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Investigations of Rodent Damage to the Thatch Palms *Thrinax morrisii* and *Thrinax radiata* on Elliott Key, BISC

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ABSTRACT

An investigation of rodent damage to native thatch palms (Thrinax spp.) on Elliott Key, Biscayne National Park, Dade County, Florida was conducted during the period February 1977 to March 1980. Island surveys revealed approximately 67% of all palms were damaged to some degree. Over 40% of the palms encountered were either dead or damaged to the point that death was imminent. Three distinct levels of palm damage were discernible on different areas of the island.

The mexican red-bellied squirrel (Sciurus aureogaster), an introduced species, was found to be primarily responsible for the palm damage. This squirrel was observed feeding on palms and using palm fiber for nesting material. Nest surveys and trapping studies indicated highest populations of squirrels in high palm damage areas. A second potential cause of palm damage were black rats (Rattus rattus). High rat populations were found at all localities investigated. High rat populations on Little Totten Key, an island with similar habitat where squirrels do not occur, did not result in palm damage. However, rats may be contributing to palm damage on Elliott Key through competition with squirrels.

Observations of marked trees suggest that palm utilization has continued for many years at a chronic level. Rate of new damage to palms was declining during the period of study. A test of the fungicide "Thiram 75" was successful in detering palm use for short periods but was not effective for periods greater than six months.

INTRODUCTION

The first observations of serious damage to the Key Thatch Palm (Thrinax morrisii Wendland.) (Synonym: T. microcarpa Sarg. after Read, 1975) on Elliott Key, Biscayne National Park, were made by the author in August 1975. At that time, it was noted that several of these native palms at a location 1.6 km (1 mi) north of the Elliott Key Marina had apparently died from damage sustained to the heart of the palm by a gnawing rodent. Several other thatch palms in the area were also damaged to varying degrees although not dead. Subsequent cursory investigations in other areas of the island revealed that the damage was widespread and thatch palms on all parts of Elliott Key were affected. The gnaw marks and manner of damage to the thatch palms suggested rodents, possibly the exotic red-bellied squirrel (Sciurus aureogaster) or the black rat (Rattus rattus) was responsible for this destruction.

In 1977, a study was initiated to determine and document the overall extent of damage to thatch palms on Elliott Key, identify the cause of the damage observed, and determine any management actions that may reduce or prevent the loss of thatch palms. The study included investigations of both red-bellied squirrel and black rat populations at locations shown on Figure 1. Field observations were conducted during February-April 1977 and February-September 1978. A follow-up survey of two palm stands was conducted during December 1979-March 1980.

The mexican red-bellied squirrel is an introduced neotropical species that has existed on Elliott Key since 1938. Two pairs of squirrels from eastern Mexico were originally released by Mr. J. Aurthur Pancoast, an early island property owner. The species adapted readily to the key's dense tropical forest which resembles its native habitat. By 1950, red-bellied squirrels were reported to inhabit most parts of the entire island (Schwartz 1952).

Prior to the introduction of the red-bellied squirrel the only mammals documented to occur on Elliott Key were the raccoon (Procyon lotor), marsh rabbit (Sylvilagus palustris), and black rat (Rattus rattus) (Schwartz 1952). Natural predators appear to be limited to raptors (which, except for owls, are fairly seasonal in abundance), snakes (indigo, rat, and eastern diamondback rattlesnake), and raccoons.

Historically, the introduction of non-native animals into an area has resulted in two major problems. One is competition with, and reduction of, one or more native animal species present; and, secondly, severe adverse effects on either prey species or vegetation of the new habitat if natural predators are not present. When Brown (1969) reported on the introduction and successful colonization of the red-bellied squirrel in 1969, he indicated that this species had apparently filled a vacant ecological niche occupied by the eastern gray squirrel (Sciurus carolinensis) in other south Florida areas (Brown 1969). The eastern gray squirrel has been historically absent from the park keys although its presence on Key Biscayne to the north and Key Largo to the south are well documented (Layne 1974). The red-bellied squirrel was believed to be an unusual case of an exotic which was in balance with its environment.

The red-bellied squirrel is similar in size and general characteristics to the eastern grey squirrel (Sciurus carolinensis) but has a much more colorful pelage. In the normal or grey phase, the fur is a black-speckled grey over the head, back and tail with vivid chestnut red belly and flanks. In a melanistic or black color phase, which is common, the animal has shinny dark black fur over the entire body. Adults normally average in weight from 500-600 g (Musser 1968). The species is almost entirely arboreal and constructs large conspicuous nests by weaving together leaves, stems, and other vegetation at selected sites within the tree canopy. The species has not been extensively studied in its native range but is believed to produce two or more litters of young per year in Florida (McGuire 1972). Only one or two young are believed to be produced per litter (Schwartz 1952, Brown and McGuire 1975).

A general ecological study of Sciurus aureogaster was conducted on Elliott Key during the period 1969-1971. In this study, McGuire (1972) listed thatch palms as one of the food sources "heavily" utilized by the squirrels. He also noted that this food source was "scattered" and in "sparse" abundance. However, McGuire did not mention any extended thatch palm damage as a result of squirrel feeding behavior.

Until 1974, squirrels did not appear to be presenting a problem. However, at that time, several incidents began to indicate that the red-bellied squirrel like so many other exotics, may be resulting in adverse impacts to the natural environment. During 1974, the red-bellied squirrel was observed on Adams Key (adjacent to Elliott) for the first time (pers. comm. Robert Holm). In early 1975, a park ranger captured a red-bellied squirrel attempting to swim from Elliott Key towards Old Rhodes Key across Caesars Creek. In August 1975, the first observations of serious damage to the thatch palms were recorded. While conducting further investigations of palm damage, an unusual abundance of gnawed stems of native hammock vegetation (usually 10-38 cm in length) were found on the ground scattered throughout the island. Gnawed tree species included (in order of abundance of gnawed branches observed): pigeon plum (Coccoloba diversifolia), wild mastic (Mastichodendron foetidissinum), poisonwood (Metopium toxiferum) and catclaw (Pithecellobium unguis-cati). All of these trees are known squirrel food sources (McGuire 1972). In early 1977, a few squirrels were observed to have spread to Sands Key just north of Elliott (Figure 1). The above range expansions and adverse impacts on vegetation resembled classical population stress conditions. This made the red-bellied squirrel a primary suspect for causing the damage observed to native thatch palms.

A second potential cause for the observed damage to thatch palms was the black rat. This species is also considered exotic to North America although its occurrence has been documented with the earliest arrivals of European man. The black rat is believed to have occurred on Elliott Key for perhaps several centuries and it exists in numerous other areas of South Florida including the lower and upper Florida keys, islands of Florida Bay, and on other monument islands (Schwartz 1952, Layne 1974). In no other location where this rat occurs in similar habitat has problems with extensive gnawing of thatch palms been reported. Therefore, the black rat was not considered a primary suspect in our investigation.

METHODS

The overall extent of palm damage on Elliott Key was determined by hiking a series of continuous cross country line transects. In most areas, four north-south transects (2 coastal and 2 inland) were hiked along the half-mile (0.8 km) wide island. Along each transect, the species, location, estimated height and degree of damaged sustained were recorded for each palm observed. Low mangrove and salt marsh areas known not to support thatch palm growth were ignored. Aerial photographs were used to aid in identifying and delineating these mangrove areas. The degree of damage recorded for each palm was rated on a scale of 0 to 5 using the criteria presented in Table 1. In addition to the 0 - 5 damage rating, qualifiers shown in Table 1 were used to further specify certain types of damage.

To evaluate the rate at which palms were being destroyed, general surveys of palm damage in the area immediately south of Elliott Harbor and at Ott Point were repeated during 1978 and compared to observations made in early 1977. In addition, approximately 225 thatch palms in the vicinity of Ott Point were marked with numbered aluminum tags. Fifty-eight palms were tagged during the spring of 1978 and the amount of damage to each palm recorded. These palms were resurveyed during late summer (September 1978) and changes in damage levels for each palm noted. An additional 167 palms at Ott Point and 62 palms near Elliott Harbor were tagged during the summer of 1978 to serve as long-term indicators by which to evaluate utilization and/or destruction rates. All of the marked palms were resurveyed during the winter of 1979-80. Statistical comparisons of palm damage levels observed between island areas and between years for given sites were made utilizing Krushal-Wallis non-parametric tests for ranked multiple groups and the Wilcoxon non-paired two sample analysis as described by Sokal and Rohlf (1969). In addition to monitoring the rate at which palms were being damaged, evaluations of palm reproduction through seedling counts were conducted at several localities on Elliott Key. These surveys were conducted in known areas of thatch palm concentrations and involved a systematic search for seedlings within the area.

Attempts were made to identify the cause of palm damage through two approaches. One approach involved direct observations of palms for feeding activity, investigations of squirrel nests for palm material, identification of stomach contents of sacrificed black rats, and inspection of palms for squirrel or rat hair or other rodent signs. The second approach was to document rodent populations on various areas of the island and correlate palm damage levels to population densities observed.

The large stand of thatch palms located at Ott Point (Figure 1) which had numerous signs of rodent damage was selected for direct observation of squirrel use. Observations were conducted from a nearby roughly constructed blind during early morning hours when the squirrels are known to be most active (McGuire 1972). Squirrel nests were investigated by removing the nests from trees in which they were observed and then separating and identifying the vegetative material used in construction. Nest investigations were made on all parts of the island. All damaged thatch palms encountered were examined closely for animal signs.

Stomach content analysis was conducted on black rats captured near a stand of damaged thatch palms. Captured rats were anesthetized, dissected and all food material occurring within the stomach microscopically identified while fresh. All plant material observed was compared to masticated palm fiber for similarities.

In order to obtain data on rodent population densities, both live trapping (mark and recapture) studies and squirrel nest count surveys were conducted. Trapping studies were conducted utilizing Tomahawk No. 202 live traps in areas of high and low palm damage. During an initial trapping period at Ott Point, 24 live traps placed on a 60 m grid covering approximately 8.5 ha were used. The trap grid interval was reduced to 30 m with the number of traps increased to 48 at all subsequent sites. This reduced grid spacing was to allow a more detailed determination of rat home ranges and movement. Trap grids were established using a surveyor's tape and hand compass. The traps were suspended in trees, 1-3 m above the ground. Most traps were mounted on boards for better stability. Trees selected varied in species and diameter at breast height (dbh). Yellow ear corn spread with peanut butter or sunflower seeds was used as bait. At all sites investigated, the traps were baited and wired open for at least one week prior to the actual trapping period to allow conditioning and increase trap success (Taber and Cowan 1971).

