Reptilian Pathogens of the Florida Everglades: The Associated Costs of Burmese Pythons

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Abstract

The predation activity of the invasive Burmese python (*Python molurus bivitattus*) was evaluated using probability and the economic costs associated with current federal and state values for endangered species. The objective was to provide a realistic valuation of the associated costs of Burmese python predation in southern Florida ecosystems for use as both a policy and management tool. Once valuation estimates were generated, the paper offers certain policy and enforcement recommendations to help address this growing problem.

Key Words: invasive species, economic valuation, Burmese python, Bayesian probability

Introduction

Exotic invasive Burmese pythons (*Python molurus bivitattus*) have severely disrupted trophic level interactions in South Florida ecosystems (Meshaka et al. 2000; Meshaka et al. 2004; Snow et al. 2006; Snow et al. 2007). Concomitantly, recent media attention has alluded to some of the damages these exotic invasive reptiles can cause. However, the real impact of these snakes in the South Florida region might better be measured by quantifying the economic impacts of predation. Similar studies have been conducted in the past focusing on the impacts of feral swine (*Sus scrofa*) (Engeman et al. 2004a; 2004b) in wetlands, general pest management (Engeman et al. 2004a), opportunistic predation (Engeman et al. 2002) of endangered species, damages to canals and levees in the Greater Everglades caused by green iguana (*Iguana iguana*) burrowing (Sementelli, et. al, in press), and even wildlife road-kills in public trust lands (Smith et al. 2003; Shwiff et al. 2007).

As one of many exotic invasive species introduced in Florida, particularly in southern Florida (Meshaka et al., 2004; Meshaka, 2006), Burmese pythons create very different problems than those presented by feral hogs and other pest species; some of which reach astounding population densities in Florida managed natural areas (Engeman et al. 2004b; Smith & Engeman 2002; Smith et al. 2007a; Smith et al. 2007b). Specifically, Burmese pythons have been identified as exotic invasive pests (see Chap. 39 F.A.C.), with specific risks (Reed 2005; Stohlgren, & Schnase 2006) and associated costs from fines borne by those who introduce these invasive herpetofauna into the environment. What is missing is a practical measure of the reptile's economic impact and a

Burmese python. Photo credit: wikimedia.org

mechanism to determine if the current program is functioning given current standards, fee structures, and enforcement.

We argue in this piece that current policy for exotic invasive herpetofauna is suffering from the same, somewhat programmatic, issues (Sementelli & Simons, 1997) exhibited in other policy arenas. By providing a probabilistic approach to the cost of predation by Burmese pythons, we are able to quantify aspects of the real impact of this invasive species on the state of Florida. Additionally, this approach enables us to make a basic determination about the current condition of the Florida state level controls on the introduction of exotic invasive species.

Methods

The approach for estimating the cost of these invasive herpetofauna is a function of three separate questions. First, we must determine what are the basic and associated impacts of predation on native species. Second, we calculate the probability of a successful predatory event and the probability that the animal predated is endangered, threatened or a species of special concern (SSC). Third, using the current costs from the Florida Wildlife Code 39 F.A.C and the USFWS Endangered Species Act we can then estimate the cost of predation on wildlife for a single Burmese python weighed by the probability of both a successful predatory event and that the act took at least one animal from either the FWC or USFWS lists. The final step for the first stage of this analysis presents the net estimated cost to the system.

To achieve this, we used Bayesian probability to estimate the probability of predation and the true value of the predated species given the best available information regarding the probability of predation. The initial assumptions for our estimates included an overall 5 % success rate for any predation attempt. Additionally, we assigned a 1% chance of the successful predation being on an animal listed on the FWC or USFWS list. These assumptions were used to establish our base rates of successful predation and predation on endangered or protected species. We further devel-

oped a secondary set of probabilities using the FWC and USFWS lists to estimate the value of a single species given current standards. This helps to illustrate how current policy systematically undervalues these predated species in this situation.

Once completed with this exercise, we then shift our focus toward a specific case study, Everglades National Park (ENP), where there is a higher than normal presence of relatively expensive "prey" (Gawlik 2001) from the FWC and USFWS lists. This, combined with confirmed observations and breeding of Burmese pythons (Meshaka et al. 2000; Meshaka et al. 2004; Ferriter et al. 2006) makes for an unusual opportunity for extensive predation of wading birds in particular. Using this data, we then estimate the cost of a single Burmese python predating in a mixed-species rookery using ranges and average clutch sizes of the species listed in Table 1. Most of these wading birds produce 2-5 eggs per clutch with an average of 3-4 in most years (Rodgers et. al. 1996), to develop what might be described as a catastrophic but plausible scenario.

