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ECOLOGY OF THE EASTERN KINGSNAKE (*LAMPROPELTIS GETULA GETULA*) IN A LONGLEAF PINE (*PINUS PALUSTRIS*) FOREST IN SOUTHWESTERN GEORGIA

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***Abstract*.—We examined demography, activity patterns, and spatial ecology of the Eastern Kingsnake (*Lampropeltis getula getula*) on a protected area in southwestern Georgia from 2002–2008. Twelve adults (10 males and two females) were radio-tracked weekly for periods ranging from 221 to 1,043 days (mean = 447). We recorded 198 kingsnakes (including 19 recaptures) captured with drift fence arrays, snake trap arrays, and incidental hand collection. Sex ratio was biased towards males (χ^2 = 30.1, P < 0.01) and age structure was skewed toward adults (χ^2 = 9.3, P < 0.01). We captured the greatest proportion of snakes in April and May (42%), and radio-telemetered snakes were most active (percentage of observations above ground) from March through June. The average 100% minimum convex polygon (MCP) home range size for radio-tagged males and females was 49.5 ± 11.4 ha and 49.4 ± 16.1 ha, respectively. The average fixed local convex hull (LoCoH) 100% isopleths yielded smaller home range estimates than MCPs (male: 42.1 ± 8.6 ha; female: 36.1 ± 10.0 ha). The mean LoCoH high density core areas (50% isopleths) were similar for males and females (male: 8.5 ± 1.5 ha; female: 9.6 ± 3.2 ha). The number of days we tracked a snake was significantly correlated with the number of locations to which a snake returned to a previously tracked location (n = 12, R^2 = 0.85, P < 0.01), suggesting site fidelity. Understanding the ecological requirements of the Eastern Kingsnake is imperative to managing and conserving a species that is facing population declines in parts of its range.**

Key Words.—activity patterns; demography; Eastern Kingsnake; Georgia; home range size; *Lampropeltis getula getula*; radio telemetry; spatial ecology

INTRODUCTION

Eastern Kingsnakes (*Lampropeltis getula getula*; Fig. 1) are distributed from southern New Jersey to peninsular Florida, west to the Appalachians and south Alabama, and are found throughout Georgia (Ernst and Ernst 2003; Krysko 2008). Historically, they were common throughout much of the southeast (Carr 1940; Gibbons 1977; Krysko and Smith 2005). However, they have become increasingly rare in parts of their southern range (Krysko 2002, 2008; Krysko and Smith 2005; Winne et al. 2007; Stapleton et al. 2008). Habitat fragmentation and loss, road mortality, pollution, natural succession of uplands, periodic extreme droughts, predation by the Red Imported Fire Ant (*Solenopsis invicta*), and collection for the pet trade have all been implicated as potential contributing factors to population declines (Wilson and Porras 1983; Krysko 2001, 2002; Ernst and Ernst 2003; Winne et al. 2007).

FIGURE 1. *Lampropeltis getula getula* (Eastern Kingsnake) from Ichauway, Baker County, Georgia, USA. (Photographed by Gabe Miller)

The apparent decline in Eastern Kingsnake populations across the range is somewhat surprising given what is known about their diet and habitat requirements. They feed on a wide array of prey such as snakes, including members of their own species, lizards, rodents, rabbits, shrews, amphibians, birds, and may depredate nests of many birds and reptiles (Conant and Collins 1998; Jenkins et al. 2001; Ernst and Ernst 2003; Winne et al. 2007; Krysko 2008). Eastern Kingsnakes can be found in a variety of habitats across their range. In a companion study conducted at Ichauway, we found that Eastern Kingsnakes selected natural Longleaf Pine

(*Pinus palustris*) and hardwood forest habitats at the landscape level and microhabitats with coarse woody debris and woody vegetation (Steen et al. 2010). Although Eastern Kingsnakes at Ichauway were largely terrestrial (Steen et al. 2010), the species may show an affinity to aquatic habitats in other parts of their range (Gibbons 1977; Conant and Collins 1998).

