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DROWNING IN A SEA OF DEVELOPMENT: DISTRIBUTION AND CONSERVATION STATUS OF A SAND-SWIMMING LIZARD, *PLESTIODON REYNOLDSI*

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***Abstract*.—Many reptile species are declining, yet there is little information on the current distribution and conservation status of most species, let alone how this may change with future development of natural habitats. We studied the distribution, habitat associations, and conservation status of Florida Sand Skinks (*Plestiodon reynoldsi*), a fossorial sand-swimming lizard endemic to Florida, USA. We used data collected between 1912 and 2006 to map the distribution of occurrences of this species and used Geographic Information System (GIS) data layers to determine the habitats in which it occurs. We found that Florida Sand Skinks occupy many different habitat types throughout their range, including human-altered areas used for agriculture. However, Florida Sand Skinks appear to be absent from urban areas. Between 1974 and 2004, the amount of natural habitat available to support populations declined by 17.8% (5.9% per decade), and this trend is predicted to continue until at least the year 2060. Projections of future development of natural and disturbed habitats show linear increases during this same time, and will further fragment the remaining natural habitats. This makes protection of habitat for this species an immediate and real concern. Florida Sand Skinks (and other sympatric species) are rapidly losing habitat due to urbanization, and much of the remaining natural habitat outside of protected areas could be lost during the next several decades.**

Key Words.—fossorial reptile; future land use; geographic distribution; habitat loss; museum records; *Neoseps*; urbanization

INTRODUCTION

Some of the most important ecological questions today focus on how ecosystems, communities, and populations persist under increasing human pressures. As humans spread into tracts of undisturbed lands, anthropogenic changes alter natural areas, particularly through the conversion of previously contiguous areas into smaller habitat fragments (Davies and Margules 1998; Collinge 2000). Fragmentation can lead to the decline or extirpation of populations through multiple causes, including road mortality (e.g., Findlay and Bourdages 2000; Boarman and Sazaki 2006), human-animal conflicts (Koeing et al. 2002), and in more subtle ways, such as changes in habitat composition (Gurevitch and Padilla 2004; McKinney 2006) or quality (Ballinger and Watts 1995; Webb et al. 2005; Fitch 2006a, 2006b).

The first comprehensive review of declining reptile populations (Gibbons et al. 2000) spurred a plethora of research on the status and conservation of this diverse and often neglected group of vertebrates (Bonnet et al. 2002). Like other imperiled species, the most endangered reptiles tend to have small geographic ranges (Reed and Shine 2002), be habitat-specialists (Reed 2004), or have difficulty recovering from disturbances (Webb et al. 2002). However, the secretive nature of many reptiles makes gathering data on their habitat associations and distribution difficult; thus, our understanding of their life history requirements remains poorly understood (Bury 2006). Fossorial snakes and lizards are among the most elusive reptiles because they seldom come to the surface, where researchers usually focus their efforts (Wake et al. 2005). Thus, fossorial species may appear rare because few specialized inventory methods exist for them (e.g., How and Shine 1999; Measey et al. 2003). This apparent rarity has hampered research into the distribution and conservation status of these diverse and ecologically important species.

Although most fossorial organisms are rarely encountered, observational data series for some species exist over long periods of time, making analysis of their distribution and conservation status possible. One such species is the Florida Sand Skink, *Plestiodon* [formerly *Neoseps*] *reynoldsi*, a fossorial lizard endemic to peninsular Florida, USA. This species moves through the sand just below the surface of the soil, and leaves behind distinctive trails, which researchers often use to record if Sand Skinks are present. Some previous work suggests that they are specific to certain vegetation types (see review in McCoy et al. 1999). However, recent evidence suggests that Florida Sand Skinks also occupy some human-altered vegetation types found on loose, sandy soils (Pike et al. 2007, 2008a). We collated historical occurrence data to: (1) characterize habitat associations based on elevation, large-scale physiographic provinces, soil type, and vegetation; (2) create an updated range map; (3) quantify land use changes within the range between 1974 and 2004; (4) assess future habitat losses through urbanization; and (5) evaluate conservation lands to determine their role in protecting habitat. Finally, we draw conclusions about the present and future ecological status of this species, which the United States Fish and Wildlife Service (USFWS) lists as Threatened and the International Union for the Conservation of Nature (IUCN) lists as Vulnerable.

MATERIALS AND METHODS

Locality data.—We obtained locality data for Florida Sand Skinks from museums, public agencies, and herpetologists. We focused on records that had detailed locality data, including GPS coordinates (for recent records) or road mileage from intersections or towns (for older records). We projected GPS coordinates onto a map of Florida using ArcGIS version 9.2 (ESRI, Redlands, California USA), and georeferenced the remaining records by hand using the best available information (e.g., distance and direction from a road intersection or center of a town). Thus, some of our occurrence records are estimated locations. However, the resolution of our range-wide study makes the accuracy of these points (to < 0.1 km) sufficient to demarcate the general distribution and habitat characteristics of this species. We considered each record as one observation, regardless of how many individual skinks or trails were present. When multiple records occurred at a single site (i.e., within 0.5 km) we only retained a single record in our final dataset.

