Knowledge, reason and emotion: using behavioral theories to understand people's support for invasive animal management

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Abstract

Species invasions contribute to global environmental change and cause declines in populations of threatened and endangered species. Significant government funds are expended on invasive species management (ISM) actions each year. Public support and compliance are critical to the success of these actions. We conducted a study to assess determinants of the general public's support for ISM actions to identify potential barriers to ISM. We administered an online questionnaire to the general public (n = 1,561) in Florida, a state severely affected by species invasions. We presented respondents with 12 different non-native animals from 4 different taxa (birds, rodents, herpetofauna, fish) to test whether their support for ISM actions depended on the animals to be managed or their perceptions of risk. We utilized structural equation models to explore how different variables directly and indirectly influenced support for management actions. Respondents tended to oppose management actions targeted towards birds and charismatic species. Respondents' support for government-implemented ISM actions was positively correlated with their awareness of the risks associated with different animals and species invasions in general, their awareness of the consequences of species invasions, and their recognition of the importance of taking actions to mitigate invasion threats. Efforts to promote public support for ISM actions should emphasize the different risks associated with invasive species and the consequences of species invasions to offset opposition to ISM actions that target charismatic species.

Keywords: Containment, Eradication; Florida; Prevention, Risk, Structural equation models

Background

Invasive species management (ISM) is inherently challenging because the actions of a wide array of stakeholders determine the effectiveness of ISM interventions. Notably, the success of ISM interventions depends on public support for management actions and voluntary compliance with ISM interventions (Genovesi 2008; Crowley et al. 2017; Shackleton et al. 2019a). Although government agencies recognize the importance of ISM interventions, they may underinvest in optimal actions, due to uncertainty about the likelihood that a species will become invasive (Epanchin-Niell 2017) and political and public opposition to ISM actions (Genovesi 2008; Crowley et al. 2017). For example, actions targeted at the grey squirrel (*Sciurus carolinensis*) in Italy (Bertolino & Genovesi 2003) and the rhesus macaque (*Macaca mulatta*) in Florida (Anderson et al. 2019) have failed due to public opposition and interference.

Existing research suggests that public support for ISM actions depends on people's perceptions of invasive species impacts (Estévez et al. 2015; Shackleton, 2019b), the charismatic appeal of invasive species (Schűttler et al. 2011; Sharp et al. 2011; Crowley et al. 2019; Shackleton et al. 2019b), the length of time that an invasive species has been established in a location (García-Llorente et al. 2008; Schűttler et al. 2011; Crowley et al. 2017), the historical success of ISM actions in people's community (Crowley et al. 2017), and invasive species denialism (Ricciardi & Ryan 2018). Gaining public support for ISM actions is particularly difficult when a species is charismatic (Crowley et al. 2017) or members of the public are concerned about animal welfare and animal rights (Moon et al. 2015). The general public may understand the need for eradication efforts (García-Llorente et al. 2008) but may believe strongly that eradication should be conducted in a humane and ecologically responsible manner (Crowley et al. 2017). Socio-demographic factors may also play a role in the public's support for ISM actions. Older members of the public may be more supportive of ISM (Bremner & Park 2007; Sharp et al. 2011) and more concerned about invasive species (Harvey et al. 2016). Men may be more supportive than women of eradication efforts and lethal control (Bremner & Park 2007; Lauber et al. 2001), while individuals with a higher level of education may be more supportive of containment and eradication efforts (Sharp et al. 2011).

Although these findings are illuminating, better understanding of how to motivate public support for different ISM actions targeted at different taxa is needed (McLeod et al. 2015; Crowley et al. 2017; Shackleton et al. 2019a,b; van Riper et al. 2019). Less than 5% of the invasive species literature is comprised of social science studies (Vaz et al. 2017; Shackleton et al. 2019b), and most behavior change research related to ISM has focused on people's knowledge, values and attitudes towards invasive species and species' impacts (McLeod et al. 2015). Limited social science studies that integrate behavioral theories have hampered ISM (Shackleton et al. 2019a,b) because managers have erroneously assumed that disseminating information through education and outreach will alter people's attitudes and behavior (McLeod et al. 2015). McLeod et al. (2015) advocated for the use of an array of behavioral theories, including Schwartz's (1977) norm activation theory, Stern et al.'s (1999) value-belief-norm theory and Slovic et al.'s (2007) affect heuristic, to inform and improve ISM actions and policy (see also van Riper et al. 2019; Coon et al. 2020).

The norm activation and value-belief-norm theories demonstrate how personal norms (a moral obligation to engage in pro-environmental behaviors, such as environmental citizenship and policy support, including support for ISM) are activated by awareness of the consequences (AC) of environmental conditions (e.g., awareness of the negative consequences of invasive species introduction, spread and establishment to other people or to things an individual values such as native species, domestic animals, or the biosphere; De Groot and Steg 2009; Coon et al. 2020). The original moral norm-activation theory (Schwartz 1977) posited that pro-social behavior (which includes pro-environmental behavior) is motivated by individuals' AC of adverse events (e.g., environmental degradation) for other people (i.e., pro-environmental behavior is motivated by altruistic values). Stern et al. (1999) generalized this model by emphasizing the importance of accounting for AC to non-human species, the biosphere, and other relevant impacts of an environmental threat (e.g., economic impacts). Stern et al. (1999) stressed that pro-environmental behaviors may be motivated by consideration of how an environmental threat impacts the individual or what they care about (i.e., pro-environmental behaviors may also be motivated by egoistic, traditionalist or biospheric values). The affect heuristic (Slovic et al. 2007) emphasizes the role of emotion in

how people frame and respond to risks (e.g., species invasions) and complex problems (e.g., implementing appropriate ISM actions). Commensurate with McLeod et al.'s (2015) recommendation that multiple behavioral theories should be used in concert to ascertain how public support for ISM actions can be attained, we developed and administered a questionnaire to measure determinants of public support for three ISM actions (prevention, eradication and containment), utilizing key constructs from the norm activation, value-belief-norm and affect heuristic theories.

