Risk Assessment Methodology

Reptile Invasiveness Scoring Kit (RISK)

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Introduction

Today's extensive global trade and travel ensure that biogeographic barriers no longer function at keeping distinct flora and fauna separate between continents (Lowe et al. 2000; Mooney and Hobbs 2000). As a result, foreign species have the ability to become more vagile, prolific, and able to broaden distribution ranges that threaten integrity of native ecosystems. Foreign species are referred to by many terms, most common of which are alien, introduced, nonnative, and exotic (Mack et al. 2000). An introduced species does not necessarily denote an invasive species, but the path from introduced to invader often involves a lag phase where an introduced species may go undetected, followed by a period of rapid growth and range expansion where it becomes established (Mack et al. 2000). An invasive species, as defined by the National Invasive Species Council (2006) is a species that is nonnative to the ecosystem under consideration and whose introduction causes or is likely to cause economic or environmental harm or harm to human health.

There are over 50,000 nonnative species in the United States alone (Pimental et al. 2005, USFWS 2012) and approximately 4,300 species are recognized as invasive species (Corn et al. 2002, USFWS 2012). Florida currently has the most species of introduced and established reptiles and amphibians in the world and the rate of accumulation of new species is increasing (Krysko et al. 2011, Meshaka 2011). Florida is a major port of entry for nonnative species that may become invasive via the exotic pet trade and by intentional and accidental introduction of nonnative species across its borders. Preventing introduction and establishment of nonnative species is the first line of defense against invasions. The Ecological Society of America (Mack et al. 2010) recommended application of screening procedures and risk analysis prior to introduction and establishment of nonnative species, and as a part of development of management strategies to prevent future introduction and establishment of invasive species.

The underlying approach of evaluating a species risk is to address: 1) factors that determine rate of entry, 2) biology and ecology of species, 3) availability of habitat and environmental factors that promote establishment in different geographical regions, 4) population dynamics of species, and 5) implications of uncertainties of risk estimates and risk reduction (Arriaga et al. 2004, Bartell and Nair 2004). These methodologies provide a baseline for assessment and prevention of introduced species that may become invasive under suitable environmental conditions, and may be qualitative, quantitative, or both.

A qualitative evaluation framework uses professional judgment and decision theory to assign species to risk ranking categories such as low, medium, and high risk based on biological characteristics/ecological correlates, often combined with climate information (USEPA 1998). Qualitative assessment often involves a series of yes/no questions where answers for each question have a numerical value (Yes = 1, No = 0); values are added and the final number is the score used to determine species rank for risk (Bomford et al. 2005, Koop et al. 2012, Lawson et al. 2013), or a value is assigned to each parameter using a ranking system (usually 1-5, lowest-highest likelihood) relative to a comparative group and scores are tallied for an overall value (Reed et al. 2012). Low overall values denote a low risk of establishment, intermediate values indicate a medium risk of establishment and high values equate with high risk of species establishment. Qualitative screening tools have been developed for a variety of plants (Pheloung et al. 1999, Daehler et al. 2004, Gordon et al. 2012, Koop et al. 2012) and some animal taxa including fish (FISK: Copp et al. 2008, Lawson et al. 2013), amphibians (AmphISK: Copp et al. 2008), amphibians and reptiles (Bomford et al. 2005), and reptiles (Fujisaki et al. 2009, Reed et al. 2012).

Quantitative frameworks incorporate ecological correlates in assessing a species' risk by quantifying cause and effect of raw data from case studies, or a compilation of previous studies and model simulation that predict species spread and associated effects (Reed 2005, Chiaverano and Holland 2014). Phylogenetic information, climate data of native and potentially invaded ranges, modeling effective population size and niche-modeling are also incorporated in quantitative techniques to predict a species invasiveness and potential for spread.

A semi-quantitative approach is rooted in the qualitative framework where results of a ranking system are produced using ecological correlates, a scoring system developed, and decision rules analyzed to assess species risk (Daehler et al. 2004, Bomford et al. 2005, Ricciardi and Cohen 2006, Corin 2014). A risk assessment framework that combines qualitative and quantitative methods may be more effective because it may more accurately capture the dynamic nature of species' interaction with their environment (Sikder et al. 2006).

The purpose of this analysis is to apply knowledge of ecological correlates of successful invasion to provide a foundation for a screening procedure that will identify potentially invasive species. Risk will be based on probability of introduction, establishment, spread, and impact. Since no universal list of ecological correlates exists we propose a taxa specific approach to assessing risk to ecological invasion. Here we present a risk assessment procedure for nonnative reptiles based on decision scoring or ranking ecological correlates of known successful invaders and locations of past and recent invasions paired with a semi-quantitative approach to identify risky species before they are imported or introduced, and to prevent further spread once established.

