POPULATION DENSITY, MOVEMENTS, AND HABITAT UTILIZATION OF KEY DEER, *ODOCOILEUS VIRGINIANUS CLAVIUM*

by

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INTRODUCTION

During the past several years the Key deer, Odocoileus virginianus clavium (Barbour and Allen 1922), has increased in numbers following a low population level in the late 1940's and early 1950's (U. S. Fish & Wildlife Service Narrative Reports 1939-1967; Dickson 1955). This response occurred after the deer were protected from intense hunting and disturbance to the population.

In December 1967, W. D. Klimstra initiated a study of the ecology of the endangered Floria Key deer. The objectives of the study were to determine: (1) movement and dispersal of the deer; (2) social behavior and organization with emphasis on their effects on population dynamics; and, (3) the reproductive and survival potential of the subspecies. Secondary objectives were to: (1) initiate nutritional studies; (2) determine trends in population size; (3) evaluate techniques for capturing animals; and, (4) accumulate miscellaneous data on life history and ecology.

Staff of the CWRL were in residence on Big Pine Key during January 1968 through mid-September 1968 and from December 1968 through December 1971 and, subsequently, periods for 2 weeks to 6 months during 1972 and 1973. Emphasis was on capturing, marking, and monitoring pregnant does and newborn fawns, transplanting deer and collecting vegetation samples. This dissertation results from data gathered from December 1968 through December 1971, when I was in residence on Big Pine Key; additional data were gathered on six trips for periods of 1 to 2 weeks during 1972 through June 1973.

My primary objectives were to: (1) determine daily and seasonal movement and dispersal; (2) determine monthly ranges and correlate these

with vegetation zonation; (3) study the population density of the herd; and, (4) evaluate the effects of social and reproductive behavior on movements, ranges, dispersal and habitat utilization.

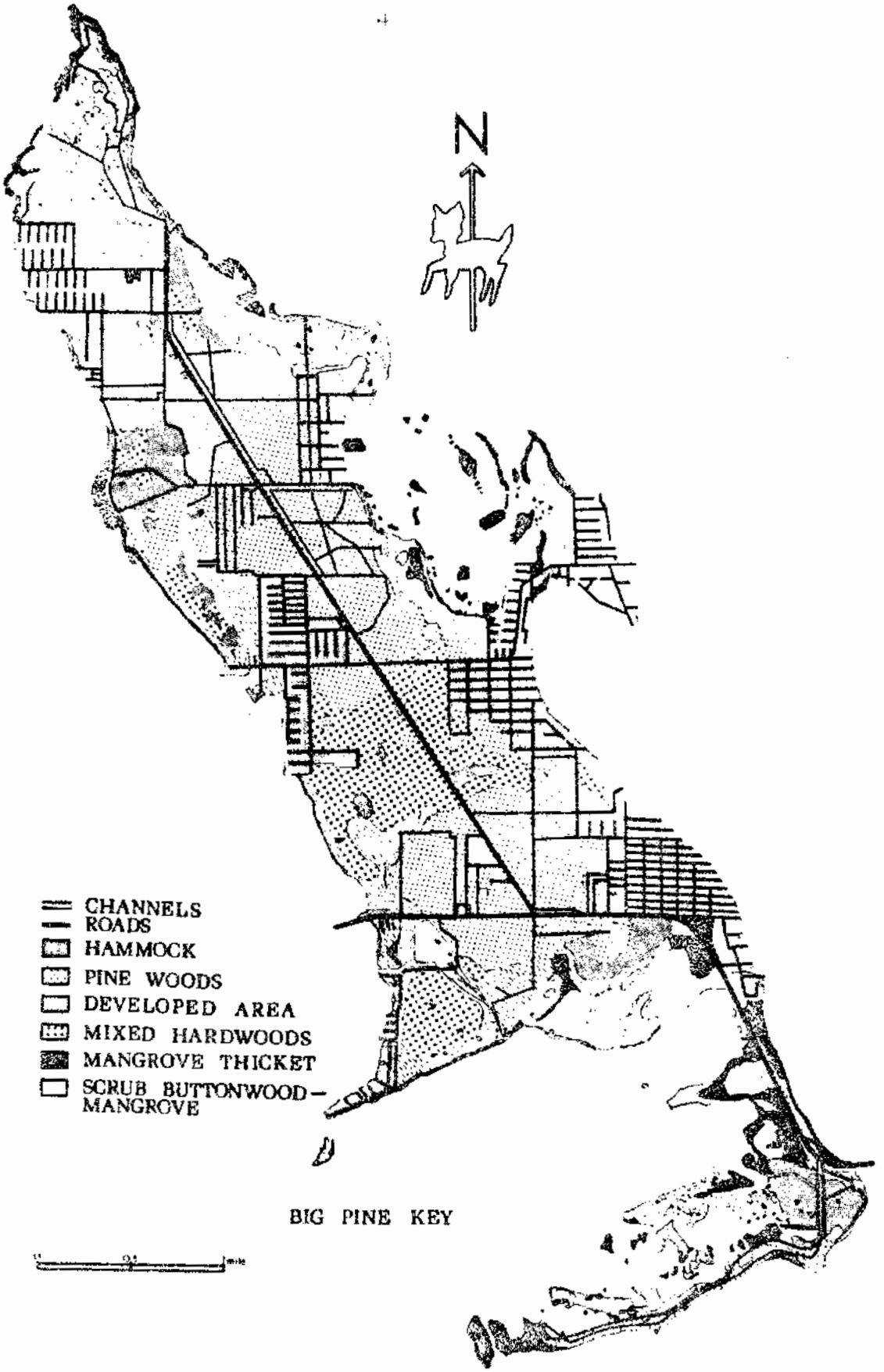
Prior to my study, the lack of data on the basic requirements of the Key deer precluded effective management. Only one technical paper (Dickson 1955) had been published on the Florida Key deer. Dickson (1955) described the soils, climate, water conditions and the plant ecology of the islands in the Key deer range; and food habits on the basis of general observations, signs of browsing and limited pellet analysis. He reported only limited data on life history and population density because the herd was much smaller than during my study.

Data from my study are available to the Fish and Wildlife Service for use in future management of Key deer. Techniques utilized were evaluated to provide insight to the validity of the results.

DESCRIPTION OF STUDY AREA

The study area, located in the lower Florida Keys, Monroe County, Florida, is within the boundaries of the Key Deer and Great White Heron National Wildlife refuges. Hoffmeister and Multer (1968:1489) presented a detailed account of the geology and possible origin of the Florida Keys, reporting that much of the Keys including Big Pine Key was low lying, rising only 2 to 3 feet above high tide.

Big Pine Key, the major area of research, is approximately 130 miles southwest of Miami. It is 2 miles wide at the widest point and 8.3 miles long (Figure 1) and includes about 6,000 acres (Dickson 1955:20). It has the highest elevation of the lower keys (10 ft.), and consists of an exposed oolitic limestone, laminated crust, except along its southern end where coral reef rock appears at the surface (Hoffmeister and Multer 1968:1500). Little soil covers the majority of the oolitic layer except where humus has accumulated. Numerous offshore dredging operations, to make "new land", and the conversion of mangrove areas into residential areas, are found along much of the privately owned coast. The construction of boat canals in subdivisions along the periphery has allowed salt water to intrude into the interior of the island. From January 1964 through December 1965, over 100 miles of ditching were completed by the Monroe County Mosquito Control District (Jack Watson, Refuge Manager, personal communication). These ditches are about 16 inches wide, 4 feet deep, vertical-sided (Figure 2), and permit tide water to flow in from the sea (Alexander and Dickson 1973). These ditches increase salt intrusion into the substratum and the rate of rain runoff and, thus, reduce penetration of fresh water into the vegetative root zone (Alexander and Dickson 1973:91). In numerous areas on Big Pine, these ditches are partly or


N
CHANNELS
ROADS
HAMMOCK
PINE WOODS
DEVELOPED AREA
MIXED HARDWOODS
MANGROVE THICKET
SCRUB BUTTONWOOD-MANGROVE
BIG PINE KEY

completely blocked by roads and fire lanes. When flushed by rain, they greatly increase the amount and distribution of fresh water available to deer.

U. S. Highway 1, across the south end of Big Pine Key, and State Road 940 running almost 3/4 the length of the island, plus fire lanes and entry roads to subdivisions, provide access to much of the Key (Figure 1), making possible vehicular access within 0.5 mile of all parts of the Key.

The flora of the Florida Keys had its origin to the south, in the Caribbean, and was translocated by the sea and birds and, to a lesser extent, by man (Stern and Brizicky 1957:44). The vegetation is derived mostly from Cuba (Simpson 1920:47). Stern and Brizicky (1957) concluded that, in the Keys, variation in the ability to withstand salt is of prime importance in plant distribution. They stated that the hammocks and pinelands are probably composed of plants with little or no salt tolerance. These areas are usually inland and thereby less subject to the effect of salt spray. Stern and Brizicky (1957) were also of the opinion that the pinelands on Big Pine Key would evolve into hammocks if fire were excluded. Fire usually destroys most hardwood vegetation associated with the pines; but the pines and palms appear to be only partially damaged by fires. The degree of damage to pine and palms is dependent on the severity of the fire and the accumulation of fuel since the last fire.

Nine plant communities including pineland, hammock, southeast point hammock, regrowth burned pineland, land previously cultivated, grass prairie, transition zones, open scrub type mangrove-prairie and beach dune communities were recognized by Dickson (1955). Yaw (1966) combined Dickson's habitat types into six: mangrove thicket, open scrub, buttonwood park, open-mixed hardwood, hammock and pinewoods. I combined Yaw's (1966)

open scrub and buttonwood park and recognized an additional type; open-developed areas. Common and scientific names of plants used herein follow Long and Lakela (1971).

Mangrove Forest

Young mangrove forests usually contain only red mangrove (Rhizophora mangle) (Figure 3) but older swamp forests show a typical trizonate configuration (Dickson 1955:14). This species begins its growth in shallow water and generally yields to black mangrove (Avicennia germinans) at about mean tide level. Mixed with the black mangrove are white mangrove (Laguncularia racemosa) and a few trees of buttonwood (Conocarpus erecta). The black mangrove grades into white mangrove and buttonwood at high tide level (Dickson 1955:14).

Scrub Mangrove-Buttonwood

This habitat includes the buttonwood prairie (Dickson 1955), the salt water marshes (Stern and Brizicky 1957) and the open scrub and buttonwood park (Yaw 1966). Such areas are typically found between the dense peripheral mangrove forest and the hardwood areas above high tide level. Although the buttonwood prairie (Figure 4) is rarely inundated, most vegetation in this habitat is resistant to salt (Dickson 1955). Near the dense mangrove forest, the vegetation is dominated by small red, black and white mangroves plus the saltwort (Batis maritima) and glasswort (Salicornia perennis). Further inland these plants are replaced by buttonwood, dropseed (Sporobolus virginicus), key grass (Monanthochloe littoralis), sea oxeye (Borrichia arborescens and B. frutescens) and sea-purslanes (Sesuvium portulacastrum and S. maritimum).

Hammock

Hammock areas on Big Pine Key are characterized by dark soils rich in humus up to 20 inches deep (Stern and Brizicky 1957:41). Hammocks were cultivated in the early 20th century and provided crops of limes and pineapples (Simpson 1920). On Big Pine Key extensive hammock areas with a luxuriant growth of vegetation are found at the southeast point, the north end, Doctor's Arm and Watson Hammock (Figure 5). These forests, dominated by broadleaved evergreen trees, are limited to relatively small areas and contain a great variety of tropical species (Stern and Brizicky 1957:45). Gumbo limbo (*Bursera simaruba*), Jamaican dogwood (*Piscidia piscipula*), poisonwood (*Metopium toxiferum*), pigeon plum (*Coccoloba diversifolia*), devil's claw (*Pisonia aculeata*), cupania (*Cupania glabra*), snowberry (*Chiococca alba*), and beef-tree (*Pisonia discolor*) are prominent species.

Hardwood

This habitat consisting of immature hammocks is confined to areas free from salt water inundation (Figure 6). Humus accumulations (1 to 10 inches) are not as deep as in mature hammocks; but, many of the same plants are found in both areas. The most distinguishing feature is the absence of mature gumbo limbo trees and the abundance of tallowwood (*Ximenia americana*), joewood (*Jacquinnia keyensis*), milk buckthorn (*Bumelia celastrina*), poisonwood (*Metopium toxiferum*), wild dilly (*Manilkara bahamensis*), Spanish stopper (*Eugenia myrtoides*), sea grape (*Coccoloba uvifera*), darling plum (*Reynosia septentrionalis*) and blackbead (*Pithecellobium keyense*).

Pineland

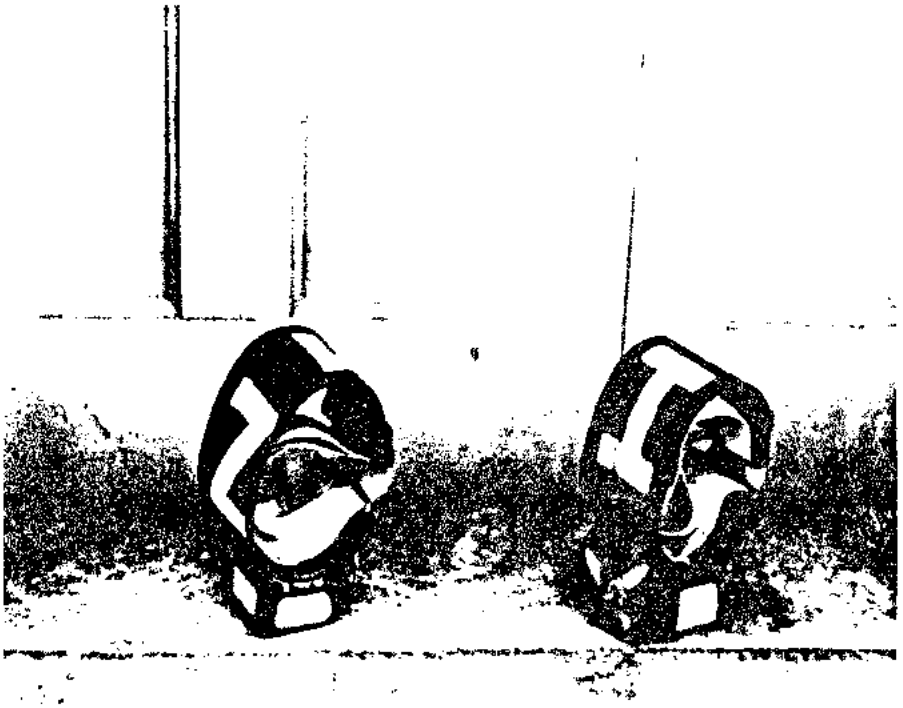
Pineland includes both pines (Figure 7) and regrowth vegetation in

burned pineland. Dickson (1955:20) stated that open pineland comprised 38 percent of Big Pine Key; during my study, pineland formed 32.4 percent. Limited humus accumulates in this area and the laminated oolitic limestone is exposed throughout except in areas free from fire for long periods. Pinelands are found on central, higher elevations of Big Pine Key. Numerous "solution holes" or "lime sinks" of varying sizes caused by irregularly dissolved limestone occur in pinelands (Stern and Brizicky 1957:41). Organic matter collects and decays at the bottoms of these holes. Because these depressions are somewhat protected from fire, a layer of soil forms in them supporting an entirely different flora from the surrounding area. Characteristic vegetation is saw palmetto (*Serenoa repens*), sawgrass (*Mariscus jamaicensis*), and buttonwood. An occasional solution hole may be 10-15 feet deep with a layer of fresh water lying over salt water. Surface water levels fluctuate with the tide, but in some holes all the water is fresh.

Dominant vegetation within the pineland (Dickson 1955) includes slash pine (*Pinus elliottii*), silver palm (*Coccothrinax argentata*), indian grass (*Sorghastrum secundum*), white indigo berry (*Randia aculeata*), Christmas berry (*Crossopetalum ilicifolium*), pineland croton (*Croton linearis*), yellow root (*Morinda royoc*), love vine (*Cassytha filiformis*) and locust berry (*Byrsonima cuneata*).

Open-Developed Areas

This habitat includes all man-made clearings, land fills and plantings (Figure 8). Representative vegetation includes purslane (*Portulaca oleracea*), finger grass (*Chloris petraea*), crowfoot grass (*Dactyloctenium aegyptium*), yard grass (*Eleusine indica*), Brazilian pepper tree (*Schinus*



terebinthifolius), nightshade (Solanum blodgetti and S. americanum), burmarigold (Bidens pilosa), sandspur (Cenchrus echinatus), mallow (Sida acuta), pepper grass (Lepidium virginicum), blue porterweed (Stachytarpheta jamaicensis), beardgrass (Andropogon glomeratus), yellow top (Flaveria linearis), coral dropseed (Sporobolus domingensis), morning glory (Ipomoea acuminata), creeping charley (Lippia nodiflora), aster (Aster tenuifolius), busy fleabane (Pluchea odorata), and pigweed (Amaranthus sp.). The introduced Australian pine (Casuarina equisetifolia) has invaded some marl fills and marl along mosquito ditches.

MATERIALS AND METHODS

Live-trapping and Tagging

Deer were live-trapped to attach ear tags, ear streamers, collars and radio transmitters. A portable drive net was the most used trapping device (Silvy et al. 1975). However, the capture gun and crossbow were used early in the study for remote injection of drugs. Nicotine salicylate, noted for its quick action and the characteristic excitement produced, and M 99, with its low mortality rate, were both used.

Nylon-net, metal-framed trail traps and a metal-framed net drop trail trap were also employed. All were set by a monofilament trip line that triggered dual door drop mechanisms of the trail traps or the metal frame of the net drop trail trap, respectively. In addition, "suspension" net trail traps were used in areas where other techniques proved impractical. These consisted of 40 x 40-foot square nets placed in a major deer trail under a large tree. Pulleys and ropes attached to a 150 lb. weight were used to set the net trap. A trigger mechanism consisting of a number 3 steel trap sprung by a monofilament trip line released a sensitive trigger mechanism that suspended the weight. The net rose as the weight fell. These traps were checked morning and evening to reduce long exposure of animals.

Hand capture of deer proved effective. Young-of-the-year were susceptible when alone along roadways at night and were easily confused with lights and the vehicle noise. Fawns less than 2 weeks old were readily captured when located; most fawns were found by tracking radio-tagged does.

With the exception of young fawns, captured deer were taken to the

Refuge headquarters for marking and attachment of transmitters. Each deer was placed in one of three classes: fawns, yearlings and adults (Severinghaus 1949). April 1 was arbitrarily designated as the birth date, as fawning occurred mainly in April and May (Hardin 1974). All captured deer, with the exception of two animals used in a study of salt tolerance and seven deer transplanted to other islands, were released at the site of capture immediately after processing.

Deer were marked by several methods. Initially, 50 deer were marked with a 10 x 1-inch nylon colored ear streamer held in place by a 1.5-inch square white plastic cattle ear tag. Ear tags were self-locking and numbered consecutively with contrasting black numbers. Tags were affixed through a hole in the ear made with a hole punch. Later in the study, a small (1 x 1.25-inch), red, self-locking, natural-colored aluminum, consecutively numbered tags (1.125-inch) were used to mark deer. Numbers were painted black to contrast with the aluminum tags.

Beginning in 1969, 207 deer were tattooed on the inside of one ear with dies containing 0.4-inch numbers or letters. Three digits were used to mark deer individually, except that very small fawns were marked with a single letter; when later recaptured, these were number-tattooed.