The first ISM action we examined was public support for prevention. Preventing the transport and release of non-native species is critical to mitigate or eliminate invasion risks and the expense of managing species invasions (Simberloff, 2013). Invasive species may be accidentally or deliberately transported via different pathways (Hellmann et al. 2008; Pyšek 2020), including the plant trade, the pet trade, and the live bait trade (Hulme 2008). We also examined public support for eradication and containment. Early detection and rapid response to any release event are vital to ensure that non-native species do not form a breeding population and become established in a new environment (Lodge 2006; Genovesi 2008). If a non-native species becomes established then eradication efforts (euthanasia of non-native species) are required, but eradication becomes increasingly expensive and less likely to succeed as the non-native population grows and spreads (Lodge et al. 2006; Yokomizo et al. 2009; Simberloff et al. 2013). If eradication becomes unlikely then containment strategies are required to limit population sizes, prevent further spread of the species and reduce invasion impacts (Simberloff et al. 2013).

We explored public support for ISM actions with specific reference to risk, AC, species charisma (which may evoke strong emotional responses in people), and socio-demographic characteristics of the public. Both the invasion process and ISM are characterized by risk. Per Haimes (2009), we define risk as a function of an invasion threat (e.g., the release of a non-native species), the probability and consequences of the threat (e.g., reduced biodiversity and species extinctions; Clavero & García-Berthou 2005; Butchart, 2010), and the time frame over which the risk manifests. We specifically focused on the ecological risks (e.g., predation, parasitism, herbivory, competition for available resources), economic risks (e.g., reduced economic returns from resource-based industries such as agriculture, fisheries and recreation), and human welfare risks (e.g., the spread of pathogens and diseases) associated with species invasions (Simberloff 2014; Meyerson et al. 2019). ISM is a risk management process, whereby potential actions (prevention, eradication, containment) generate trade-offs in terms of current and future costs, benefits, and risks (Haimes 2009). We posited that the public's support for ISM (risk management) actions would depend on their risk perceptions pertaining to both the invasion process and specific invasive species. Previous research suggests that the public is often unaware of the actual or potential risks associated with species invasions or may misinterpret these risks (Gozlan et al. 2013; Mayer et al. 2015), which results in disagreement about ISM actions (Estévez et al. 2015).

People's support for ISM actions (a pro-environmental behavior) thus depends on their AC pertaining to species invasions (McLeod et al. 2015; Coon et al. 2020). Slimak and Dietz (2006) found that people's ecological risk perceptions, including their perceptions of invasion risks, are a function of their AC. Within the context of our study, an individual's ability to recognize how species invasions may adversely impact native species and human well-being and livelihoods is encompassed in AC. Consistent with Stern et al. (1999) and De Groot and Steg (2009), we posited that individuals' support for government-implemented ISM actions would depend on two separate, but related, consequences of not mitigating species invasions:

1) the general negative environmental, economic and social consequences of species invasions (i.e., an awareness of negative consequences to others and the environment); and 2) how species invasions negatively impact what the individual cares about (i.e., an awareness of the specific and personal negative consequences of species invasions for the individual's livelihood or property, the welfare of their family and pets, or native species the individual cares about). Individuals' recognition of these adverse consequences of species invasions generates the intention (or willingness) to engage in pro-environmental behaviors (De Groot and Steg 2009; Coon et al. 2020). For the purposes of this study, we focused on how people's willingness to make a useful contribution to government efforts to manage species invasions (e.g., reporting sightings of non-native species or staying informed about non-native species) may reinforce their support for government-implemented ISM. We posited that people who are aware of the adverse consequences of species invasions are more likely to recognize the importance of taking actions to mitigate invasion risks, which would generate a moral obligation to also support government-implemented ISM actions (see also Mayer et al. 2015; Caplenor et al. 2017; Coon et al. 2020).

The norm activation and value-belief-norm theories assume rational choice, i.e., that people's actions are motivated by the expected outcomes of these actions, and the values and probabilities attached to these expected outcomes (McLeod et al. 2015). The role of emotions in forming people's attitudes towards invasive species and their support for ISM is not encompassed in these theories. However, the affect heuristic (Slovic et al. 2007) recognizes that people may base judgements and decisions on their feelings, rather than cognitive deliberation, especially when dealing with complex problems like species invasions. Positive emotional responses mitigate or offset perceived risks (Finucane et al. 2000), for example invasion risks. Animals often evoke strong emotional responses in people (especially when these animals are charismatic), which in turn influences people's support for animal management (Jacobs et al. 2014). The public's support for ISM may thus depend on their emotional response to the charisma (also commonly referred to as the ''attractiveness'', ''appeal'', or ''beauty'') of the species to be managed (Jarić, 2020; see also Shackleton et al. 2019b). Charismatic invasive species are characterized by visual (e.g., morphology), acoustic (e.g., bird calls), olfactory (e.g., floral fragrances), behavioral (e.g., anthropomorphic behaviors) or symbolic (e.g., cultural) traits that affect people's perceptions, attitudes, and behaviors toward them (Shackleton et al. 2019b; Jaric´ et al. 2020).

To test how type of invasive species, species charisma, risk, AC, willingness to assist in ISM, and socio-demographics influence public support for ISM actions, we developed and administered a questionnaire to measure public support for government-implemented ISM actions targeting invasive birds, fish, rodents and herpetofauna that pose an array of ecological, economic and human welfare risks. We predicted that: 1) support for ISM actions would be positively correlated with people's concerns about invasion risks; 2) members of the public would be more supportive of ISM actions for animals that are not charismatic; and 3) support for government-implemented ISM actions would be positively correlated with individuals' AC and willingness to assist in ISM (Fig. 1). We also predicted that respondents' demographics would influence their support for ISM actions, specifically support would be correlated with respondents' gender, age, and education level.