Methods

To develop a risk assessment methodology we first conducted an in-depth review of invasive species risk assessments (Mazzotti and Briggs-Gonzalez 2014). We also conducted a synopsis of biological, ecological, and historical information of target nonnative species to assess likelihood of and consequences of establishment (bioprofiles sent separately). From these sources, we compiled ecological correlates to identify potentially invasive species and developed a qualitative screening process based on decision rules (Bomford et al. 2005, Bomford et al. 2009, Copp et al. 2008, Fujisaki et al. 2010, Reed et al. 2012, Lawson et al. 2013). This framework is a combination of previously developed screening tools and modified for nonnative reptile species currently present or in the process of being imported/introduced into Florida. We present this screening tool for future review and input from professional expertise and stakeholder perspective to build consensus and support for its application. We also provide a guideline on types of data to include for a semi-quantitative approach in evaluating species risk.

Introduction and establishment of invasive species is an identified global problem and efforts need to target reduction or elimination of species introductions. Guidelines for risk assessments applied to invasive species start with identifying introduction pathways of nonnative species. Identified pathways for nonnative reptiles are as introductions via the pet trade, deliberate introduction for personal aesthetics, deliberate introduction for human consumption, deliberate introduction for biocontrol, cargo hitchhikers, nursery-trade hitchhikers, as deliberate release of pets and/or specimens, and as accidental release of pets and/or specimens (Bomford et al 2009, Romagosa 2009).

Evaluate import records

Wildlife trade whether for pets or as live specimens, is the most important pathway for introductions on a global scale (Kraus 2009), and the US provides one of the largest global markets (Romagosa 2014). Before a species can be introduced, it must first be imported (legally or illegally). Only legal import records exist and these are maintained by the State of Florida through US Fish and Wildlife Services Law Enforcement Management Information System (LEMIS). These LEMIS records are the most complete records available for both live CITES-listed and CITES-unlisted species into the US, however these data must be considered a minimum estimate of trade by the US (Romagosa 2014). If the proposed A series of Freedom of Information Act (FOIA) requests were filed through the USFWS for import records, vetted and cross-referenced by Dr. Christina Romagosa from 1968-2010 and continue to recently acquired 2013 records (Romagosa 2009, pers. comm. C. Romagosa). Between the period 1999-2010 over 12 million wild caught reptiles were imported into the US (Figure 1, from Romagosa 2011) and of these 9,299,922 reptiles were imported through Florida ports alone (Figure 2 from Romagosa 2011).

Implement qualitative risk assessment screening tool

Using reviewed LEMIS records, each target nonnative reptile species in the trade route can be qualitatively assessed using the presented decision rules screening tool. This qualitative assessment tool (Table 1) will require validation by reviewers/stakeholders to produce a final qualitative assessment framework for implementation. This screening tool addresses the transition phases of a species' invasion: arrival/establishment, spread, persistence, and impact (Bomford et al. 2003). We present associated ecological correlates of each transition phase and outline specific questions that address measures of each correlate. Each question is answered with either a yes/no question or on a number scale ranging from 0-2. There are 81 questions, and final score is calculated as the sum of scores from each transition phase, The minimum score is 0 and the maximum score is 94 which is then normalized to 100%; thus similar to other risk assessment analyses (Bomford et al. 2005, Bomford et al. 2009, Copp et al. 2008, Lawson et al. 2013) a species that scores between 0-25% is considered Low Risk, 26-49% is considered of Intermediate Risk, and a score of 50-100% denotes a species of High Risk or warrants Further Investigation.

Conduct climate matching analysis

The next step in the risk assessment protocol is to conduct climate matching to quantify potentially suitable habitats in the State of Florida relative to a target species native range. Climate variables that have been identified as relevant include a suite of rainfall, temperature, and other environmental data available from world meteorological stations (imported from BIOCLIM, Busby 1991, Table 2). Climate matching programs such as CLIMATE rank climate matching from zero (poorest match) to 10 (highest match) (Bureau of Rural Sciences 2006). CLIMEX 3.0 (Sutherst et al. 2007) scores climate variables from zero (no match) to a one (complete match). Species that score higher on the climate matching analyses are defined as risky species.

Geographic range size

To estimate a species geographic range size (km^2), the species native range can be plotted and verified using georeferenced distribution maps. The final area is calculated using geographic information systems (Fujisaki et al. 2010). Species geographic range size does not imply invasibility or a lack thereof; however, a large geographic range illustrates a species' potential for adaptability to novel environments.

