Native and Alien Iguanas on Saint Lucia, West Indies

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Status of Native Saint Lucian Iguanas

The taxonomy of the Green Iguana (*Iguana iguana*) remains unresolved. Malone and Davis (2004) conducted genetic analyses that "imply that at least three cryptic species may exist [within the taxon currently recognized as *I. iguana*] under the evolutionary and phylogenetic species concepts (Central American, South American, [and] South American [Caribbean] + Lesser Antillean)." They also indicated that their data supported at least two radiations into the Lesser Antilles, "first onto Saint Lucia and more recently onto Saba and Montserrat." Lazell (1973) dismissed the contention that *I. iguana* is a recent introduction (e.g., by Carib peoples; Underwood 1962) to the Eastern Caribbean, although *I. iguana* on Martinique (not considered by Lazell) was introduced in the 1960s (Breuil 2009). Breuil (2002) also rejected Lazell's argument that *I. iguana* is native to Guadeloupe, where it occurs with the endemic Lesser Antillean Iguana (*I. delicatissima*). Powell (2004) and Powell and Henderson (2005) highlighted the importance of insular populations classified currently as *I. iguana* and the risks of assuming they comprise a single species.

The native population of *I. iguana* on Saint Lucia is restricted to the island's northeastern coast, and possibly has been restricted to the eastern coast since the 19th Century (Tyler 1850)[1]. As long as this population is small and has a restricted range, it remains a conservation priority for the Forestry Department of the Ministry of Agriculture, Lands, Forestry & Fisheries (MALFF), the statutory body responsible for terrestrial biodiversity conservation on Saint Lucia. During a biophysical inventory of Saint Lucia's forest resources in 2009, the decision was made to formally refer to the population on Saint Lucia as *Iguana* cf. *iguana* — i.e., similar to, but not confirmed as, *Iguana iguana* (Daltry 2009a, Morton 2009) — and to refer to this population as "the Saint Lucia Iguana," without implying any resolution of the prevailing taxonomic uncertainty.

Concerns about the survival of the Saint Lucia Iguana were expressed by the Saint Lucia Forestry Department (SLFD) and J. Gilardi in the 1990s (Anonymous 1998, Bendon 2003), initiating work in the 2000s by the Durrell Wildlife Conservation Trust (Durrell) and SLFD to evaluate the status of the population and the threats facing it (Morton 2007). More recently, SLFD and Rare Animal Relief Effort (RARE) built upon earlier awareness-raising efforts (Bendon 2003) by means of a "pride" campaign (Narcisse 2009, RARE 2010). This campaign promoted the Saint Lucia Iguana as a flagship species for the island's endangered deciduous seasonal forest habitat, and in particular the deciduous seasonal forests of Saint Lucia's northeastern corridor. Both the pride campaign's iguana mascot and the northeastern corridor were given the name Iyanola, a phonetic version of Iouanalao, the Amerindian name for Saint Lucia, meaning "the land of the iguana" (Jesse 1960). In this respect, the importance of the Saint Lucia Iguana to conservation efforts on the island would remain unchanged regardless of its future taxonomic status. It is Saint Lucia's

[1] Lazell's (1973) report of iguanas on Maria Major island off the southern tip of Saint Lucia is in error (J. Lazell, in litt., 23.VI.2010).


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Saint Lucia Iguana (left) and an iguana from Montserrat (right). Note the differences in scalation between these two West Indian iguana populations.

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Iyanola, Saint Lucia's Pride Campaign mascot for the Saint Lucia Iguana and the name bestowed on the island's northeastern corridor, its last known refuge.

largest native terrestrial animal, striking in its appearance, and a cultural signifier of long standing. As such, it is a valuable flagship species that represents a globally threatened habitat type in the insular Caribbean (WWF and McGinley 2007), an area that appears to be the last remaining stronghold of a number of species and subspecies endemic to Saint Lucia, particularly birds and reptiles (Daltry 2009a, 2009b; Morton 2009; Toussaint et al. 2009).

