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Activity Patterns and Habitat Use of Box Turtles (*Terrapene carolina bauri*) on a Florida Island, with Recommendations for Management

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Abstract. – **Egmont Key, located at the mouth of Tampa Bay, has a large population of Florida box turtles (*Terrapene carolina bauri*) (Cryptodira: Emydidae). From 1991 to 1993, we studied box turtle habitat and substrate use, activity, and the environmental variables associated with more than 1400 captures of over 800 turtles. Most turtles were resting with their heads out when encountered. Activity occurred at air temperatures > 17°C, and turtles were encountered most often at high humidities on sunny days. There were no differences among males, females, and juveniles in air temperature, substrate temperature, or relative humidity at capture site. Turtles are active year-round on Egmont Key. Activity patterns were similar between males and females, but varied seasonally. During cool weather, most adult activity occurred during the warmer parts of the day, but as the season progressed, activity became bimodal with peaks in the morning and late afternoon. Juvenile temporal activity did not change with season. Box turtles used habitats nonrandomly, and season influenced habitat use of adults but not juveniles. Juveniles were found most often in palm-pepper forest whereas adults were more widely distributed, especially on lawns of mown grass. Box turtles congregated around fruiting plants, but cockroaches likely form the most important prey. As Egmont Key is developed as a state park, substantial changes are expected in vegetation structure and composition, and in visitor use. These changes are likely to have a direct impact on the resident box turtle population. Based on our findings, we suggest ways to reduce impacts in order to ensure the long-term survival of this unique island population.**

The Florida box turtle, *Terrapene carolina bauri*, may be considered a common turtle (Dodd and Franz, 1993) in peninsular Florida, although little is known of its biology other than its distribution and general habitat preferences (Carr, 1940, 1952; Iverson and Etchberger, 1989). Indeed, there are few studies of the life history of box turtles south of Maryland (Stickel, 1950, 1978), North Carolina (Stuart and Miller, 1987), Tennessee (Dolbeer, 1969), Arkansas (Reagan, 1974), and Missouri (Schwartz and Schwartz, 1974; Schwartz et al., 1984), despite the nearly ubiquitous presence of *T. carolina* in the southeastern United States.

Although widespread in Florida, box turtle populations generally are not perceived to be as large or as dense as populations farther north (e.g., Neill, 1948; Dolbeer, 1969). Carr (1952) stated that the only place Florida box turtles reached the densities of *T. carolina* seen in northern Georgia was in the limestone flatwoods region west of Homestead in Dade County, an area since extensively urbanized. Box turtles have been reported occasionally from barrier islands (Martof, 1963; Jackson and Jackson, 1970; Blaney, 1971; Lee, 1972; Gibbons and Harrison, 1981; Conant et al., 1990) and the Florida Keys (Duellman and Schwartz, 1958; Lazell, 1989), but literature references leave the impression that box turtles are rare (see above) or absent (Gibbons and Coker, 1978) on islands.

In 1990, we initiated a herpetofaunal survey of Egmont Key, Hillsborough County, Florida, prior to the development of the island as a state park. During the course of the survey (Franz et al., 1992), we discovered a large population of Florida box turtles. On subsequent visits, we marked more than 800 turtles. Inasmuch as an increase in human activities was expected on the island as a result of management (including prescribed fire and chemically- and mechanically-based exotic vegetation removal) and visitor use, we began a long-term study to monitor the box turtle population in order to assess impacts. Here, we report data on box turtle activity and habitat use on Egmont Key, and suggest management recommendations to conserve this large population.

METHODS

Study Site. — Egmont Key is a 180-ha elongate island located in the mouth of Tampa Bay, Hillsborough Co., Florida (27°36'04"N, 82°45'40"W) (Fig. 1). The highest natural elevation is approximately 3.0 m, although most of the island lies less than 1.25 m in elevation. The substrate consists of a combination of compact sand and crushed shells, with little organic soil except under dense vegetation. The island is surrounded by moderate-energy white sandy beaches on the west, north, and south, and generally narrow low-energy beaches to the east.

The island has a long history of human occupation (Stafford, 1980; Franz et al., 1992) and island habitats are highly modified by the introduction of many exotic plants. The primary vegetation types include the following (Fig. 1):

Sea oats meadows: Sea oats (*Uniola paniculata*) meadows are located on the southeastern coast and on the overwash

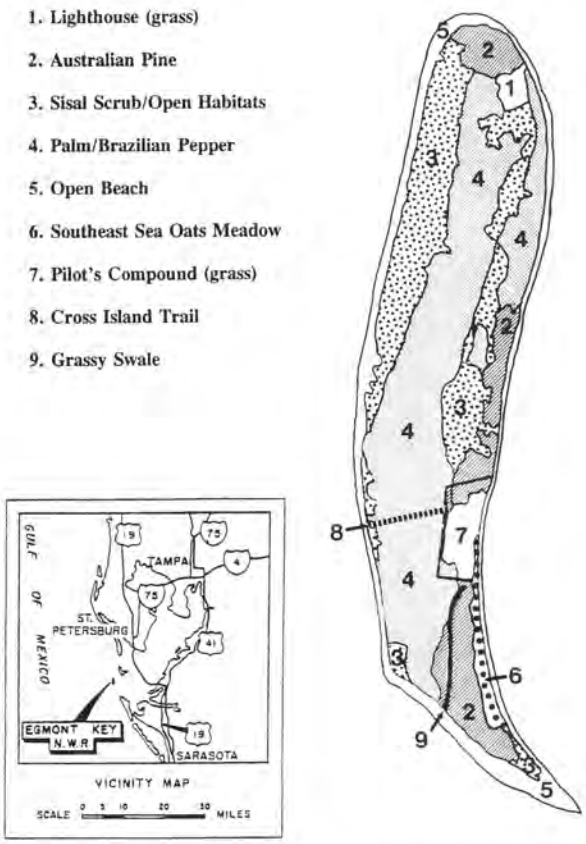

Figure 1. Location and habitat of Egmont Key in western peninsular Florida, with vegetation based on a March 1993 aerial survey. Studies were concentrated on the box turtle population south of the Cross Island Trail.