Semi-quantitative analyses

A semi-quantitative analysis tests nonnative reptile species for associations with each ecological correlate and selects a set of variables that most effectively predict establishment success. There are a multitude of statistical analyses that can be used to test for species associations with ecological correlates. Multiple logistic regression analyses are appropriate for use on binary variables such as yes/no responses. Questions that present responses on a scale may be analyzed using general linear models or discriminant function analyses. Statistical models that incorporate effects of all variables are most effective at reflecting the dynamic nature of species invasion. Species association with ecological correlates can then be combined with climate matching results and estimated geographic range for a full model approach.

Three characteristics associated with establishment success have been identified across taxa: climate/habitat match, establishment success elsewhere, and propagule pressure (number arriving and/or number of release events) (Bomford et al. 2009, Fujisaki et al. 2010). Since no ecological correlate adequately predicts species introduction and establishment, risk assessments that account for these three factors will be more reliable (Hayes and Barry 2008). Complete records to address these three factors, however, do not exist, especially for reptiles and amphibians and assessing nonnative herpetofauna risk will most broadly depend on climate matching (Bomford et al. 2009). A qualitative framework aims to provide valuable information on establishment success elsewhere and propagule pressure, and when paired with climate matching and geographic range data a testable framework can be implemented for target nonnatives.

A test of this framework would start with a comparison of established versus non-established nonnative reptile species and validate the relevance of each correlate toward a species becoming established (Table 3, from Fujisaki et al. 2010). Standard evaluation of a screening tool is to determine how accurately the tool can identify species to invasion categories (non-invaders, minor invaders, major invaders), thus an overall test of the screening tool would be to compare differences of scores between known species that fall within these categories (Gordon et al. 2012).

Summary

- Preventing introduction and establishment of nonnative species is the first line of defense against invasions.
- Results of this project can be applied to setting priorities to prevent establishment of invasive reptiles in Florida.
- The underlying approach of evaluating a species risk is to address: 1) factors that determine rate of entry, 2) biology and ecology of species, 3) availability of habitat and environmental factors that promote establishment in different geographical regions, 4) population dynamics of species, and 5) implications of uncertainties of risk estimates and risk reduction.
- Risk assessment methodologies may be qualitative, quantitative or both.
- This screening tool is presented for future review and input from professional expertise and stakeholder perspective to build consensus and support for its application.
- This framework should be tested with a comparison of established versus non-established nonnative reptile species to validate relevance of each correlate toward a species becoming established.

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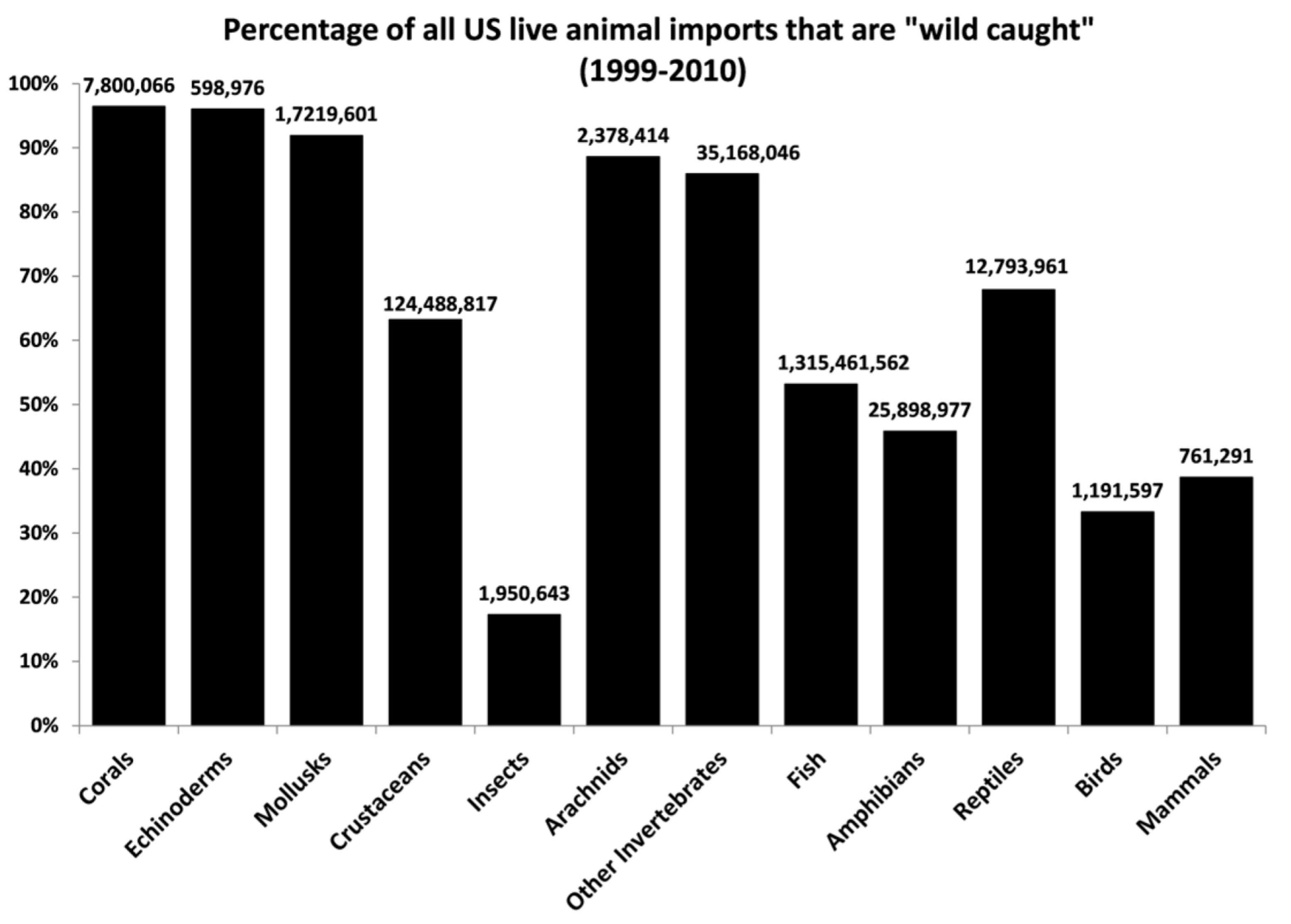

