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PERSPECTIVES AND PARADIGMS

Cats in a bag: state-based spending for invasive species management across the United States is haphazard, uncoordinated, and incomplete

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Abstract Invasive species are an increasing source of economic loss, costing nations billions of dollars annually. Significant financial resources are spent to manage invasive species, but few comprehensive syntheses of the economic expenditures associated with this management effort exist. As a relatively affluent developed country, the United States should serve as a model of how to both manage invasive species and, more critically, understand the economic costs of doing so. To begin understanding the scale of expenditures on invasive species in the U.S., our goal was to quantify spending on invasive species management at the state level. We contacted natural resource management officials from all 50 states following a standardized protocol. While 47 of the 50 states provided expenditures for at least one of the five years requested (2017–2021), the distribution of expenditures by state varied dramatically, suggesting that actual expenditures might be much higher than those reported. While most states shared annual expenditures, they varied by an order of magnitude from $28,370 for Connecticut to $118,695,389 for Washington. Specifically, a widespread lack of careful and consistent expense tracking and coordination within and between states made clear and correct evaluation difficult. While the expenditures we obtained are almost certainly a significant underestimate, they also represent a serious lack of accounting at a state level. Hence, better tracking and coordination, within and between states, will be critical to handle the ongoing invasive species crisis.

Keywords Department of natural resources · State spending · United States · Budgets

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Introduction

Invasive species are responsible for a wide range of global ecological and economic damage (Pimentel et al. 2005; Pyšek et al. 2020; Simberloff 2015). While the far-reaching ecological damages of

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invasive species are often cited (e.g., Dorcas et al. 2012; Walsh et al. 2016; Blackburn et al. 2019; Dueñas et al. 2021), it is their marked economic impacts that often demonstrate the extent of the problem. Invasive species severely damage agriculture (Paini et al. 2016), human and animal health (Sheppard et al. 2011), infrastructure (Boelman et al. 1997, Connelly 2007), and reduce recreational opportunities (e.g., tourism; Lauber et al. 2020). Collectively, damages and expenditures due to invasive species in the United States (U.S.) alone range from at least $21 billion/year to over $120 billion/year (Fantle-Lepczyk et al. 2022; Pimentel et al. 2005), with global estimates totaling $423 billion/year in 2023 (IPBES 2023). Aside from these national and global estimates, cost estimates often focus on individual species (Epanchin-Niell 2017). For example, the coqui tree frog (*Eleutherodactylus coqui*) caused $7.6 million in direct damage to property values in Hawai'i (Kaiser & Burnett 2006). However, most individual invasive species have not been evaluated in terms of economic impact (Cuthbert et al. 2024). Furthermore, even amongst studies that have evaluated costs, they are often non-standardized in terms of spatial, temporal, and measurement scales used to estimate economic impact, making comparisons and summaries amongst species, countries, and regions difficult.

The economic cost of invasive species is multifaceted in that cost is comprised of both the damage caused by invasive species to society and the environment as well as the various actions required to control and manage the species and mitigate or repair damage (Vaissière et al. 2022). Management actions can be considered proactive, focusing on preventing the species from being introduced to an area, or reactive, focusing on mitigating a species after it is introduced to an area. Reactive management includes actions such as eradication, containment, and control (Poland et al. 2021; Liebhold and Kean 2018). Proactive management includes actions that save managers time and money by mitigating invasions before they spread, such as the development of biosecurity plans and monitoring of potential points of invasion (Vanderwoude et al. 2021). For instance, zebra mussels (*Dreissena polymorpha*) pose a threat to powerplants by clogging waterways and coolant intake pipes but spending up to $324,000 on preventative management at each lake with a powerplant results in a net benefit to society over waiting until the mussels have established to control them (Leung et al. 2002). If we are to effectively allocate resources towards control and management of invasive species, including prevention, it is essential that we coherently and transparently track the full range of expenditures needed for invasive species management actions at all stages and scales to help managers, governments, and the public better understand the true costs of invasions and value of early action.

At present, we lack comprehensive cost estimates of how much money organizations and agencies are spending on managing invasives collectively and where they are spending it. In the U.S., the General Accounting Office (GAO) attempted to estimate costs of invasive species activities across 10 federal agencies and seven U.S. states in 1999 and 2000 (GAO 2000) but received incomplete and widely varying answers. Since the GAO report, no similar evaluation has been conducted within the U.S. or elsewhere. As a result, this knowledge gap persists, which poses a challenge to effective allocation of resources and management as we lack an understanding of how limited resources are being used over time, across space, and in relation to the economic damage caused by invasive species. Likewise, countries divided into smaller administrative units, like the U.S., may lack any standardized reporting of how money is spent to manage invasive species, whose distribution has little regard for these human-centric geographical divisions.