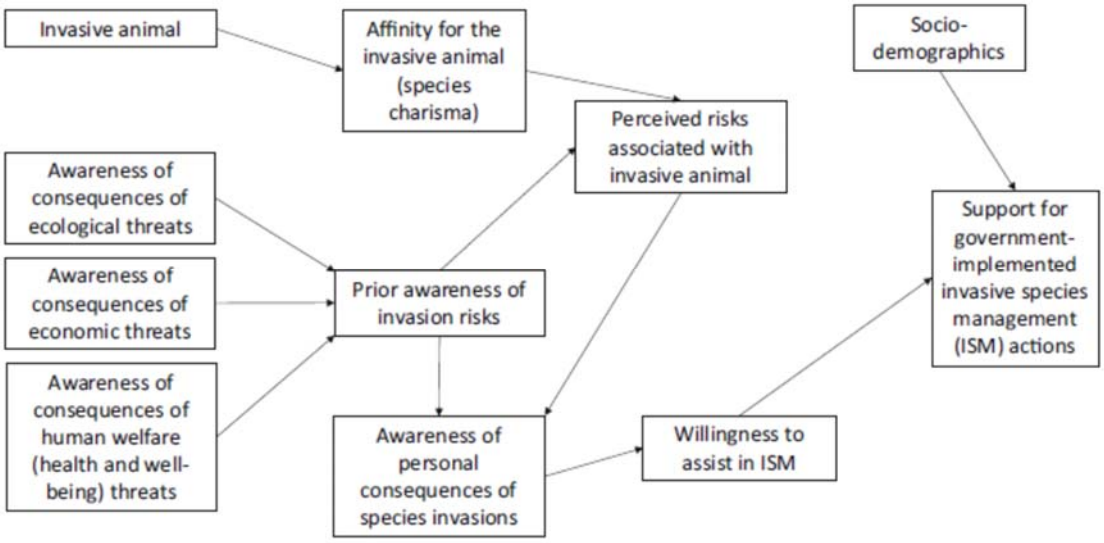

Fig. 1 Conceptual model of the public's support for invasive species management

Methods

Study area

We conducted this research in Florida because, with three significant trade ports, a large volume of non-native and invasive species flow into Florida (Hardin 2007). In 2013 > [7,000 birds, > [750 mammals, > [600,000 herpetofauna and > [20 million fish were imported into the state according to the United States Fish and Wildlife Service (USFWS) Law Enforcement Management Information System (LEMIS) division. Many of these animals, in particular herpetofauna and fish, were imported to supply the pet trade (Krysko et al. 2016). Florida residents actively engage in the non-native pet trade (Episcopio-Sturgeon and Pienaar 2019), which was the introduction pathway associated with over 80% of the non-native herpetofauna species introduced in Florida between 1863 and 2010 (Krysko et al. 2011) and is the largest source of introduced fish in Florida (Padilla and Williams 2004).

Florida has > [123 established non-native species (Hardin 2007), including the largest number of established herpetofaunal species in the world (Krysko et al. 2016). Many species introductions have resulted in established breeding populations because Florida's climate mirrors the native environment of many released non-native species (Simberloff 1996; Hardin 2007). The susceptibility of Florida to species invasions threatens the state's ecosystems and biodiversity, including the > [147 vertebrate species and subspecies and > [1,700 invertebrate species that are endemic to Florida (FWC 2019). For example, the introduction of the Burmese python (*Python bivittatus*) has resulted in population-level effects on native mammals and threatens wading bird colonies in southern Florida (Dorcas et al. 2012; Sovie et al. 2016; Orzechowski et al. 2019).

Sample population

We administered an online questionnaire to the Florida public. Based on available funding, we paid a company that administers online surveys (Qualtrics) to recruit 1,500 survey respondents. Qualtrics partners with online panel providers to recruit survey participants, who receive monetary compensation upon proper completion of the questionnaire (e.g., no speeding through the questionnaire, no nonsensical written answers). We instructed Qualtrics to use proportional quota sampling to attain a non-probability sample of Florida residents. Non-probability sampling is a sampling method in which members of the target population

do not have an equal chance of participating in a study. We instructed Qualtrics to sample Florida residents who were representative of the Florida population in terms of age and education demographics using quotas based on the 2010 U.S. Census: 18–24 years of age (n = 150; 10%); 25–34 years (n = 270; 18%); 35–44 years (n = 270; 18%); 45–54 years (n = 300; 20%); 55–64 years (n = 285; 19%); ≥ 65 years (n = 225; 15%); high school graduate or GED (n ≥ 435; ≥ 29%); some college/associate or technical degree (n ≥ 450; ≥ 30%); Bachelor's degree (n ≥ 270; ≥ 18%); graduate or professional degree (n ≥ 150; ≥ 10%). Qualtrics implemented the questionnaire from June 1st to July 5th, 2019.

Questionnaire design

Each questionnaire included images and a description of four invasive 'case study' animals that varied in taxa (birds, rodents, herpetofauna, fish), charisma, types of invasion risk, ranges throughout Florida, and appropriate ISM actions. We selected case study animals in consultation with the Florida Fish and Wildlife Conservation Commission (FWC) according to three criteria: 1) they are of concern to the FWC; 2) the animals likely varied in charisma based on physical appearance (e.g., coloration, texture and moisture of skin, tooth structure), behavior (e.g., crawling, jumping, flight), and symbolic traits (e.g., religious associations with reptiles, health concerns pertaining to rodents); and 3) the animals presented different types and levels of ecological, economic, and human welfare risks (Table 1). We intentionally selected animals that had received little or no media coverage in Florida to avoid response bias based on erroneous media reports. While species such as the nutria (*Myocastor coypus*) and the cane toad (*Rhinella marina*) have received considerable media coverage in other regions of their invasive range, all species included in the surveys had received limited media coverage in Florida prior to our research. The risks we presented were based on reports provided by the FWC and discussions with invasion scientists.

