climate Change Resilience



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 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 not have 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 need to integrate invasive species management into climate change adaptation actions to be fully effective across all sectors and increase the likelihood of achieving federally mandated goals.**

This paper provides a blueprint for transforming how invasive species are considered within US climate change planning, processes, and policies, and is 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.

Recommendations

Recommendation 1: All 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 according to agency capabilities and mandates. Executive Order No. 14008, *Tackling the Climate Crisis at Home and Abroad* directed all US Federal Agencies and Departments to develop and implement action plans that strengthen the adaptive capacity of the United States to climate change and build resilience in the coming decades (Executive Order No. 14008). Twenty-six Climate Change Adaptation Plans have been produced as of 2023, yet only eight directly reference invasive species and just four (Departments of Commerce, Defense, Interior, and Agriculture) 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. This paper recommends that all agencies and Departments task appropriate personnel to ensure that their respective plans incorporate and address invasive species risks 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[3]. 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[4]. 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

[3] [Editor's note: We will discuss tools here on 11/13+ for possible inclusion, or we may decide to combine with footnote 4 below]

[4] The White House Climate Mapping for Resilience and Adaptation (CMRA) Tool, DOI Strategic Hazard Identification and Risk Assessment Project, or USGS Flood and Storm Tracker tool could be adapted to include or expand invasive species data where available.

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

Recommendation 2: Increase support for, and recognition of, national and regional networks and programs as experts working at the intersection of climate change and invasive species. Climate change is expected to magnify invasive species impacts and change the abundance and distributions of established invasive species, which will reduce climate resiliency in novel and unexpected ways. Established invasive species that benefit from a changing climate will become more difficult to manage and may interact synergistically with climate change when native ecosystems, agricultural systems, and infrastructure systems are stressed. Therefore, expanding efforts to manage established invasive species will improve climate change adaptation outcomes. However, effective management strategies, control tools, and responses at adequate scales are often lacking. Significantly increased support for the Regional Invasive Species and Climate Change (RISCC) Management Networks, collaborative interest networks (such as the National Fish, Wildlife, & Plants Climate Adaptation Network), Tribal climate action and Indigenous knowledge collectives, NOAA Climate Adaptation Partnerships, USGS Climate Adaptation Science Centers, USDA Climate Hubs, innovation grants, research collaboratives, and extension programs are needed to translate science, tools. and technology into practical and actionable management solutions. 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 change-informed 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 US 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. This paper recommends two actions to broaden the reach and increase the effectiveness of both international invasive species prevention and climate action.

1. 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 US-Affiliated Islands.

2. Federal agencies working internationally (including Agriculture, Commerce, Defense, Homeland Security, Interior, and State) 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 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.

Recommendation 4: Ensure Early Detection and Rapid Response strategies account for up-to-date climate data, projections, and models across all geographies. Early detection and rapid response (EDRR) is widely recognized as a key tenet 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 EDRR 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 (used to identify 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 (determinations of risk based on shared mechanisms of spread), and prioritization strategies to most effectively allocate rapid response resources. Importantly, these efforts must be carried out through strong collaborations and clarity of regulatory authority across jurisdictions, including high-level federal interagency approaches, state, Tribal, territorial, and other non-federal entity defined roles and responsibilities, and robust information sharing and cooperative response efforts. 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 that threaten 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. Once established, managing the impact of an invasive species 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. This paper recommends two actions to decrease the long-term impacts of invasive species to climate change preparedness and resilience:

1. To identify unmet fiscal resource needs and find opportunities to increase cost effectiveness, an intentional interagency gaps analysis focusing on long-term investments should 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. For the nation 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, and multispectral remote sensing).

Case Studies

In support of the recommendations of this paper, 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 action steps mentioned in the above recommendations, emphasizing the ways that invasive species disrupt climate change resilience across a broad scope of geographies and taxa. These cases are intended to resonate across a breadth of experience, 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 manyways, including repeated defoliation, interrupted sap flows, fungal infections, and in many cases, the rapid decline and death of the tree. Carbon sequestration rates in US forests are experiencing severe native and non-native forest pest disturbance and 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). Continued damage to forests from established invasive pests like the emerald ash borer (*Agrilus planipennis*) and hemlock wooly adelgid (*Adelges tsugae*) must be mitigated; the introduction of additional invasive pests that will add to cumulative carbon loss and forest management burdens must be prevented.
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 throughout the United States. 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. 2020). Climate adaptation plans in regions affected by fire-associated invasive grass species should focus on improving ecosystem resilience through both traditional invasive species management strategies such as mechanical, chemical, and biological control, and resilience-enhancing programs such as native plant restoration, Indigenous-led land management, and encouraging active management through agriculture or other land uses that reduce fuel loads.

Infrastructure Resilience: Flood control, Water supply, Watershed Protection, 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 US insular territory of Guam, costing billions of dollars in damages and propelling 12 of Guam's native bird species to extinction, while severely threatening another 10 (Soto et al. 2022; Wiles et al. 2003).

