Species Status Assessment for the pygmy three-toed sloth (*Bradypus pygmaeus*) Version 1.1

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Executive summary

We (the US Fish and Wildlife Service; Service) received a petition dated November 15, 2013, to list the pygmy three-toed sloth (*Bradypus pygmaeus*) as threatened or endangered under the U.S. Endangered Species Act of 1973, as amended (Act). On June 9, 2014, we made a substantial 90-day finding that the listing may be warranted (79 FR 32900).

This document is an evaluation of the present and future conservation status of the sloth and follows the Species Status Assessment (SSA) framework we developed for review of species' biology and extinction risk. We analyzed the best scientific and commercial data available on the status of the species and projected its status into the future under several alternative scenarios considering plausible future threats and conservation actions.

SSAs are science, not decision, documents. The listing decision will be made after reviewing the science in this document, along with all relevant statutes, regulations, and policies. The outcome of the decision process will be published in the Federal Register, and the public will have appropriate opportunities for commenting. The SSA report is intended to be updated as new information becomes available and to support relevant actions under the Act into the future.

The pygmy sloth is endemic to Isla Escudo de Veraguas, a small Panamanian island. Having only been described as a full species in 2001, there is little detail available on the species' life history and habitat requirements. It is an arboreal folivore, and based on knowledge of related sloths, very likely has a generation time of around 6-10 years, giving birth to one offspring near annually.

Threats to the sloth's viability include the small extent (4.3 km^2) of Escudo and the naturally limited size of the species' single population. Together, these make the sloth vulnerable to random declines due to demographic stochasticity and/or to environmental catastrophes (e.g., storms). In addition, tourist visits to Escudo and management of the island's ecosystems are presently subject to little regulation. As a result, demand for collection of sloths to use in hands-on photographic experiences or in the zoo and pet trade, could endanger the species, if access to the island is not better controlled. Local fishermen who camp on the island also build temporary shelters from trees used by the sloths. An acceleration in the rate of deforestation would exacerbate existing threats to the species.

A grassroots conservation effort includes robust outreach and education programs to teach local communities about conservation of Escudo ecosystems and the sloth, and to help develop sustainable livelihood options in the region. The same conservation group leads monitoring surveys of the sloth's population.

In this SSA, we use the concepts of **resiliency**, **redundancy**, and **representation** to gauge the current and future condition of the species. **Resiliency** is a population's ability to be self-sustaining and to withstand natural demographic and environmental variability (stochasticity); it is improved in large, connected populations. Highly **redundant** species have a large number of populations, which safeguards against rare, localized catastrophic events. **Representation** is a measure of the species' capacity to adapt to changing environments.

We assess that the pygmy sloth presently has moderate to high resilience because although the best available data indicate that both its abundance and the extent of habitat available on Escudo have not considerably declined, there remains substantial uncertainty in these estimates and the impacts of tourism on both metrics. Moreover, the species has only one population, which was created by isolation from its closest mainland relatives. This demographic bottleneck left the species with low genetic diversity. Thus, the species has low redundancy and low representation.

We forecast the species' status under two alternative future scenarios and six climate change scenarios (encompassing the uncertainty in sea level rise trajectories) to determine how deforestation, the demand for sloths in the pet and tourism market, and the potential for the already small extent of Escudo to be further reduced by rising sea level would affect the species. Under a *status quo* future, where the island's management remains relatively unregulated, we forecast a decline in sloth abundance and resilience (Table 1) by the year 2050 due to likely collection, and the potential for moderate deforestation. The degree of declines likely to occur is uncertain. If local conservation capacity is improved, we anticipate the sloth's population will remain near steady and resilience will be high due to increased conservation and enforcement capacity of tourism. In all cases, redundancy and representation are projected to remain low. Regardless of the climate scenario, well under 1% of the island is projected to be inundated by rising sea level.

Table ES1: Summary of the present and future condition of the pygmy three-toed sloth. Although six future climate scenarios were evaluated (see main text), none changed the conditions from those projected here.

	Current	***Status quo* future (2050)**	**Future with improved conservation capacity (2050)**
Resiliency	Moderate - high	Low–moderate	High
Redundancy	Low	Low	Low
Representation	Low	Low	Low

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Chapter 1—Introduction

The pygmy three-toed sloth (*Bradypus pygmaeus,* Anderson and Handley 2001) is a close relative of the widespread brown-throated sloth (*B. variegatus*), and is native only to Isla Escudo de Veraguas, a small island off Panama's Caribbean coast. In 2013, the species was petitioned for listing under the Endangered Species Act of 1973, as amended (Act). We (the U.S. Fish and Wildlife Service; Service) published a substantial 90-day finding indicating that the petitioned action may be warranted on June 9, 2014 (79 FR 32900).

We use the Species Status Assessment (SSA) framework (Smith et al. 2018, entire) to review the species' biology and its conservation status considering the threats facing it. We project the status of the species into the future under alternative threat and conservation scenarios and given the conditions needed to maintain long-term viability. The SSA report is intended to be updated as new information becomes available, and to support relevant actions under the Act into the future.

In this SSA, we use the concepts of **resiliency, redundancy, and representation** to gauge the current and future condition of the species. **Resiliency** is a population's ability to be self-sustaining and to resist demographic stochasticity; it is improved in large, connected populations. Highly **redundant** species have many populations, and **representation** is a measure of the species' capacity to adapt to changing environments, which is improved by high genetic variability and the use of diverse habitats.

The SSA is not a decision document and does not lead directly to our decision on whether to propose listing of the species under the Act. Rather, the SSA is a review of the available information strictly related to the conservation status of the focal species. The listing decision will be made after reviewing the science in this document and all relevant statutes, regulations, and policies. The outcome of the decision process will be published in the Federal Register, and the public will have appropriate opportunities for commenting. Because both readers and decision-makers may have differing interpretations of risk, in Appendix I we calibrate the likelihood statements used throughout the text to help standardize discussion of uncertainty.

Chapter 2 – Biology of the pygmy three-toed sloth

Taxonomy, phylogeny, and physical description

The pygmy three-toed sloth (*Bradypus pygmaeus*; hereafter "pygmy sloth") is an arboreal mammal that is tan-colored with a near-white face and black stripes over the eyes (see cover photo; Anderson and Handley 2001, p. 18). The species is most closely related to the brown-throated three-toed sloth (*B. variegatus*; hereafter "brown-throated sloth"; Ruiz-Garcia et al. 2020, pp. 468–470; Anderson and Handley 2001, pp. 9–15) but is found only on the small Panamanian island Isla Escudo de Veraguas (hereafter, "Escudo"). The pygmy sloth was originally separated taxonomically from the more widespread brown-throated sloth (native to central America including mainland Panama and northern South America) based on its consistently smaller size and distinct skeletal structures (Anderson and Handley 2001, 9–18). To our knowledge, there has since been no taxonomic debate regarding the species' separation.

Full-grown pygmy sloths are around 500 mm length and weigh approximately 3 kg (Voirin 2015, p. 703; Anderson and Handley 2001, p. 18). On average, compared with the brown-throated sloth, the pygmy sloth is 40% lighter in mass and 15% smaller in length (Anderson and

Handley, p. 21). Using a combined index of body size measurements, the pygmy sloth averages seven standard deviations smaller than the mainland brown-throated sloth (Anderson and Handley 2002, p. 1053). Detailed description of morphological characters that separate the pygmy sloth from other three-toed sloths (*Bradypus* spp. hereafter, "three-toed sloths") are described in Anderson and Handley (2001, pp. 22–25).

Escudo is the oldest island of the Bocas del Toro archipelago (around 9,000 years separated from the mainland) and the most distant from the mainland among those in the very young archipelago (Anderson and Handley 2001, p. 4). The brown-throated sloth inhabits the other islands and declines in size along a gradient associated with island age (Anderson and Handley 2002, p. 1052). The cline suggests repeated and ongoing evolution of dwarfism on the islands (Anderson and Handley 2002, p. 1048; Anderson and Handley 2001, p. 9–18), but only the Escudo sloths (i.e., pygmy sloths) are distinct enough to warrant status as a separate species (Anderson and Handley 2001, entire).

A possible explanation for the evolution of dwarfism in island endemic mammals, including the pygmy sloth, is that smaller size facilitates coping with resource limitation; in the sloth, it may also enable movement within the tangled mangrove thickets (Anderson and Handley 2001, p. 26; Anderson and Handley 2002, pp. 1045–1046).

More recently, very limited phylogenetic data (from N = 1 pygmy sloth and N = 65 brown-throated sloths, only 1 of which was from mainland Panama and not from the nearest regions to Escudo) support separation of the pygmy sloth from its mainland relatives. These genetic data suggest a much deeper evolutionary origin, 4–14 million years since separation from the modern brown-throated sloth lineage, is possible (Ruiz-Garcia et al. 2020, pp. 473–474). Genetic sequencing of a pygmy sloth type specimen, pale throated sloth specimen from French Guiana, and brown-throated sloth specimen from Peru also indicates the pygmy sloth constitutes a distinct lineage within three-toed sloths, diverging 8 Ma (Gibb et al. 2016, pp. 626, 628). However, the brown-throated sloth contains strong geographic structuring of genetic variation within the species (Ruiz-Garcia et al. 2020, entire) and data supporting the deeper evolutionary hypothesis contains a limited sample size that lacks data from mainland brown-throated sloths nearest Escudo. The limited amount of data substantiating the deeper evolutionary hypothesis and the strong with-in species genetic variation seen in brown-throated sloths leaves open the possibility that future sampling may support the intuitive island-origination hypothesis, if northeast Panamanian brown-throated sloths are indeed more closely related to the pygmy sloth than are the more distant brown-throated sloths (Voirin 2021, pers. comm.).

