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INDIRECT MONITORING OF A RARE LIZARD: EFFECTS OF SAMPLING INTENSITY, SEASON, AND MANAGEMENT PRACTICES

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***Abstract*.—We examined the effects of sampling intensity, season, and planned burning on indirect monitoring of the rare Florida Sand Skink (*Plestiodon* [*Neoseps*] *reynoldsi*) using cover boards. Our study was carried out initially within 18 400-m^2 enclosures replicated across three fire return intervals, so that we could estimate population density with simulated removal trapping. We installed cover boards at three densities (six replicates each). Sampling intensity influenced number of recorded presences (distinctive trails under the cover boards) and the rate at which the first presence was recorded, and we recommend that cover boards be installed at a density of at least 200/ha. Infrequent sample occasions prevented the application of robust occupancy models, so we repeated the study using 36 enclosures and daily observations of cover boards. Our results indicated that indirect sampling does not reflect population size with reasonable certainty and that fire return interval influences occupancy. We suggest that managers note the habitat structure when they interpret monitoring results. More presences were recorded during the spring, and we recommend that monitoring be confined to that season. Managers interested in detecting population changes of Florida Sand Skinks over relatively short periods of time must rely on direct monitoring with pitfall traps and possibly employ mark-release-recapture methods.**

Key Words.—fire; Florida Sand Skink; occupancy; *Plestiodon* [*Neoseps*] *reynoldsi;* sampling intensity; season; species recovery

INTRODUCTION

Sampling rare species is a difficult undertaking (Sudman et al. 1988; Gaston 1997; Christman 2000; McDonald 2004). A great deal of sampling effort often is required just to determine whether a rare species is present in a particular place (McArdle 1990; Green and Young 1993; Nicholson and Barry 1995; Kéry 2002; Driscoll, 2010). Determining whether a rare species is present often is easier if indirect monitoring, using a reliable sign of presence, can be employed (Caughley 1977). Furthermore, when monitoring relies on detecting a sign, rather than an individual, it may be less invasive and potentially less harmful. We evaluated the use of indirect monitoring to detect presence of a rare, cryptic lizard, the Florida Sand Skink (*Plestiodon* [*Neoseps*] *reynoldsi*), and explored the possible extension of indirect monitoring to estimate abundance. Determining whether a population of a rare, cryptic species is stable or decreasing in size is immensely more difficult than determining its presence. The difficulty is compounded further when the determination is part of a monitoring program (Bakker and Doak 2009). The abundance and distribution of a species tend to be positively linked (Gaston et al. 2000) and, if numbers of a sign could be reliably related to numbers of individuals, then a powerful management tool for evaluating population trends of the Florida Sand Skink would become available.

The Florida Sand Skink is federally listed as threatened and is restricted to the Florida Scrub ecosystem of the central ridges of Florida, USA. These ridges are composed of deep fine sands that were deposited along ancient shorelines and sustain habitat associations, such as the Florida Scrub, that are virtually unique to them. The Florida Sand Skink is mostly found just below the surface of the sandy soil, moving through the dense medium by undulating its tail and body (termed Sand Swimming; Mushinsky and Gans 1992; Fig. 1A). The species currently occupies the remaining isolated patches of Florida Scrub on the ridges, which were once part of a highly inter-connected system. The Florida Sand Skink has a single mating period each spring, during which adults are most active. Shortly after the spring mating period, in May and June, females produce a single clutch of eggs (Ashton 2005). Hatchlings are active after their emergence between July and October (Ashton and Telford 2006). Generation length has been estimated to be about 4 y (McCoy et al. 2010), and maximum lifespan to be at least 10 y (Meneken et al. 2005).