We designed the questionnaire so that each respondent randomly received one bird, herpetofauna, rodent, and fish case study animal (four animals in total). This design ensured that each animal was presented to at least 500 respondents. We did not distribute all 12 animals to each respondent to prevent respondent fatigue arising from an overly long questionnaire. We thoroughly pre-tested the questionnaire with 20 Florida residents using both conventional and cognitive pre-testing. We asked pre-test participants to describe their emotional reactions to the different case study animals and what had triggered these reactions (i.e., we tested that the animals varied in charisma), if they had any prior knowledge of these animals, and their perceptions of the risks presented by the animals. The pre-tests indicated that individuals were unaware or minimally aware of the 12 selected case study animals (i.e., although participants might have been aware that an animal was invasive in another state or country, none of them were aware that the case study animals had been introduced into Florida), the species included in the surveys elicited different emotional responses, respondents understood questions as we intended, and the information presented in the questionnaire did not introduce response bias (such as untruthful or misleading responses that the respondent believes are socially desirable or extreme responses that do not accurately reflect the respondent's true views). Pre-test participants resided in different regions of Florida, confirming that lack of awareness of the selected case study animals was not regionally based.

We first assessed respondents' prior awareness of the adverse consequences of species invasions (which we refer to as 'prior awareness of invasion risks') before presenting them with specific risks associated with the case study animals. We informed respondents that invasive animals pose ecological risks (outcompete native wildlife for resources, spread

diseases to native wildlife, pollute waterways, eat native wildlife or their eggs), economic risks (property damage, crop and livestock damage, negatively affect tourism, infrastructure damage, and harm to recreational and commercial fisheries) and human welfare risks (direct injury to people, spread diseases and parasites, harm or poison pets, and indirect injury to people). We asked respondents which of these adverse consequences of species invasions they were previously aware of (yes = 1, no = 0). We elicited respondents' prior awareness of invasion risks in this manner because pre-tests confirmed that members of the public did not have sound prior knowledge of the ecological, economic, or human wellbeing risks (and adverse consequences) associated with invasive species. Asking respondents if invasive species pose ecological, economic, and human wellbeing risks without defining what we meant by these risks would likely have resulted in biased responses (i.e., respondents may have agreed that species posed these risks because they assumed this was the correct response or they did not want to appear uninformed). Our approach to measuring prior awareness of invasion risks provided us with a far more accurate measure of which risks and adverse consequences respondents were aware of, and which risks and consequences were less commonly known (as confirmed during pre-tests)

We then introduced the case study animals included in the study. We first explored respondents' affinity for the animals (a measure of affect or emotional response based on animals' charisma) by presenting them with images of the animals and asking them ''based on the physical appearance of the [species], indicate your level of agreement with the following statements: 1) this animal looks threatening to me; 2) I would enjoy seeing this animal in the wild in Florida; 3) I would like to have this animal in my neighborhood; 4) I would be interested in having this animal as a pet; and 5) this animal looks appealing to me'' (strongly disagree = -2, disagree = -1, neither agree nor disagree = 0, agree = 1, strongly agree = 2). We followed these images with information about the animals, including the ecological, economic, and human welfare risks (presented as human health and well-being risks for ease of understanding) each animal poses (Table 1) and where they are currently or historically found in Florida. We assessed respondents' perceptions of the ecological, economic, and human welfare risks posed by the case study animals based on the information we provided to respondents (very unconcerned = -2, unconcerned = -1, neutral = 0, concerned = 1, very concerned = 2). We also measured if respondents perceived the animals to be a 'serious risk to Florida' and a 'risk to [their] family or household' using a five-point scale (strongly disagree to strongly agree). We measured respondents' support for management actions for each of the animals (prevention, eradication, or containment; for ease of understanding, these were presented to respondents as prevention, euthanasia, and control programs) on a 5-point scale (strongly oppose = 1, oppose = 2, neutral = 3, supportive = 4, strongly supportive = 5).

Drawing on Stern et al. (1999), De Groot and Steg (2009) and van Riper and Kyle (2014), we measured respondents' 'awareness of personal consequences of species invasions' by asking them ''how much of a threat do you think non-native species are to you in terms of: 1) threats to your livelihood; 2) eliminating native species you care about; 3) harming your family, your pets, or yourself; 4) damaging your property; and 5) increasing your taxes to fund management actions?'' (not a threat = 1, a small threat = 2, a moderate threat = 3, a large threat = 4). Drawing on Coon et al. (2020), we measured respondents' 'willingness to assist in ISM' by asking them how likely they would be to commit to the following actions that aid in preventing the release and controlling the spread of non-native species in Florida: 1) reporting sightings of non-native species; 2) preventing the release of any pets [they] obtain; 3) avoiding purchases that can transport non-native species to Florida; and 4) staying

Table 1 Information presented in surveys about the risks and appropriate management actions for species