Figure 1. Percentage of all live animal imports declared as "wild caught" (1999-2010). The numbers above each bar represent the quantity of individuals imported for that taxonomic group (from Romagosa 2011).

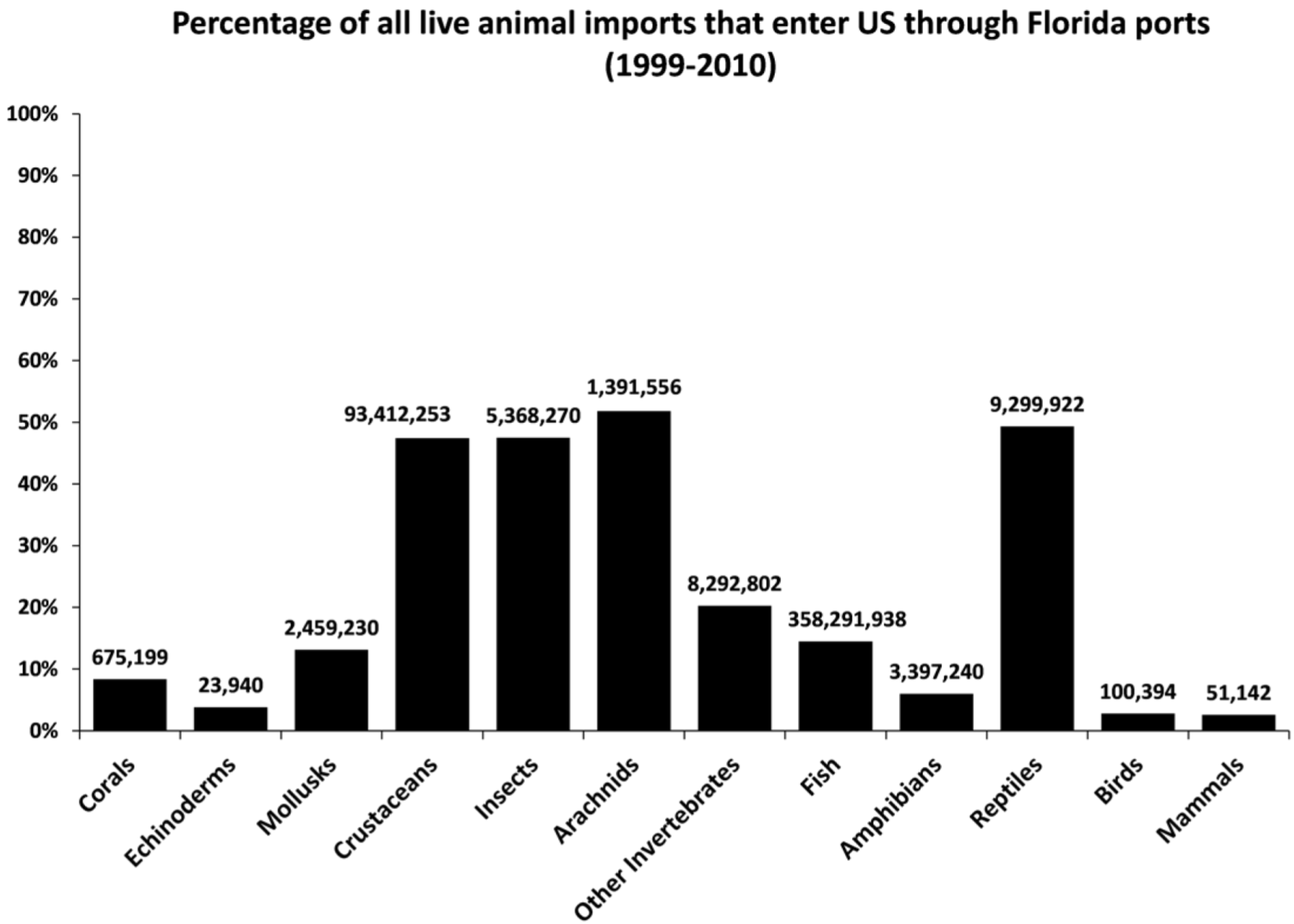

Figure 2. Percentage of all live animal imports that entered US specifically through Florida ports of entry (1999-2010). The numbers above each bar represent the quantity of individuals imported for that taxonomic group (from Romagosa 2011).

Table 1. Qualitative screening procedure for nonnative reptiles for the State of Florida targeting ecological correlates. Each ecological correlate is presented, a specific question addresses each correlate and can be answered with Yes/No or with on a scale. The guidance of how to weight responses for each score is presented and formula for calculating sums is provided.

Arrival/Establishment

Ecological Correlate	**Question**	**Score and Guidance**
(1.1) Taxonomic Order	Does the species belong to any of the following Orders? (Most successful orders are: Squamata-Lacertilia (lizards), and Squamata-Serpentes (snakes) (possibly Crocodilian though only data on one species (Fujisaki et al. 2010)) 0 – No 1 – Yes	________ A score of: 0 = ‘No’; while a score of 1 = ‘Yes’, unless otherwise explained