A collar made of Boltaron (thermal plastic) was first used in December 1968. Collars were made to fit the neck contours of deer in each age and sex class. With does, the open ends of the "U"-shaped collar were riveted (brass rivets). Where growth and expansion of the neck had to be accommodated in the cases of fawns and bucks in rut, elastic straps were placed on the inside of the collar and attached by rivets at the bottom of the "U". These straps passed through brass rod guides embedded in the open ends of the plastic collar, permitting expansion and contraction.

Because these collars sagged in time, a "C"-shaped collar was designed with ends overlapping at the side of the neck with elastic bands to resist expansion to the point of completely opening the "C" (Figure 9). This allowed for the weight of the collar and/or radio to be supported by the Boltaron and not by the elastic.

Collars were made of two thicknesses (0.090 inch and 0.125 inch) of Boltaron and of two colors (black and white). Various colors of scotch-lite reflective tape in the form of numbers, letters or other symbols were attached to collars for ready identification of deer during both day and night. Radios were mounted on, and antennas embedded in, the Boltaron collar.

Fawns were marked with a 1 x 1.25-inch Boltaron strip riveted to one end of an 8-inch piece of nylon elastic. The loose end of the nylon elastic was riveted to the Boltaron after being placed around the animal's neck. Radios with small whip antennas mounted to the Boltaron strip comprised the radio package.

Two styles of sheep bells were attached to deer by means of nylon elastic straps. Ends of the strap were riveted together after being placed around the neck.

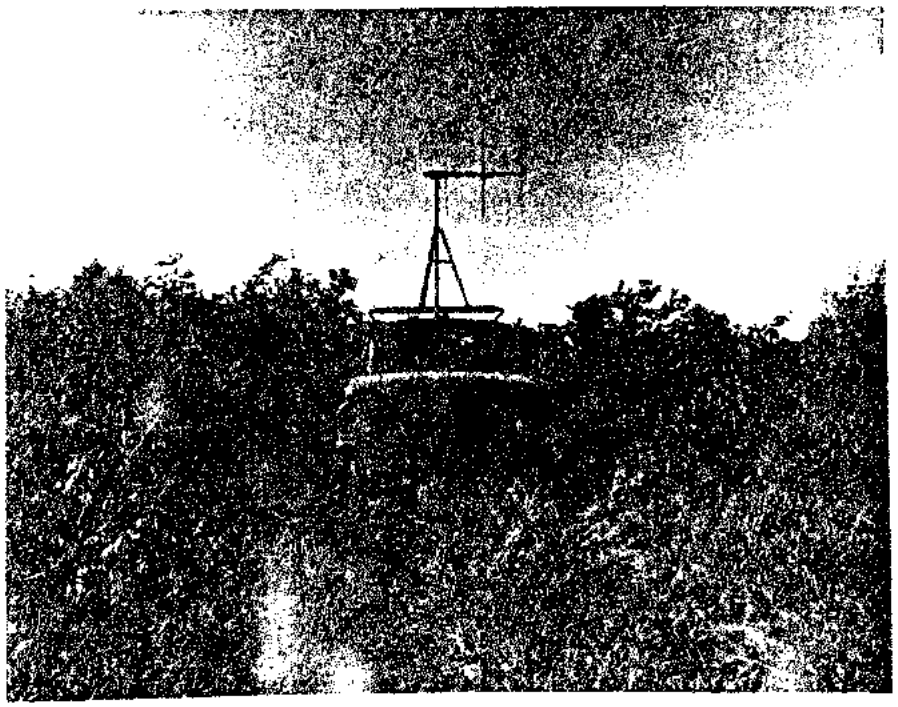
Radio Telemetry

Twenty adult males, 38 adult does, 7 yearling males, 6 yearling females, 31 male fawns and 17 female fawns were trapped for radio tracking. The receiving system consisted of two 12-channel A.V.M. receivers and two Hy Gain Model 23, 2-meter, hand-held and truck-mounted antennas designed by A.V.M. Electronics Corporation, Champaign, Illinois. Transmitters were built by W. H. Cochran, A.V.M. Electronics Corporation, and James Buitt.

Transmitters were pulsating broadcasters and operated at discrete frequencies between 148.000 and 148.300 megacycles/second with a power output of 0.91 watts. A crystal oscillator circuit transistor and a 12-inch wire antenna constituted each transmitter. Transmitters were powered by either four or six, 1.4-volt mercury batteries. The receivers were 12-channel transistorized, crystal controlled, double conversion super-heterodyne mechanisms, powered by eight size AA penlight batteries. The receivers weighed approximately 3 pounds and were contained in an aluminum case, 9 x 4 x 5 inches. Receivers were equipped with both a small speaker and a phone jack for audible detection of transmitters. A signal strength meter permitted visual detection of transmitter signals.

Transmitters for adult animals were designed to operate 300-600 days and provide a minimum range of 1 mile. Three stage transmitters used later were designed for greater field life and distance. Adult radio packages weighed up to 454 grams, depending on the use of two-stage or three-stage radios; the latter required more batteries. The use of 11-inch, stainless steel whip antennas was discontinued in favor of copper wire embedded in the Boltaron collar. A test was made of one radio powered by solar cells.

Newborn fawns were radio-marked with single-stage "quail" radios (17 grams) mounted on a 1 x 1.5-inch piece of Boltaron with a 0.30-inch diameter, 8-inch long steel cable, whip antenna (Figure 10). These units, attached by elastic bands around the neck, had a theoretical life of 30 days with one battery and provided a signal range of approximately 0.12 mile. With increase in size, fawns were equipped with larger battery packs for longer transmitter life. After about 9 months of age, fawns were equipped as adults.



All lost and non-operating radios were replaced when animals could be recaptured. In addition, radios on adult bucks were replaced prior to and following the rut, when bucks were most readily captured.

Mobile receiving stations were directional yagi antennas mounted through the roof of a pickup truck cab (Figure 11), with a lead-in cable. Radio-tagged deer were located by circling and obtaining bearings from different locations; each animal location was plotted on a map in relation to landmarks. Success and accuracy depended on the layout of access roads. A hand-held antenna (the same antenna as used in the mobile station) was used to locate deer to check physical condition and behavior, and to determine precise habitat utilization.

Movements

Radioed deer were monitored for 24-hour periods at random intervals (Random Numbers Table) to evaluate movement and habitat utilization. Each 24-hour period was divided into six equal 4-hour segments; one 4-hour segment was randomly selected and during that time deer were located. These radio-determined locations, plotted on maps, provided a record of location for each animal.

Average distances in feet between successive daily locations were used to calculate a movement index for each deer. This index was a relative measure of an individual's movements compared to others of the same or different age and sex classes. Movements overlapping successive months were recorded as belonging to the earlier month.

The size of range by month, and major and minor axes of the range, were calculated for animals for which there were 15 or more locations per month. Range size was calculated using Mohr's (1947) technique. All

inland water areas were included in range estimates. The major axis was determined by measuring the straight line that connected the two most distant locations for each animal and the minor axis was the widest point in the range perpendicular to the major axis.

A total range (Mohr 1947) for each deer was calculated using data collected throughout the study. The percent monthly use of the total range by each animal provided a measure of range increase or decrease.

Observations and road mortalities for 223 marked animals were used to determine movements of animals on and off Big Pine and No Name keys. Surveys on outlying keys and tracking of transplanted deer provided further information on movements.

Habitat Use

Habitat portions within monthly ranges were determined from an overlay of monthly range outlines on a vegetative cover map (Figure 1). The mean percent habitat composition of monthly ranges served as an index to habitat utilization for each sex and age class.

Effects of sunrise and sunset on utilization of habitat were measured by separating the day into three periods based on official sunrise and sunset at Key West, Florida. The period between sunrise and sunset was taken as 100 units, with sunset to midnight given positive values greater than 100; then, negative values beginning with -1 were assigned from sunrise to the previous midnight. In this way, data collected at different times of the year, as day length varied, were comparable.

To determine the effect of weather on use of habitat, cloud cover, wind speed and direction, and moonlight were recorded. Cloud cover was subjectively classed as light, medium or heavy. Wind speed was divided

into light (0-5 mph), medium (5-15 mph), strong (15-30 mph), and extra strong (over 30 mph) categories; wind direction was referred to eight compass points. Moonlight was recorded as no moon, quarter moon, half moon, three-quarter moon and full moon. If cloud cover obscured the moon, data were recorded as no moon. Maximum and minimum daily temperatures, as well as rainfall data, were obtained from the Big Pine Key Area Weather Station.

Deer were located in various plant cover types as described by Yaw (1966) and Johnson (1967) and as updated in my study to reflect land development through December 1968 (Figure 1). Further habitat changes were identified by comparing these data to data compiled during June 1973 (Table 1).

Population Density

A weekly 10-mile road census was conducted at 2230 hours over a predetermined route within the refuge on Big Pine Key from June 1968 through June 1972 (Figure 12). This census was completed in 1-1.5 hours depending on number of deer observed and attempts to capture. Two persons, spotlighting from opposite sides of a vehicle, observed and recorded deer by age and sex; those that could not be classified were recorded as unidentified. Sightings of marked deer were recorded and in most cases they were individually identified.

From January through December 1971, a biweekly 44-mile road census covering all major roads on Big Pine key (Figure 12) was run twice a day, beginning 1 hour before sunrise and again at sunset. These censuses were designed to estimate the density of the deer population on Big Pine Key.

Ten pellet transects (Neff 1968) 0.1 mile by 20 feet were established

Table 1. - Summary of habitat types of Big Pine Key, Monroe Co., Florida, prior to January 1969 and of land cleared from January 1969 through June 1973.

Habitat Type	Available Habitat Prior to January 1969 (in acres)	Land Cleared January 1969-June 1973 (in acres)
Developed	1,506(49)*	418(24)
Subdivisions	1,060(48)	366(22)
Roads	146(46)	49(23)
Fire lanes	31(75)	none
Canals	87(64)	3(49)
Mosquito ditches	182(40)	none
Hammock	223(62)	none
Buttonwood	1,386(58)	36(32)
Mangrove	579(48)	95(5)
Hardwood	698(21)	57(43)
Pinewood	1,384(60)	178(22)
Totals	5,776(50)	418(24)

*Percent of this area on Big Pine Key found within the boundary of the Key Deer National Wildlife Refuge.

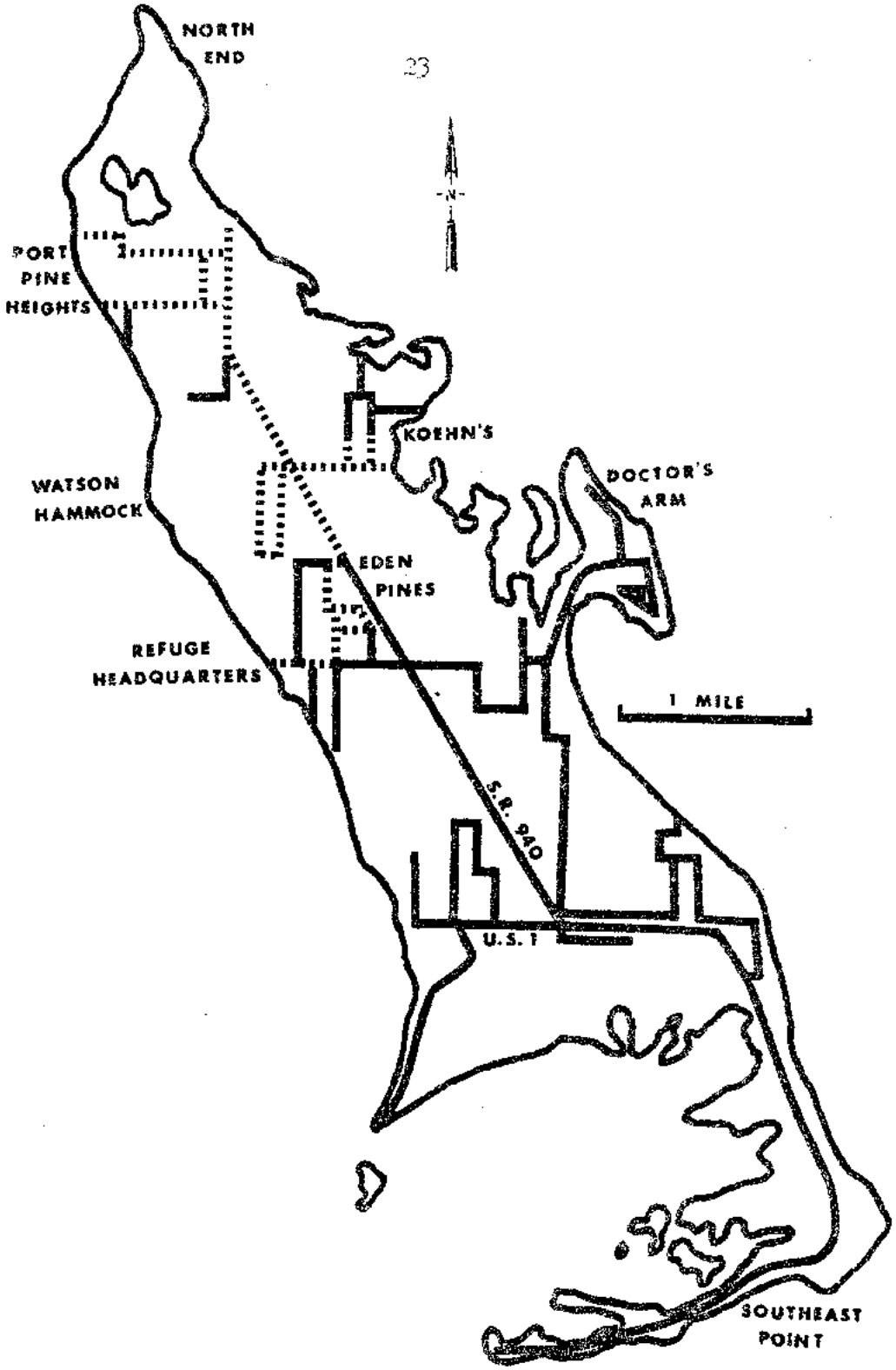


Figure 12. Outline map of Big Pine Key, Monroe Co., Florida, showing roads traversed during 10-mile census (broken lines), and during sunrise-sunset census (broken plus solid lines), June 1968-June 1972.

on refuge land in February 1969 to determine deer use of major vegetation types. Pellets were removed prior to the establishment of the transects and, while the transects were being examined, at 3-month intervals.

Islands other than Big Pine Key were visited to estimate number of deer, to evaluate deer activity and to determine habitat utilization. No Name Key was visited almost daily.

The population size was estimated by applying the Schumacher-Eschmeyer method to deer found dead. The number of deaths per year was used as an aid in estimating population trends.

Data Analysis

All locations of deer were coded on IBM cards. Data recorded for each radio-marked individual included identification number, sex, age, date, time, vegetation type, minimum and maximum daily temperatures, cloud cover, moonlight, wind direction and speed, rainfall, reproductive and social behavior (Hardin 1974). The analyses were performed on an IBM 370 computer. Analysis of variance, Scheffe multiple comparisons, and Chi-square tests, plus minor computations, were made on an Olivetti Programma 101 desk-top computer.

Statistical tests followed methods in Glass and Stanley (1970); all analyses were conducted at a 0.05 level of significance. Differences among ranges, major and minor axes, and movements were determined by analysis of variance (ANOVA) and Scheffe multiple comparison tests unless otherwise stated. Chi-square tests were used to determine whether or not a difference existed between habitat utilization and availability, effects of time of day on habitat use, weather effects on habitat use and the difference between habitat composition of ranges and available habitat.

When referring to data by seasonal quarters, the first quarter (winter) includes January through March, the second (spring) April through June, the third (summer) July through September, and the fourth (fall) October through December. In most tables, data are presented beginning with the second quarter so that a continuous record is presented for each animal through the year, until it enters the succeeding age class.

EVALUATION OF LIVE-TRAPPING METHODS

Deer were captured 364 times; 131 were recaptures (Table 2). The productivity and efficiency of trapping techniques depended on mortality, availability of canals, density of habitat, availability of large trees, time required to capture and process each animal, and cost.

Of the seven techniques employed, the portable net in conjunction with hand capture was most productive (Silvy et al. 1975). However, use of the portable net was possible only when deer were cornered between canals. This technique resulted in only three known deaths out of 227 captures.

The use of nicotine provided the possibility of capturing deer in most habitats; but, 6 of 23 deer captured died. Variability in the concentration of nicotine supplied by the manufacturer may have caused some mortality. In areas where no other method is feasible, nicotine drugs might be justified even with a 26 percent loss of animals, especially in areas lacking canals.

Of the 15 animals drugged with M99, none was captured. Because of the dense vegetation and the long time from injection until the animal collapsed, all animals escaped.

Although eight deer were taken in trail traps, the time (2 hours per trap per day) required to check traps was excessive; this technique killed one animal. Five animals escaped from traps either by breaking through the mesh or through mechanical failure of the door-drop mechanism. The "suspension"-net trap was useful for capturing deer in areas where other techniques were impractical; however, the distribution of large trees determined its usefulness. A radio-tagged doe was observed to discontinue use of a well-used trail after being trapped in such a device. This was

Table 2. Summary of capture data by method and sex and age class for Key deer, Key Deer National Wildlife Refuge, Monroe Co., Florida, January 1968 - June 1973.

Capture Method	Animals Captured							Ratio			
	Total	AM*	AF	YM	YF	FM	FF	Buck:Doe:Fawn	YM:YF	FM:FF	AF:YF
Portable net	227	45	88	27	20	34	13	0.67:1:0.44	1:0.74	1:0.38	1:0.23
By hand from canal	21	7	9	0	1	1	3	0.70:1:0.44	0:1	0.33:1	1:0.11
By hand	88	10	6	0	3	49	20	1.11:1:7.67	0.00:3	1:0.41	1:0.50
Capture gun (nicotine)	14	3	6	1	3	1	0	0.44:1:0.11	0.33:1	1:0	1:0.50
Crossbow (nicotine)	3	1	1	0	1	0	0	0.50:1:0	0:1	------	1:1
Box trail trap	3	1	0	0	0	2	0	0.50:0:1	------	2:0	------
Suspension trail trap	3	0	2	1	0	0	0	0.50:1:0	1:0	------	2:0
By hand from between islands	2	0	1	0	0	1	0	0:1:1	1:0	1:0	1:0
By hand from vegetation exclosure	1	0	0	1	0	0	0	1:0:0	1:0	------	------
By hand after hit by automobile	2	0	0	0	1	1	0	0:1:1	0:1	1:0	0:1
Totals	364	67	113	30	29	89	36	0.65:1:0.88	1:0.97	1:0.40	1:0.26

*Sex and age classes: AM = adult males, AF = adult females, YM = yearling males, YF = yearling females, FM = fawn males, FF = fawn females.

an advantage as unwanted recapture was avoided. However, the trail traps were not selective for individual deer and their operation was demanding both in time and regularity in scheduling. Difficulty was experienced with protection of these traps; one net suspension trap was mistaken as poaching and destroyed by concerned citizens; a second trap was stolen.

Hand-capture of animals was effective for deer under 6 months old (Table 2). Considerable time was necessary to locate susceptible animals, and the method was most effective at night when fawns could be confused by lights and the vehicle motor.

Techniques used were sufficient for life history, mobility, and dispersal studies. Difficulties arose recapturing individual deer to attach a collar or radio, and in capturing individuals in areas where the portable net could not be used.