Habitat associations.—We downloaded Geographic Information System (GIS) coverages from the Florida Geographic Data Library website (http://www.fgdl.org, last accessed: 19 August 2008), and focused on biotic and abiotic factors that influence the distribution of Florida Sand Skinks, including physiographic provinces (Telford 1959), soils (Campbell and Christman 1982; Pike et al. 2007, 2008a), elevation, and landcover (Telford 1959, 1962; Pike et al. 2007, 2008a). Most of these factors (e.g., elevation, physiographic provinces, soil type) are static over the timescale encompassed by this study, and thus did not change since the collection of each specimen. When this was the case, we generated a list of the biotic and abiotic associations of each Florida Sand Skink record. However, landcover changes rapidly with local increases in human populations (Duncan et al. 2004). To circumvent this bias, we identified the vegetation types used by Florida Sand Skinks through a literature survey and supplemented this with information from a subset of the point locality records (see “Temporal habitat changes” below).

Geographic distribution.—Preliminary modeling of the geographic range of Florida Sand Skinks using climatic variables and habitat types vastly over predicted the known range, as happens with many reptiles (Araújo and Pearson 2005; Araújo et al. 2006). We therefore used occurrence records to define the range. We buffered each location point by 10 km and joined the outer margins of the buffered area to produce one large polygon. This buffer likely encompasses yet undocumented populations, but could also slightly over-predict the actual range. However, this is inevitable given that the vagility of this and other ecologically similar species is largely unknown.

Temporal habitat changes.—We first evaluated historical changes in landcover and then estimated future changes in Florida Sand Skink habitat through 2060 using spatially-referenced urban growth predictions. Because recent information on habitat associations of this species suggests that they occupy both human-altered and natural habitats (Pike et al. 2007), but not urban environments (see below), we pooled all landcover types into three categories for analysis: (1) urban; (2) disturbed; and (3) natural habitats. We excluded all wetlands from our analyses because Florida Sand Skinks do not occur in aquatic habitats (Lee 1969). All landcover types that have developed properties (e.g., homes, businesses, roads) comprised the urban habitat. Disturbed habitat included citrus groves, pastures, and other anthropogenically-altered areas. Natural habitats were those that consist of native vegetation, such as Sand Live Oak (*Quercus geminata*), pine flatwoods, and other vegetated areas.

These habitat categories allowed the comparison of location-specific and range-wide landcover changes between 1974 and 2004. To assess location-specific changes, we used the oldest (1974) and the newest (2004) available landcover datasets, and excluded from this analysis any records collected prior to or after these years. These coverages allowed us to determine the habitat type for each Florida Sand Skink record collected during this time. Our primary assumption was that locations occupied by Florida Sand Skinks after 1974 had suitable habitat at the time of observation. We compared the proportion of Florida Sand Skinks in each habitat category by year (1974 or 2004) using contingency table analysis (α = 0.05; see similar methodology in McCallum and Trauth 2003).

Next, we focused on actual changes in habitat within the entire range during the same time period. We used a repeated measures analysis of variance (ANOVA; α = 0.05) with habitat (urban, disturbed, or natural) as the factor, year (1974 or 2004) as the repeated measure, and

TABLE 1. The relative importance of each county to the persistence of the Florida Sand Skink (*Plestiodon reynoldsi*) in Florida, USA. The number of Florida Sand Skink locations within each county and their associated percentages stem from our collated locality data (N = 230 unique locations), although five counties lacking point data appear within the estimated range (see text for details). We calculated the area available for Florida Sand Skinks by summing the disturbed and natural habitat types (i.e., excluding urban and wetland areas) falling within the species' range. Also shown is the percentage of each county falling within the range. We calculated the amount of remaining natural habitat using 2004 landcover data. We present this as the percentage of area within each county that falls inside the species range. We ranked counties based upon their overall importance in supporting the species. We determined this by taking the area potentially available for Florida Sand Skinks as a proportion of the overall suitable habitat (disturbed and natural habitat) within the total range of the species. The amount of protected area represents officially recognized managed areas (excluding wetlands) within the range as of 2007.

County	Number of locations (%)	Area available for Florida Sand Skinks in ha (% of county within range)	Estimated natural habitat remaining in ha (% of county within range)	Rank importance (% of range)	Current amount of protected area (ha)
Desoto	n/a	850 (0.1)	< 1 (< 0.1)	12 (0.1)	0
Glades	n/a	21,365 (8.4)	5,809 (19.3)	6 (3.1)	7,293
Hardee	n/a	17,355 (10.5)	4,125 (17.5)	8 (2.5)	81
Highlands	72 (31.3)	134,482 (46.9)	24,736 (12.0)	3 (19.7)	19,177
Lake	20 (8.7)	94,300 (31.5)	37,048 (17.3)	4 (13.8)	24,088
Marion	29 (12.6)	155,917 (36.2)	98,201 (42.2)	1 (22.8)	106,862
Orange	5 (2.2)	34,546 (13.3)	16,520 (12.5)	5 (5.1)	7,165
Osceola	6 (2.6)	12,950 (3.3)	5,370 (12.4)	9 (1.9)	1,737
Polk	97 (42.2)	147,520 (28.3)	46,976 (15.4)	2 (21.6)	33,535
Putnam	1 (0.4)	19,042 (8.9)	11,278 (36.3)	7 (2.8)	11,801
Seminole	n/a	1,108 (1.2)	855 (5.7)	11 (0.2)	407
Sumter	n/a	1,939 (1.3)	148 (2.6)	10 (0.3)	0

the proportion of each habitat type (within the range) per county as the dependent variable. Unless otherwise stated, in cases where we refer to county metrics we are discussing only the portions of each county that occurred within the estimated range of Florida Sand Skinks.