Geographic range and habitat use

Escudo is 4.3 km^2 in area and lies about 18 km from the Panamanian mainland (Fig. 2.1; Anderson and Handley 2001, p. 5). About 2.5% of the island is composed of red mangrove (*Rhizophora mangle*) thickets scattered along the north coast (ZSL 2017, p. 11; Voirin 2015, p. 705; Kaviar et al. 2012, p. 1–3). The remainder of the island is a mixed species tropical forest (ZSL 2017, p. 11). Although once thought restricted to the mangroves (Anderson and Handley 2001, p. 5), the pygmy sloth does enter the interior forest, venturing greater than 200 m from mangroves (ZSL 2017, p. 9; Voirin 2015, p. 705; Kaviar et al. 2012, p. 2). It is uncertain whether sloths on Escudo are reliant on the mangroves or whether some live entirely within the interior forest (Voirin 2015, p. 705).

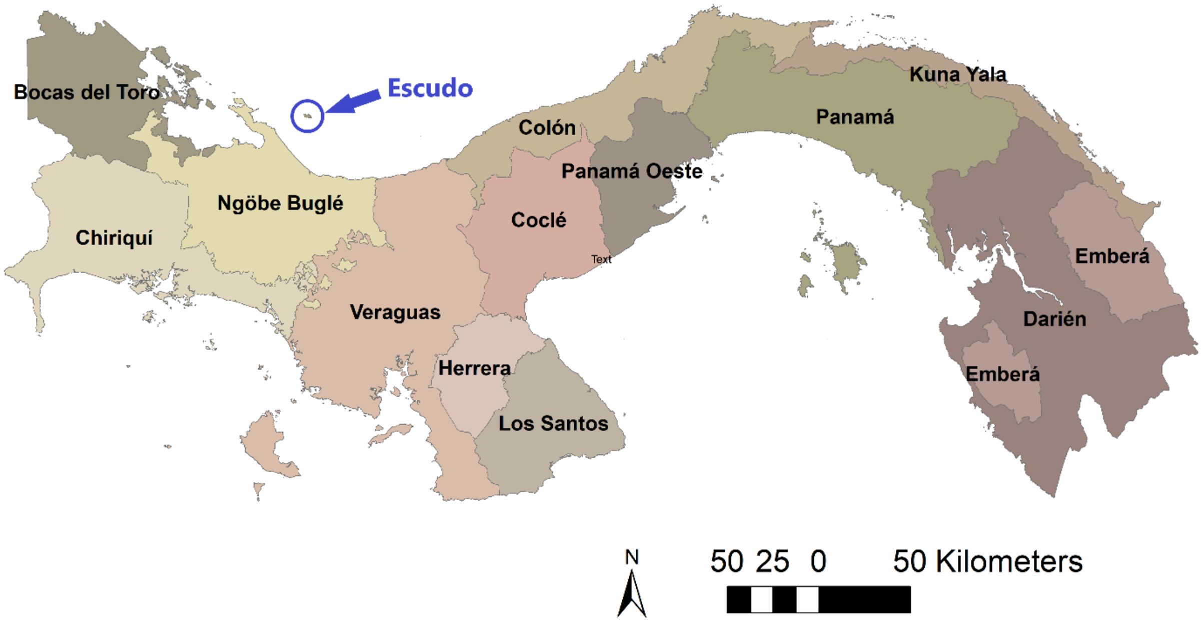


Figure 2.1—Map showing the location of Isla Escudo de Veraguas ("Escudo") off the coast of Panama. Note that Escudo belongs administratively to Bocas de Toro province, not the nearer Ngobe Bugle province. Map data are provided freely from GADM.org, the Database of Global Administrative Areas.

Some evidence indicates that three-toed sloths are relatively well-suited to persistence in small habitats. In Suriname, a 7-ha urban forest fragment was home to 135 pale-throated sloths (*B. tridactylus*) (20.1 sloths/ha; Pool et al. 2016, p. 26). The brown-throated sloth was present at 26 individuals/ha in another urban forest fragment in Brazil (Silva et al. 2013, p. 530). Surveys in larger natural habitats found three-toed sloths at lower densities (up to 6.7 individuals per hectare; Pool et al. 2016, p. 30). The higher densities in urban forest patches may be due to immigration from surrounding deforested patches, the lack of natural predators (true of Escudo, as well), presence of early-successional species preferred as food plants, and/or due to the relatively easy mating opportunities in a small habitat (Pool et al. 2016, pp. 30–31). Alternatively, high densities may occur in natural habitats, too, but denser, taller vegetation may make detecting sloths harder (Pool et al. 2016, pp. 30–31).

Although never studied outside of their Escudo habitat, pygmy sloths very likely require intact forest. Related brown-throated sloths strongly avoid open cattle pastures in Costa Rica, where the lack of overstory trees makes movement and foraging difficult for the arboreal sloths (Garces-Restrepo et al. 2017, p. 2257; Mendoza et al. 2015, entire).

Diet, physiology, and behavior

All three-toed sloths are arboreal folivores; they consume leaves with relatively low nutritional quality (Anderson and Handley 2001, p. 2). The low quality of their diets necessitates physiological and behavioral adaptations including limited movements and low muscle mass (Anderson and Handley 2001, p. 2). Three-toed sloth body temperature declines at night, during rainy periods, and during periods of especially low activity. This incomplete homeothermy (warm-bloodedness) helps reduce energy expenditure (Gilmore et al. 2008, pp. 130–131).

Pygmy sloths consume red mangrove, *Cecropia*, guava (family Myrtaceae), and *Slonea* (family Eleocarpaceae) leaves on Escudo, but it is not known which, if any, species are required (Smith et al. 2021, p. 386; Voirin 2015, p. 706). Wild pygmy sloths have been observed using at least 15 plant species (including mangroves) for food and refuge, including *Inga multijuga* (Smith et al., 2021; Smith, 2022; Superina, 2022).

Individual variation in three-toed sloth dietary preferences can be large (Chiarello 2008, p. 271–274), although this may not be true for *B. pygmaeus*, given the relatively low diversity of trees in their island habitat. At least in other sloths, the leaf species ingested as a newborn may shape preferences later in life (Raines 2005, p. 562).

Like all sloths, the pygmy sloth hosts green algae in its fur. Whether the algae provide the sloths with camouflage coloration, nutrients absorbed through their hair, nutrients through consumption, or whether the algae are simply commensals with little impact on the sloths is uncertain (Pauli 2014, entire; Suutari et al. 2010, entire).

Reproductive biology

Few data exist specific to pygmy sloth reproduction. Generation length, or average age of parents of the current cohort, is estimated to be 10.6 years for three-toed sloths based on mean generation lengths of members of the same order with similar mass (Pacifici et al., 2013). In three-toed sloths more broadly, age at first reproduction is between 3 and 6 years and reproductive frequency is approximately annual (Anderson and Handley 2002, p. 1051; Taube et al. 2001 p. 184). Based on demographic data for three-toed sloths, an average generation time, or time between birth of an individual and birth of its offspring, of around 6-10 years for three-toed sloths may be reasonable (Anderson and Handley 2002, p. 1051; Taube et al. 2001, p. 184). Longevity and survivorship are little-known for three-toed sloths.

The maned sloth (*Bradypus torquatus*) and brown-throated sloth have only one offspring per pregnancy following gestation of 100–180 days (Benirschke 2008, p. 168; Taube 2001). Newborns of these species weigh between 200 and 250 g (Benirschke 2008, p. 168). Similar details on reproductive parameters specific to pygmy sloths are not known, but surveys on Escudo conducted between 2014 and 2017 found between 0 and 35% of females were pregnant at any given time, with pregnancy much more common in spring than autumn (ZSL 2017, p. 15).

Population biology

Genetic data, although limited, indicate Escudo has a single population of pygmy sloths (Silva 2013, p. 138). In addition, because pygmy sloths have been documented moving up to several hundred meters into the interior forest (ZSL 2017, p. 9; Voirin 2015, p. 705), a distance comparable to the size of interior forest areas separating Escudo mangrove patches (less than 500 m; ZSL 2017, p. 11), it is probable that sloths are moving throughout the available habitat and thus only a single population of the species is likely.

Resiliency, redundancy, and representation

SSAs use the concepts of resiliency, redundancy, and representation ("the three Rs") to gauge the current and future condition of the species (Smith et al. 2018, entire). Resiliency is a population-level characteristic and is a population's ability to be self-sustaining and to resist demographic stochasticity. It is improved in large, connected populations, and those exhibiting high rates of reproduction. Redundancy is related to a species' distribution across multiple locations (e.g., having many geographically dispersed populations). More redundant species are more secure from the potential effects of random, catastrophic, local events. Representation is improved in species with high genetic variability or which inhabit a wide range of ecological settings; both these characters facilitate adaptation to future environmental changes, whether natural or anthropogenic.

Table 2.1—Pygmy three-toed sloth needs at the individual and species level.