Brown tree snakes cause up to 200 electrical blackouts per year when they climb trees near power poles and then cross the insulators between the poles and the power wires, completing an electrical circuit. 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 US rivers. In Hawaiʻi, 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 ʻōhiʻa lehua (*Metrosideros polymorpha*) trees 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 south Florida, weakening built infrastructure. Currently limited to southern 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 US, such as the southwestern states and areas in the US 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 Hawaiʻi, 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 may become “the most lethal disturbance ever recorded” in the Caribbean region (Alvarez-Filip et al. 2023). 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 would put 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 Hawaiʻi and Florida, other US 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, 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.
3. *[Editor’s note: possible inclusion of European green crab]*

Cultural Practices: First Foods, Medicinal Plants, Traditional Arts

1. Preventing agricultural diseases boosts food security in island communities that are already impacted by climate change: In the mid-1990s, an epidemic of an invasive taro blight (*Phytophthora colocasiae*) struck the US insular territory of American Sāmoa, decimating the production of a culturally important subsistence and staple food crop. In many Pacific Island food production systems, taro patches can be resilient to climate events, sequestering freshwater during flooding while providing a sustainable food source. Chemical treatments are not effective against this fungus-like pathogen, and manual control is only advantageous during mild infections. Blight-resistant cultivars were identified elsewhere in the US 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*) spread the fungal disease laurel wilt to swamp bays, redbays, and sassafras trees (Olatinwo et al 2021). The bay trees are culturally important to Indigenous peoples, including roles in traditional Tribal medicine and funeral practices. In Hawaiʻi, two species of Ceratocystis fungus cause rapid ʻōhiʻa death, leading to rapid decline and death of endemic ʻōhiʻa lehua (*Metrosideros polymorpha*) tree across four islands. The loss of ʻōhiʻa threatens this keystone species of Indigenous Hawaiian culture, with traditional uses of ʻōhiʻa

ranging from the construction of temples from its wood to the stringing of ʻōhiʻa blossom leis for ceremonies. The emerald ash borer's (*Agrilus planipennis*) rapid destruction of ash trees across the eastern United States and Canada imperils traditional art forms of basketmaking and cultural ties to the trees themselves across many tribes and first nations. The loss of culturally important natural resources caused by these invasive pathogens and insects add to the cumulative burden to Indigenous groups that, similar to many other underserved communities, are already losing access to cultural resources from the interacting effects of changing land use, shifting ecological relationships, and altered phenology due to climate change.

Island Sustainability: Human Health, Food Systems, Traditional Practices

1. <u>Preventing the spread of invasive beetles protects food security, shorelines, and cultural practices</u>: 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 Hawaiʻi 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, coconuts provide 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 US-Affiliated Pacific Islands, and the continental United States (Hao et al. 2022).
2. <u>Controlling invasive disease vectors decreases disease transmission in areas already highly vulnerable to the negative impacts of climate change</u>: Invasive disease vectors, particularly the *Aedes* mosquito genus members *aegypti* and *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 US and affiliated jurisdictions (Filho et al. 2019; Seok et al. 2023). Mosquito-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 the *Aedes* mosquito genus is well-recognized component One Health and builds climate resilience for both people and wildlife.
3. <u>Controlling invasive ants protects multiple aspects of island sustainability while building resilience to climate change</u>: Invasive ants represent a significant threat to climate resilience and sustainability in the US 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 Hawaiʻi's little fire ant (*Wasmannia auropunctata*) management expenditures by just US$8 million would yield $1.2 billion in reduced control costs over 10 years, while Gutrich et al. (2007) estimated if the red imported fire ant (*Solenopsis invicta*) were to establish and spread in Hawaiʻi 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 US Pacific Islands region are understaffed and under-resourced, and at a 2022 regional conference on invasive species threats, none of the US Pacific Island countries and territories had developed emergency response plans for priority invasive ants (PESC 2022). Knowledge sharing tools and the implementation of EDRR systems for invasive ants are urgently needed at all scales: federal, regional, jurisdictional, state, and island.

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 US insular Pacific, namely the Commonwealth of the Northern Mariana Islands (CNMI) and the State of Hawaiʻi. USDA APHIS initiated commercial cargo controls in 1992 to prevent the transport of the snake off of Guam (Schwiff et al. 2010; Hall 1996) and in 2002, the US Geological Survey established a multi-agency Brown Tree Snake Rapid Response Team for training, logistics, and outreach. In 2020, the US DOI allocated $3.4 million in grant funding toward suppression and control in Guam, and prevention, detection, and rapid response efforts in the CNMI and Hawaiʻi. 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. success of sustained cooperative prevention, strong regulatory framework, and strong research programs. 1996) and in 2002, the USGS established a multi-agency Brown Tree Snake Rapid Response Team for training, logistics, and outreach. In 2020, the DOI allocated US$3.4 million in grant funding toward suppression and control in Guam, and prevention, detection, and rapid response efforts in the CNMI and Hawaiʻi. 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 eradication efforts by the USDA Animal and Plant Health Inspection Service 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 dedicated federal and state fiscal and staffing resources for 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. Overarching federal actions addressing invasive species—such as the interagency cooperation, sustained commitments, research programs, and protective policies seen in these success stories—will have the best possible outcomes when coupled with an integrated approach to communicating the value that invasive species prevention and management brings to climate change adaptation, mitigation, and action.

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