The recovery of the Florida Sand Skink has been a concern for land managers and biologists. A great deal of effort has been expended to understand the patterns of distribution and abundance of the species within and

FIGURE 1. A) The Florida Sand Skink (*Plestiodon* [*Neoseps*] *reynoldsi*) from Archbold Biological Station, Florida, USA. B) Sinusoidal trails left in the sand. (Photographed by Carol Rizkalla).

among patches of the Florida Scrub, but these patterns are still not well understood (McCoy et al. 1999). Pitfall trapping has been the most successful method for the safe capture and study of the species (Andrews 1994; Ashton and Telford 2006), but the construction and maintenance of trap arrays are relatively expensive and time consuming. Placing cover boards strategically in the field is a more cost- and time-effective method for detecting presence of the Florida Sand Skink (Sutton et al. 1999; Pike et al. 2007, 2008a, b). The movements of individuals near the surface of the ground leave distinctive sinusoidal trails (Fig. 1B), and cover boards serve to protect the trails from erasure by wind and rain. In a previous study of the Florida Sand Skink, we compared data obtained from cover boards to data obtained from pitfall traps within enclosures (Sutton et al. 1999). The total number of individuals captured in pitfall traps over the three intervals was related strongly to the observed number of cover boards with trails underneath, suggesting that this sign may provide a means for indirect monitoring of abundance.

In the current study, we conducted two sampling exercises within a set of enclosures. The first exercise was designed to determine how sampling intensity (density of cover boards), season (spring versus fall), and management practice (time since last prescribed burn) affected the use of cover boards to detect presence of the Florida Sand Skink. We simultaneously captured individuals by pitfall trapping, and thus also were able to examine the possibility of using cover boards to estimate abundance. Monitoring trends in abundance has become an increasingly important part of the recovery process for the Florida Sand Skink, but clearly is difficult for this rare, cryptic species. Our premise was that sign (number of cover boards with trails underneath) is a reliable surrogate for abundance, and thus can be used to detect population change quickly and effectively. The second sampling exercise was designed to determine if increased sample size improved the relationship between the presence data collected from cover board sampling and the abundance data collected from pitfall trapping. This exercise employed more pitfall traps and cover boards, and decreased the time between sampling events.

MATERIALS AND METHODS

The study site was Archbold Biological Station (ABS), Lake Placid, Florida, USA (27°10'53"N, 81°21'08"W), an approximately 2,100 ha natural preserve of Florida Scrub. The pyrogenic Florida Scrub at ABS has been subjected to prescribed burning during the last 40 y. The main property at ABS is subdivided into burn units that are managed according to different fire return intervals (Main and Menges 1997). The burning strategy mimics the fire return intervals needed to maintain a shifting mosaic of successional seres. The actual burn frequency of each unit is affected by several factors, including adverse climatic conditions during a particular year and occurrence of wildfires.

We conducted our experiments within enclosures installed in 12 burn units representing the variation in fire return interval found at ABS. Primary habitat in the burn units was scrubby flatwoods, which is a well-drained habitat with many low-growing, xeric species, such as *Quercus inopina*, *Q. chapmannii*, *Q. geminata*, *Serenoa repens*, and *Sabal etonia*. The sparse overstory is dominated by *Pinus clausa* and *P. elliotii*. At the initiation of the study, four of the burn units were recently burned (< 6 y since the last fire), four were intermediately burned (7–17 y since the last fire), and four were long unburned (> 18 y since the last fire). Three replicates within each unit brought the total number of enclosures to 36. Each enclosure was a 20 × 20 m (400-m^2) four-sided fence constructed from metal flashing inserted in about 30-cm deep trenches (Fig. 2). This design effectively confined individuals of the Florida Sand Skink, which likely remain within 10 cm of the surface (Telford 1959).

We sampled the Florida Sand Skink within enclosures directly with pitfall trapping and indirectly with cover boards. We installed 16 regularly spaced pitfall-trap arrays within an enclosure, each consisting of a 2-m

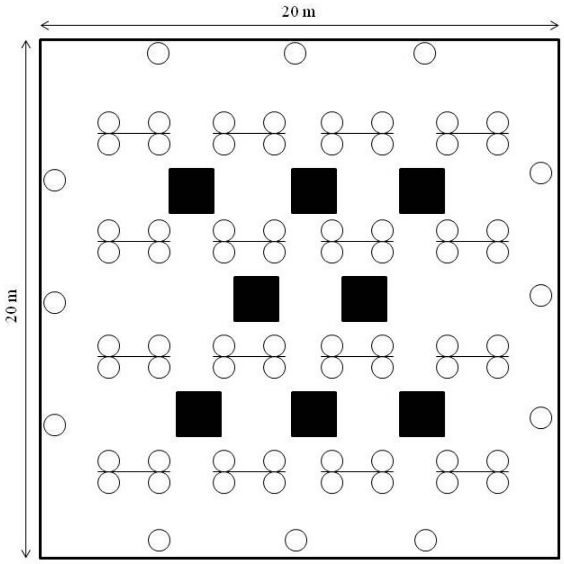

FIGURE 2. Diagram of an enclosure showing the layout of 76 pitfall traps and eight coverboards used to find the Florida Sand Skink (*Plestiodon* [*Neoseps*] *reynoldsi*).

