SOUTH FLORIDA RESEARCH CENTER

Report SFRC-83/01
Status of the Eastern Indigo Snake in Southern Florida National Parks and Vicinity

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INTRODUCTION

The status and biology of the eastern indigo snake, Drymarchon corais couperi, the largest North American snake (Lawler, 1977), is poorly understood. Destruction of habitat and exploitation by the pet trade have reduced its population levels in various localities to the point that it is listed by the Federal government as a threatened species. Conant (1975) reported its range as southeast Georgia, peninsular Florida, and the lower keys, with disjunct populations in west Florida, and southern Alabama. No specimens have been recorded in Alabama since 1954 (Neill, 1954), and it may now be extinct in that state (Mount, 1975). In southern Florida, the indigo snake has been reported to occur in several habitats, including dry Everglades marsh, tropical hammocks, and muckland fields (Carr, 1940).

The purpose of the present study was to determine the occurrence, distribution, and status of the eastern indigo snake in three National Park Service areas in southern Florida: Everglades National Park, Big Cypress National Preserve, and Biscayne National Park. We did this primarily by analyzing records of sightings in these areas. We also determined the distribution of the indigo snake in the Florida Keys. We include biological information on habitat use, seasonal variation in sightings, food habits, size, parasites, and sex ratio for snakes observed and examined in and adjacent to Everglades National Park.

STUDY AREA

Within Everglades National Park, the indigo snake occurs in seven habitats: pine forests, tropical hardwood hammocks, freshwater marshes, coastal prairies, mangrove forests, abandoned farmland, and developed sites.

The pinelands of Everglades National Park are remnants of the pine forest that once covered most of the oolitic limestone ridge that stretches along the coast of southeastern Florida. Within the park, pine forests cover 8,000 ha, including the hammocks and prairies within the pine forests. The pine forests are composed of open stands of slash pine (Pinus elliottii) with a diverse understory of hardwood shrubs and low palms. The persistence of this habitat type is fire-dependent, and the variable density of the understory is a reflection of its recent fire history (Robertson, 1953). The understory is made up of saw palmetto (Serenoa repens) and a variety of mainly tropical species, including rough velvetseed (Guettarda scabra) and poisonwood (Metopium toxiferum). In the absence of fire, pine forests succeed to tropical hardwood forests with a senescent overstory of pine and no regeneration within a period of fifteen to twenty-five years (Robertson, 1953).

"Hammock" is the name given locally to tropical hardwood forests. Hammocks occur in patches in the pinelands, in tree islands in the marshes, and on artificially elevated sites, such as canal banks and Indian middens. Several thousand of these small tree islands exist, but the total area of hammocks is less than 260 square km for the three southernmost counties of Florida (Birnhak and Crowder, 1974). The forest canopy is made up of many tropical hardwood species, including strangler fig (Ficus aurea), poisonwood, and gumbo limbo (Bursera simaruba). Understory shrubs and trees, consisting of approximately 40 hardwood species, include tetrazygia

(Tetrazygia bicolor) and wild coffee (Psychotria nervosa). The humid hammock environment also supports epiphytic orchids, bromeliads, and ferns including clamshell orchid (Encyclia cochleata), wild pine (Tillandsia fasciculata), and resurrection fern (Polypodium polypodioides) (Olmsted et al., 1980a).

Everglades freshwater marsh or "glades" represents the most widespread habitat within Everglades National Park, occupying more area than all other vegetation types combined (Robertson, 1955). This habitat is seasonally inundated for varying lengths of time and depths. The most common plant is sawgrass (Cladium jamaicense), but many other grasses and sedges such as Muhlenbergia filipes, Rhynchospora sp., and Eleocharis cellulosa are present in mixed and pure stands. The composition of the vegetation communities reflects slight differences in elevation and substrate. Ponds occur in depressions throughout the glades. Plants around these "gator holes" include willow (Salix caroliniana), alligator flag (Thalia geniculata), and maidencane (Phragmites australis) (Olmsted et al., 1980b).

Coastal prairie habitat occurs near Flamingo and Cape Sable, between mangrove and tropical hardwood hammock vegetation zones (Olmsted et al., 1981). Typical plants include salt-tolerant grasses and herbs such as Spartina sp., Sesuvium portulacastrum, and Salicornia sp. (Robertson, 1955).

The mangrove forest habitat extends along the coast inward to the freshwater marshes. This habitat, which covers approximately 140,000 ha in southern Florida (Olmsted et al., 1981) and 93,000 ha inside Everglades National Park (Klukas, 1973), is dominated by four species: red mangrove (Rhizophora mangle); black mangrove (Avicennia germinans); white mangrove (Laguncularia racemosa); and buttonwood (Conocarpus erectus) (Olmsted et al., 1981). Mangrove forests usually occur along mudflats, bays, and tidal creeks as a dense thicket ranging in height from a few up to 25 m.

Approximately 4,000 ha of abandoned farmland, in various stages of succession, exist inside Everglades National Park (Loope and Dunevitz, 1981), mostly adjacent to Long Pine Key. Pine forests and marshes originally covered this area, but the present vegetation varies from forbs and grasses to trees, reflecting different stages of succession. Grass-forb stages are five- to seven-years old, and the oldest tree stages are close to 35-years old. In approximately 2,000 ha of former marsh and pine forest, the substrate was altered by rock plowing and was subsequently invaded by exotic plant species, such as Brazilian pepper (Schinus terebinthifolius) (Loope and Dunevitz, 1981).

Developed sites in Everglades National Park occur at the main park visitor center, Flamingo, and Pine Island. Each of these sites are a few hectares in size and consist of buildings, paved parking areas, and manicured lawns. These areas are heavily frequented by humans.

Big Cypress National Preserve contains pine forests, tropical hardwood hammocks, and coastal and freshwater marshes similar to those found in Everglades National Park. In addition, the Big Cypress swamp includes cypress forest (43.6%), dominated by bald cypress (Taxodium distichum), and mixed swamp forest (6.4%) dominated by red maple (Acer rubrum), dahoon holly (Ilex cassine), myrsine (Myrsine floridana), willow, and swamp bay (Persea palustris) (Duever et al., 1979).

The dominant habitats of Biscayne National Park are tropical hardwood hammocks and mangrove forests. Stands of buttonwood are often situated between these habitats (Craighead, 1963; USDI, 1978).