Capture Mortalities

Of captured animals, six (3 yearling females, 1 adult female, 1 yearling male and 1 male fawn) died from nicotine salicylate; one adult male died when its neck was broken after entangling antlers in the trap netting; and three animals (1 adult male, 1 yearling male and 1 male fawn) died after running into the trapping vehicle (Table 2). One yearling male, found in a vegetation exclosure, was killed because its jaw was broken and one adult doe recaptured by hand was killed because it was blind. Three animals (1 adult male, 1 adult female and 1 male fawn) died from injuries caused by the portable net. The death of two other adult males may have resulted from capture and handling techniques.

Times and Areas where Deer were Captured

Attempts were made to capture deer at every opportunity. Seventy-eight

percent of captured animals were trapped between 2200 and 0659 hours (Table 3). Of 81 deer trapped between 0700 and 3159 hours, 59 (73 percent) were fawns. Initially, deer were sought at all hours, day and night; later, trapping effort was concentrated in those hours in which more efficient results were achieved. Future trapping effort should be concentrated during these hours.

Of 233 deer captured for the first time, 208 were taken within refuge controlled lands or in subdivisions surrounded by these lands. Seven of the 25 animals not caught on refuge lands were taken on No Name Key. Port Pine Height Subdivision supplied most captures (100) followed by Eden Pines (43) and Koehns (39) subdivisions (Figure 2). Of 131 animals recaptured, only 3 were captured south of the refuge boundary. Eighty-eight animals were recaptured in Port Pine Heights, 26 and 8 being recaptured in Eden Pines and Koehns subdivisions, respectively. Future trapping effort should be concentrated in Port Pine Height, Eden Pines and Koehns subdivisions.

Table 3. Summary of hours when Key deer were captured, Key Deer National Wildlife Refuge, Monroe Co., Florida, January 1968 - June 1973.

Hours When Captured	Total	AM*	AF	YM	YF	FM	FF
0100 - 0159	26	4	13	2	2	3	2
0200 - 0259	17	7	5	0	2	1	2
0300 - 0359	11	2	4	0	2	1	2
0400 - 0459	26	6	12	2	1	3	2
0500 - 0559	55	9	20	4	6	12	4
0600 - 0659	22	7	3	6	1	5	0
0700 - 0759	4	2	0	0	1	1	0
0800 - 0859	3	0	0	0	0	1	2
0900 - 0959	12	1	2	0	0	4	5
1000 - 1059	7	0	0	0	0	5	2
1100 - 1159	6	0	1	0	0	5	0
1200 - 1259	5	0	1	0	0	3	1
1300 - 1359	0	0	0	0	0	0	0
1400 - 1459	3	0	0	0	0	3	0
1500 - 1559	2	0	0	0	0	1	1
1600 - 1659	4	0	1	2	0	1	0
1700 - 1759	9	0	1	0	0	6	2
1800 - 1859	8	0	0	0	1	5	2
1900 - 1959	1	0	0	0	0	1	0
2000 - 2059	11	2	2	0	0	5	2
2100 - 2159	7	3	0	0	1	2	1
2200 - 2259	19	1	8	1	4	5	0
2300 - 2359	65	12	24	8	6	10	5
2400 - 2459	41	10	16	5	2	7	1
Totals	364	66	113	30	29	90	36

*Sex and age classes: AM = adult males, AF = adult females, YM = yearling males, YF = yearling females, FM = fawn males, FF = fawn females.

EVALUATION OF TAGGING METHODS

All 233 deer captured alive were collar-marked except for 1 animal that received only an ear tag and streamer, and 1 animal that received only an ear tattoo. Of the 233 deer marked, 50 were recaptured once, 8 twice, 10 three times, 4 four times, 2 five times and 1 adult buck six times. These recaptures allowed an evaluation of tagging methods.

Ninety percent of 78 ear tags and streamers were lost, largely due to tissue damage and deterioration of the ear caused by the tags. No streamer endured for 2 years. Although one of 50 white plastic ear tags stayed on about 3 years, 95 percent were lost. The aluminum metal ear tag, used on 184 deer later in the study, was still on one animal after 3.5 years; but, 25 percent were lost within 1 year. One small red metal tag affixed before this study, was still on an adult doe almost 5 years later. All 27 recoveries from deer that were number-tattooed for over 3 years showed such identification held up well.

Due to the salt water, leather collars (10) quickly rotted, lasting from 1 to 5 months. The maximum life of six plastic-coated nylon collars was 9 months, although one was known to be lost within 1 week after tagging. "U"-shaped Boltaron collars lasted longer on does than on bucks. On bucks with radios they (17) lasted from 2 to 10 months; without an attached radio, between 4 and 11 months. The necessity of expansion collars for males and fawns presented difficulties. The rubber in the nylon elastic of "U"-shaped collars stretched due to the constant weight of the transmitter and/or collar. Once the elastic failed, the collar hung below the animal's neck and allowed a foot to become entangled and the collar was usually lost. Collars without radios gave better service as they were lighter. Radioed "C"-shaped collars were observed to last from 6 months

to 2 years; without a radio, they lasted 9 months to 2.5 years.

Few (2 percent) Boltaron collars were lost from adult does. Those lost were light weight (0.090-inch) plastic while all heavy-weight (0.125-inch) Boltaron collars were on for almost 4.5 years. Three of 13 doe collars with radios were being carried, though not transmitting, after 3 years.

Two fawns carried collars for 2 years after attachment with no problems. In both cases, the elastic had broken down and had stretched to accommodate the increase in neck size. Five fawns carried bells for about 1 year. These bells were extremely useful in locating an animal; however, complaints by residents about bells tinkling during the night required removal.

Only 1 percent of the collars on breeding, adult males lasted through the rut; loss was due to fighting. Occasionally split rivets straightened and separated, or the elastic frayed, allowing a collar to become loose-fitting, and to catch on branches. Loose collars caused abrasion on the animals' necks; one tight collar caused an infection and blindness.

Scotch-lite reflective tape was never lost from a collar. It was not possible to find enough distinguishable numbers, letters, and symbols of white reflective tape to mark individually a large number of deer. The 3-inch-wide collar limited the space for numbers that were large enough to be seen readily; but, collars large enough for two numbers caused neck abrasions and inhibited neck movement. The use of different colored reflective tape (white, red, blue, yellow and green) on black and white Boltaron collars solved some of the problem. Color combinations of reflective tape and colored Boltaron were difficult to distinguish at night

under artificial light, and therefore could not be used. White reflective tape on a black collar was the most readily distinguished combination. Yellow on black, red on white, blue on white and green on white were readily distinguishable in the order listed (Klimstra 1974).

EVALUATION OF THE RADIO TELEMETRY SYSTEM

Of 187 radios placed on 119 deer, 98 were recovered, 38 were still being carried by animals when field observations were terminated, and 51 were either lost or were on animals not seen during the last 6 months of field study. The maximum number of deer bearing functional transmitters at one time was 41 during May 1971.

Average field life of the radios was not determined as attempts were made to replace radios at every opportunity after 8-9 months to insure continuous data. Two radios failed immediately and one radio operated continuously for 20 months; two radios placed on adult animals, but subsequently lost due to collar design, continued to transmit for nearly 2 years.

Stainless steel whip antennas were not suitable for use in the Keys because of salt corrosion and breakage. Embedding antennas in the Boltaron collar virtually eliminated that problem; however, this reduced the range by 25 to 30 percent. Two-stage transmitters provided a working range of 0.5 to 1 mile whereas three-stage radios could be located up to 2 miles. Fawn radios had a working range of 0.25 mile and a life of 30 days, making it necessary to replace them at 20-day intervals.

The one radio powered by a solar cell stopped transmitting at night after 2 weeks. Thereafter it worked only when the solar cells were in direct sunlight. The heavy cover of most habitats prevented successful use of available solar cell radios.

Key deer adjusted to carrying transmitters immediately as no abnormal behavior, as described by Jeter and Marchinton (1964:147), was observed. The difference may have been more the result of capture techniques than transmitter attachment.

RATIONALE FOR MOVEMENT ANALYSIS

Comparing movement and range data for Key deer during this study with those of other studies was difficult because of the different deer and environment studied, the different methods utilized, and the differences in data analysis. The majority of movement studies of white-tailed deer in North America have been obtained through direct observation of deer or through tag returns; but, they have not made extensive use of indirect observation through telemetry. For example, Downing et al. (1969), noting that because much of the movement data collected was from hunter returns of tagged animals, suggested that much of this movement was temporary in nature, taking place only during hunt day. The limited radio-telemetry data on Florida deer (Marchinton 1964, 1968; Harlow and Jones 1965; Jeter and Marchinton 1964; Marchinton and Jeter 1966; and Bridges and Marchinton 1969) have all been short-term studies and therefore are not sufficient to evaluate deer movement patterns.

Studies in other parts of the country may not be comparable to my study because of the different habitat and subspecies of deer involved. The Key deer, located in a subtropical climate and habitat, is comparable to no other North American deer herd. The Key deer being an island subspecies made it even more difficult to compare movements and ranges with counterparts on the mainland.

The term "home range" was first used by Seton (1909:26) who pointed out that "No wild animal roams at random over the country; each has a home region, even if it has not an actual home." Burt (1940:25) defined home range as, "that area about its established home which is traversed by the animal in its normal activities of food gathering, mating and caring for young." The home range is too generalized and, therefore, monthly,

seasonal and annual ranges have been substituted. Few studies have provided data on seasonal changes in range and movements. Therefore, most studies imply that ranges and movements are static rather than dynamic, changing with time and season as well as differing with sex, age and reproductive status. Marchinton et al. (1970:76) stated that movement patterns and ranges could be delineated with about 2 months of radio-tracking, and thus did not view movement patterns and ranges as being dynamic.

Lastly, investigators seldom estimated movement or range by the same methods. During my study, ranges were estimated according to the minimum home range method (Mohr 1947) because it decreases the amount of subjectivity.

Sanderson (1966:231), in a review of mammalian movement studies, pointed out that biologists should lose some of their preoccupation with shape and size of range and distance of movement and should shift emphasis from the movements per se to the reasons for the movements. He further emphasized that, as shape and size of movement patterns are probably of little or no consequence, investigators should be studying the biological needs of the animal as related to time of year, varying weather, time of day and available habitat. During my study, movement and range data were analyzed with respect to these variables. Therefore, comparisons between my data and those of other investigators are in general terms only.

Changes in range size and movement indices for Key deer were correlated with sex, age and reproductive status. Range data were not considered as good as movement data as a basis for interpreting life history. However, when both kinds of data were available, greater accuracy in the interpretation of life history data was obtained. All consecutive daily

locations were used to obtain movement indices and, no matter how few for a given deer, represented that animal. However, range estimates varied with the number of locations for a given animal in a given month. A sample of 15 daily locations was considered sufficient to determine a monthly range because 15 locations usually represented at least 75 percent of the mean monthly range. Fifteen locations per month approximated the median 75 percent range area for 20 animals tested. However, great variation existed among individual deer; some animals reached 100 percent of their monthly range within the first 5 days of the month, whereas others did not reach this level until the last location of the month.

Another drawback in using range data was that a few "exploratory movements" outside a "normal" range might greatly distort the estimate of monthly range; but, such movements, when made over a period of days, probably did not greatly influence daily movement indices. If made in 1 day, an "exploratory movement" averaged out with all other consecutive daily movements and yielded a more accurate picture of monthly movements. Theoretically, a deer could have a large movement index and a small range or a small movement index with a large range, thereby giving a false impression of "true" monthly movements if only ranges were considered.

RESULTS AND DISCUSSION

Movement by Month and Season

From 58 deer continuously radio-tracked at random hours, 421 monthly ranges (Table 4) were estimated, and 470 monthly movement indices were obtained (Table 5). Ranges and movement indices were also obtained for a male fawn for 5 months following capture and translocation to Big Pine Key.

The major and minor range axes (Tables 6 & 7) provided a quantitative measure of shape for each range. Both the sizes and dimensions of ranges varied seasonally by sex and age classes. Movements of deer were correlated more with the width of the range ($r = 0.729$) than with the length ($r = 0.649$) or area ($r = 0.595$) of the range. However, the width of the area traversed by a deer gave a better indication of deer movements, the length gave a better indication of total area used.

Adult Male Movement

Adult males confined their movements to the smallest area in January and the largest area in September (Table 4). Area covered during April, May, September, October and November was significantly larger than that covered during other months. Areas used in winter were significantly smaller than those for other seasons. The largest area used by an individual adult male was 1,079 acres during September 1970, while the second largest was 724 acres during April 1969. The smallest area traversed was 30 acres during July 1969; the second smallest was 88 acres during January 1969.

The length of the area covered by an adult buck during a month varied from a low in January to a high in September (Table 6). The width of this

Table 4. Summary of mean monthly range (in acres) by sex and age class of Key deer, Key Deer National Wildlife Refuge, Monroe Co., Florida, 1969-1972.

Period	AM*			AF			YM			YF			FM			FF			All Deer		
	N	$\bar{X}$	S.D.	N	$\bar{X}$	S.D.	N	$\bar{X}$	S.D.	N	$\bar{X}$	S.D.	N	$\bar{X}$	S.D.	N	$\bar{X}$	S.D.	N	$\bar{X}$	S.D.
Apr	(10)	326	193	(12)	121	25	(7)	329	391	(4)	258	168	(1)	42	**	(1)	40	**	(35)	232	225
May	(10)	415	183	(15)	130	63	(6)	313	266	(4)	173	146	(4)	37	11	(1)	68	**	(40)	222	196
June	(10)	289	158	(15)	122	34	(6)	232	160	(4)	168	196	(3)	43	13	(1)	68	**	(39)	179	139
Spring	(30)	343	181	(42)	125	44	(19)	293	282	(12)	200	161	(8)	40	10	(3)	53	14	(114)	210	188
July	(10)	212	147	(16)	124	49	(5)	132	35	(4)	81	32	(4)	53	22	(1)	37	**	(40)	133	95
Aug	(11)	245	191	(18)	126	50	(3)	204	83	(3)	90	12	(4)	92	72	(1)	48	**	(40)	157	123
Sept	(7)	596	269	(17)	163	63	(2)	298	277	(4)	138	74	(6)	239	301	(1)	52	**	(37)	259	242
Summer	(28)	321	251	(51)	138	56	(10)	187	123	(11)	104	52	(14)	144	209	(3)	46	8	(117)	181	171
Oct	(5)	343	192	(17)	178	14	(2)	624	417	(4)	152	100	(4)	255	140	(1)	490	**	(33)	246	170
Nov	(6)	412	116	(15)	167	115	(2)	380	70	(3)	120	27	(4)	226	208	(2)	104	9	(32)	225	157
Dec	(9)	285	132	(15)	124	44	(3)	358	99	(3)	243	165	(7)	150	44	(5)	90	23	(42)	184	116
Fall	(20)	338	147	(47)	157	72	(7)	440	221	(10)	170	111	(15)	198	129	(8)	144	141	(107)	215	148
Jan	(7)	211	125	(9)	96	35	(2)	262	90	(1)	95	**	(5)	125	44	(4)	127	54	(28)	146	89
Feb	(7)	231	122	(8)	124	39	(2)	265	169	(1)	180	**	(5)	143	28	(4)	108	21	(27)	165	90
Mar	(7)	289	185	(8)	96	28	(2)	255	53	(2)	100	5	(5)	129	39	(4)	109	52	(28)	164	124
Winter	(21)	244	143	(25)	105	35	(6)	261	89	(4)	119	41	(15)	132	36	(12)	115	42	(83)	158	102
Year	(99)	315	192	(165)	135	58	(42)	288	230	(37)	155	116	(52)	140	137	(26)	109	87	(421)	193	160

*Sex and age classes: AM = adult males, AF = adult females, YM = yearling males, YF = yearling females, FM = fawn males, FF = fawn females

**Insufficient data for standard deviation calculation

Table 5. Summary of mean daily movement (in feet) by time of year and sex and age class of Key deer, Key Deer National Wildlife Refuge, Monroe Co., Florida, 1969-1972.

Period	AM*	AF	YM	YF	FM	FF	ALL DEER
	N $\bar{X}$ S.D.	N $\bar{X}$ S.D.	N $\bar{X}$ S.D.	N $\bar{X}$ S.D.	N $\bar{X}$ S.D.	N $\bar{X}$ S.D.	N $\bar{X}$ S.D.
Apr	(10)2502 1335	(12)1235 313	(8)1638 530	(4)1309 94	(8)407 236	(5)616 255	(47)1373 974
May	(10)2008 566	(15)1222 360	(6)1765 777	(4)1725 1490	(7)424 155	(2)465 303	(44)1359 812
June	(10)1815 864	(15)1147 357	(6)1468 289	(4)947 178	(4)605 136	(1)772 **	(40)1279 619
Spring	(110)2108 985	(165)1251 386	(20)1625 546	(12)1327 853	(19)455 198	(8)598 245	(131)1340 819
July	(11)1454 538	(16)1194 235	(6)1389 397	(4)1275 244	(6)870 315	(1)786 **	(44)1240 400
Aug	(11)1737 628	(18)1195 393	(5)1699 434	(4)1456 1028	(6)866 306	(1)757 **	(45)1353 593
Sept	(8)2010 739	(18)1335 312	(3)2968 1739	(3)1455 254	(9)1244 521	(2)1443 929	(43)1569 758
Summer	(34)1706 646	(52)1243 324	(14)1838 989	(11)1390 366	(21)1029 439	(4)1107 662	(132)1386 611
Oct	(9)2363 635	(16)1448 588	(2)3120 1220	(4)1401 71	(5)1787 567	(2)1273 787	(38)1750 714
Nov	(6)2474 595	(16)1460 586	(3)2789 603	(4)1166 378	(5)1529 578	(3)1344 330	(37)1700 734
Dec	(13)2290 1154	(14)1243 208	(3)2280 1435	(4)1634 444	(7)1415 413	(5)1339 201	(46)1677 845
Fall	(28)2353 884	(46)1390 502	(8)2635 971	(12)1400 366	(17)1558 503	(10)1327 334	(121)1707 767
Jan	(7)1752 742	(9)1112 260	(2)2095 885	(1)1029 **	(5)1331 360	(4)1202 133	(28)1391 548
Feb	(8)1624 499	(8)1161 195	(2)2295 697	(1)1246 **	(6)1418 **	(4)1153 180	(29)1422 447
Mar	(7)1772 593	(8)1016 269	(2)2258 663	(2)1250 209	(6)1581 497	(4)1073 298	(29)1425 563
Winter	(22)1712 588	(25)1097 242	(6)2216 592	(4)1194 163	(17)1450 373	(12)1143 202	(86)1413 516
Year	(110)1981 839	(165)1251 386	(48)1914 830	(39)1354 591	(74)1200 579	(34)1065 415	(470)1460 714

*Sex and age classes: AM = adult males, AF = adult females, YM = yearling males, YF = yearling females, FM = fawn males, FF = fawn females

**Insufficient data for standard deviation calculation

Table 6. Summary of mean monthly major axis (in miles) by sex and age class of Key deer, Key Deer National Wildlife Refuge, Monroe Co., Florida, 1969-1972.