long, 15-cm deep metal fence that diverted individuals into two 3.8-L buckets countersunk at each end of the fence. The total trapping effort within an enclosure was 64 pitfall traps in the arrays plus 12 pitfall traps regularly spaced along the sides of the enclosure. We put in several centimeters of sand in the buckets and an elevated cover to provide shelter from predators and direct exposure to the sun. Periodically, we also installed cover boards in selected enclosures (see below). The cover boards were made of plywood and were 0.6 × 0.6 m in size.

Detecting presence at different cover board densities.—We examined the ground beneath cover boards for trails left by the Florida Sand Skink during spring (March to June) and late summer (August to September) of 2008. We placed cover boards in a grid within 18 of the enclosures, selected in a stratified random manner, to ensure that the three categories of fire return intervals were equally represented. Pitfall trapping in the selected enclosures had revealed the presence of individuals in both spring and late summer of 2007. We installed cover boards at densities of 100 cover boards/ha (four cover boards/enclosure), 200 cover boards/ha (eight cover boards/enclosure), or 400 cover boards/ha (16 cover boards/enclosure), apportioned equally among the categories of fire return intervals. We checked each cover board for trails every 6 d.

We measured effectiveness of the different cover board density treatments for detecting presence of the Florida Sand Skink as number of days with at least one recorded presence and as number of days until first detection (Efficiency; Sutton et al. 1999). One typically cannot count the number of individual trails under a cover board with certainty, nor can one relate number of individual trails to number of individuals, even if they could be counted; so we simply recorded any number of trails under a cover board as a presence. We used Mann-Whitney U-tests to compare results between cover board densities and times since last fire, within seasons. We rearranged the data to provide an estimate of the minimum number of sampling periods necessary to infer that the Florida Sand Skink is not present at a site with 90% confidence (McArdle 1990; Kéry 2002): $N = \log(1-\alpha) / \log(1-p)$, where N is the number of sampling units, α is the probability of an individual appearing in a sample of N units, and p is the probability of an individual appearing in a single sample unit. We calculated p for each enclosure as the number of 6-d sampling periods in which presence was detected divided by the total number of sampling periods.

Using cover boards to estimate abundance.—During the first sampling exercise, we collected individuals of the Florida Sand Skink from pitfall traps during the spring (March to June) and late summer (August to September) of 2007–2009. We checked each pitfall trap for captured individuals every 3 d. We marked captured individuals with six digit identification codes using elastomer tags (Northwest Marine Technology, Shaw Island, Washington, USA; see Penny et al. 2001 for methods), and we released them back into the enclosures in which they were captured.

We estimated abundance within enclosures in 2008, the year in which cover boards also were installed, in two ways. The first was the number of individuals captured during the spring and during the late summer trapping seasons (cf. Sutton et al. 1999). Although this estimator is biased, we assumed that it would include most of the individuals that were catchable during the particular season, because of the extensive pitfall trapping effort, and that these individuals are likely to have created most of the trails under the cover boards. We also used the capture histories of individuals over the six trapping seasons (2007–2009) to calculate another biased estimator, the minimum number alive, in 2008. Minimum number alive added in those individuals seen before a particular season, not seen during that season, but seen again later. We assumed that this estimator would include most of the potentially catchable individuals during the particular season. Unbiased mark-release-recapture methods did not prove useful because we did not account for varying sampling intensity through time. We used correlation analysis to relate the number of days with presence, from cover board sampling, to the estimates of abundance, from pitfall sampling.