plain of the southern part of the west central coast. They are covered by a thick layer of dense grasses (0.5 m in height) interspersed with bare areas of compact shell sand. Gopher tortoises (*Gopherus polyphemus*) make clearly defined pathways through the thick grasses. Clumps of sea grapes (*Coccoloba uvifera*), prickly pear (*Opuntia* sp.), half flower (*Scaevola plumieri*) and Australian pine (*Casuarina equisetifolia*) either border or are interspersed within the meadow, especially on the southeastern coast.

Australian pine groves: Groves of Australian pine (*Casuarina equisetifolia*) are located on the southern, eastern, and extreme northern tip of the island. These groves are deeply shaded with little or no understory, and are carpeted by a dense layer of fallen needles.

Sisal scrub: Sisal (*Agave sisalana*) scrub occupies much of the central and northern sections of the island, the area most intensively disturbed during the occupation of Fort Dade (Stafford, 1980). In addition to sisal, the vegetation is dominated by Spanish bayonet (*Yucca aloifolia*), poison ivy (*Toxicodendron radicans*), palms, and various grasses and small shrubs. Canopy cover is sparse with much bare ground exposed to direct sunlight.

Lawn grass: Mowed lawns occur in the vicinity of the lighthouse and in the inholding of the Tampa Bay Pilot's Association (TBPA). Turtles find shelter under houses built on stilts within the TBPA compound. Sea grapes and half flower are found scattered around the lawn's periphery, and occasional small groves of cabbage palm (*Sabal palmetto*) are located within it. A shallow depression fills with brackish water during periods of heavy rainfall at the rear of the TBPA compound.

Palm-pepper forest: Extensive forests composed of a mixture of cabbage palm, Australian pine, and Brazilian pepper (*Schinus terebinthifolius*) overstory dominate much of the central and southern end of the island. Additional patches of the palm-pepper forest are found in the eastern region of the island. There is generally scant herbaceous understory, although dense stands of Brazilian pepper can be nearly impassible to humans. Much of the forest floor is shaded. The ground layer consists of a mixture of organic soil, shell-sand, and loose leaf litter of fallen palm fronds.

Egmont Key is exposed to frequent storms, and vegetation composition may change abruptly in response to wind and wave overwash. For example, the large sea oats meadow on the central western side of the island was replaced by extensive areas of bare sand following a series of destructive storms in 1992 and 1993. In parts of the island, especially in the south, numerous shallow drainage ditches have been dug; such ditches are gently sloped, 1-2 m wide, and less than 0.5 m deep. These ditches fill with water during heavy rains, as does a shallow swale running south from the TBPA compound (Fig. 1), and they are frequented by box turtles during wet weather.

Egmont Key is a National Wildlife Refuge leased to the State of Florida for use as a state park. Visitor use is concentrated around the island beaches where more than 1000 boats may anchor on a holiday weekend (R. Baker, *pers. comm.*). Only day visitation is permitted on land except at the TBPA. The island is patrolled by rangers from the Florida Park Service.

Twelve species of amphibians and terrestrial reptiles are known from the island (Franz et al., 1992; Smith et al., 1993), including a large population (mean estimate 1140, range 700-1700) of gopher tortoises, *Gopherus polyphemus* (Mushinsky and McCoy, 1994). No native mammals are

Figure 2. Florida box turtle, *Terrapene carolina bauri*, resting as found on southern Egmont Key.

Figure 3. Part of a morning's catch of box turtles on Egmont Key that had congregated under this single tree of fruiting sea grape. October, 1992.

present, although raccoons (*Procyon lotor*) that occasionally find their way to the island, perhaps released by humans, can be detrimental to the box turtle population (Franz and Dodd, 1993). Domestic cats have been kept at the TBPA compound; in recent years, some cats have been removed while others have been neutered to help control the population.

Data Collection. — Box turtles were collected by visual search during 12 three-day trips in 1991 (January, March, April), 1992 (January, February, April, June, October), and 1993 (April, May, June, July). Collecting was concentrated on the southern 36.4 ha of the island, although all parts of the island were searched several times during the course of the study. Upon capture, the following data were recorded directly in the field: carapace length (CL), plastron length (PL), shell depth (SD, taken between vertebral scutes 2 and 3) [shell measurements recorded with a 50 cm caliper to the nearest mm], weight (using a Pesola spring balance to the nearest g), sex, shell damage, air and substrate temperature (using an Atkins series 396 digital thermometer), relative humidity at the turtle (using a Nester RH pen), weather conditions, site location, habitat (palm-pepper, Australian pine, swale, sea oats meadow, sea grape, sisal scrub, lawn, other), substrate (shell sand, pine needles, organic soil, leaf litter, palm fronds, grass), activity (feeding, under cover, walking, resting, other), time captured, and whether the turtle's head was in or out. Each individual was given a unique number by notching the carapace (Cagle, 1939), photographed for future recognition, and released.

