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Evaluation of Invasive Avifauna Management Strategies in North America

Christopher L. Castillo
University of Nebraska, Kearney, castillocl@lopers.unk.edu

EVALUATION OF INVASIVE AVIFAUNA MANAGEMENT STRATEGIES IN NORTH AMERICA

CHRISTOPHER L. CASTILLO
DEPARTMENT OF BIOLOGY; UNIVERSITY OF NEBRASKA AT KEARNEY

MENTOR: DR. SAILI MOGHE

ABSTRACT:

Human action has long been the cause of species introductions into new ecosystems (lodge 1993. Now, these non-native species are a major global problem both ecologically and economically (Bled et al. 2011). Invasive species can alter habitats, decrease biodiversity, damage human settlements, and destroy agriculture (Townsend Peterson and Vieglais 2001; Kumschick and Nentwig 2010). The United States has been particularly affected by invasive introductions, a multitude of which have been avian species. Various management techniques have been used with a 'trial and error' strategy. This review examines some of those methods as they have been applied to specific invasive bird populations in the United States and evaluates their effectiveness. It is concluded that an integrated management strategy should be implemented to combat invasive avifauna, focusing first on prevention, then exclusion, and finally removal. Such a strategy must be driven by sound research and vigorous impact assessments.

INTRODUCTION

'Alien invader' is not a term that often holds any real meaning outside of science fiction. However, in the field of ecology, the impacts of an alien invader can be as dangerous as any fictionalization. These types of organisms are more commonly referred to as an invasive species and defined as one which, due to human action, has been introduced to and become established in a geographical area in which it would otherwise not be present (Bled et al. 2011). Invasive species run the phylogenetic gamut, from microorganisms to vertebrates (Bled et al. 2011). As humans have increased our range globally, so too have we unnaturally increased the range of many of the species we transport (Lodge 1993). A species invasion typically follows the basic progression of (1) transport, (2) introduction by release or escape, (3) establishment, and (4) spread (Duncan et al. 2003).

Invasive species can cause massive and severe ecological and economic damage (Kumschick and Nentwig 2010). Deleterious habitat alteration, native species extinctions, declines in biodiversity, loss of agriculture, and damage to infrastructure are only a few of the major impacts caused by invasive species (Townsend Peterson and Vieglais 2001). As more and more species are being transplanted and established outside of their native ranges, the need to develop novel methods of control and management to mitigate impacts has grown increasingly imperative (Clark et al. 2016). Currently, introduced species are dealt with one by one, and as such, much research has been focused on developing predictive models that can be applied across taxa at the beginning of an invasion (Townsend Peterson and Vieglais 2001). However, progress in this regard has been markedly slow due to the vast complexities and unpredictability of invasions (Townsend Peterson and Vieglais 2001). Moreover, it can be difficult and confusing deciding which invasive species should be targeted or prioritized and which methods should be used (Kumschick and Nentwig 2010).

Control and management methods are varied and often species-specific. They range from preventing invasions at their first sign to lethal removal and eradication. Since not all introduced species reach the level of 'invasive,' occasionally a management strategy will consist of doing nothing at all. This, however, is rare as very few introduced and established species have a positive or neutral effect on their new ecosystems. Determining the most effective management strategy is often trial and error. Moreover, researchers have found it extremely difficult to develop and implement control and management strategies that reduce the number of invaders while not affecting native taxa (Clark et al. 2016). Techniques such as trapping and poisoning are not species-specific and can often do much more harm than good. Harvesting – the permanent, lethal removal of individuals from a population – is often suggested as a population control method; however, it can lead to overcompensation, meaning a population will ramp up reproduction and grow much more quickly (Zipkin et al. 2009). Obviously, no control method will be problem free. Similarly, it is very unlikely that any single method would produce complete success. In addition, the efficacy of control strategies changes spatiotemporally (Baker and Bode 2016). For all of these reasons, invasive species research and management is a perplexing but imperative field of study.

The United States has experienced a vast number of species introductions from nearly all known taxa (Townsend Peterson and Vieglais 2001). Non-native birds in particular have been translocated into the country since before colonization (Duncan et al. 2003). Rock doves (*Columba livia*), house sparrows (*Passer domesticus*), European starlings (*Sturnus vulgaris*), and common mynas (*Acridotheres tristis*) are just a few examples of successful avian invaders in the United States. They can be responsible for crop losses, habitat degradation, out-competition of native species, and damaged utilities and infrastructure. Control and management strategies for established, non-native bird populations have been implemented for the past two centuries with varied results. This review will focus on several categories of alien management techniques and their efficacy for non-native avian species in the United States. These management strategies will be reviewed as they have been applied to distinct, established population of invasive species.

