PUBLIC DRAFT PREPARED AUGUST 3 2023

ISAC's Climate Change Subcommittee: Laura Brewington, Carrie Brown-Lima, Leigh Greenwood, LeRoy Rodgers, Paul Zajicek

Working Concept Title: Integrating Invasive Species into Climate Change Resilience is Crucial to Success

Section 1:

Across the nation, the ever-growing crises and complexities of climate change must be addressed through not only direct mitigation, adaptation, and cultural evolution, but also through the strategic mitigation of threats to the success of those key actions. Invasive species are one such threat – they create severe and persistent impacts that fundamentally alter natural and built landscapes, damaging or destroying the resilience needed to deliver solutions that rise to the challenge of climate change. Broad scale changes to national priorities and paradigms surrounding invasive species work, from the perspective of climate change resilience at every federal level, is therefore necessary to achieve climate change resilience – and a failure to integrate invasive species into these approaches will slow or even prevent meeting climate adaptation goals.

The effects of invasive species reach every place, every priority, and every agency – and while any given invasive species has a distinct range and niche, the inherent diversity of these plants, animals, bacteria, fungi, and more renders their collective impacts widespread, severe, and ever increasing. Like climate change, the problems caused by invasive species may be diffuse, gradual, and complex; at other times they are incredibly rapid, highly localized, and utterly devastating.

Invasive species directly impede efforts to promote climate resiliency across a broad spectrum of socio-economic and environmental issues. At the same time, climate change is increasing the magnitude of invasive species impacts, while simultaneously promoting new biological invasions regionally and globally. The negative effects of both invasive species and climate change are further compounded by their complex, often synergistic interactions.

To achieve transformative adaptation to climate change that benefits all sectors and communities, the nation must actively plan to prevent and mitigate invasive species impacts. This paper puts forward the following high-level recommendations.

Recommendation 1: Amend Climate Adaptation Plans to explicitly incorporate invasive species from multiple perspectives. Executive Order 14008, *Tackling the Climate Crisis at Home and Abroad* directed all US Federal agencies and Departments to craft action plans that will strengthen the adaptive capacity of the United States to climate change and build resilience in the coming decades. Twenty-six Climate Adaptation Plans have been produced, yet only eight directly reference invasive species and just four of those (Departments of Commerce, Defense, Interior, and Agriculture) meaningfully link non-native or invasive species to the nation's climate readiness and resilience. These links are presented as uni-directional; they focus on how a changing climate will influence the spread and impacts of invasive species. The plans must be amended to reflect that invasive species will also negatively impact climate resilience and adaptation efforts.

A review of the 26 Climate Adaptation Plans yielded three common action themes that will be impacted by invasive species. This paper recommends that all agencies and Departments task their appropriate personnel to update their respective actions so that they incorporate invasive species risks and maximize opportunities for equitable, cross-cutting solutions to the climate crisis. 1) Climate literacy, data and information, and communication: Support new climate research that incorporates invasive species at relevant spatial and temporal scales. Finance better projections for invasive species in the context of a changing climate. 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. 2) Infrastructure: Ensure that all US infrastructure (gray, green) will be made more resilient to climate change by preventing and managing invasive species. Examples include reducing invasive annual grasses to manage wildfire; controlling invasive burrowing animals to stabilize riparian systems. 3) Supply chains and transportation: Maintain supply chains and reduce commercial disruptions by preventing the unintended transport or ingress of invasive species by air, sea, rail, and roadways. The Pacific Islands region is a particular point of vulnerability for the United States due to inadequate inspection and sanitation capabilities, as well as increasing commercial, military, and tourism traffic between Asia, the US-Affiliated Pacific Islands, and the mainland US.

Recommendation 2: Increase support 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 the impacts and change the habitat ranges of established invasive species, which will then reduce climate resiliency in novel ways and new areas. 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 crops, and infrastructure systems are stressed. Therefore, aggressive action to improve management of established invasive species will improve system resiliency and outcomes of climate change mitigation efforts. However, effective management strategies, control tools, and responses at adequate scale are often lacking. Significantly increased support for Regional Invasive Species and Climate Change Management (RISCC) networks, innovation grants, research collaboratives, and extension programs is needed to develop science and technology into practical management solutions. The tools for effective management of a given established invasive species may exist, but knowledge, resources, capacity or willingness to take action must also be present to meet each challenge. The interdisciplinary approaches of RISCC networks and other expert groups must be elevated to complement and enhance the federal agencies' responses and needs.