Data Analysis. — The sampling periods were grouped into four seasons for analysis (Jan-Feb = winter; Mar-Apr = spring; May-July = summer; Oct = autumn). The data on temperatures and relative humidity were tested first for normality. Inasmuch as these data were not normally distributed, the Kruskal-Wallis test was used to test for seasonal and sex (males, females) or life stage (juveniles defined as < 110 mm CL unless obvious secondary sexual characters [e.g., distinctly concave plastron] were present) differences among these variables when turtles were captured. The variable 'time' was partitioned into 1-hr categories beginning at 0600. We excluded the month of October 1992 from the analysis of the effects of season on time of capture because a large number of turtles (n=90) caught at dawn (0700) prevented us from sampling during most of the remaining morning hours. Analyses of the categorical data on capture by sex, life stage, season, habitat, substrate, and time were carried out using the Kruskal-Wallis and Friedman's x^2 tests, and Log-Linear Model-Maximum Likelihood (LLMML) analysis (SAS Institute, Inc., 1992). For LLMML analysis, the model initially was run to test for interactions between variables. If no interaction was found, the model was rerun and the significance probability was determined using the revised values for df and x^2.

Statistical procedures were carried out using the SAS program for microcomputers (SAS Institute, Inc., 1988). The level of significance was set at P=0.05.

RESULTS

We collected data from a total of 1448 captures of 811 box turtles on Egmont Key. Not all captures were accompanied by full data sets, and not all captures were fully analyzed.

Activity. — The majority (915 of 1360 captures, 67%) of box turtles were resting when encountered (Fig. 2). Most turtles were on the surface of the ground, were not buried beneath leaf litter, and were alert but not moving. In 1019 of 1317 (77%) captures, the turtle's head was out of the shell. Turtles were encountered often in trails which they constructed as they bulldozed through the moist organic soil or leaf litter, or they rested in shallow depressions (termed forms) at the base of grass clumps or in loose vegetation. The trails and forms were similar to those described by Stickel (1950) in her study of Maryland box turtles.

In addition to resting, box turtles were found walking (254 captures, 19%), completely under cover (111 captures, 8%), feeding (63 captures, 5%) or in other activities (17 captures, 2%). Box turtles were encountered walking mainly across the lawn at the TBPA compound during early morning hours. Box turtles completely under cover were buried under several cm of leaf litter in depressions left by fallen palm trees or under dense palm frond litter. Although gopher tortoise burrows are abundant on Egmont Key, box turtles were found in burrows only once, on the afternoon of 23 April 1993. This was the only time that relative humidities dropped below 50% during the study and a time when few box turtles (n=13) were observed; only abandoned gopher tortoise burrows appeared to be used.

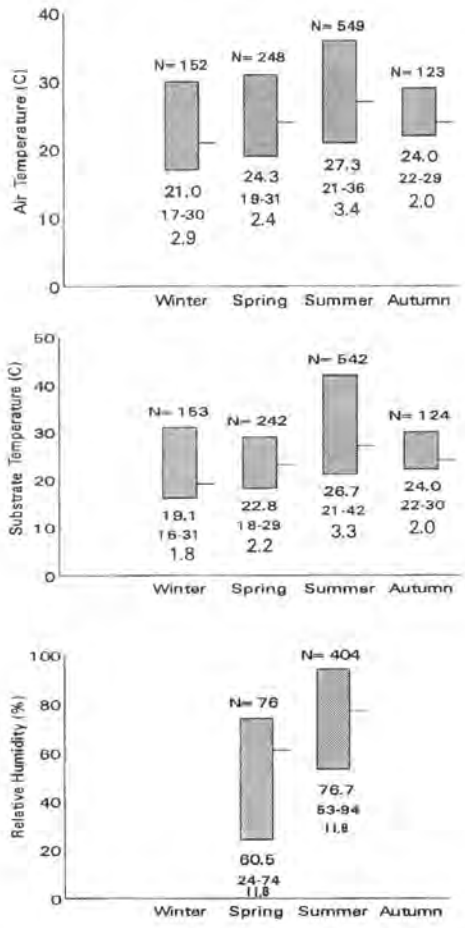

Figure 4. Seasonal variation in air temperature (A), substrate temperature (B) and relative humidity (C) at which box turtles were captured on Egmont Key. The bars give the range and the line to the right of the bar shows the mean. The mean, range, and standard deviation are given below the bar.

Box turtles were observed eating ripened fruits (prickly pear, sea grape, half flower, cabbage palm) and cockroaches, and one scat that was examined contained several Brazilian pepper seeds. Large numbers of box turtles congregated under fruiting plants during early morning hours (Fig. 3); as many as 30 individuals were found under a single sea grape bush in October 1992. We found turtles also congregating under fruiting prickly pear cactus, especially during the late afternoon in and adjacent to the sea oats meadow on the southeast coast; usually two to five turtles were observed at one time. Cockroaches are extremely abundant on Egmont Key and were captured as box turtles bulldozed trails through the leaf litter and surface debris. Individuals also were observed swimming (10), drinking (2), mating (2), digging (1), on its carapace upside down (1), in a palm stump hole where it had fallen (1), and resting over a recently completed nest (2005 h on 17 June 1993).

Environmental Conditions. — Most box turtles were captured under clear, sunny skies (780 of 1356 captures, 58%), although turtles were captured under a variety of other weather conditions, including cloudy (310 captures, 23%), partly cloudy (226 captures, 17%) and rainy (40 captures, 3%). Box turtles appeared to be most active following rainfall, especially after dry weather.

Box turtles were captured at air temperatures ranging from 17° to 36°C, substrate temperatures of 16° to 42°C, and relative humidities of 24% to 94% (Fig. 4); turtles were not captured below these temperatures despite searches during cooler weather. The high substrate temperatures were encountered as the box turtles walked across bare shell sand in the late afternoon on hot summer days. The air temperatures (x^2=389.87, df=3, P=0.0001), substrate temperatures

Table 1. Loglinear Model-Maximum Likelihood Analysis of the effect of season on time captured, by sex (male, female) and life stage (juvenile). A significant P (<0.05) indicates that values are not uniformly distributed.