METHODS OF INVASIVE AVIFAUNA MANAGEMENT

Not all alien species are the same; likewise, not all introductions cause the same impacts (Duncan et al. 2003). In fact, recent research suggests that it cannot be conclusively determined if invasive species can directly cause biodiversity loss (Gurevich and Padilla 2004). Moreover, more recent reviews show little evidence that invasions, by avian species specifically, are detrimental to biodiversity (Strubbe et al. 2011). Nonetheless, there is no denying that invasive species can present problems to ecosystems and human establishments, and many invasive bird species certainly fit into this category. Yet, bird species are not often the target of control or management programs compared to other introduced taxa (Kumschick and Nentwig 2010). The following are examples of implemented management strategies for established, non-native bird species that are ranked from least to most intrusive.

No Management Action Taken

As mentioned previously, management strategies for invasive bird species are often limited. However, that is not always due to lack of policy or research. For example, the cattle egret (*Bulbucus ibis*) is endemic to old world tropical environments (Peterson and Vieglais 2001). In the latter half of the twentieth century, this species became serendipitously established in South America through limited anthropogenic factors and eventually spread to the southeastern United States (Telfair 1994). Although it has been calculated that only 5.4% of all potential habitat in the United States would be usable by cattle egrets, their distribution has increased significantly (Peterson and Vieglas 2001). This range expansion, notwithstanding research by the Gulf States Marine Fisheries Commission, has shown that there is little conflict in the Gulf States with native species due to differing nesting temporalities and diets. In fact, surveys have shown that there have been significant reproductive declines in the gulf populations of egrets since the 1970s (Runde et al. 1991). As such, no control action has been taken for established (and possibly soon to be extirpated) cattle egret population in the southeastern United States (GSMFC 2005).

Similarly, the cattle egret was introduced onto the Hawai'ian islands in order to control agricultural pests (Reed et al. 2012). Hawai'i in particular has been ravaged by the impacts of invasive species in the last century. Specifically, their endemic avian populations have suffered greatly (Duffy and Capese 2012). Cattle egrets are now established on the islands and as such, any eradication or control program would need to expand statewide due to the species' ability to fly between islands (Reed et al. 2012). Nevertheless, cattle egrets appear to be a much less serious threat to endemic species compared to other invasive species. Therefore, no management action has been taken to control their populations on the islands either since those resources can be deployed more efficaciously elsewhere (Reed et al. 2012).

Exclusion and Physical Barriers

Next to taking no management action, the most cost effect control method is exclusion. More often than not, this strategy does not involve dealing directly with the target species, but rather entails physical barriers or some type of habitat modification.

Red-whiskered bulbuls (*Pycnonotus jocosus*) are a popular decorative bird species throughout the world owing to their unique appearance and melodious song. This has led to their introduction to many areas in the United States including Hawai'i, California, and Florida with varying results. Historically, the establishment phase for this species in a new ecosystem lasts upwards of ten years (Van Riper et al. 1979). This is likely due to their low rates of dispersal (Clergeau 2001). This species poses a major threat to agriculture in areas where it has become well established. For example, research in Oahu, Hawai'i recorded a 75% damage rate to certain fruit orchards attributed to the red-whiskered bulbul and another closely related invasive avian species (Cummings et al. 1994). A simple tactic employed by the State of Hawai'i was to bar the importation of any red-whiskered bulbuls to the islands in an attempt to prevent the establishment of further colonies on other islands. Furthermore, a public relations campaign was started to educate citizens on the agricultural threats posed by this species. This exclusion strategy was deemed successful after a decade after no new populations were discovered on any island other than Oahu. Complete eradication of the species, however, was determined to be impossible (Islam and Williams 2000; Reed et al. 2012). There have been other, more direct attempts to control red-whiskered bulbul populations, such as trapping; however, there is a lack of data on the success of these methods. Barring the lack of data on the most cost effective strategy, exclusion and public education seem to be the most effective method for stymying the spread of introduced red-whiskered bulbuls.