The vegetation of the Florida Keys consists of a mangrove fringe similar to that found in Everglades National Park. The interior vegetation of the upper keys (Soldier Key to the south end of Big Pine Key) consists primarily of tropical hardwood hammocks. These differ from those in Everglades by being generally lower and scrubbier, a condition which occurs clinally from east to west (from Soldier Key to Key West) (Geroge Avery, pers. comm.), as does decreasing amounts of rainfall (Robertson, 1955). There is evidence that pineland once occurred on north Key Largo (Alexander, 1953). On the lower keys, vegetation consists of pine forests and low, scrubby, tropical hardwood hammocks. Pinelands occur primarily on Little Pine, Big Pine, No Name, Cudjoe, and Sugarloaf Keys with smaller areas of pine forest on neighboring keys (Robertson, 1955). The understory of the pine forest on the keys differs from that of Everglades by having a continuous tall canopy of thatch palm (Thrinax morrisii), and silver palm (Coccothrinax argentata). Both pinelands and hammocks are more xeric in the keys than on the mainland (Robertson, 1955). Solution holes are present in both the upper and lower keys. Considerable amounts of natural vegetation have been lost in the Florida Keys due to development (Robertson, 1955), and this trend continues at present.

Our greatest trapping effort was on Long Pine Key, in Palma Vista I hammock in Everglades National Park (Fig. 1). This 20.9 ha hammock remained above water throughout the year and contained both mature and successional components. The mature forest had a closed canopy of hardwoods, including live oak (Quercus virginiana), poisonwood, and wild tamarind (Lysiloma latisiliqua). Approximately one-third of the hammock was a successional component characterized by an overstory of pine and an understory similar to the closed canopy of the mature stage. Its substrate was oolitic limestone covered by a litter layer 10- to 60-cm deep. There were numerous solution holes within the forest. Other habitats surrounding the main trapping site included pine forests and successional stages of former farm fields. The second trap site was near Flamingo at Bear Lake trail, an elevated canal bank covered by tropical hardwood trees. The bank passed near an Indian midden covered by tropical hardwood hammock. The bank and hammock were surrounded by mangrove forest and coastal prairie. The third trap site was on Long Pine Key along a fire road bordering pineland and a monotypic stand of wax myrtle (Myrica cerifera).

METHODS

Information on indigo snakes in southern Florida national parks was obtained from observations of snakes in the parks (Appendix 1), animals captured during this study (Appendix 2), previous reports in the literature, and from museum specimens (Appendix 3). Information on museum specimens from southern Florida was obtained from the Florida State Museum (UF), Museum of Comparative Zoology (MCZ), University of Miami Reference Collection (UMRC), Carnegie Museum of Natural History (CMNH), Los Angeles County Museum (LACM), Peabody Museum of Natural History (PMNH), Louisiana State University (LSU), University of Michigan Museum of Zoology (UMMZ), Illinois Museum of Natural History (IMNH),

U.S. National Museum (USNM), Savannah Science Museum (SSM), and University of South Florida (USF). In addition, biologists familiar with the Florida Keys were contacted for information on indigo snake sightings in this area. We also had access to records of indigo snake sightings made by Everglades National Park personnel and visitors since 1949. From 1977 to 1981, a special effort was made to encourage documentation of observations. Park personnel were responsible for 95% of all of these indigo snake sightings which constitute most of the observations used in this paper. Research personnel filed 62% of the observations since 1977. The records are biased somewhat by their concentration in areas where park personnel are most active. However, we made specific efforts to search for snakes in all suitable habitats.

At the first trap site in Palma Vista I hammock, we attempted to capture snakes using drift fences at two locations. These were constructed of two walls of aluminium screening or clear plastic at least 1-m high and placed at 90^{o} in a cross configuration. Each axis measured 30.5-m long. The fences were fitted with 23-cm flaps of screening along both sides of the bottom to accommodate having little or no soil in which to bury the trap bottom. These flaps were contoured to the bedrock or buried in the litter to prevent snakes from burrowing under the fence. Twelve 183-cm funnel traps similar to those used by Fitch (1951) were located along the fence. The first trap, at trap site one, was set up on February 5, 1980, continued in operation through August 29, 1980, and was checked on 117 days. The second trap, at trap site one, ran from May 22, 1980 through August 29, 1980, and was checked on 62 days. At the second trap site, near Flamingo, we set a fence (16-m long) in the mangrove area for 7 days in May 1980. Later, at the third trap site on a fire road in pine forest, we moved the trap from site two and checked it on 19 days during May 1980.

Traps were usually checked once a day while in operation. We marked all captured snakes by clipping ventral scales (Brown and Parker, 1976). We weighed and determined the sex of each snake and measured its snout-vent and tail length. We palpated each snake to remove stomach contents and to determine whether females were gravid. They were then released on the opposite side of the fence from where they were captured. Any snakes encountered within the study area, or on the bordering roads, were also marked and their locations recorded. Rainfall and temperature data were taken from the N.O.A.A. weather station at Royal Palm Ranger Station inside Everglades National Park (Rose et al., 1981).

Observations of indigo snakes at the trap site showed that smaller individuals traveled along the bottom of the fence and freely entered the traps. Larger snakes traveled along the fence from ground level to a height of 50 cm, sliding up and down along the fence in a roller coaster fashion. Depending on where in the cycle they would encounter a trap, they would either enter or move over it. Enlarging the diameter of the anterior end of the funnel would probably have improved trapping success.