Comparison		df	x^2	P
Males				
	Season	2	34.75	0.00
	Time	15	145.11	0.00
	Season*Time	20	127.59	0.00
Females				
	Season	2	20.27	0.00
	Time	15	129.46	0.00
	Season*Time	19	66.63	0.00
Juveniles				
	Season	2	5.23	0.07
	Time	14	19.30	0.15
	Season*Time	17	13.92	0.67

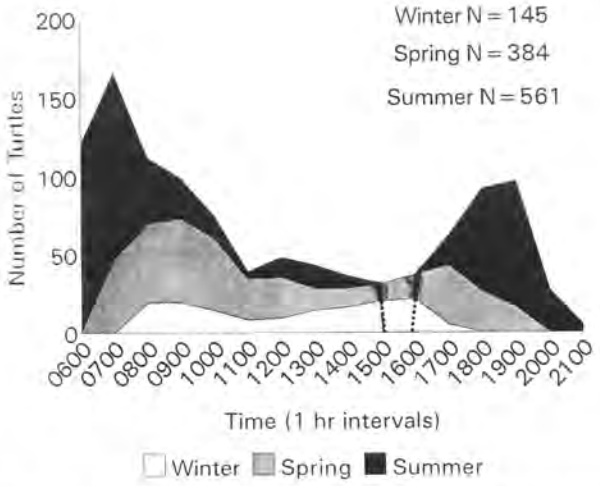

Figure 5. Seasonal variation in temporal activity of adult box turtles on Egmont Key. The dotted lines going to 0 indicate that no activity occurred during the summer between 1500 and 1600 hrs.

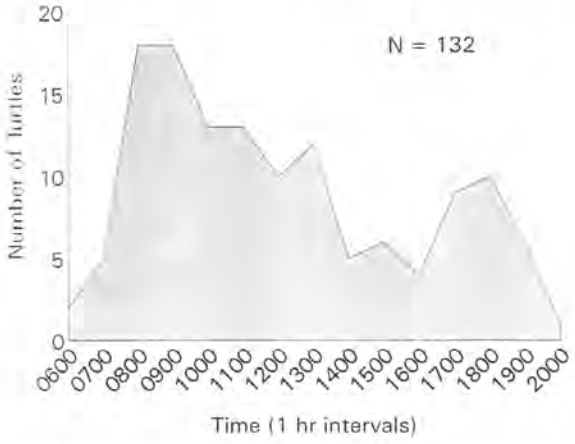

Figure 6. Temporal activity of juvenile box turtles on Egmont Key. Season had no effect on juvenile temporal activity.

(x^2=552.85, df=3, P=0.0001), and relative humidities (x^2=71.67, df=1, P=0.0001) at which box turtles were captured varied significantly among seasons. However, we detected no difference among males, females, and juveniles in terms of the air temperature (x^2=4.45, df=2, P=0.11), substrate temperature (x^2=4.12, df=2, P=0.13), and relative humidity (x^2=4.87, df=2, P=0.09) at which turtles were captured.

Time Captured. — Nearly all turtles were captured from dawn until dusk. During winter, this resulted in an 0700 to 1700 h EST activity period which gradually shifted to 0600 to 2000 h EDT in summer. Only five of 1448 box turtles were captured after sunset, despite casual searches on most nights that we were on the island, and those five turtles were active at approximately 2145 h on 27 July 1993 during a heavy rain shower.

Male and female box turtles used time in a nonrandom fashion that was influenced by season, although juveniles were captured fairly uniformly with respect to time of day regardless of season (Table 1). There was no significant difference between male and female patterns of time use (Kruskal-Wallis test, x^2=1.65, df=1, P=0.20). In winter, adults were nearly uniformly active from 0700 to 1700 h EST, whereas in spring there was a morning activity peak followed by rather constant activity until 1900 h. During the summer, activity became much more bimodal and virtually ceased during the hot afternoon (Fig. 5). Juveniles, on the other hand, exhibited a prolonged period of morning to early afternoon activity followed by a brief period of activity in the late afternoon (Fig. 6). The pattern was repeated regardless of season (Table 1). Although the autumn data were limited to only one collection, individuals were active from 0700 to 1800 h EDT, with a peak during the early morning.

Habitat Use. — Most box turtles were found either in palm-pepper forest (n=634 of 1337 captures, 47%) or on the lawn at the TBPA compound (n=427, 32%). Few box turtles were observed in either sisal scrub (n=4) or buttonwood (n=3) habitats, and these were excluded from further analysis. Although precise vegetation maps are not available for Egmont Key, the concentration of box turtles on the lawn at the TBPA compound is much higher than might be expected considering the small amount of lawn habitat available (1.6 ha; 4.4% of the habitat on the southern section of the island).

Box turtles were found nonrandomly with respect to habitats on Egmont Key (Table 2). Season influenced habitat use by adults, but only among males did it form a significant influence (Table 2). Juvenile habitat use also was nonrandom, although there was no significant interaction between season and habitat use (Table 2). The interaction between season and habitat differed between males and juveniles (Table 2), but the basic overall patterns of habitat use were statistically similar (Kruskal-Wallis test, x^2=64.4, df=1, P=0.0001).