Damage valuation

Making monetary determinations for damages to protected species are often seen as being obtuse and imprecise. Some of the best models, however, have applied costs as damage per unit of property (Engeman et al. 2004a), and include some mechanism to determine the probability of an event (Engeman et al. 2002). As an extension of this logic we are applying costs based on the unit value of prey and the joint probability of a predatory event occurring. To accomplish this we divided the model into three stages. Stage one computes the basic probability of a successful predation on some sort of endangered prey.

As a starting point for this discussion, we will initially assume a completely level terrain, with no natural barriers, and a random distribution of prey items throughout the geographic area. These initial assumptions do not account for wading bird colonies where there are dense clusters of wading birds. However, we begin to address this specialized case later in the paper. Additionally we conservatively estimate [to say "underestimate" implies we are being intentionally incorrect] the rates of successful predation (.05) as well as the probability of predation upon some endangered species (.01). These simplifications will enable us to make a fair estimate of the least amount of monetary damage possible in a generic situation. As a means to incrementally introduce more realism into our estimates, Table 1 presents several prey species, a conservative estimate of the probability of a

Probabilities			
Species	Predation Success given encounter	Encounter	Joint Probability
Great Egret	.3	.5	.15
Hispid Cotton Rat	.3	.4	.12
Marsh Rice Rat	.3	.4	.12
Cotton Mouse	.5	.3	.15
Marsh Rabbit	.4	.3	.12
Gray Squirrel	.3	.2	.06
Raccoon	.2	.2	.04

Table 1 presents several prey species, a conservative estimate of the probability of a successful predation, the probability of encountering said prey species, and a final estimate of satisfying both criteria (encounter and predation).

successful predation, the probability of encountering said prey species, and a final estimate of satisfying both criteria (encounter and predation).

Using these simplified assumptions and the base probability listed above, the initial estimate for a successful predation upon some endangered or protected prey item was calculated at 0.0005. This starting point helps to account both for the probability of encountering an endangered prey species and being able to successfully predate it. Table 1, in contrast, offers more realistic estimates. Though still conservative, we relax the assumptions that a Burmese python in the wild will only hunt successfully 5% of the time. However, we will retain the assumption of no a priori expected frequencies (Cochrane 1954) on common prey items fitting a non static Poisson distribution.

The next stage of the analysis computes an estimate for the probability of a specific listed species being taken. This developed from the FWC and USFWS lists of endangered, threatened, and SSC species local to the South Florida region. Not all listed species are typically prey for Burmese pythons; therefore, we are left with a list of nine vertebrate wildlife species that are or have been observed as prey items for Burmese pythons in Florida, with associated probabilities developed from information regarding availability, size, and behaviors.

The final stage of the analysis computes the real cost of predation for Burmese pythons.

We took the Bayesian estimate from above, combined it with the estimates of predating one of the nine listed species, and then multiplied them by the current statutory "take" value of the prey animals. Species not on the list were valued at $0, others, including

Table 2

Animal	Base Probability	Cost	FWC Stat FL	USFWS Stat Fed	Pred Cost
American Alligator	0.04	$500	SSC		$21.09
Limpkin	0.22	$500	SSC		$111.32
Reddish Egret	0.22	$500	SSC		$111.32
Snowy Egret	0.22	$500	SSC		$111.32
Little Blue Heron	0.22	$500	SSC		$111.32
White Ibis	0.22	$500	SSC		$111.32
Florida Sandhill Crane	0.22	$500	T		$111.32
Wood Stork	0.11	$25,000	E	E	$2,789.59
Everglades Mink	0.03	$500	T		$16.92

all FWC –endangered, threatened, and SSC status prey were valued at $500, and USFWS federally endangered and threatened class species were valued at $25,000, consistent with current policy (USFWS Endangered Species Act of 1973).

During stage three of the analysis we computed the probability of taking a specific species as a prey item. This was conducted as a mechanism to illustrate how the current policies systematically undervalue these protected species by including an estimate of the real impact of predation on the system. This enabled us to create a conservative, useful heuristic to estimate the "real" costs of Burmese python predation per feeding.

Results

In a nonspecific area of South Florida, a single successful python feeding (with a Bayesian probability of success estimated at 0.0005) results in a cost of $3,495.50 in current dollars. In turn, this conservatively translates into $6,991 per month, and $83,892 per year in feedings for a single Burmese python. This accounts for our conservative estimates of the probability of success while also accounting for differences in prey species in our base probability estimate, reflecting the fact that it would be easier to prey upon a heron than an alligator in most situations.

As illustrated by Table 2, the real value of an Everglades mink in this situation is less than $20 and the real value of an American alligator is less than $25, given their uncommon characteristics or susceptibility relative to other listed prey items. American alligators, for example, are known to predate Burmese pythons, making them less likely prey items. Also, minks and other medium-size mammals probably predate opportunistically, even upon juvenile Burmese pythons, placing them in a similar category as the American alligator. Predation on the federally endangered wood stork has an approximate cost of $2,800.