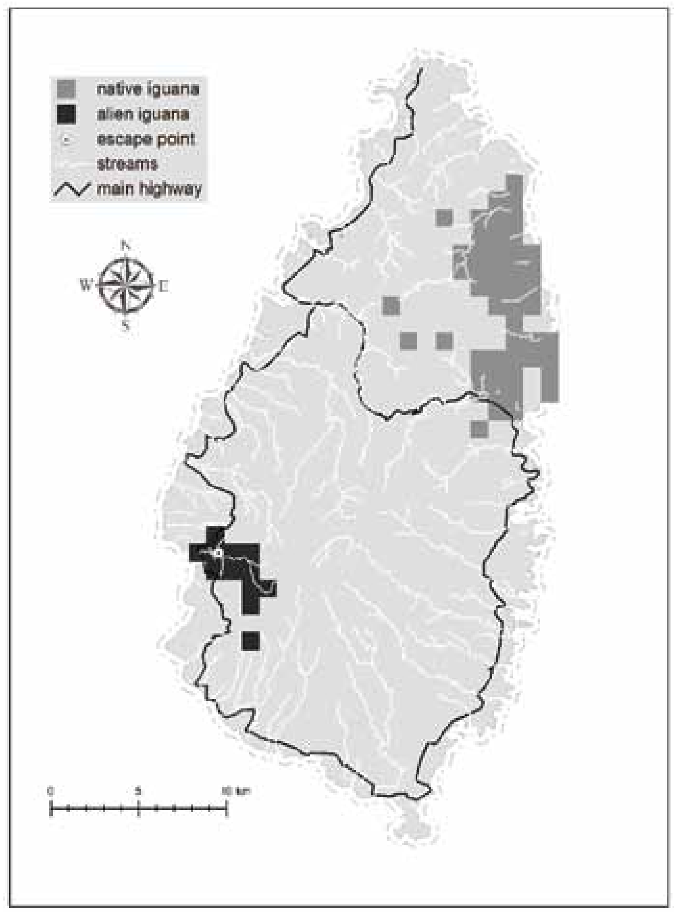
If Saint Lucia were to produce its own Red List, the Saint Lucia Iguana would require a Red List assessment of Critically Endangered (IUCN 2001) at a national level. If this population were to be accorded specific or subspecific taxonomic status, however, it would qualify for a *global* status of Critically Endangered. In either case, this assessment is based on IUCN's (2001) criteria B1a, b (i, ii, iii): Extent of occurrence estimated to be less than 100 km^2 (both the extent of occurrence and area of occupancy are <50 km^2); data indicating that the population is severely fragmented or known to exist at only a single location (one location — northeastern Saint Lucia); and indicators showing continuing decline, observed, inferred, or projected, in the (i) extent of occurrence, (ii) area of occupancy, and (iii) area, extent, and/or quality of habitat (effects of tourism developments, sand-mining, livestock grazing, and other documented threats that are known to reduce the quality and extent of suitable habitats). Historical population baselines are not available for the Saint Lucia Iguana, but this assessment infers a decline in the population based on its very restricted range and the identification of a number of ongoing pressures and threats, most notably that of introduced mammalian predators and the threat of proposed, large-scale tourist development on Saint Lucia's northeastern coast (Morton 2007).

The current range of the Saint Lucia Iguana corresponds to one of the two areas on the island farthest from paved roads (i.e., least accessible to humans, their commensals, and domesticated animals). The other area is a mountainous region of Saint Lucia's highest peaks, from which no iguanas are known (perhaps due to a lack of suitable nesting habitat). This distribution implies that hunting (which still occurs on a small scale, primarily for food; Bendon 2003, Morton 2007) might have been one important historical driver of the inferred decline in the Saint Lucia population. It also underlines one of the threats arising from proposed development on the northeastern coast, over and above conversion of habitat: The improvement of road access and hence human access that, if not regulated in some form, can be expected to increase hunting pressure as well as the density of non-native mammalian predators such as mongooses, dogs, cats, and rats. Improved road access and a higher human population in the northeast might also increase the likelihood that alien iguanas, now establishing on Saint Lucia, are transported into this area, either deliberately as pets or food or inadvertently stowed away in goods.

Introduction and Establishment of Alien Iguanas – Potential Impacts

The question of the taxonomic status of the Saint Lucia Iguana has again come to the fore with the confirmation in 2008 that non-Saint Lucian Green Iguanas are breeding in the dry and mesic forests around Soufrière in the southwest of the island (Morton 2008, Global Invasive Species Database 2010a). The most pressing concern for biodiversity conservation on Saint Lucia is the likelihood of hybridization between native and alien iguanas, potentially compromising the unique genetic identity and locally adapted gene complexes of the Saint Lucia population. *Iguana iguana* is known to hybridize with its congener, *I. delicatissima*, on Eastern Caribbean islands to which it has been introduced (e.g., Day and Thorpe 1996, Breuil et al. 2007).