Period	AM*			AF			YM			YF			FM			FF			ALL DEER		
	N	$\bar{X}$	S.D.	N	$\bar{X}$	S.D.	N	$\bar{X}$	S.D.	N	$\bar{X}$	S.D.	N	$\bar{X}$	S.D.	N	$\bar{X}$	S.D.	N	$\bar{X}$	S.D.
Apr	(10)	1.23	.70	(12)	.63	.11	(7)	1.04	.70	(4)	1.18	.73	(1)	.37	**	(1)	.43	**	(35)	.93	.59
May	(10)	1.62	.65	(15)	.75	.32	(6)	1.13	.74	(4)	.95	.84	(4)	.35	.06	(1)	.39	**	(40)	1.00	.66
June	(10)	1.24	.57	(15)	.70	.27	(6)	1.06	.63	(4)	1.03	.81	(4)	1.03	.81	(1)	.41	**	(39)	.90	.54
Spring	(30)	1.36	.66	(42)	.70	.26	(19)	1.08	.66	(12)	1.05	.72	(8)	.37	.06	(3)	.41	.02	(114)	.94	.60
July	(10)	1.05	.49	(16)	.63	.14	(5)	.81	.10	(4)	1.14	1.14	(4)	.48	.16	(1)	.40	**	(40)	.79	.47
Aug	(11)	1.44	.69	(18)	.69	.18	(3)	.81	.11	(3)	.62	.04	(4)	.46	.01	(1)	.36	**	(40)	.87	.53
Sept	(7)	1.79	.71	(17)	.85	.30	(2)	1.70	1.27	(4)	.75	.24	(6)	.62	.09	(1)	.49	**	(37)	1.02	.61
Summer	(28)	1.39	.67	(51)	.72	.23	(10)	.99	.57	(11)	.85	.68	(14)	.53	.13	(3)	.42	.07	(117)	.89	.54
Oct	(5)	1.14	.53	(17)	.89	.42	(2)	1.68	.16	(4)	.76	.30	(4)	1.19	.56	(1)	2.39	**	(33)	1.04	.52
Nov	(6)	1.55	.33	(15)	.72	.27	(2)	1.53	.31	(3)	.79	.16	(4)	1.11	.99	(2)	.67	.17	(32)	.98	.53
Dec	(9)	1.27	.42	(15)	.74	.20	(3)	1.10	.27	(3)	1.21	.69	(7)	1.00	.77	(5)	.56	.10	(42)	.94	.48
Fall	(20)	1.32	.43	(47)	.79	.32	(7)	1.39	.35	(10)	.90	.44	(15)	1.08	.73	(8)	.82	.64	(107)	.98	.50
Jan	(7)	.98	.37	(9)	.64	.16	(2)	1.27	.16	(1)	.61	**	(5)	.70	.18	(4)	.69	.16	(28)	.79	.29
Feb	(7)	1.01	.40	(8)	.64	.13	(2)	1.21	.14	(1)	.77	**	(5)	.73	.13	(4)	.65	.11	(27)	.80	.29
Mar	(7)	1.29	.67	(8)	.56	.08	(2)	1.23	.12	(2)	.59	.07	(5)	.75	.19	(4)	.76	.33	(28)	.86	.46
Winter	(21)	1.09	.49	(25)	.61	.13	(6)	.85	.58	(4)	.64	.10	(15)	.72	.16	(12)	.70	.21	(83)	.79	.36
Year	(99)	1.30	.59	(165)	.72	.26	(42)	1.08	.59	(37)	.91	.59	(52)	.72	.48	(26)	.67	.40	(421)	.91	.52

*Sex and age classes: AM = adult males, AF = adult females, YM = yearling males, YF = yearling females, FM = fawn males, FF = fawn females

**Insufficient data for standard deviation calculation

Table 7. Summary of mean monthly minor axis (in miles) by sex and age class of Key deer, Key Deer National Wildlife Refuge, Monroe Co., Florida, 1969-1972.

Period	AM			AF			YM			YF			FM			FF			ALL DEER		
	N	$\bar{X}$	S.D.	N	$\bar{X}$	S.D.	N	$\bar{X}$	S.D.	N	$\bar{X}$	S.D.	N	$\bar{X}$	S.D.	N	$\bar{X}$	S.D.	N	$\bar{X}$	S.D.
Apr	(10)	.61	.12	(12)	.45	.09	(7)	.57	.16	(4)	.52	.14	(1)	.19	**	(1)	.21	**	(35)	.51	.15
May	(10)	.57	.18	(15)	.75	.32	(6)	.59	.23	(4)	.35	.07	(4)	.20	.05	(1)	.32	**	(40)	.45	.18
June	(10)	.52	.18	(15)	.42	.13	(6)	.47	.14	(4)	.41	.16	(3)	.23	.09	(1)	.26	**	(39)	.43	.16
Spring	(30)	.56	.16	(42)	.43	.11	(19)	.54	.18	(12)	.42	.14	(8)	.21	.06	(3)	.26	.06	(114)	.46	.17
July	(10)	.46	.20	(16)	.40	.10	(5)	.37	.14	(4)	.50	.40	(4)	.20	.03	(1)	.26	**	(40)	.40	.19
Aug	(11)	.40	.19	(18)	.43	.17	(3)	.54	.24	(3)	.43	.14	(4)	.33	.11	(1)	.35	**	(40)	.42	.17
Sept	(7)	.64	.15	(17)	.46	.11	(2)	.58	.20	(4)	.44	.16	(6)	.37	.09	(1)	.33	**	(37)	.48	.15
Summer	(28)	.48	.20	(51)	.43	.13	(10)	.46	.19	(11)	.46	.25	(14)	.31	.05	(3)	.31	.05	(117)	.43	.17
Oct	(5)	.46	.23	(17)	.45	.16	(2)	.98	.40	(4)	.47	.22	(4)	.52	.17	(1)	.60	**	(33)	.51	.22
Nov	(6)	.63	.11	(15)	.41	.13	(2)	.69	.07	(3)	.41	.11	(4)	.41	.04	(2)	.41	.07	(32)	.49	.15
Dec	(9)	.59	.11	(15)	.41	.13	(3)	.76	.14	(3)	.51	.07	(7)	.39	.10	(5)	.34	.04	(42)	.47	.16
Fall	(20)	.57	.16	(47)	.44	.15	(7)	.80	.22	(10)	.47	.14	(15)	.43	.12	(8)	.39	.10	(107)	.49	.18
Jan	(7)	.49	.14	(9)	.41	.14	(2)	.51	.36	(1)	.32	**	(5)	.40	.11	(4)	.41	.14	(28)	.43	.15
Feb	(7)	.54	.21	(8)	.43	.11	(2)	.54	.37	(1)	.54	**	(5)	.41	.08	(4)	.41	.14	(27)	.46	.15
Mar	(7)	.56	.19	(8)	.38	.08	(2)	.56	.10	(2)	.39	.08	(5)	.41	.04	(4)	.37	.10	(28)	.44	.14
Winter	(21)	.53	.17	(25)	.41	.11	(6)	.54	.24	(4)	.41	.11	(15)	.41	.08	(12)	.39	.10	(83)	.45	.14
Year	(99)	.53	.18	(165)	.43	.13	(42)	.57	.22	(37)	.44	.17	(52)	.36	.12	(26)	.36	.12	(421)	.46	.17

*Sex and age c;asses: AM = adult males, AF = adult females, YM = yearling males, YF = yearling females, FM = fawn males, FF = fawn females

**Insufficient data for standard deviation calculation

area was smallest in August and greatest in September (Table 7). No seasonal difference could be detected in either the length or width of the area covered. The greatest length of a range was 3.05 miles during August 1969; the second longest was 3.03 miles during April 1969. The widest range was 0.91 mile during February 1970; the second widest was 0.85 mile in May 1970. The shortest range of an adult male was 0.22 mile during July 1969 with the second shortest being 0.50 mile during February 1969. The narrowest range was 0.15 mile during July 1969, the second smallest, 0.17 mile during August 1969.

Adult males moved least in July and most in April (Table 5). No significant differences were detected in either monthly or seasonal movement. Adult males moved least in summer and most in fall. Spring movement was significantly larger than that during summer. Adult males moved more in fall than in summer and winter. Movement during spring and fall was significantly greater than during winter and summer. The longest movement index for an adult male was 5,891 feet daily during April 1969, while the second largest was 3,940 feet daily during June 1969. The smallest movement index was 629 feet daily during July 1969, with the second smallest being 1,072 feet during June 1969.

Adult males made longest movements and used the greatest area during the rut (September through November) and made shortest movements and used the least area during July when male deer had rapidly growing antlers. During other periods, area used was nearly the same except during March to May when there was a substantial increase in area. After a November peak in movement, adult males moved less until March, when they again increased their movement. These increased movements corresponded with the reproductive season, when adult does with newborn fawns were responding

differences were detected. A movement index of 2,162 feet daily in November 1970 was the largest recorded. The second largest was 2,161 feet in November 1970. The smallest index was 697 feet daily in August 1969, with the second smallest being 698 feet in January 1970.

Beginning in September, adult does increased movement and moved most during November; however, area used was maximal during October when the breeding season was at its peak. Much of this movement was probably a result of harassment by males. During the rest of the year, movement and area used remained constant except just prior to fawning, when adult does showed reduced movement. Downing and McGinnes (1969:711) and Marchinton and Jeter (1966:204) noted decline in movement of pregnant does prior to parturition. However, Michael (1965:47) indicated that most does showed only slight or no seasonal variation in size of range used.

Yearling Male Movement

For yearling males there was a variation in area used from a low in July to a high in October (Table 4). Apparently because of small sample size, no significant differences were detected in monthly area used. Areas used in summer were smallest while those used in fall were largest. Areas used in the fall were significantly larger than those for other seasons. Ranges of 1,190 acres during April 1969 and 918 acres during October 1970 were the two largest recorded. The smallest range was 58 acres during June 1970; the second smallest was 72 acres during July 1970.

Yearling males had short ranges in July and August and long ranges in September (Table 6). Widths of ranges were shortest in July and longest in October (Table 7). There was no significant difference between seasonal range lengths. Seasonal range widths differed significantly, with fall width being larger than other seasonal widths. The

longest range for a yearling male was 3.33 miles during September 1970, whereas the second longest was 2.52 miles during April 1969. The two widest ranges were 1.26 miles during October 1970 and 0.91 mile during August 1969. The two shortest ranges were 0.36 mile during June 1970 and 0.49 mile during May 1970. The two narrowest ranges were 0.17 mile during July 1970 and 0.25 mile during January 1970.

Yearling males moved least in July and most in October (Table 5); however, no significant differences were detected. Yearling males moved least in spring and most in fall, although no significant differences were detected. The largest monthly index for a yearling male was 4,913 feet daily during September 1969, while the second was 3,273 feet during November 1970. The smallest movement index was 943 feet daily during March 1970, with the second being 1,070 feet in May 1970.

Movements and area used by yearling males were similar to those of adult males except that movements for yearling males were much larger earlier in the rut (September and October). Yearling males used the greatest area during October at the height of the rut; this was a full month after the peak for adult males. Areas used by yearling males tended to be larger than those for adult males from October through February; during other months, ranges for adult males were larger. Yearling males moved most in October, 1 month earlier than adult males. Although yearling male movements generally decreased from October through March, movements by yearling males were much greater than those for adult males during the latter part of the breeding season. Adult males became sexually active before yearling males; however, yearling males tended to remain sexually aggressive longer in the season. This behavior probably resulted in some yearling males sireing offspring of females that came into estrus

late in the breeding season.

Yearling Female Movement

The range occupied by yearling females was smallest in July and largest in April (Table 4); but, these differences were not significant. The range during spring and fall was significantly larger than in summer; only the spring range was significantly larger than in winter. The largest monthly range was 567 acres during June 1970; the second largest was 480 acres during April 1970. The smallest was 34 acres during October 1969 with the second smallest being 47 acres during July 1970.

Ranges were shortest in January and longest in December (Table 5). In contrast, the width of the range was least in January and greatest in February (Table 6). There was no significant seasonal difference between length and width of ranges. The longest range was 2.83 miles during July 1970 and the second longest was 2.24 miles during June 1970. The widest range was 1.10 miles during June 1970 with the second widest being 0.70 mile in April 1970. The shortest range was 0.34 mile during October 1969 while the second shortest was 0.41 mile in May 1969. The two narrowest ranges were 0.18 mile during October 1969 and 0.22 mile during September 1970.

Yearling females moved least in June and most in May (Table 5). Although no significant seasonal differences were detected, yearling females moved most in fall and least in winter. The largest movement index for a yearling female was 3,939 feet daily during May 1970, while the second largest index was 2,947 feet during July 1970. The smallest movement index for a yearling female was 713 feet daily during July 1969, with the second smallest being 713 feet during May 1969.

Yearling females tended to show rather unstable movement indices for

the entire year; but, two peaks and three depressions were identified. One peak occurred at the end of the breeding season in December when a few animals were being harassed by bucks; the other occurred in May when they were forced from "normal" ranges by their mothers upon the arrival of fawns. One depression in movement occurred in June following the May peak which suggested reduced movements after being chased from "normal" ranges by their mothers. Limited data reflected a second depression in November and a third in January, separated by a peak in December when yearling females were pursued by bucks.

Ranges of yearling females also showed three peaks. One was recorded the latter part of the breeding season in December, a second at the end of the breeding season in February, and a third in April during the peak fawning season. The two peaks during December and February seemed to indicate a late breeding season for some yearling females. Yearling females born early in the previous fawning season may have estrous patterns similar to those of adult females; however, those born late may not be reproductively active until late during their yearling year. Observations of two yearling-bred females with small fawns late in the fawning season tend to support this theory. Roseberry and Klimstra (1970:27) in Illinois, also noted that yearling females tended to breed somewhat later than most older does; however, Jackson and Hesselton (1971) observed mean breeding dates for yearling females in New York to be 1 day earlier than those for older does.

Fawn Movement

The ranges of male fawns were smallest in May and largest in October (Table 4). During the first 6 months of life (April-September), the area used was significantly smaller than that during the following 6 months

(October-March). Areas used by male fawns during October and November were significantly larger than those for other months. The size of areas used by male fawns differed significantly by season; the largest area was used in the fall and the smallest in the spring. The largest range recorded for a male fawn was 850 acres during September 1970 with the second largest being 424 acres during October 1969. The smallest range was 26 acres during May 1971 with the second smallest being 27 acres during April 1972.

Areas used by female fawns were smallest in July and largest in November (Table 4). As for male fawns, area used during the first 6 months of life was significantly smaller than that used during the second 6 months. In addition, the area used by female fawns during October through December was significantly larger than that during January through March. Spring and summer areas used by female fawns did not differ significantly from each other; but, fall ranges were significantly larger than winter ranges, and fall and winter ranges were significantly larger than those of spring and summer. The largest monthly range recorded for a female fawn was 490 acres during October 1969; the second largest was 181 acres during May 1969. The smallest was 37 acres during July 1970 with the second smallest being 40 acres during April 1972.

A male fawn, captured as it swam between Water and Big Torch keys and released on Big Pine Key, had a range of 1,316 acres in February. This range was much larger than the 143 acres recorded for other male fawns for that month. During March, the transplanted fawn had a range that was similar to those of other male fawns (124 to 129 acres). However, in April, May and June the ranges were much smaller (90, 119 and 16 acres, respectively) than those of other yearling males (186 acres in April, 313 acres in June and 232 acres in July).

Ranges for male fawns were shortest in May and longest in October (Table 6). Ranges were narrowest in April and widest in October (Table 7). The lengths and widths of areas used by male fawns in fall were significantly larger than those for the combined spring and summer period. Major axes of 2.58 miles during November 1969 and 2.52 miles during December 1969 were the longest recorded for male fawns. The longest minor axes were 0.68 and 0.65 mile during October 1969. The two shortest minor axes for a male fawn was 0.16 mile during May 1971.

For female fawns, ranges were longest in October and shortest in May (Table 6). Widths of ranges were shortest in June and July and longest in October (Table 7). No significant difference was detected for either seasonal lengths or seasonal widths of ranges. The two longest ranges for a female fawn were 2.39 miles during October 1969 and 1.25 miles during March 1969. The widest range was 0.60 mile during October 1969 and the second widest was 0.55 mile during January 1970. The two shortest ranges were 0.36 mile during August 1970 and 0.39 mile during May 1970. The narrowest range was 0.21 mile during April 1972 with the second being 0.25 mile during January 1970.

Male fawns moved most in October and least in April (Table 5). Movement for the first 6 months (April-September) of the fawn's life was significantly less than during the second 6 months (October-March). Seasonal movement for male fawns was lowest in spring and highest in fall. Male fawns moved significantly less in spring than during any other season. In addition, movement during the summer was significantly less than that of either the fall or winter. The largest movement index for a male fawn was 2,352 feet daily during November 1969, with the second largest being 2,225 feet daily during April 1972, the second smallest was 484 feet in

April 1972.

Movement of female fawns was least in May and highest in September (Table 5). As with male fawns, movement during the first 6 months of life was significantly less than during the second 6 months. Movement was minimal in spring and maximal in fall; however, no significant differences could be detected for seasonal movement. The largest movement index for a female fawn during a single month was 1,829 feet daily during October 1969 with the second largest being 1,680 feet during December 1970. The smallest individual movement index was 456 feet daily during April 1972 with the second smallest being 757 feet in July 1970.

The February movement index for the male fawn captured as it swam between Water and Big Torch keys and then radio-tagged and released on Big Pine Key was 2,937 feet daily. This was larger than the index of 1,418 feet daily for other male fawns during February. The movement indices for this animal during the months March through June were much lower than for animals of a similar sex and age class. Movement indices for this animal were 1,258 feet daily in March, 980 feet in April, 1,071 feet in May and only 614 feet during June prior to radio failure.

In general, as fawns of both sexes grew older, they used more land area and their movement increased. During the first 2 weeks of life there was little movement except when "moved" by the doe. For the first month of life, fawns stayed close to where the doe had left them; size of area used reflected only the doe's placement of the fawn from day to day, which in turn was affected by the habitat of the doe's range. If the fawn and doe were undisturbed, the fawn was more likely to spend a greater period of time in a given area before it was moved to a new site. At 1.5 to 2 months, fawns were apt to wander alone in the area where left by the doe.

Strode (1954:6) observed fawns in the Ocala National Forest, Florida stayed hidden; they moved little during the first several days of life. He found that after the first couple of weeks, fawns occasionally accompanied their mothers on trips. Byford (1970), working in southwestern Alabama, noted that spotted fawns 1-2 months old had ranges comparable to adult deer. As Key deer fawns became older some wandered into old familiar areas without the doe. Fawns up to 2 months of age did not move at night, staying bedded. After 4 to 5 months of age, areas used by fawns tended to duplicate closely those of the adult females. This was also noted by Byford (1970) for a radio-tagged, 4-month-old fawn and adult doe. During the rut, Key deer fawns became "lost" from their mothers, and at this time their movement was greatest, reaching a peak in September for females and in October for males. Following the rut, most female fawns returned to their mothers and movement indices of the two were again similar; however, most male fawns did not return to the mother. Those that did return, usually broke association with the doe prior to fawning of the next year. Strode (1954:6) observed that yearlings usually stayed with their mother until the next fawns were dropped.

During the rut, ranges of male fawns were somewhat larger than those of adult females. The largest ranges utilized by female fawns occurred during October, the height of the breeding season. Limited data for female fawns may have yielded questionable results. Because no female fawns were observed to breed, little significance can be placed on this increase in range during October.

Differential Movement

The sizes of winter ranges for adult and yearling males were significantly larger than those for other sex and age classes. In contrast,

adult female ranges did not differ significantly from those of either yearling or fawn females. Male fawns had winter ranges that differed from all sex and age classes except female fawns. During the spring, adult and yearling male ranges were found to differ significantly (adult males having smaller ranges) and both had ranges significantly larger than those of other sex and age classes. Adult and yearling male summer ranges also differed significantly (yearling male ranges being larger) and were significantly larger than ranges for other sex and age classes. Differences in fall ranges between adult and yearling males were non-significant, but were significantly larger than those of other sex and age classes.