Individual	Species
Fresh, likely young, red mangrove, tropical trees (e.g., *Inga*, *Cecropia*, *Sloanea spp.),* and possibly other plant species as food.	Resiliency: Appropriate forest extent to contain viable population.
Red mangrove thicket habitats; also use the adjacent forest.	Resiliency: Appropriate forest contiguity to contain viable population.
Requirements for reproduction unknown	Resiliency: Appropriate density of individuals for finding mates. Redundancy: Individuals distributed across multiple locations to reduce risks from catastrophic events. Representation: Population contains genetic diversity to enhance adaptive potential.
Citations: Chiarello 2008, p. 271; Smith et al. 2021, p. 386; Voirin 2015, p. 706; Garces-Restrepo et al. 2017, p. 2257; Mendoza et al. 2015, entire	

Evaluation of each R is conducted considering the species' needs (Table 2.1) and its responses to current and future conditions. Based on the species' biology described above, the pygmy sloth requires food plants, intact, connected forest habitats, and like most species, sufficient conspecific individuals to find a mate.

Chapter 3–Threats and conservation measures

Deforestation

Small-scale (very likely less than 1% of the island since 2001) but continuing harvest of red mangroves and interior forest trees occurs on Escudo for construction of temporary huts used by fishermen (ZSL 2017, p. 16) and possibly for timber for tourism development in nearby regions (Feller, 2022). Up to a few hundred people may stay in simple wooden structures on the island at peak times (Voirin et al. 2015, p. 706) and a small number of Indigenous people have expressed interest in permanent residency on Escudo (Smith 2021, pers. comm.). Stacked planks and coconuts suggest timber and non-timber forest products may also occasionally be exported from the island (ZSL 2017, p. 16). Activities of deforestation and timber harvest occur on nearby Peninsula Valiente as part of a new industry that has been driven by a demand for tropical hardwoods to support the ongoing coastal, tourist, retirement, and leisure industry development throughout the archipelago (Feller, 2022). This industry and deforestation may also extend onto Escudo as demand and development increases (Feller, 2022). Additionally, there have been reports as recent as April 2022 of individuals illegally removing endemic plant species from the island (Jordan, 2023, pers. Comm.). Reduced forest extent due to deforestation means less area available to pygmy sloths within their already limited range on the small island of Escudo.

Continued forest loss would eventually lead to a reduced pygmy sloth population, but the lack of good information on pygmy sloth movements, densities, and their relative reliance on mangrove versus interior forest currently prohibit knowledge of that threshold. Evidence from urban populations of related species does indicate three-toed sloth species may be relatively resilient to life in small forest fragments (see *Geographic range and habitat use* in Chapter 2; Pool et al. 2016, pp. 26–30), but it is not clear whether this extends to the pygmy sloth.

Tourism and development around Escudo

As the nearby coastal regions of Bocas del Toro, Veraguas, and Ngobe-Bugle provinces grow in popularity with local and especially foreign tourists, so too has the volume of visits to Escudo and the demand for infrastructure there (ZSL 2017, pp. 3, 17). Both Panamanians and foreign investors are interested in developing the island for greater tourism commercialization (Smith 2021, pers. comm.; Voirin 2021, pers. comm; Voirin 2015, pp. 706–707).

The legality of development on Escudo itself is uncertain. Although included by Panama in 2009 as part of a larger marine protected area (ZSL 2017, p. 3), in 2012 the island was classified as open to tourism, scientific, entertainment, and cultural development (Voirin 2015, p. 706–707). Indigenous communities claim ownership of the island and several Tribes have offered the island for sale (Voirin 2021, pers. comm.), although it is difficult to gauge the seriousness of such offers from the information available. Thus, the actual benefits that come from the protected status of Escudo are unclear (e.g., fishing continues along with harvest of other wildlife, including sea turtles; ZSL 2017, pp. 3 and 17).

Casinos, banks, and lodges have all been suggested for the island or nearby mainland. Private investors who have bought large swaths of undeveloped mainland coast close to Escudo are now marketing subdivided real estate and developing large resorts (Jordan 2021, pers. comm.; Voirin 2021, pers. comm.; Bilbao 2017, not paginated). At least one major developer is alleged to have used fraudulent means and even threats of violence to secure thousands of acres of beachfront property from rural and Indigenous sellers (Bilbao 2017, not paginated).

Coastal development would enable larger tour boats that operate along other parts of the coastline to reach the small island, very likely bringing more frequent visits to Escudo with up to 500 visitors at a time (Smith 2021, pers. comm.; Voirin 2021, pers. comm.; Oberle and Rodriguez 2020, entire). Construction of major roads and ports will improve accessibility of these newly developed mainland coastal areas (Bilbao 2017, not paginated), making the trip to Escudo easier for many more people (Bilbao 2017, not paginated). The prospect is concerning enough that the IUCN Director General and President of the Species Survival Commissions wrote in 2020 to the Panamanian Ministry of the Environment and the Panamanian Ministry of Tourism to express concern about increasing tourism impacts on Escudo species, including the pygmy sloth (Oberle and Rodriguez 2020, pp. 1–2).

In general, Escudo and its surrounds has very limited government presence or regulatory enforcement because of its remote location and semi-autonomous nature as an Indigenous-inhabited territory that is administratively part of the mostly distant Bocas del Toro province. A management plan for Escudo was under development, but the Panamanian Ministry of Environment halted work on the effort because of a lack of resources (Jordan 2021, pers. comm.). The plan could have instituted a maximum number of visitors for Escudo and banned camping, collecting, and bringing pets or pests to the island (Jordan 2021, pers. comm.). The management plan could be completed soon, but the outlook is not promising (Jordan 2021, pers. comm.).

While smaller scale, Indigenous-led pygmy sloth tourism has been less disruptive than the more industrial form (Voirin 2021, pers. comm.), the permit requirements for tourists to visit the island is not enforced (ZSL 2017, p. 17–18). Small-scale tourist operations are also likely to be out-competed by larger organizations entering the market. Although large scale tourism has not yet reached Escudo as it has in the surrounding archipelago, tourism is steadily increasing and tourist boats arrive without notice and are reportedly damaging coral reefs and sea turtle nesting grounds (Smith 2021, pers. comm.), indicative of at least some operators' lack of concern or knowledge about harm to the island's ecology.

Although Panama has a mandatory environmental impact assessment process (Gonzalez 2008, pp. 320–327), reviews are sometimes diminished by demand for development (e.g., Gonzalez 2008, pp. 328–333) and often initiated too late in a project's progression to revise plans or prevent identified environmental harms (Jordan 2021, pers. comm.). Consultations between government environmental authorities and developers can be rapid and leave little room for adjustment of project plans (Jordan 2021, pers. comm.).

Collection for tourism, pet, and zoo demand

Desire for up-close or in-hand photos of pygmy sloths will likely increase along with tourist visitation as global popularity of sloths and demand for pet and zoo-housed sloths have grown tremendously (Voirin 2015, p. 706). The risk of sloths being smuggled away from Escudo is greater as more unregulated visitors reach the island (Jordan 2021, pers. comm; Voirin 2021, pers. comm.). This is despite a general lack of knowledge regarding husbandry techniques for three-toed sloths and three-toed sloths rarely surviving more than several months in captivity (Voirin et al. 2014a, p. 2; Espinoza and Cliffe 2013, p. 4; Raines 2005, p. 557).

Despite the challenges of keeping three-toed sloths in captivity, one pygmy sloth researcher reported he receives near-daily emails asking where to procure pygmy sloths (Voirin 2021, pers. comm.). He also described concern over international smuggling efforts by both Panamanian and European actors, although these activities cannot be substantiated (Voirin 2021, pers. comm).

In 2013, the Dallas World Aquarium (DWA) sent a team to Escudo and collected 11 pygmy sloths for export to their zoo in Texas (Espinoza and Cliffe 2013, p. 2). Despite the cooperation of Panamanian authorities at the national level, the attempted export was stopped by protesters at the Bocas del Toro Airport and the pygmy sloths were surrendered to the Smithsonian Institution, which returned them to Escudo (Espinoza and Cliffe 2013, p. 4; Superina, 2022, pers comm.). The local indigenous congress was not aware of DWA's plans to export pygmy sloths and had not authorized them, despite needing to under Panamanian legislation (Superina, 2022, pers comm.). At least two of the sloths died after being returned to Escudo (Superina, 2022, pers comm.).

In a subsequent letter to the Panamanian National Environment Authority (ANAM), the Director General of the IUCN and the Chair of the IUCN Species Survival Commission expressed concern that there had been no collaborative investigation of the impact of such an export on the wild population and that there was no justification for any expectation of success of a captive breeding program, given the difficulties of keeping three-toed sloths in captivity (Marton-Lefèvre 2013, entire). Separately, members of the IUCN SSC Anteater, Sloth, and Armadillo Specialist Group and pygmy sloth experts wrote a letter to the Association of Zoos and

Aquariums (AZA) to address falsehoods in a letter sent to AZA by the owner of a privately owned nature reserve (Superina, 2022). In it, they strongly criticized the Dallas World Aquarium's attempt to unilaterally export pygmy sloths without consulting the broader sloth conservation community and pointed out a number of falsehoods and misrepresentations Dallas World Aquarium had forwarded regarding the state of and justification for sloth husbandry, and the condition of the pygmy sloth and Escudo (Voirin et al. 2013, entire).

Climate change and loss of island area

As progressing global climate change causes sea level to rise due to warming, expanding ocean water, and melting glaciers, the extent of the pygmy sloth's island habitats may be reduced (IPCC 2019, pp. 6–13). Any loss of habitat area from the already small island could reduce the number of sloths supported on Escudo. However, we analyze this future potential in detail in Chapter 5 of this report and find that the threat of inundation is minimal.