Competition between native and alien populations is another concern (Henderson and Powell 2009). IUCN's Global Invasive Species Database (2010b) moots the possibility that competition between introduced Green Iguanas and their congener, *I. delicatissima*, might threaten those native



The distribution of the Saint Lucia Iguana and a population of introduced alien Green Iguanas on Saint Lucia, shown as presence in 1 x 1-km squares. The distribution of the Saint Lucia Iguana was determined during five months of island-wide face-to-face questionnaires in 2004–05 (Morton 2007). "False absences" were minimized by questioning large numbers of respondents about iguana sightings in squares where the presence of iguanas had been independently determined prior to the survey. From this, we determined the minimum number of respondents that had to be questioned per square in order to yield 95% confidence that at least one respondent would report a sighting if, in fact, iguanas were present. Sightings determined as "false presences" for the Saint Lucia Iguana (for questionnaire returns, for example, describing captive iguanas or clearly referring to other species, notably *Cnemidophorus vanzoi*) were excluded, although some of the outlying 1 x 1-km squares in the distribution shown here could be false positives, where the presence of iguanas has not been confirmed by searches. The distribution of alien iguanas was determined from questionnaire responses collected in 2008–09. This latter questionnaire is an ongoing effort to maintain an updated demarcation of the spread of the alien population.

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Saint Lucia Iguanas (A, adult male and B, adult female) and alien iguanas introduced in Saint Lucia (C, adult male and D, adult female). The more numerous and prominent nuchal tubercle of the alien iguana, and its larger subtympanic scale, are clearly visible, as is the difference in the color of the iris.

populations. Mean clutch size for the alien iguana is 40 (N = 4 clutches), but with a maximum (to date) of 60, which might more closely represent the true mean as sample size increases. By contrast, mean clutch size for Saint Lucia Iguanas (N = 14) is 23, suggesting that the aliens could out-reproduce the native iguanas. Competition could also be asymmetrical in favor of the aliens if, as the limited data imply, the aliens attain a greater body mass, although this might reflect lower mortality from predators in a population that is putatively still rare compared with that of the Saint Lucia population.

Burton (2004) cited another concern over the introduction of *I. iguana* onto Grand Cayman, the native range of *C. lewisi*, namely confusion of public awareness messages for the conservation of *C. lewisi*. This is a substantive concern given the growing discontent over negative impacts of introduced Green Iguanas on Grand Cayman. As Krysko et al. (2007) noted, the introduction of *I. iguana* to Florida in the 1960s raised little concern, but by the 1990s, the population had exploded and public discontent with iguanas grew.

Other negative impacts of alien iguanas, such as crop damage (particularly to ornamentals), the risk of *Salmonella* infections, or possible predation on bird eggs are almost certainly exaggerated, although invasive iguanas can be a nuisance and are likely to have at least some economic impact on vegetation. What is clear is a high level of public discontent in places where invasive Green Iguanas have become established, in large part due to delayed and inadequate intervention during the early stages of invasion. In Puerto Rico, alien iguanas are considered an air-strike risk on runways at the Luis Muñoz Marín International Airport, causing the suspension of flights six times in one two-month study (Engeman et al. 2005). Sementelli et al. (2008) documented damage to public infrastructure caused by burrowing iguanas introduced into Florida.

At this time, the alien iguana population on Saint Lucia appears to be geographically isolated from the native population, but by dint of small population size rather than any impenetrable geographic barriers. Even if the mountainous rain-forested interior of Saint Lucia does provide a barrier (we have found no reports of Saint Lucia Iguanas in this region), the alien population could still disperse around the coast and come into contact with the native population. Successful nesting outside of captivity has been recorded in the Soufrière area, and questionnaire returns and field observations suggest that the introduced population has dispersed at least 2 km from the site of the initial introduction, a hotel on the outskirts of Soufrière. Mapping captures and reported sightings imply dispersal has been primarily along the riverine corridors of the River Soufrière and some of its tributaries, although this conclusion might reflect a sampling bias, as these lower lying areas are more readily accessible by search teams than the very steep slopes that characterize much of the area.