Eastern Kingsnakes are primarily diurnal but can become crepuscular or nocturnal in hot weather (Conant and Collins 1998; Ernst and Ernst 2003; Krysko 2002, 2008). They spend a majority of their time underground or concealed under cover, particularly in stump holes and small mammal burrows (Steen et al. 2010), hence little is known about their behavior (Wund et al. 2007; Krysko 2008). Over most of their range, Eastern Kingsnakes are inactive during winter when they retreat to hibernacula such as caves, rock crevices, clay and gravel banks, mammal burrows, Gopher Tortoise (*Gopherus polyphemus*) burrows, hollow logs and stumps, root systems of shrubs and trees, old sawdust mounds, and abandoned buildings (Ernst and Ernst 2003; Wund et al. 2007). However, during the winter months in Florida they are active on warm days (temperatures ≥ 24° C; Krysko 2002).

Eastern Kingsnakes breed from March through June (Ernst and Ernst 2003). During this period, males are more likely to be encountered above ground because they are actively searching for mates (Krysko 2008). Females lay 3–29 eggs in June or July, approximately 45–60 days after mating (Krysko 2008) and hatching occurs from late July through mid October (Ernst and Ernst 2003).

With the exception of a few published studies, much of the information pertaining to Eastern Kingsnakes is based on anecdotal observations. Yet, understanding basic ecological requirements and behavior of Eastern Kingsnakes is paramount to successful conservation and management (Dodd 1987). Therefore, the objective of this study was to present a compilation of six years of data, focusing on aspects of Eastern Kingsnake demography, behavior, and spatial ecology for a population within a protected area in southwestern Georgia.

MATERIALS AND METHODS

Study area.—We conducted this study from March 2002 through August 2008 at Ichauway, the research site of the Joseph W. Jones Ecological Research Center in Baker County, Georgia, USA. The 12,000-ha site is dominated by 80–100 year old, second growth Longleaf Pine/Wiregrass (*Aristida stricta*) savanna and is managed using prescribed fire on a one- to two- year rotation. Hardwood species (*Quercus* spp.) occur primarily along riparian corridors with patches mixed within the landscape. More than 30 seasonal wetlands, numerous hardwood depressions, and approximately 45 km of riparian habitat are interspersed throughout the property. Ichauway is surrounded by agricultural land, which is the dominant land use in southwestern Georgia (Goebel et al. 2001).

Snake captures.—In March 2003, we installed eight snake trap arrays (Burgdorf et al. 2005) in Longleaf Pine habitat characterized by open canopy pine, occasional oaks (*Quercus falcata*, *Q. virginiana*, and *Q. laurifolia*) and native groundcover species including Wiregrass, Broomsedge (*Andropogon* spp.), and Bracken Fern (*Pteridium aquilinum*); an additional eight arrays were opened in similar habitat in April 2005. We selected trap locations non-randomly in similar habitat that consisted of at least 40 ha of contiguous blocks within conservation zones in the northern section of the property. Traps were generally monitored from March through October and were checked two to three time/week from 2003–2008.

We occasionally captured kingsnakes at drift fences with pitfall and funnel traps around three isolated depressional wetlands from 2002–2008. In June 2002, we installed the first drift fence encircling a 2.7-ha Cypress-Blackgum swamp (*Taxodium ascendens-Nyssa sylvatica*) with 88 pitfall traps. We checked traps daily from June 2002 through January 2004. In October 2002, we constructed a second drift fence encircling a 0.73-ha grass-sedge wetland with 44 pitfall traps. Wetland vegetation consisted of Blackgum, Buttonbush (*Cephalanthus occidentalis*), Persimmon (*Diospyros virginianus*), and mixed grasses and sedges. We checked traps every one to two days from October 2002 through December 2008. We installed a third drift fence with 34 pitfall traps around a 0.54-ha ephemeral hardwood depression in November 2005 and we checked these traps every one to two days from November 2005 through June 2008.