Adult males had longer winter ranges than did adult females and fawns of both sexes; however, no significant difference was detected between length of adult male winter ranges and those of yearling males and females. There was no significant difference in width of winter ranges among the sex and age classes. During the spring, ranges for adult males were longer than those of adult females and male fawns. Adult male spring ranges were wider than those of adult females and male and female fawns. Also, yearling males had significantly wider ranges in spring than did female fawns. Adult males had longer summer ranges than those of adult females and male and female fawns; however, there was no significant difference in the width of the ranges. During the fall, adult males had significantly longer ranges than those of adult females; and, yearling males had ranges significantly wider than those of all other sex and age classes.

Adult males moved significantly more than did any other sex and age class in the spring. Adult and yearling females moved more than did male fawns, while yearling males moved significantly more than did either male

or female fawns.

Based on all location points for 18 adult male and 21 adult female deer during 1969 and 1970, 39 ranges were determined. Ranges of adult males (790 acres average) were significantly larger (Student's t-test) than the average range (429 acres) of females. Ranges could not be determined for the other sex and age groups because of the age class changes on 1 April each year. The largest 2-year range of an adult male was 1,366 acres while the second largest was 1,335 acres. The smallest 2-year range was 741 acres and the second smallest was 879 acres. For adult females, the largest 2-year range was 854 acres while the second was 845 acres. The smallest was 227 acres and the second smallest 235 acres.

The largest yearly range of an adult male was 1,366 acres in 1969, while the second largest was 1,335 acres in 1970. Maximum yearly ranges of 854 and 845 acres were recorded for two different adult females during 1970. The two largest yearling male ranges were 1,550 and 1,355 acres for two animals during 1970. Ranges of 1,446 acres during 1970 and 532 acres in 1969 were the two largest yearly ranges for yearling females. The largest male fawn range was 1,257 acres during 1970 with the second largest being 694 acres in 1969. Only one female fawn was radio-tracked long enough to allow an estimate of yearly range. This range was 586 acres for the 9 months the animal was radio-tracked during 1969.

On a yearly basis, adult males had significantly longer ranges than did adult and yearling females and male and female fawns. The yearly ranges of adult males were significantly wider than those of adult females and male and female fawns.

Data for the lengths of ranges of yearling males did not correlate

well with monthly range size. The largest ranges occurred in October, whereas ranges were longest in September. Yearling males probably made greater linear movements during September at the start of the rut, resulting in increases in range length without complimentary increase in range width or range size.

Annual movement indices, determined by pooling all monthly indices for a given age and sex class, indicated that adult and yearling males moved significantly more than did the other sex and age classes, whereas male and female fawns moved significantly less.

Male Key deer generally had larger ranges and moved more than did females of the same age classes. Adult males moved more and had larger ranges during April through August than did other sex and age classes; however, yearling males moved more and had larger ranges during September through March. Previous studies of deer movements invariably indicated greater movement by bucks (Severinghaus and Cheatum 1956, Progulske and Baskett 1958, Jeter and Marchinton 1964, Thomas et al. 1964 and Downing et al. 1969, to name a few); but, Marchinton and Jeter (1966:197) noted that yearling bucks had ranges similar to or smaller than does. Carlsen and Farmes (1957:401) noted "younger deer" moved much longer distances than "older deer." However, Downing et al. (1969:21) observed 3.5-year-old bucks moved greater distances than younger bucks.

Radio-tracked adult male (20) and female (38) Key deer had dynamic ranges; all animals increased the size of their 1969 range during 1970. Differences in monthly ranges and movement indices for individual animals were seasonal, whereas differences between two animals were reflected in habitat differences that comprised individual ranges.

During the breeding season males made long movements from previous

"stable" ranges into new areas where they had not been located previously. All 20 males radio-tracked during 1969 and 1970 made such movements. For example, a male whose range prior to the rut was a heavily populated housing subdivision was compatible with people, usually bedding in overgrown yards of unoccupied residences. At night he visited landscaped yards sampling the vegetation. Escape cover, when he was pursued by dogs, consisted of a mangrove fringe near the water's edge and a large undeveloped lot. During early September he left the residential area and did not relocate in his old range until after the breeding season. The above sequence of events occurred during both years the animal was radio-tracked. Four bucks that made long movements set up new ranges in the Hammock area, whereas five others moved back and forth from the Hammock to their old ranges. Six radio-tagged adult females from the northern quarter of Big Pine Key also made at least one trip into the Watson Hammock area.

In contrast, Marchinton and Jeter (1966:201) stated that in the South, little shifting of ranges related to seasonal changes occurred. They further stated that in no case did movement occur that might be construed as a home range shift and that large seasonal shifts in home range were not the typical behavior pattern of at least the deer in central and northwest Florida. Michael (1965:47), working in Texas, indicated does showed only slight or no seasonal variation in ranges. Ellison (1969:221), in Texas, found no apparent seasonal movements except that during the winter deer were attracted to an oat patch. He also indicated that cattle stocking caused deer to move off his study area. However, Downing et al. (1969:23) concluded that in spite of the numerous studies showing that deer movements were confined within a small area, under

some conditions permanent changes in ranges took place. They reported that irregular movements could be expected during three periods of the year: (1) hunting season; (2) during the rut (these movements were not permanent); and, (3) summer (yearling and 2-year-old deer showed irregular movements during the fawning season).

Adult females and their fawns did not always move together as indicated by an adult female and her female fawn during the period following birth of the fawn until August of the same year. The adult doe's movement index averaged about 200 more feet a day than did her fawn's index. Ranges also showed a comparable difference. These, plus general observations, and telemetry data indicated they did not always move together during this period. This fawn was located with its mother only twice (14 percent) in 14 consecutive daily locations in May. Although telemetry locations were not accurate to a small area (i.e. two signals coming from a 2,500 square-foot area may not mean the two animals are together) different locations could readily be determined if signals were coming from two different areas. Therefore, the above data indicated the two animals were probably together more than they might actually have been, and the data, therefore, were biased in that direction. Sight locations might show the doe and fawn separated more than the telemetry information indicated. Fawns were rarely seen at night in open areas frequented by feeding does, whereas during daylight hours does and fawns were together more often. The fawn was thought to be with its mother on only 11 occasions (38 percent) in 29 consecutive locations during June. This fawn was thought to be with its mother on only 12 occasions (26 percent) in 47 locations during July and August.

Byford (1970) radio-tracked a 4-month-old fawn and its mother and found they were never located together during the first 16 days after capture; they were together 22 of 23 times following this period. Both had the same range as well as the same diel movement patterns during the study period. He also noted that a 1 to 2-month-old fawn had a home range comparable to other adult deer in the area but diel movements were less. The influence of trapping was not evaluated and this may have influenced movement.

Atypical Movement

Ninety percent of all radio-tracked deer made long trips from their "normal" ranges, either to return later or to set up "new" ranges elsewhere. The longest movements from the point of original capture were 7 miles for an adult and a yearling male. The longest move recorded for an adult female was 5 miles, and for a yearling female 4 miles. Fawns did not make extended movements from their range; however, one male fawn was located over 1.5 miles from his capture site. The longest move during a 24-hour period was over 4 miles by a yearling male. Many movements were dispersal, as often there was no return to "original" ranges.

Dispersal of deer on Big Pine Key was difficult to determine as many deer made long "exploratory" movements. Unless the animal was tagged as a newborn fawn it was difficult to determine its "original" range. Movements of older animals may have represented returns to "old" ranges and not true dispersal. Extreme movements, perhaps caused by the drought of 1970-1971, complicated analysis of movement data. Extension of ranges by adult bucks during the rut made it difficult in many cases to evaluate dispersal.

All radio-tracked yearling males dispersed from their areas of birth. Only three of five yearling females were known to have dispersed; the

other two made long trips but returned. Adult bucks, especially during the rut, made trips to all parts of Big Pine Key, returning to "normal" ranges following the rut. However, 16 adult bucks were several miles from these "normal" ranges on various occasions. Some movement from "original" ranges on Big Pine were probably the result of increasing deer population levels, or to shifts in response to clearing of habitat in subdivision development. Two adult does seemed to have moved in response to clearing for a housing development.

Five sightings (one unconfirmed) of marked deer off Big Pine Key were recorded. One adult doe was captured and marked on 17 June 1971 as she swam between Big Pine and Porpoise keys. During dry weather this adult doe, which had a fawn on Porpoise Key, swam an 0.8-mile channel between Porpoise and Big Pine Key. Porpoise Key was a small island having no fresh water, while Big Pine was the closest source of permanent fresh water. She usually moved to Big Pine around 1800 hours, and returned to Porpoise between 1100-1300 hours the next day. Trips to Big Pine were discontinued for 7 days after heavy rains but resumed when pools of rain water were exhausted. Since the wind seldom was from a direction affording olfactory cues by which to orient, it was unknown how she began and maintained the proper direction to arrive at the appropriate key rather than others nearby. This doe continued these trips to Porpoise periodically until 31 July, at which time she remained on Big Pine Key. The fate of the fawn was undetermined.

Two adult does captured on Big Pine Key were later observed on No Name Key with young fawns. One swam Bogie Channel twice daily for 2 weeks, moving to No Name in early to mid-morning and returning to Big Pine around dusk. Since there appeared to be adequate acceptable water and

food on No Name, there was no apparent explanation for returns to Big Pine. This doe was last seen on Big Pine Key in June 1973. The second adult doe was captured in Koehn's Subdivision on Big Pine and stayed in south Watson Hammock during April-May of 1971 (Figure 2). Sightings of this deer on No Name Key represented a move of about 4 miles. She probably did not swim to and from Big Pine Key daily, but moved to No Name and stayed. This deer was last seen on No Name Key in June 1973.

An adult buck was sighted twice on No Name Key by residents of Big Pine Key in April 1971; 1 week later it was observed in the Doctor's Arm Subdivision on Big Pine; on 2 February 1973 it was killed by a vehicle on Big Pine Key.

There were several reports by fishing guides of deer swimming between Big Pine, No Name, and Little Pine keys and between Big Torch and Water keys. Several of the sightings probably involved the adult doe mentioned previously. A male fawn was captured on 7 February 1969 as it swam between Water and Big Torch keys. Within 1 week this animal, radio-tagged and released in Eden Pines Subdivision on Big Pine Key, had moved over 4 miles to the north end of Big Pine, the portion closest to Water Key. It was last observed June 1969, at which time its radio had ceased to function.

To better understand deer movements, seven deer were relocated from Big Pine Key to outlying keys. An adult male captured 6 May 1971 in Port Pine Height Subdivision was released on Mayo Key where no fresh water was available. Four days later this deer returned to Big Pine Key. This deer was retrapped on 20 December 1972 and released on Big Johnson Key. No acceptable water seemed available at the time of release. Within 1 week he was located on Little Pine Key where acceptable water was available; he

was still there in early September 1973.

On 15 July 1971 an adult buck was moved from Big Pine to No Name Key where there was fresh water and a resident deer population. Radio-contact was lost soon after release but the deer was sighted on No Name Key 2 weeks later. At that time it was on the west side of the Key immediately across the channel from Big Pine, after having been released on the east side. One week later this animal was reported near the center of Big Pine; about 1 week later it was located within 0.5 mile of the original capture site.

A yearling male, trapped on Big Pine on 26 December 1972, was released on Mayo Key where no fresh water was available. Radio failure shortly after release did not permit further recording. Two adult males were placed on No Name Key in December 1972, where there was adequate suitable water. As of early September, 1973, both animals were still on this Key.

With the onset of fawning and the antagonism between adult does and fawns from the previous year, long movements were made by both yearling bucks and does. Such movements lessened after fawns were 1 to 2 months old, when there seemed to be less antagonism between the doe and her yearlings.

Not only were yearling animals involved in such long movements but 2-year-old animals and adult bucks also made frequent trips. One 2-year-old doe was over 2 miles south of her "normal" area on several occasions but was again sighted back in her previous range. These movements were preliminary stages of dispersal, for many animals later established "new ranges". Not only did yearling bucks make exploratory trips but yearling does and 2-year olds of both sexes did also. Hawkins et al. (1971:220), in a study of white-tailed deer in southern Illinois found yearling males were the most likely to disperse to new areas; however, representatives

from all other classes were also known to have left the study area.

With the polishing of antlers in early September, the antagonism between males increased. Fights between large adult males and yearling males were unlikely and yearling males were not scarred as were adult males. Therefore, confrontation between these two age groups probably led to an early retreat by the yearling males before physical damage occurred. Such was not the case with adult males, as observations of broken antler tines and scars were common.

Although bucks of all ages made long trips out of their ranges, yearling bucks seemed constantly on the move during the rut. In contrast, adult bucks spent a few days to 1 week in a new area before returning to old ranges or moving on to new ones. Such continued movements led yearling bucks into new areas at great distances from their former ranges. Returns were usually made to old ranges, but wandering eventually led to a change in principal area of activity as new territories became more familiar.

Marchinton and Jeter (1966:201) noted that increased movement of yearling males occurred in northwest Florida at the onset of rut. They saw their radio-tagged yearling male with does but thought he was kept from breeding and that his movements were an avoidance response to prevent conflict with larger males.

Of the 223 deer marked on Big Pine Key, only 5 were recorded elsewhere; and, none of 187 radio-tagged deer was located off Big Pine. Because of the interest by residents of the Keys in the research, sightings of marked deer on keys other than Big Pine would have been reported if they were frequent. Therefore, I conclude that dispersal of deer from Big Pine Key was infrequent.

Transplanting experiments showed that deer left keys without suitable water. Only a buck released on No Name Key returned to its original range from a key that had suitable water. Either this animal had strong homing ability or was unable to find fresh water. The season of transplanting, sex, age, experience, extent of rainfall and distribution of acceptable water are important factors in evaluating this behavior. Bridges and Marchinton (1969:83) radio-tracked a transplanted doe released 8.5 miles from its capture site on Elgin Reservation, Florida. This doe traveled 23 miles during a 5-week period, then settled down to a 340-acre area. Marchinton and Jeter (1966:193) released two pen-reared deer in east central Alabama. A yearling female covered an area of 2,800 acres before settling in a 900-acre area. A male fawn utilized 500 acres before and a 255-acre area after "adjustment". Hawkins and Montgomery (1969:200) translocated 28 deer in southern Illinois, 6, 25 and 36 airline miles from point of capture. Although there was no significant difference in movements between sex and age classes, sub-adult bucks were harvested or died an average of 3.30 miles from their release sites compared with 2.13 miles for sub-adult does and 1.03 miles for adult does. Six of 9 (67 percent) adult does, 2 of 4 (50 percent) yearling females, 0 of 2 (0 percent) adult males, 7 of 7 (100 percent) doe fawns and 3 of 6 (50 percent) buck fawns stayed in the release area (Hawkins and Montgomery 1969:200). They concluded that doe fawns and adult does nearing parturition seemed best for transplanting. However, two (a pregnant adult doe and a yearling doe) of the 28 translocated deer (7 percent) returned to original capture sites. The adult doe returned 25 miles in 90 days while the yearling doe returned 6 miles in 23 days.

Aside from the 12 keys where Dickson (1955) either observed deer

tracks or droppings, various sign of deer were observed on Mayo, Porpoise, Water, Summerland, Sugarloaf, Treetop Hammock, Big Knockemdown, Big Munson, and Wahoo keys, and an unnamed island southeast of Ramrod Key (Figure 13). No deer or deer sign were found on Horseshoe, Crawl, Raccoon, East and West Bahia Honda, Big and Little Spanish, Content, Cutoe, Newfound Harbor Keys (except Big Munson), Loggerhead, and Mud keys. Extension of the Key deer range seems to have occurred since 1955; however, much of this increase was seasonal and temporary. Relatively fresh deer tracks were noted even when acceptable water seemed unavailable, suggesting movement to adjacent keys with a return to the"home base". During a drought, deer on other keys either survived without fresh water or returned to a key having permanent fresh water. It appeared that utilization of Annette, Howe, Mayo, Porpoise and the Newfound Harbor keys required a return to Big Pine Key during drought. Deer on Grassy, Little and Big Johnson and Crawl keys possibly commuted to Little Pine Key when water holes on these adjacent keys were dry or too brackish. Use of Water Key required a swim to and from Big Torch Key; and, those deer using Wahoo, Toptree Hammock, and Big Knockemdown keys probably returned to either Cudjoe or Summerland Key for acceptable water.

Habitat Types Within Monthly Ranges

Radio-tagged Key deer showed preference for specific habitat types, as indicated by evaluation of the proportion of habitat types making up the monthly ranges. Further, utilization of each habitat type was not in direct proportion to its availability.

The vegetation of the refuge on Big Pine Key consisted of open-developed areas (subdivisions and roadsides, 17.1 percent), pineland (32.4

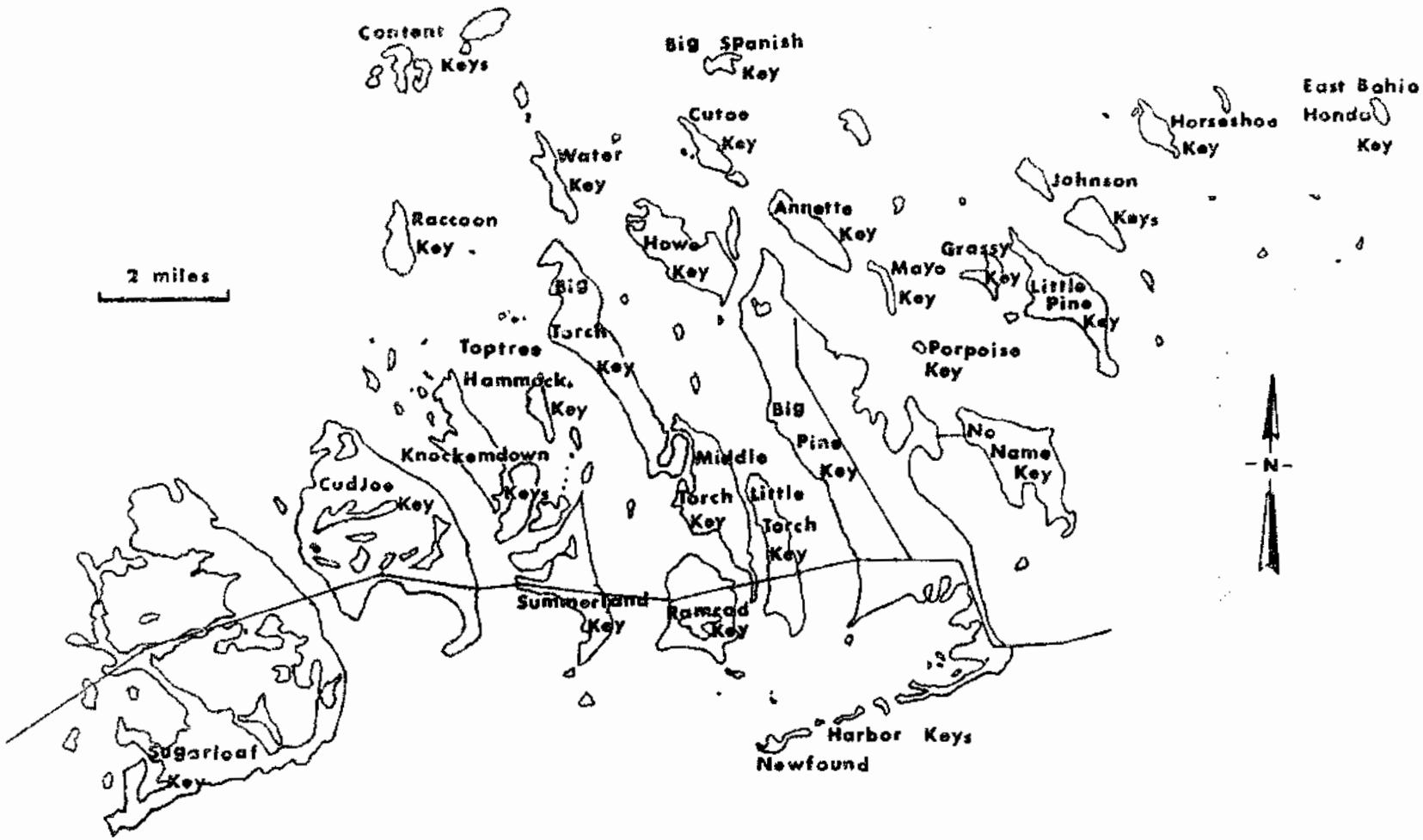


Figure 13. Outline map of the easternmost islands of the lower Florida Keys, Monroe Co., Florida.

percent), buttonwood (31.1 percent), hardwoods (5.4 percent), hammocks (4.7 percent), and mangroves (9.4 percent). In contrast, the mean range for all deer consisted of 3.6 percent hammock, 39.9 percent pineland, 18.0 percent developed area, 9.6 percent hardwood, 4.6 percent mangrove and 26.3 percent buttonwood (Table 8). Thus, there was a significant difference between mean range habitat composition and the availability of the habitat types in the study area. Ranges were made up of a greater percentage of pineland and hardwood and less mangrove and buttonwood than expected. Hammock and open-developed areas were used in the same proportion as was available.