Set traps were examined every afternoon and captured animals were tagged in one ear with serially numbered Monel metal tags (National Tag Co.) and/or toe clipped for permanent identification (Baumgartner 1940). Data recorded included date, time, trap location, type catch (i.e., initial or recapture), species, weight, standard body measurements, sex, pelage color, and identification number. The Schnabel formula for population estimates as described by Flyger (1959) was applied to recapture frequencies to determine animal densities. When known population losses occurred through trap deaths, the Overton (1965) modification of the Schnabel formula was applied to account for such losses.

Leaf nest surveys were conducted by walking a series of 92 m (300') transects at each site investigated. On Adams Key, transects surveyed varied from 50 m to 300 m in length depending on location and amount of forest habitat available. All nests observed while walking a transect were recorded. The lateral distance at which nests could be observed varied with location, time of day, and weather conditions. The maximum distance at which nests could be observed was noted for each transect sampled and nests per unit area were computed based on area observed. Observations recorded included tree species and dbh in which the nest occurred, and nest location along the survey transect. Surveys were conducted on clear days during mid-day hours to obtain good forest visibility.

RESULTS AND DISCUSSION

Palm Damage Observations

Extent of Damage

A summary of the results of thatch palm observations made over the entire island is presented in Table 2. Similar damage to other genera of palms on the island was not evident. Two species of thatch palm were noted to occur, Thrinax morrisii and

T. radiata Lodd. ex Schult. (Synonym: T. parviflora Sw. after Read, 1975). Of 956 palms observed, 735 (77%) were T. morrisii and 221 (23%) were T. radiata. A statistical comparison of the distribution of palms within each damage class between T. morrisii and T. radiata (Wilcoxon two-sample test) revealed that damage levels were significantly greater in T. morrisii ($p < 0.01$) where 606 (82%) were observed to be damaged to some degree. Damage ratings of 4 or higher were observed in 445 (60.5%) of these palms. At this level the palm showed signs of extensive gnawing in the center crown including the terminal bud, or was dead.

Only 37 (17%) of the T. radiata located were observed to show signs of damage and only 14 (6%) were damaged in the terminal bud or were dead. The reasons for less damage to T. radiata are not entirely clear. Distribution of these palm species (Figure 3) may be one reason. T. morrisii although generally concentrated on the western side of Elliott Key was found in several localities. T. radiata was found in only one large stand near the center of the island approximately 2 km (1.25 mi) south of the northern end. Height may be another factor as mature T. radiata are generally taller (6-10 m) than T. morrisii (2-6 m). The height of many T. radiata made it difficult to observe evidence of slight rodent damage (classes 1-3) but heavier damage (classes 4-5) was easily noted.

On Elliott Key, upland hardwood vegetation, with which thatch palms are associated, can be divided into twelve distinct stands. These stands are separated by low lying marsh or mangrove zones, or by man-induced breaks such as formerly cleared land, roads or burned areas (Figure 2). Palm damage in each of these areas was analyzed separately to allow for comparison of the severity of damage at various locations. The computed mean level of palm damage, based on weighted values applied to the number of palms in each damage class indicates that palm damage was greater in some areas than others (Table 3). Multiple comparisons utilizing the Kruskal-Wallis non-parametric test for damage values revealed three distinct and significantly different areas in respect to level of palm damage ($p < .05$). These three differently impacted areas are depicted in Figure 3.

The most severe damage has been in the area designated WE lies immediately north of the Elliott Key Harbor (Figure 2, Table 3). In area WE, 95% of the palms encountered were dead. Over 80% of those palms were classed as old kills (all fronds brown and weathered or missing). The computed mean level of damage in area WE was of a 10.12 rating value (= class 5OH). An intermediate level of damage occurred east of the high damage area (area EE) and in an area on the south end of Elliott Key (area WA). Mean damage values for these areas were 6.7 and 8.7 respectively. Of 46 palms located in the intermediate damage areas, 30 were found to be dead (approximately 65%). The remaining areas on Elliott Key were significantly lower ($0.05 > p > 0.02$) in the level of damage observed. Mean damage ratings in these areas ranged from 2.7-5.0 (damage class 2-3). Within the areas of least damage, large numbers of Thrinax morrisii occur only in areas WD (near Ott Point) and in areas WF and WE.

Surveys were conducted on three other keys in the monument to determine if palm damage was limited to Elliott Key. Surveys of both Adams Key and Sands Key revealed no damage to palms. Both of these keys support populations of black rats and have been invaded recently by red-bellied squirrels. The third island surveyed was Little Totten Key which lies in the southern portion of the monument. This key has numerous T. morrisii and a large black rat population. However, no damage to thatch palms was evident on Little Totten Key.

Rate of Palm Damage

A comparison of palm damage levels observed between 1977 and 1978 along the western side of Elliott Key south of Elliott Harbor and in the vicinity of Ott Point is shown in Figure 4. A significant increase in the overall mean level of damage observed was noted in both areas ($p < .05$). Of 112 palms observed in the area south of Elliott Harbor during February 1977, 85% (95 palms) were not damaged and the remaining 15% were rated in damage class 1. A sampling of 61 palms in this same area in March 1978 revealed less than 50% of the palms were not damaged while some palms were rated as high as damage class 4.

In the vicinity of Ott Point, the average palm damage level increased from a mean rating of 1.72 to 2.29 during the period February 1977 to September 1978. This represented a significant upward shift in palm damage levels ($.05 > p > .01$). Although the number of palms in damage class 4 decreased, the proportion of palms in all other damage classes showed some increase. Of particular concern, is the large increase in the proportion of palms which had fatal damage to the terminal bud (damage class 5).

When the increase in average damage rating observed in the area south of Elliott Harbor and at Ott Point were compared, we found that rate of increase in damage level, that is the increase in mean level per month, was higher near Elliott Harbor (.06 vs. .03 increase/mo). This would indicate that the individual palms within the area immediately south of Elliott Harbor were being subjected to heavier utilization by rodents during the period of our study than palms at Ott Point. However, past impacts at Ott Point were greater as evidenced by the higher mean damage level.

Although a higher overall mean level of palm damage was found at Ott Point in 1978 than in 1977, some recovery of palms was found to take place during 1978. Of 58 palms tagged in May 1958, 65% showed recovery to a lower damage class by September 1978. Thirteen percent of the palms remained at the same damage rating while only 6% had a higher damage rating. The remaining 17% of the palms were originally damaged into the terminal bud and could not recover. These data indicate that either damage is seasonal and some recovery takes place each year prior to new attacks or that palm utilization in the vicinity of Ott Point was on a declining trend after early 1978.

To determine further palm utilization trends and to provide a longer-term picture of the palm damage problem, surveys of tagged palms were repeated at Ott Point and Elliott Harbor during February-March 1980. The 1979-80 survey revealed an overall mean damage rating of 2.24 at Ott Point. This was not significantly different from the 1978 level($p > .05$). Of 215 tagged palms monitored since 1978 at Ott Point, 21% remained undamaged, 28% remained at the same damage level, 20% decreased in damage, and 31% increased in damage level. Forty of the 215 had terminal bud damage or were dead and unable to recover. At Elliott Harbor, construction activities were expanded southward into our study area during 1979. It is believed that squirrels completely abandoned the area at that time and a high level of thatch palm recovery was observed. Of 62 palms originally marked, none had shown increased damage, 29 had recovered to a lower damage class and 17 were unchanged in damage rating although existing damage was not recent. The remaining 16 palms had been destroyed by construction activities.

Palm Reproduction

A systematic search for palm seedlings (plants less than 1 m in height) at a few of the larger palm stands yielded the following counts:

203 seedlings at Ott Point (approximately 225 mature trees)

22 seedlings in the thatch palm grove south of Elliott Harbor (approximately 100 mature trees)

1 seedling in area north of Casuarina burn site 1.5 km north of Elliott Harbor (17 mature trees located)

0 seedlings on Little Totten Key (stand of 7 mature trees)

No evidence of rodent damage to seedlings was noted at any of the sites investigated.

CAUSE OF PALM DAMAGE

Rodent Observations

Observations of thatch palms from the blind at Ott Point resulted in only one sighting of squirrel feeding activity. Following three continuous hours of observation from the blind, a melanistic squirrel was observed to approach a 3 m tall *T. morrisii* and begin gnawing at the base of the branches. The gnawing activity continued for less than a minute before the squirrel left hurriedly through the woods. Other observation periods at the blind resulted in only one additional squirrel sighting. A melanistic squirrel was observed for approximately 45 seconds digging in leaf litter of the forest floor. It then fled, climbing a tree and moving out of sight. The apparent extreme shyness of *S. aureogaster* made observations of their activity through this approach mostly unsuccessful.

A total of 24 squirrel sightings were made while searching the island to record the extent of palm damage. Twelve of these squirrels were melanistic and 12 were of the gray color phase. This 50:50 color ratio agrees with that reported by McGuire (1972). One squirrel, a female gray phase, was found dead with the forward half of the body missing. The hind portion had been cleanly severed by what was assumed to be a predator.

Usually no more than two or three squirrels were seen on any given day during the damage surveys. However, on March 2, 1977, seven squirrels were observed feeding on the seeds and bark of Casuarina equisetifolia south of Sea Grape Point. Park rangers from Elliott Harbor reported seeing similar concentrations of feeding squirrels in Casuarina near Sea Grape Point at other times. Other feeding observations included a gray color phase squirrel feeding on mastic (Mastichodendron foetidissmum) fruits and a 10 min observation of a melanistic squirrel striping bark and gnawing the stems of a pigeon plum (Coccoloba diversifolia). Examination of broken and gnawed stems left by this squirrel revealed that they were similar to the large abundance of such twigs and gnawed limbs observed in the hammocks throughout the survey. Although no sighting of squirrels feeding on thatch palms were made during the damage surveys, one squirrel was observed leaving a freshly gnawed, heavily damaged T. morrisii (class 4-T) near Sands Cut on the north end of Elliott Key.