The alien iguanas are easily distinguished from the natives by having a larger number of more densely packed, and more prominent nuchal tubercle scales, which are, by comparison, much reduced in size and number in Saint Lucia Iguanas. In addition, the subtympanic plate that distinguishes *I. iguana* from *I. delicatissima* is much larger relative to the tympanum in the alien population, whereas the scales immediately anterior to this subtympanic plate are proportionately much larger in the Saint Lucia Iguana. The eye of the Saint Lucia iguana, at least in adults, also appears to consistently have a much darker iris than that of the alien.

Management of the Alien Iguanas

The pathway of introduction to Saint Lucia for alien iguanas appears to have been via the pet trade, as appears to be the case for all alien populations of *I. iguana* introduced into the Caribbean and elsewhere (Kraus 2009). A few individual Green Iguanas (reports vary from four to six) were held in a private collection, without a permit, in Soufrière until at least 2002 (M. Morton, pers. obs.), after having been imported, again without a permit, as hatchlings from a pet shop in Canada during the late 1980s (M. Bobb, pers. comm.). The origin of these hatchlings is unknown. Although the undesirability of these animals being held in an unsecured private collection in Saint Lucia was noted in 2002, confusion over legal instruments apparently hindered their confiscation (two remaining in captivity in 2009 were belatedly confiscated and euthanized). In early 2008, reports of free-living iguanas, adults and hatchlings, in the Soufrière area were collated and mapped. Although the founding individuals were still in captivity in 2002 (M. Morton, pers. obs.), a questionnaire of Soufrière residents collected reports of iguana sightings prior to 2000 (Krauss 2010a), suggesting that they bred in captivity and offspring apparently escaped prior to 2002 (although this has been denied by the former owners).

The current geographical separation of Saint Lucia and alien iguanas on the island and the apparently restricted distribution of the alien population could provide an opportunity for eradicating the aliens. It might also offer an opportunity to mitigate some of the risks of mixed messages in public awareness campaigns that could arise from simultaneously trying to protect one iguana population while attempting to eradicate another.

Simulations of population growth using the population viability analysis software VORTEX (Lacy 1993, Lacy et al. 2009) have led to some predictions regarding the potential success of eradication efforts[2]. Simulating a worst-case scenario of 60% juvenile mortality (i.e., the same as that estimated for adult Green Iguanas in Panama; Rand and Bock 1992) and an alien population established since 1990 (i.e., a few years after hatchlings initially were imported) predicted that extinction probabilities greater than about 30% are very unlikely — regardless of any hunting pressure we could feasibly apply (Morton 2010). By contrast, a relatively modest hunting pressure (60–180 adults or 600–1,000 juveniles removed per year) could raise extinction probabilities to almost 100% in a best-case scenario of 90% juvenile mortality and a population established for only four years (i.e., accounting only for the first recorded appearance of hatchlings in the wild. This best-case juvenile mortality is slightly lower than that reported by Harris (1982) and van Devender (1982), but those studies could not distinguish loss of juveniles through emigration and death). The same hunting pressure is predicted to increase extinction probabilities to about 80–90% for intermediate scenarios (75% juvenile mortality and/or a population established since 2002, the last year when all the known founder iguanas were confirmed to be in captivity). VORTEX simulations also predicted the most likely current alien iguana population size under the worst-case scenario to be in the tens of thousands, which is inconsistent with the difficulty of finding alien iguanas around Soufrière, suggesting, at least for the moment, that the worst-case scenario is not the most accurate representation of reality. All scenarios predict explosive population growth if unchecked by aggressive management interventions.

In 2010, the SLFD and Durrell established a four-year collaborative partnership to eradicate the alien population of *I. iguana* (Krauss 2010b). To date, however, even relatively modest hunting pressures used in the simulations described above exceed the alien iguana removal rates that we have been able to achieve in the first year of this project, despite intensive searches. At this time (late 2010), only 21 adults (including sub-adults) and 132 hatchlings have been removed. All iguana removals have been the result of intensive visual searches supplemented by reports from local residents, which led to captures by hand or pole-noose. Captured iguanas are euthanized by lethal injection administered by the Veterinary Department of MALFF. Our low capture rate is likely due to a combination of the cryptic nature of iguanas at rest in trees and an iguana population putatively at low densities. Attempts to evaluate different search and capture approaches are under way.