From April 2002 through December 2008, we also collected Eastern Kingsnakes opportunistically throughout the property; however, we did not implement a concerted effort to target snakes until 2005, when we encouraged other researchers and maintenance workers (~100) to aid in collection when Eastern Kingsnakes were observed during their field operations. We recorded capture locations either using a GeoExplorer 3 GPS unit or a Juno ST (accuracy ± 1–5m; Trimble Navigation Ltd., Sunnydale, California, USA), or we plotted locations by hand using ArcGIS 9.1 (Environmental Systems Research Institute, Redlands, California, USA).

For captured individuals, we took the average of two independent measurements and recorded snout-to-vent length (SVL), tail length, body mass, and determined sex by cloacal probing. We individually marked snakes using passive integrated transponders (PIT) tags injected

TABLE 1. Captures of Eastern Kingsnake (*Lampropeltis getula getula*) using three different sampling methods at Ichauway, Baker County, Georgia, from 2002–2008. Drift fences were placed around isolated wetlands, whereas snake traps were placed in Longleaf Pine habitat. Incidental captures occurred across the site. A detailed description of the study site can be found in Materials and Methods.

Capture Method	M	F	Sex Unknown	Juvenile	Adult	Age Unknown	Recaptures
Snake Traps	57	27	8	39	45	8	10
Drift Fences	9	4	1	13	1	0	5
Incidental Captures							
On Road	49	13		7	46	0	2
In Field	16	12	1	5	24	0	2
Total	131	56	11	74	116	8	19

subcutaneously between the dorsal and ventral scales located on the lower third of the body (Gibbons and Andrews 2004) or by heat brand (Weary 1969). Individuals were grouped into juvenile (< 900 mm SVL) or adult (> 900 mm SVL) categories (Krysko 2008). We returned snakes to their original capture location within 2–3 days. We calculated the mean body condition index (BCI = [Body mass/SVL^3] x 10^5; Romero and Wikelski 2001; Winne et al. 2007) for all adult (SVL > 900 mm) snakes by year. Snakes captured in 2002 were not included in BCI calculations due to the small sample size of individuals with recorded measurements (n = 4). We used linear regression (α = 0.05) to ensure that BCI was not significantly correlated with SVL (n = 102, R^2 < 0.01, P = 0.4) and therefore would be suitable for further analysis (Winne et al. 2007). Recaptured individuals were not included in the analyses.

Radio-telemetry.—We radio-tracked 12 Eastern Kingsnakes (10 males and 2 females) from June 2005 through August 2008. Snakes were surgically implanted with 9-g radio transmitters that had an 18 month battery life (model SI-2; Holohil Systems Ltd., Carp, Ontario, Canada). We implanted new 18 month transmitters in five individuals after the first 18 month tracking period. Transmitters were implanted using methods described in Reinert and Cundall (1982). We tracked snakes 1–2 times per week by homing in to their location and we recorded UTM coordinates using GPS as described above. We recorded snake behavior at each location (i.e. basking, moving, feeding, underground). We created a spatial layer including all telemetry locations in ArcGIS 9.1. Home range sizes were estimated using two methods: minimum convex polygon (MCP; Mohr 1947) and fixed local convex hull (LoCoH; Getz and Wilmers 2004; Getz et al. 2007). We calculated 100% MCPs using the Hawth's Tools extension in ArcMap 9.1 (Beyer 2004) to allow for comparison with other studies of Eastern Kingsnake home range size. We also estimated home range size using LoCoH to quantify areas of high density use within a home range; this method has been shown to be more robust than parametric kernel methods (Getz and Wilmers 2004; Getz et al. 2007). We used the LoCoH extension (University of California, Berkley, California, USA) in ArcGIS 9.1 to calculate high density 50% isopleths (50% of all locations) and low density 100% isopleths (containing all locations). We used linear regression to determine if there was a relationship between body size (SVL) and home range size (LoCoH 100% isopleths) and number of days tracked and the number of locations to which a snake returned. We defined a return location as a previous location that an individual revisited after moving to at least one new location. We considered locations > 2 m apart as unique. We pooled male and female location data for analysis because of low female sample size (n = 2).