Nesting Materials

Fourteen squirrel nests were investigated for nesting material (Table 4). Nests observed ranged in size from 15 cm x 15 cm x 8 cm to 36 cm x 36 cm x 25 cm and were found to be of two distinct types. One type consisted of loosely woven leaves with no distinct internal nest cavity. The second type was substantially stronger in construction with tightly woven leaves and contained an inner chamber. The first type nest may only be used periodically or for a short period of time and is normally smaller in size than nests containing an inner chamber. The inner cavity of the chambered nests was always found to be lined with soft plant material. Materials used for nest lining included palm fiber, Casuarina needles (modified stems), spanish moss (Tillandsia usneoides), the sea grass (Thalassia testudinum), and an unidentified algae (Table 4).

McGuire (1972) described finding only one type of natural leaf nest on Elliott Key. A dome type with inner cup (cavity) of tightly packed, singular leaves. He also found open nests with no dome covering in nest boxes which he had provided. He concluded protection provided by the covered box did not necessitate the construction of a domed nest. Although McGuire reported examining over 100 nests, he did not report finding natural leaf nests in which there was no inner cavity.

McGuire analyzed 67 leaf nests for construction materials. He found mahogany leaves and twigs to be the primary material used in over 70% of the nests examined (McGuire, 1972). It is perplexing, however, that he reported finding "shredded bark" in only three nests. In one of these cases, he identified the shredded fibers as that of a papaya (Carica papaya) located approximately 200 yds from the nest site. Every chambered nest observed during our study contained some soft shredded fiberous material lining the chamber. In five out of eight of these nests the lining material was palm fiber. McGuire reported conducting his observations in the spring of 1972 which corresponds seasonally with our observations.

Although trapping studies revealed that the black rat (Rattus rattus) was abundant on Elliott Key at all sites, we were not able to examine any rat nests for the possible use of palm fiber. It appears that the rats are utilizing the abundant cavities in the porous limestone rock substrate of the key for den sites. Frequently rats released following trapping would bound away a short distance and then disappear into a cavity in the forest floor. No evidence of rat nesting was found in tree crevices or other such sites above ground.

Leaf Nest Density Surveys

Counts of the number of leaf nests along plot transects were conducted near Elliott Harbor at University Dock, on the southern end of Elliott Key (Nordt homesite, Figure 1), and on Adams Key. Results of each transect observed at each location are summarized in Table 5.

A total of 12 survey transects were conducted in mature hardwood forest in the area surrounding Elliott Harbor. The average number of nest/ha observed on these transects was 38.8 nest/ha. Variability between transects was large ranging from over 118/ha to none observed. A mean of 38.8 nests/ha is almost twice that reported by McGuire for this area in 1972. The Elliott Harbor site is located at the edge of a high palm damage area (area WE, average damage rating > 5.0) and the frequency of nests observed exceeded that of other Elliott Key locations.

Eight transects each were surveyed at University Dock and near the old Nordt homesite on Elliott Key. University Dock is within a low palm damage zone (< 3.0 rating) and the Nordt homesite represented a medium level of palm damage (> 3.0 < 5.0). However, the average number of nests observed per hectare was not significantly different at these sites ($T = 0.3249$ @ 14 d.F., $p > .05$). There were 28.1 nests/ha observed at University Dock and 22.5 nests/ha observed at the Nordt homesite.

As a comparison to the Elliott Key areas investigated, four transect surveys were conducted on Adams Key where red-bellied squirrels have been known to occur since 1974 and where, although thatch palms are not abundant, no palm damage has been observed. Results of these surveys revealed an extremely high frequency of leaf nests (89.1/ha). This high occurrence of squirrel nests was surprising considering the relative short period the island is known to have been populated with squirrels and the lack of palm damage observed. A possible explanation is that Adams Key was used as an island resort prior to establishment of the park and much of the native vegetation removed or disturbed. At present, most upland areas are in various stages of successional regrowth or recently cleared of the exotic plant Casuarina. Therefore, although a larger area of foraging habitat is available, only a small area (8-10 ha) of mature forest with suitable nest trees is available. This may result in a high density of nests with lower actual population levels than was observed on Elliott Key.

The theory for high nest counts on Adams Key is supported to some extent by our observations on Sands Key where the red-bellied squirrel is also only recently known to occur. Although no formal transect surveys were conducted, a general survey of the large mature hardwood forest on the south end of the island revealed only eight squirrel nests. The approximate distance covered in transiting the hammock was 840 m with an estimated lateral visibility into the canopy of approximately 12 m. Nest density based on these observations was 7-9 nests/ha. On Sands Key, a large area (60-65 ha) of relatively undisturbed mature hammock exists.

Trapping Studies

Rodent population studies involving mark and recapture were conducted at four sites. These sites included the area of damaged palms at Ott Point, a mature hammock area at University Dock, the same area trapped by McGuire (1972) near Elliott Harbor, and a site on Little Totten Key for comparative purposes. Both Ott Point and University Dock were within low damage zones (average palm damage rated at damage class 3 or less). The Elliott Harbor site was immediately adjacent to a high palm damage area where nearly all palms were severely damaged or dead. It was felt the Elliott Harbor site would provide information on changes in squirrel population levels since they were determined by McGuire in 1972. The site selected on Little Totten Key was within well-developed mature hardwood hammock. Included within the area trapped on Little Totten Key were several undamaged T. radiata.

A summary of trapping results at each of the above sites is shown in Table 6. Both Sciurus aureogaster and Rattus rattus were caught on each of the trap sites on Elliott Key. Only R. rattus was captured on Little Totten Key. The red-bellied squirrel appeared to be extremely trap-shy and nest surveys at all sites studied indicated a higher population of squirrels than trapping results revealed. Trap success was greatly hindered by raccoons (Procyon lotor) at Ott Point and Elliott Harbor when using peanut butter and corn for bait. A change to sunflower seeds greatly reduced the raccoon problems while continuing to capture rats and squirrels.

Following 22 days of trapping at Elliott Harbor (1,056 trap-nights) only five squirrels had been caught, two females and three males. One of these females and two males were melanistic. None of these squirrels were captured more than once. As no recaptures were obtained, the standard Lincoln-Peterson index or more recent modification of this analysis could not be used to estimate population size. If the five squirrels captured represented the total number of residents present, squirrel density would be 1.06 animals/ha. This is slightly less than the 1.41 animals/ac (based on 46 animals captured following 46 trap nights) reported by McGuire for this site in February-March, 1972.

At Ott Point only two squirrels were captured on the trapping grid. However, seven recaptures of these squirrels were made. Both squirrels were female and of the melanistic color phase. Although the trap grid covered areas of both relatively mature tropical hardwood forest and densely vegetated regrowth area, all squirrel captures were in or immediately adjacent to the mature hardwood hammock in the northwest section of the trap grid (Figure 5). One female was captured four times at three locations. Both squirrels were caught at least once at two of the same grid locations. The maximum distance between recapture sites was 565 ft. Using the Schnabel (1938) formula for population estimate as described by Flyger (1959), population density for the entire trap grid would have been 0.24 squirrels/ha. Population density when considering only the area of mature hammock available was 0.36 animals/ha.

In mature forest adjacent to University Dock, four squirrels were captured following 21 nights of trapping with 48 traps (1,008 trap nights). Three squirrels, two males and one female, were melanistic, and the fourth was a gray female. No squirrel recaptures were made and therefore no population estimate formula could be applied. If the four squirrels represented the entire population present, squirrel density at this site would be 0.89 animals/ha.

Although the density of squirrels as indicated by trapping efforts appeared less than in 1972 when McGuire conducted studies on Elliott Key, the highest level of palm damage occurred around the grid where the most squirrels were trapped. However, the low overall success in trapping squirrels and the lack of recaptures at two trap sites makes these comparisons dubious.

Success in trapping black rats (Rattus rattus) was much greater at all sites. Twelve black rats were captured on the Elliott Harbor grid. Seven of these rats were recaptured one or more times. A breakdown of rat recapture frequency at each site trapped is shown in Table 7. Applying the Schnabel (1938) formula, with the Overton (1965) modification for population loss, an overall rat density of 3.21 animals/ha was determined for Elliott Harbor. Twenty-four rats were captured with only 438 trap nights of effort at Ott Point. Nineteen of these were tagged before release and 13 were recaptured one or more times. However, the larger area covered by the 200 ft interval grid at Ott Point resulted in an overall population density approximately equal to that observed at Elliott Harbor. At University Dock, the density of rats was found to be 5.44 animals/ha. This is based on 29 individuals totaling 160 captures (131 recaptures).

While some correlation of squirrel density based on captures and nest counts could be seen with palm damage levels, similar correlations with black rat population densities did not seem apparent. Past population density studies of Rattus rattus, outside of urban areas or agricultural situations, have been sparse but a density of 5.4 animals/ha does not appear to be unusually high (Mohr 1947, Krebs 1972).

To further investigate whether the black rat was a species responsible for palm damage, two tests were employed: (1) Trapping studies were conducted on Little Totten Key in an area surrounding a stand of undamaged thatch palms to verify the presence and determine the density of black rats; and, (2) Stomach content analysis were conducted on rats captured near damaged palms at Ott Point.

A high density of rats was found on Little Totten where squirrels do not occur. Twenty-five traps placed on a 30 m grid interval for 18 nights resulted in 39 total captures of 20 individuals. The 19 recaptures obtained resulted in an estimated population density of 10.1 rats/ha. This was the highest rat density of all sites investigated.

Stomach Analysis

Five black rats were captured in the immediate vicinity of damaged palms at Ott Point and the content of their stomachs analyzed. None of these rats had evidence of palm fiber in their stomachs. Stomach contents from each animal dissected are shown in Table 8.

Rodent Repellent Tests

To evaluate the feasibility of using a chemical repellent as a management tool to protect thatch palms, treatment tests were conducted on a select number of palms near Elliott Harbor. "Thiram 75" (Tetramethyl thiuram disulfide), a turf fungicide that has been found to repel rodents from golf course greens, was used in application tests. This repellent was recommended by the U.S. Fish and Wildlife Service, Gainesville, Florida. A 10% active solution (mixed with water) was applied by portable pressure pump sprayer to the crown of each palm treated. Initially, 13 *T. morrisii* which had varying degress of palm damage (classes 0-4) were treated. The trees were labeled as to date and degree of rodent damage at the time of spraying. Several undamaged thatch palms were sprayed to test the effect of the fungicide on the palms. Follow-up surveys of the treated palms were conducted for a one month period with no apparent harmful effect from the fungicide or further rodent damage observed.