(1.2) Taxonomic Family	Does the species belong to any of the following Families? (Most successful families are: Proteidae, Typhlopidae, Ranidae, Leptodactylidae, Chamaeleonidae, Gekkonidae, Rhacophoridae, Agamidae, Teiidae, Trionychidae, Bufonidae (Bomford et al. 2005)) 0 – No 1 – Yes	________ (0-1)
(1.3) Taxonomic Invasive History	Does the species have invasive congeners/subspecies? 0 – No 1 – Yes	________ (0-1)
(1.4) History of Species Spread	Has the species naturalized (established viable populations) beyond its native range? 0 – No 1 – Yes	________ (0-1)
(1.5) History of Introductions (Location and Rate)	Does the species have a history of introductions outside its natural range? 0 – No 1 – Yes	________ (0-1)
(1.6) History of Invasive Success	Has the species become naturalized where introduced? 0 – No 1 – Yes	________ (0-1)
(1.7) Habitat Breadth	Does the species have broad climate suitability (environmental versatility)? 0 – No 1 – Yes	________ (0-1)
(1.8) Generality/Native Range Size (Species Origin and Size)	Is the species native or naturalized in regions with similar climates? 0 – No 1 – Yes	________ (0-1)
(1.9) Temperature Tolerance Range	Does the species have a wide temperature tolerance range? 0 – No 1 – Yes	________ (0-1)