Species	Ecological risks	Economic risks	Human welfare risks	Management action
Birds				
Egyptian goose (*Alopochen aegyptiaca*)	Compete with native wildlife for resources. Interbreed with native birds. Destroy nests of native birds. Drown native birds.	Eat crops (grain and potatoes). Damage crops (defecating and trampling).	May be aggressive towards people. May transmit avian influenza to humans.	Containment
Chestnut-fronted macaw (*Ara severus*)	Steals nesting cavities of native birds. Transmits diseases to native birds. Spreads non-native plant seeds.	Transmits diseases to poultry (chickens, ducks, turkeys)	May transmit diseases to humans	Eradication
Red-whiskered bulbul (*Pycnonotus jocosus*)	Competes with native birds for resources. Transmits diseases to native birds. Spreads non-native plant seeds.	Damage fruit and vegetable crops	May transmit avian influenza and other diseases to humans	Eradication
Herpetofauna				
Common caiman (*Caiman crocodilus*)	Eats native wildlife. May compete with native American alligators and crocodiles for resources. May transmit parasites to native wildlife.	May attack livestock	May attack humans. May attack and kill pets.	Eradication
Nile monitor (*Varanus niloticus*)	Eats native wildlife. Competes with native wildlife for resources.	May feed on poultry (chickens, ducks, and turkey). Burrows can damage property.	May attack humans. May attack and kill pets.	Containment
Cane toad (*Rhinella marina*)	Eats native wildlife. Competes with native wildlife for resources. Toxic to most wildlife that try to eat it.	Will eat almost anything (pet and livestock feed). High veterinary bills for pets inflicted by cane toad's toxin.	Toxic skin-gland secretions can harm people and frequently kill pets	Containment
Rodents				
Nutria (*Myocastor coypus*)	Damage wetlands and marshes by burrowing and overgrazing. Destroy nests of native birds. Transmit diseases and parasites to native wildlife.	Damage crops (sugarcane, rice, corn)	May transmit salmonella and other diseases to humans. Burrows may lead to injuries from collapsing banks.	Eradication
Gambian pouched rat (*Cricetomys gambianus*)	Compete with native wildlife for resources. Spread diseases to native wildlife. Spread non-native plant seeds.	Feed on different fruit crops	May transmit monkeypox and other diseases to humans	Eradication
Black-tailed prairie dog (*Cynomys ludovicianus*)	Eat native plants. Transmit diseases to native wildlife.	Livestock can be injured stepping in burrows. Damage crops.	May transmit bubonic plague and other diseases to humans	Prevention
Fish				
Vermiculated sailfin catfish (*Pterygoplichthys disjunctivus*)	Causes erosion and siltation by burrowing. May transmit diseases to manatees. Harasses manatees.	Erosion from burrows may reduce property values. Can damage fishing gear. May reduce fishing catches.	Burrows may lead to injuries from collapsing banks	Containment
Red-bellied pacu (*Piaractus brachypomus*)	Spread non-native plant seeds. Competes with native fish for resources.	May harm freshwater fisheries	May harm humans with powerful bite (close relative of the piranha)	Prevention
Asian swamp eel (*Monopterus albus*)	Transmits diseases to native wildlife. Competes with native fish for resources and can travel on land. Damages habitat by burrowing.	Burrows may reduce property value	Carries parasites that can infect humans	Eradication

informed about non-native species (not at all likely = 1, somewhat likely = 2, moderately likely = 3, very likely = 4). Finally, we collected information on respondents' gender, age, education level, income level, and ethnicity.

Data analysis
We conducted principal factor analysis using Stata/SE (version 15.0) to test whether questionnaire items could be combined to generate composite variables (e.g., by summing individual items to generate scores that measured respondents' awareness of personal consequences of species invasions and willingness to assist in ISM). We used the Kaiser-one criterion (retain factors with an eigenvalue > 1) to determine which factors to retain and which items loaded onto those factors (Floyd and Widaman 1995; Santos 1999). We used Cronbach's alpha (≥ 0.7) to ascertain the reliability and internal validity of items.

We estimated structural equation models (SEM) using R (version 3.6.1) to determine which explanatory variables were directly or indirectly correlated with respondents' support for ISM actions. We utilized the ''piecewiseSEM'' package because this updated version of SEM allowed us to estimate random effects generalized least squares (GLS) models (Lefcheck 2016). We estimated three SEMs for each of the ISM actions. We estimated random effects models to account for the fact that many respondents were presented with more than one animal for which the same management action applied. We estimated > 45 models for each management action that differed in the explanatory variables included in the model. We compared models utilizing Fisher's C (and corresponding p-value) and the Bayes-Schwarz Information Criterion (BIC). We selected models with the lowest BIC as our best fit models (Huang 2017; Lin et al. 2017).

We effects-coded case study animals for both the eradication and containment models to avoid multicollinearity. We denoted the presence of an animal on a survey such that one animal was the reference animal (coded as -1) and the other animals were either present (1) or absent (0) on the survey. The red-whiskered bulbul was the reference animal for the eradication model and the vermiculated sailfin catfish was the reference animal for the containment model based on this effects-coding approach. We binary coded animals for the prevention model because only two animals were included in this model.

Results
We received a total of 1,561 completed questionnaires from the 7,500 individuals who were eligible to take the survey based on the survey quotas (completion rate of 20.8%). A total of 1,249 respondents (80.0%) were female, exceeding the Florida female population (51.1%; U.S. Census Bureau 2012; see Table S1 in supporting information). Respondents' median age was 45–54 years old, which exceeded the median age for Florida residents (40.7 years old; U.S. Census Bureau 2012). Respondents' median education level (some college/associate or technical degree) was consistent with the median education level of Florida residents. A total of 1,206 respondents (77.3%) identified themselves as white, which was consistent with Census data (75% of Florida's population was white; U.S. Census Bureau 2012).

We generated a composite score, entitled 'prior awareness of invasion risks', to assess respondents awareness of the adverse consequences associated with the ecological risks (out-compete native wildlife for resources, spread diseases to native wildlife, pollute waterways, eat native wildlife or their eggs), economic risks (property damage, crop and livestock damage, negatively affect tourism, infrastructure damage, harm to recreational and commercial fisheries) and human welfare risks (direct injury to people, spread diseases and parasites, harm or poison pets, and indirect injury to people) generated by species invasions (range of 0–13). Respondents' prior awareness of invasion risks was skewed left (7.66 ± 3.74), indicating that respondents tended to be aware of invasion risks and the adverse consequences of species invasions. Respondents scored highest in their awareness of human

welfare risks associated with invasive species and lowest in their awareness of economic risks associated with invasive species (see Table S2 in supporting information).

When asked to assess the charisma of the case study animals, respondents were most likely to agree that the pouched rat, caiman, monitor and swamp eel look 'threatening' (median = agree). Respondents were most likely to agree that the macaw and bulbul look 'appealing' and were animals they would enjoy seeing in the wild in Florida (median = agree). With the exception of the bird species, respondents were likely to disagree that they would want any of the case study animals in their neighborhood. Respondents were likely to strongly disagree that they would want any of the case study animals as pets, although their level of disagreement was lower for the macaw and bulbul (median = disagree; see Table S3 in supporting information).