House finches (*Carpodacus mexicanus*) are an almost indistinguishable species of passerine. Their small stature and muted coloration makes them difficult to differentiate from many other songbirds. Despite their diminutive appearance, they can be quite the agricultural nuisance (Hill 1993). Native to the west coast of the United States and Mexico, they have established populations throughout the country, including Hawai'i, where they would not be able to disperse naturally. Like many songbirds, they are voracious frugivores, feeding on just about any deciduous fruit they can find (Clark and Hyngstrom 2005). Research in Hawai'i found that at one study area, 30%-50% of the loss of sorghum crops was due exclusively to house finch foraging (Berger 1994). Several strategies have been proposed and implemented to combat the impacts of house finches. One of the less invasive and more cost effective strategies is exclusion netting. This process involves wrapping fruit bearing trees in orchards and on farm land in plastic netting in order to prevent house finches from reaching their desired food (Clark and Hygnstrom 2005). Similarly, removal of large piles of objects such as brush, branches, farming equipment, and building materials can deter house finch nesting, which in turn, deters foraging (Clark and Hygnstrom 2005). Other methods of controlling house finch populations have been implemented as well, including harassment, trapping, poisoning, and shooting. Little data exists, however, on their efficacy, and they are all considered to be far more time consuming and costly compared to the exclusion methods mentioned above (Clark and Hygnstrom 2005).

Canada geese (*Branta candensis*) are considered a major pest species and one that impacts ecosystems, agriculture, and economies. As its name would suggest, it is endemic to Canada and found year-round in the most northern habitats of North America. Normally, this species migrates southward into the United States and Mexico prior to the breeding season; however recently, non-migratory populations of geese have become established in non-native areas, becoming the bane of the recreational golfer (Conover 2011). In 1992, there were estimated to be only 300,000 non-migratory Canada geese in urban areas of the United States, but by 2008 that estimate had risen to 5.5 million (Gosser et al. 1997; Conover 2011). Due to their migratory nature, this species falls within the protections of the Migratory Bird Treaty Act of 1918. Hunting of this species is permitted at certain points of the year and is often considered the preferred method of population control; however, legal take is not able to keep up with population growth (Gosser et al. 1997). Compounded with that, urban, non-migratory populations of geese are difficult to control due to the lack of public hunting areas (Conover 2011).

A common, nonlethal management strategy employed to deter Canada geese from foraging in a particular area is exclusion (Gosser et al. 1997). Boulders are often placed around small bodies of water around which gaggles could potentially forage. The boulders work as possible cover for predators, making the geese leery of inhabiting that area. Fences are also used around bodies of water to deter the geese from landing. Geese naturally forage on land and seek refuge in the water, and as such, inhibiting their ability to do so makes the area less than appealing (Gosser et al. 1997). This strategy, however, also affects other native species of waterfowl as it prevents them from using the habitat, as well.

Exclusion fences may be a passive method of controlling geese populations; however, they can directly mitigate the damage done by large populations of this gregarious species. Similarly, electric fences have been used to deter geese from roosting in a particular area. These fences deliver a nonlethal shock that geese are quick to avoid (Gosser et al. 1997). However, such a strategy poses multiple concerns regarding its potential effect on other wildlife, pets, and humans. Research has shown that nonlethal methods for controlling geese populations are most effective when used together (Gosser et al. 1997). Nonetheless, the most effective strategies for managing problem geese populations are shown to be physical harassments such as sound deterrents and, in general, the more invasive the management program to the target species, the more efficacious it is (York et al. 2000).

Nonlethal Chemical Control

The use of chemicals to control invasive species is mostly used on plants and arthropods. However, there are many examples of this technique being applied to vertebrates in a variety of ways. The monk parakeet (*Myipositta monachus*), like most parrots, is a native of South America (Avery et al. 2012). It is an extremely popular species in the pet trade. Between 1968 and 1972, over 65,000 monk parakeets were imported into the United States (Spreyer and Bucher 1998). It has since remained extremely sought after. From 2006 to 2012, monk parakeets accounted for nearly 97% of all parrots exported from South America for the pet trade (Bush et al. 2014). Owing to intentional and accidental releases, it now has established ranges in the United States and Canada, as well as multiple countries in Europe and Asia (Avery et al. 2008).