RESULTS

The records we have assembled delineate the overall distribution of the indigo snake in southern Florida (Fig. 1, 2). It ranges from Miami along the Atlantic

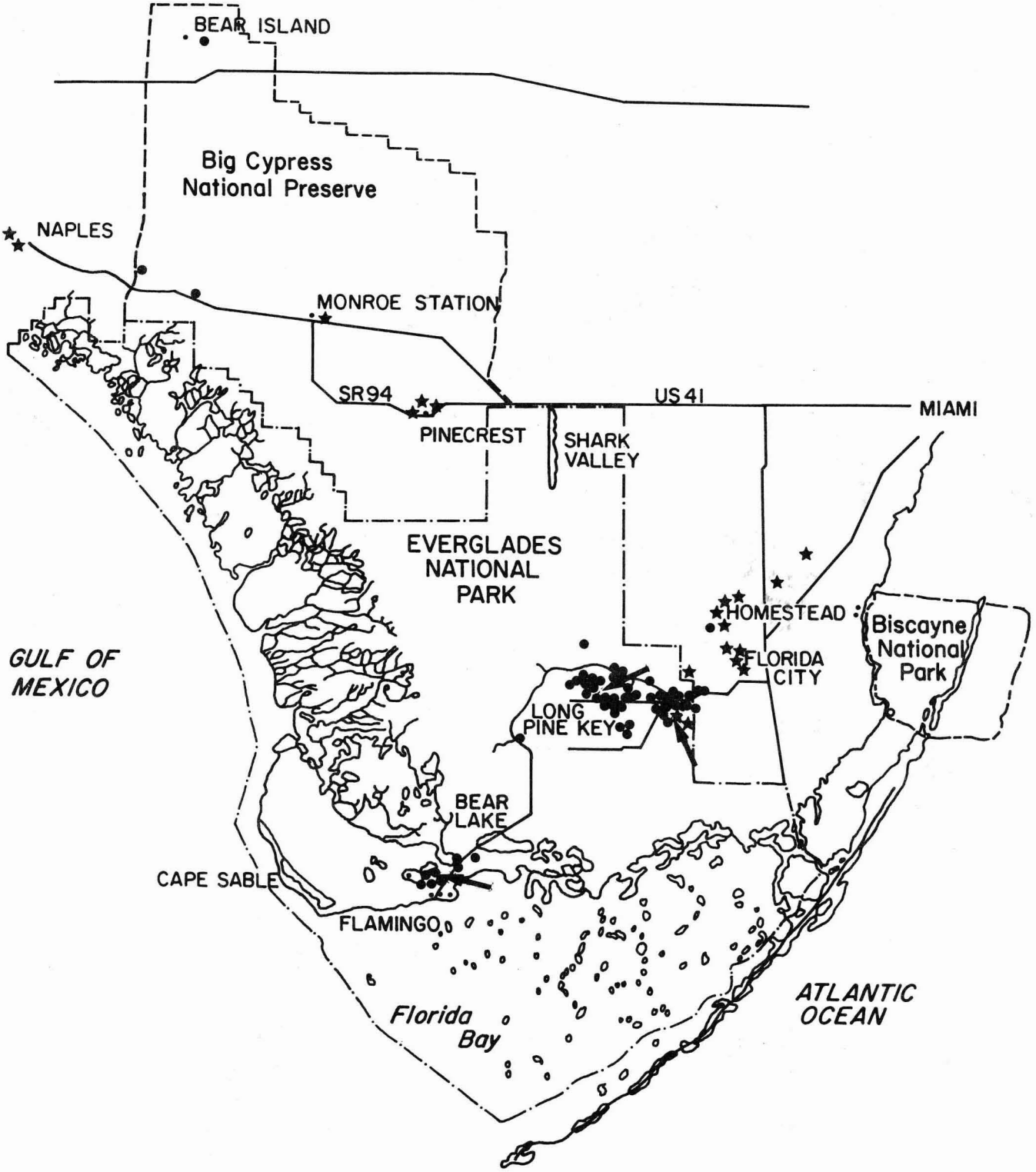

Figure 1. Distribution of the indigo snake in southern Florida. Dots represent observations, stars represent museum specimens, and arrows show location of trap sites.