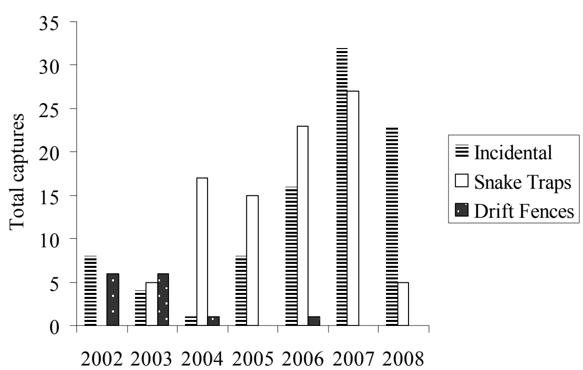

FIGURE 2. Total number of Eastern Kingsnakes (*Lampropeltis getula getula*) captured incidentally, in snake traps, and in drift fences, including 19 recaptures, at Ichauway, Baker County, Georgia, USA from 2002–2008. Effort was not standardized throughout the course of this study.

RESULTS

Snake captures.—We documented 198 Eastern Kingsnake captures; of these, 92 were captured in snake traps, 14 in wetland drift fences, and 92 were incidentally captured (86% on roads). We recaptured 19 snakes over the course of the study (Table 1). Captures (all methods combined) varied from 14 snakes

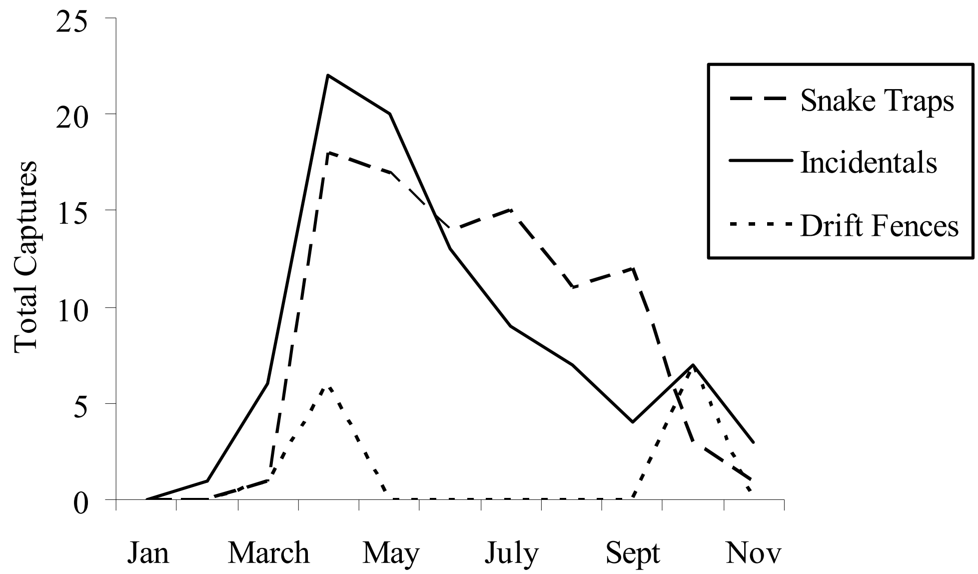

FIGURE 3. Total monthly captures (and recaptures) of Eastern Kingsnakes (*Lampropeltis getula getula*) using three different sampling methods, at Ichauway, Baker County, Georgia, USA from 2002–2008.

in 2002 to 59 in 2007, which may reflect the variation in the number of operational drift fences, additional snake traps and increased incidental collection effort in 2005 (Fig. 2). We did not estimate population size due to the small number of recaptures and the variability in sampling effort. Most snake captures occurred in April and May, however, captures increased in October as well, but to a lesser degree (Fig. 3). Radio-tagged snakes were most active (defined as number of above ground observations) from March through June with peaks in August and in November (Fig. 4).