Although the "Thiram 75" treatment served as a successful short-term deterent to palm damage, the frequency at which reapplications would have to be made appeared undesirable. "Thiram 75" has been effective against rodents when sprayed on golf courses where it is subjected to frequent watering for up to six months (pers. comm. Rick Owens, FWS). Under low rainfall conditions on the keys, it could be expected to protect palms for possibly more than a six month period. However, a resurvey of the treated palms during March 1978 revealed that 50% had increased in damage during the year. During May 1978, approximately sixty additional palms in the Elliott Harbor area were threated with "Thiram 75." Expansion of construction activities at Elliott Harbor interfered with evaluation of longer-term effectiveness of "Thiram 75."

CONCLUSIONS

The results of our study indicated that the problem of thatch palm damage on Elliott Key is severe with over 67% of the palms encountered being damaged to some extent and over 40% of the palms encountered either dead or damaged to the point that death is imminent. However, several factors indicate that the utilization of thatch palms has been a chronic problem with damage probably occurring for many years prior to the initial recorded observations in 1975. One factor is the large proportion of palms that were either dead or severely damaged so that death was imminent, while few palms (21%) were observed to be in early damage stages. The three years of monitoring of palm damage at Ott Point has supported this further in that the mean damage level for palms observed has fluctuated from year-to-year while accumulations of palms in the terminal or dead category increased. In addition, long-term observations of the rate of decay of dead palm stumps has revealed that many fallen stumps, which had characteristic signs of death from rodent damage (e.g., circular hole gnawed into heart area), were perhaps ten or more years old.

These results suggest that palm utilization continues at a chronic level and may vary in severity with squirrel population levels and/or availability of alternative food sources, nesting material and perhaps fresh water availability. The incidence and degree of palm damage would be expected to increase during particularly bad years when food and nesting materials are not abundant or during cyclic periods of high population levels. The overall level of palm damage at Ott Point appeared to decrease during the period monitored.

Rainfall greatly affects the availability of fresh water and to some extent the availability of alternate food sources. Rainfall data had only begun to be collected within the Park at the time of this study and it is not known how rainfall during this period related to long-term average conditions on the island. Records from the nearest mainland monitoring station (Homestead) indicated rainfall was above the long-term average in 1977, 1978 and 1979 (U.S. Geological Survey, 1976-79). A comparison of monthly rain totals collected within the park and the Homestead station is shown in Table 9. This comparison indicates that rainfall on the islands is generally less than that received at the Homestead station, but the changes in annual amounts received follow similar patterns. This would indicate that rainfall was probably also above average for the park islands during our study. The highest level of rainfall recorded for Elliott Key was during 1979, which may account for the decreased level of palm use observed during that year.

The rate of increase in the mean level of palm damage at Elliott Harbor and at Ott Point (Figure 6) was varied over our short period of study. Therefore a projected date when total palm loss would be expected could not be determined. In fact, the relatively high seedling germination observed may allow for sufficient replacement of lost palms during periods of low palm utilization to prevent total palm loss. Continued long-term monitoring of the marked palms on Elliott Key is needed to provide a clearer picture of overall trends in loss of palms.

The factors resulting in three distinct levels of palm damage on different areas of Elliott Key are not entirely clear. The highest mean number of squirrel nests/ha were observed near Elliott Harbor immediately adjacent to the high damage zone. This is also where the most squirrels were trapped. It is therefore felt squirrel density was highest in this area. However, the lack of squirrel recapture data prevents actual population estimates. Nest counts in the intermediate damage zone at the south end of Elliott (Nordt homesite) were not found to be higher than University Dock (low damage) and no evidence of a population difference was found between these area.

At least two other factors may also affect the amount of palm use by area. One factor is the availability of alternate food and/or nest lining materials mentioned earlier. Areas with a high number of mast producing trees or alternate nesting materials may have less demand for the palm. Another influence may be the density and distribution of palms. A high density and evenly distributed palm occurrence would tend to make the largest number of palms available within the home range of the largest number of individuals. The greatest distance between sites that McGuire (1972) trapped a single squirrel was approximately 360 m. The mean size of home range of 21 squirrels for which sufficient recaptures were available was 1.3 ha. Therefore, a clumped palm distribution would reduce availability of palms to many resident squirrels. The widest distribution of large numbers of palms did occur in the high damage zone north of Elliott Harbor. The clumped occurrence of the 200+ palms at Ott Point may account for their generally low damage level.

Although squirrels were found to be extremely shy and direct observation of feeding activity was mostly unsuccessful, the single observation obtained of a squirrel gnawing on a thatch palm provided conclusive proof that squirrels do feed on the palms. In addition, the observation of a squirrel stripping bark and gnawing stems of a pigeon plum tree revealed that squirrels were indeed responsible for such damage observed throughout the hammocks. These observations, combined with more tentative evidence of highest squirrel populations in high palm use areas and the marked recovery of palms coinciding with construction activities at Elliott Harbor, indicate that the red-bellied squirrel is the primary cause of the palm damage observed.

The high frequency of palm fiber lining in inner cavities of the squirrel nests examined indicates a high utilization of palms for this purpose. Nest lining materials are obtained by stripping the tough pliable fibers along the stalk of the frond near or at its emergence from the trunk and by stripping off the matting material from the trunk at the frond base. Early attacks on palms appear to be primarily for this purpose. However, following removal of several fronds, softer inner tissue surrounding the terminal bud becomes exposed. Further damage from this point appears to be for food or possibly moisture as the gnawing is normally concentrated onto one side and small chips are eaten off. This attack continues until a hole is eaten directly into the heart of the palm and the terminal bud completely destroyed.

It is concluded from the high population of black rats found on Little Totten Key (where no palm damage was evident) and the lack of correlation of rat density to palm damage levels on Elliott Key, that the black rat is not primarily responsible for the palm damage observed. However, the possibility exists that competition for food and/or nesting resources between black rats and squirrels may result in greater palm utilization by squirrels. This hypothesis could possibly be tested on Adams Key where nest counts indicated a high squirrel density but use of palms was not evident. Due to time constraints, trapping studies were not conducted on Adams Key to determine rat population levels. Such trapping studies, by determining density of rats, would reveal potential competition levels.

Trapping proved to be an unreliable method of estimating squirrel densities. This was due to a high level of interference of traps by raccoons, the large number of black rats captured thereby reducing net effort toward squirrels, and the apparent extreme shyness of the squirrels. Leaf nest surveys appeared to be a much more reliable and less time-consuming indicator of relative abundance of squirrels in an area. This is particularly true if an effort is made to determine recent use or construction of nests. Discussions of previous investigators on this technique have primarily centered around differences in the number of cavity sites available between forest areas which may affect the number of leaf nests constructed and on movement of independent juveniles following building of nests (Allen 1942, Fitzwater and Frank, 1944, Uhlig 1956, McGuire 1972). Uhlig (1956) concluded that juvenile gray squirrels build the majority of new nests and that the proportion of leaf nests built in the summer and early winter closely correlates with spring and summer rearing success. In monitoring squirrel populations at selected sites on Elliott Key, the interest would be in changes occurring at a given locality and, therefore, number of tree cavity sites would be relatively constant. It is also evident in the subtropical forests present on Elliott Key that natural den cavities are scarce. Brown and McGuire (1975) reported that much of the squirrel population appeared to rely heavily on leaf nests in the tree tops for shelter. Our observations support this conclusion. The fact that Elliott Key is an island restricts movement of juveniles and makes abandonment of early built nests less likely. Therefore, it is felt a nest monitoring program would be a sufficient procedure for long-term observations of changes in squirrel population levels.

The fungicide "Thiram 75" was effective in providing a short-term deterent to palm use. However, it appears that effectiveness of application could not be expected to exceed six months. In addition, a labor intensive effort would be required to protect significant numbers of palms on Elliott Key over long periods. Successful detering of palm use may also ultimately result in destruction of an alternative food or nesting material source. This is particularly true for alternative soft nest fiber which might be obtained by stripping bark from coconut, wild papaya, or a native tree species. A general treatment program for all palms with this fungicide is not reasonable, however the use of Thiram 75 may be desirable at certain localities or designated large palm stands.

MANAGEMENT RECOMMENDATIONS

Stated management policies of the National Park Service dictate that manipulation of population numbers of exotic plant or animal species, up to and including total eradication, will be undertaken whenever such species threaten protection or interpretation of resources being preserved in the park (NPS Management Policy Guidelines, 1978). Control programs are particularly encouraged against exotic species which have a high impact on protected park resources and where the program has a reasonable chance for successful control. However, careful consideration is required prior to developing control programs against exotic species which have almost no impact on park resources and where there is minimal probability for successful control. The exotic red-bellied squirrel population on Elliott Key has resulted in a high level of impact to a native palm species. This palm is considered by the Florida Committee on Rare and Endangered Plants and Animals to be threatened in its statewide occurrence. Therefore, control or total eradication of this squirrel is warranted. However, based on reported literature, successful control without major impact to other animal species is not a likely prospect.

Artificial control of small mammals to reduce negative impacts of their occurrence has been one of the most active areas of applied ecology or wildlife management. There is extensive literature on control through the use of toxicants, traps, and chemosterilants; of biotic control through the use of pathogens, predators, and vegetative manipulation; and of damage prevention through the use of repellents, frightening devices, and mechanical protectors of various kinds (Howard 1962 and 1967, Giles 1969, Woodzicki 1973, Golley et al. 1975, Borrecco 1976, Jackson 1976, Wagner 1976, and others). However, few of these techniques lend themselves to a park situation requiring preservation and little or no alteration of natural processes within the environment. In practically all reported cases, control has been implemented for either economical purposes involving agricultural crop loss or in urban situations relating to health problems. Seldom has control of small mammals been attempted in natural forest ecosystems. Attempts at eliminating or effectively controlling rodents by killing (e.g., shooting, traps, microbiological agents, toxicants, etc.) have been highly time and manpower consumptive and relatively unsuccessful (Jackson 1976). Management by environmental manipulation resulting in a reduced carrying capacity has been most successful (Borrecco 1976). However, environmental manipulation is the least desirable alternative to maintain a natural forest ecosystem. Therefore, a squirrel control eradication program or on Elliott Key could not have high prospects for success and would require a labor intensive effort.