We also estimated future habitat loss and urbanization using a recent urban growth scenario for Florida (for full details see Zwick, P.D., and M.H. Carr. 2006. Florida 2060: A population distribution scenario for the state of Florida. Research project prepared for 1000 Friends of Florida). We updated the current (2004) land use coverage with urban growth predictions for 2020, 2040, and 2060. This allowed estimation of natural habitat losses and urban growth rates within the range of the Florida Sand Skink. We calculated the proportion of unprotected natural habitat and urban area within each county at each time period and used repeated measures ANOVAs (α = 0.05) to analyze changes in these two habitats over time. The proportion of urban or unprotected natural habitat in each county was the dependent variable, and year (2004, 2020, 2040, and 2060) was the repeated measure in these analyses. Because we were more interested in whether these variables increased or decreased over time, and not interested in differences among counties, we did not include a factor in these analyses.

TABLE 2. Physiographic provinces in which Florida Sand Skinks occurred within peninsular Florida, USA and the corresponding number and percentage of locality records (N = 230) within each.

Physiographic province	Number of records (%)
Caloosahatchee Incline	2 (0.9)
Central Valley	6 (2.5)
Desoto Plain	2 (0.9)
Intraridge Valley	19 (8.3)
Lake Harris Cross Valley	1 (0.4)
Lake Upland	7 (3.0)
Lakes Wales Ridge	103 (44.8)
Marion Upland	5 (2.2)
Mount Dora Ridge	26 (11.3)
Osceola Plain	8 (3.5)
Polk Upland	23 (10.0)
Sumter Upland	2 (0.9)
Winter Haven Ridge	26 (11.3)

This species is patchily distributed (Branch et al. 2003), and certainly not all natural or disturbed habitats support Florida Sand Skink populations. Thus, we intend for our temporal habitat change analyses to discern the relative changes in habitat within the Florida Sand Skink's range and emphasize the potential loss of habitat to urbanization.

RESULTS

Locality data.—We collected 501 independent Florida Sand Skink records from 1912 – 2006; of these, 230 records had sufficient locality data to georeference. Reliable records occurred in seven counties within peninsular Florida (Table 1).

Habitat associations.—Florida Sand Skinks occurred at a mean elevation of 35.2 ± 0.62 m above sea level (range: 8 – 76 m) and in several physiographic provinces that vary considerably in elevation (Table 2). Although Florida Sand Skinks occurred in many different soil types (Table 3), most records (51.7%; N = 119) were from excessively drained (i.e., xeric) soils (χ^2 = 183.4, df = 4, $P < 0.001$). Florida Sand Skinks also occurred in somewhat moist soil types, including very poorly drained soils outside of wetland areas (Table 3). Although xeric soil types appear most important to the lizard's presence, our records span many soil moisture types except for wetlands (Table 3). Florida Sand

TABLE 3. Soil types in which Florida Sand Skinks are known to occur and their associated water storage capacity ("drainage"). Also indicated are the number and percentage of Florida Sand Skink locations ($N = 230$) that occurred within each soil type. Soil types were categorized by their drainage capacity as defined by the Natural Resources Conservation Service.

Soil type	Drainage	Locations (%)
Adamsville fine sand	Somewhat poorly drained	1 (0.4)
Apopka sand	Well drained	3 (1.3)
Archbold sand	Moderately well drained	30 (13.0)
Astatula sand	Excessively drained	54 (23.5)
Basinger fine sand	Poorly drained	5 (2.2)
Candler sand	Excessively drained	39 (17.0)
Daytona sand	Moderately well drained	1 (0.4)
Duette sand	Moderately well drained	1 (0.4)
Fort Meade sand	Well drained	1 (0.4)
Immokalee sand	Poorly drained	2 (0.9)
Lake Sand	Excessively drained	2 (0.9)
Millhopper fine sand	Moderately well drained	5 (2.2)
Myakka sand	Poorly drained	3 (1.3)
Orlando fine sand	Well drained	1 (0.4)
Paola sand	Excessively drained	11 (4.8)
Pomello fine sand	Moderately well drained	6 (2.6)
Pomana fine sand	Poorly drained	1 (0.4)
Pompano fine sand	Poorly drained	1 (0.4)
Satellite sand	Somewhat poorly drained	22 (9.6)
Smyrna and Myakka fine sands	Poorly drained	5 (2.2)
Sparr sand	Somewhat poorly drained	2 (0.9)
St. John's sand	Poorly drained	1 (0.4)
St. Lucie sand	Excessively drained	13 (5.7)
Tavares sand	Moderately well drained	19 (8.3)
Zolfo fine sand	Somewhat poorly drained	1 (0.4)

Skinks also occurred in a wide variety of vegetation types, but appear noticeably absent from urban areas (Table 4).

Geographic distribution.—Our estimate of the geographic range of the Florida Sand Skink (Fig. 1) encompasses over 1.24 million ha, and spans 300 km from north to south. However, after excluding wetlands and current urban areas, the potential area of Florida Sand Skink occurrence fell to 682,775 ha or 55% of the overall range (Fig. 2). Our method of defining the overall range also included portions of five adjacent counties, which may support Florida Sand Skinks but lack supporting records (Table 1, Fig. 1). A portion of Volusia Co. was initially included in the overall range, but because this area lacked terrestrial habitat, we excluded it from the final range map and from further analysis.