We developed occupancy models to estimate site occupancy (proportion of area occupied, ψ) in each enclosure (MacKenzie et al. 2003; Durso et al. 2011). We first tested a null model, and then sequentially added the board treatment and burn interval covariates to model detection. Models were evaluated with AIC weights (Burnham and Anderson 2002). The burn interval covariate was tested for occupancy. Models with ΔAIC < 2 were averaged for ψ calculation. Goodness-of-fit was tested by comparing the observed X^2 statistic to that from 100 parametric bootstrap simulations. We used correlation analysis to relate the estimates of ψ from the best or averaged model to the estimates of abundance.

During the second sampling exercise, we collected individuals and examined cover boards within all 36 enclosures during the spring and late summer of 2011 and 2012. We installed cover boards at a density of 200/ha (eight cover boards/enclosure), and checked daily for trails. All other field procedures were identical to those used in the first sampling exercise. We used correlation analysis to relate both the number of days with presence and the number of days until detection, from cover board sampling, to the estimates of abundance, from pitfall sampling. In between the installation of enclosures in 2007 and trapping in 2011–2012, some of the plots were subjected to prescribed burning, as part of the normal burn rotation at ABS. Also, several plots changed burn status as time passed. Thus, correlations within burn regimes could be calculated by at least three methods, and we present results from all of them. Method 1 maintains the classification of the plots into recently burned, intermediately burned, and long unburned as it existed in 2007; Method 2 changes the classification to reflect the prescribed burning and the passage of time between 2007 and 2011–2012; and Method 3 uses the absolute time since last burn.

Although the methods of analysis largely remained the same in the second sampling exercise, the increased sampling frequency allowed us to include the effect of environmental conditions on probability of detection. We collected data on environmental conditions on the day before each observation in 2011: maximum air temperature, rainfall, soil temperature at a depth of 10 cm, and soil moisture at 10 cm. These data were available from the weather station at ABS. To model occupancy, we also considered time since fire; the percentages of bare ground, live vegetation, and dead vegetation; canopy height, and leaf litter biomass (g/m^2). We collected vegetation data in June-July 2011 within 16 1-m^2 quadrats per enclosure. We averaged values in each quadrat over the enclosure. High correlation between canopy height, live vegetation, and bare ground precluded the consideration of the former two variables in the models, however. We collected leaf litter samples, 0.1-m^2 in area, during the same period at 10 locations per enclosure. We oven dried samples at 60° C to constant weight. We also included an index of disturbance in the models, based on anecdotal evidence suggesting that individuals of the Florida Scrub Jay (*Aphelocoma coerulescens)* and Eastern Coachwhip (*Masticophis flagellum flagellum*) were pushing the pitfall trap covers aside. Whether they also were preying upon captured individuals of the Florida Sand Skink is unknown. The index simply ranked apparent disturbance from zero to two (none, some, severe).

RESULTS

Detecting presence at different cover board densities.—We collected Florida Sand Skinks in pitfall traps within all 18 enclosures during the spring of 2008, and cover boards detected presence within all 18 enclosures. We collected individuals within 16 enclosures during the late summer of 2008, but cover boards detected presence only within 14 enclosures. The number of days with presence and the number of days until detection were strongly correlated ($r_S = -0.74$, $P < 0.010$). Note that measuring the number of days with presence is virtually identical to measuring the total number of recorded presences ($r_S = 0.96$, $P < 0.010$).

Cover boards detected presence more rapidly during the spring than during the late summer, but the difference was not significant ($U = 128.0$, $P = 0.279$). During the spring, 16 cover boards ($U = 5.0$, $P = 0.041$) and eight cover boards ($U = 8.0$, $P = 0.132$) per enclosure both detected presence more rapidly than four cover boards per enclosure. Sixteen cover boards per enclosure provided only marginally more rapid detection than eight cover boards, however. Presence was detected more rapidly in long unburned enclosures than intermediately burned enclosures ($U = 4.5$, $P = 0.026$), but not in recently burned enclosures ($U = 12.0$, $P = 0.394$). During the late summer, 16 cover boards ($U = 8.0$, $P = 0.132$) and eight cover boards ($U = 4.0$, $P = 0.026$) per enclosure again detected presence more rapidly than four cover boards per enclosure. Neither long unburned ($U = 16.0$, $P = 0.818$) nor recently burned ($U = 11.5$, $P = 0.310$) enclosures detected presence more rapidly than intermediately burned enclosures.