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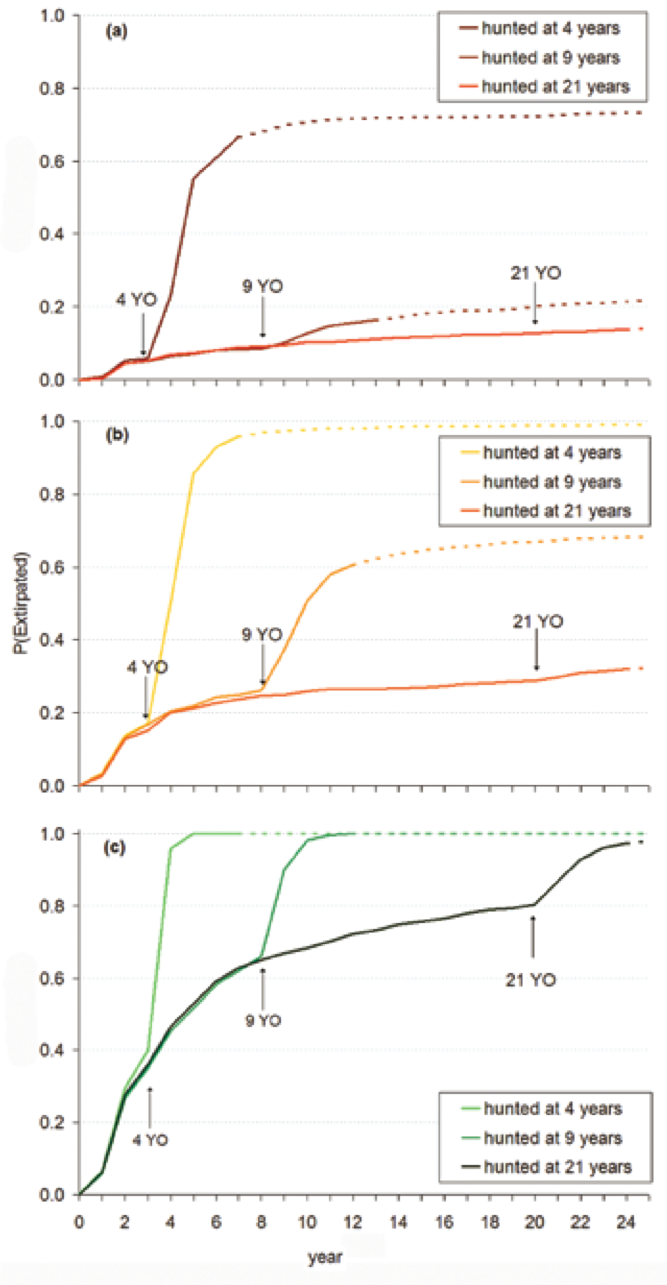
[2] Population viability analyses (PVAs) have been criticized for not providing valid predictions of extinction risk, especially over long time-scales (e.g., >100 yrs), as they assume constant ecological (and anthropogenic) processes that are unlikely (Boyce 2001). Their utility in comparing the relative effects of alternative management scenarios, however, has been noted (Boyce 2001). Another common criticism of PVAs is that all of the model parameter values are rarely known for the species being examined. As White (2000) commented, if parameter estimates are largely guesses, then model predictions are also guesses. Boyce (2001), however, pointed out that obtaining accurate estimates for all parameters is unrealistic and should not detract from the heuristic use of PVAs, for example, when comparing alternative management scenarios. For the scenarios presented here, some parameter estimates were taken from published literature on *I. iguana*. Age of first reproduction was estimated at two years, which is pessimistic when compared with Zug and Rand's (1987) estimates (but see and Pratt et al. 1994, cited in Rodda 2003). Reproduction was assumed to be polygynous (references reviewed in Rodda 2003). Adult mortality was set at 60% using Rand and Bock's (1992) estimates, and juvenile mortality was set at (as a worst case, and presumably pessimistic) the same. As a best case (and probably optimistic), it was set to 90%, as noted above. Two parameters were based on unpublished data collected by us in 2010, albeit using small samples: Sex ratio at birth was assumed to be 1:1 based on a sex ratio of 37:40 from a sample of 77 hatchlings. Mean clutch size was estimated at 40 ± 12.18 based on a sample of four gravid females in 2010. Other parameters were guesses. Percent of adults breeding was estimated as 62.7% for males (given polygyny) and 100% for females. Environmental variation was set to have no effect on breeding (i.e., no variation in reproductive success from year to year). Carrying capacity was set as high as VORTEX allows (60,000) to model unchecked growth in an expanding population. More details are provided in Morton (2010). Although all of these parameter values are uncertain, we believe they are biologically plausible (and more likely to err on the side of pessimism) — and they do allow us to model different management scenarios. As more data accumulate from alien iguana captures in Saint Lucia, we will be able to refine our parameter estimates and run further simulations. For now, they demonstrate the potential utility of this tool and allow us to simulate responses of a population the size of which is beyond our means to reliably estimate at this point.