On average, respondents were concerned about the ecological and economic risks posed by the case study animals included on their surveys (median = concerned) and were very concerned about the human welfare risks posed by the pouched rat, prairie dog, caiman, pacu, and swamp eel (median = very concerned; see Table S4 in supporting information). Respondents were likely to agree that the case study animals included on their surveys were a serious risk to the state of Florida (median = agree), except the prairie dog, bulbul, and macaw (median = neither agree nor disagree). Respondents were most likely to agree that the cane toad was a risk to their family, household, or pets (median = agree) and least likely to agree that the macaw presented these same risks (median = disagree; see Table S5 in supporting information). On average, respondents were supportive of ISM actions for the case study animals included on their surveys (median = supportive), except for the macaw and bulbul (median = neutral; see Table S6 in supporting information). We found no difference in support for ISM actions, based on whether respondents lived in counties in which the case study animals were present.

Principal factor analysis

Based on the principal factor analysis, we created the following composite variables: 1) respondents' affinity for case study animals (to measure animals' charisma); 2) respondents' perception of risks associated with case study animals; 3) respondents' awareness of personal consequences of species invasions; and 4) respondents' willingness to assist in ISM; see Table S7 in supporting information). Respondents' affinity for case study animals (a measure of species charisma) captured respondents' affect (emotional response) for each animal based solely on the images of the animals. This score was skewed right across all ISM models (mean = -1.86 for the prevention model; mean = -3.23 for the eradication model; mean = -3.47 for the containment model; range of -10 to 10), implying that respondents tended not to find the case study animals charismatic. Respondents' perception of risks associated with case study animals encompassed their concern about the risks (ecological, economic, and human welfare) associated with the animals and the risks the animals pose to Florida and their family or household. This score was skewed left across all ISM models (mean = 3.28 for the prevention model; mean = 3.56 for the eradication model; mean = 3.96 for the containment model; range of -10 to 10), indicating that respondents tended to perceive the risks associated with the case study animals. Respondents' awareness of personal consequences of species invasions was skewed slightly left (mean = 13.41 for the prevention model; mean = 13.37 for the eradication model; mean = 13.49 for the containment model; range of 5 to 20), implying that respondents tended to be aware of the consequences of species invasions to what they care about. Respondents' willingness to assist in ISM was skewed left (mean = 13.08 for the prevention model; mean = 13.15 for the eradication model;

mean = 13.12 for the containment model; range of 4 to 16), signifying that respondents tended to perceive that they could make a useful contribution to managing invasion threats. The distributions of all composite variables and items included in these variables are included in the supplementary materials (Tables S8–S12).

SEM models

Although there was no direct correlation between the case study animals and respondents' support for prevention or containment, respondents who received the Asian swamp eel and the Gambian pouched rat as case study animals were more likely to support eradication, whereas respondents who received the chestnut-fronted macaw and the common caiman were less likely to support this action (Tables S13–S15, Figs. 2, 3 and 4). Across the ISM actions, respondents' perceptions of risks associated with case study animals were positively correlated with their support for ISM actions. For both prevention and containment, respondents' prior awareness of invasion risks was directly positively correlated with their support for these actions. Respondents' prior awareness of invasion risks also indirectly increased their support for all ISM actions by increasing their perceptions of risks associated with case study animals, their awareness of personal consequences of species invasions, and their willingness to assist in ISM. Across ISM actions, respondents' support for government-implemented ISM was directly positively correlated with their willingness to assist in ISM. For eradication and containment, respondents' support for ISM was directly positively correlated with their awareness of personal consequences of species invasions, although this awareness also indirectly influenced respondents' support for all government-implemented ISM actions by increasing their willingness to assist in ISM.

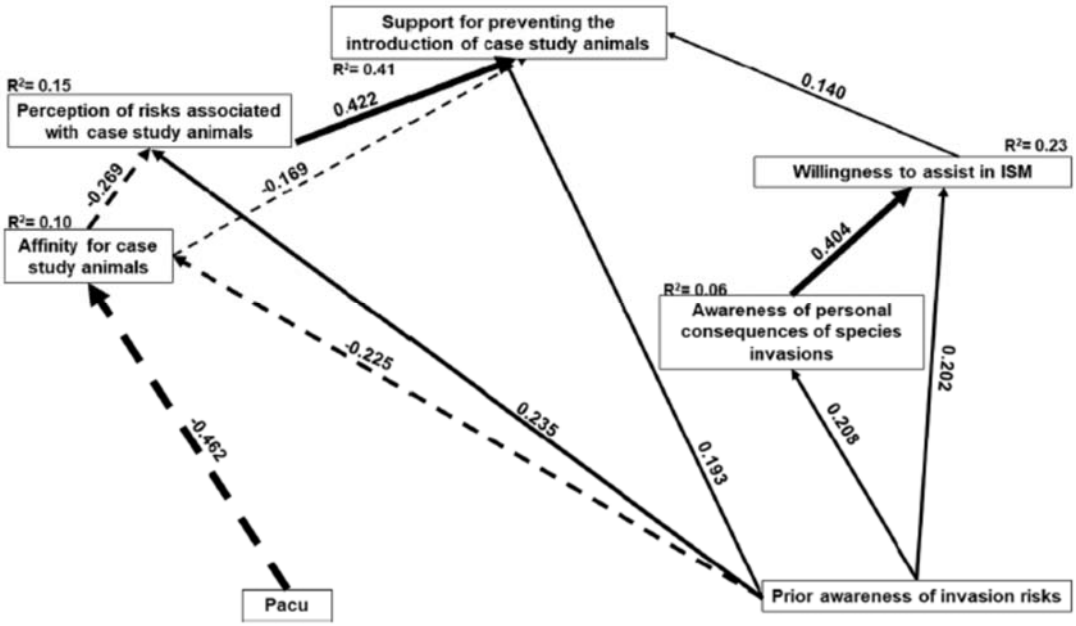

Fig. 2 Prevention of the introduction of case study animals structural equation model (SEM). Solid arrows indicate a positive correlation and dashed arrows indicate a negative correlation. Thicker arrows represent a stronger correlation