Demography.—We captured 131 male and 56 female Eastern Kingsnakes across all years and capture methods (Table 1). The sex ratio for all captures was male biased (χ^2 = 30.1, P < 0.01). In addition, captures were biased toward adult snakes when data were pooled across all years and capture methods (116 adults versus 74 juveniles: χ^2 = 9.3, P < 0.01). We observed a male bias associated with snakes captured using snake traps (n = 74, χ^2 = 10.6, P < 0.01) and incidental hand collection (n = 90, χ^2 = 17.8, P < 0.01). Individuals captured in snake traps displayed an even age distribution (n = 84, χ^2 = 0.4, P = 0.5), whereas incidental captures were adult biased (n = 92, χ^2 = 25.0, P < 0.01). There was a male bias for adult snakes captured in snake traps (n = 38, χ^2 = 10.5, P < 0.01) and incidentally (n = 61, χ^2 = 13.8, P < 0.01). However, an equal sex ratio was observed for juveniles captured using both methods (snake traps: n = 35, χ^2 = 1.4, P = 0.2; incidental: n = 18, χ^2 = 2.0, P = 0.2). Body condition indices (BCI) of adult snakes did not differ among years (Table 2; n = 97, R^2 = 0.02, P = 0.2).

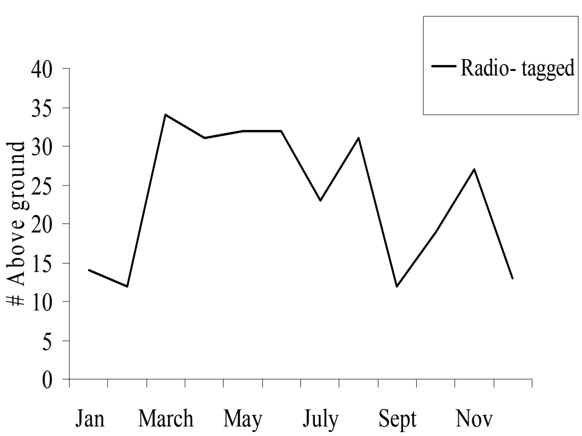

FIGURE 4. Number of above ground observations of radio-tagged Eastern Kingsnakes (*Lampropeltis getula getula*) at Ichauway, Baker County, Georgia, USA from 2005–2008.

TABLE 2. Average body condition index (BCI) for Eastern Kingsnakes (*Lampropeltis getula getula*) by year at Ichauway, Baker County, Georgia from 2003–2008. Juveniles (SVL < 900) and recaptures were not included. Body condition index did not differ among years (n = 97, R^2 = 0.02, P = 0.20).

Year	*n*	Average BCI	SD
2003	7	0.042	0.002
2004	9	0.045	0.002
2005	13	0.042	0.001
2006	17	0.040	0.001
2007	49	0.041	0.001
2008	22	0.039	0.002

TABLE 3. Location and home range data for 12 telemetered Eastern Kingsnakes (*Lampropeltis getula getula*) at Ichauway, Baker County, Georgia, 2005–2008.

Snake ID	Days Tracked	No. Unique locations	No. Return Locations	No. Return Locations ≥ 6 months	Sex	SVL (mm)	MCP	LoCoH	
							100% (ha)	100% Isopleth (ha)	50% Isopleth (ha)
1	369	52	4	1	M	860	18.9	18.9	9.3
2A3F	261	30	2	-	M	954	31.2	28.7	15.8
4B1E	1,043	154	19	5	M	910	132.2	96.9	7.2
258	348	50	6	1	M	1,341	80.6	76.0	9.0
586E	235	32	1	-	M	1,152	26.5	21.1	1.1
655A	243	27	1	-	M	938	13.0	11.6	1.6
701E	624	79	6	-	M	873	56.5	49.5	8.4
1113	554	83	6	-	M	1,144	30.9	30.1	7.7
5209	221	23	-	-	M	963	39.6	34.9	9.3
5803	324	45	5	-	M	1,096	66.2	53.7	16.0
2225	788	111	8	3	F	1,054	33.4	26.1	12.8
4937	357	62	5	-	F	921	65.5	46.0	6.4
Male Mean (*SE*)	422.2 (81.3)	-	-	-	-	1,022.9 (48.9)	49.5 (11.4)	42.1 (8.6)	8.5 (1.5)
Female Mean (*SE*)	572.5 (215.5)	-	-	-	-	987 (66.5)	49.4 (16.1)	36.1 (10.0)	9.6 (3.2)
Total Mean (*SE*)	447.2 (74.1)	-	-	-	-	1,013.6 (41.4)	49.5 (9.6)	41.1 (7.2)	8.7 (1.3)