Not only was habitat selection apparent when all deer were considered, but each sex and age class appeared to select for specific habitat types; and some differed significantly by season. In general, following birth, males on an annual basis had ranges made up of less pineland and more open-developed, hardwood, buttonwood and mangrove. Hammock made up a greater proportion of fawn and adult ranges than it did of yearling ranges. Range habitat types of fawns followed those of adult does on an annual basis. Yearling females had ranges with more pineland and hammock than did any other sex or age class. Mangrove made up equal proportions of adult and yearling female ranges.

Ranges of each sex and age class were made up of habitats that differed significantly from those available. The combination of habitats used during each season and year was significantly different from that available. However, other apparent differences were non-significant; given sufficient sample sizes these would probably be significant.

Adult Males

Ranges of adult males contained more hardwood and buttonwood and less

Table 8. Plant community composition, in percent, of the mean monthly ranges of 58 Key deer, Key Deer National Wildlife Refuge, Monroe Co., Florida, 1969-1972.

Period	N	Hamm*		Pine		Open		Hard		Mang		Butt		Mean Range
		$\bar{X}$	S.D.	$\bar{X}$	S.D.	$\bar{X}$	S.D.	$\bar{X}$	S.D.	$\bar{X}$	S.D.	$\bar{X}$	S.D.	(acres)
Apr	35	2.9	7.9	35.2	30.1	17.2	16.3	10.4	9.3	4.9	3.3	29.3	22.5	232
May	40	4.4	9.5	41.6	28.4	16.2	28.4	10.3	10.1	3.7	2.9	23.8	16.1	222
June	39	4.1	11.0	39.8	32.1	17.0	14.7	11.0	11.7	4.9	4.1	23.2	19.1	179
Spring	114	3.8	9.6	39.0	30.1	16.8	14.7	10.6	10.4	4.5	3.5	25.3	19.3	210
July	40	2.1	6.7	35.9	32.0	22.2	19.8	9.1	12.2	5.6	8.6	26.6	23.6	133
Aug	40	4.0	9.0	42.9	31.3	17.8	15.3	9.3	9.6	4.0	3.7	22.8	20.5	157
Sept	37	4.2	8.5	43.9	28.2	17.5	15.1	9.1	8.7	3.6	2.9	22.5	18.6	259
Summer	117	3.4	8.1	40.8	30.5	19.2	16.9	9.2	10.2	4.4	5.7	24.0	21.0	181
Oct	33	3.6	7.1	46.9	28.2	15.0	13.4	9.8	10.8	3.3	3.0	21.5	17.7	246
Nov	32	1.7	4.3	43.3	30.4	17.9	13.5	9.3	9.5	3.7	2.7	30.9	45.3	225
Dec	42	2.3	5.6	39.7	29.8	20.4	15.8	8.3	9.3	4.0	3.7	25.2	20.2	184
Fall	107	2.5	5.8	43.0	29.4	18.0	14.5	9.4	9.8	3.7	3.2	25.8	29.4	215
Jan	28	5.8	12.8	33.4	32.9	16.9	14.5	9.1	9.8	4.9	4.8	30.0	25.0	146
Feb	27	4.1	8.3	28.9	29.3	16.3	14.2	11.1	9.7	5.6	3.6	34.1	24.3	165
Mar	28	5.4	8.4	31.4	27.6	20.2	15.5	8.8	7.9	7.7	14.3	30.8	22.4	164
Winter	83	5.1	10.0	31.3	29.7	17.8	14.7	9.6	9.1	6.1	9.0	31.6	23.7	158
Year	421	3.6	8.5	39.0	30.1	18.0	15.3	9.6	9.9	4.6	5.6	26.3	23.6	193

*Habitat type: Hamm = hammock, Pine = pineland, Open = open-developed areas, Hard = hardwood, Mange = mangrove, Butt = buttonwood

mangrove and pineland than expected from the habitat available (Table 9). The percent composition of open-developed and hammock types was used in the same proportion as that available. During winter, ranges contained a greater proportion of hammock, hardwood and buttonwood and less pineland, open-developed areas and mangrove. A similar situation existed in spring except pineland also made up a greater proportion of the range. During summer, pineland and mangrove made up a smaller proportion of the range while open-developed areas, hardwood and buttonwood made up a greater proportion. Fall ranges contained more hammock, pineland, hardwood and buttonwood and less open-developed areas and mangrove.

Adult Females

Ranges of adult females contained more pineland and hardwood and less buttonwood and mangrove (Table 10). Range utilization showed more hammock in winter and spring and less in summer and fall. Pineland made up a greater proportion of the range during all but winter. On an annual basis, open-developed and hardwood areas constituted the greater proportion of the range vegetation. The percentage of hammock and open-developed habitat types did not differ significantly among seasons.

Yearling Males

Ranges contained more pineland and hardwood and less hammock, open-developed areas and mangrove than expected (Table 11). Winter ranges contained more hammock and pineland and less open-developed areas, hardwood, mangrove and buttonwood. In spring, ranges were made up of more pineland and hardwood and less hammock, open-developed areas, mangrove and buttonwood than expected. Hammock and mangrove areas made up a smaller area of summer and fall ranges while pineland, hardwood and

Table 9. Plant community composition, in percent, of mean monthly ranges of 11 adult male Key deer, Key Deer National Wildlife Refuge, Monroe Co., Florida, 1969-1972.

Period	N	Hamm*		Pine		Open		Hard		Mang		Butt		Mean Range
		$\bar{X}$	S.D.	$\bar{X}$	S.D.	$\bar{X}$	S.D.	$\bar{X}$	S.D.	$\bar{X}$	S.D.	$\bar{X}$	S.D.	(acres)
Apr	10	1.9	3.2	17.7	14.7	21.2	13.6	2.2	7.0	5.8	1.6	41.4	22.3	326
May	10	3.6	4.5	26.4	10.9	24.5	9.2	10.8	5.5	4.0	1.0	30.7	9.9	415
June	10	1.1	1.9	19.6	16.7	26.4	13.3	10.9	6.9	6.2	2.2	35.8	15.7	289
Spring	30	2.2	3.5	21.2	14.3	24.0	12.0	11.3	6.3	5.3	1.9	36.0	16.6	343
July	10	0.2	0.4	19.2	23.0	24.1	14.5	8.8	7.4	5.8	4.5	41.9	22.1	212
Aug	11	6.3	12.4	35.2	21.0	19.2	12.4	11.2	8.1	6.4	4.0	24.5	9.5	245
Sept	7	8.2	14.4	29.0	10.8	14.0	7.2	11.8	5.9	5.5	2.2	35.8	9.1	596
Summer	28	4.6	10.7	27.9	20.4	19.6	12.4	10.5	7.2	6.0	3.7	33.6	16.6	321
Oct	5	8.5	9.1	52.4	14.4	11.4	10.3	7.8	5.0	2.2	2.1	17.7	6.3	343
Nov	6	4.5	6.3	51.5	22.8	13.2	11.4	8.8	10.3	3.8	2.4	54.6	96.0	412
Dec	9	6.2	9.4	29.8	23.3	16.9	13.1	10.4	5.7	3.5	2.5	33.1	22.0	285
Fall	20	6.3	8.2	42.0	23.2	14.4	11.6	9.3	6.9	3.3	2.3	35.7	53.3	338
Jan	7	9.1	11.7	16.9	28.4	10.9	12.9	12.6	5.2	4.2	3.8	46.3	28.8	211
Feb	7	4.4	6.5	10.1	13.8	12.6	8.6	14.4	6.9	7.5	3.1	51.5	17.4	231
Mar	7	6.4	8.3	14.3	16.1	19.1	12.0	11.0	4.9	5.9	1.4	43.2	19.5	289
Winter	21	6.6	8.8	13.8	19.6	14.2	11.3	12.7	5.6	5.9	3.1	47.0	21.6	244
Year	99	4.6	8.2	25.7	21.2	18.8	12.4	10.9	6.6	5.2	3.0	37.6	28.8	3.5

*Habitat type: Hamm = hammock, Pine = pineland, Open = open-developed areas, Hard = hardwood, Mang = mangrove, Butt = buttonwood

Table 10. Plant community composition, in percent, of the mean monthly ranges of 15 adult female Key deer, Key Deer National Wildlife Refuge, Monroe Co., Florida, 1969-1972.

Period	N	Hamm*		Pine		Open		Hard		Mang		Butt		Mean Range
		$\bar{X}$	S.D.	$\bar{X}$	S.D.	$\bar{X}$	S.D.	$\bar{X}$	S. D.	$\bar{X}$	S.D.	$\bar{X}$	S.D.	(acres)
Apr	12	6.5	12.7	34.9	27.3	20.7	21.4	8.3	10.1	5.2	4.1	24.5	15.5	121
May	15	5.1	12.7	43.7	30.2	17.3	17.2	8.2	8.5	4.1	3.5	21.6	13.3	130
June	15	5.9	14.6	43.0	32.6	18.2	17.2	10.7	12.6	4.4	4.8	17.8	14.9	122
Spring	42	5.8	13.1	40.9	29.8	18.6	18.1	9.2	10.4	4.5	4.1	21.1	14.4	125
July	16	3.5	7.8	46.6	32.8	17.9	19.0	6.5	10.0	7.5	12.7	18.0	13.8	124
Aug	18	3.7	8.5	47.7	30.7	18.5	17.9	9.2	10.8	3.0	3.3	18.0	17.6	126
Sept	17	3.8	7.4	54.0	24.8	17.5	15.9	7.5	9.2	2.5	2.5	14.8	15.4	163
Summer	51	3.7	7.8	49.4	29.2	17.9	17.2	7.8	9.9	4.2	7.7	17.0	15.5	138
Oct	17	3.8	8.1	52.4	27.1	15.2	13.1	8.0	7.6	2.9	3.5	17.7	16.9	178
Nov	15	1.7	4.6	47.1	28.6	20.1	13.7	7.8	9.2	3.1	2.8	20.3	19.0	167
Dec	15	0.7	2.3	41.6	28.1	25.8	19.1	7.0	11.2	3.9	3.0	21.0	12.9	124
Fall	47	2.1	5.7	47.3	27.7	20.2	15.7	7.6	9.2	3.3	3.1	19.6	16.2	157
Jan	9	9.0	19.2	31.9	33.2	16.3	15.1	10.5	14.1	6.8	6.4	25.4	22.4	96
Feb	8	6.7	11.1	28.3	26.2	16.6	18.9	12.3	10.1	5.9	4.2	30.2	25.4	124
Mar	8	10.2	11.1	26.8	25.4	20.8	21.3	11.9	10.1	5.7	3.9	27.2	19.6	96
Winter	25	8.7	14.0	29.1	27.6	17.8	17.8	11.5	11.3	6.1	4.9	27.5	21.7	105
Year	165	4.5	10.2	43.6	29.3	18.7	17.0	8.7	10.0	4.3	5.4	20.3	16.7	135

*Habitat type: Hamm = hammock, Pine = pineland, Open = open-developed areas, Hard = hardwood, Mang = mangrove, Butt = buttonwood

Table 11. Plant community composition, in percent, of the mean monthly ranges of nine yearling male Key deer, Key Deer National Wildlife Refuge, Monroe Co., Florida, 1969-1972.

Period	N	Hamm*		Pine		Open		Hard		Mang		Butt		Mean Range
		$\bar{X}$	S.D.	$\bar{X}$	S.D.	$\bar{X}$	S.D.	$\bar{X}$	S.D.	$\bar{X}$	S.D.	$\bar{X}$	S.D.	(acres)
Apr	7	0.6	1.5	45.5	35.4	9.6	9.6	11.6	11.0	4.7	4.0	28.1	30.8	329
May	6	0.9	2.3	45.3	30.8	13.0	4.7	11.3	12.8	3.9	3.1	25.5	23.0	313
June	6	0.3	0.7	48.0	34.0	10.6	6.0	10.5	9.0	4.3	2.7	26.4	24.2	232
Spring	19	0.6	1.5	46.2	31.7	11.0	7.0	11.2	10.4	4.3	3.2	26.8	25.0	293
July	5	0.0	0.0	27.9	26.1	23.1	22.6	5.1	5.3	3.3	2.1	40.6	38.2	132
Aug	3	0.3	0.5	36.0	32.7	12.9	10.8	6.8	5.4	2.7	1.1	41.3	35.1	204
Sept	2	7.4	10.4	43.3	2.3	18.6	12.2	10.1	9.3	3.1	1.8	17.6	8.0	298
Summer	10	1.6	4.6	33.4	24.1	19.1	17.1	6.6	5.7	3.1	1.6	36.2	32.0	187
Oct	2	1.9	2.0	33.9	12.9	21.6	21.1	9.0	2.6	6.9	1.5	26.8	2.1	624
Nov	2	1.7	2.4	16.6	23.5	16.7	12.1	16.8	3.1	4.9	1.3	43.3	33.5	380
Dec	3	3.2	5.6	34.2	30.0	30.7	16.3	12.4	5.8	3.7	1.8	25.7	22.8	358
Fall	7	2.4	3.6	29.1	22.0	19.8	13.9	12.7	4.9	5.0	1.9	31.1	7.9	440
Jan	2	8.8	12.4	46.9	1.3	9.8	1.8	8.0	6.2	4.7	6.6	22.0	8.8	262
Feb	2	12.6	17.8	38.3	4.2	10.7	11.2	12.3	3.5	6.5	0.2	19.7	6.1	265
Mar	2	8.3	11.7	48.4	3.6	12.0	4.7	8.2	2.6	4.2	1.2	19.1	4.7	255
Winter	6	9.9	11.2	44.5	5.5	10.8	5.6	9.5	4.0	5.1	3.2	20.3	5.4	261
Year	42	2.5	5.7	40.1	26.4	14.4	11.6	10.1	8.1	4.2	2.7	28.8	23.2	288

*Habitat type: Hamm = hammock, Pine = pineland, Open = open-developed areas, Hard = hardwood, Mang = mangrove, Butt = buttonwood

open-developed areas made up a greater proportion. Buttonwood areas made up a greater area of summer ranges but less of the fall ranges.

Yearling Females

Yearling females showed use of open-developed areas and hardwood and less of hammock, mangrove and buttonwood than expected (Table 12). Hammock and mangrove areas made up less of ranges than expected during all seasons. Pineland, hardwood and buttonwood made up a greater area of ranges during all seasons but winter when they made up less than expected. Open-developed areas made up the expected proportion of summer ranges, a greater portion in winter and fall and less in spring.

Fawns

Male fawn ranges contained greater proportions of pineland and less open-developed areas, mangrove and buttonwood than expected (Table 13). Ranges of male fawns had less hammock, open-developed areas, hardwood, mangrove and buttonwood and more pineland in winter. In spring, ranges contained more hammock and pineland and less open-developed areas, hardwood and mangrove. Summer ranges were made up of more pineland, open-developed areas and hardwood and less mangrove and buttonwood. Hammocks comprised expected proportions of summer ranges. Ranges in fall contained more areas of hammock, open-developed areas and mangroves.

Female fawn ranges contained more pineland, open-developed areas and hardwood and less hammock, mangrove and buttonwood than expected (Table 14). Ranges of female fawns contained less hammock, open-developed areas, hardwood, mangrove and buttonwood and more of pineland than expected in winter. In spring, ranges contained less hammock, mangrove and buttonwood and more pineland and open-developed areas. Summer ranges had greater

Table 12. Plant community composition, in percent, of the mean monthly ranges of five yearling female Key deer, Key Deer National Wildlife Refuge, Monroe Co., Florida, 1969-1972.

Period	N	Hamm* $\bar{X}$	Hamm* S.D.	Pine $\bar{X}$	Pine S.D.	Open $\bar{X}$	Open S.D.	Hard $\bar{X}$	Hard S.D.	Mang $\bar{X}$	Mang S.D.	Butt $\bar{X}$	Butt S.D.	Mean Range (acres)
Apr	4	0.3	0.6	41.0	38.8	18.9	11.3	14.8	10.5	3.4	3.0	21.7	22.3	258
May	4	0.0	0.0	32.0	40.7	16.4	8.3	21.6	16.8	4.7	3.7	25.1	25.8	173
June	4	0.0	0.0	35.9	47.0	10.6	9.8	24.0	18.1	7.3	6.1	22.3	25.0	168
Spring	12	0.1	0.3	36.3	38.5	15.3	9.7	20.1	14.6	5.1	4.4	23.0	22.1	200
July	4	0.0	0.0	35.4	47.3	15.0	12.7	20.1	16.5	5.8	4.6	23.8	26.7	81
Aug	3	0.0	0.0	33.3	57.7	16.8	15.0	15.5	15.1	5.2	4.6	29.1	25.5	90
Sept	4	0.0	0.0	30.9	47.4	19.7	22.1	14.0	13.5	5.4	4.2	30.0	23.6	138
Summer	11	0.0	0.0	33.2	44.9	17.2	15.6	16.6	13.8	5.5	4.0	27.5	22.8	104
Oct	4	0.0	0.0	24.1	40.2	17.4	22.7	20.1	24.0	4.2	0.6	34.3	20.6	152
Nov	3	0.0	0.0	32.3	55.9	26.2	21.9	13.7	17.4	5.0	4.5	22.8	20.3	120
Dec	3	0.9	1.5	45.8	44.8	22.5	10.9	5.3	8.1	3.2	3.5	22.4	26.4	243
Fall	10	0.3	0.8	33.1	42.1	21.6	17.9	13.7	17.8	4.1	2.8	27.3	20.6	170
Jan	1	0.0	**	0.0	**	48.5	**	6.8	**	9.4	**	35.4	**	95
Feb	1	0.0	**	0.0	**	43.5	**	3.9	**	8.0	**	44.6	**	180
Mar	2	0.0	0.0	27.9	39.5	36.2	28.9	1.7	2.3	7.2	6.3	27.2	1.9	100
Winter	4	0.0	0.0	14.0	27.9	41.1	17.7	3.5	2.8	7.9	3.8	33.6	8.4	119
Year	37	0.1	0.5	32.1	39.5	20.4	16.2	15.6	14.9	5.3	3.8	26.6	20.4	155

*Habitat type: Hamm = hammock, Pine = pineland, Open = open-developed areas, Hard = hardwood, Mang = mangrove, Butt = buttonwood

**Insufficient data for standard deviation calculation

Table 13. Plant community composition, in percent, of the mean monthly ranges of 21 male fawn Key deer, Key Deer National Wildlife Refuge, Monroe Co., Florida, 1969-1972.