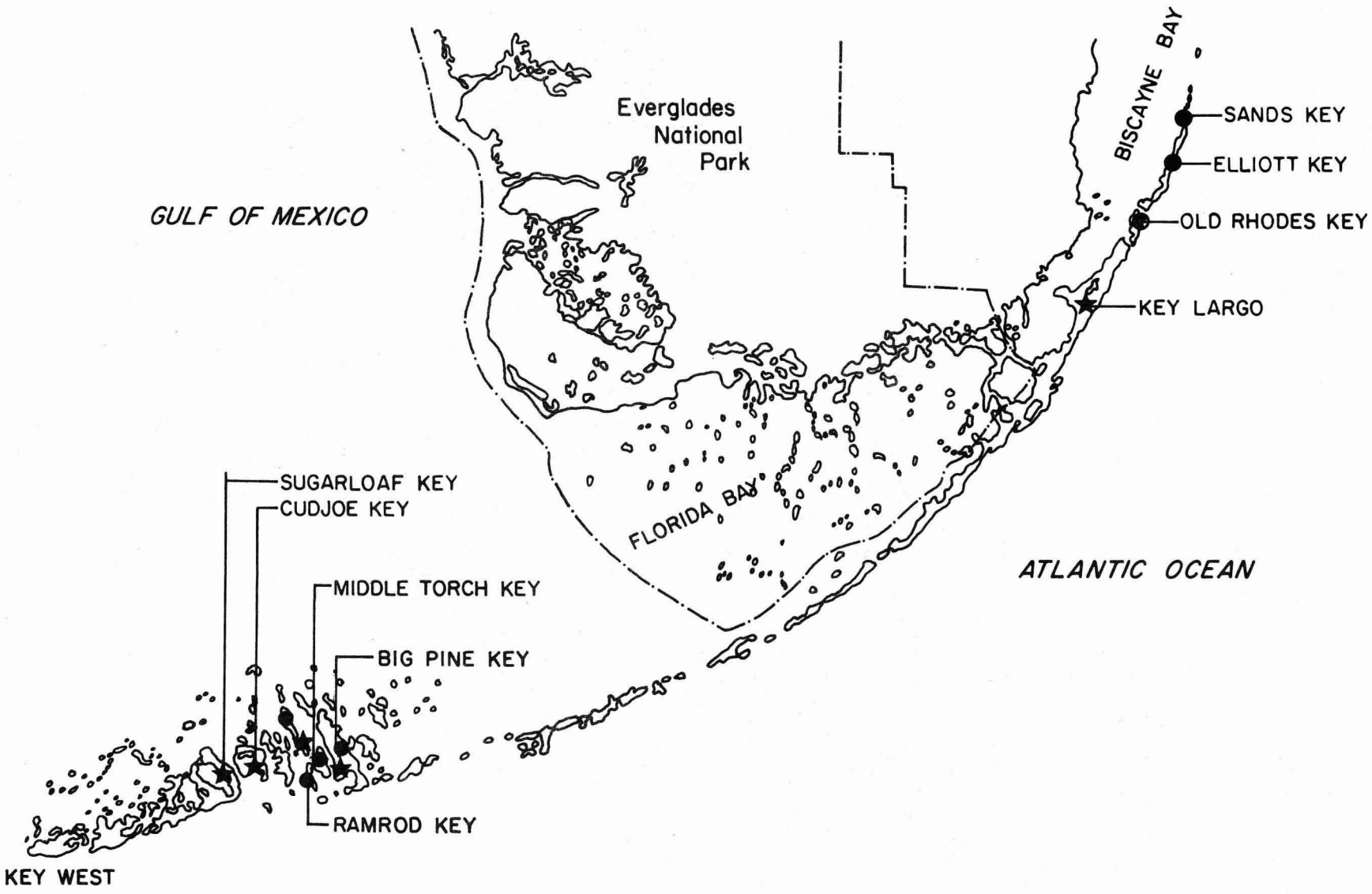

Figure 2. Distribution of the indigo snake in the Florida Keys including Biscayne National Park. Dots represent observations and stars represent museum specimens.

Coastal Ridge east to the coast, south through Florida City to Flamingo. Additional records exist west of Miami to Naples, including the Big Cypress Swamp. The indigo snake also occurs on the keys of Biscayne Bay and the upper and lower Florida Keys.

In Everglades National Park, 98 observation records of indigo snakes were primarily from Long Pine Key, Flamingo, and along the Shark Valley roadway. Indigo snakes have been recorded from seven habitats inside Everglades National Park. Thirty percent of our indigo sightings have occurred in pineland, which is one of the habitats least subject to flooding. Five of these observation records (17%) were of indigo snakes using solution holes in pine forests.

Sightings of indigo snakes in hammocks comprised 20% of our observation records. Two of these observation records (10%) were of animals using solution holes. Six sightings associated with the trapping site at Palma Vista I hammock represented at least three individuals that were captured and marked (Appendix 2). Six sightings along the Bear Lake Trail were in the Indian midden hammock and along the canal bank. We also know of three additional sightings along Bear Lake Trail.

Twenty percent of our observation records were associated with marsh habitat. However, only one of these was definitely in "open glades." Two others were in isolated plant communities within the marsh, a custard apple (Annona glabra) patch, and a Paurotis palm (Acoellorrhaphe wrightii) thicket. All other observations were sightings of animals on or along roadsides adjacent to marsh habitat. It is impossible to ascertain from the reports whether these animals were associated with the marsh or, as is more likely, the nearby hammocks. Indigo snakes have been seen along Shark Valley Road, which traverses through freshwater marsh; however, two of the records (Fig. 1) probably resulted from six snakes released there in the 1950's (Erwin Winte, pers. comm.). In recent years, only two sightings have been recorded along the Loop Road through Shark Valley, despite the large number of visitors and park personnel in that area.

Four percent of indigo snake observations occurred in coastal prairie. One-half of these observations reported snakes exiting or entering from another habitat.

Indigo snakes in mangrove swamp habitat accounted for 6% of the observations. Three of these sightings were made on the high berms along canal banks rather than within the flooded mangroves. Two sightings place the indigo snake in the interior of mangrove forest, indicating that it does use this habitat. Both of these sightings occurred within wading bird colonies.

Fourteen percent of the observations of indigo snakes have occurred in former farmland, the Hole-in-the-Donut in Everglades National Park. Five percent of these reported indigo snakes exiting or entering abandoned farmlands from adjacent pine forests and hammocks. Previous accounts have detailed the occurrence of indigo snakes in agricultural fields in southern Florida (Carr, 1940) and in Georgia (Speake et al., 1979). The available data from southern Florida demonstrate that the indigo snake uses abandoned farmland, but the number of records are relatively few for the amount of time park personnel have spent in the area.

Five percent of observations were in developed sites. Developed areas represent a relatively small area within Everglades National Park, but because these sites are highly frequented by park personnel and visitors, the chances of a snake being observed are high.

It is probable that the relatively large home range of any individual indigo snake includes more than one habitat (Speake et al., 1979). In fact, 11% of our observations document indigo snakes moving from one habitat to another.

Records of indigo snakes in Big Cypress National Preserve included three museum specimens from Pinecrest, one from Monroe Station, and observations in the Bear Island area, and on Turner River Road.

Thirteen observations of indigo snakes have been recorded within Biscayne National Park: seven at Elliott Key; three at Sands Key, including one animal swimming from Elliott to Sands Key; one at Old Rhodes Key; and three at Convoy Point. Twenty-nine percent of the observations were in hammocks, 14% in the mangroves, and 14% in developed areas. Sufficient information was not available to determine the habitats associated with nearly half of the observations.

In the Florida Keys, our records show the distribution of the indigo snake only on Key Largo and Biscayne National Park keys in the upper keys with a disjunct population in the lower keys on Big Pine, Big Torch, Middle Torch, Little Torch, Ramrod, Cudjoe, and Sugarloaf Keys. Sightings inside National Key Deer Wildlife Refuge on Big Pine Key by refuge personnel are infrequent with only six sightings between 1978 and 1981 (Steven Klett, pers. comm.)

Indigo snakes appear to be completely diurnal. We have only one observation of a snake active at night (Thornton, 1977). The results of a t-test show significant seasonal variation in occurrence of sightings ($p < .05$) in Everglades, with 63% of our sightings occurring during the dry season, November through April. At this time, only 19% of the annual rainfall occurs and average temperatures are $6^{o}C$ cooler than temperatures in the wet season (May through October).

The number of sightings each month was negatively correlated with the average monthly temperatures ($r = -0.76$, $p < .01$) and mean monthly rainfall ($r = -0.72$, $p < .01$). Activity patterns of many of the Everglades animals are attuned to the wet and dry seasons, which influence seasonal activities including feeding, reproduction, and movement (Smith and Vrieze, 1979; Ogden et al., 1978; Kushlan, 1976; Kushlan and Kushlan, 1980). Sufficient data are not presently available to determine whether this is also true of the indigo snake.

As a result of our trapping effort, one indigo snake and 26 other snakes were captured for a total of 33 times. Twenty-three Everglades racers (Coluber constrictor paludicola) were captured 28 times, two eastern garter snakes (Thamnophis sirtalis sirtalis), one eastern diamondback rattlesnake (Crotalus adamanteus), and one Everglades rat snake (Elaphe obsoleta rossalleni), were each captured once.