(1.10)	**Climate Match (Habitat Compatibility) – rainfall and temperature data**	What is percent climate match from the climate matching analysis?	________ A score of: 0 = 0-25% 1 = 26-49% 2 = 50-100%
(1.11)	**Reproductive Success**	Is the species able to reproduce in the target area's climatic conditions?	________ A score of: 0 = Low success 1 = Intermediate success 2 = High success
(1.12)	**Reproductive Frequency**	What is the reproductive frequency of this species (number of reproductive bouts per year)?	________ A score of: 0 = 1 bout/year 1 = 1-2 bouts/year 2 = >2 bouts/year
(1.13)	**Reproductive Mode**	Can this species store sperm? 0 – No 1 – Yes	________ (0-1)
(1.14)	**Hermaphroditic Individuals**	Have hermaphroditic individuals and/or protandry/protogyny been observed in the species? 0 – No 1 – Yes	________ (0-1)
(1.15)	**Possibility of Parthenogenesis**	Has parthenogenesis been observed in the species? 0 – No 1 – Yes	________ (0-1)
(1.16)	**Intrinsic Rate of Population Growth**	What is the theoretical rate of population growth of the species?	________ 0 = >10 years 1 = 10 > 5 years 2 = <1 year
(1.17)	**Detection Probability**	Is the species easily detectable? 0 – No 1 – Yes	________ (0-1)
(1.18)	**Species Manageability**	Is the species susceptible to specific control measures (i.e. trapping)? 0 – No 1 – Yes	________ (0-1)
(1.19)	**Ability/Proneness to Escape**	What, if any, special housing requirements are needed for this species?	________ A score of: 0 = 'No' 1 = Minimal specifications (i.e. closed cage) 2 = Species requires specific housing conditions

(1.20)	**Previous Introduction Time Span**	What is the introduction history of the species in the target area?	_________ A score of: 0 = Introduction within 1 year 1 = within 5 years 2 = >5 years
(1.21)	**Release Event Location**	How many locations has the species been released at in the target area?	_________ A score of: 0 = 1 location 1 = 2-5 locations 2 = >5 locations
(1.22)	**Propagule Pressure**	How many release events have involved numerous individuals?	_________ A score of: 0 = < 3 events 1 = 4-10 events 2 = >10 events
(1.23)	**Biocontrol History**	Does the species have a history of being released in its non-natural range as a means of biocontrol? 0 – No 1 – Yes	_________ (0-1)
(1.24)	**Trade Value**	Is the species deliberately introduced for human consumption (i.e. meat, leather trade) 0 – No 1 – Yes	_________ (0-1)
(1.25)	**Research/Ornamental Value**	Is the species popular for research or ornamental (aquarium/terrarium) purposes? 0 – No 1 – Yes	________ (0-1)
(1.26)	**Species Impact**	In the species' naturalized range, are there impacts to other species (i.e. habitat displacement, predator/prey dynamics)? 0 – No 1 – Yes	_________ (0-1)
(1.27)	**Sale Price**	How costly is the sale price of this species?	_________ A score of: 0 = 'Expensive' 1 = 'Intermediate' 2 = 'Affordable'
(1.28)	**Species Maintenance**	How costly is it to maintain and house a healthy individual of this species?	_________ A score of: 0 = 'Affordable' 1 = 'Intermediate' 2 = 'Expensive'
(1.29)	**Deliberate Release**	Does the species have a history of deliberate releases as a result of complications in the pet trade (i.e. individuals attaining body sizes too large to house in casual tanks)? 0 – No 1 – Yes	_________ (0-1)
		Sum of Scores	

Spread

Ecological Correlate	Question	Score and Guidance
(2.1) Vagility and Mobility	Are juveniles or adults known to migrate (i.e. for breeding, foraging, brumation)? 0 – No 1 – Yes	________ (0-1)
(2.2) Habitat Breadth/Range	Does the species tolerate a wide range of habitats in its native or introduced range? 0 – No 1 – Yes	________ (0-1)
(2.3) Water Conditions	Does the species tolerate a wide range of water quality conditions, especially oxygen depletion, and high temperature? 0 – No 1 – Yes	________ (0-1)
(2.4) Nesting Flexibility	Does the species have the ability to nest in a broad range of environments? 0 – No 1 – Yes	________ (0-1)
(2.5) Dispersal Size and Distance	Are life stages small and/or likely to be dispersed unintentionally? 0 – No 1 – Yes	________ (0-1)
(2.6) Human Aided Dispersal	Are life stages likely to be dispersed intentionally by humans (intentional introduction for personal aesthetics)? 0 – No 1 – Yes	________ (0-1)
(2.7) Dispersal Ability	Is the species known to be dispersed unintentionally through cargo transport (attach to ships, cars, planes, etc.)? 0 – No 1 – Yes	________ (0-1)
(2.8) Dispersal Ability	Is the species known to be dispersed unintentionally through the nursery-trade? 0 – No 1 – Yes	________ (0-1)
(2.8) Egg Dispersal	Does natural dispersal occur as a function of dispersal of eggs? 0 – No 1 – Yes	________ (0-1)
(2.9) Egg Dispersal	Are eggs of the species known to be dispersed by other animals (externally)? 0 – No 1 – Yes	________ (0-1)
(2.10) 'Stepping Stone' Dispersal	Does natural dispersal occur as a function of offspring dispersal (along linear and/or 'stepping stone' habitats adjacent to the original habitat)? 0 – No 1 – Yes	________ (0-1)
(2.11) Gregariousness and Sociality	Is the species known to be social/tolerate other individuals (have a tendency to group together for extended periods)? 0 – No 1 – Yes	________ (0-1)