Because of the relatively poor overall detection noted in the late summer, we provide an estimate of the minimum number of sampling periods necessary to infer that the Florida Sand Skink is not present at a site with 90% confidence, as well as the results of all subsequent analyses, only for the spring. Mean probabilities of detection were 0.22 ± 0.17 (four boards), 0.39 ± 0.15 (eight boards), and 0.58 ± 0.21 (16 boards). The minimum number of sample periods necessary to infer

TABLE 1. Pearson correlation coefficients between number of individuals and three presence/absence measures of the Florida Sand Skink (*Plestiodon* [*Neoseps*] *reynoldsi*) in 2011. Data are presented individually for burn intervals (Method 2 – see Methods). The asterisk (*) indicates $P < 0.05$. The abbreviation PAO = Proportion of Area Occupied.

Season	Burn Interval	Days with Presence	Days to Detect	PAO
Spring	All	0.66*	-0.52*	0.17
	Recent	0.31	-0.57	0.16
	Intermediate	0.45*	-0.42	0.56*
	Long	0.84	-0.94	0.61
Late Summer	All	0.44*	-0.26	0.11
	Recent	0.29	-0.43	0.37
	Intermediate	0.41	-0.13	0.27
	Long	0.58	-0.62	-0.99*

that the Florida Sand Skink was not present at a site, with 90% confidence, were 27.4 periods (four boards), 7.4 (eight boards), and 4.5 (16 boards). Because rapidity of detection differed among fire return intervals, we expected probability of detection also to differ. Mean probabilities were 0.56 ± 0.17 (long unburned), 0.28 ± 0.15 (intermediately burned), and 0.36 ± 0.27 (recently burned). Consequently, the minimum number of periods necessary to infer absence also will differ among fire return intervals.

Using cover boards to estimate abundance.—Pitfall trapping in spring 2008 suggested that numbers of individuals were similar among cover board treatments. Mean numbers of individuals captured per enclosure for the three cover board treatments in spring 2008 were 6.0 ± 3.3 (four boards), 5.5 ± 2.4 (eight boards), and 5.5 ± 4.5 (16 boards). Slightly more than half of the individuals were captured in long unburned plots (see McCoy et al. 2013). Approximately 50% of the variation in number of individuals captured was explained by number of days with presence from cover board sampling. Minimum number alive increased the estimated population size by only approximately one individual per enclosure, and the correlations with the cover board data were very near those for number of individuals captured; so, we report correlations only for number of individuals captured.

Of the 168 cover boards that we distributed across 0.72 ha of known Florida Sand Skink habitat in spring 2008, 70 did not record a presence, and 58 recorded only one presence. Of the 2,688 cells (168 cover boards × 16 sampling occasions) in the occurrence matrix, 185 (6.9%) were occupied. Proportion of area occupied (ψ) values were 0.45 ± 0.19 (four boards), 0.36 ± 0.13 (eight boards), and 0.40 ± 0.17 (16 boards). Number of individuals captured was not correlated with ψ overall ($r_S = -0.28$, $P = 0.256$), but the correlation strengthened with increasing number of cover boards (four boards = -0.06, eight boards = -0.24, 16 boards = -0.67). Occupancy modeling indicated that detectability was a function of board treatment, and that burn interval did not influence occupancy. Because of the sparseness of the occurrence matrix, the models were a poor fit, however, and did not improve on the ability to predict abundance from the number of days with presence, recorded from cover board sampling.

Starting in spring 2011, we attempted to populate the occurrence matrix more completely by increasing the number of enclosures and checking cover boards daily. This change yielded an occurrence matrix in the spring 2011 of 20,736 cells (288 cover boards × 72 sampling occasions), a 7.7-fold increase in sampling effort over 2008. Only 832 (4.0%) cells were occupied, however. So, while occurrence increased absolutely by 4.5-fold, it decreased relatively by 1.7-fold.