During this study, eight indigo snakes were captured, marked, and released. In addition, eight previously preserved or road-killed specimens were examined. Data for each specimen are listed in Appendix 2. Sex was positively determined for 16 snakes, 62.5% of which were males and 37.5% females. This does not differ significantly from an expected 50:50 ratio ($x^2 = 1.47$, d.f. = 1, $p > .10$). Duellman and Schwartz (1958) examined 11 indigo snakes from southern Florida in which they found 8 males and 3 females. This sample also does not differ from a 50:50 ratio ($x^2 = 2.26$, d.f. = 1, $p > .10$). In each of these comparisons, any lack of difference may be an artifact of small sample size.

Information on the food habits of the eastern indigo snake are not well documented, although in captivity the animal is known to be a voracious feeder on a wide variety of prey including birds, reptiles, mammals, and amphibians. No food items were found by palpation of the indigo snakes captured in this study. Three preserved specimens, inspected for stomach contents, had eaten a cotton rat (Sigmodon hispdius), a southern toad (Bufo terrestris), and a rough green snake (Opheodrys aestivus). In the wild, we have one observation of an indigo snake eating a brown water snake (Nerodia taxispilota), another eating a corn snake (Elaphe guttata guttata), and one observation of an indigo snake eating a ringed snake believed to be a coral snake (Micrurus fulvius fulvivus). Babis (1949) reported that the stomach contents of an indigo snake collected in Everglades National Park contained two pygmy rattlesnakes (Sistrurus miliarius barbouri) and four turtle eggs, and Dilley (1954) reported an indigo snake in Everglades National Park eating a mangrove salt marsh snake (Nerodia fasciata compressicauda). An indigo snake was also observed eating a road-killed corn snake in Homestead (Roger Hammer, pers. comm.).

Twelve snakes of known sex were measured and had a mean total length of 158.0 cm (s.d. = 55.18) (Appendix 2). Mean total length of six males was 191.9 cm (s.d. = 33.48) ranging from 151.9 cm to 251.6 cm. Six females were measured: three, less than 100 cm in length, were relatively recent hatchlings based on data presented by Moulis (1976). The mean total length of those greater than 100 cm was 169.8 cm (s.d. = 19.86). The largest female was 185.5 cm, the smallest 65.2 cm. We have measurements of seven large specimens of unknown sex. Their total lengths were 236.2 cm, 193.0 cm, 206.0 cm, 148.4 cm, 212.4 cm, 194.3 cm, and 121.8 cm ($\bar{x}$ = 187.4 cm, s.d. = 39.28). Schmidt and Davis (1941) report that the average size of adults of this subspecies was about five feet (150 cm). Carr (1940) mentioned that indigo snakes attained a tremendous size in the hammocks between Cape Sable and Paradise Key, and Conant (1975) reported the record size to be 262.9 cm. Our data confirmed the large size of the southern Florida population of indigo snakes.

All live snakes examined appeared in good physical condition. Gamisid mites of the family Trombiculidae were noted on indigo snakes #3, #6 and #8 (Appendix 2), and ticks of the genus Amblyoma were found on indigo snakes #4 and #5. The ticks were identified by Michael Bodri, University of Maryland. The pentastomid Kirecephalus coarctatus, a parasitic arthropod was found in the gut of one preserved specimen. This parasite was identified by Richard Franz, Florida State Museum.

None of the captured animals were found to be gravid by palpation. One preserved indigo snake that we dissected contained 10 fully shelled eggs. This number is within the range of clutch sizes, 4 to 12 eggs, reported in the literature (Groves, 1960; Moulis, 1976). The date of capture was not recorded for the preserved specimen.

DISCUSSION

Within Everglades National Park and nearby areas, indigo snakes are widely distributed. They occur in seven habitats. From the available data, we can make no estimate of the population size or density. Indigo snakes were found most frequently in the pine forest and hammocks of the Long Pine Key area. We believe that the population density is highest here, and that it constitutes the snake's primary area in the park. The fact that three individuals were captured in close proximity to each other in the main study area, and then were not seen again suggests that the animals use overlapping home ranges of large size. We believe that hardwood hammocks throughout the park provide an important habitat for indigo snakes, based upon the relatively large number of observations compared with the small total area occupied by hammocks.

Over most of its range, the eastern indigo snake inhabits xeric sandhills of the coastal plain. Its association with the gopher tortoise (Gopherus polyphemus) is well known (Kochman, 1978; Lawler, 1977). Laboratory experiments have demonstrated that the indigo snake is highly susceptible to dessication (Bogert and Cowles, 1947) so that the presence of humid retreats such as gopher tortoise burrows may be considered to be a critical factor for survival of the indigo snake in xeric areas. In the pine forests and hammocks of the Everglades, solution holes seem to replace the tortoise burrow in supplying a moist and cool microhabitat. Six percent of observations mention indigo snakes using solution holes.

Considering both the large area of freshwater marsh and the high frequency of park personnel in these areas, we do not consider Everglades marsh to be a primary habitat for the indigo snake. However, indigo snakes do occur there, and it is clear that this is not a species restricted to upland habitats. Other marginal habitats include coastal prairie which is probably too hot and dry for indigo snakes, except in the Cape Sable area, where gopher tortoise burrows occur. Mangrove forest is also considered to be a marginal habitat and population levels appear to be low in these areas. Indigo snakes utilize abandoned farmland within Everglades National Park, but this appears to represent only a portion of the home range of these animals, which primarily use adjacent pine forests and hammocks. Despite much human activity in developed sites, the small number of observations in these areas is indicative of the limited use of this habitat by indigo snakes.

Very few observations of indigo snakes exist in Big Cypress National Preserve. Although indigo snakes are probably less common in the preserve than in Everglades National Park, the paucity of observation reports probably results more from a lack of reporting rather than reflecting a true measure of their abundance. Thornton (1977) noted that the Old Loop Road (S.R. 94) was once one of the best places in the state for indigo snakes, but they are rarely seen there at present. Fred Dayhoff (pers. comm.), a long-time resident and former park ranger, reported

that collecting of indigo snakes along the Loop Road was common in the 1950's, and that he has seen no specimens there in recent years. He believes that the only area where snakes are relatively common in the Big Cypress is near Bear Island. Protection of wildlife in the preserve has only begun in the last few years, and we believe that indigo snake populations should increase with continued protection.