Given the lack of knowledge about economic expenditures across the U.S., we initiated a study with the simple intent of understanding how much each state was spending to manage invasive species. Because answering this question rapidly became too broad (e.g., pests in agriculture, and urban environments alone are considered by very different agencies) we focused our inquiry to ask how much state departments of natural resources were spending to manage invasive species. Specifically, we requested "any information about expenditures used on invasive species control and management". By circumscribing our inquiry in this way, we hoped to focus the study on comparable agencies with similar mandates across the country and highlight the cost of invasive species in natural systems. Our approach allowed for invasive species to be defined by the state agency, as some states use specific programs (e.g., Aquatic Invasive Species programs) to organize invasive species

management. Here, our focus is on the challenges, needs, and future directions of accounting for invasive species control and management costs, while providing a summary of the methodology and results of our attempt (supplemental information) for illustrative purposes and to help guide future research attempts.

Challenges

Rather than effectively compiling the costs and spending details of invasive species on the U.S. economy and natural systems, we found that most states lack clear and accessible record keeping regarding financial expenditures related to managing invasive species. Some state agencies would not respond to our inquiry or had no mechanism with which to estimate the requested information (n = 3). While 47 states did have the information, their reported expenditures varied by orders of magnitude from $28,370 for Connecticut all the way to $118,695,389 for Washington (Table S1). This variance extended beyond expenditures, as the process of who to contact from state to state was not the same (Table S3). Such variance clearly indicated to us that not only is the invasive species problem wildly out of control, which is well recognized, but that management costs are perhaps not clearly understood even within the state agencies, like a department of natural resources, that are charged with managing the expenditures. Furthermore, while the data we obtained represent a component of expenses, the variability in them and the challenges we found make drawing analytical conclusions difficult. Specifically, financial data were reported and described in a haphazard manner that lacked any standardization within and across states. Furthermore, while we were able to summarize invasive species management costs from 47 states, only seven states provided information categorized by management action. As such, we still lack a clear understanding of *how* money is being spent and for which specific management actions. Notably, this haphazard nature of expenditures mirrors the haphazard nature of local policies related to invasive species management across the U.S. (Reed et al. 2023).

Aside from the inconsistent nature of financial data, our findings suggest that there is wide variation in spending over time and space. Most state expenditures ranged from the high thousands to low million-dollar figures (Figure S1). While the expenditures exhibited spatiotemporal variance, it is notable that when all costs are considered together ($399,112,718), they represent just a very small fraction of the estimated annual damage caused by invasive species. In fact, based on previous estimates of damage to the U.S. economy (Pimentel et al. 2005; Fantle-Lepczyk et al. 2022), state natural resource agencies are spending less than 2.0% the amount of money lost due to invasive species on their control. In other words, we are investing very little to mitigate a growing problem.

The high expense outliers in our study lead to questions regarding the nature of these states' expenses—are they being proactive against incipient invasive species, keeping better budget records, or actually dealing with more severe invasive species issues? Outliers are seen in the cost per area, where most costs are concentrated within median ranges of $9.25/km^2, yet the mean is higher, at $52.03/km^2 (Figure S3). Due to the unclear reporting of these expenditures, we are unable to determine if outliers are due to a significant invasive species problem, or some states keeping more detailed or differently calculated records than others. On a regional scale, our study reflects trends in the InvaCost database (Fantle-Lepczyk et al. 2022), with states in the western U.S. reporting greater invasive species management costs. Similarly, reporting per capita costs of invasive species management we allow for comparisons of costs with population densities across spatial scales (Figure S2). For example, Wyoming, the least populous state, has the greatest per capita cost at $205.76, and also has one of the highest costs per land area, at $468.52/km^2. The disparity in expenditures may also reflect variation in the wealth of different states, as those with higher gross domestic productivity may have more funds available for the management of invasive species (Sharma et al. 2010). Similarly, greater wealth is often indicative of more trade and the commensurate increased risk of invasions, but there is also a greater capacity to control and prevent potential damage by invasive species (Bradshaw et al. 2024). We also found quite a bit of variation in responsiveness when attempting to contact state agencies. Specifically, it took us between 1 and 6 attempts to contact state agencies (mean = 2.32; Table S3). For 19 states we needed two separate points of contact, one for aquatic invasive species and another contact

for terrestrial invasive species. When contacting state agencies, we were clear that this request was for natural resources departments, to limit variation amongst states. Many states provided additional contact information for invasive species managers in other departments, which was outside the scope of this project. We followed up with officials first via e-mail, and then attempted contact via telephone. This approach allowed us to evaluate the availability of these data. Data were provided in various formats, including project tracking spreadsheets, invasive species reports, and budget estimates.