***Spatial ecology*.**—We radio tracked 12 Eastern Kingsnakes from 221–1,043 days (mean = 447; range = 23–154 unique locations; Table 3). Eleven of the 12 snakes returned to previous locations at least once (mean = 5.7, range = 1–19) including four individuals that returned to a previous location (n =10) more than six months after initial location (Table 3). The number of days tracked was significantly correlated with the number of return locations (Fig. 5, n = 12, R^2 = 0.85, P < 0.01). We observed radio-tracked individuals mostly underground (67.3%, n = 648; Fig 6). Mean 100% MCP home range for male snakes (n = 10), female snakes (n = 2), and all individuals (n = 12) were similar (Table 3). Mean LoCoH estimates calculated using 100% isopleths (all locations) yielded smaller home range estimates than 100% MCPs due to the exclusion of unused areas and outlying points (Table 3). Mean LoCoH high density core areas (50% isopleths) were similar for all three groups (Table 3).

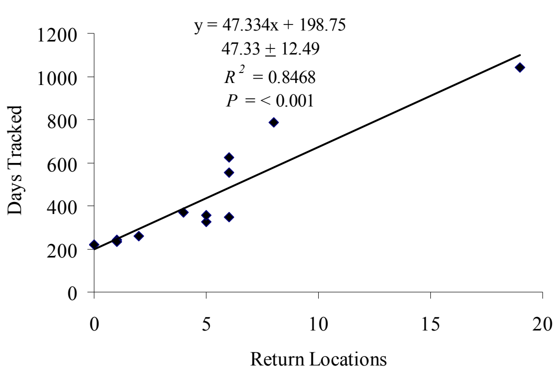

FIGURE 5. Relationship between the number of days tracked and the number of locations to which an animal returned for 12 radio-telemetered Eastern Kingsnakes (*Lampropeltis getula getula*) at Ichauway, Baker County, Georgia, USA from 2005–2008.

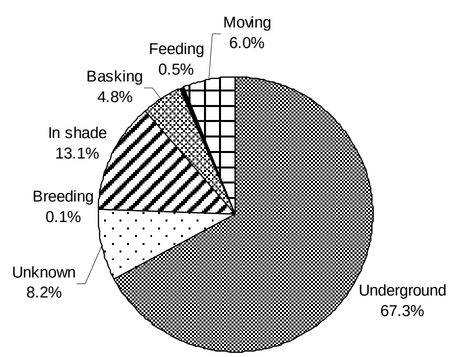

FIGURE 6. Behavioral activities for radio-telemetered Eastern Kingsnakes (*Lampropeltis getula getula*) at Ichauway, Baker County, Georgia, USA from 2005–2008

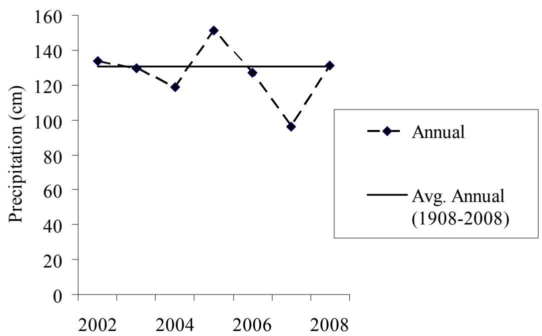

FIGURE 7. Annual 2002–2008 and average annual precipitation (1908–2008) for Ichauway, Baker County, Georgia, USA. Drought conditions were observed during April–June 2004 and throughout the entire 2007 calendar year (National Drought Mitigation Center, http://www.drought.unl.edu/dm/ archive.html).