It is felt that the squirrel population on Elliott Key is not likely to significantly affect the forest vegetative community beyond documented effects on thatch palms. Other studies have shown that small mammals in general have a minimal role in influencing forest ecosystem structure and function under natural fluctuating conditions (Potter 1976). Squirrels like most small mammals place major foraging emphasis on seeds, fruits, and buds of the vegetation. Under high squirrel population levels, destruction of these tissues may have more important consequences to future forest growth and energy flow patterns than that represented by the loss of the energy content of the tissue consumed. However, in mature forest, this effect is probably minimal (Potter 1976). In mature forest systems, significant numbers of seed may be destroyed in low seed production years but seed consumption normally does not limit regeneration in good seed years (Potter 1976). Bark consumption by rodents (such as the extensive gnawing of vegetation we observed throughout the hammocks) can result in girdling of trees and seedlings (Hamilton 1941); however, death due to girdling is more frequent among younger trees than old ones and has not been found to have much effect on mature forest (Potter 1976).

Impacts of the red-bellied squirrel on other fauna of Elliott Key are also probably not significant in most cases. The major predator on the squirrels are believed to be raptorial birds which, with the exception of the screech owl, are highly migratory and seasonal in abundance. The increased availability of prey items that the squirrels represent may allow for an increased concentration of raptors on the islands during winter. However, systematic routine raptor surveys during the winter season for several years are needed to document possible relationships to squirrel numbers. The only non-avian predator that is likely to consume squirrels is the raccoon. This consumption is probably limited to young discovered in nests considering the low agility of raccoons. The effect that squirrels may be having on reptiles and lower invertebrates utilized as food is unknown. This aspect of small mammal ecology has not been adequately studied in forest ecosystems. However, as with other predator-prey relationships, it is unlikely that squirrels significantly control the occurrence of their prey items (Krebs 1972, Golley et al. 1975, Potter 1976). An exception to this may be the squirrel's impact on the highly vulnerable Liguus tree snail. Representatives of this species are known to have once occurred on Elliott Key with a particular color phase (subspecies) named from the island. Recent efforts to locate live specimens of Liguus snails on Elliott Key have been unsuccessful. The loss of this snail on Elliott coincides with population increases in the red-bellied squirrels. Other park islands continue to support snail populations.

For the above reasons, I do not feel that an immediate intensive program directed at eliminating, the squirrel population on Elliott Key is warranted unless further impacts to the plant or animal communities are demonstrated. I recommend instead, to test the feasibility and determine best methods of eliminating squirrels on the smaller more recently established populations on Sands and Adams Keys. A monitoring program which evaluates both changes in squirrel numbers and the use of thatch palms on Elliott Key should be maintained. During years of stress on the island (e.g., low mast crops and/or rainfall) or during periods of unusually high populations of squirrels, temporary squirrel reduction through the use of toxicants or shooting could be made. During these periods, treatment of thatch palms with "Thiram 75" could also serve to protect larger stands such as those at Ott Point and south of Elliott Harbor.

Specific management actions needed in carrying out these recommendations are as follows:

1. Objective: Determine feasibility and method required to control or eliminate squirrels.

   Actions:

   a. Conduct literature search for best potential control methods.

   b. Secure NPS approval for implementation of control tests.

2. Objective: Determine long-term squirrel population changes.

   Actions:

   a. Conduct squirrel leaf nest surveys during the spring along 100 m transects at each of the following locations: Elliott Harbor (south woods), University Dock, Nordt House, Sands Key (south mature hammock), and Adams Key. A minimum of five transects should be established at each location.

3. Objective: Document continued level of thatch palm use.

   Actions:

   a. Conduct resurveys of marked thatch palms at Elliott Harbor and Ott Point during each spring.

   b. Mark a representative sample of thatch palms at a selected northern location on Elliott Key and near the Nordt Home site for inclusion in the annual monitoring program.

   c. Record degree of damage to each marked thatch palm in accordance with established rating criteria.

4. Objective: Detect and prevent further spread of squirrels.

   Actions:

   a. Conduct general surveys on all non-squirrel inhabited park keys with upland forest (Old Rhodes, Meigs, Totten, etc.) at least twice annually to detect possible spread of red-bellied squirrels.

   b. Upon detection, every effort should be made to insure that all pioneers are eliminated.

   c. Conduct test control programs on the more recently established populations on Sands and Adams Keys (see Item 5 for program requirements).

5. Objective: Determine potential stress conditions.

   Actions:

   a. Conduct annual surveys during April to record abundance of mast crops and evaluate potential food availability for squirrels. This will require development of a standardized evaluation rating criteria for known food items.

   b. Maintain accurate rainfall records for the park islands and evaluate regularly to determine periods of potential stress.

6. Objective: Reduce squirrel numbers during periods of stress.

   Actions:

   a. Initiate squirrel control efforts during periods of documented population stress or unusually high thatch palm use.

b. Develop and secure approval of a control implementation plan. Such a plan should outline specific methods and location of control efforts to be implemented.

7. Objective: Provide additional protection to thatch palms during periods of unusual squirrel population highs or stress conditions.

   a. Initiate a temporary palm treatment program utilizing the approved fungicide "Thiram 75." The largest concentrated stands of palms should receive highest priority for treatment during such periods. Palm treatments should include spraying at six month intervals until squirrel populations are reduced.

8. Objective: Determine the extent to which competition with black rats may be resulting in increased palm use.

   a. Conduct trapping studies on Adams Key to document black rat population levels and to obtain comparison of squirrel trapping success with nest counts. These studies should utilize Tomahawk No. 202 live traps placed on 100 ft grid intervals covering a minimum of 15 ac. For comparative purposes, this study should be conducted during the spring.

9. Objective: Determine relationship of squirrel populations to levels of predator bird species on Elliott Key.

   a. Conduct systematic raptor census on Elliott Key and other major park keys during winter months annually.

   b. Compare results of raptor surveys to squirrel population levels for possible correlations.

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Table 1. Numeric values and evaluation criteria for rating rodent damage to thatch palms on Elliott Key, Biscayne National Park, Florida.

Damage Rating	Extent of Damage
0	No apparent damage.
1	Gnawing at base of (1-3) fronds and/or gnawing on (1-3) flower buds.
2	More extensive gnawing at base of (4-6) fronds and/or flower buds.
3	Extensive gnawing to the base of (4-6) fronds with (1-4) fronds drooping as a result, some leaves gnawed as well. Extensive gnawing on flower buds and fiber around center crown of palm.
4	Extensive gnawing in center crown of palm including terminal bud. (In most cases a hole has been gnawed in the crown.)
5	Recently killed palm. Terminal bud has been severely gnawed. Stems of (1-4) fronds still attached and green.
Qualifiers	
T	Terminal bud has been gnawed off completely.
H	A large hole (2-4" dia.) gnawed into center crown.
Old	Dead palm with no signs of recent death. Fronds (1-3) still attached but all brown.
Stump	Dead palm stump with no fronds attached. Stump may be upright or lying on ground.

Table 2. Results of thatch palm damage survey conducted on Elliott Key, Biscayne National Park, Florida, during March 1977. Damage rating criteria are presented in Table 1.

Damage Rating	*T. morrisii*		*T. radiata*		Total	
	No. Trees	%	No. Trees	%	No. Trees	%
0	129	(17.5)	184	(83.2)	313	(32.7)
1	71	(9.6)	7	(3.1)	78	(8.1)
2	40	(5.4)	10	(4.5)	50	(5.2)
3	43	(5.8)	6	(2.7	49	(5.1)
3T	7	(0.9	0	-	7	(0.7)
4	37	(5.0)	0	-	37	(3.8)
4T	30	(4.0)	6	(2.7)	36	(3.7)
5	36	(4.8)	3	(1.3)	39	(4.0)
5H	41	(5.5)	0	-	41	(4.2)
5 old H	171	(23.2)	3	(1.3)	174	(18.2)
5 old T	64	(8.7)	2	(0.9)	66	(6.9)
Stump	66	(8.9)	0	-	66	(6.9)
Total	735	(76.8)	221	(23.2)	956	(100.0)

Table 3. Comparisons of palm damage based on weighted values for number of Thrinax morrisii in each damage class by hammock area of Elliott Key.

Damage Rating	Damage Value	WA		WB		EB		WC		EC		WD		WE		EE		WF		EF		All Areas	
		Weighted Values for No. Palms Observed* by designated area																					
0	1		0		0	(1)	1		0	(1)	1	(106)	106		0	(5)	5	(9)	9	(7)	7	(129)	129
1	2	(1)	2		0	(1)	2		0		0	(45)	90	(1)	2	(4)	8	(8)	16	(11)	22	(71)	142
2	3		0	(4)	12		0	(2)	6		0	(23)	69		0	(1)	3	(7)	21	(3)	9	(40)	120
3	4	(2)	8	(1)	4		0	(1)	4		0	(24)	96		0		0	(9)	36	(6)	24	(43)	172
3T	5	(1)	5		0	(1)	5		0		0	(4)	20	(1)	5		0		0		0	(7)	35
4	6		0		0		0		0		0	(31)	186	(2)	12		0		0	(4)	24	(37)	222
4T	7		0		0		0		0		0	(8)	56	(12)	84	(2)	14	(6)	42	(2)	14	(30)	210
5H	8	(3)	24		0		0		0		0	(8)	64	(29)	232		0		0	(1)	8	(41)	328
5T	9	(2)	18		0		0		0	(1)	9	(15)	135	(15)	135		0	(2)	18	(1)	9	(36)	324
50H	10	(6)	60		0		0		0			(4)	40	(143)	1430	(15)	150		0	(3)	30	(171)	1710
50T	11	(4)	44		0		0		0			(10)	110	(49)	539		0	(1)	11		0	(64)	704
S	12		0		0		0		0			(5)	60	(59)	708		0	(2)	24		0	(66)	792
Σ of weighted values			161		16		8		10		10		1032		3147		180		177		147		4888
No. palms			(19)		(5)		(3)		(3)		(2)		(283)		(311)		(27)		(44)		(33)		(735)
$\bar{x}$ damage value			8.5		3.2		2.7		3.3		5.0		3.7		10.1		6.7		4.0		3.9		6.7
Std. deviation			2.7		0.5		2.1		0.6		5.6		3.1		1.4		4.1		1.9		.5		32.8

*Number of palms within the damage class are indicated in parenthesis.

Table 4. Summary of investigations of red-bellied squirrel leaf nest on Elliott Key, Biscayne National Park, Florida.