Anecdotally, erosion has been increasing on Escudo (Smith 2021, pers. comm.), although its extent is not quantified, and it is not known whether this is due to sea level rise, storms, coastal deforestation, or other human-caused shoreline disturbance.

Predation and disease

The pygmy sloth has no native predators on Escudo (Voirin 2015, p. 705). Indigenous people do not hunt or consume the sloth, despite previous rumors to the contrary (Voirin 2015, p. 706; Voirin et al. 2014b, p. 3). There is no indication of infectious disease or parasitism significant to population persistence in three-toed sloths, although the literature is limited and not specific to pygmy sloth populations.

Conservation measures

An ongoing project is employing innovative and integrative activities to support pygmy sloth and Escudo conservation (ZSL 2017, entire). Led by veterinarian Diorene Smith and funded in part by the Zoological Society of London, the project includes repeated population surveys, education of Indigenous communities and schoolchildren regarding Escudo ecology and the benefits of conservation, and cooperation with the Indigenous government and local fishermen's association to develop the community-based natural resources management program (ZSL pp. 19–27).

As of 2017, at least four years of pygmy sloth surveys have been completed in the Escudo mangroves, island habitats have been mapped, and litter and deforestation events recorded (ZSL 2017, pp. 19–27). In addition, multiple workshops have been held with fishermen who work around and camp on the island to understand their needs, to communicate the importance of Escudo conservation, and to develop sustainable livelihood alternatives (ZSL 2017, pp. 19–27). A scientific review committee had also been created to evaluate research activities on Escudo in partnership with Indigenous governance. Overall, the aim is to improve monitoring and planning of activities around Escudo, reduce threats to the island habitats, and track the sloth's population.

As of 2017, the national Ministry of the Environment could not afford to visit Escudo independently (ZSL 2017, p. 18). This hinders enforcement of tourism permit requirements and all anti-littering and -deforestation laws. On occasion, the agency sent a ranger to the island with researchers, but no more than twice per year (ZSL 2017, p. 18). Nonetheless, Escudo is technically a protected area with management shared between the national Ministry of the Environment and the local Indigenous council (Voirin et al. 2014a, p. 5). Plans were in the works to develop a comprehensive management plan for Escudo (ZSL 2017, p. 22), to foster cooperation between communities and government agencies in enforcement of environmental laws, and to prevent illegal logging, pollution, and wildlife collection. Additionally, in June 2022, a workshop was held in collaboration with the Ministry of Environment and the Ngäbe - Buglé indigenous authorities to develop the management plan for the conservation of the pygmy sloth (Smith, 2022, pers comm.). The information generated by this pygmy sloth conservation action plan is expected to also serve as the basis for the future management plan for Isla Escudo de Veraguas (Smith, 2022, pers comm.), but as of 2022 that plan has not yet been developed.

Pygmy sloths have been listed under CITES Appendix II since 2013. The CITES secretariate acknowledged the initial omission of the pygmy sloth from Appendix II was an oversight considering they are thought to be split from brown throated sloths, which have been included in Appenix II since 1983 (Superina, 2022). Since inclusion in Appendix II, there have been 10 specimens or bodies traded internationally, 8 of which were identified of Panamanian origin and exported from the US (CITES Trade Database).

Chapter 4 – Current status

In this section we assess the current status of the pygmy sloth in terms of the three Rs (see Chapter 2). Redundancy is the simplest of the three Rs for this species: with only one wild population and no captive individuals, the pygmy sloth naturally has very low redundancy. Although very few large cyclones and storms reach Escudo, it is seismically active (Feller 2021, pers. comm.) and loss of the Escudo population would equate to global extinction. Indeed, the IUCN classifies the pygmy sloth as critically endangered, its highest level of threat, largely because the species' extent of occurrence is so small (< 100 km^2) and it is known from only one location less than 10 km^2 in extent (Smith et al. 2022, unpaginated). We note that although the Red List provides an expert-validated assessment of conservation threat, the IUCN's rating system is not directly comparable to the definitions of "threatened" and "endangered" used for ESA status determination.

With respect to representation, the isolation of a small number of founder individuals when the pygmy sloth separated from the mainland population of brown-throated sloths (likely around 9,000 years ago; Anderson and Handley 2001, p. 4) would have created a natural genetic bottleneck (a sharp decrease in a population's genetic diversity as a result of a reduction in population size; Silva 2013, p. 138). Today, genetic variation in the population is low; allelic diversity (the number of different forms of a gene across the population) and heterozygosity (the frequency with which individuals carry greater than one allele at a given gene) are comparable to those of a genetically distinct, isolated population of brown-throated sloth in the Atlantic Forest of Brazil, but are lower than the same measures for populations of brown-throated sloths in the Amazon forest (Silva et al. 2018, p. 1301). The limited sampling of pygmy sloth that has been done does not indicate a history of inbreeding depression (the loss of heterozygosity due to mating with close relatives; Silva et al. 2018, p. 1301). Because the pygmy sloth only inhabits Escudo, the habitats it uses have little ecological variation. For these reasons, we consider the pygmy sloth's ability to adapt to changing environments and thus representation to be naturally low.

To assess the population's resiliency, we define two criteria (Table 4.1). A population abundance criterion and a forest extent criterion. We incorporate the knowledge that the species has likely always been rare by basing the population abundance criterion on detection of a population decline in addition to considering absolute abundance as rarer species are at elevated risk of extinction, even if the rarity is natural (Flather and Sieg 2007, entire; Johnson 1998, entire). The forest extent criterion subsumes the pygmy sloth's requirements for shelter, connectivity, and native food plants.

Table 4.1—Criteria for evaluating resilience of the pygmy three-toed sloth.

Habitat and demographic criteria	Condition categories
Population abundance	**High (3 points):** Surveys and expert opinion indicate no population decline relative to a 2014–2015 baseline (ZSL 2017, p. 13); Literature and expert opinion indicate negligible impact of tourism and human habitation on species behavior, ecology, or individual sloth removal from the population. **Moderate (2 points):** Possible population decline relative to the 2014-2015 baseline (ZSL 2017, p. 13); evidence of some impacts of tourism and human habitation on species behavior, ecology, or individual sloth removal from the population. **Low (1 point):** Certain population decline relative to a 2014–2015 baseline (ZSL 2017, p. 13); evidence of large negative impacts of tourism and human habitation on species behavior, ecology, or individual sloth removal from the population.
Forest extent	**High (3 points):** Red mangrove thickets and native interior forest show negligible reduction in extent relative to its baseline (as reported in ZSL 2017, p. 11 for mangroves; remainder of the island for interior forest). **Moderate (2 points):** At least one of red mangrove thickets or interior forest is reduced in extent relative to its baseline, but neither substantially. **Low (1 point):** At least one of the red mangrove thickets or interior forest is substantially reduced in extent relative to its baseline.

Where the population has a total resilience of at least 5 points, we consider it to have high resilience, indicating high probability of population viability. In cases where the population has a total resilience between 3 and 5 points, we consider it to have moderate resilience, indicating moderate probability of population viability. Finally, if the population has a total resilience of 3 points or less we consider it to have low resilience, indicating low probability of population viability.

The most recent estimate of total pygmy sloth population size is 2,000–2,500 individuals and the population is thought to be declining (Smith et al., 2022, unpaginated). Previous estimates of 500-1,500 individuals were estimated based on sighted pygmy sloths, their densities in the mangroves, the densities of brown-throated sloths on the Panamanian mainland, and assumptions about relative habitat quality on the mainland versus the island (Voirin 2015, p. 705). It is difficult to estimate the true size of the population due to difficulty of sighting (and therefore counting) pygmy sloths in the denser interior forest compared to the coastal mangroves; in other species, up to 95% of known-present sloths are not sighted by surveyors (Voirin 2015, p. 705 and Montgomery et al. 1973 cited in Voirin 2015, p. 705). All estimates indicate an extremely small number for an entire species (Smith et al, 2022, unpaginated).