During the winter, box turtles were observed most often in the palm-pepper forest (Fig. 7). With the warmer temperatures of spring and summer, however, adults increasingly were found on the lawn at the TBPA compound. During the autumn when sea grapes were fruiting, the concentration of box turtles around sea grapes increased dramatically. The main difference between adult habitat use also occurred in autumn when male use of the palm-pepper forest decreased in relation to female use of the forest. Juveniles for the most

Table 2. Loglinear Model-Maximum Likelihood Analysis of the effect of season on the habitat where the turtle was captured, by sex (male, female) and life stage (juvenile). A significant P (<0.05) indicates that values are not uniformly distributed.

Comparison		df	x^2	P
Males				
	Season	3	27.86	0.00
	Habitat	5	175.46	0.00
	Season*Habitat	14	165.96	0.00
Females				
	Season	3	6.19	0.10
	Habitat	5	77.48	0.00
	Season*Habitat	11	87.84	0.00
Juveniles				
	Season	3	29.00	0.00
	Habitat	4	131.04	0.00
	Season*Habitat	6	3.29	0.77

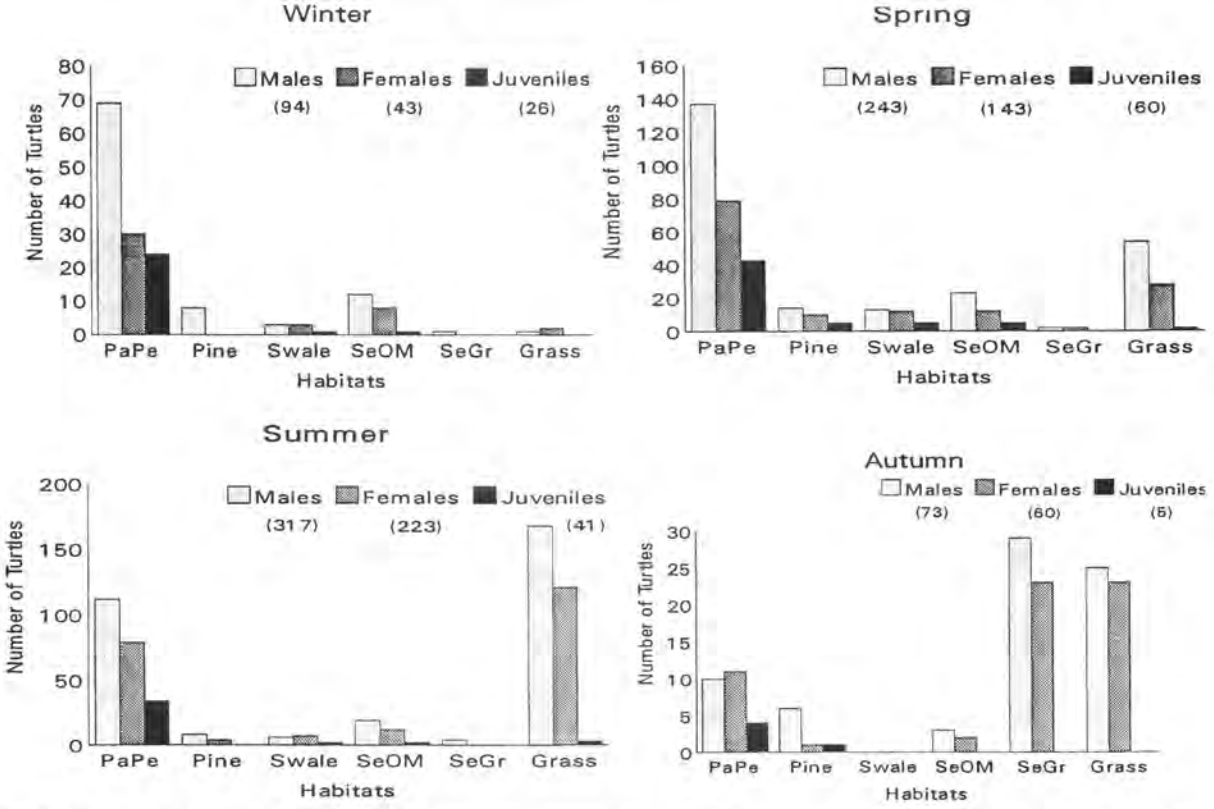

Figure 7. Seasonal variation in habitat use of box turtles on Egmont Key. PaPe = Cabbage palm-Brazilian pepper forest. Pine = Australian pine groves. Swale = grassy swale on south of island. SeOM = sea oats meadow. SeGr = immediate vicinity of sea grape bushes. Grass = grassy lawn at the TBPA compound.

part remained in the palm-pepper forest and only infrequently ventured into other habitats, mostly during the summer.

Box turtles used habitats differently with respect to the time of day in which they were active (Fig. 8), even after adjusting for the effects of season (Friedman's test, x^2=378.5, df=5, P=0.000). The lawn at the TBPA compound was used mostly during the early morning hours. The peak of morning