Nest Size (cm)	Tree spp.	Approx. ht. above ground	Materials	Remarks
30 x 30 x 13	Mahogany	7 m	Mahogany leaves and twigs	No internal cavity; old and abandoned Passiflora vine entangled in nests. Ants. Some weaving of twigs at base. Old. No fresh vegetation
28 x 28 x 20	Mahogany	8 m	Outer: Mahogany leaves. Inner: *Casuarina* needles and palm (spp.?) fiber	Old. No fresh vegetation
36 x 36 x 25	Pigeon Plum	8 m	Outer: Mahogany leaves Pigeon Plum leaves Inner: *Casuarina* needles	Passiflora vine heavily entangled in nest.
33 x 33 x 25	Mahogany	7 m	Outer: Mahogany leaves Inner: Palm fiber and Mahogany leaves	Entrance at bottom. Old pigeon plum fruit in nest cavity. Extremely solid
28 x 28 x 30	Mahogany	7 m	Mahogany leaves and twigs	No internal cavity. Base of sticks (for support?)
	Sargent Palm	6 m	Outer: Mahogany, Milkbark Sargent Palm leaves Inner: Palm fiber and Mahogany leaves	Entrance on lower side. Opening 7-8 cm.

Table 5. Summary of squirrel leaf nest surveys conducted at four locations on islands within Biscayne National Park, January-September 1978

Location	Transect	Length (feet)	Width (feet)	No. Nests	Nests/ Ac.	Mean Density (Sd
Elliott Harbor	1	300	50	10	29.0	
	2	"	50	11	31.9	
	3	"	30	10	48.4	
	4	"	30	2	9.7	
	5	"	30	3	14.5	
	6	"	30	0	0	
	7	"	30	2	9.7	
	8	"	30	2	9.7	
	9	"	30	2	9.7	
	10	"	40	0	0	
	11	"	40	6	21.8	
	12	"	40	1	3.6	$\bar{x}$ = 15.7 (14.6)
University Dock	1	300	40	4	14.5	
	2	"	40	3	10.9	
	3	"	40	5	18.2	
	4	"	40	2	7.3	
	5	"	30	3	14.5	
	6	"	40	2	7.3	
	7	"	30	3	14.5	
	8	"	40	1	3.6	$\bar{x}$ = 11.4 (4.9)
Nordt Homesite	1	300	30	2	9.7	
	2	"	30	3	14.5	
	3	"	30	2	9.7	
	4	"	30	1	4.8	
	5	"	30	2	9.7	
	6	300	30	0	.0	
	7	"	30	1	4.8	
	8	"	30	4	19.4	$\bar{x}$ = 9.1 (6.0)
Adams Key	1	163	50	13	69.5	
	2	325	50	8	21.4	
	3	163	50	8	42.8	
	4	325	50	4	10.7	$\bar{x}$ = 36.1 (26.0)

Table 6. Summary of trapping results at four island sites within Biscayne National Park. Trapping studies were conducted utilizing Tomahawk No. 202 live traps placed on either a 30 m or 60 m grid interval.

Species/Location	No. Trap Nights	Total Captures	No. Individuals	No. Recaptures	Area Trapped (ha)	Estimated Density/ (ha)
Scuirus aureogaster						
Elliott Harbor	1056	5	5	0	4.7	1.06
Ott Point	438	9	2	7	8.7	0.86*
University Dock	1008	4	4	0	4.5	0.89
Little Totten Key	450	0	0	0	-	-
Rattus rattus						
Elliott Harbor	1056	23	12	11	4.7	3.21
Ott Point	438	52	24	218	8.7	2.72
University Dock	1008	160	29	131	4.5	5.44
Little Totten Key	450	39	20	19	2.3	10.13

*Density based on area of mature forest trapped only.

Table 7. Recapture frequency for the black rat (Rattus rattus) at four trapping study sites within Biscayne National Park.

	Times Recaptured												
Location*	1	2	3	4	5	6	7	8	9	10	11	12	Total Recaps
Ott Point	7	3	0	1	1	1	-	-	-	-	-	-	28
Elliott Harbor	4	2	1	-	-	-	-	-	-	-	-	-	11
University Dock	8	4	2	2	0	3	0	2	0	2	1	3	131
Totten Key	8	0	0	0	1	1	-	-	-	-	-	-	19

*Trap nights of effort were as follows: Ott Point 438, Elliott Harbor 1056, University Dock 1008, Little Totten Key 450.

Table 8. Results of stomach content analysis of black rats (Rattus rattus) captured at Ott Point, Elliott Key, Biscayne National Park, Florida, 1978.

Animal No.	Stomach Contents
Rat 1	Brown leaf fragments Green Leaf fragments Chitinous insect parts Sunflower seeds (trap bait)
Rate 2	Large plant tissue sheet Sunflower seed remains
Rat 3	Leaf fragments Insect fragments Sunflower seed (trap bait
Rat 4	Finely ground brown matter with leaf fragments Unidentified grey mass
Rat 5	Brown leaf tissue Sunflower seeds (trap bait)

Table 9. A comparison of rainfall observations made at two island locations and at park headquarters (Convoy Point) with those reported by the U.S. Geological Survey (1976-79) for Homestead during the period November 1976-June 1979.

		Inches of Rainfall			Homestead	
Year/Month		Elliott Harbor	Adams Key	Convoy Point	Reported	(36-39 yr Average)
1976	Nov.	3.49	3.11	2.76	2.73	(2.07)
	Dec.	1.32	1.93	1.43	1.28	(1.20)
1977	Jan.	1.15	1.80	1.53	1.38	(1.59)
	Feb.	2.35	1.01	1.89	1.59	(1.92)
	Mar.	1.94	0.88	1.53	0.74	(1.97)
	Apr.	0.27	0.66	0.20	1.02	(2.90)
	May	10.18	15.62	5.08	16.17	(6.42)
	Jun.	7.08	7.06	8.19	6.84	(9.56)
	Jul.	6.59	4.02	5.21	6.71	(7.79)
	Aug.	7.03	8.00*	10.70	11.95	(7.84)
	Sep.	10.57	4.83	6.74	10.70	(9.27)
	Oct.	3.90	3.09	1.50	1.58	(7.37)
	Nov.	6.17	7.09	5.08	2.98	(2.09)
	Dec.	11.71	2.31	1.97	1.66	(1.21)
Annual Total		58.94	56.37	49.62	63.32	(59.93)
1978	Jan.	4.90	3.33	3.88	2.17	(1.61)
	Feb.	3.63	3.00*	4.62	5.22	(2.01)
	Mar.	2.78	2.41	2.62	3.11	(2.00)
	Apr.	9.10	4.75	5.21	2.96	(2.35)
	May	6.92	4.75	2.92	7.06	(6.44)
	Jun.	2.47	4.57	3.50*	10.24	(9.58)
	Jul.	4.11	1.83	2.07	5.61	(7.73)
	Aug.	4.19	6.58	5.45	9.18	(7.88)
	Sep.	1.62	2.29	8.88	8.96	(9.26)
	Oct.	10.96	10.50	5.87	6.77	(7.36)
	Nov.	2.55	2.11	1.90	1.83	(2.03)
	Dec.	6.13	5.52	3.25	1.75	(1.23)
Annual Total		59.36	51.34	50.17	64.86	(60.03)
1979	Jan.	3.07	2.67	2.46	1.41	(1.60)
	Feb.	0.90	1.17	0.33	0.39	(1.98)
	Mar.	1.06	0.67	0.40	0.35	(1.96)
	Apr.	14.10	5.80	8.18*	12.88	(3.10)
	May	7.78	4.23	8.25	7.53	(6.40)
	Jun.	3.44	2.47	1.87	2.60	(9.40)
Six Month Total		29.85	17.00	21.54	25.66	24.44

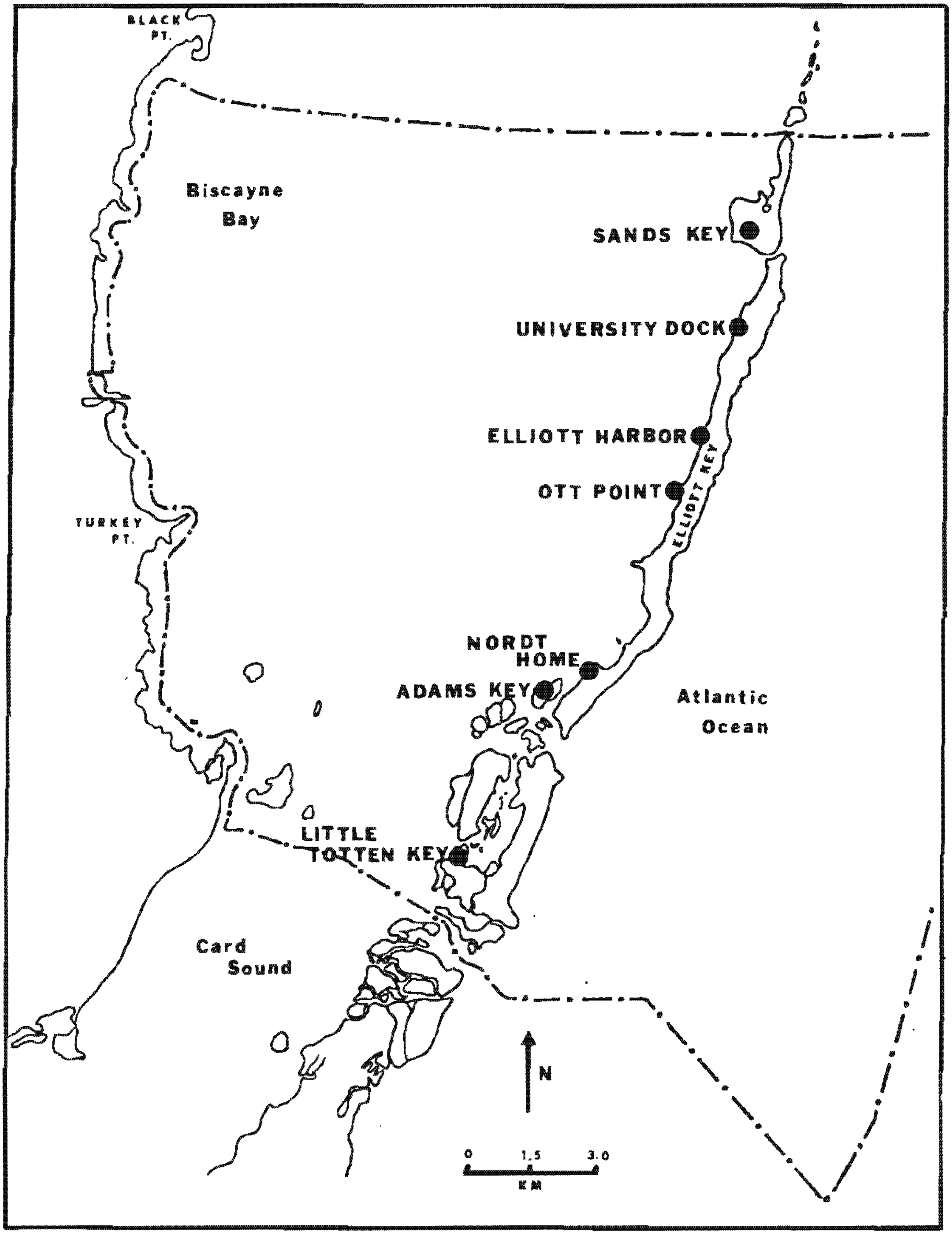

Figure 1. Biscayne National Park, Dade County, Florida. Palm damage studies were conducted on Elliott, Sands, Adams and Little Totten Keys. Rodent trap sites were located at Ott Point, Elliott Harbor, and University Dock on Elliott Key and on Little Totten Key.