In its native range, the monk parakeet has a reputation as an agricultural pest, and as such, it was feared that it would decimate crops in North America (Avery et al. 2012). However, that fear has yet to be realized (Tillman et al. 2001). Nonetheless, monk parakeet population numbers are increasing at an untenable rate (Avery et al. 2008). This combined with their penchant for constructing large nests on electrical poles and utility structures poses a direct problem for humans (Avery et al. 2006). Research has shown that the use of the chemical Diazacon can be a useful tool in controlling monk parakeet populations (Avery et al. 2008). Diazacon (20, 25-diazacholesterol) is a reproductive inhibitor and has been shown to effectively block reproduction in captive monk parakeets (Yoder et al. 2007). This same strategy was implemented on feral monk parakeet populations in Florida with significant success (Avery et al. 2008). Mean nest productivity, defined as nestlings plus viable eggs, was measured at 4.15 at untreated sites; whereas, mean nest productivity at treated sites was only 1.31 (Avery et al. 2008). These results are quite promising since a nonlethal management strategy is always preferable to a lethal one, especially in the public eye. Moreover, inhibiting reproduction has been proven to slow population growth of wildlife, which can have its own benefits (Bomford 1990). With the exponential growth of feral monk parakeet populations in the United States, this strategy seems to be a cost effective route and would likely only be bolstered by other management programs. However, the major drawback to this method is the ingestion of Diazacon by non-target species, which could be quite detrimental especially for endangered species or vulnerable populations. This concern can potentially be abated with the implementation of bait stations that exclude non-target species (Avery et al. 2008). Physical means of monk parakeet control are also being implemented and will be discussed in another section.

As discussed earlier in this review, red-whiskered bulbuls are natives to Asia and have been introduced in Hawai'i, California, and Florida. This species can outcompete endemic species for food and habitat. In Hawai'i, exclusion and public education were shown to be successful means of quelling population expansion. It is well documented that this species can have severe impacts on agriculture, specifically fruit orchards in its native range, but research suggests that it may also be a threat in its introduced ranges (Cummings et al. 1994). A study in Florida did not find any depredation of orchards attributable to red-whiskered bulbuls; however, other research has shown damage specifically to mango orchards (Carleton and Owre 1975; Islam and Williams 2000). In order to combat this, one management strategy implemented was chemical control. In laboratory trials, three different chemicals, methyl anthranilate, methiocarb, and ziram were tested as repellents to red-whiskered bulbuls and the closely related red-vented bulbul (*Pycnonotus cafer*).

Similarly, in field experiments, methiocarb and ziram were applied to target fruit sources as deterrents (Cummings et al. 1994). Application of these chemicals led to a 65% reduction in fruit consumption in laboratory tests and a 14% reduction in field experiments (Cummings et al. 1994). Thus, chemical deterrents may be a viable strategy to control invasive red-whiskered bulbul populations by limiting food sources. However such a ploy would suffer from the same drawbacks as many other passive strategies, that is the impact on non-target species. Application of a chemical deterrent on food sources is not specific and could lead to nutritional deficits in vulnerable populations. Similarly, if this method is applied to orchards, the chemicals used would obviously need to be verified as safe for human consumption. Moreover, the aforementioned studies suffer from small sample size and as such, the results may not be applicable in a broader context (Cummings et al. 1994). More research is needed into the efficacy of chemical application as a means to control red-whiskered bulbul depredation. As with most management programs, a combination of strategies would likely be the most effective.

Direct Nonlethal Physical Methods

Physical means of population control or deterrent are used frequently with invasive species. These are more intensive than physical barriers, but less so than relocation or removal. Although ubiquitous, house sparrows (*Passer domesticus*) are a Eurasian native introduced to the New World in the 19th century (Leasure 2013). Despite their cosmopolitan lifestyles and nationwide distributional success, house sparrows impact native populations in a variety of ways. House sparrows are known to be quite aggressive, both intraspecifically and interspecifically (Barrows 1889). Research has shown that house sparrow aggression and competition for nests accounted for 54% decline in the number of cliff swallows (*Petrochelidon pyrrhonota*) that successfully reared at least one chick at one study site in Arkansas (Leasure et al. 2010). As such, multiple strategies have been implemented to attempt to control house sparrow populations (Glacking 2000). One of which is trapping. Trapping, however, has had mixed results (Leasure, Kennan, and James 2010). Trapping has been shown to be initially successful, with cliff swallow populations showing a 97% increase after a multi-year sparrow removal strategy (Leasure 2013). However, sparrows are quick to learn to avoid traps altogether, and it is only a matter of time before their population numbers recover (Summer-Smith 1963). Other means of control, however, both lethal and nonlethal, appear to be more successful as a means to manage house sparrow populations.