While our results paint a troubling picture of the financial aspect of managing invasive species, it is important to note several caveats in interpreting our findings. First, while we obtained data from 47 of the 50 states, given the haphazard nature of accounting there are certainly costs missing from our dataset due to inconsistent record keeping, and variance in assigning and tracking expenses. Second, our data are not an exhaustive account of funds spent on managing invasive species since many other state agencies (e.g., Departments of Agriculture, Transportation) may also dedicate funds to invasive species management. A case in point is Connecticut which has a Department of Energy & Environmental Protection, with the Environmental Conservation Branch, consisting of the Bureau of Natural Resources and the Bureau of Outdoor Recreation. While we obtained information from the Bureau of Natural Resources, and more specifically, the Division of Forestry, there are many other divisions that spend resources on invasive species management. Similarly, the Nebraska Department of Natural Resources reported spending $94,000 on aquatic invasive species (Table S2), but other state agencies such as the Department of Environmental Quality, Nebraska Forest Service, and Nebraska Game and Parks Commission are actively managing invasive species as well. There are some states, like Nebraska, that have invasive species partnerships. Invasive species partnerships can aid in coordinated efforts, but these groups are not the same across states. Most often, there are components of academic institutions, such as Cooperative Extension, or nonprofit groups who may lead these efforts. While the Nebraska Invasive Species Program is a partnership between the Nebraska Game and Parks Commission, University of Nebraska, and USGS Nebraska Cooperative Fish & Wildlife Research Unit, it is important for invasive species partnership programs to include all agencies, including forestry and environmental protection agencies to improve coordination and effectiveness. Likewise, federal agencies spend significant resources on managing invasive species (e.g., BLM received a $137.1 million appropriation in FY2022 just for managing wild horses and burros; Vincent 2022), although with the caveat that state expenditures may also come directly from federal dollars (e.g., federal pass through). As a result, our estimates should be considered conservatively, but also cautiously, and as such, are best taken in the context of other states and for illustrative purposes. Third, even though we sought to gather data over time, most states provided, or were able to provide, only a single year of data, thus giving only a snapshot of expenditures, which also reflects the opaque nature of such accounting. Without a time series of expenses, we cannot be sure if our estimates are representative or atypical and we cannot see if there are substantial changes over time. Given that invasion rates are increasing (Seebens et al. 2017), the inability to evaluate management costs over time makes it unclear if expenditures are even keeping pace with changes or if funding for management is simply falling behind. As invasive species are a global issue, understanding the relationship between management costs and escalating invasion rates is critical for effective invasive species management.

Recommendations

The haphazard nature of accounting indicates there is a need to provide a centralized or unified structure to assess and standardize invasive species management costs across the U.S. For example, state agencies which have a designated invasive species manager (i.e., aquatic invasive species specialists) offered limited information regarding overall invasive management funding. We suggest biologists and all those who manage invasive species on the ground should be encouraged to maintain detailed records of management actions as a first step towards coordinating actions to control invasive species. Because invasive species work is undertaken by government agencies, nonprofit organizations, and volunteer groups, using a template to record management actions and expenditures would aid in standardizing this information.

Invasive species management is often funded through a variety of sources and maintaining comprehensive records on the funding of management actions will allow for better management and coordination over time, especially in periods of job transitions, and can aid in collaborative management efforts for invasive species with other departments and states. While a variety of state agencies spend money managing invasive species, other private organizations and non-profit invasive species councils also fund the control and suppression of invasive species. These additional costs need to be part of a broader understanding of the invasive species calculus, and collaborating with these groups would aid in a comprehensive understanding of expenditures on invasive species management. Notably, nowhere do we account for or estimate the economic costs of volunteerism in managing invasive species by non-profit organizations.