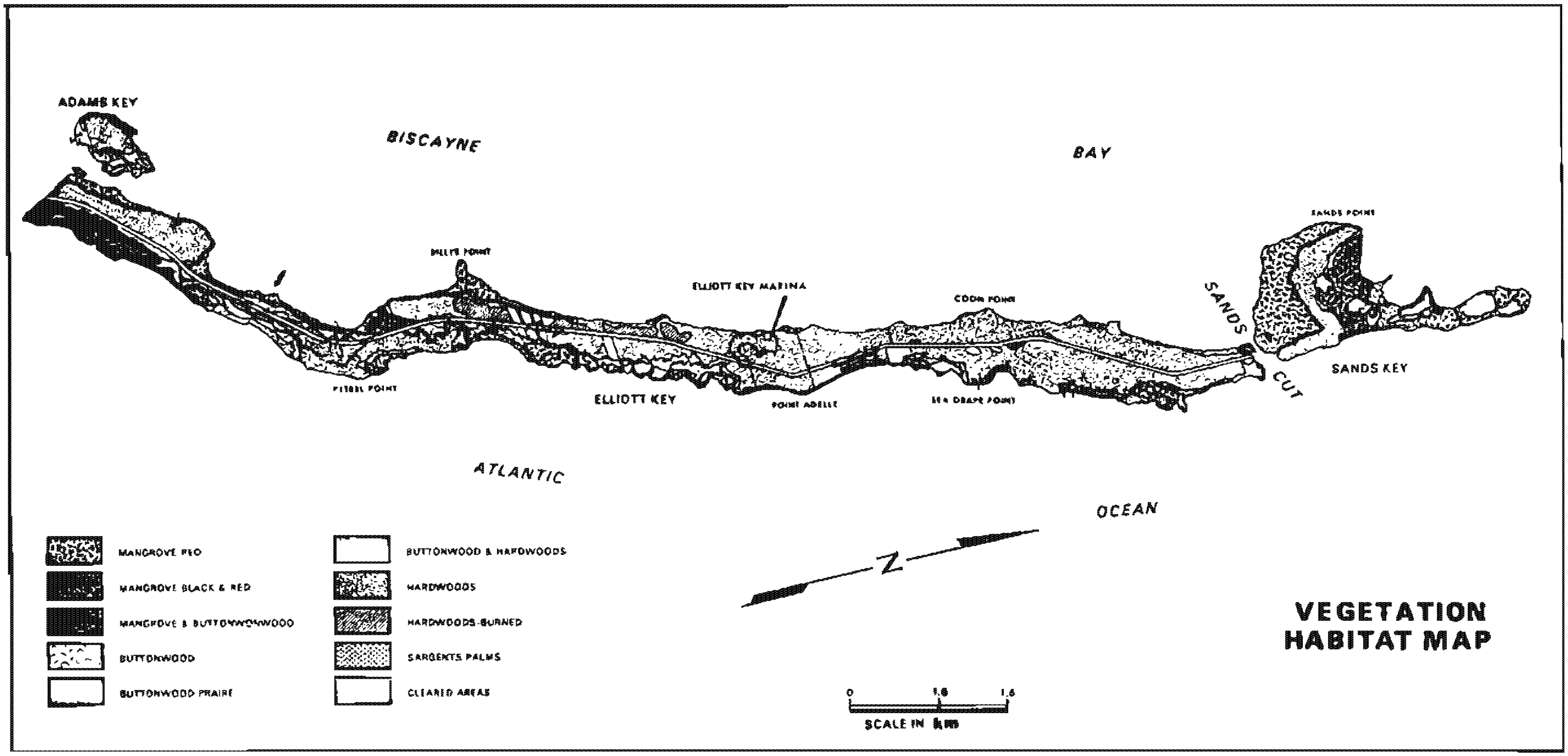

Figure 2. Elliott Key, Biscayne National Park, Florida. Vegetation habitat map showing interrupted distribution of hardwood forest areas.

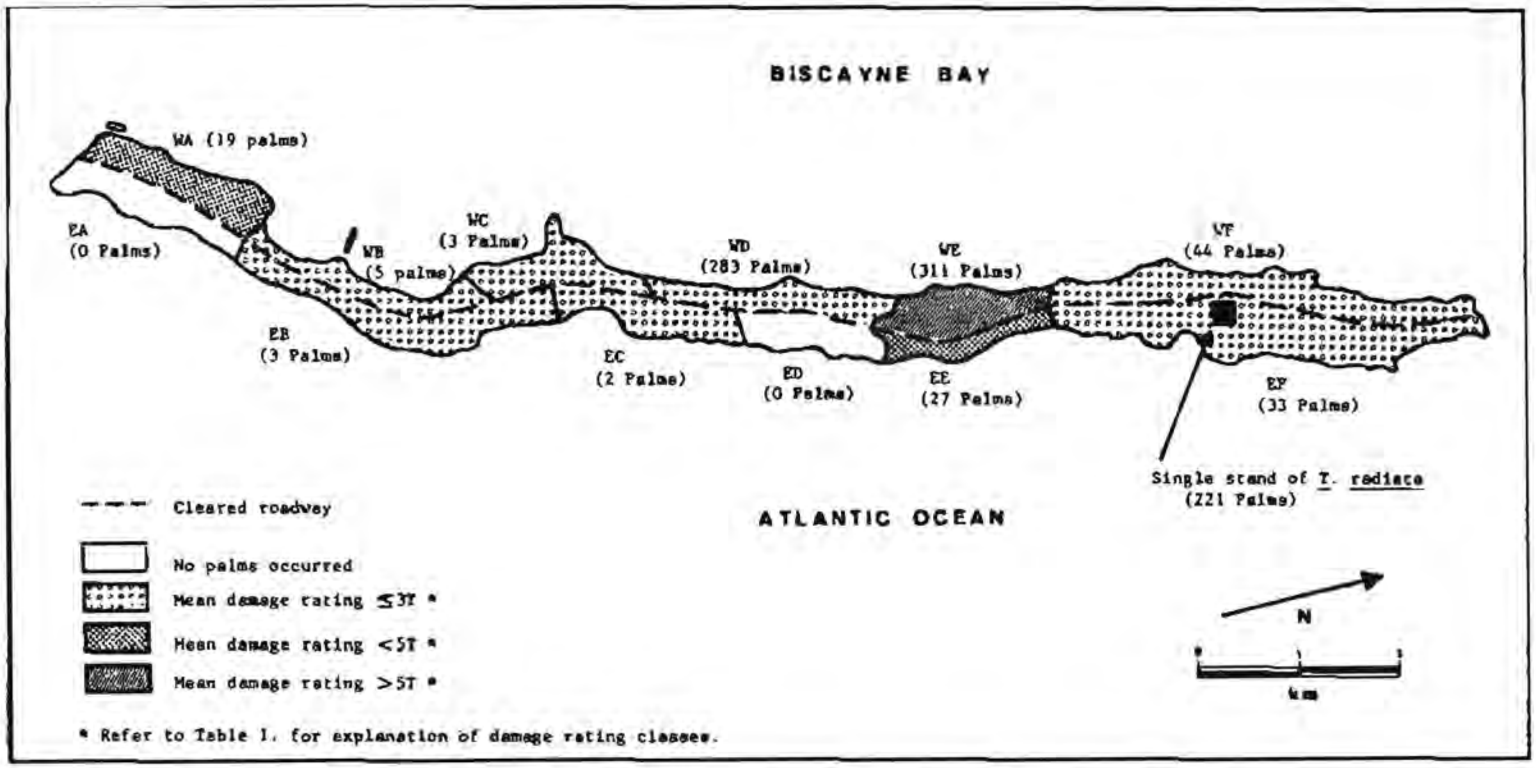

Figure 3. Elliott Key, Biscayne National Park, Florida. Distribution of three distinct levels of palm damage observed. Discrete forest areas used in statistical analysis are indicated by letter designations. Number of T. morrisii in each area are indicated in parenthesis.