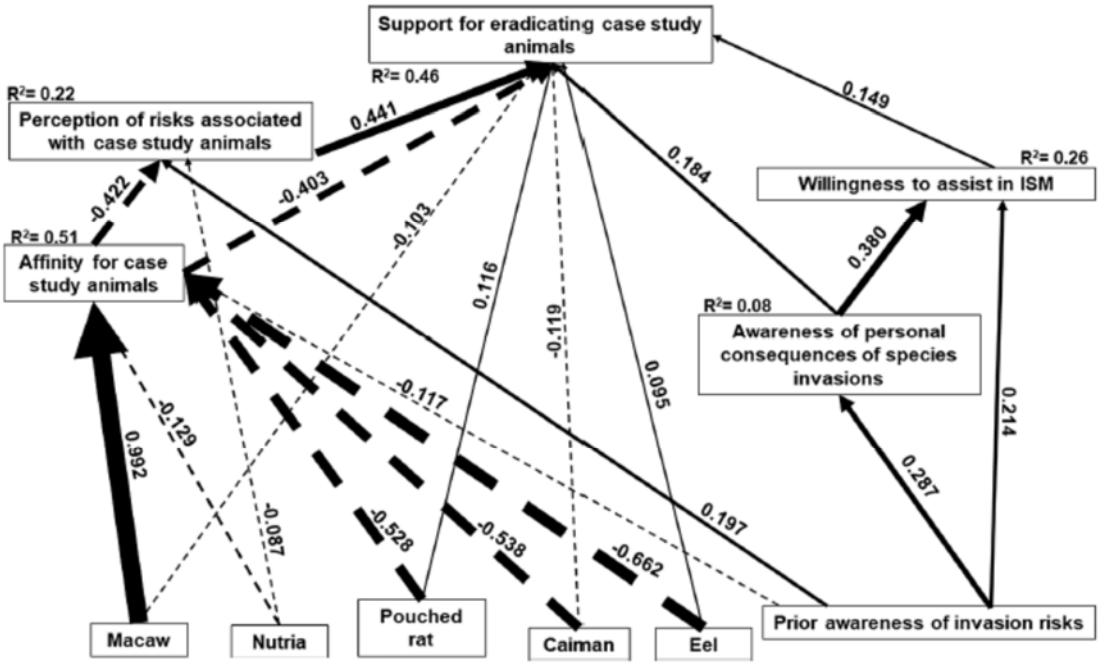

Fig. 3 Eradicating case study animals structural equation model (SEM). Solid arrows indicate a positive correlation and dashed arrows indicate a negative correlation. Thicker arrows represent a stronger correlation

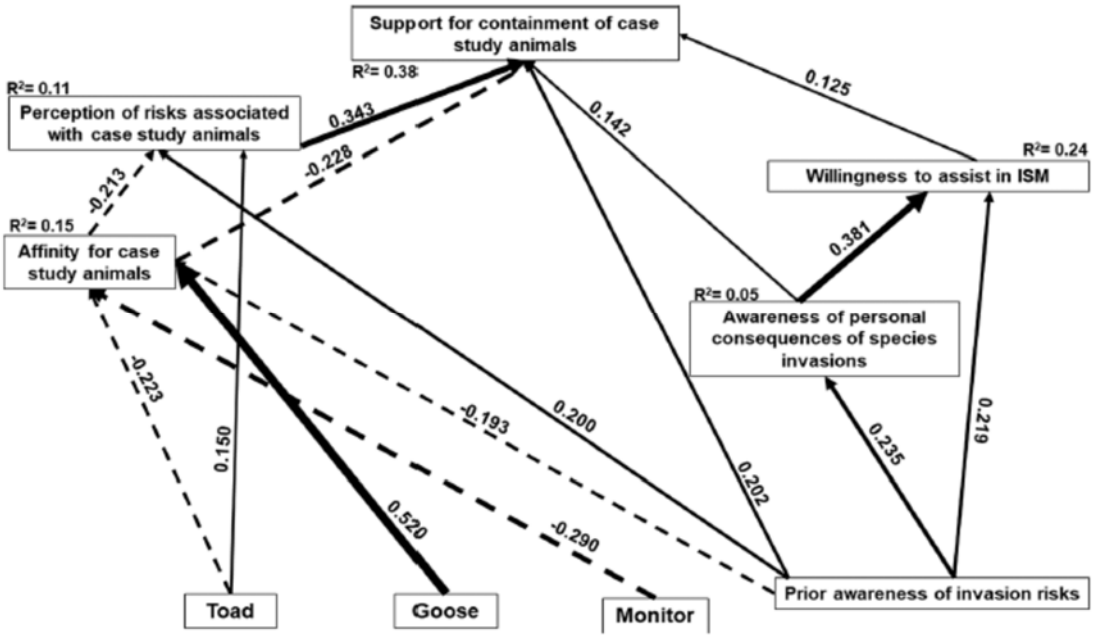

Fig. 4 Containment efforts for case study animals structural equation model (SEM). Solid arrows indicate a positive correlation and dashed arrows indicate a negative correlation. Thicker arrows represent a stronger correlation

Respondents' support for government-implemented ISM was correlated with their affinity for case study animals (i.e., species charisma) both directly and indirectly (negative correlation between affinity for case study animals and risk perceptions pertaining to the animals). Lower affinity for the red-bellied pacu, Asian swamp eel, Gambian pouched rat, nutria, cane toad, and Nile monitor increased respondents' support for ISM because respondents' affinity for these case study animals was negatively correlated with their support for ISM. Respondents'

higher affinity for the macaw and Egyptian goose reduced their support for ISM. Respondents' opposition to eradicating the common caiman was lessened by lower affinity for the caiman (which was not generally considered a charismatic species by respondents). In addition to increasing their risk perceptions pertaining to individual case study animals, awareness of personal consequences of species invasions and willingness to assist in ISM, respondents' prior awareness of invasion risks indirectly increased their support for government-implemented ISM by reducing their affinity for the case study animals. Across all ISM actions, respondents' support for ISM was not correlated with their demographic characteristics.