Recommendation 3: Integrate climate change data and informed practices into invasive species prevention efforts. Preventing the introduction of new invasive species is undeniably the most effective strategy to mitigate the long-term cumulative impacts of biological invasions. Given the high cost of invasive species to the US economy ($1.26 trillion between 1960 and 2017, Crystal-Ornelas et al., 2021), devastating impacts to biodiversity, and limited options to successfully eradicate invasive species once established, more effective and comprehensive prevention measures are urgently needed within and across national borders. Federal laws, policies, and regulations seeking to prevent the introduction of new invasive species must therefore integrate the best available climate and invasion science to improve risk reduction activities, enhance interagency information transfer, and increase cooperation among international trade partners.

Recommendation 4: Ensure Early Detection and Rapid Response strategies account for up-to-date climate data, projections, and models. Early detection and rapid response (EDRR) is widely recognized as a key tenet of effective invasive species management for when an invasive species evades prevention mechanisms. Detecting newly established invasive species in the earliest stages of establishment enables a more effective rapid response – greatly increasing the chance of success of eradicating or containing 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 integrating climate change modelling efforts with horizon scanning tools (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), and prioritization strategies to most effectively allocate rapid response resources. Importantly, these efforts must be carried out through strong collaborations across jurisdictions, including high-level federal interagency approaches, non-federal partner defined roles and responsibilities, and robust information sharing and cooperative response efforts.

The long-lasting and devastating impacts of invasive species can permanently alter entire ecosystem function and landscape-level climate change resilience. Every Agency and Department within the federal response to climate change must act within their strengths and jurisdictions to abate these threats; the natural systems affected by the intertwined impacts of climate change and invasive species will not provide the nature-based solutions, biodiversity targets, or whole-landscape resilience necessary to tackle climate change without a cohesive response that includes invasive species management. These actions must be integrated throughout the planning and implementation- and to be effective, this will require a transformation of how invasive species are considered within climate change planning, processes, and policies.

Section 2:

In support of the recommendations outlined in Section 1 of this paper, Section 2 presents a selection of case studies on the current or averted impacts invasive species have on climate change resilience and readiness in the United States. The examples below include a broad scope of taxa and climate resilience goals, emphasizing both successes and failures associated with action or inaction. These cases are intended to resonate across a breadth of experience, capabilities, and agency mandates and spark innovation around what cross-cutting solutions may be required for transformative adaptation to the dual hazards of climate change and invasive species.

Natural Climate Solutions: Carbon sequestration, storage, and cycles

- Forest pests and pathogens can reduce a tree's ability to capture and store carbon in many ways - repeated defoliation, interrupted sap flows, fungal infections, and in many cases, the rapid decline and death of the tree. Carbon sequestration rates in U.S. forests experiencing severe insect or disease disturbance are an estimated 47 million tons of CO_2 lower, per year, compared

to sequestration rates in undisturbed forests (Quirion et al. 2021). Damage to forests from established pests like the emerald ash borer and hemlock wooly adelgid must be mitigated; the introduction of additional pests that will add to the cumulative carbon loss and forest management burden must be prevented.

- Numerous invasive grass species are contributing to increases in wildfire intensity and frequency in ecosystems throughout the US. For instance, the invasion and disturbance cycle of cheatgrass (*Bromus tectorum*) leads to increased frequency and extent of wildfires (Balch et al. 2012) with permanent alterations to native plant communities, wildlife habitats, and ecosystem services such as carbon storage (Germino et al. 2016, Nagy et el. 2020). Climate resiliency plans in regions affected by fire-associated invasive grass species should focus on improving ecosystem resilience through both direct invasive species management, and resilience enhancing programs such as native plant community restoration.
- *Not yet written up:* Invasive grasses in the southeast (e.g., cogongrass) intensify wildfire in forestry systems resulting in reduced timber yields and decreased carbon storage intervals.
- *Not yet written up:* Invasive understory plants contribute to regeneration debt in eastern forests, which reduces carbon sequestration and decreases forest adaptive resilience to stressors.