Monk parakeets as described previously are an invasive species that have taken hold in multiple states. In south Florida, they have caused considerable damage to electrical utility stations with their large, bulky nest structures (Avery et al. 2006). These nests can cause power outages and even fires (Newman et al. 2008). Chemical means have been used to inhibit reproduction of monk parakeets and were discussed previously; however, physical means have also been employed to curtail parakeet populations more directly. Nest removal has been implemented at utility stations for decades (Avery et al. 2007, Avery et al. 2012). Despite the simplicity of such a strategy, nest removal is only effective in the short term (Newman et al. 2008). Nest removal can cost anywhere from $415 to $1,500 per nest, with a 5 year removal project by the Florida Power and Light Company estimated to have cost between $1.3 and $4.7 million (Avery et al. 2007). Moreover, nest removal has been shown to be efficacious if the birds themselves are trapped as well, because if left, parakeets will merely rebuild their nest (Newman et al. 2008). Not only is this strategy time and labor intensive, but there has also been considerable public backlash in regards to techniques used for nest removal such as water cannons (Newman et al. 2008). Therefore, despite its usefulness in the short term, nest removal does not appear to be an effective strategy for controlling monk parakeet populations. However, this strategy is necessary in order to prevent power outages and reduce the risk of electrical fires. It is suggested that additional methods should be implemented as a long-term strategy, such as reproduction inhibition as discussed previously, as well as public education, in order to effectively control monk parakeet populations while ensuring public safety (Newman et al. 2008).

Removal and Lethal Control

In many cases, especially in the most severe, partial or complete removal of the invasive species is implemented. The brown-headed cowbird is technically native to the central plains of the Midwest (Ortega 1998). However, due to land use conversion, this species has been able to expand continent-wide (Sauer et al. 2003). It currently poses grave threats to native populations in California (Siegle and Ahlers 2004). In large part, this is due to the fact that brown-headed cowbirds are brood parasites. This means the female will lay her eggs in another species' nest. After the chick hatches, it often pushes any other eggs out of the nest and is then fed and raised by the host species, thinking the chick to be their own (Klein and Rosenburg 1986; US FWS Southwestern Willow Flycatcher Recovery Plan 2002). This is detrimental to the reproductive success of the host species, which are often natives. Many control options are being implemented nationwide (Siegle and Ahlers 2004). The predominant strategy used by the US Department of the Interior is trapping and killing cowbirds. This program has thus far been the most successful in reducing the rate of nest parasitism of native species (US FWS Southwestern Willow Flycatcher Recovery Plan 2002). It has the added benefit of having short-term effects on local populations as well. However, it can be rather costly and very time-consuming as trapping needs to be monitored daily to verify that native species are not caught (Rothstein and Cook 2000). Moreover, such a strategy raises a number of ethical concerns, especially given that brown-headed cowbirds are not necessarily an alien species by definition (US FWS Southwestern Willow Flycatcher Recovery Plan 2002).

In several case studies, trapping of brown-headed cowbirds has yielded mixed results. The least Bell's vireo (*Vireo bellii pusillus*) is endemic to the central valley and southern coast of California (Robinson et al. 1995). However, due to several factors, including brood parasitism, it has been extirpated from the central valley and has experienced declines along the coast (Laymon 1987; Robinson et al. 1995; Franzreb 1989). Since the initiation of trapping at one study site in Southern California, parasitism rates have dropped from almost 50% to below 1%. However, the number of cowbirds caught in traps has remained constant (Griffith and Griffith 2000). Conversely, trapping of cowbirds at a study site in the Cleveland National Forest had no effect on declining vireo populations (Winter and McKelvey 1999).

The black-capped vireo (*Vireo atricapilla*), which is similar to the least Bell's vireo, formally inhabited shrub land of central southern United States. Due to multiple factors, it has been reduced to several isolated populations (Hayden et al. 2000). Cowbird trapping programs were initiated in Texas and over the course of the vireo's breeding season, the rate of parasitism dropped from 90% to just under 10% (Summers et al. 2000). However, it should be noted that this program was conducted alongside other forms of control (Ekrich et al. 1999). As such, it cannot be determined if trapping was solely responsible for these results. These case studies show that trapping as a means of controlling cowbird populations have variable results at best; however, it can be somewhat successful on a small, local scale.