Temporal habitat changes.—Of the 230 records with usable locality data, we included 135 (58.7%) collected between 1974 and 2004 in our analysis of habitat changes. Using 1974 landcover maps, there were no Florida Sand Skink locations in urban areas and most

TABLE 4. Vegetation types in which Florida Sand Skinks are known to occur. Vegetation types were classified using the Florida Land Use, Cover, and Forms Classification System (Florida Department of Transportation. 1999. Florida Land Use, Cover and Forms Classification System. Handbook. Tallahassee, Florida), and then categorized to distinguish the major characteristics of each (e.g., disturbed or urban; see text for details). We used landcover data from the year 1974 to classify vegetation types for Florida Sand Skink records obtained between 1974 and 2004 (see text for details) and supplemented these with descriptions from the literature. Note that while many authors refer to Florida Sand Skinks being present in "scrub" or "rosemary scrub" habitat (e.g., Telford 1959; Campbell and Christman 1982), these are not distinguished in the FLUCFCS.

Vegetation type	Category	Source
Forest regeneration	Disturbed	this study
Hardwood or hardwood/coniferous mixed forest	Natural	this study
Herbaceous rangeland	Natural	this study
Open land (rural and other open lands)	Disturbed	this study
Palmetto prairie	Natural	Pike et al. 2007
Pasture (improved and unimproved)	Disturbed	Pike et al. 2007
Pine-palmetto flatwoods	Natural	Telford 1959
Sand live oak	Natural	Pike et al. 2007
Sand pine	Natural	Campbell and Christman 1982
Shrub and brushland	Disturbed	Pike et al. 2007
Transitional lands	Disturbed	this study
Tree crops (active and abandoned citrus, coniferous plantations, nurseries, vineyards, other)	Disturbed	this study
Turkey oak barren	Natural	Pike et al. 2008b
Xeric scrub	Natural	Pike et al. 2007

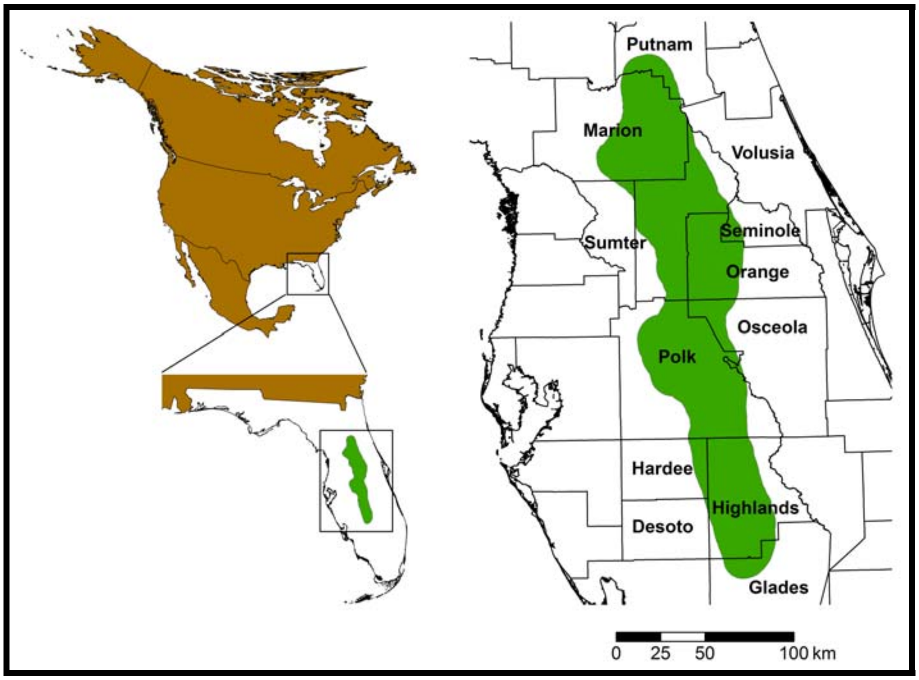

FIGURE 1. Map of North America showing Florida, USA and emphasizing the estimated distribution of the Florida Sand Skink, *Plestiodon reynoldsi* (green). See text for details on how the overall geographic range was determined.

locations were in natural habitats (Fig. 3a). By 2004 habitats changed significantly where Florida Sand Skinks occurred (χ^2 = 28.1, df = 2, $P < 0.0001$; Fig. 3a). During this time 18.5% of Florida Sand Skink locations were lost to urban development, coinciding with a decline in the proportion of locations in natural habitat (Fig. 3a).

We also analyzed overall changes in the amount of habitat throughout the species range between 1974 and 2004. Habitat changed significantly during this time ($F_{1,30}$ = 6.69, P = 0.004; no significant interaction term), with urban area increasing by 21.3% (7.1% per decade) and natural habitat decreasing by 17.8% (5.9% per decade; Fig. 3b).

The similar trends seen in the overall range and point location data (Fig. 3) suggest that our point location dataset is largely representative of landcover trends. At least 80.7% (N = 109) of locations still existed as natural or disturbed habitats in 2004, which represented a mean average annual loss in habitat of 2.7%. The 2004 landcover dataset suggested that no relationship existed between the proportion of remaining natural habitat in each county and the proportion of the overall range that the county encompassed (r = 0.25, P = 0.44). The rank importance of each county was also unrelated to the proportion of remaining natural habitat (r = 0.45, P = 0.14). Thus, counties supporting more of the overall range have similar amounts of natural habitat available to protect as counties supporting less of the overall range.