Current FFWCC rulemaking regarding the release of Burmese pythons into Florida ecosystems has improved from a simple fine of $500 per snake per event to more stringent regulations, fees, and fine structures as a means to begin addressing the real cost of this issue. It is important to note that the new rulemaking begins to systematically address this issue. It is also important to realize, however, that a single successful predation on a wood stork continues to reflect a net loss. In "regular" predation, after one month (assuming a minimum of two successful predations) Burmese pythons can generate a $6,491 loss. After a year that damage estimate increases to $77,892. This illustrates that current environmental fine structures and policies, though very progressive in nature, might not completely encompass the damage costs of invasive species in the state of Florida (Sementelli & Simons 1997).

If we apply these results to the case of Everglades National Park, where there is a relatively high concentration of both pythons and wood storks, then the cost of a single predation session can skyrocket to $250,000 per feeding. This assumes a large python is able to consume a total of ten wood stork chicks from 2-3 closely located nests in a successful hunting session. This in turn translates into $500,000 per month, and $6,000,000 per year in current dollars. In this "worst case" scenario, current fine structures cannot even begin to reconcile the value of lost wildlife.

Key Largo: A Second Case

While conducting radio-telemetry work on federally-listed Key Largo woodrats (Neotoma floridana) on 13 April 2007, the alarming capture of an 8 ft. Burmese python in Key Largo Hammock Botani-

Table 3

Animal	Base Probability	Cost	FWC Stat FL	USFWS Stat Fed	Pred Cost
American Crocodile	0.08	$25,000	E	T	$2,095.51
Key Largo Woodrat	0.16	$25,000	E	T	$4,177.74
Key Largo Cotton Mouse	0.22	$25,000	E	T	$5,565.89
White -crowned Pigeon	0.22	$500	T	Not Federally Listed	$111.32

cal State Park (KLHSBP) in the Florida Keys allows us to investigate a second specific case study independent of Everglades National Park. The captured python had depredated two of these federally-listed mammals (FDEP, unpubl. data), one of which was carrying a transmitter. This case study involves a terrestrial environment in the Florida Keys as well as the adjacent estuarine mangrove wetlands. (Note also that a second Burmese python, approximately seven feet in length, was found on Key Largo on 11/1/07. Necropsy revealed remains of the endangered Key Largo woodrat in the snake's gut (Snow 2007 personal communication).

Four additional listed species are at risk in this Florida Keys' module: Key Largo Woodrats, the Key Largo cotton mouse (*Peromyscus gossypinus allapticola*), American crocodiles (*Crocodylus acutus*), and nesting white-crowned pigeons (*Columba leucocephala*). With Burmese pythons as well-documented predators of American alligators in ENP (Snow et al. 2006, 2007), American crocodiles likewise surely are at risk in KLHSBS. In particular, hatchling crocodiles would be at a much higher risk of predation as they are not defended by nesting females in early life-history stages as are American alligator nests and hatchlings. This factor could potentially alter American crocodile population size and age-class structure in an already greatly imperiled South Florida breeding range (USFWS 1999).

Working from our generic model as a starting point, a single successful python feeding in the Keys (still reflecting Bayesian probability of success estimated at 0.0005) results in a cost of $11,950.45 in current dollars. In turn, this conservatively translates into $23,900.90 per month, and $286,810.80 per year in feedings for a single Burmese python. This also includes our conservative estimates of the probability of being successful while again accounting for differences in prey species in our base probability estimate (for example, it would be easier to prey upon a Key Largo cotton mouse than an American crocodile in most situations).

However, if we incorporate certain basic biological information, the presence of Burmese pythons becomes more troubling in this case. Consider first that the American crocodile does not guard its nest nor young like its counterpart, the American alligator. If we incorporate the fact that an American crocodile in south Florida has an average clutch size of 38 eggs with a range of 15-56 eggs (Kushlan & Mazzotti 1989), one then begins to realize just how conservative these damage estimates are. In ad-

dition, the 13 April 2007 incident lends credibility to the notion that these depredations might, in certain conditions, cost as much as $50,000 to $150,000 per feeding session.

Discussion

Current Florida policy 39 F.A.C. can fine individuals caught releasing exotic invasive herpetofauna into the wild $500 with the potential for additional fines and court costs beginning at roughly $300. Even using the conservative estimate of $255 per feeding, the point at which the cost of feeding exceeds the conservative cost of the fine imposed is under two successful predations (approximately 1.96), which could be met in as little as three weeks after a single snake has been unlawfully released. Given this information, it is safe to state that the current regulatory civil penalty solution to discourage the release of invasive herpetofauna is inadequate. If we include the associated costs for removing these invasive species such as the use of animal care and control services, dedicated trappers, and private vendors (see discussion in Sementelli, et al. in review), one can safely state that the current regulatory policy is best understood as inadequate (Mazmanian & Kraft 2001) .