Infrastructure Resilience: Flood control, Water supply, Watershed Protection, Structures

- Water hyacinth (*Pontederia crassipes*) is an invasive aquatic plant that aggressively colonizes freshwater ecosystems in the southern United States, negatively impacting water supply, flood control, navigation/transportation, commerce, and human health (Villamagna and Murphy 2010). Its rapid growth and accumulation significantly obstructs waterways, flood control systems, and water supply infrastructure, increasing risks of flood damage and human safety (Vissichelli 2018). Proactive and sustained control within the plant's current distribution should be emphasized, and in areas that are likely to become suitable for water hyacinth with climate change, monitoring and aggressive control efforts to promptly eradicate or contain new populations is the most effective approach.
- For 80 years, 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 scale 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).
- *Not yet written up:* Tamarisk (salt cedar) high transpiration rate creates water loss and dense growth disturbs channel flow, resulting in dramatic riparian impacts across the already water-stressed southwestern US rivers.
- *Not yet written up:* Riparian invasives expanding into struggling Platte River, worsening already climate change affected low flows. Reduced water levels allowed substantial expansion of

invasive species, which has further decreased river flows in a worsening climate-invasives feedback loop.

- *Not yet written up:* Densely overgrown invasive Arundo donax (giant reed) stands become dislodged during high water events, causing blockages in waterways and resulting in bridge collapses.
- *Not yet written up:* Green iguana burrowing causes erosion on canal banks and levees in south Florida, weakening built infrastructure. Iguanas will also get farther N as climate change allows.
- *Not yet written up:* Conehead termites damage structural wood. This is a recent border prevention failure in Florida, rapid response is now underway.
- *Not yet written up:* Supply chain disruptions due to invasive species contaminants: both inbound and outbound trade with contaminants, such as brown marmorated stink bug and many species of ants, can cause supply chain disruptions as well as international military transport concerns.
- *Not yet written up:* Supply chain disruptions due to forest pests found in wood packaging: ongoing issues with wood boring insects found in wood packaging despite existing international regulations can affect and delay all parts of the inbound international supply chain - including cargo and ship rejection at the ports.

Resilient Coastal Communities: Coral reefs, Saltwater marshes

- Stony coral tissue loss disease (SCTLD), 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. 2021). 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 in Hawaii and the US-Affiliated Pacific Islands.
- *Not yet written up:* Nutria burrowing destroys the banks of canals, ditches, ponds and lakes- while nutria's intense herbivory permanently destabilizes the integrity of wetland soils in crucial coastal areas such as coastal marshes.
- *Not yet written up:* Roseau cane scale is destroying the native Phragmites 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, basketmaking

- *Not yet written up:* Taro blight recently decimated taro cultivation in American Samoa. Taro is a socially and economically important field crop with central role in cultural identity and the resulting impacts have been grievous.
- *Not yet written up:* Non-native ambrosia beetles are spreading a fungus causing laurel wilt, a tree disease, to swamp and red bays all along the southeastern USA. The bay trees are culturally important, including roles in traditional tribal medicine.
- *Not yet written up:* Emerald ash borer's destruction of ash trees imperils cultural traditions of basketmaking across many tribes and first nations.

Human health and wellbeing: Island sustainability, agriculture, vector-borne disease

- 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 invasive coconut rhinoceros beetle (CRB, *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 can cause up to 50% tree mortality (Moore 2009; Manley et al. 2018). Recent ecological niche modeling work shows that as the global climate warms, the pest has the potential to spread through all islands in the tropical Pacific and on to the Americas (Hao et al. 2022).
- 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 (Leal Filho et al. 2019; Seok et al. 2023). Mosquito-borne disease compounds the strain on already limited public health resources- a burden that will further be exacerbated by climate change- therefore addressing this invasive vector is a crucial component of building climate resilience.
- *Not yet written up:* Little fire ant destroys coastal agriculture, traditional practices, and transforms island ecosystems.

Section 3:

This section is not yet written. It will contain;

- The ISAC Climate Change subcommittee plans to reach out to staff at each member Agency and request summary on specifics of how top-down implementation of relevant recommendations from Section 1 within their own systems would be accomplished. Agencies with multiple independent departments (e.g. USDA APHIS and USDA Forest Service) will be asked to provide answers appropriate to each. The resulting information will be used to formulate Section 3's content.