Predicted effect of hunting pressure applied to juveniles and adults in the alien iguana population establishing in Saint Lucia. The graphs show the predicted probability that the population will be extirpated if it is experiencing: (a) Low (60%) juvenile mortality, (b) moderate (75%) juvenile mortality, or (c) high (90%) juvenile mortality in addition to the hunting pressure applied. The three lines in each graph illustrate uncertainty over how long this population has been establishing; i.e., hunting is simulated as being applied to a four-year-old population (hunting starts at point 4 YO), a nine-year-old population (at 9 YO), or a 21-year-old population (at 21 YO). For a population experiencing high juvenile mortality in addition to hunting (c), the probability of extirpation is high, regardless of how long the population has been establishing. For moderate or low juvenile mortality in addition to hunting (b, a), a high probability of extirpation exists only for the younger populations (first hunted at 4 YO or 9 YO). Simulations were carried out using VORTEX (Lacy et al. 2009); this figure was adapted from Morton (2010), who detailed the VORTEX model parameter values used in the simulations.

A pilot study in September 2009 also deployed 50 Tomahawk live traps and 20 releasing-lock snares in about 0.5 km^2 within the core area of iguana sightings, but no iguanas were captured by either method over a four-week period. Traps and snare enclosures were baited with aromatic fruit (e.g., mango, banana) plus fragments of red fabric, as iguanas are known to respond to red items such as hibiscus flowers (e.g., Alberts 2003). Our lack of success could be attributable to the arboreality of the iguanas, the putative low population density, and/or an apparent super-abundance of food (foliage), which would render the baited traps less attractive. Further trapping efforts are projected for the nesting season in 2011, which is presumably from February to early May — based on the timing of nesting in Saint Lucia Iguanas (Morton 2007) and consistent with the timing of alien hatchling captures in 2010. During this period, female iguanas presumably spend a greater proportion of their time on the ground and, post-nesting, are likely to be more motivated to feed after having suspended feeding while gravid (Rodda 2003). We also plan to pilot and evaluate the use of detector dogs to locate alien iguanas in 2011. Detector dogs have been used to locate another alien invasive arboreal reptile, the Brown Tree Snake (*Boiga irregularis*) on Guam, both in airport cargo (Vice and Engeman 2000) and free-living in trees (Savidge et al. 2008).

Given the allopatric distribution of the two iguana populations on Saint Lucia, we believe that no hybridization has yet occurred. Tissue samples from both populations have been banked in order to search for alleles unique to the alien population. These will allow us to survey the native population for evidence of introgression. Although the alien iguana population currently appears to be restricted to a relatively small area in Saint Lucia, it is reproducing and will presumably increase its range. Krysko et al. (2007) suggested that a population explosion of alien *I. iguana* in Florida followed Hurricane Andrew in 1992. Possible effects of Hurricane Tomas on Saint Lucia in October 2010 are unknown. The Soufrière area was among the worst affected by severe flooding and extensive landslides. Alien iguanas, both adults and young of the year, however, have been captured in the core area since Tomas struck. As with many other invasive species, reptilian invasions are often characterized by an extended lag period, sometimes lasting decades, which precedes an explosion in numbers and range (e.g., Krysko et al. 2007, Kraus 2009). Questionnaire returns from 2009 and 2010 suggested that the alien iguana population in Saint Lucia might now be moving, or about to move, beyond this lag period into a period of rapid growth. Efforts to eradicate the alien iguana population must include strategies for preserving the Saint Lucia Iguana in the face of ongoing threats emanating from the possibility of contact with the alien iguana population.