Indigo snakes have been found on three keys in Biscayne National Park and, with further observations, will probably also be located on Totten Key and possibly on some of the smaller keys in the park. This population can be considered secure, facing no serious threats at present.

The distribution of the indigo snake in the Florida Keys consists of a population in the northern upper keys and a disjunct population in the lower keys. The distribution may reflect remaining suitable habitat. On the upper keys, indigo snake records occur on those keys where mature tropical hardwood hammock remains. In the lower keys, the indigo snake primarily occurs on Big Pine and surrounding keys, and the distribution is similar to that of pine forests in this area. Continuing development in the Florida Keys poses a threat to the indigo snake population there.

Approximately 4% of indigo snake observations involve snakes swimming in both fresh and salt water. This behavior may be a means of dispersal between islands in the Florida Keys.

Little information has been published on the seasonal activity and movement of indigo snakes. Speake et al. (1979) found that activity levels in Georgia were highest between August through November when average range totaled 97.4 ha. Within this period, activity was highest in August. From May through July, indigo snakes were found to have an average range of approximately one-half that of fall, and their home range for December through April was smallest, averaging 4.8 ha. They found that indigo snakes were active during the winter, during periods when air temperature increased to 11°C. Based on these results, one would expect activity levels in southern Florida to be low in December-April when the average monthly temperature was approximately 14°C, and for activity to increase during May through July corresponding to an increase in temperatures.

Our only measure of seasonal activity in Everglades National Park is frequency of sightings. Frequency of sightings by month differ greatly from the results of the Georgia study. The three coldest months in Georgia (December-February) are characterized by the lowest activity levels while in Everglades a high number of sightings have been made during this time. A similar situation is found for the months August through October when activity is high in Georgia and frequency of sightings is low in Everglades. Due to differences in temperature, higher activity levels would be expected during the winter in Everglades than in Georgia when the average temperature is 8°C higher than in Georgia and well above the minimum thermal level for indigo snakes determined by Speake et al. (1979).

Most observations (75%) of indigo snakes in Everglades occur during November through March. These months correspond to the time when indigo snakes mated in a captive colony in Georgia (Speake et al., 1979). If mating takes place during

these months in the Everglades, and this is supported by our only observation of indigos mating in February (Amanda Mueller, pers. comm.), one might expect an increase in activity at that time in order to find mates. There is no pressure for indigo snakes to restrict their ranges during this time, as there is in Georgia where indigo snakes occupy gopher tortoise colonies (Speake et al., 1979).

Several problems exist with use of these data to determine seasonality of activity at Everglades. It is only speculative that an increase in activity will lead to an increase in observations. It is also possible that the increase in observations may be the result of an increase in the activity of observers rather than an increase in the activity of indigo snakes. During the dry season, conditions are more hospitable for outdoor activity because of cooler temperatures, fewer biting insects, and reduced rainfall. Also, more park personnel are on duty during this time. Undoubtedly, these factors lead to more field observation time, and bias the results. The significance of these biases is uncertain.

The major threats to the indigo snake throughout its range are habitat destruction and collection for the pet trade. These do not appear to be serious threats to the population inside Everglades National Park or Biscayne National Park. In Big Cypress National Preserve, where hunting and uncontrolled access by off-road vehicles are allowed, and where indigo snakes were commercially collected in the past, illegal collecting and wanton killing may continue to be the most serious threats. Indigo snakes from southern Florida continue to be exploited (Anon., 1979). There is no evidence that this is occurring inside the park boundaries, but special protection needs to be provided.

In the Florida Keys, indigo snakes are in serious danger of extirpation because of the extensive loss, to development, of pine forests and tropical hardwood hammocks. Protection of remaining habitat is needed to protect the indigo snake in these areas.

Animals killed by traffic represent 8% of indigo snake observation records in Everglades National Park and may be the greatest danger to indigo snakes inside the park. Greater publicity about the status of this threatened species may decrease this hazard.

Another threat is disruption of genetic purity of the local population by the transportation and release of snakes from other areas. The genetic identity of extant indigo snake populations should be protected to the greatest degree possible.

We conclude that the indigo snake is secure within Everglades National Park and Biscayne National Park where it is widely distributed and relatively common in pine and tropical hardwood forests and, to a lesser extent, in coastal habitats and freshwater marshes. Preservation of these habitats is the best assurance of the continued existence of the snake within these park areas. In Big Cypress National Preserve, the indigo snake faces the more immediate threat of collection, but with adequate enforcement of existing regulations and greater public awareness, as well as preservation of habitat, the indigo snake population should stabilize there. In the Florida Keys, only maintenance of remaining natural habitats will protect the indigo snake.

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Appendix 1. Observations of indigo snakes in southern Florida.

Observation Number	Date	Time	Habitat	Comments
1	26 Jan 1949	N/A[1]	Mangrove	Approx total length 150 cm, swimming
2	14 Dec 1949	N/A	Mangrove	Total length 193 cm, dead on road
3	15 Jan 1951	N/A	Freshwater marsh	Total length 194 cm, male, see Table 2, #18
4	12 Feb 1951	N/A	Coastal Prairie	Approx total length 150 cm, male, dead on road, see Table 2, #19
5	24 Nov 1951	1115	Freshwater marsh	Approx total length 200 cm, in Paurotis palm, edge of road
6	13 Jan 1952	N/A	Freshwater marsh	Adult, in custard apple head
7	18 Jan 1952	N/A	Freshwater marsh	2 individuals, on road
8	19 Mar 1952	N/A	Freshwater marsh	Approx total length 180 cm, on road
9	28 Oct 1952	N/A	Freshwater marsh	On road
10	27 Dec 1952	1030	Hammock	2 adults, 1 with ticks, at Bear Lake
11	28 Dec 1953	1230	Freshwater marsh	Total length 236 cm, swimming
12	11 Mar 1954	1530	Pineland	Approx total length 184 cm, eating corn snake in solution hole
13	16 May 1957	1700	Hammock	Approx total length 91 cm, eating snake
14	14 Aug 1958	1500	N/A	Approx total length 200 cm
15	7 Nov 1958	1600	Developed site	Approx total length 200 cm, in maintenance area

Appendix 1. Continued.