DISCUSSION

In this study, we captured the greatest number of Eastern Kingsnakes in snake trap arrays or incidentally along roads and in the field. Although we did not standardize effort in this study, it appeared that these methods were biased toward males, possibly due to increased movements during reproductive periods. Eastern Kingsnakes captured in snake traps included a fairly even distribution of juveniles and adults, which may reflect the true population structure, whereas incidental captures were adult biased, potentially due to lower detection of small snakes. In addition, we more often captured adult male Eastern Kingsnakes in snake traps and incidentally than females, whereas juveniles captured using both methods had an even sex distribution. This may reflect similar movement and activity patterns for male and female juveniles. Pitfall traps with drift fence arrays contributed to only 7% of total captures and were heavily biased toward juveniles (93%), because large snakes can readily escape from pitfall traps. Additionally, recaptured individuals may learn to avoid the drift fence entirely.

Previous literature has documented biannual peaks of kingsnake activity in the spring and fall (Jenkins et al. 2001; Krysko 2002; Ernst and Ernst 2003). Our findings were consistent with these studies, in that snakes were captured mostly in the spring and again, to a lesser degree, in the fall. Peak captures of snakes may reflect emergence of snakes from hibernacula or movements related to searching for mates in the spring and movements to hibernacula in the fall. Radio-tagged snakes were above ground throughout much of the year. Using radio telemetry, we were able to observe snakes basking outside refugia in winter months, when they were not necessarily actively moving throughout the landscape and susceptible to capture in traps or incidental collection.

Eleven of the 12 radio-telemetered kingsnakes in this study returned to previous locations at least once suggesting that Eastern Kingsnakes may exhibit site fidelity. However, the extent to which they show long term fidelity to particular sites within a home range is not known. Eastern Kingsnakes at Ichauway used larger home ranges than reported elsewhere. Mean home range size for all telemetered snakes was 96% larger than Black Kingsnakes (*L. g. nigra*) in Tennessee (Jenkins et al. 2001) and 37% larger than reported for Eastern Kingsnakes in New Jersey (Wund et al. 2007). The large home range sizes for Eastern Kingsnakes at Ichauway may be explained by the length of time snakes were tracked. We tracked kingsnakes on average 447 days compared to on average 85 and 94 days, respectively, in the two aforementioned studies. Additional, long term data are needed to examine home range size, movement patterns, and site fidelity for this species across its range.

We believe that the large number of Eastern Kingsnakes captured in our study (179), coupled with a low recapture rate (10%), indicate a locally abundant population on Ichauway. Furthermore, BCI did not vary across years, suggesting that the population at Ichauway may have been fairly stable through the duration of this study. Winne et al. (2007) documented a decline in body condition in a decreasing population of Eastern Kingsnakes around a large isolated wetland in South Carolina.

Ichauway has approximately 4,000 ha of fire-maintained Longleaf Pine/Wiregrass savanna. This relatively undisturbed, contiguous habitat coupled with low incidental road mortality (11%), and abundance of available refugia (small mammal burrows and stumpholes) may explain the persistence of an apparently stable Eastern Kingsnake population. We found no evidence that regional droughts (Fig. 7) or the Red Imported Fire Ant, the dominant ant species (Stuble et al. 2009), had negative effects on Eastern Kingsnakes at Ichauway. Furthermore, Ichauway is located in a largely agricultural landscape and has potential for exposure to agrochemicals. Again, we found no evidence to suggest that this landscape/land use had negative impacts on kingsnakes. Long term data on other Eastern Kingsnake populations are needed to determine the status of the species in the southeastern U.S. It is important to understand the ecology of this species in different habitats, including those that could be considered as reference sites, to shed light on potential risks in altered or disturbed habitats. Additional studies examining other populations, especially those that are located in marginal habitats, can be used in comparison to the Ichauway population and may aid in understanding potential threats and in identifying conservation opportunities.

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