Urban development is predicted to increase significantly, with no sign of slowing through 2060 ($F_{3,33}$ = 18.22, $P < 0.00001$; Fig. 4). Urbanization increased in every county except Desoto Co., which only contains a small amount of potential Florida Sand Skink habitat (Table 1; Fig. 1). Excluding Desoto Co., the overall predicted increase in urban area ranges from 3.8% in Seminole Co. to 42.2% in Hardee Co. The expected average increase in development within each county is 3.6% per decade (Fig. 4). During this same time, we expect the proportion of unprotected natural habitat to decrease significantly ($F_{3,33}$ = 16.33, $P < 0.00001$; Fig. 4). As with urban areas, Desoto Co. retained its original amount of natural habitat. Apart from this, the overall predicted loss of natural habitat ranges from 1.2% in Seminole County to 11.3% in Polk County. The average loss of natural habitat in each county by decade is expected to be 1.0% (Fig. 4).

There are currently 212,146 ha of publicly owned or managed upland areas within the range of the Florida Sand Skink; this is 24.3% of the upland area within the range (Table 1). Thus, 75.7% of the species range currently remains unprotected, of which 26.5% contains human development, and the remaining 49.2% is under threat from development.

Larger counties located within the range of the Florida Sand Skink have larger amounts of protected areas than do smaller counties (r = 0.78, P = 0.003; Table 1). To evaluate the best-case scenario for conserving this and other sympatric species, we combined the total area of

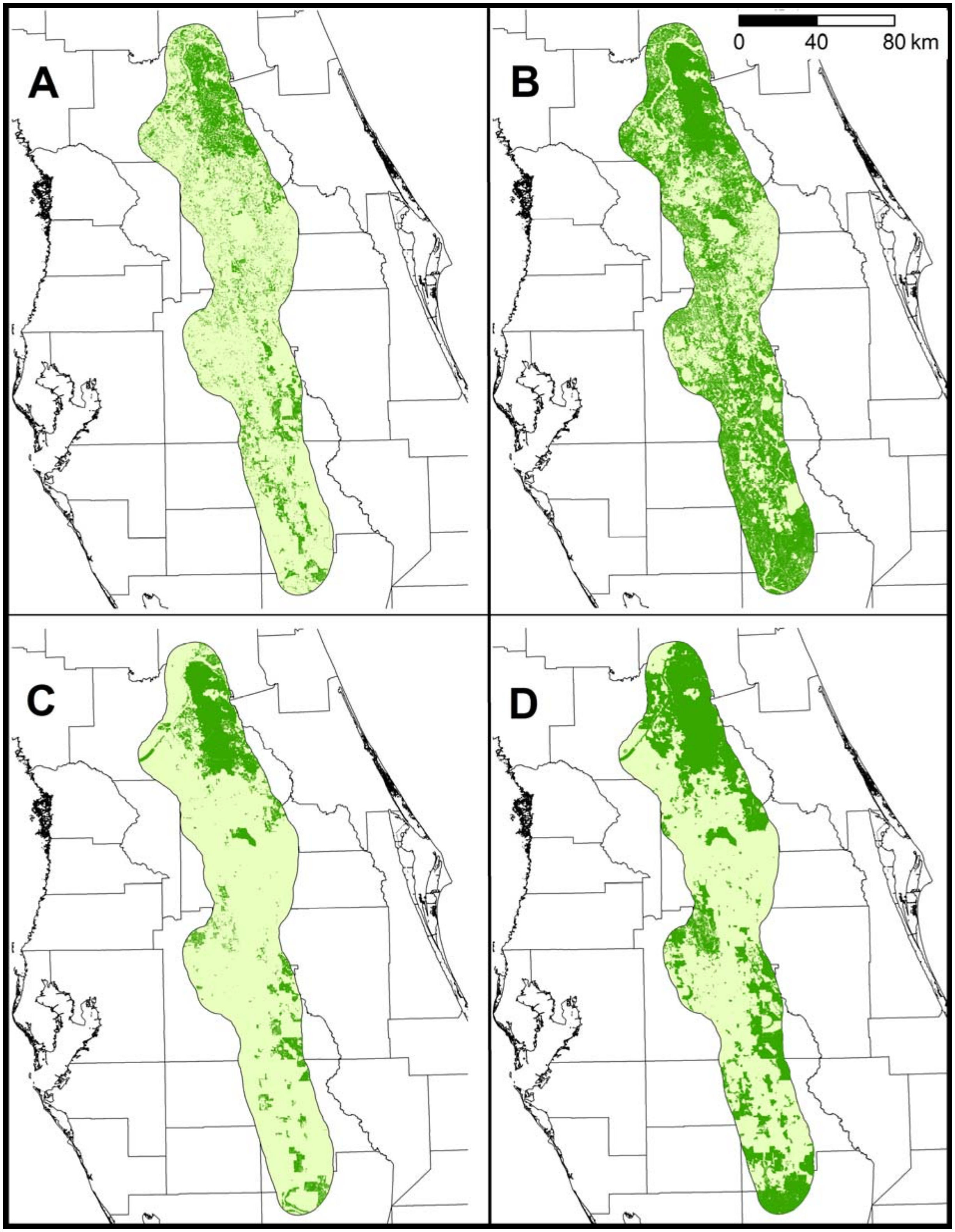

FIGURE 2. Maps of central Florida, USA, showing an outline of the geographic range of the Florida Sand Skink, *Plestiodon reynoldsi* (lightly shaded) and (A) all of the natural habitat remaining as of 2004; (B) all of the disturbed and natural habitat; (C) the current extent of conservation lands within the range of the Florida Sand Skink; and (D) the current and proposed extent of conservation lands within the range of the Florida Sand Skink (all dark shaded).

currently managed lands with that of proposed conservation acquisitions. Proposed non-wetland acquisitions totaled 118,741 ha. If purchases of all proposed conservation lands ensue, the amount of upland habitat protected will amount to 330,887 ha. This is a 20.5% increase in protected habitat. Under this scenario, 51.6% of the natural and disturbed habitat remaining within the Florida Sand Skink's range (as of the year 2004) gains protection. If acquisition of all proposed lands ensues, the tight correlation between the area within each county in which Florida Sand Skinks could occur and the total amount of protected area remains (r = 0.90, P < 0.0001). Thus, individual counties would protect lands appropriate for Florida Sand Skinks in proportion to the amount of habitat available in each jurisdiction.