Observation Number	Date	Time	Habitat	Comments
16	12 Feb 1959	1625	Pineland	Approx total length 245 cm
17	28 Nov 1961	1530	Developed site	Approx total length 213 cm, weighed 3.5 kg, headquarters building
18	17 Feb 1974	1330	Coastal Prairie	Approx total length 135-150 cm
19	15 Jun 1977	1500	Freshwater marsh	East Everglades, berm of roadside canal
20	20 Jan 1978	1300	Pineland	Entered solution hole
21	12 Feb 1978	1500	Mangrove	Approx total length 150 cm
22	14 Nov 1978	1300	Hammock	At Bear Lake Trail
23	9 Dec 1978	0950	Freshwater marsh	On road
24	14 Dec 1978	1500	Freshwater marsh	Approx total length 180 cm, on road
25	27 Jan 1979	1100	Hammock	Approx total length 135-150 cm
26	Mar 1979	1000	Hammock	Approx total length 150 cm
27	15 Mar 1979	1330	Mangrove	Approx total length 180 cm
28	2 May 1979	1400	Former agricultural land	Approx total length 120 cm
29	3 May 1979	1000	Former agricultural land	Approx total length 135 cm
30	30 Jul 1979	0900	Hammock	Total length 180 cm, several ticks present
31	1 Aug 1979	1000	Hammock	Approx total length 90-120 cm
32	28 Oct 1979	1230	Freshwater marsh	Dead on road
33	1 Nov 1979	1200	Hammock	Approx total length 150 cm, in solution hole
34	24 Nov 1979	0920	Pineland	Approx total length 180 cm

Appendix 1. Continued

Observation Number	Date	Time	Habitat	Comments
35	11 Dec 1979	1600	Hammock	Approx total length 150 cm, dead on road, east of Everglades National Park
36	23 Jan 1980	0915	Pineland	Approx total length 150 cm, entered solution hole
37	Feb 1980	N/A	Hammock	Adult
38	5 Feb 1980	1200	Pineland	
39	7 Mar 1980	1015	Pineland	Approx total length 150 cm
40	17 Mar 1980	1100	Pineland	Total length 71 cm, see Table 2, #1
41	17 Mar 1980	1600	Pineland/Hammock	Total length 175.5 cm, see Table 2, #2
42	Apr 1980	A.M.	Hammock	2 Adults, Bear Lake Trail
43	Apr 1980	N/A	Freshwater marsh	Adult, on road
44	Apr 1980	N/A	Pineland	Adult
45	3 Apr 1980	1515	Mangrove/coastal prairie	Adult
46	15 Apr 1980	1130	Freshwater marsh	In Big Cypress
47	16 Apr 1979	1665	Freshwater marsh	Approx total length 200 cm, on road
48	2 May 1980	1200	Pineland	Approx total length 90 cm, dead on road
49	4 May 1980	1230	Former agricultural land	Approx total length 150 cm
50	8 May 1980	1300	Coastal Prairie/ Developed site	Approx total length 150-180 cm
51	8 May 1980	1000	Pineland/ Developed site	Approx total length 135 cm, in residence area
52	10 May 1980	0950	Pineland	Approx total length 90 cm
53	27 May 1980	1000	Former agricultural land	Approx total length 215 cm

Appendix 1. Continued

Observation Number	Date	Time	Habitat	Comments
54	11 Jun 1980	0800	Farmland/Pineland	Total length 149.1 cm, dead on road from Florida City
55	1 Jul 1980	1500	Hammock	Total length 98.7 cm, see Table 2, #3
56	7 Jul 1980	0830	Pineland	Approx total length 170 cm
57	18 Jul 1980	1430	Hammock/Former agricultural land	Total length 185.5 cm, see Table 2, #4
58	23 Jul 1980	1530	Pineland	Total length 151.9 cm, see Table 2, #5
59	3 Aug 1980	1300	Pineland/Hammock	Approx total length 105 cm
60	22 Aug 1980	1700	Pineland/former agricultural land	Approx total length 120 cm
61	3 Sept 1980	1010	Pineland	Approx total length 135 cm
62	26 Sept 1980	1853	Pineland	Coiled
63	26 Sept 1980	0845	Pineland	
64	2 Oct 1980	1550	Pineland/former agricultural land	Approx total length 135 cm
65	10 Oct 1980	1130	Pineland	Approx total length 100 cm
66	31 Oct 1980	1320	Hammock	Crossing road
67	31 Oct 1980	0900	Freshwater marsh	Approx total length 170 cm
68	2 Nov 1980	1128	Freshwater marsh	Adult
69	6 Nov 1980	0900	Pineland	Total length 251.6 cm, entering solution hole, see Table 2, #6
70	18 Nov 1980	1330	Former agricultural land	Swimming
71	31 Nov 1980	1045	Freshwater marsh	Approx total length 100 cm
72	3 Dec 1980	1615	Former agricultural land	Approx total length 180 cm

Appendix 1. Continued

Observation Number	Date	Time	Habitat	Comments
73	8 Dec 1980	1500	Hammock	Approx total length 150-180 cm, at Bear Lake Trail
74	6 Jan 1981	1100	Former agricultural land/pineland	Approx total length 120-150 cm
75	11 Feb 1981	1345	Agricultural land	Dead on road,east of Everglades National Park
76	23 Feb 1981	1445	Freshwater marsh	
77	26 Feb 1981	1230	Hammock	Approx total length 150 cm
78	7 May 1981	1220	Mangrove	Adult
79	12 May 1981	1100	Former agricultural land	Approx total length 167-180 cm
80	10 Jun 1981	1300	Former agricultural land	Approx total length 180 cm
81	30 Aug 1981	N/A	Pineland	Total length 174.1 cm, see Table 2, #7
82	29 Oct 1981	1700	Pineland	Approx total length 150 cm
83	30 Oct 1981	1500	Pineland	Approx total length 150 cm
84	30 Nov 1981	1300	Freshwater marsh	Approx total length 120 cm
85	7 Dec 1981	1030	Freshwater marsh/ pineland	Approx total length 150-180 cm
86	1 Jul 1979	N/A	Developed site	Total length 166 cm, male, on Big Pine Key
87	Jan 1944	N/A	Cypress	In Big Cypress
88	4 Jan 1982	1000	Pinelands/former agricultural land	Beginning to cross road
89	5 Jan 1982	1000	Pinelands/fresh-water marsh	Exiting solution hole
90	5 Jan 1982	1030	Freshwater marsh	Approx total length 150-180 cm, eating a brown water snake