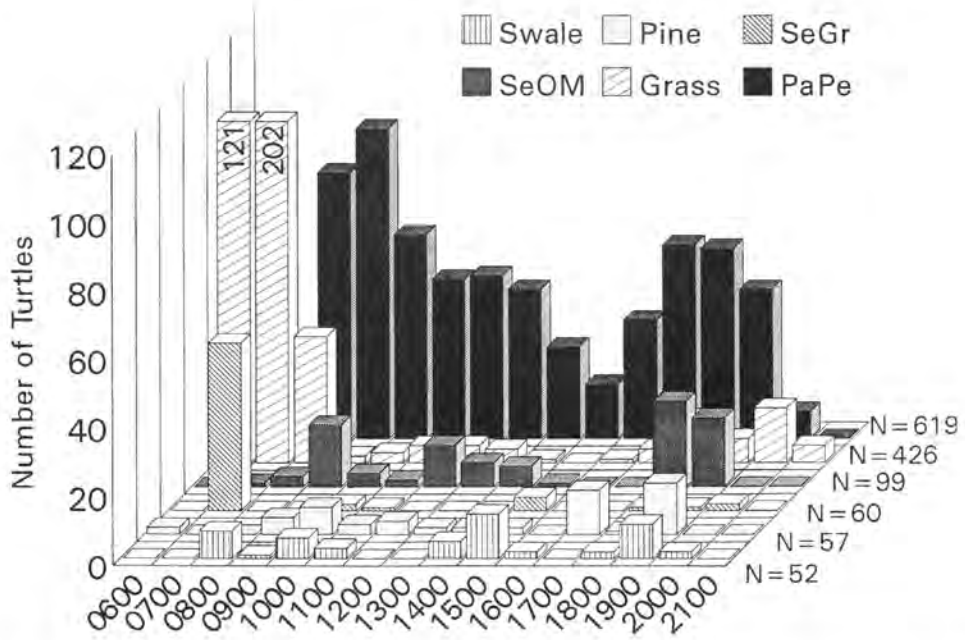

Figure 8. Temporal variation in habitat use by box turtles on Egmont Key. PaPe = Cabbage palm-Brazilian pepper forest. Pine = Australian pine groves. Swale = grassy swale on south of island. SeOM = sea oats meadow. SeGr = immediate vicinity of sea grape bushes. Grass = grassy lawn at the TBPA compound.

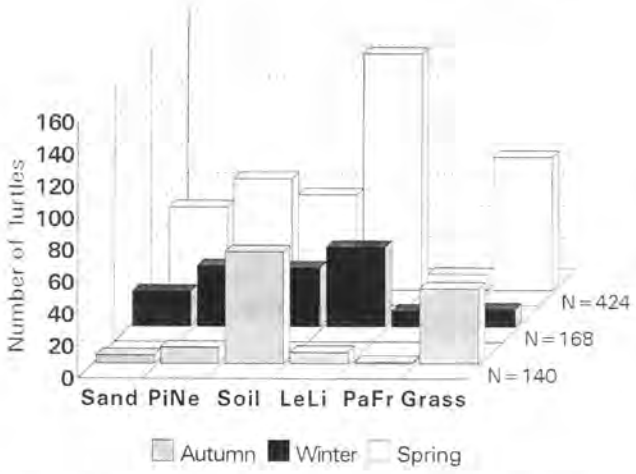

Figure 9. Substrate use by box turtles on Egmont Key during the winter, spring and autumn. No differences exist between the sexes or between adults and juveniles. Sand = shell sand. PiNe = Australian pine needles. Soil = organic soil. LeLi = leaf litter. PaFr = whole or nearly entire palm fronds. Grass = lawn grass at the TBPA compound.

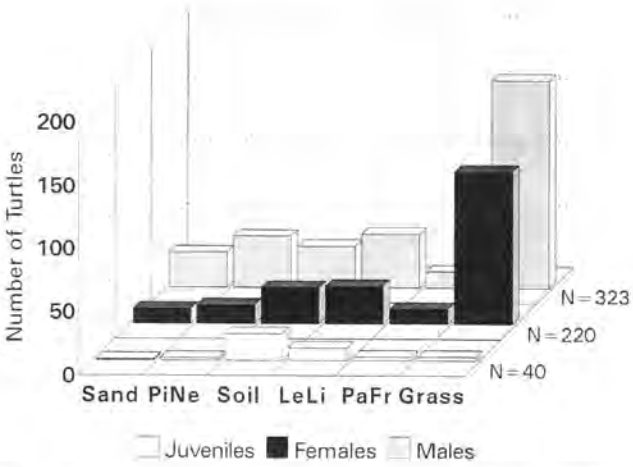

Figure 10. Variation in substrate use by box turtles on Egmont Key during the summer. Sand = shell sand. PiNe = Australian pine needles. Soil = organic soil. LeLi = leaf litter. PaFr = whole or nearly entire palm fronds. Grass = lawn grass at the TBPA compound.

activity among the sea grapes resulted from data collected in October 1992 when the sea grapes were fruiting. Use of the sea oats meadow differed seasonally, with morning activity in the winter as sunlight warmed the open ground, and evening activity in the summer as the sun went down behind a line of tall Australian pines. The use of palm-pepper forest closely followed general activity patterns (see above).

Substrate Use. — Box turtles were found most commonly on grass (432 of 1345 captures, 32%), followed by leaf litter (288, 21%), organic soil (250, 19%), Australian pine needles (177, 13%), shell sand (120, 9%), and whole palm fronds (49, 4%). The remaining 29 turtles were found in water, of which 23 were captured in April 1992 after heavy rains; box turtles found in water were not considered in the analysis of substrate use.

Male, female, and juvenile box turtles did not use substrates uniformly (Table 3), and adult substrate use varied seasonally, although juvenile substrate use did not (Table 3). In winter, turtles were found primarily on pine needles, organic soil, and leaf litter (Fig. 9). In the spring, they shifted to leaf litter and grass, a pattern maintained in the autumn (Fig. 9). During these seasons, the patterns of substrate use did not differ significantly among males, females, and juveniles (Table 4). In the summer, however, the patterns of substrate use between adults and juveniles changed significantly from that of the other seasons (Table 4). Males were found slightly more often on pine needles and sand than females. Juveniles, however, almost were never found on grass substrates but frequented organic soil and leaf litter (Fig. 10).

Table 3. Loglinear Model-Maximum Likelihood Analysis of the effect of season on the substrate where the turtle was captured, by sex (male, female) and life stage (juvenile). A significant P (<0.05) indicates that values are not uniformly distributed.