DISCUSSION

Locating fossorial amphibians and reptiles is often difficult, but existing data sources can yield important insights into their distribution and conservation status. For example, our results question the common assertion that Florida Sand Skinks only occur on the central Florida ridges and only in natural habits (e.g., Telford 1959, 1962; Campbell and Christman 1982; McCoy et al. 1999) because historic records occur in many different types of habitats and off of the major Florida ridges. Florida Sand Skinks occur in many different soil types with various hydrological conditions, and in altered habitats, but we found no evidence that they inhabit urban areas. Although Florida Sand Skinks do inhabit disturbed habitats, we do not yet understand how important these areas are to population persistence or for providing connectivity between populations living in isolated natural habitats. Urban growth models revealed that much of the remaining habitat may be lost in the coming decades (Fig. 5). However, the rate of urban growth is higher than the rate of natural habitat loss, indicating that the urban growth model we used predicts that development targets disturbed habitats. This provides sufficient opportunity to purchase natural lands prior to development, and implement appropriate conservation actions. Finally, our focus on absolute habitat loss in the region does not consider other negative effects associated with habitat fragmentation, such as edge effects or minimum patch size requirements.

The most important finding in this study is the rapid rate of habitat loss that occurred over a 30-year period. In 1974, each county within the range of the Florida Sand Skink had on average 41.0% of its original upland habitat. By 2004, this fell to 22.8% and the amount of urban habitat tripled during this time. Presently, urban areas encompass an average of 25.2% of the total unprotected upland area in each county, and this increase is predicted to continue steadily into the future (Fig. 4). Our results also show that much of the remaining habitat

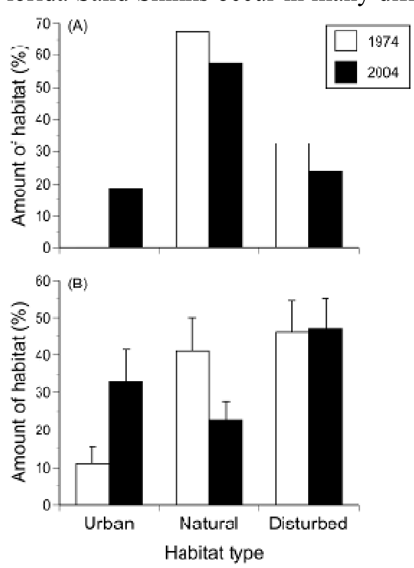

FIGURE 3. Change in the amount of habitat (categorized as urban, natural, or disturbed) over a 30-year period: (A) at known Florida Sand Skink locations (N = 135), showing the percentage of locations in each habitat type. We placed all Florida Sand Skink records into one of the three categories, precluding error bars. (B) Within the entire geographic range, shown as the mean percentage of each habitat type by county (+ 1 SE, calculated after excluding wetlands but including protected areas).

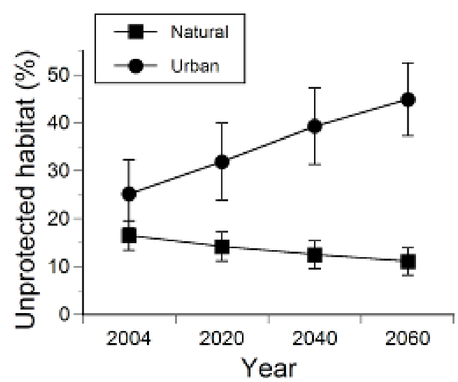

FIGURE 4. Predicted future landcover change within the range of the Florida Sand Skink. Shown is the mean percentage (± 1 SE) of urban and natural habitat within each county throughout the range as calculated using current (2004) and future predictions of urban growth (through 2060). These values represent unprotected habitat only, and exclude currently protected areas and wetlands. Because of this, values differ somewhat from the values presented in Fig. 3.