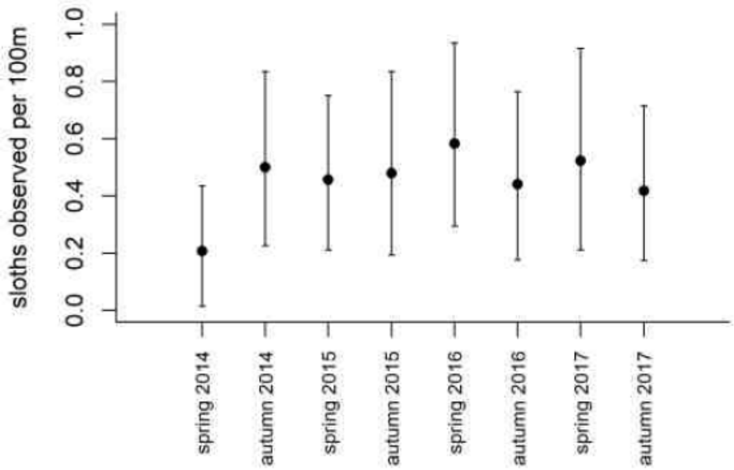
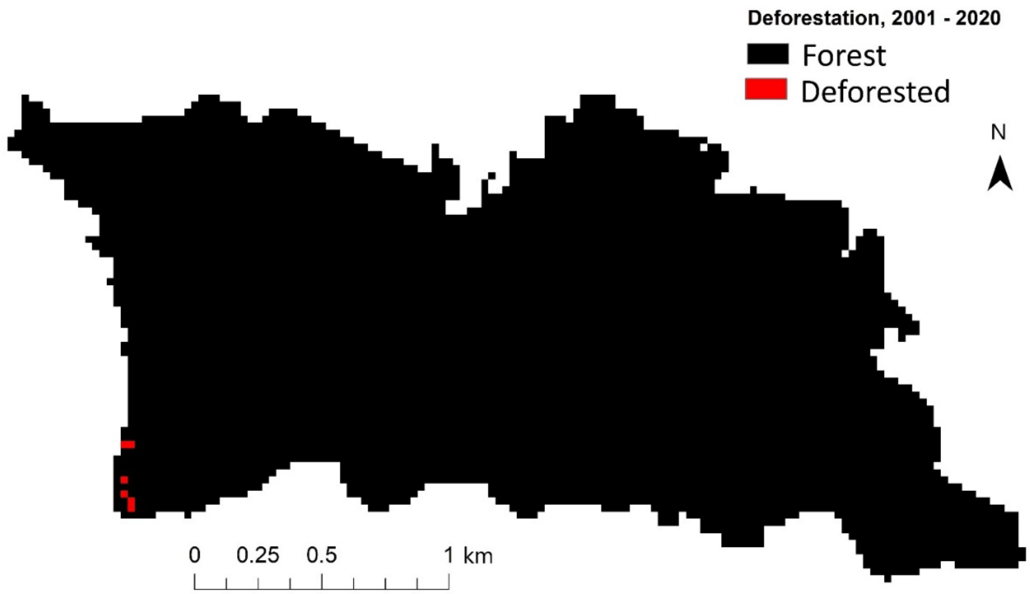


Fig. 4.1—Encounter rate of pygmy sloths from repeated surveys of mangrove transects on Isla Escudo de Veraguas, 2014–2017. Shown are the mean (dot) and 95% confidence interval. Original figure, data collection, and analysis by D. Smith (ZSL 2017, p. 13).

The most recently available population trend data come from twice-annual surveys conducted from 2014–2017 in the mangrove portions of Escudo. They showed no change in encounter rate of sloths, although the uncertainty in abundance was large (Fig. 4.1; ZSL 2017, p. 13). No systematic survey methods suitable for the denser interior forest where sloths are harder to detect exist. Additionally, literature and expert opinion indicates that tourism is increasing on the island and attempts to remove pygmy sloths from the island for use in the tourism industry occur (Espinoza and Cliffe 2013, p. 2; Jordan 2021, pers. comm; Voirin 2021, pers. comm.). Little is known of the impacts of increased human presence on the island to pygmy sloth behavior and ecology. While recent surveys do not provide evidence of a decline in population, the most recent IUCN Red List assessment suggests the population is decreasing (Smith et al., 2022, unpaginated). To account for the uncertainty in population estimates and tourism impacts and for the elevated extinction risk of a species with such a small population size, we assign 2 points for the population abundance criterion; no decline is indicated from the limited surveys, but expert opinion suggests the trend is decreasing and the species is far from fully surveyed.

To assess forest extent, we downloaded and analyzed Landsat-derived deforestation data (approximately 30 m resolution) for the years 2000–2020 from the Global Forest Change server (data from Hansen et al. 2013, not paginated). We calculated the number of deforested pixels using the zonal statistics function in ArcGIS 10.7.1 software on the downloaded GeoTiff files. These data are the current (2021) global standard for monitoring tropical forests and reveal only 0.11% of pixels with at least 50% tree cover in 2000 (totaling 3.95 km^2) were deforested by 2020.

Fig. 4.2—Map of forest extent and satellite-detected deforestation on Escudo for the years 2001–2020. Data from Hansen et al. 2015. Note that deforestation less than approximately 30 x 30m (one pixel) may not be detected by this product.



None of the satellite-indicated deforestation occurred along the north coast of the island where the rarer mangrove habitats exist (Fig. 4.2). However, ground-based mapping of deforestation events shows tree clearing has occurred in mangrove areas of Escudo (ZSL 2017, p. 16). Additionally, the most recent IUCN Red List assessment indicates habitat degradation has resulted in continuing decline in the quality of habitat and area of occupancy (Smith et al, 2022). The discrepancy is likely because the satellite product we used does not detect all partial clearing at the scale of less than a single pixel. Mangrove clearings are reported to be of "small scale" (ZSL 2017, p. 16). Thus, actual deforestation is likely somewhat greater than 0.11%. However, visual inspection of recent satellite imagery and descriptive records of "low but consistent" levels of forest clearing from the ground-based surveys on Escudo (ZSL 2017, p. 16) support the finding that the population scores relatively high for the forest extent criterion. Given the uncertainty of the actual deforestation rate over the last 20 years and the absence of information on the species' tolerance of deforestation or impacts of smaller and consistent clearings on the population, we assign a score of 2.5-3 for the forest extent criterion. Summing the scores from the two resilience criteria indicates that the species currently has moderate to high resilience (4.5–5 out of 6 points).

Chapter 5 – Projection of future viability

In the final step of the SSA analysis, we forecast the future condition of the species under multiple alternative future scenarios (Smith et al. 2018, entire). These scenarios are built to represent plausible conditions given the range of potential threats and conservation the species may experience. The scenarios are not intended to encompass all possible outcomes, and none should be construed as a prescription for conservation activities. Rather, they are designed to project future viability of the species under different plausible conditions chosen to reflect the range of possible futures.

Based on our assessment, we concluded that two important potential threats to pygmy sloth viability in the future are (1) increased development and tourism around—and visitation to—the island, and (2) increased inundation of Escudo due to progressing climate change. To project the future viability of the species under the plausible range of conditions considering how these threats may develop, we constructed 12 scenarios comprising possible future conditions pygmy sloths will experience on Escudo as regional development and climate change proceed.

Specifically, our projections include "*status quo*" and "improved conservation capacity" alternatives to assess potential impacts of growing development and tourism, and for each of these two futures, we assessed six climate change projections encompassing the uncertainty in sea level rise trajectories for the year 2050. This is approximately 30 years from the completion of the first version of this SSA and would include time for climate change and development to progress, as well as for conservation activities affecting Escudo to grow. Likely around 3-5 generations of pygmy sloths would be included in a 30-year timeframe, although this is assumed based on other better-studied three-toed sloth species (Anderson and Handley 2002, p. 1051). Sea level rise projections through 2050 are also less uncertain than extending beyond the middle of the century, where the differences between sea level rise scenarios based on different emission pathways becomes much larger (Sweet 2022, section 2).

Tourism and development

A comprehensive understanding of the current and future conditions of tourism on Escudo is currently lacking due to uncertainty in plans for imminent coastal development and the inherent difficulty of monitoring and regulation associated with the remote nature of the island. Observational accounts indicate that although large tourism operations are not currently reaching Escudo, the amount of tourism arriving to the island is increasing and, if the planned development of the nearby remote coastline occurs, tourism, including from large outfitters, will likely increase in volume (Jordan 2021, pers. Comm; Smith 2021, pers. comm.; Voirin 2021, pers. comm.).

International tourist visitation to Panama grew by 150% between 2000 and 2008, reaching over 1.5 million visitors, although up to 30% were short-term cruise visitors (USAID 2009, p. 9). Historically, tourism has been biased towards Panama City for its shopping and other urban attractions, but nature-based tourism is an increasing portion of Panama's market (Beaton and Hadzi-Vazkov 2017, pp. 23–29). Tourism grew fast in the coastal and island regions of Bocas Del Toro province (to which Escudo belongs, although it is removed from the rest of the administrative area; Fig. 2.1) from the 1990s onwards.

Ngobe-Bugle and Veraguas, the two provinces whose mainland area lie closest to Escudo, have far less tourist infrastructure, but growing accessibility to vast stretches of beach and rainforest. For instance, beginning in 2004 and continuing into at least 2017, a major road was under construction from Santa Fe to the coastal city of Calovebora in northern Veraguas province (Bilbao 2017, not paginated). The road's route passes through a portion of Santa Fe National Park and is a major new access point to undeveloped areas within easy boating distance of Escudo (Bilbao 2017, not paginated).

Developers have for several years been amassing land holdings in the region, planning for, and now reselling lots for future homes and hotels (Jordan 2021, pers. comm). As a primary example, Max Van Rijswijk, a controversial Dutch developer, has acquired properties (allegedly by stronghanded and even violent means) and is promoting a planned complex ("Verawa World") of over a dozen resorts with more than 3400 beds and fifty attractions across 10 km of beach along the coast of Veraguas (Verawa World Resorts 2020, not paginated; Bilbao 2017, not paginated). While this specific planned complex does not have planning for development of

Escudo proper, it would very likely increase tourism and impacts to the island of Escudo. Additionally, while this proposed project is in a separate province, Bocas del Toro has also experienced massive land purchases and development by foreign entities (Feller, 2022).

As additional people move to and visit the region, the very strong demand for sloths taken from the wild for tourists' "sloth selfies" or for sale into the pet trade (Greenfield 2020, not paginated) will likely impact pygmy sloths (Voirin 2021, pers. comm.; Jordan 2021, pers. comm.). In neighboring Colombia, one trader alone is believed to have captured and sold 10,000 sloths over 30 years before arrest and sentencing to over five years house arrest (Zimmerman 2016, not paginated). Hundreds of Colombian sloths are captured annually with many exported out of the country, and Costa Rican sloths are collected for in-country use in hands-on tourism impacts (Gorder 2021, not paginated; Moreno and Plese 2006, p. 12).