Comparison		df	x^2	P
Males				
	Season	3	100.49	0.00
	Substrate	5	38.17	0.00
	Season*Substrate	14	150.77	0.00
Females				
	Season	3	73.90	0.00
	Substrate	5	63.75	0.00
	Season*Substrate	15	103.33	0.00
Juveniles				
	Season	3	32.44	0.00
	Substrate	5	46.50	0.00
	Season*Substrate	11	11.94	0.37

DISCUSSION

Box turtles on Egmont Key appear to lead a rather sedentary life centered on locating food, shelter during unfavorable periods of heat, cold, and humidity, and reproduction. Most of the day is spent resting in forms or trails on the surface, or, when weather becomes excessively hot or cold, buried under leaf litter. Peak activity is correlated with warm temperatures, high humidity, and rainfall, and habitats that supply these optimum requirements are used on a daily or seasonally varying basis. Most activity occurs during

Table 4. Comparison of seasonal substrate use among sexes and life stages. Comparisons used the Kruskal-Wallis test.

Comparison	Season	x^2	df	P
Male vs Female	All Seasons	4.63	1	0.03
Male vs Juvenile	Winter	0.33	1	0.56
	Spring	1.97	1	0.16
	Summer	13.13	1	0.00
	Autumn	0.26	1	0.61
Female vs Juvenile	Winter	0.00	1	0.93
	Spring	0.65	1	0.42
	Summer	24.31	1	0.00
	Autumn	1.14	1	0.29

early morning hours, especially during the summer and autumn when turtles congregate to feed on ripened fruits. In terms of their activity, Florida box turtles on Egmont Key act much like the northern subspecies of *T. carolina* (Stickel, 1950; Dolbeer, 1969; Reagan, 1974; Madden, 1975), although their activity extends throughout the year (Carr, 1952; this study).

The use of gopher tortoise burrows by *T. carolina* has been reported in a few other studies (review in Jackson and Milstrey, 1989; Brandt et al., 1993), and box turtles occasionally use mammal burrows for hibernation (Ernst and Barbour, 1972). However, on Egmont Key, box turtles seem to use only abandoned tortoise burrows and then only during periods of low humidity. Box turtles appear to be sensitive to low humidities. For example, Bogert and Cowles (1947) reported that a female Florida box turtle lost 17.3% of her body weight during a 45-h period at a temperature of 38°C and a relative humidity of 37%. Reagan (1974) also noted a preference for high relative humidities (85%) by Arkansas box turtles. Others have noted a seeming preference for high humidities, but without quantification (e.g., Stickel, 1950), or that box turtles become inactive during dry periods (Strang, 1983). The use of gopher tortoise burrows during low humidities is probably opportunistic, but may be particularly advantageous on parts of the island lacking deep organic soil or leaf litter.

Box turtles are omnivorous, eating a wide variety of fungi, plant material, insects, and carrion (Cahn, 1937; Carr, 1952; Klimstra and Newsome, 1960; Stuart and Miller, 1987). Elsewhere, they are reported to congregate under fruiting plants (Klimstra and Newsome, 1960; Dolbeer, 1969) as they do on Egmont Key. Fruits are likely important seasonal sources of both food and moisture, especially since fruits may be abundant during the autumn, the driest time of the year in central Florida. On Egmont Key however, the primary food source is likely to be the huge populations of cockroaches that inhabit virtually every part of the island. Raking through the leaf litter reveals hoards of cockroaches, but few other invertebrates. Organic soils are fairly shallow, and the remaining substrate is composed of compact shell sand where relatively few invertebrates are found.

On Egmont Key, box turtles neither hibernate nor go into an extended period of summer inactivity. Instead, activity is relegated to periods of favorable temperatures (>17°C) and humidity. During the cooler months of the year, activity is rather evenly spaced during the day, and gradually shifts toward the morning hours as temperatures rise. In the summer, most activity stops during the hot afternoon as the turtles seek shelter in the cooler organic soil and leaf litter. Habitats providing favorable temperature and humidity conditions are used accordingly, e.g., open meadows are used in the winter or late in the day in summer when they are no longer exposed to direct sunlight. In the hot months, turtles frequent the palm-pepper forest that provides high humidity, relatively cooler air, and cooler substrate temperatures in which to bury themselves. Seasonal shifts in habitat use, presumably in response to moisture and temperature, are reported for box turtles throughout their range (Stickel, 1950; Dolbeer, 1969; Reagan, 1974; Madden, 1975). Field ambient temperatures are closely correlated with body temperature in box turtles (Adams et al., 1989).

Nearly all studies of box turtles focus on adults because the juveniles and young are nearly impossible to find. On Egmont Key, however, juveniles comprised 15.3% (124 of 811) of our sample and 10% of all captures. Hence, substantial data were available to allow examination of differences in habitat use between adults and juveniles. Trends in habitat use, substrate use, and time of activity differ between juveniles and adults, although the magnitude of the difference varies seasonally, much spatial and temporal overlap occurs, and no differences exist among the environmental variables recorded at capture. Juveniles tend to preferentially inhabit areas with abundant organic soils and ground cover, especially the palm-pepper forest, and are rather uniformly active throughout the morning regardless of season. Several reasons are possible for differences in habitat use, including a greater abundance of small prey, cover sites (from both environmental extremes and predators), and more thermal stability in the closed canopy forest than in the open habitats. Although the Australian pine forest may offer thermal stability, turtles are very conspicuous on the dark needles and prey abundance is probably less than in the palm-pepper forest. The pine needles also form a dense carpet that small turtles may find it difficult to bury into.