Period	N	Hamm* $\bar{X}$	Hamm* S.D.	Pine $\bar{X}$	Pine S.D.	Open $\bar{X}$	Open S.D.	Hard $\bar{X}$	Hard S.D.	Mang $\bar{X}$	Mang S.D.	Butt $\bar{X}$	Butt S.D.	Mean Range (acres)
Apr	1	0.0	**	100.0	**	0.0	**	0.0	**	0.0	**	0.0	**	42
May	4	14.2	13.1	61.3	7.2	0.0	0.0	6.5	9.7	1.2	2.4	16.8	15.8	37
June	3	19.7	17.1	62.3	13.1	4.9	8.4	0.0	0.0	1.8	3.2	11.3	18.5	43
Spring	8	14.5	14.1	66.5	16.0	1.8	5.2	3.3	7.2	1.3	2.4	12.6	15.4	40
July	4	7.1	14.2	32.8	24.9	42.8	31.9	16.2	25.3	1.9	3.3	14.2	15.7	53
Aug	4	5.7	7.6	47.8	47.7	12.8	19.6	4.1	5.0	3.0	3.8	26.6	37.3	92
Sept	6	3.2	5.3	46.0	36.4	14.8	16.0	7.1	8.1	3.6	3.6	25.5	27.8	239
Summer	14	5.0	8.6	42.7	35.0	22.2	24.6	8.8	14.3	2.9	3.4	22.6	26.6	144
Oct	4	1.8	3.6	49.0	38.8	10.8	9.2	5.9	7.7	3.9	3.8	28.8	30.0	255
Nov	4	0.0	0.0	42.9	30.7	9.0	10.9	9.6	7.5	4.4	1.7	34.1	30.6	226
Dec	7	2.3	6.2	44.8	32.0	10.4	10.0	9.3	11.4	6.0	6.0	27.2	25.8	150
Fall	15	1.6	4.5	45.4	31.1	10.1	9.3	8.5	9.1	5.0	4.5	29.4	26.3	198
Jan	5	0.0	0.0	56.2	35.4	11.5	8.6	1.6	3.9	3.3	2.4	27.2	30.1	125
Feb	5	0.0	0.0	53.8	33.4	10.9	5.4	3.3	3.7	3.6	3.2	28.4	29.0	143
Mar	5	0.0	0.0	51.8	31.0	12.8	6.3	3.3	2.2	4.6	2.8	27.5	28.7	129
Winter	15	0.0	0.0	54.0	30.9	11.8	6.5	2.8	3.2	3.8	2.7	27.7	27.1	132
Year	52	4.0	8.7	50.4	30.7	12.6	15.5	7.1	9.6	3.5	3.6	24.5	25.2	140

*Habitat type: Hamm = hammock, Pine = pineland, Open = open-developed areas, Hard = hardwood, Mang = mangrove, Butt = buttonwood

**Insuficient data for standard deviation calculation

Table 14. Plant community composition, in percent, of the mean monthly ranges of six female fawn Key deer, Key Deer National Wildlife Refuge, Monroe Co., Florida, 1969-1972.

Period	N	Hamm*		Pine		Open		Hard		Mang		Butt		Mean Range
		X	S.D.	X	S.D.	X	S.D.	X	S.D.	X	S.D.	X	S.D.	(acres)
Apr	1	0.0	**	56.4	**	0.0	**	3.0	**	5.9	**	34.7	**	40
May	1	0.0	**	100.0	**	0.0	**	0.0	**	0.0	**	0.0	**	52
June	1	0.0	**	93.0	**	7.0	**	0.0	**	0.0	**	0.0	**	68
Spring	3	0.0	0.0	83.1	23.4	2.3	4.0	1.0	1.7	2.0	3.4	11.6	20.0	53
July	1	0.0	**	87.1	**	12.9	**	0.0	**	0.0	**	0.0	**	37
Aug	1	0.0	**	70.0	**	30.0	**	0.0	**	0.0	**	0.0	**	48
Sept	1	0.0	**	18.5	**	46.2	**	10.0	**	4.6	**	20.8	**	52
Summer	3	0.0	0.0	58.7	35.7	29.7	1617	3.3	5.8	1.5	2.7	6.9	12.0	46
Oct	1	0.0	**	35.8	**	23.6	**	25.0	**	1.9	**	13.7	**	490
Nov	2	0.0	0.0	34.9	49.4	22.3	11.2	6.7	9.5	3.8	5.4	32.3	45.7	104
Dec	5	0.0	0.0	44.7	43.7	22.8	16.7	6.3	9.4	3.7	5.1	22.5	28.1	90
Fall	8	0.0	0.0	41.2	38.3	22.8	13.3	8.7	10.3	3.5	4.4	23.8	28.1	144
Jan	4	0.0	0.0	38.8	38.2	30.8	10.2	9.8	10.5	2.9	4.6	17.8	20.9	127
Feb	4	0.0	0.0	34.4	41.5	25.0	15.3	14.1	19.3	3.4	3.5	23.3	26.9	108
Mar	4	2.0	4.0	38.1	36.9	26.1	11.3	9.6	12.0	21.0	38.6	28.0	34.8	109
Winter	12	0.7	2.3	37.1	35.2	27.3	11.5	11.2	12.5	9.1	22.2	23.0	25.8	115
Year	26	0.3	1.6	46.1	36.5	23.3	14.0	8.3	10.7	5.7	15.3	20.1	24.4	109

*Habitat type: Hamm = hammock, Pine = pineland, Open = open-developed areas, Hard - hardwood, Mang = mangrove, Butt = buttonwood

**Insufficient data for standard deviation calculation

areas of pineland, open-developed areas and hardwood and less hammock, mangrove and buttonwood. Fall ranges had more pineland, open-developed areas and hardwood and less hammock and buttonwood.

Habitat Use as Estimated by Telemetry

It is apparent that habitat within monthly ranges, although differing from that available, may not reflect actual utilization of habitat. Not indicated is the actual time spent in each habitat nor activities carried out there. The use of telemetry enabled estimates of time spent in each habitat type.

The 11,253 locations recorded for 81 deer included 2,591 for 12 adult males, 4,202 for 21 adult females, 1,189 for 9 yearling males, 1,187 for 5 yearling females, 1,364 for 27 male fawns, and 720 for 14 female fawns. Because of small samples, conclusions for yearling males and females, and for fawns during April through October, are not conclusive.

Percentages of all radio-determined locations on Big Pine Key, compared with available habitats (in parentheses), were: open-developed areas 12.9 (17.1), pineland 34.4 (32.4), buttonwood 23.2 (31.1), hardwood 13.4 (5.4), hammock 6.5 (4.7), and mangrove 9.6 (9.4) (Table 15). A Chi-square test indicated a significant difference between habitat use as determined by telemetry and available habitat. Deer made greater use of pineland, hardwood and hammock and less of buttonwood and open-developed areas than expected. Mangrove was utilized at the expected level. Habitat use as determined by telemetry differed significantly during each season and year for each sex and age class. Other apparent differences were non-significant; however, given sufficient sample sizes these would probably be significant.

Table 15. Plant community composition, in percent, of radio locations for 81 Key deer, Key Deer National Wildlife Refuge, Monroe Co., Florida, 1969-1972

Period	Open*	Pine	Butt	Hard	Mang	Hamm	Number of Locations
Winter	12	26	29	12	11	10	2,418
Spring	12	35	27	12	09	06	3,140
Summer	13	37	19	15	10	06	2,899
Fall	15	39	18	15	08	05	2,796
Year	13	34	23	13	10	07	11,253

*Habitat type: Open = open-developed areas, Pine = pineland, Butt = buttonwood, Hard = hardwood, Mang = mangrove, Hamm = hammock

Table 16. Plant community composition, in percent, of radio locations for 12 adult male Key deer, Key Deer National Wildlife Refuge, Monroe Co., Florida, 1969-1972.

Period	Open*	Pine	Butt	Hard	Mang	Hamm	Number of Locations
Winter	04	08	43	19	12	13	568
Spring	11	19	37	15	15	03	807
Summer	14	23	24	16	12	11	646
Fall	12	37	15	16	06	14	570
Year	11	22	31	16	12	10	2,591

*Habitat type: Open = open-developed areas, Pine = pineland, Butt = buttonwood, Hard = hardwood, Mang = mangrove, Hamm = hammock

There was increased use of hardwood, buttonwood and hammock by males from birth to adulthood with decreased use of pineland and mangrove. Open-developed areas were utilized more by yearling males than by either fawn or adult males. There was decreased use of mangrove, pineland and open-developed areas and increased use of hammock by females from birth to adulthood. Yearling females utilized buttonwood and hardwood more than did either fawn or adult females.

Adult Males

Adult males utilized hardwood, hammock and mangrove more and open-developed areas, buttonwood and pineland less than expected (Table 16). There was increased use of pineland and decreased use of buttonwood from winter to fall. Open-developed areas were used less than expected during winter, hammock areas less in spring, and mangroves less in fall.

Adult Females

Adult females, on an annual basis, used pineland, hardwood and hammock more than expected and open-developed areas, buttonwood and mangrove less (Table 17). Hammock was used less in winter, spring and summer while pineland use increased in spring and summer. Use of mangroves in spring and summer decreased.

Yearling Males

Annual habitat use by yearling males (Table 18) was similar to that of adult males. Seasonal use showed an increase of hardwood areas from winter to fall, decrease of hammock in spring and summer, and increase of pineland in winter and spring.

Table 17. Plant community composition, in percent, of radio locations for 21 adult female Key deer, Key Deer National Wildlife Refuge, Monroe Co., Florida, 1969-1972.

Period	Open*	Pine	Butt	Hard	Mang	Hamm	Number of Locations
Winter	12	25	25	13	09	16	707
Spring	15	39	23	10	06	08	1,176
Summer	13	44	18	14	06	06	1,190
Fall	17	37	20	15	08	03	1,129
Year	16	37	21	13	07	07	4,202

*Habitat type: Open = open-developed areas, Pine = pineland, Butt = buttonwood, Hard = hardwood, Mang = mangrove, Hamm = hammock

Table 18. Plant community composition, in percent, of radio locations for 9 yearling male Key deer, Key Deer National Wildlife Refuge, Monroe Co., Florida, 1969-1972.

Period	Open*	Pine	Butt	Hard	Mang	Hamm	Number of Locations
Winter	17	31	13	09	16	13	178
Spring	11	38	27	10	12	02	541
Summer	15	23	25	11	19	06	288
Fall	16	21	24	19	10	10	182
Year	14	31	24	11	14	06	1,189

*Habitat type: Open = open-developed areas, Pine = pineland, Butt = buttonwood, Hard = hardwood, Mang = mangrove, Hamm = hammock

Yearling Females

Annual habitat use by yearling females was similar to adult females except that yearlings used hammock less (Table 19). The use of buttonwood decreased from winter to fall while pineland and hardwood use decreased in winter. There was decreased use of open-developed areas and mangrove in spring and summer.

Fawns

Male fawns used pineland and mangrove greater and open-developed and buttonwood less than expected on the basis of availability. In contrast, use of hardwood and hammock was similar to their availability (Table 20). Female fawns made greater use of pineland and hardwood and less of buttonwood (Table 21), whereas open-developed, mangrove, and hammock areas were utilized according to availability.

Male fawns made extensive use of hammock, pineland and hardwood in spring (the period of their birth) but open-developed areas and mangrove areas were used little. Female fawns' use of buttonwood decreased in spring and summer. As with male fawns, little use of open-developed areas during spring was evident. Female fawns used buttonwood and hardwood less in spring and summer and hammock less from winter to fall. Heavy use was made of mangrove during spring and summer while pineland use decreased in winter.

Habitat Preference

To evaluate habitat preference, the percent of total locations, as determined by telemetry, within each habitat type was compared to the proportion of similar habitat type within deer monthly ranges. Each sex and age class was analyzed separately to estimate habitat perference or

Table 19. Plant community composition, in percent, of radio locations for five yearling female Key deer, Key Deer National Wildlife Refuge, Monroe Co., Florida, 1969-1972.

Period	Open*	Pine	Butt	Hard	Mang	Hamm	Number of Locations
Winter	24	04	54	07	11	00	114
Spring	10	44	24	17	03	02	333
Summer	09	34	21	28	07	01	392
Fall	17	39	17	19	08	00	348
Year	13	36	24	20	07	00	1,187

*Habitat type: Open = open-developed areas, Pine = pineland, Butt = buttonwood, Hard = hardwood, Mang = mangrove, Hamm = hammock

Table 20. Plant community composition, in percent, of radio locations for 27 male fawn Key deer, Key Deer National Wildlife Refuge, Monroe Co., Florida, 1969-1972.

Period	Open*	Pine	Butt	Hard	Mang	Hamm	Number of Locations
Winter	11	44	26	03	15	01	492
Spring	01	57	14	11	00	18	190
Summer	12	44	12	09	16	07	299
Fall	09	48	20	08	15	01	383
Year	09	47	20	07	13	05	1,364

*Habitat type: Open = open-developed areas, Pine = pineland, Butt = buttonwood, Hard = hardwood, Mang = mangrove, Hamm = hammock

Table 21. Plant community composition, in percent, of radio locations for 14 female fawn Key deer, Key Deer National Wildlife Refuge, Monroe Co., Florida, 1969-1972.

Period	Open*	Pine	Butt	Hard	Mang	Hamm	Number of Locations
Winter	19	37	19	16	04	06	359
Spring	01	45	16	05	30	02	92
Summer	21	63	00	00	15	00	85
Fall	23	47	11	13	07	00	184
Year	18	43	14	12	09	03	720

*Habitat type: Open = open-developed areas, Pine = pineland, Butt = buttonwood, Hard = hardwood, Mang - mangrove, Hamm = hammock

avoidance according to the method of Neu et al. (1974). All differences presented below are significant.

Although pineland, open-developed, hardwood and buttonwood habitat made up a greater proportion of deer ranges than expected on the basis of availability, and hardwood and mangrove less, the utilization of hammock and mangrove, as determined by telemetry, was greater. In general, it appeared that hardwood made up a large proportion of deer ranges and was preferred, whereas hammock and mangrove made up less but were also preferred. Pineland, open-developed and buttonwood made up a large proportion of the range but were avoided. Avoidance of a habitat type that made up a large proportion of a range did not necessarily suggest that it was not important. Such a habitat may be important but, because preference was based on time spent in an area (percent of random daily locations), the animal might have met its needed requirements of the habitat in less time (i.e. drinking water in a pine habitat). Preference for a habitat type that made up a minor part of a range might suggest that only a small area was needed to meet requirements. Avoidance of a habitat making up a small proportion of a range, may suggest there was a greater area of this habitat than required. And, preference for a habitat making up a major part of a range, might indicate a habitat was scarce and in demand. Understanding of these avoidance and preference patterns requires knowledge of the behavior and life history of the deer (to be discussed later). Even so, individual variation, physiographic arrangement of habitat and population pressures may have introduced distortions into apparent patterns of habitat selection.

Adult Males

Analysis of habitat composition of ranges of adult males by season

(Figure 14) indicated a larger than expected proportion of hardwood, open-developed areas and buttonwood, and less mangrove and hammock during all seasons and less pineland in winter (the rut). However, telemetry data indicated a preference for mangrove, hardwood and hammock (Figure 15). Pineland, open-developed and buttonwood habitats were used less even though they made up a large proportion of the range. Although deer fed in all habitats, the open-developed areas were used for this purpose almost exclusively (Hardin 1974). Reduced use of open-developed areas, which made up a large proportion of the range, indicated that feeding requirements of adult males were met in short periods of time or there was more of this habitat than required. Buttonwood and pineland, making up a large part of the range but avoided, supplied much of the accessible water. The increased preference for pineland during the rut correlated with adult female use of this area. In their search for females in estrus, adult males moved to these areas.

Hardwood areas were preferred and made up a greater than expected proportion of adult male ranges. These areas were used for bedding, feeding and escape, and water was available in some of them (Hardin 1974).

The increased use of hammock throughout the reproductive season, and general observations (Hardin 1974) indicated that, when pursued by bucks, females entered heavy cover. Mangrove, used as bedding sites, was a preferred habitat during the hot summer months.

Adult Females

Pineland, open-developed areas, hardwood and hammock made up a greater than expected proportion of adult female ranges during at least one season (Figure 16). There was no selection for, nor avoidance of buttonwood within the range; however, mangrove was a preferred habitat

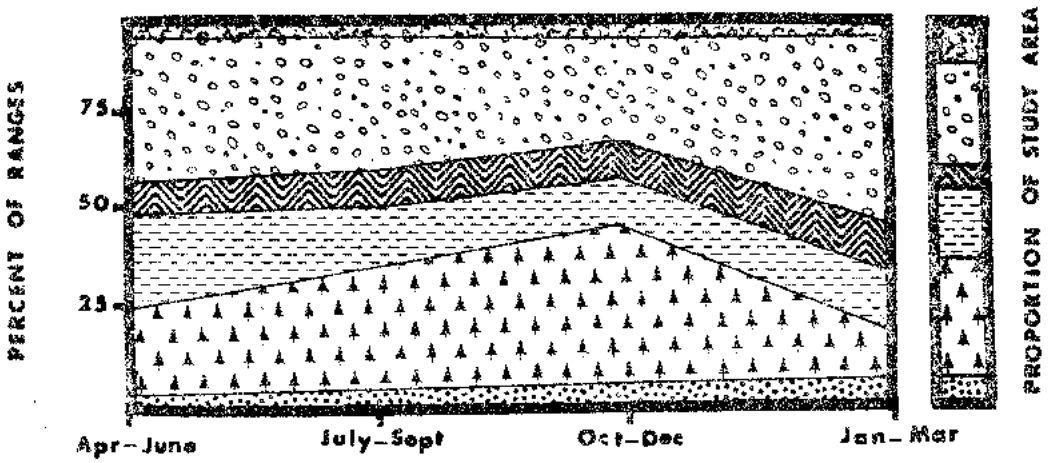


Figure 14. Plant community composition, in percent, of the mean monthly ranges of 11 adult male Key deer compared to that available, Key Deer National Wildlife Refuge, Monroe Co., Florida, 1969-1972. Habitat types from top to bottom are mangrove, buttonwood, hardwood, open-developed areas, pineland and hammock.

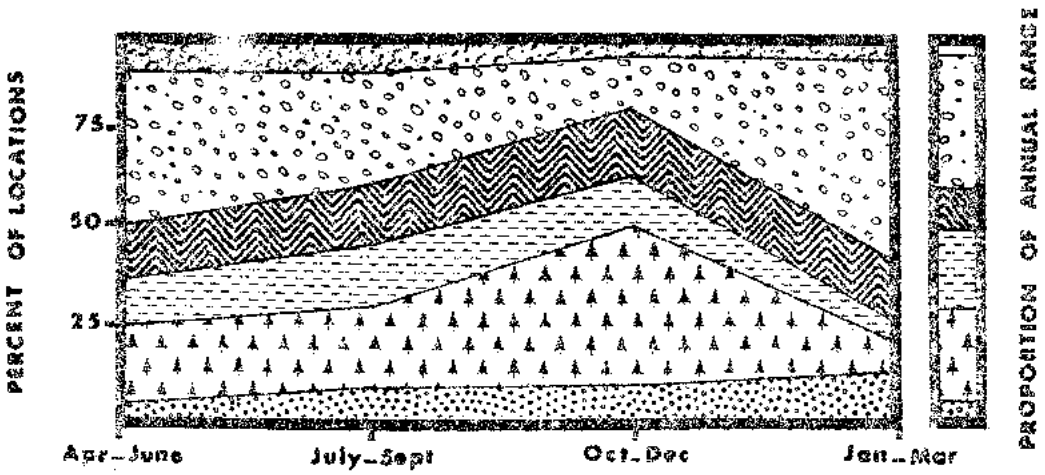


Figure 15. Plant community composition, in percent, of radio locations for 12 adult male Key deer compared to that available, Key Deer National Wildlife Refuge, Monroe Co., Florida, 1969-1972. Habitat types from top to bottom are mangrove, buttonwood, hardwood, open-developed areas, pineland and hammock.