Correlations between number of days with presence and number of individuals captured indicated that the two variables were related in both trapping seasons (spring: $r = 0.66$, $P < 0.001$, n = 36, late summer: $r = 0.44$, $P = 0.008$, n = 36; Table 1, Fig. 3A). Significant correlations between days to detection and number of individuals were present only in the spring trapping season and showed a similar trend, a significant relationship among all enclosures ($r = -0.52$, $P = 0.002$; Table 1, Fig. 3B). Using Method 2 (changing the classification of plots to reflect the prescribed burning and the passage of time between 2007 and 2011), mean numbers of individuals captured per enclosure in the three burn treatments were 14.2 ± 6.5 (recently burned), 5.2 ± 5.5 (intermediately burned), and 8.8 ± 8.4 (long unburned). Although correlations were highest in long unburned enclosures in the spring ($r = 0.84$), a low sample size (n = 4) precluded statistical significance at $P = 0.05$. Alternatively, the relationship was not as strong in intermediate enclosures ($r = 0.45$, n = 21) but was significant ($P = 0.042$). The correlation between days to a detection and number of individuals was highest in long unburned enclosures ($r = -0.94$, $P = 0.224$; Table 1, Fig. 3B). Using Method 1 (maintain the original classification of the plots), mean numbers of individuals captured per enclosure in the three burn treatments were 6.4 ± 6.3 (recently burned), 4.8 ± 4.2 (intermediately burned), and 13.8 ± 7.6 (long unburned). Correlations between numbers of individuals and numbers of days with presence ranged from 0.62 to 0.67 (P = 0.017–0.031), and between numbers of individuals and days to detection from -0.33 to -0.64 (P = 0.036–0.325). In the latter case, the only significant relationship was for the long unburned enclosures. Method 3 (absolute time since last burn) yielded substantially poorer correlations than either Method 1 or 2.

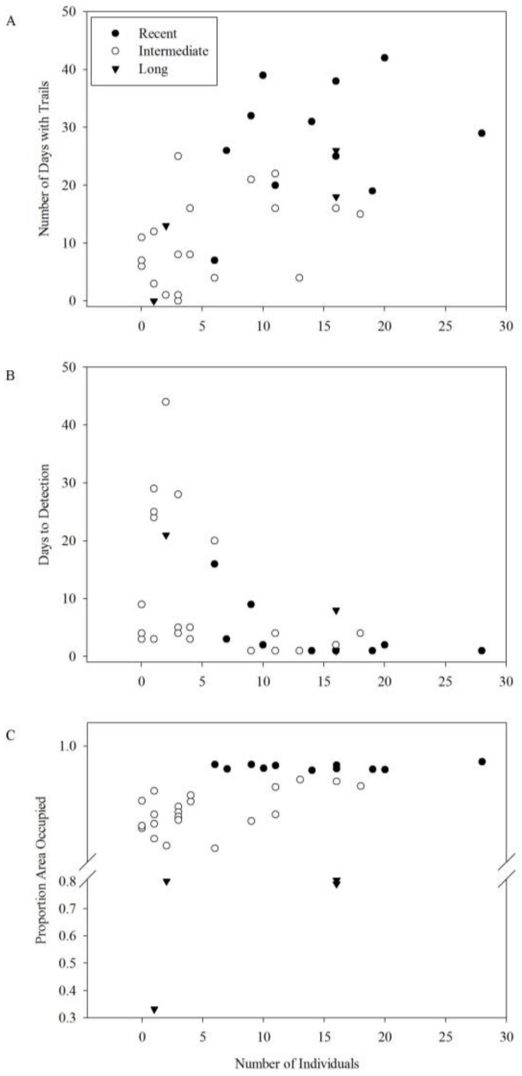

FIGURE 3. Relationship between estimated number of individual Florida Sand Skinks (*Plestiodon* [*Neoseps*] *reynoldsi*) in 36 enclosures in three burn intervals in the spring of 2011 and A) days with trails under a cover board, B) days to detection, and C) proportion area occupied.

TABLE 2. Coefficient estimates for model-averaged occupancy models of the Florida Sand Skink (*Plestiodon* [*Neoseps*] *reynoldsi*) in 2011.