Management Recommendations

The interior of Egmont Key has had little human intervention since Fort Dade was abandoned in 1921. Human activities generally have been confined to the TBPA compound, the lighthouse area in the north, and the surrounding beaches. With the development of the island as a state park, however, patterns of human use may change. State park policies call for management protocols that will return parks to the vegetational composition that existed prior to European settlement. On Egmont Key, a survey in 1876 noted that the island was "...surrounded on all sides by a smooth beach, and is mostly, first rate cabbage hammock and prairie with no mangrove" (Franz et al., 1992). An 1821 letter reported that live oak hammock occurred on the island, although evidence of such a forest no longer exists. It is therefore unclear as to what the "natural" vegetation of Egmont Key was prior to European settlement, and if fire formed an important component of the ecosystem.

Management plans call for the removal of exotic vegetation using both mechanical and chemical means. Work has begun to clear the stands of Brazilian pepper and Australian pine. In addition, park personnel plan to begin using prescribed fire in 1994 to thin woody vegetation and reduce presently high fuel loads. Scars on palm trees show that fire has burned parts of the island in the past. Some box turtles also show extensive fire scars on their carapace. However, the origin of these fires is unknown.

The levels of visitor use throughout the island are not

projected to increase with the development of the historical aspects of the park (R. Baker, *pers. comm.*). Park-related facilities may be constructed (primitive campsites primarily for small groups of special-interest visitors, restrooms, ranger residence, and a visitor center); these will be concentrated in the northern one-third of the island. A tour boat landing zone will encompass the northern end of the island. A shore bird protected zone is designated on the southern tip of the island, but this area is not used by box turtles or gopher tortoises. Although Park and refuge personnel are aware of the significance of the turtle population on Egmont Key, future management plans must address their biological requirements.

If management proceeds as anticipated, the vegetation structure of Egmont Key will change substantially. At least on a short-term basis, removal of exotic vegetation and prescribed burning will increase sunlight reaching the forest floor with a concomitant increase in temperature and a decrease in humidity. Opening the canopy will expose the moist organic soil to the direct effects of wind, increasing evaporation and exposing soil to erosion caused by severe thunderstorms. A hot spring or summer fire is likely to not only eliminate the leaf litter used by box turtles, especially the smaller size classes, but also to result in substantial direct mortality (Babbitt and Babbitt, 1951; Carr, 1952) and substantially reduce the cockroach population.

In addition to direct impacts from altering the vegetation structure, visitor use and allowing overnight stays on the island may result in the illegal collection of turtles and tortoises, especially the attractive small size classes which are so conspicuous on Egmont Key. Current Florida law allows possession of two box turtles, although animals are nominally protected on the island. However, once off the island, there is no way to ensure that the turtles did not come from Egmont Key. Visitor use also might impact activity patterns, especially of the gopher tortoises, and increase the potential for the introduction of mammalian predators.

Terrapene carolina generally is perceived to be a common species in Florida although no studies provide data on population size or status, and many threats are present (Dodd and Franz, 1993). Within Florida, the Egmont Key box turtle population may be unique because of its large size resulting from its isolation from the mainland, the absence of mammalian predators, and the large number of cockroaches which serve as a prey base. Little or no predation has resulted not only in large numbers of all size-classes, but also in their general conspicuousness. Dodd and Franz (1993) point out that common species may not be as common as perceptions indicate, however, and that management protocols need to take them into consideration. Consideration also must be directed at the timing of various management actions. While we prefer ecosystem management over individual species management, we believe that the large turtle populations on Egmont Key can and should be maintained as restoration proceeds.

We make the following suggestions to reduce impacts on turtles from vegetative restoration and development of the island for its biological and historical attributes. 1) Chemical elimination of exotic vegetation should not be conducted, unless the herbicide is injected or otherwise directed only at the target tree. Spraying should not occur when Brazilian pepper is fruiting. 2) A firm rationale for using fire as a management tool needs to be developed, especially in the absence of data on its historic occurrence and importance. Fire may not be appropriate if mesic or xeric hammocks are the desired vegetation types. If fire is used in management, initial burns should be conducted during the winter at a time of low wind speed and high humidity in order to ensure a cool fire. If fuel loads are deemed too high to conduct a cool fire, a head fire under windy conditions would pose the least harm to buried box turtles. In order to ensure turtles are buried as deep as possible, burns should be conducted during or immediately after a period of cold temperatures. If summer burns are used, they should occur in late afternoon on days with low humidity. 3) Burns should avoid impacting fruiting plants, especially prickly pear, sea grape, and half flower, as much as possible. Burns should not be conducted when these important food sources are fruiting. 4) Small plots should be burned rather than simultaneously burning a large section of the island. 5) The restoration of the vegetation community should include planting native oaks and cedars as soon as possible to compensate for canopy removed during exotics control. 6) Surveys should be undertaken to determine impacts from site location of visitor facilities on all native species, especially the turtles, rattlesnakes, and unique mole skink (Smith et al., 1993), prior to construction. Visitor facilities should not be located in high density turtle areas. 7) Camping should be allowed only under ranger supervision. Camping should not be allowed in areas of high turtle use. 8) Pets should not be permitted on the island. Existing cats in the TBPA compound should be removed and if raccoons are found on the island, they should be removed. 9) Visitors should be given brochures concerning the protected status of native plants and animals, especially the box turtles and gopher tortoises. Visitors should be advised not to approach or handle turtles. Signs should reinforce this information. 10) Because of the high price of box turtles in the international pet trade, park personnel should be especially vigilant on Egmont Key. Poachers should be dealt with severely. 11) Finally, we recommend that a long-term program be set up to monitor the Florida box turtles and gopher tortoises on Egmont Key in order to ensure the survival of these unique island turtle populations.

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