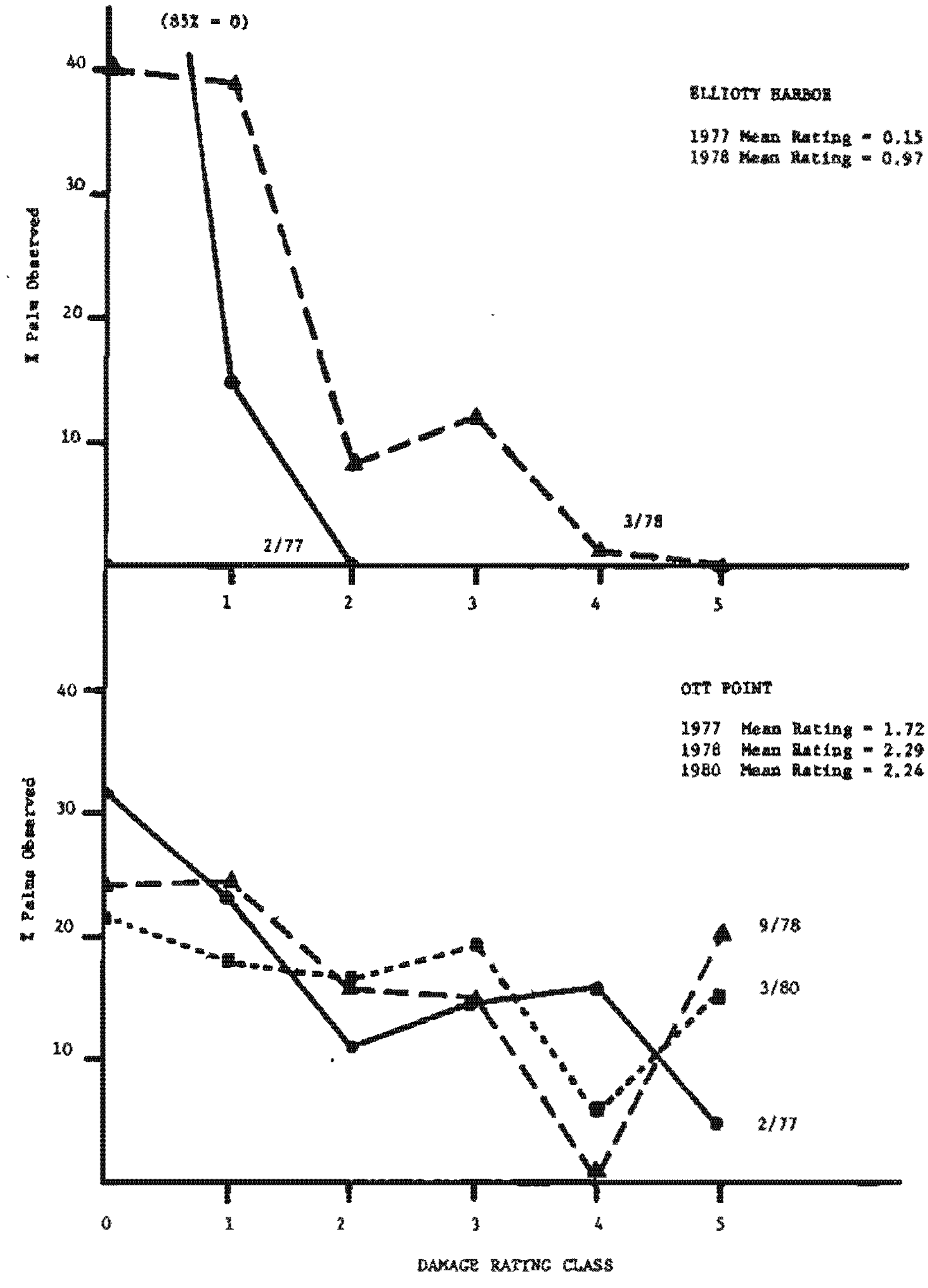

Figure 4. Comparison of changes in palm damage levels observed at two study sites during the period February 1977 through May 1978.

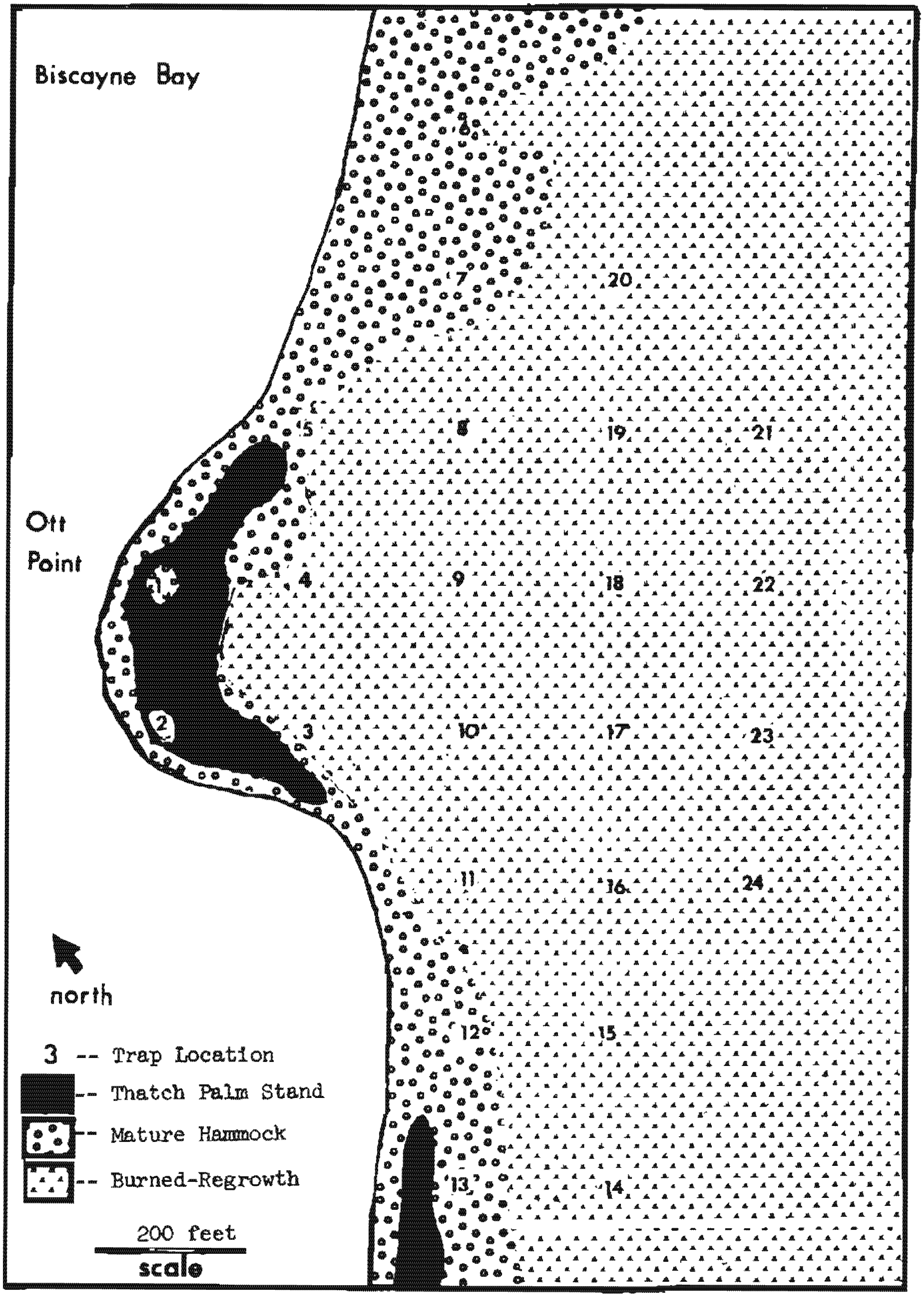

Figure 5. Trap grid established at Ott Point on Elliott Key in Biscayne National Park. Shown are portions of the grid located in each vegetative type.

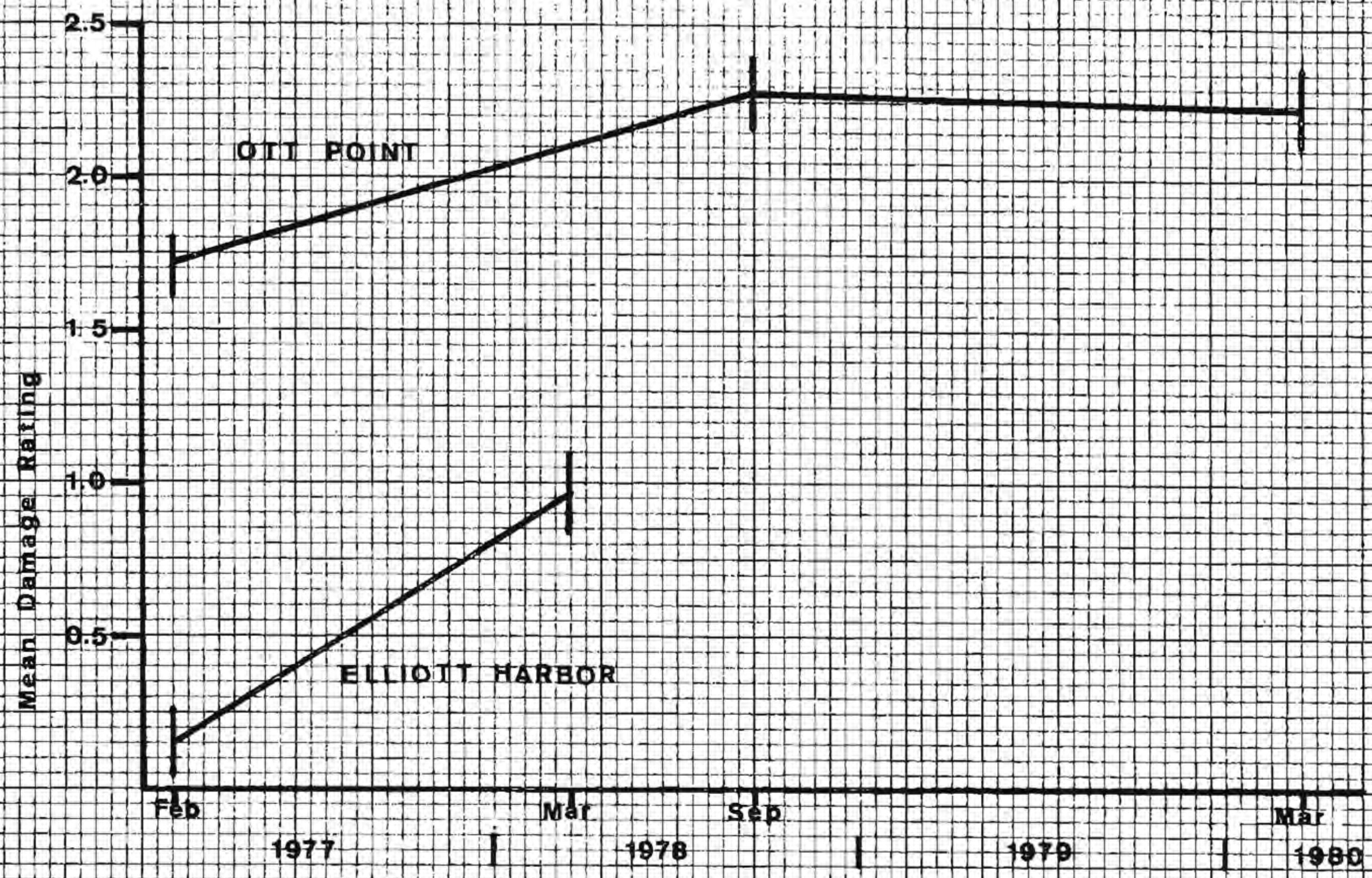

Figure 6. Change in mean palm damage rating observed at two study sites where marked thatch palms were monitored during the period February 1977-March 1980. Standard error of the calculated means are indicated by vertical bars.