Panamanian law (Article 23 of Law 41) requires that public or private projects, including tourism developments, be vetted through an environmental impact assessment (EIA) process administered by the national Ministry of the Environment (Gonzales 2008, p. 324; Bethancourt 2000, not paginated). By law, the impact study must describe the proposed project, its anticipated effects on the environment, and must suggest measures to limit or compensate for such impacts (Bethancourt 2000, not paginated). Public comment is to be invited and promoted by the agency (Gonzales 2008, p. 325). Failure to complete an impact assessment can yield a fine of three to 100 thousand U.S. dollars (Bethancourt 2000, not paginated). Members of the public can appeal EIA outcomes to the Ministry (Bethancourt 2000, not paginated), although the recourse following such appeals is unclear.

Ideally, the EIA identifies potential effects, and alternatives, before a project is started (Gonzales 2008, p. 322). In practice, developers often do not file for an EIA or do so very late in the project's progress, likely too late to make substantive changes (Jordan 2021, pers. comm.). Consultations that do take place are frequently cursory (Jordan 2021, pers. comm.). Indeed, the Ministry of the Environment website has no tourism-related EIAs posted for any of Veraguas, Bocas Del Toro, and Ngobe-Bugle Provinces for 2017–2019 (the most recent years posted available; http://consulweb.miambiente.gob.pa/eia/listaeia.aspx, Accessed June 11, 2021). Many EIAs are available for other categories of projects.

If by 2050, the lack of environmental law enforcement capacity in the remote Escudo region (ZSL 2017, p. 18) continues, the limitations of Panama's EIA process are not rectified, and the unplanned nature of regional development (Jordan 2021, pers. comm.) persists, modest to large declines in the species' population are likely due to capture and the stresses of increased visitation. We therefore project a population abundance score of 1–2 points for this *status quo* scenario, encompassing the uncertainty in how severe the impacts of potential future smuggling and tourist crowding would be.

If, on the other hand, the ongoing conservation efforts (see *Conservation Measures* in Chapter 3) lead to improved conservation capacity around Escudo, pygmy sloth population declines could likely be avoided. A future with improved conservation capacity would include the regular presence of well-equipped conservation officers from the national Ministry of the Environment and/or Indigenous governments, and only sustainable, well-regulated, tourist visits to Escudo with no pygmy sloths captured or disturbed. A completed management plan would include enforcement of specific limitations on the volume and activities of tourists and fishermen through the permitting system to avoid pygmy sloth collection and deforestation. Under this scenario we predict population abundance criterion will be high (3 pts), with negligible impact of tourism and no population declines.

Loss of habitat

Sea level rise

Given its small island habitat, the pygmy sloth's viability is sensitive to the potential for further reduction in the available areas on Escudo, for example due to sea level rise. We used climate models forecasting where land presently above water will be lost due to sea level rise to project the extent of pygmy sloth habitat expected to be lost under different climate change scenarios. Specifically, we included six alternative climate trajectories defined by the (1) degree of greenhouse gas emissions reduction achieved (three Relative Concentration Pathways, RCPs 2.6, 4.5, and 8.5) by 2050 and (2) two different rates of Antarctic ice sheet melting, an uncertain but potentially major contributor to global seal level rise (Kulp and Strauss 2018, p. 2; Kopp et al. 2017, entire; Kopp et al. 2014, entire).

The RCPs are Intergovernmental Panel and on Climate Change (IPCC) scenarios that describe alternative future trajectories of greenhouse gas emissions and that are used to drive climate model projections in response to higher or lower future emission rates (IPCC 2014, pp. 8). In the RCP names, the values 2.6, 4.5, and 8.5 refer to the rate at which energy is trapped by Earth's atmosphere in watts per m^2 at the height of warming for the given scenario; thus, RCP 8.5 is a scenario indicating faster warming than RCP 4.5. RCP 8.5 is considered a "high-emission business as usual scenario;" i.e., towards the upper end of what might occur without climate change mitigation policy (Riahi et al. 2011, pp. 54). RCP 4.5 is based on a lower-emissions future in which renewable energy, greater energy efficiency, and carbon capture and storage are more widely implemented (Thomson et al. 2011, pp. 77). RCP 2.6 represents stringent cuts to greenhouse gas emissions sufficient to limit warming to 2 °C (van Vuuren et al. 2011, entire).

All the model outputs were sourced from Climate Central's Coastal Risk Screening Tool (https://coastal.climatecentral.org), an online mapping application that displays projections for chosen combinations of RCPs and years. The tool uses a high-resolution elevation map to identify locations connected to the ocean and below the projected sea level (i.e., inundated; Kulp and Strauss 2018, p. 9) based on either of two climate models (Kopp et al. 2014 and Kopp et al. 2017) that differ in the rate of Antarctic ice sheet melting.

We held other options available in the Coastal Risk Screening Tool steady across all 6 scenarios. This included setting the "projection type" to include sea level rise but not annual or less frequent storm surges, the year of the projection to 2050, and assuming medium luck in the accuracy of model projections (which the application does by using the 50th percentile output from model simulations). Escudo does not experience tropical cyclones and short-term (e.g., 12-hour) inundation from storm surge is not likely to kill mangroves (Feller 2021, pers. comm.; Krauss et al. 2006, pp. 962–963). We downloaded the mapped sea level rise projection images for each scenario and used the interactive supervised classification tool in ArcMap 10.7.1 to determine the percent of map pixels (and thus island habitat) forecast to be inundated on Escudo.

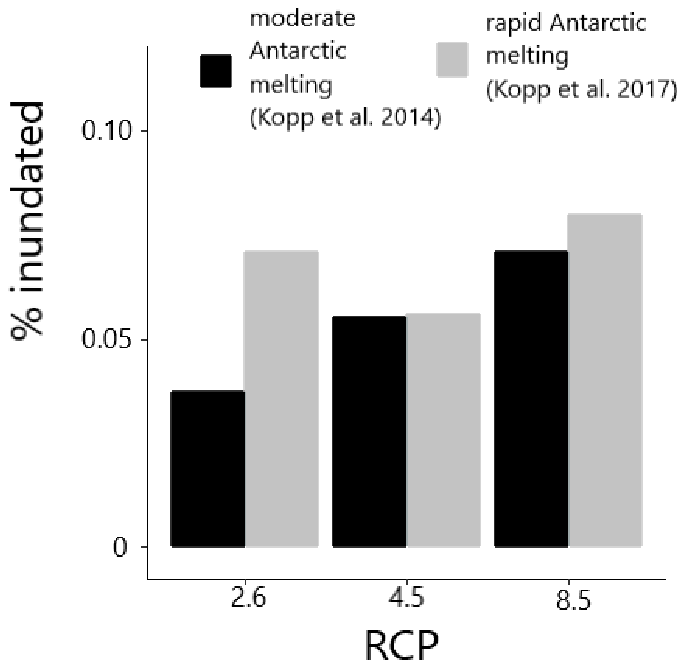


Fig. 5.1—Percent of Escudo projected to be inundated by rising sea level under 6 alternative climate change scenarios for the year 2050. None approach even 1% of the island. Model details are described in the main text.

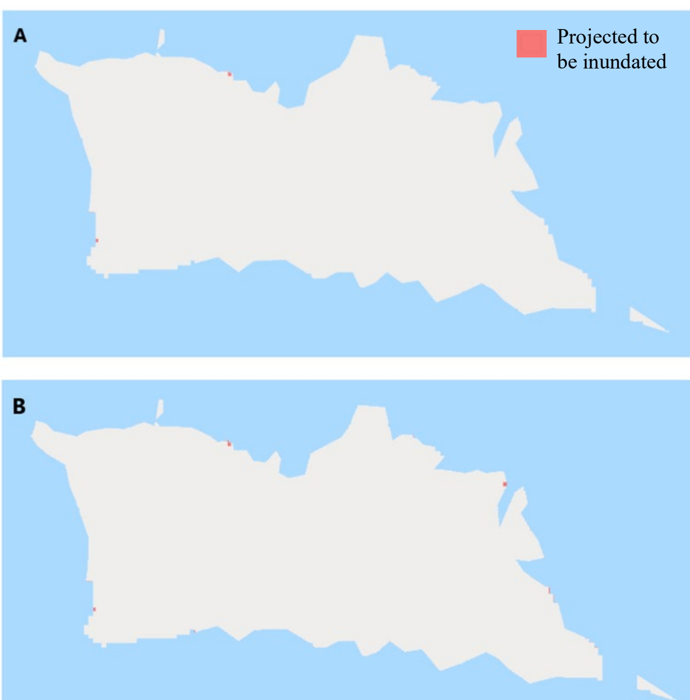


Figure 5.2—Low (A; year 2050 under RCP 2.6 without rapid West Antarctic melting) and high (B; year 2050 under RCP 8.5 with rapid Antarctic melting) estimates for the area of Escudo that will be inundated by sea level rise. Maps are downloaded from Climate Central's Coast Risk Screening Tool, June 2021. Model details are described in the text.