CONCLUSION

Invasive species are hardly a new phenomenon. Humans have been transporting species from their native range to new frontiers for millennia (Duncan et al. 2003). However, the rise of globalization has accelerated the spread of alien species (Ricciardi 2013; Evans et al. 2013). Non-native populations are becoming established and burgeoning much more rapidly than native populations can adapt to deal with them, and this trend is not predicted to slow at any point in the near future (Evans et al. 2013). Recent research shows that current extinction rates are 1,000 times higher than pre-human rates (De Vos et al. 2014). Although this is caused by a wide range of factors overall, invasive species are now the leading cause of extinction for avifauna (Clavero and García-Berthou 2005). Furthermore, invasive species can present a number of issues for humans, as well, including damage to agriculture and infrastructure, spread of disease, and habitat degradation. The number of invasive species management options are many; however, it goes without saying that they are not all equally efficacious. Similarly, no single control method is completely effective on its own.

Passive physical barriers and exclusion devices are useful to prevent habitat or agricultural damage; however, they can negatively alter the landscape and can exclude native species from utilizing an area. Chemical control methods are successful at inhibiting reproduction in some species and can deter other species from damaging crops. Nonetheless, these chemicals can detrimentally affect non-target species, and they could potentially expose consumers to harmful chemicals on and in their food. Direct, physical methods of control, such as nest removal and trapping with relocation, are successful in the short term and show immediate, limited success. These methods, however, are not viable long term solutions as they are cost prohibitive and extremely time consuming compared to other methods. Lethal removal through hunting and trapping is objectively successful as a means of population control. Moreover, this method has proven to be the most effective solution for certain pest species. However, this strategy often faces vociferous public backlash and is not always feasible.

The most cost-effective management and long term method is the prevention of alien population establishment. Preventing an invasive species from taking hold would eliminate the need for any physical, chemical, or lethal control program. This, obviously, is much simpler in theory than in practice and often times, invasive species are not noticed until after a population has become established. In order to deal with such a variable situation, an integrated management approach is the soundest option. This refers to the simultaneous implementation of multiple programs in order to curb the establishment and/or spread of invasive species while also considering the spatiotemporal context of the invasion (Baker and Bode 2016).

Based on the research presented in this review, I suggest implementing an integrated, multi-faceted management strategy to contend with the problem of invasive avifauna. Such a strategy would require both short term and long term methods to adequately counter an introduced population. This strategy would consist of three phases of management proportional to the progression of the invasion. Those phases would be prevention, exclusion, and removal. Since the most effective management tactic is precluding a non-native species introduction, this would be the initial phase. This should include identifying potentially invasive species and banning or closely monitoring their import and transportation. In addition, impact assessments must be conducted into potential risk to habitats, agriculture, public health, and/or infrastructure. At this point, a public information campaign may need to be started to familiarize the public with the species and the problems its introduction could present.

Once an established population of the invading species is identified, the next phase, exclusion, would be initiated. This phase would focus on preventing the establishment of new colonies. A monitoring program would need to be established to study and track the initial population. At this point, passive exclusion barriers should be set up around potential foraging areas and food sources. These could include netting around fruit trees, the use of chemical deterrents around nesting or feeding areas, and/or fencing or barriers around water sources that are not detrimental to native species. If the invasion continues unfettered, the next phase of the strategy, removal, would be initiated. Tactics at this point could vary substantially. Population growth and recruitment should be limited by use of chemical castration and nest removal; however other strategies can be utilized. Depending on the species, public take should be permitted at certain points of the year. Encouraging the public to responsibly hunt the invasive species has the added benefit of generating income for further conservation management and interest in recreational activities. Lethal removal may be needed at this point as either an alternative or supplement to public take. Lethal removal, however, should be preceded and/or accompanied by public education and outreach to quell potential backlash. Scientific monitoring and impact assessments will be critical during all phases of this strategy to monitor and track overall population dynamics and changes. The research collected from the aforementioned strategy would be instrumental in constructing an omnibus and effective invasive species model. Ideally, such a model could then be applied to any invading, non-native population – regardless of taxon – to successfully prevent establishment and spread.

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