Covariate	Spring		Late Summer	
	β	*SE*	β	*SE*
P				
Intercept	-1.58	0.25	-10.41	14.89
Rain	-0.98	0.21		
SoilMoist	14.77	7.64		
AirTemp			-0.07	509.54
SoilTemp			0.39	432.77
ψ				
Intercept	5.99	3.59	4.78	2.01
TSF	-0.15	0.08		
Bare	-1.64	4.81	-2.59	3.38
Dead	-3.58	11.19	5.58	7.76
Disturb			-0.28	0.66

Three occupancy models were averaged, and indicated that detectability of trails was influenced by rainfall and soil moisture (Table 2). Occupancy was primarily a function of time since fire, and to a lesser extent proportion bare ground and dead cover. For each enclosure, ψ ranged from 0.33 to 0.99, but only correlated significantly with number of individuals in intermediate burn intervals ($r = 0.56$, $P = 0.008$; Table 1, Fig. 3C). Model fit was poor.

The results for 2012 largely mirrored those of 2011. In the spring, the occurrence matrix again was not well-populated: it contained 19,872 cells (288 cover boards × 69 sampling occasions), of which only 1,231 (6.2%) were occupied. Occupancy was increased absolutely compared to both 2008 and 2011, but the rate was decreased slightly compared to 2008. Occupancy model fit was poor, and ψ values explained less than 40% of the variation in number of individuals. Number of days with presence explained about 42% of the variation in number of individuals ($r = 0.70$, $P < 0.001$). Using Method 2, mean numbers of individuals captured per enclosure in the three burn treatments were 7.3 ± 4.0 (recently burned), 3.1 ± 2.6 (intermediately burned), and 5.4 ± 4.8 (long unburned). Correlations once again were highest in long unburned enclosures ($r = 0.88$), but low sample size precluded statistical significance at $P = 0.05$. Alternatively, the relationship was not as strong in intermediate enclosures ($r = 0.56$, n = 21) but was significant ($P = 0.023$). Using Method 1, mean numbers of individuals captured per enclosure in the three burn treatments were 4.1 ± 4.4 (recently burned), 3.6 ± 2.6 (intermediately burned), and 6.2 ± 3.8 (long unburned). Correlations between numbers of individuals and numbers of days with presence ranged from 0.62 to 0.70 ($P = 0.008$–0.031). Method 3 (absolute time since last burn) again yielded substantially poorer correlations than either Method 1 or 2.

DISCUSSION

Our previous study (Sutton et al. 1999) clearly illustrated the utility of cover boards in sampling the Florida Sand Skink and documenting its presence. The density of cover boards in this previous study was more-or-less arbitrarily set at 100/ha; and, in the current study, we asked whether higher densities of cover boards could improve detection. We found that increasing cover board density to 200/ha improved both the probability and rapidity of detection, but a further increase to 400/ha yielded only a marginal improvement. The 6-d intervals between cover board examinations may have masked a larger gain in rapidity of detection, however. Furthermore, estimated population sizes in the 2008 study (1–13 during the spring sampling season) were somewhat lower than those in the previous study (5–26; Sutton et al. 1999), which may have affected both relative probability and relative rapidity of detection.

We found that season, spring versus late summer, had an important influence on detection. Although population densities increased in late summer, because of the input of juveniles, the overall activity was much reduced. Each individual accounted for about 75% fewer presences in late summer. Because of the much lower level of activity, the presence of marked individuals sometimes was not detected at all, even at the highest cover board density. When presence was detected, detection took marginally longer in late summer. These seasonal differences likely result from environmental factors. The spring trapping season encompasses the dry season in central Florida and late summer includes the wet season. As temperature and rainfall increase, sand skinks burrow to greater depths (Andrews 1994) making cover boards less likely to detect a trail at the surface.

We also found that fire history, recently burned versus intermediately burned versus long unburned, had an important influence on detection. Detection was relatively low for the intermediately burned enclosures, and it took longer to detect a presence in intermediately burned enclosures than in recently burned and long unburned enclosures. Much of this difference likely is attributable to variation in population density among enclosures: total numbers of individuals trapped were lowest in intermediately burned enclosures and highest in long unburned enclosures. This pattern mirrors a general trend found at ABS (Ashton and Knipps 2011; McCoy et al. 2013); and, interestingly, supports some previous speculations about the habitat preference of the Florida Sand Skink (McCoy et al. 1999). The more rapid detection in recently burned enclosures than in the intermediately burned enclosures may indicate a greater vagility of individuals in those enclosures. Recent burns create more open habitat which may allow for greater ease of movement.