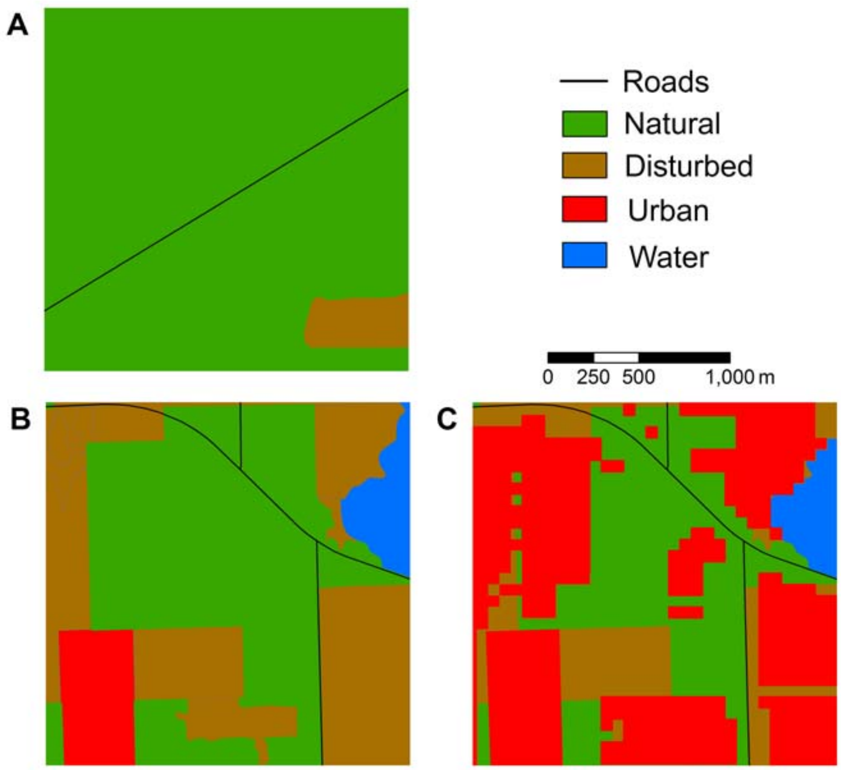

FIGURE 5. Local-scale landcover within the range of the Florida Sand Skink representative of (A) managed, protected areas, and a comparison between a single non-protected area in the years (B) 2004 and (C) 2060. Note the typical amount of habitat fragmentation in protected areas (A), and how habitat loss and fragmentation are predicted to increase with increases in urban landcover (B and C).

is unprotected and therefore at risk of development by 2060. Although future acquisition of conservation lands could improve protection of Florida Sand Skinks throughout their range, we could not evaluate how this might quantitatively affect long-term habitat loss. To do this would require re-running the original urban growth models presented by Zwick and Carr (*op. cit*.), but under the assumption that all proposed conservation areas receive protection from development.

We know little about the biogeographic characteristics of Florida Sand Skinks other than they evolved in a patchy environment and populations exhibit strong genetic structuring (Branch et al. 2003). At least four distinct genetic lineages of Florida Sand Skinks exist, and this species needs conservation strategies that manage these different lineages and preserve genetic diversity throughout its range (Branch et al. 2003). Further study of the phylogeography of this species will help us strategically target critical areas to better guide future conservation efforts. Although we focused on one species from the upland habitats of central Florida, our detailed analysis of habitat change applies to many of the other endemic species present in the region (e.g., McConnell and Menges 2002; Branch et al. 2003).

Conclusion.—Because Florida Sand Skinks are cryptic and generally not readily noticed in many areas, regulatory agencies could improve pre-construction endangered species assessments by broadening the areas in which they expect to find this species to include all upland habitat types (as outlined in Pike et al. 2008b). This would ensure that populations under threat of development receive documentation, and that developers follow appropriate legislation for mitigating impacts to such areas. Our work suggests that unless conservation partners purchase large amounts of protected habitat or provide much better protection for existing populations (thus making it more difficult to extirpate known populations) the outlook for this species is grim; timing of these actions is critical because much of the remaining unprotected natural habitat will likely be lost during the next several decades.

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Inventory), Eitan Grunwald, Kenney Krysko (Florida Museum of Natural History), Paul Moler (Florida Fish and Wildlife Conservation Commission), Alan Resetar (Field Museum of Natural History), Steve Rogers (Carnegie Museum of Natural History), and Kevin de Queiroz (National Museum of Natural History). The following museums provided online access to their specimens through the Combined Index to Herpetology Collections database: University of Kansas National History Museum, Natural History Museum of Los Angeles County, Louisiana State University Museum of Natural Sciences, Museum of Comparative Zoology, University of Colorado Museum, and the California Academy of Sciences. An Endeavour International Postgraduate Research Scholarship and a University of Sydney International Postgraduate Award (both to DAP) supported preparation of this manuscript.

Literature Cited

Araújo, M.B., and R.G. Pearson. 2005. Equilibrium of species' distributions with climate. Ecography 28:693–695.

Araújo, M.B., W. Thuiller, and R.G. Pearson. 2006. Climate warming and the decline of amphibians and reptiles in Europe. Journal of Biogeography 33:1712–1728.

Ballinger, R.E., and K.S. Watts. 1995. Path to extinction: impact of vegetational change on lizard populations on Arapaho Prairie in the Nebraska sandhills. American Midland Naturalist 134:413–417.

Boarman, W.I., and M. Sazaki. 2006. A highway's road-effect zone for Desert Tortoises (*Gopherus agassizii*). Journal of Arid Environments 65:94–101.

Bonnet, X., R. Shine, and O. Lourdais. 2002. Taxonomic chauvinism. Trends in Ecology and Evolution 17:1–3.

Branch, L.C., A.-M. Clark, P.E. Moler, and B.W. Bowen. 2003. Fragmented landscapes, habitat specificity, and conservation genetics of three lizards in Florida scrub. Conservation Genetics 4:199–212.

Bury, R.B. 2006. Natural history, field ecology, conservation biology and wildlife management: time to connect the dots. Herpetological Conservation and Biology 1:56–61.

Campbell, H.W., and S.P. Christman. 1982. The Herpetological Components of Florida Sandhill and Sand Pine Scrub Associations. Pp. 163–171 *In* Herpetological Communities. Scott, N.J., Jr. (Ed.). U.S. Fish and Wildlife Service, Wildlife Research Report 13.