A lack of transparency in expenditures also cripples the fight against invasive species because the economic costs are effectively hidden from the public. This invisibility minimizes the risk invasive species pose to society and the environment and undermines public support for exclusionary measures since the narrative often focuses on controlling individual pests after they are spreading (e.g., spotted lantern fly). If, instead, the public was aware of how much funding was spent every year on invasive species control and management, the scale of the problem and its economic impact would be more obvious. Increasing transparency will aid in the standardization of costs amongst state agencies, volunteer groups, and other organizations (Hulme et al. 2024). Rather than scattering the cost of invasive species control across multiple agencies, state governments should work to compile, understand, and disseminate this important knowledge to their constituents. For example, the InvaCost database found invasive species management costs to be unspecific and diverse across regions, which reflects a lack of central structure, coordination and standardization for these expenditures (Fantle-Lepczyk et al. 2022). Our study began as an effort to exemplify how much invasive species were costing each state but has led us to the startling conclusion that most states do not know and have no way to share the cost of invasive species control even within a single, generic, agency. This ignorance suggests that we are ill equipped to undertake critical coordination efforts, which are needed to stop the continuing spread of invasive pests across the nation. Furthermore, this ignorance is frustrating given that a similar issue with economic accounting was raised over two decades ago in the GAO report (GAO 2000). While we recognize that there are organizations already in place, such as the National Invasive Species Council (NISC), for which the goal is to provide leadership to coordinate strategic actions among local, tribal, and state governments, there is a need to strengthen these efforts (Reaser et al. 2019). Furthermore, while little data are available for the costs of invasive species on tribal lands, it is important to note that including Indigenous groups in inter-agency coordinated efforts is crucial to the success of these programs (Reo et al. 2017). In addition, collaborative efforts based on regional similarities, such as in the western U.S, can be effective in controlling the spread of aquatic invasive species, like zebra mussels (Columbia River Basin Team 2018). The U.S. is a nation of states, but it is critical that they function as a single entity to counter the challenges posed by invasive species as species distributions are unfettered by political boundaries.

A first step would be for each state to understand how much money they are spending on invasive species control and to then coordinate its efforts as part of a binding national effort. If one state is spending millions of dollars to control a pest, but a neighboring state spends very little, the chance of successfully controlling the population is remote. Worse, it might give the impression that success is unachievable. Coordination is, of course, done to some degree by the federal government for particular species, but there is no standing policy or state-by-state agency tracking expenditures made by each state in their individual struggles against invasive species. This lack of coordination must change if the nation is to have any reasonable hope of countering the damage caused by current and future invaders. Invasive species are quintessentially a national problem, yet, to a large degree, the management is meted out in a piecemeal response, which most states are currently underequipped to track and coordinate. One of the great advantages of the U.S. is that federal problems can be managed effectively across state lines, but only when they are recognized as such. Currently most invasive species are not.

Taken together our findings suggest that state natural resource agencies are spending very little to

manage invasive species and, more importantly, have poorly organized central accounting practices for costs. We recommend that accounting be standardized across states using a centralized database both to provide transparency in expenses as well as to allow for an understanding of how and which funds are being used for which invasive species management action. Such standardization would allow a broader understanding of how funding is distributed, reveal inequities in species funding, and provide a measure of efficiency in expenditures related to management costs. To assess spending efficiency, states should evaluate the effectiveness of management actions and compare between approaches. Specifically, looking at the differences between proactive and reactive management can help to identify the best approaches to use, from local to regional scales. Furthermore, a strategic understanding of how funds are utilized would make a stronger case for dedicating more resources towards managing invasive species. Undoubtedly our study underestimates the expenditures made on invasive species management, but the fact that is it so difficult to assess suggests a unified and coherent reporting system for agency expenditures on the management of invasive species would be an important first step in improving the U.S. response and may be a model for other countries.

Conclusion

The most salient aspect of our results suggests that most states are not currently tracking invasive species expenditures coherently. While some actions in some states might be carefully monitored, others appear be completely ignored or categorized in another way entirely, making them difficult to compare (e.g., agricultural damage might fall under an agricultural agency, natural area damage under forestry even for the same pest species), and making it hard to associate expenditures with invasive species and effectively assess costs and damage. Such information is critical not only to properly assess responses to multi-state invasive species, but also to coordinate as a nation. For example, prevention/exclusion is universally recognized as the most effective way to handle the invasive species threat, yet it is the stage in invasion biology that is least funded. If only one state prioritized prevention, it would have little impact (except for Hawai‘i with obvious geographical advantages and Florida with is numerous entry points and favorable climate). Collaborative invasive species efforts across regions, and even locally, are important in controlling invasive species and spreading awareness. In fact, every state should have a clear and unified assessment of how and on which species public funds are spent. Without a coordinated effort to assess the total economic impact invasive species have, and in turn prioritize a unified response, the U.S. will continue to operate as a series of 50 countries with different priorities, actions, and assessments while experiencing waves of damaging invasions costing billions of dollars and degrading natural and agriculture systems.

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Data availability The supplemental material includes a published summary of the data, including state agency contacted and reported expenditure amounts.

Declarations

Conflict of interest The authors have no relevant financial or non-financial interests to disclose.

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