Similarities in 2011 between recently burned and long unburned enclosures may demonstrate a lag in population response. Eight of the enclosures categorized as recent burns in 2011 were categorized as long unburned in 2008. Because of their long generation times, Florida Sand Skink population densities and occupancy patterns likely would not show a response to habitat management within a short time span.

Although results to date indicate that number of days with presence is related strongly to number of individuals, they also suggest that the amount of variance explained is too low to use number of days with presence as a reliable index of number of individuals for a particular site. In our original study (Sutton et al. 1999), number of presences explained about 67% of the variation in number of individuals. The original study included seven sites in relatively-homogeneous habitat. In the current study, which included 18–36 sites with a greater range of environmental variation, number of days with presence explained 42–50% of the variation in number of individuals. With 50–58% of the variation unexplained, the power to detect a meaningful short-term reduction in numbers with reasonable certainty would be extremely low. Between-year variation in overall population size, estimated for three consecutive years at ABS, was about 5–7% (Earl McCoy et al., unpubl. report); so, a reasonable monitoring goal might be to detect 10% fewer individuals over a one-year span. The likelihood that a 10% reduction in number of individuals could be detected depends on how accurately the reduction is reflected in the presences recorded by the cover boards, and our results indicate that the accuracy is only 50% or less. The confidence interval around the regression of estimates of numbers of individuals on numbers of presences indicates that the reduction in numbers of individuals would need to be more than 40% to be detectable with cover boards at $\alpha = 0.10$ (Earl McCoy et al., unpubl. report), however. Furthermore, uncontrollable temporal changes are likely to add additional uncertainty to the relationship, with a concomitant reduction in the likelihood of detection. For example, any change in the dispersion of individuals between samples as a result of changing habitat structure, in relation to placement of cover boards, is likely to affect the distribution of number of presences among cover boards.

Occupancy models failed to improve the relationship between number of days with presence and number of individuals. Although these data produced seemingly realistic estimates of occupancy after modeling, they did not accurately represent population abundance. One hundred of the 288 cover boards never documented a presence in 2008, for instance. Those boards were relatively well distributed across 18 enclosures; thus, it is possible that an enclosure could be saturated at a density of 200/ha. The data collected from cover boards at lower density were not better, however. We were unable to test differences between 2008 and 2011–2012 explicitly because of the difference in methods and the application of fire during the interval between samples. The number of individuals captured in 2011–2012 in the same 18 enclosures used in 2008 was substantially greater than the 2008 number. Although occupancy estimates more than doubled between sampling exercises, this increase more likely is attributable to the difference in number of sampling occasions. Indeed, year-to-year variation in occupancy-abundance relationships has produced a random pattern in some species (Gaston et al. 2000). It appears, therefore, that the accuracy gained from documenting occupancy of the Florida Sand Skink is not high enough to detect population change in the short term.

Sampling recommendations.—Our results lead to several recommendations concerning cover board sampling practices for the Florida Sand Skink. First, we recommend that researchers and managers consider employing a standard cover board density of 200/ha. We leave it to individual researchers and managers to decide whether any gains made by increasing density further is offset by the increased cost and effort involved. Second, we recommend that cover board sampling, especially survey work conducted in locations with little or no sampling history, be restricted to spring. Third, we recommend that careful notation be made of habitat types, habitat structures, and fire histories wherever sampling is undertaken. Although this recommendation will not improve detection directly, having such data will aid in making comparisons among sampling locations. Fourth, we recommend that studies similar to ours be carried out in types of scrub habitat other than the scrubby flatwoods type in which our enclosures were installed. Lastly, we recommend against the use of cover boards to monitor relatively small, short-term population trends. Accurate population monitoring to detect such trends will require the considerable expense and effort of pitfall trapping and possibly employ mark-release-recapture methods. We suggest, however, that cover boards may prove useful for detecting relatively large, long-term trends (but see Rodda et al., In press), which will be necessary to determine the recovery of the Florida Sand Skink.

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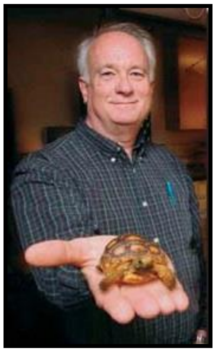

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