Appendix 1. Continued

Observation Number	Date	Time	Habitat	Comments
91	19 Jan 1982	1645	Pinelands	Total length 194.6 cm, see Table 2, #8
92	30 Dec 1981	1200	Freshwater marsh	Approx total length 200-230 cm, dead on road
93	15 Nov 1981	1600	Pinelands	Total length 197 cm, dead on road
94	1971-1974	N/A	N/A	Several indigo snakes seen on Elliott Key, Biscayne National Park
95	22 Jan 1976	1300	Developed site	Elliott Key, Biscayne National Park
96	24 May 1976	a.m.	Hammock	Old Rhodes Key, Biscayne National Park
97	19 Aug 1976	N/A	N/A	Convoy Point, Biscayne National Park
98	3 Feb 1977	1000	N/A	Approx total length 100 cm, on Sands Key, Biscayne National Park
99	5 Feb 1977	1315	Hammock	Approx total length 90 cm, on Sands Key, Biscayne National Park, entered solution hole when disturbed.
100	11 Feb 1977	1600	N/A	Approx total length 200 cm, swimming from Elliott Key to Sands Key, Biscayne National Park
101	25 Feb 1977	N/A	N/A	Elliott Key, Biscayne National Park
102	10 May 1977	1000	Hammock	Crossing road at Elliott harbor, Biscayne National Park
103	24 Jan 1982	N/A	Schinus, mangrove	W. of Convoy Pt. on N. Canal Dr., Biscayne National Park, dead on road

Appendix 1. Continued

Observation Number	Date	Time	Habitat	Comments
104	1977-1978	N/A	Hammock	Approx total length 180 cm, Elliott Key, Biscayne National Park, in tree.
105	1977-1978	N/A	Developed site	Under Ranger's bunkhouse Elliott Key, Biscayne National Park
106	1977-1978	N/A	Mangrove edge	Convoy Point, Biscayne National Park, in tree
107	13 Oct 1962	N/A	N/A	Dead on road, Ramrod Key

[1] N/A = not available

Appendix 2. Data on indigo snakes examined in and adjacent to Everglades National Park.

ID#	Date	Sex	Snout-vent Length (cm)	Tail Length (cm)	Weight (gm)	Location
1	17 Mar 1980	Female	60	10.5	81	Near trap site at Palma Vista I
2	17 Mar 1980	Female	145.5	31.0	1428	Pineland
3	1 Jul 1980	Female	82	16.7	230	Trap site at Palma Vista I
4	18 Jul 1980	Female	160.7	24.8	1800	Near trap site at Palma Vista I
5	23 Jul 1980	Male	132.8	19.1	900	Parachute Key
6	6 Nov 1980	Male	232.0	19.6	4230	Pinelands, Block A
7	30 Aug 1981	Male	146.5	27.6	N/A	Pinelands, Block E
8	19 Jan 1982	Male	164.2	30.4	N/A	Pinelands, Block B
9	11 Feb 1981	Male	150.8	31.5	N/A	East of Everglades
10	24 Nov 1961	Female	53.5	11.7	N/A	Flamingo
11	N/A	Female	140	7.5	N/A	N/A
12	N/A	N/A	110	11.8	N/A	N/A
13	15 Nov 1981	Male	163.3	33.5	N/A	Between Pineland Block M and Y
14	11 Jun 1980	N/A	116.9	31.5	N/A	Florida City
15	3 Jan 1980	Male	N/A	N/A	N/A	Gumbo Limbo Hammock
16	15 Oct 1958	Male	N/A	N/A	N/A	Block K
17	N/A	N/A	180	26	N/A	N/A
18	15 Jan 1951	Male	N/A	N/A	N/A	S.W. of Royal Palm
19	12 Feb 1951	Male	N/A	N/A	N/A	Flamingo canal

[1] N/A = Not available

Appendix 3. Museum specimens of indigo snakes from southern Florida.

Year	Location	Specimen[1]
1906	Lemon City	USNM 03815300
1929	Homestead	UMMZ 67701
1932	Pinecrest	USNM 08530700
1932	Pinecrest	USNM 08530800
1932	Miami	USNM 08530900
1934	Pinecrest	PMNH R140
1937	Key Largo	CMNH 19862
1948	Key Largo	IMNH 5126
1950	Ochopee	UF 47363
1950	Key Largo	UMMZ 102272
1951	45 mi. W. of Miami	UMMZ 103997
1951	South Miami	UMMZ 103996
1951	Florida City	IMNH 26859
1951	Naples	UMMZ 103400
1952	Sugarloaf Key	UMMZ 106276
1953	Homestead	UMMZ 108346
1955	Cape Sable	UMRC 55-191
1955	5 mi. N. Royal Palm State Park	UMRC 55-198
1955	4 mi. E. Goulds	UMRC 55-631
1955	Cape Sable	UMRC 55-190
1955	5 mi. N. Royal Palm State Park	UMRC 55-199
1955	11 mi. E. Royal Palm State Park	UMRC 55-193
1956	Collier Seminole State Park	MCZ 83162
1957	Cutler	LACM 59104
1959	Big Pine Key	LACM 58886
1960	Miami	UF 47457
1963	Florida City	PMNH R7110
1963	Florida City	LSU 38529
1963	Big Pine Key	PMNH R7103
1966	Big Pine Key	LACM 103877
1967	Homestead	CMNH 51022
1967	SR 27, 4 mi. E. of Everglades National Park	MCZ 97245
1967	Homestead	CMNH 46736
1967	Florida City	UMMZ 128174
1970	Big Pine Key	UF 44400
1970	Big Pine Key	USF
1971	Key Largo	SSM 72.2399
1972	Monroe Station	UF 47374
1973	Snake Bight Trail, EVER	UF 33988
1978	Key Largo	UF 47456
1978	Big Pine Key	MCZ 156984
1978	Cudjoe Key	UF 43835
1979	Middle Torch Key	MCZ 158991
N/A	Naples	UF 45618

[1] See method section for abbrevations.