- To support that these implementation narratives can yield successful outcomes, relevant success stories will be used to illustrate where federal action has yielded clear results. These are some of the success story concepts being considered for this section:
    - Natural Climate Solutions- Forest Carbon Sequestration: Asian longhorned beetle (repeated successes of EDRR, some are still in progress) eradications prevent widespread losses of forest carbon and destruction of urban tree canopy infrastructure resilience.
    - Infrastructure: Prevention of brown tree snake reaching other islands from Guam- given the billions in damages and other enormous potential risks the snake poses to other islands within the US insular Pacific, namely the Northern Mariana Islands and the State of Hawaii, the USDA APHIS initiated commercial cargo and military facility controls in the 1990s to prevent the transport of brown tree snake off of Guam. 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)

- Human Health and Wellbeing- Food security: The papaya tree PRSV resistance breeding averted a massive collapse of papaya in Hawaii and beyond. (success of research used to create resistant host material)
- Human Health Risk: Gambian pouched rat (success of EDRR) eradication in the Florida Keys has reduced human health risk.
- Human Health Risk: Giant african land snail (repeated successes of EDRR, some are still in progress) eradications in Florida reduce human health, agricultural damage, and biodiversity loss risks.

References

THE REFERENCE LIST IS INCOMPLETE AND MAY CONTAIN ERRORS IN THIS DRAFT.

Balch, J. K., Bradley, B. A., D'Antonio, C. M., & Gómez-Dans, J. (2013). Introduced annual grass increases regional fire activity across the arid western USA (1980–2009). Global Change Biology, 19(1), 173-183.

Ban, S. S., Graham, N. A., & Connolly, S. R. (2014). Evidence for multiple stressor interactions and effects on coral reefs. Global change biology, 20(3), 681-697.

Bishop, T. B., Nusink, B. C., Lee Molinari, R., Taylor, J. B., & St. Clair, S. B. (2020). Earlier fall precipitation and low severity fire impacts on cheatgrass and sagebrush establishment. Ecosphere, 11(1), e03019.

Crystal-Ornelas, R., Hudgins, E. J., Cuthbert, R. N., Haubrock, P. J., Fantle-Lepczyk, J., Angulo, E., ... & Courchamp, F. (2021). Economic costs of biological invasions within North America. NeoBiota, 67, 485-510.

Howell, A., Winkler, D. E., Phillips, M. L., McNellis, B., & Reed, S. C. (2020). Experimental warming changes phenology and shortens growing season of the dominant invasive plant Bromus tectorum (cheatgrass). Frontiers in Plant Science, 11, 570001.

Hughes, T. P., Kerry, J. T., Baird, A. H., Connolly, S. R., Dietzel, A., Eakin, C. M., ... & Torda, G. (2018). Global warming transforms coral reef assemblages. Nature, 556(7702), 492-496.

Kriticos, D. J., & Brunel, S. (2016). Assessing and managing the current and future pest risk from water hyacinth,(Eichhornia crassipes), an invasive aquatic plant threatening the environment and water security. PloS one, 11(8), e0120054.

Mansoor, S., Farooq, I., Kachroo, M. M., Mahmoud, A. E. D., Fawzy, M., Popescu, S. M., ... & Ahmad, P. (2022). Elevation in wildfire frequencies with respect to the climate change. Journal of Environmental management, 301, 113769.

Moore, A. Guam Coconut Rhinoceros Beetle (CRB) Eradication Program Semi-annual Progress Report. University of Guam Cooperative Extension Service (2009), p. 13.

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 US Great Basin carbon storage. Journal of Applied Ecology, 58(2), 327-337.

Norby, M., & Washburn, A. (2008). Sustainability in a Time of Climate Change: Developing an Intensive Research Framework for the Platte River Basin and the High Plains Proceedings from the 2008 Climate Change Workshop.

Pelling, M. (2010). Adaptation to climate change: from resilience to transformation. Routledge.

Reaser, J. K., Burgiel, S. W., Kirkey, J., Brantley, K. A., Veatch, S. D., & Burgos-Rodríguez, J. (2020). The early detection of and rapid response (EDRR) to invasive species: a conceptual framework and federal capacities assessment. Biological Invasions, 22, 1-19.

Sreekanth, D., Pawar, D. V., Mishra, J. S., & Naidu, V. S. G. R. (2023). Climate change impacts on crop--weed interaction and herbicide efficacy. Current Science (00113891), 124(6).

Vissichelli M (2018) Invasive species impacts on federal infrastructure. National Invasive Species Council Secretariat, Washington, DC

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.