Collinge, S.K. 2000. Effects of grassland fragmentation on insect species loss, colonization, and movement patterns. Ecology 81:2211–2226.

Davies, K.F., and C.R. Margules. 1998. Effects of habitat fragmentation on carabid beetles: experimental evidence. Journal of Animal Ecology 67:460–471.

Duncan, B.W., V.L. Larson, and P.A. Schmalzer. 2004. Historic landcover and recent landscape change in the North Indian River Lagoon Watershed, Florida, USA. Natural Areas Journal 24:198–215.

Findlay, C.S., and J. Bourdages. 2000. Response time of wetland biodiversity to road construction on adjacent lands. Conservation Biology 14:86–94.

Fitch, H.S. 2006a. Collapse of a fauna: reptiles and turtles of the University of Kansas Natural History Reservation. Journal of Kansas Herpetology 17:10–13.

Fitch, H.S. 2006b. Ecological succession on a natural area in northeastern Kansas from 1948 to 2006. Herpetological Conservation and Biology 1:1–5.

Gibbons, J.W., D.E. Scott, T.J. Ryan, K.A. Buhlmann, T.D. Tuberville, B.S. Metts, J.S. Greene, T. Mills, Y. Leiden, S. Poppy, and C.T. Winne. 2000. The global decline of reptiles, déjà vu amphibians. BioScience 50:653–666.

Gurevitch, J., and D.K. Padilla. 2004. Are invasive species a major cause of extinctions? Trends in Ecology and Evolution 19:470–474.

How, R.A., and R. Shine. 1999. Ecological traits and conservation biology of five fossorial 'sand-swimming' snake species (Simoselaps: Elapidae) in south-western Australia. Journal of Zoology 249:269–282.

Koeing, J., R. Shine, and G. Shea. 2002. The dangers of life in the city: Patterns of activity, injury, and mortality in suburban lizards (*Tiliqua scincoides*). Journal of Herpetology 36:62–68.

Lee, D.S. 1969. Moisture toleration: A possible key to dispersal ability in three fossorial lizards. Bulletin of the Maryland Herpetological Society 5:53–56.

McCallum, M.L., and S.E. Trauth. 2003. A forty-three year museum study of Northern Cricket Frog (*Acris crepitans*) abnormalities in Arkansas: upward trends and distributions. Journal of Wildlife Diseases 39:522–528.

McConnell, K., and E.S. Menges. 2002. Effects of fire and treatments that mimic fire on the Florida endemic Scrub Buckwheat (*Eriogonum longifolium* Nutt. var. *gnaphalifolium* Gandog.). Natural Areas Journal 22:194–202.

McCoy, E.D., P.E. Sutton, and H.R. Mushinsky. 1999. The role of guesswork in conserving the threatened Sand Skink. Conservation Biology 13:190–194.

McKinney, M.L. 2006. Urbanization as a major cause of biotic homogenization. Biological Conservation 127:247–260.

Measey, G.J., D.J. Gower, O.V. Oommen, and M. Wilkinson. 2003. Quantitative surveying of endogeic limbless vertebrates – a case study of *Gegeneophis ramaswamii* (Amphibia: Gymnophiona: Caeciliidae) in southern India. Applied Soil Ecology 23:43–53.

Pike, D.A., K.S. Peterman, and J.H. Exum. 2007. Use of altered habitats by the endemic Sand Skink

(*Plestiodon reynoldsi* Stejneger). Southeastern Naturalist 6:715–726.

Pike, D.A., K.S. Peterman, and J.H. Exum. 2008a. Habitat structure influences Sand Skink (*Plestiodon reynoldsi*) presence in altered habitats. Wildlife Research 35:120–127.

Pike, D.A., K.S. Peterman, R.S. Mejeur, K.D. Nelson, M.D. Green, and J.H. Exum. 2008b. Sampling techniques and methods for determining the spatial distribution of Sand Skinks (*Plestiodon reynoldsi*). Florida Scientist 71:93–104.

Reed, D.H. 2004. Extinction risk in fragmented habitats. Animal Conservation 7:181–191.

Reed, R.N., and R. Shine. 2002. Lying in wait for extinction: Ecological correlates of conservation status among Australian elapid snakes. Conservation Biology 16:451–461.

Telford, S.R., Jr. 1959. A study of the Sand Skink, *Neoseps reynoldsi* Stejneger. Copeia 1959:110–119.

Telford, S.R., Jr. 1962. New locality records for the Sand Skink (*Neoseps reynoldsi*) in central Florida, with comments on the habitat. Quarterly Journal of the Florida Academy of Sciences 25:76–77.

Wake, M.H., G. Parra-Olea, and J.P.-Y. Sheen. 2005. Biogeography and molecular phylogeny of certain New World caecilians. Pp. 48–64 *In* Ecology and Evolution in the Tropics: A Herpetological Perspective. Donnelley, M.A., B.I. Crother, C. Guyer, M.H. Wake, and M.E. White (Eds.). University of Chicago Press, Chicago, Illinois, USA.

Webb, J.K., B.W. Brook, and R. Shine. 2002. What makes a species vulnerable to extinction? Comparative life history traits of two sympatric snakes. Ecological Research 17:59–67.

Webb J.K., R. Shine, and R.M. Pringle. 2005. Overstory removal restores habitat quality for an endangered snake in a fire suppressed landscape. Copeia 4:893–89.

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