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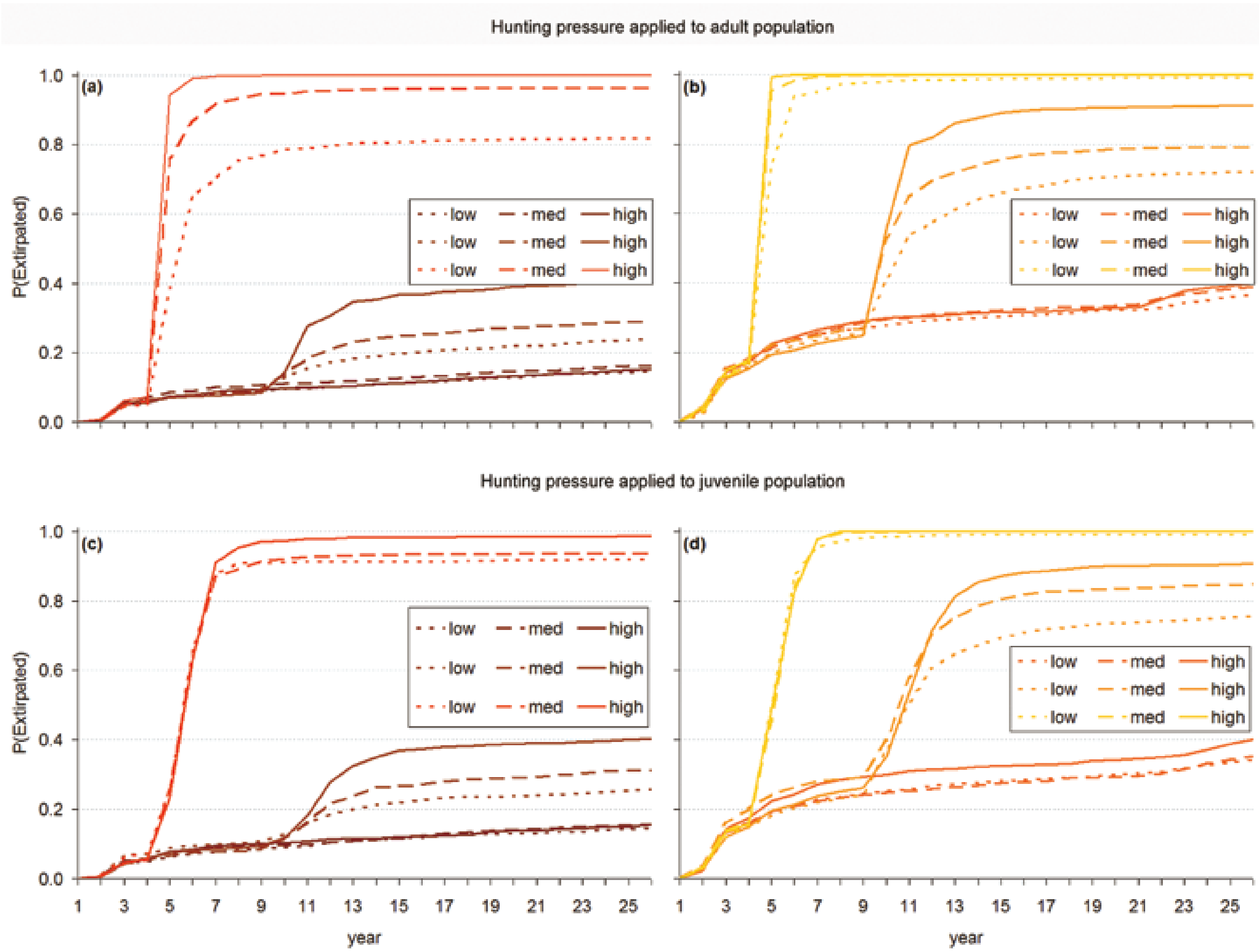

Predicted sensitivity to extirpation of the alien iguana population establishing in Saint Lucia depending on whether hunting pressure is applied to the adult population (a, b) or the juvenile population (c, d). Populations experiencing low juvenile mortality in addition to hunting (a, c) and moderate juvenile mortality (b, d) are shown. For populations with high juvenile mortality, the probability of extirpation under hunting is high in all cases. Simulations were carried out using VORTEX (Lacy et al. 2009); figure adapted from Morton (2010).

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