(2.12) Dispersal	Is dispersal of the species density-dependent? 0 – No 1 – Yes	________ (0-1)
(2.13) Reproductive Colonization	Can females colonize alone? 0 – No 1 – Yes	________ (0-1)
	Sum of Scores	

Persistence

Ecological Correlate	Question	Score and Guidance
(3.1) Reproduction	Does the species produce viable gametes? 0 – No 1 – Yes	________ (0-1)
(3.2) Growth Rate	Does the species have a rapid growth rate? 0 – No 1 – Yes	________ (0-1)
(3.3) Age at Reproductive Maturity	Does the species reach reproductive maturity at a young age?	________ A score of: 0 = the time between birth/hatching until reproductive maturity >2.5 years 1 = the time between birth/hatching until reproductive maturity < 2.5 years
(3.4) Fecundity	What is the clutch size of this species (number of eggs per reproductive bout)?	________ 0 = >10 eggs 1 = 10>20 eggs 2 = < 20 eggs
(3.5) Reproductive Potential	Is the species iteroparous, capable of producing multiple clutches in its life-span? 0 – No 1 – Yes	________ (0-1)
(3.6) Generation Time	What is the species' known minimum generation time (average time from independence of a female to the time at which that female's offspring are completely independent) in years (~3.08 years for python)?	________ A score of: 0 = >6 years 1 = 3.5-6 years 2 = < 3.5 years
(3.7) Gestation Time	Does the species have a short gestation time? 0 – No 1 – Yes	________ (0-1)
(3.8) Opportunistic or Aseasonal Breeding	Does the species have a defined breeding period? 0 – No 1 – Yes	________ (0-1)

(3.9) Maximum Longevity	How long-lived is this species?	________ A score of: 0 = <10 years 1 = >10 years
(3.10) Functional Population Size	Does the species require a minimum population size to maintain a viable population? 0 – No 1 – Yes	________ (0-1)
(3.11) Life cycle	Does the species require specific habitat features to complete its life cycle? 0 – No 1 – Yes	________ (0-1)
(3.12) Phenotypic Plasticity (Genetic Diversity)	Does the species have high phenotypic plasticity? 0 – No 1 – Yes	________ (0-1)
(3.13) Response to Human Disturbance (Human Commensalism)	Does the species tolerate or benefit from environmental disturbance? 0 – No 1 – Yes	________ (0-1)
(3.14) Survival Probability (Juvenile)	Are there effective natural enemies/predators of juveniles of the species present in the target area? 0 – No 1 – Yes	________ (0-1)
(3.15) Survival Probability (Adult)	Are there effective natural enemies/predators of adults of the species present in the target area? 0 – No 1 – Yes	________ (0-1)
(3.16) Salinity Tolerance	Does the species have a wide salinity tolerance or is the species euryhaline? 0 – No 1 – Yes	________ (0-1)
(3.17) Extent of Diet	Does the species exhibit a broad diet? 0 – No 1 – Yes	________ (0-1)
(3.18) Diet Adaptation	Has the species been observed eating food sources not found in its natural range? 0 – No 1 – Yes	________ (0-1)
(3.19) Offspring Size	Does the species produce large neonates at birth/hatching? 0 – No 1 – Yes	________ (0-1)
	Sum of Scores	

Impact

Ecological Correlate	Question	Score and Guidance
(4.1) Habitat Impact	In the species' naturalized range are there impacts to aquatic or terrestrial habitats? 0 – No 1 – Yes	________ (0-1)
(4.2) Adult Body Size	What ultimate body size does the species achieve?	________ A score of: 0 = <0.5 m 1 = >0.5 m body length excluding tail
(4.3) Trophic Level (Dietary Breadth)	Is the species a voracious predator, i.e., wide prey base? 0 – No 1 – Yes	________ (0-1)
(4.4) Native Wildlife Predation	Does the species create additive predation pressure on native species, (especially to vulnerable species or species that have low or no predation)? 0 – No 1 – Yes	________ (0-1)
(4.5) Omnivorous	Is the species omnivorous? 0 – No 1 – Yes	________ (0-1)
(4.6) Reduction of Habitat Quality	Does feeding or other behaviors of the species reduce habitat quality for native species? 0 – No 1 – Yes	________ (0-1)
(4.7) Level of Parental Care	Does the species exhibit an extended period of parental care of eggs and/or young? 0 – No 1 – Yes	________ (0-1)
(4.8) Age of Maturity	Is the species age of maturity altered by external conditions? 0 – No 1 – Yes	________ (0-1)
(4.9) Competitiveness	Does the species out-compete native species? 0 – No 1 – Yes	________ (0-1)
(4.10) Parasitism	Is the species parasitic on other species? 0 – No 1 – Yes	________ (0-1)
(4.11) Anti-Predation Ability	Is the species unpalatable to predators? 0 – No 1 – Yes	________ (0-1)
(4.12) Vulnerability, Susceptibility to Predation	Is the species easily preyed upon? 0 – No 1 – Yes	________ (0-1)