This need not be the case, however. A number of policy strategies might be employed to begin alleviating this problem, and some have begun to be implemented. First, the new F.A.C. rulemaking takes an important step toward the consistent statewide regulation of exotic invasive species as pets, including the adoption of licensing fees and microchips to offset the cost of managing these invasive species (FFWCC Rulemaking 4/ 2007). Arguably, some of these fees might be used to offset some of these expanded program costs (Sementelli, et al. in review). Second, even though current rulemaking has become quite progressive, one might still argue for even more stringent fine structures and other penalties for the release of herpetofauna in Florida (Sementelli, et al. in review).

It is currently far too profitable to keep and sell non-native species in the current policy environment as a single vendor might conservatively clear as much as $1,500 per month selling exotic invasive herpetofauna. Such a revenue stream helps to illustrate how the current regulatory environment lacks the "teeth" necessary to curtail the in-

Burmese python in zoological garden in Gdańsk. Photo credit: wikimedia.org

troduction of exotic invasive species. In the long term, if current policies remain as are, we are far more likely to see our second scenario ($6,000,000 in lost fauna) than our initial estimate ($6,120) given a relatively stable increase in exotic predatory herpetofauna in the south Florida region.

Recent coverage in regional media has elevated this problem in the public eye, making it more visible (McCombs & Shaw 1993). Photographs of giant snakes consuming alligators and other local fauna provide people with the sort of powerful imagery needed to move policies (Miller 2002) to the forefront of discussion. The initial steps taken in this study can provide valuable support for policy agenda setting (Kingdon 1984). Additionally, by conducting an economic valuation of the cost of current strategies, we have arguably presented this programmatic and policy issue in a context that can be understood by the broadest audiences. Rather than simply identifying and understanding the release of herpetofauna as isolated incidents, this study links these releases to their broader impacts on the south Florida ecosystems both in and out of parks and other protected public trust land areas. Additionally, it provides a basic framework to begin understanding the broader costs associated with the release of invasive species. Future studies might also include the costs of removal, relocation, and regulation of these invasive exotic species in Florida. This simple analysis of the price impact of the day to day actions of these creatures is sufficient to warrant more detailed discussions of policy change.

Conclusions

Until recently, there was far too much unregulated access to exotic species as pets. Few if any legislative controls or policies have addressed the situation adequately. There were neither age nor licensing requirements to keep many exotic species such as herpetofauna, rodents, wild cats and other animals. Though this is not a new problem, we are finally reaching a critical mass of interest in this regulatory issue as it affects a heavily populated area with an advantageous sub-tropical climate, plentiful food sources, and relatively easy access.

It appears difficult if not impossible to solve this problem at the point of release, where a single pet owner releases, loses, or otherwise introduces a Burmese python into the environment. Arguably, none of these solutions will be effective if the "back door" is not also shut. This means there must be an additional shift in policy away from allowing the private ownership of demonstrably invasive and destructive species. Specifically, it would appear to be more effective to begin addressing this problem at the points of sale (herpetofauna shows, pet stores, etc.) through the use of enabling legislation and political support for its implementation (Mazmanian & Sabatier 1989). This is but one element to a solution for an extremely complex problem, for Burmese pythons have already established a large breeding population in the region (Meshaka et al. 2000, 2004; Snow, et al 2007). Undoubtedly, numerous associated costs through trapping, removal, and even the predation of other common pets, as these invasive exotic species move into more urban, suburban, and exurban areas, will soon become evident. Considering tourist visitation to Everglades NP exceeds one million people annually, the costs could also include injuries or possibly even the loss of human life. This is an area where people, especially children, may come into deadly contact with one of the world's largest snakes.

The introduction of exotic amphibians and reptiles has clear economic impacts on the regional ecology (Sementelli, et al. in review), but it also can affect the day-to-day operations of state and local government through increases in 911 calls, lost hours due to service interruptions from animals occupying urban dens, and greater encroachment into recreational parks as well as public trust preserves.

Therefore, even though we have provided some simple monetary estimates of the damage a single Burmese python might have on an ecosystem, it is important to realize these values should be treated as a lower boundary for the estimates of ecological damage. As this research suggests, it is imperative to reconsider current civil penalty fine structures, as well as costs of removal and animal management strategies for these invasive species. Until coordinated efforts are made to both remove, and manage the rates of invasive species introduction, the scope of this problem is likely to get much worse, more visible, and more sensationalized until it becomes a political issue but only once it has become too late to address meaningfully, if not already so.

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