The extent of Escudo habitat inundated ranged from 0.04% (RCP 2.6, no rapid West Antarctic melting) to 0.08% (RCP 8.5, rapid West Antarctic melting; Fig. 5.1 & 5.2). Even if we assumed for the most pessimistic scenario (0.08% of the entire island inundated) that the entirety of the inundated habitat was concentrated within the 2.5% of the island that is mangrove forests, only slightly more than 3% of the mangroves would be inundated. However, although inundation is focused on coastal edges of the island and includes some locations on the north coast where mangroves grow, part of the inundation will occur outside the mangroves, so the 3% figure is likely an overestimate. Moreover, red mangroves can possibly keep pace with sea level rise by growing taller and accumulating peat beneath their stilt roots (Mckee et al. 2007, entire; Feller 2021, pers. comm.). The interior forest habitat is much more extensive than mangroves (ZSL 2017, p. 11) and even less area is projected to be lost on a percentage-wise basis compared to the mangroves. Thus, we project that loss of habitat due to sea level rise will be at most 3% across mangrove and interior forest habitats.

Deforestation

Deforestation presents a second potential cause of lost habitat, but forecasting future rates of deforestation is difficult due to the discrepancies between ground observations of deforestation and satellite data and the unknown impact that, if implemented, development plans and potential subsequent tourism increases might have on deforestation. Under a *status quo* future, deforestation may continue as it occurs now, at low and consistent levels, or it may increase, given the interest expressed by some Indigenous people in living on Escudo, and the possibility of tourism infrastructure development on the island. Therefore, we allow for the possibility that the mangroves and/or interior forest may be cleared beyond a negligible amount by assigning a score of 1.5–2.5 points to the forest extent resilience criterion in the *status quo* future (Table 5.1). With improved conservation capacity, we project that deforestation levels would remain low and possibly even lower than current levels as it would lead to increased monitoring and enforcement of use of the island, and thus we assign a score of 2.5-3 points.

Overall future resiliency, redundancy, and representation
Regardless of the climate change scenario, if the conservation capacity around Escudo does not improve (i.e., remains at the *status quo*), the total resilience of the pygmy sloth is projected to be 2.5–4.5 points, potentially falling into the low resilience category (Table 5.1). If conservation capacity is improved around Escudo, we project that the pygmy sloths could have high resilience despite their natural rarity (5.5–6 points). However, high uncertainty exists in both current and future resiliency due to the limitation and uncertainty of data on population abundance, rates of deforestation, and effects of tourism and development on the species.

Redundancy is not projected to change under any of the future scenarios; we expect there to remain only the single Escudo population. Representation may decrease somewhat if tourists arriving at the relatively accessible island edge and beaches stress pygmy sloths into retreating into the interior forest and as such reduce the habitat types used, further limiting adaptive potential. However, this possible response is only speculative at this point.

Table 5.1—Current and projected resiliency, redundancy, and representation of the pygmy sloth for two alternative future scenarios in the year 2050.

	Current	***Status quo* (2050)**	**Improved conservation capacity (2050)**	**Uncertainty**
Resiliency	4- 5 (moderate - high)	2.5–4.5 (low–moderate)	5.5–6 (high)	High
Population abundance	2 (moderate)	1 – 2 (low–moderate)	3 (high)	High
Forest extent	2 - 3 (moderate - high)	1.5–2.5 (low – high)	2.5 - 3 (high)	High
Redundancy	Low	Low	Low	Low
Representation	Low	Low	Low	Low

Literature cited

1. Anderson, R.P. and C.O. Handley. 2002. Dwarfism in insular sloths: biogeography, selection, and evolutionary rate. *Evolution* 56:1045-1058.
2. Anderson, R. and C. Handley. 2001. A new species of three-toed sloth (Mammalia: Xenarthra) from Panamá, with a review of the genus Bradypus. *Proceedings of the Biological Society of Washington* 114:1-33.
3. Beaton, K., Hadzi-Vazkov, M. 2017. *Panama's growth prospects: Determinants and sectoral perspectives.* International Monetary Fund. Working paper 17/150. pp. 1–30.
4. Benirschke, K. 2008. Reproductive parameters and placentation in anteaters and sloths. Chapter 16 in *The biology of the Xenarthrans*. Vinzcaino, S.F. and Loughry, W.J., *eds.* University Press of Florida. Gainesville, FL. pp. 160–171.
5. Bethancourt, G. 2000. "Estudios de impacto ambiental: ¿A quienes favorece?" *Panama America*. https://www.panamaamerica.com.pa/opinion/estudios-de-impacto-ambiental-a-quienes-favorece-54974.
6. Bilbao, G. 2017. *Atlantic conquest*. The Pulitzer Center. https://pulitzercenter.shorthand.com/atlanticconquest/index.html. Accessed June 7, 2021.
7. Chiarello, A.G.. 2008. Sloth ecology: an overview of field studies. Chapter 25 in *The biology of the Xenarthrans*. Vinzcaino, S.F. and Loughry, W.J., *eds.* University Press of Florida. Gainesville, FL. pp. 269–280.
8. Espinoza, M. and Cliffe, R. 2013. *The establishment of a captive contingency population for* Bradypus pygmaeus*, the pygmy three-toed sloth*. Accessed from https://mongabay-images.s3.amazonaws.com/13/DWA-Pygmy-sloth-field-report.pdf. March 9, 2021.
9. Flather, C.H. and C.H. Sieg. google. 2007. Species rarity: definition, causes and classification. pp. 40–66 in *Conservation of rare or little-known species: biological, social, and economic considerations*. Raphael, M.G. and Molina, R, *eds.* Island Press. Washington, USA.
10. Feller, I. Personal communication. Phone call to J. Daskin. July 7, 2021.
11. Garces-Restrepo, M.F., Pauli, J.N., and Peery, M.Z. 2017. Natal dispersal of tree sloths in a human-dominated landscape: Implications for tropical biodiversity conservation. *Journal of Applied Ecology* 55:2253–2262.
12. Gonzalez, C.G. 2008. Environmental Impact Assessment in Post-Colonial Societies: Reflections on the Proposed Expansion of the Panama Canal. *Tennessee journal of law and policy*. 4(2):303–354.
13. Gibb, G.C., Condamine, F.L., Kuch, M., Enk, J., Moraes-Barros, N., Superina, M., Poinar, H.N., Delsuc, F., 2016. Shotgun mitogenomics provides a reference phylogenetic framework and timescale for living xenarthrans. Molecular Biology and Evolution 33, 621-642.
14. Gilmore, D., Duarte, D.F., Peres da Costa, C. 2008. The physiology of two- and three-toed sloths. Chapter 13 in *The biology of the Xenarthrans*. Vinzcaino, S.F. and Loughry, W.J., *eds.* University Press of Florida. Gainesville, FL. pp. 130–142.
15. Gorder, G. 2021. "No Sloth Selfies - The Rush to protect Latin America's slowest mammal." *InSight Crime.* https://insightcrime.org/news/no-sloth-selfies-rush-protect-latin-america-slowest-mammal/.
16. Greenfield, P. 2020. "Why can't we leave them alone? The troubling truth about selfies with sloths." *The Guardian.* https://www.theguardian.com/environment/2020/jun/02/why-cant-we-leave-them-alone-the-troubling-truth-about-selfies-with-sloths-aoe.
17. Hansen, M.C., Potapov, P.V., Moore, R, Hancher, M. Turubanova, S.A., Tyukavia, A., Thau, D., Stehman, S.V., Goetz, S.J., Loveland, T.R., Kommareddy, A., Egorov, A., Chini, L., Justice, C.O., Townshend, J.R.G. 2013. High-resolution global maps of 21st-century forest cover change. *Science* 342:850–853.
18. IPCC (Intergovernmental Panel on Climate Change). 2019. Summary for Policymakers. Pörtner, H.-O., Roberts, D.C., Masson-Delmotte, V., Zhai, P., Tignor, M., Poloczanska, E., Mintenbeck, K., Alegría, A., Nicolai, M., Okem, A., Petzold, J., Rama, B. and Weyer, N.M. (eds.) In: *IPCC special report on the ocean and cryosphere in a changing climate*. pp. 1–35.
19. IPCC. (2014). *Climate change 2014 synthesis report. Contribution of working groups I, II and III to the fifth assessment report of the intergovernmental panel on climate change* [core writing team, R.K. pachauri and L.A. meyer (eds.)]. Geneva, Switzerland: https://www.ipcc.ch/site/assets/uploads/2018/02/SYR_AR5_FINAL_full.pdf
20. IUCN. 2012. *IUCN Red List Categories and Criteria*: Version 3.1. Second edition. Gland, Switzerland and Cambridge, UK: IUCN. pp. 1–32.
21. Johnson, C.N. 1998. Species extinction and the relationship between distribution and abundance. *Nature* 394:272-274.
22. Jordan, O. 2021. Personal communication. Phone call to J. Daskin. June 22, 2021.