Discussion

Our analysis suggests that the general public's support for government-implemented ISM is positively correlated with their prior awareness of invasion risks, AC related to species invasions, willingness to assist in ISM, which invasive animals are being managed, and individuals' emotional and cognitive evaluation of the threats posed by different invasive animals. Consistent with McLeod et al.'s (2015) recommendations, our findings highlight the importance of using conservation behavior theories that incorporate risk perceptions, affect (emotional responses), and AC to explore the public's support for ISM actions to develop a more integrated and holistic understanding of public support for ISM (see also Shackleton et al. 2019b). Our findings suggest a causal chain similar to that theorized by Stern et al. (1999), in which individuals who are aware of, and concerned about, invasion risks (as a whole) and/or the specific risks associated with individual species (e.g., cane toads) are more likely to commit to actions that mitigate these risks, including supporting ISM actions (see also Estévez et al. 2015; Shackleton et al. 2019b; Coon et al. 2020; Episcopio-Sturgeon and Pienaar 2020). Informing the public about the different risks associated with species invasions is crucial, but simply highlighting the ecological risks is not sufficient. People typically discount ecological risks when lesser known, less valued native species are affected (Gozlan et al. 2013). We found that respondents were least aware of the economic risks and the range of potential injuries associated with species invasions. Our findings suggest that public engagement and communication efforts should focus on the economic and human welfare risks associated with invasive species, which may be of greater relevance to many people (Shackleton et al. 2019b). Communication efforts should also highlight if invasive species pose direct risks to individuals or their households and how individuals may make useful contributions to mitigating species invasions, in order to reinforce moral obligations to support government-implemented ISM actions (Mayer et al. 2015; Caplenor et al. 2017; Coon et al. 2020).

Clear articulation of risks is particularly important for charismatic species, which evoke strong emotional responses in people. We found that respondents' affinity for animals mitigated their perceptions of invasion risks associated with these animals, which in turn reduced their support for ISM actions (see also Crowley et al. 2019; Shackleton et al. 2019b). The public tends to value species that are charismatic even if they are non-native or invasive (Bremner and Park 2007; Sharp et al. 2011; Crowley et al. 2019; Jarić et al. 2020). We found additional evidence that people's support for ISM actions decreases when the target animals are birds (Bremner and Park 2007; Crowley et al. 2019), which tend to be charismatic in terms of appearance, acoustics, behavior, and symbolic meaning (Jarić et al. 2020). However, if an uncharismatic animal poses risks (e.g., the Asian swamp eel) then people are more likely to support management actions, particularly when there are well-documented negative consequences for individuals' family or pets (e.g., risks of poisoning posed by the uncharismatic cane toad; van Dam et al. 2002). Interestingly, we found evidence that if an

invasive animal resembles a native animal (e.g., the common caiman resembles the American alligator, *Alligator mississippiensis*, and the American crocodile, *Crocodylus acutus*, which are both native to Florida), then people are less likely to support eradication of the animal even if they have low affinity for the animal and perceive the risks posed by the animal. Additional research is needed to identify how physical and behavioral traits of an animal influence support for ISM actions, especially if an animal closely resembles a native or culturally significant animal (Jarić et al. 2020).

Contrary to previous research (Lauber et al. 2001; Bremner and Park 2007; Sharp et al. 2011; Harvey et al. 2016), we found no correlation between respondents' socio-demographic characteristics and their support for ISM actions. We posit that people's beliefs are better predictors of their behavior than their sociodemographic characteristics. For example, findings of positive correlations between people's age and education and their support for management actions may have indirectly captured older or more educated individuals' greater awareness of invasion risks and associated higher levels of AC. We note that our sample was skewed in terms of gender composition, which is consistent with findings that questionnaire respondents are more likely to be female (Porter and Whitcomb 2005; Smith 2008). We therefore expected lower levels of support for eradication efforts and lethal control of case study animals (Lauber et al. 2001; Bremner and Park 2007). However, the median level of support for prevention and containment of the case study species (supportive) was identical to the median level of support for eradication of the nutria, Gambian pouched rat, common caiman and Asian swamp eel (supportive). Support for eradication was only lower for the two charismatic birds (the chestnut-fronted macaw and the red-whiskered bulbul).

Careful, thoughtful communication and outreach is required to engage the public in ISM actions or counteract public opposition to these actions, especially eradication of species or management of species that are charismatic (Osinki et al. 2019; Shackleton et al. 2019a,b). Although risk perceptions pertaining to both the invasion process and individual invasive species are important to engender public support for ISM actions, the charisma of species to be managed is an equally important consideration in implementing ISM. Our findings suggest that improving the public's understanding of the ecological, economic and human welfare risks associated with individual invasive species and species invasions as a whole may enhance the public's recognition of the importance of mitigating invasion risks. Communication about ISM actions and public engagement should highlight why reducing species invasions is important at the individual, household, and community level, and how people can assist in ISM actions. While most personal actions that the public can take pertain to prevention (e.g., not releasing unwanted non-native pets), increased public compliance with eradication and containment efforts is equally crucial to ISM (Crowley et al. 2017). Communicating risks that matter to the public and recognizing the importance of emotions in how people interpret invasion risks may increase the likelihood that the public will take an active role in preventing species invasions and supporting eradication and containment efforts.

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Ethics declarations

Conflicts of interest

We have no conflicts of interest to report.

Ethics approval

This research was approved on April 10th, 2019 by the University of Florida Institutional Review Board (IRB protocol #201900993).

Data availability

Data that support the findings of this study are available on reasonable request from the corresponding author, EFP. The data are not publicly available due to their containing information that could compromise the privacy of research participants.

Code availability

The coding generated during the current study is available from the corresponding author on reasonable request.

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