(4.13) Parasite Host/Vector	Does the species host, and/or is it a vector for recognized pests and pathogens, especially nonnative pests and pathogens? 0 – No 1 – Yes	________ (0-1)
(4.14) Hybridization Ability	Does the species hybridize naturally with native species? 0 – No 1 – Yes	________ (0-1)
(4.15) Association/Danger to Humans (Venomousness)	Is the species poisonous or poses other risks to human health? 0 – No 1 – Yes	________ (0-1)
(4.16) Economic Impact	Does the species reduce agricultural productivity/increase production costs? 0 – No 1 – Yes	________ (0-1)
(4.17) Economic Impact	Does the presence of the species decrease property values? 0 – No 1 – Yes	________ (0-1)
(4.18) Human Association	Is this species associated with or liable to human commensalism (are suitable habitats abundant near human settlements)? 0 – No 1 – Yes	________ (0-1)
(4.19) Human Health and Safety	Does this species pose a health risk to humans or threaten human safety? 0 – No 1 – Yes	________ (0-1)
(4.20) Pets and Livestock Health and Safety	Does this species pose a health risk to pets or livestock or threaten their safety? 0 – No 1 – Yes	________ (0-1)
	Sum of Scores	

Formula for calculating Score:
Total Sum = Sum of Scores (Arrival/Establishment) + Sum of Scores (Spread) + Sum of Scores (Persistence) + Sum of Scores (Impact)
Total Score = Total Sum/94 * 100%
Maximum Score = 94 = 100%
Species Rank Scores: 0-25% Low Risk
26-49% Intermediate Risk
50-100% High Risk/Warrants Further Investigation

Table 2. Climate/habitat variables of nonnative reptiles to evaluate climate matching with species' native range compared to the State of Florida. Variables are imported from BIOCLIM of meteorological stations worldwide and matching can be calculated using CLIMATE or CLIMEX 3.0 programs (compiled from Bomford et al. 2009, Fujisaki et al. 2010).

Temperature variables (°C)	
	Mean annual temp
	Minimum temp of coolest month
	Maximum temp of warmest month
	Average temperature range
	Mean temperature of coolest quarter
	Mean temp of warmest quarter
	Mean temp of wettest quarter
	Mean temp of driest quarter
Rainfall variables (mm)	
	Mean annual rainfall
	Mean rainfall of wettest month
	Mean rainfall of driest month
	Mean rainfall of monthly coefficient of variation
	Mean rainfall of coolest quarter
	Mean rainfall of warmest quarter
	Mean rainfall of wettest quarter
	Mean rainfall of warmest quarter
Other variables	
	Relative humidity
	Soil moisture

Table 3. Variables that are significantly different between established and failed species with t-test (numerical variables) and chi-square test (categorical variables) at a level of 0.05 (*) and with Bonferroni correction (**) and selected variables in the final model (***) using discriminant analysis (DA), logistic regression (LR), and classification tree (CT) (Taken from Fujisaki et al. 2010).

	p	DA	LR	CT
Taxonomic order[a]	**	[b]	***	
Minimum temperature match				
Maximum temperature match				***
Mean temperature match				
Rainfall total match				
Rainfall pattern match				
Soil moisture match				
Relative humidity match				
Native range size				
Juvenile diet	*	[b]	[b]	
Adult diet	**	[b]	[b]	
Number of eggs				
Parthenogenesis		[b]		
Number of years to reach reproductive maturity	**			
Import quantity				
Price		***		
Manageability	**	***	***	***
Error rate (%)		27.1	23.9	38.2
Effective sample size		68	67	67

We used establishment probability 0.5 for cut-off with logistic regression. Error rates are based on cross validation for discriminant analysis and logistic regression, and root node error for classification tree

[a] Crocodilians were not included in the chi-square test, logistic regression, and classification tree since there is only one exotic crocodilian in the training data

[b] Variables are not included in analysis