23. Jordan, O. 2022. Personal communication. Email with D. Panos. July 29, 2022.
24. Kaviar, S., J. Shockey, and P. Sundberg. 2012. Observations on the endemic pygmy three-toed sloth, *Bradypus pygmaeus* of Isla Escudo de Veraguas, Panamá. *PLoS ONE* 8(10).
25. Kopp, R.E., R.M. DeConto, D.A. Bader, C.C. Hay, R.M. Horton, S. Kulp, M. Oppenheimer, D. Pollard, and B.H. Strauss. 2017. Evolving understanding of Antarctic ice-sheet physics and ambiguity in probabilistic sea-level projections. *Earth's future* 5:1217-1233.
26. Kopp, R.E., R.M. Horton, C.M. Little, J.X. Mitrovica, M. Oppenheimer, D.J. Rasmussen, B.H. Strauss, and C. Tebaldi. 2014. Probabilistic 21st and 22nd century sea-level projections at a global network of tide-gauge sites. *Earth's Future* 2:383-406.
27. Krauss, K.W., R.R. Twilley, T.W. Doyle, and E.S. Gardiner. 2006. Leaf gas exchange characteristics of three neotropical mangrove species in response to varying hydroperiod. *Tree Physiology* 26:959-968.
28. Kulp, S.A. and B.H. Strauss. 2018. CoastalDEM: A global coastal digital elevation model improved from SRTM using a neural network. *Remote Sensing of Environment* 206:231-239.
29. Marton-Lefevre, J. 2013. Letter to Vergara, S. National Environmental Authority (ANAM) of Panama. September 23, 2013.
30. McKee, K.L., D.R. Cahoon, and I.C. Feller. 2007. Caribbean mangroves adjust to rising sea level through biotic controls on change in soil elevation. *Global Ecology and Biogeography* 16:545-556.
31. Mendoza, J.E., Peery, M.Z., Gutierrez, G.A., Herrera, G., Pauli, J.N. 2015. Resource use by the two-toed sloth (*Choloepus hoffmanni*) and the three-toed sloth (*Bradypus variegatus*) differs in a shade-grown agro-ecosystem. *Journal of tropical ecology* 31:49–55.
32. Moreno, S. and T. Plese. 2006. The illegal traffic in sloths and threats to their survival in Colombia. *Edentata* 7:10-18.
33. Oberle, B. and Rodriguez, J.P. 2020. Letter to Concepción, M. Ministry of the Environment of the Republic of Panama. November 3, 2020.
34. Pacifici, Michela, Luca Santini, Moreno Di Marco, Daniele Baisero, Lucilla Francucci, Gabriele Grottolo Marasini, Piero Visconti, and Carlo Rondinini. “Generation Length for Mammals.” Nature Conservation 5 (November 13, 2013): 89–94. https://doi.org/10.3897/natureconservation.5.5734.
35. Pauli JN, Mendoza JE, Steffan SA, Carey CC, Weimer PJ, Peery MZ. 2014 A syndrome of mutualism reinforces the lifestyle of a sloth. Proc. R. Soc. B 281:20133006.
36. Pool, M., R. Boateng, A. Ako-Adounvo, R. Allen-McFarlane, D. Elizondo, H. Paturault, H. Alhawas, and G. Middendorf. 2016. Sloths in the city: unexpectedly high density of pale-throated three-toed sloths (Bradypus tridactylus) found in an urban forest patch in Paramaribo, Suriname. *Edentata* 17:25-33.
37. Raines, J. 2005. Captive health and husbandry of the Bradypodidae. *Zoo Biology* 24:557-568.
38. Riahi, K., Rao, S., Krey, V., Cho, C., Chirkov, V., Fischer, G., Kindermann, G., Nakicenovic, N., and Rafaj, P. (2011). RCP 8.5—A scenario of comparatively high greenhouse gas emissions. *Climatic Change, 1-2*(109), 33-57.
39. Ruiz-García, M., D. Chacón, T. Plese, and J.M. Shostell. 2020. Molecular phylogenetics of Bradypus (three-toed sloth, Pilosa: Bradypodidae, Mammalia) and phylogeography of *Bradypus variegatus* (brown-throated three-toed sloth) with mitochondrial gene sequences. *Journal of mammalian evolution* 27:461-482.
40. Silva, S.M., J.A. Dávila, B. Voirin, S. Lopes, N. Ferrand, and N. Moraes-Barros. 2018. The curious case of *Bradypus variegatus* sloths: populations in threatened habitats are biodiversity components needing protection. *Biodiversity and conservation* 27:1291-1308.
41. Silva, S.M. 2013. *Contribuições para a conservação de* Bradypus variegatus *(preguiça comum): processos históricos e demográficos moldando a diversidade nuclear*. Universidad de São Paulo. pp. 1–141.
42. Smith, D. ‘Peer Review Comments on Pygmy Sloth SSA’.
43. Smith, D., A. Ibáñez, H. Taylor, R. Flores, I. Sam, and D. Teles. 2021. Especies arboreas por el perezoso pigmeo, *Bradypus pygmaeus*, en la Isla Escudo de Veraguas, Panama. Pages 386 in XVIII Congreso Nacional de Ciencia y Tecnología - APANAC 2021 http://congreso.apanac.org.pa/.
44. Smith, D. R., Allan, N. L., McGowan, C. P., Szymanski, J. A., Oetker, S. R., & Bell, H. M. (2018). Development of a species status assessment process for decisions under the U.S. endangered species act. *Journal of Fish and Wildlife Management*, 9(1), 302-320.
45. Smith, D., Voirin, B., Chiarello, A. & Moraes-Barros, N. 2022. *Bradypus pygmaeus*. *The IUCN Red List of Threatened Species* 2022: e.T61925A210445926. Accessed on 21 March 2023.
46. Superina, M. ‘Peer Review Comments on Pygmy Sloth SSA’.

47. Suutari, M., M. Majaneva, D.P. Fewer, B. Voirin, A. Aiello, T. Friedl, A.G. Chiarello, and J. Blomster. 2010. Molecular evidence for a diverse green algal community growing in the hair of sloths and a specific association with *Trichophilus welckeri* (Chlorophyta, Ulvophyceae). *BMC Evolutionary Biology* 10:86.
48. Taube, E., Karavec, J., Vie, J., and Duplantier, J. 2001. Reproductive biology and postnatal development in sloths, *Bradypus* and *Choloepus*: review with original data from the field (French Guiana) and from captivity. *Mammal review* 31(3–4):173–188.
49. Sweet, W.V., B.D. Hamlington, R.E. Kopp, C.P. Weaver, P.L. Barnard, D. Bekaert, W. Brooks, M. Craghan, G. Dusek, T. Frederikse, G. Garner, A.S. Genz, J.P. Krasting, E. Larour, D. Marcy, J.J. Marra, J. Obeysekera, M. Osler, M. Pendleton, D. Roman, L. Schmied, W. Veatch, K.D. White, and C. Zuzak, 2022: Global and Regional Sea Level Rise Scenarios for the United States: Updated Mean Projections and Extreme Water Level Probabilities Along U.S. Coastlines. NOAA Technical Report NOS 01. National Oceanic and Atmospheric Administration, National Ocean Service, Silver Spring, MD, 111 pp. https://oceanservice.noaa.gov/hazards/sealevelrise/noaa-nostechrpt01-global-regional-SLR-scenarios-US.pdf
50. Thomson, A. M., Calvin, K. V., Smith, S. J., Kyle, G. P., Volke, A., Patel, P., et al. (2011). RCP4.5: A pathway for stabilization of radiative forcing by 2100. *Climatic Change, 1-2*(109), 77-94.
51. USAID. 2009. *USAID Conservation of Central American watersheds program. Deliverable No. 2: Business model document for a destination management organization in Bocas del Toro Province, Panama.* Contract No. EPP-I-04-03-00014-03.
52. van Vuuren, D.P., E. Stehfest, M.G.J. Elzen, T. Kram, J. Vliet, S. Deetman, M. Isaac, K.K. Goldewijk, A. Hof, A.M. Beltran, R. Oostenrijk, and B. Ruijven. 2011. RCP2.6: exploring the possibility to keep global mean temperature increase below 2°C. *Climatic Change* 1-2:95-116.
53. Verawa World Resorts. 2020. "Verawa World and Moreno–Partners join forces to create first of 6 new beachfront resorts in Panama." https://pronewsreport.com/2020/12/11/verawa-world-and-moreno-partners-join-forces-to-create-first-of-6-new-beachfront-resorts-in-panama/. Accessed Jun 9, 2021.
54. Voirin, B. 2021. Personal communication. Phone call with J. Daskin. March 30, 2021.
55. Voirin, B. 2015. Biology and conservation of the pygmy sloth, *Bradypus pygmaeus*. *Journal of Mammalogy* 96:703-707.
56. Voirin, B., M.F. Scriba, D. Martinez-Gonzalez, A.L. Vyssotski, M. Wikelski, and N.C. Rattenborg. 2014a. Ecology and neurophysiology of sleep in two wild sloth species. Sleep 37:753-761.
57. Voirin, B., Smith, D., Chiarello, A. and Moraes-Barros, N. 2014b. IUCN Red List of Threatened Species: *Bradypus pygmaeus*. Website viewed Dec 18, 2020. https://www.iucnredlist.org/en.
58. Voirin, B., Superina, M., Smith, D.J., Plese, T., Quintero, L.R., Pool, M., Turner, C., Manupella, M.C., Tisdale, R.K., Moraes-Barros, N., and Salceda, A. 2013. Letter to Vehrs, K.L., Association of Zoos and Aquariums. October 16, 2013.
59. Zimmerman, M.L. 2016. "Wildlife for sale: Morethan 5,000 traffickers arrested this year in Colombia." *Mongabay*. https://news.mongabay.com/2016/12/wildlife-for-sale-more-than-5000-traffickers-arrested-this-year-in-colombia/. Accessed July 14, 2021.
60. Zoological Society of London (ZSL). 2018. *Conserving the pygmy sloth*. Project summary 2017. pp. 1–29.

Appendix I—Calibration of likelihood terminology

Likelihood Terminology	Likelihood of the occurrence/ outcome
Virtually certain	> 99% probability
Extremely likely	95–99% probability
Very likely	90–95% probability
Likely	66–89% probability
More likely than not	50–65% probability
As likely as not	About 50% probability
Unlikely	< 50% probability