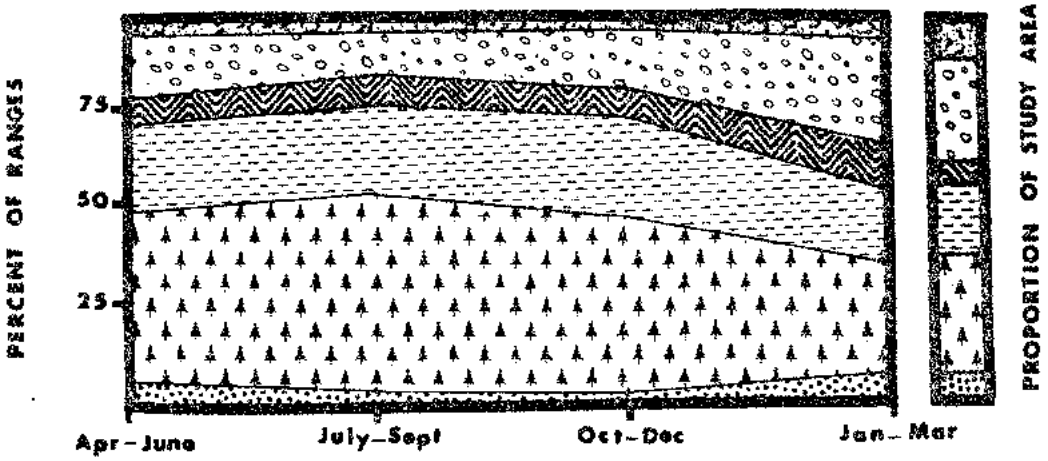


Figure 16. Plant community composition, in percent, of the mean monthly ranges of 15 adult female Key deer compared to that available, Key Deer National Wildlife Refuge, Monroe Co., Florida, 1969-1972. Habitat types from top to bottom are mangrove, buttonwood, hardwood, open-developed areas, pineland and hammock.

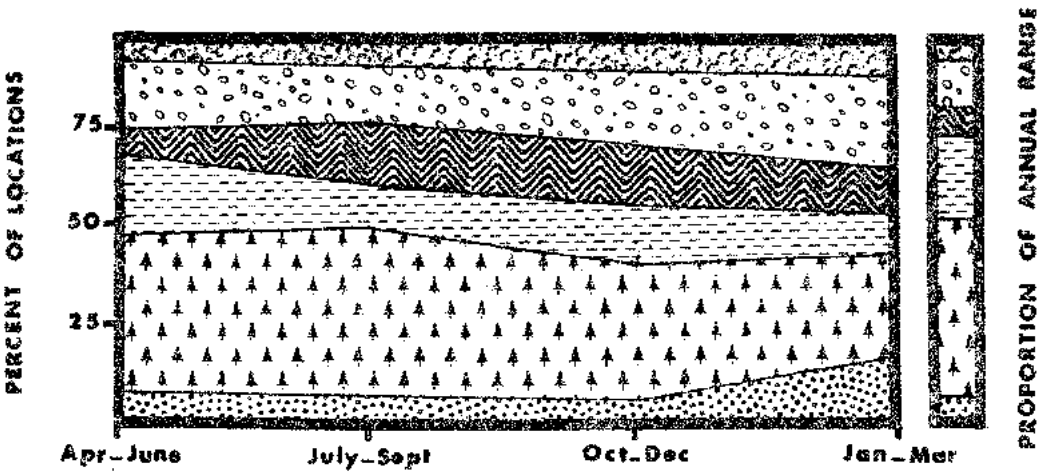


Figure 17. Plant community composition, in percent, of radio locations for 21 adult female Key deer compared to that available, Key Deer National Wildlife Refuge, Monroe Co., Florida, 1969-1972. Habitat types from top to bottom are mangrove, buttonwood, hardwood, open-developed areas, pineland and hammock.

(Figure 17). Preferred use of a small area may indicate that mangrove was sufficient for feeding. As with adult males, adult female use of hardwood areas indicated their importance as escape cover. Open-developed and pineland areas, normally used for feeding, were used less even though they made up a large proportion of the range. The decreased preference for pineland during rut and pre-fawning periods, with increased preference for hammock and buttonwood, may indicate an avoidance of harassment by bucks and stress prior to fawning, respectively. Availability of water was probably a factor in the decreased preference of pineland and the increased use of hammock and buttonwood.

Yearling Males

In a comparison of range composition (Figure 18) and habitat use (Figure 19), buttonwood made up a greater part of the range than expected; but, this habitat was avoided, especially during the late breeding season. Pinewood was used less during all but the late breeding season when heavy use occurred. Because yearling males were observed to avoid conflicts with adult bucks during the breeding season, yearling males used pineland less early in the season when adult bucks used it most. Because bottonwood made up a large portion of their ranges but was used less, yearling males appeared to spend less time in areas with little cover; this was confirmed with telemetry. During the late rut when adult males were less active sexually, yearling males preferred pineland and hammock where adult females were found. There was an increase preference for hammock from April through March. Open-developed areas appeared to be preferred during periods when they made up a less than expected proportion of the range. Hardwood areas were preferred during all but the pre-fawning period. Mangrove was preferred throughout the year with peak use in July

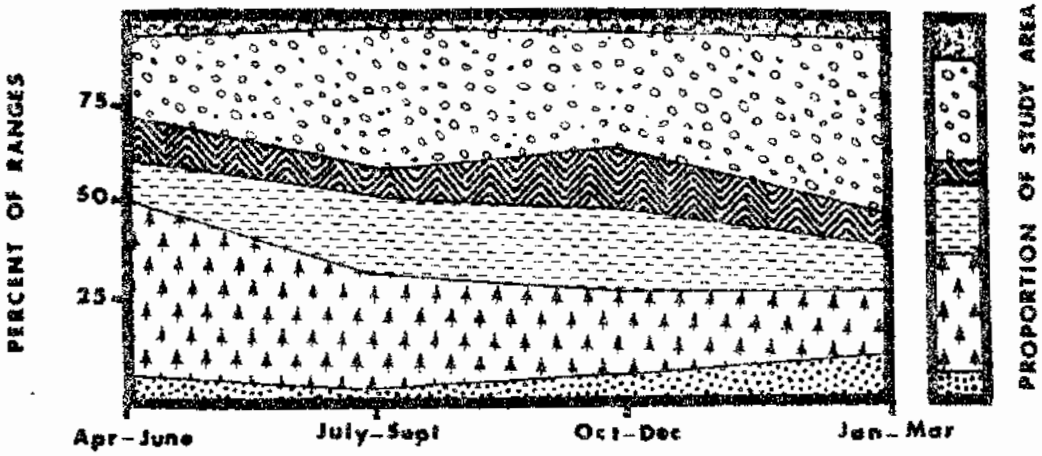


Figure 18. Plant community composition, in percent, of the mean monthly ranges of nine yearling male Key deer compared to that available, Key Deer National Wildlife Refuge, Monroe Co., Florida, 1969-1972. Habitat types from top to bottom are mangrove, buttonwood, hardwood, open-developed areas, pineland and hammock.

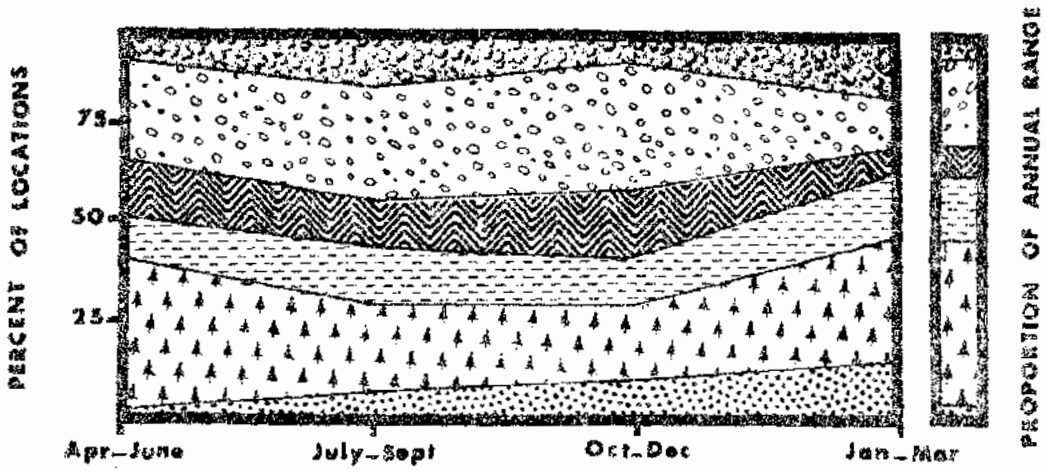


Figure 19. Plant community composition, in percent, of radio locations for nine yearling male Key deer compared to that available, Key Deer National Wildlife Refuge, Monroe Co., Florida, 1969-1972. Habitat types from top to bottom are mangrove, buttonwood, hardwood, open-developed areas, pineland and hammock.

through September when cool bedding was available.

Yearling Females

Buttonwood made up a greater proportion than expected of ranges only during winter, whereas pineland made up less of the range (Figure 20). Yearling females showed a preference for buttonwood during the late breeding season, whereas the preference for pineland, where adult bucks were, decreased (Figure 21). This could be correlated with an avoidance response to bucks during the late breeding season and to adult does during the early fawning season (Hardin 1974). Developed areas made up a large proportion of ranges but were avoided. Hardwood made up more of the range than expected and was preferred. Use of mangrove increased during the reproductive season even though it made up less of the range than expected. A preference for hammocks was observed during the fawning season.

Fawns

Ranges of male fawns contained a greater than expected area of hammock and pineland earlier in their lives than later (Figure 22), indicating these habitats were preferred most often by does as birth areas. Following birth, male fawns had ranges containing less hammock than expected during their first year of life; however, pineland continued to be a preferred habitat. Mangrove areas were preferred during all but early in the fawn's life, while hardwood and hammock were preferred only during the quarter of their birth (Figure 23). Open-developed areas made up a greater than expected proportion of ranges only during summer when they were also preferred.

Few female fawns were radio-tracked and, therefore, data are not

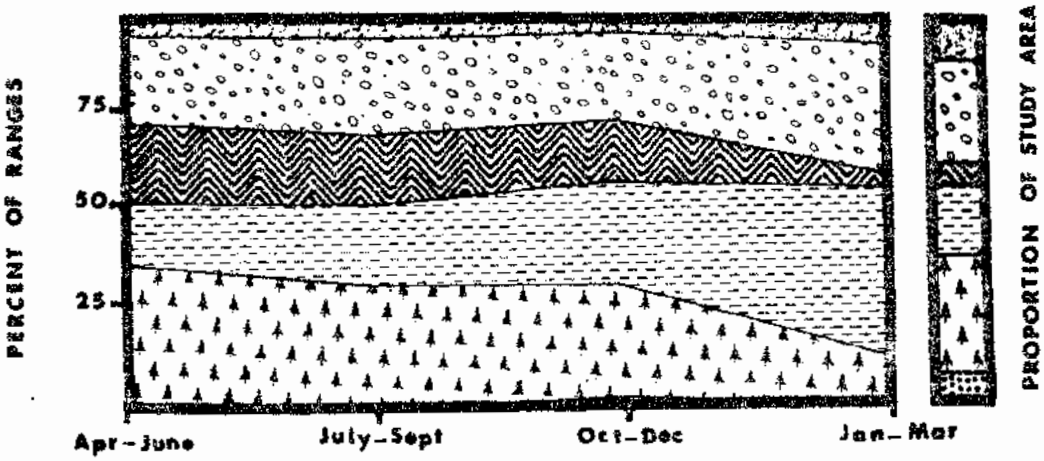


Figure 20. Plant community composition, in percent, of the mean monthly ranges of five yearling female Key deer compared to that available, Key Deer National Wildlife Refuge, Monroe Co., Florida, 1969-1972. Habitat types from top to bottom are mangrove, buttonwood, hardwood, open-developed areas, pineland and hammock.

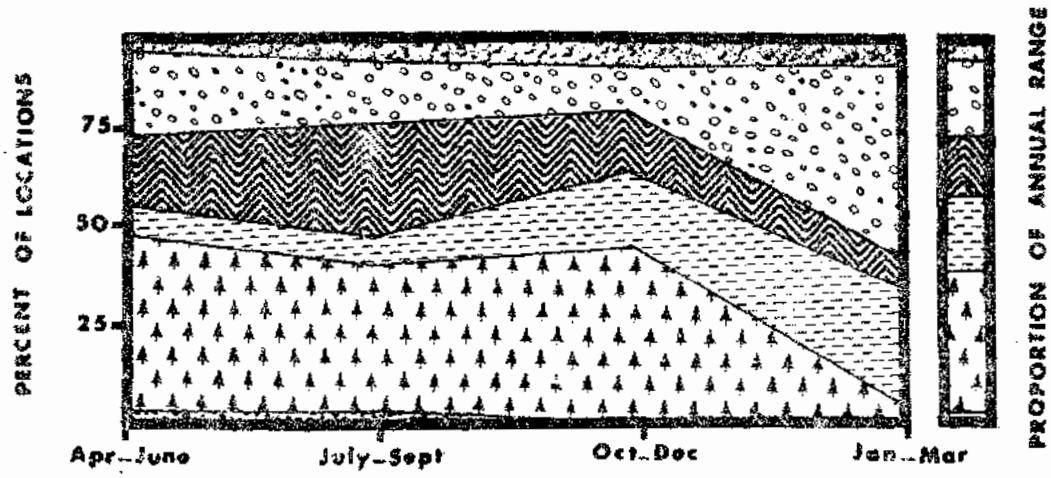


Figure 21. Plant community composition, in percent, of radio locations for five yearling female Key deer compared to that available, Key Deer National Wildlife Refuge, Monroe Co., Florida, 1969-1972. Habitat types from top to bottom are mangrove, buttonwood, hardwood, open-developed areas, pineland and hammock.

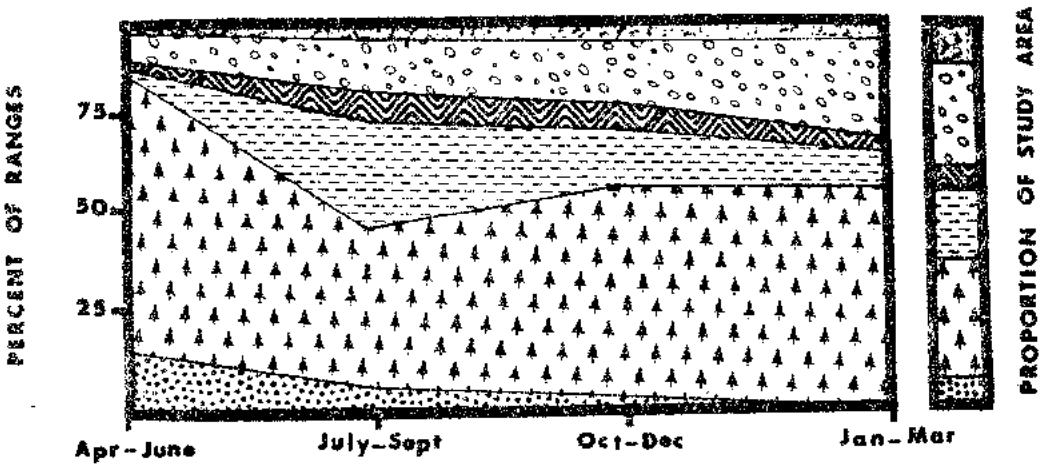


Figure 22. Plant community composition, in percent, of the mean monthly ranges of 21 male fawn Key deer compared to that available, Key Deer National Wildlife Refuge, Monroe Co., Florida, 1969-1972. Habitat types from top to bottom are mangrove, buttonwood, hardwood, open-developed areas, pineland and hammock.

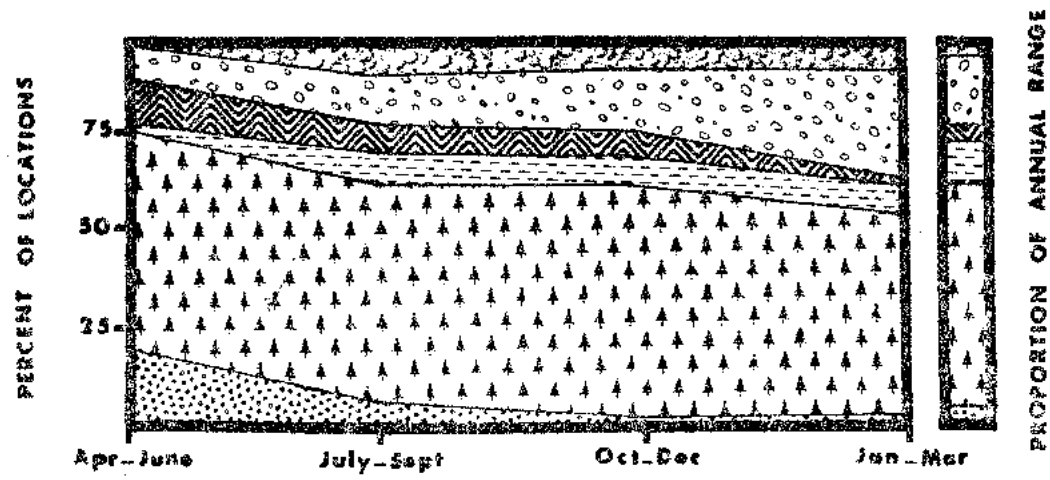


Figure 23. Plant community composition, in percent, of radio locations for 27 male fawn Key deer compared to that available, Key Deer National Wildlife Refuge, Monroe Co., Florida, 1969-1972. Habitat types from top to bottom are mangrove, buttonwood, hardwood, open-developed areas, pineland and hammock.

extensive. The use of pineland by female fawns reflects adult doe preferences of these as birth areas (Figures 16 and 24). Female fawns showed a preference for pineland during the summer breeding season (Figure 25). Hardwood was preferred during all but summer while hammock and buttonwood were preferred during January through June. Open-developed areas were avoided during all seasons while mangrove was given preference the first 6 months of life.

Habitat Preference Related to Environmental Factors

Daylight

Daytime locations, as determined by telemetry, were in significanly different habitats from nocturnal ones both annually and seasonally (Table 22). Pineland was used to the same degree during day and night. Open-developed areas were used significantly more at night while buttonwood, hardwood, mangrove and hammock were used less.

During the first 4 months following birth, fawns were not active at night. Adult bucks tended to use open-developed areas much less at night during the rut from fall through winter than during spring through summer, probably because they were following does rather than feeding. White (1973:480) noted that adult bucks voluntarily ate less during the rut.

Except for newborn fawns and yearling females, all deer made more use of open-developed habitats in daytime during spring through summer than during other seasons. This may have been in response to attacks by mosquitoes. During fall through winter, yearling females utilized open-developed areas more extensively at night than other times, probably to avoid buck harassment.

All animals tended to occupy hardwood more during daylight than at

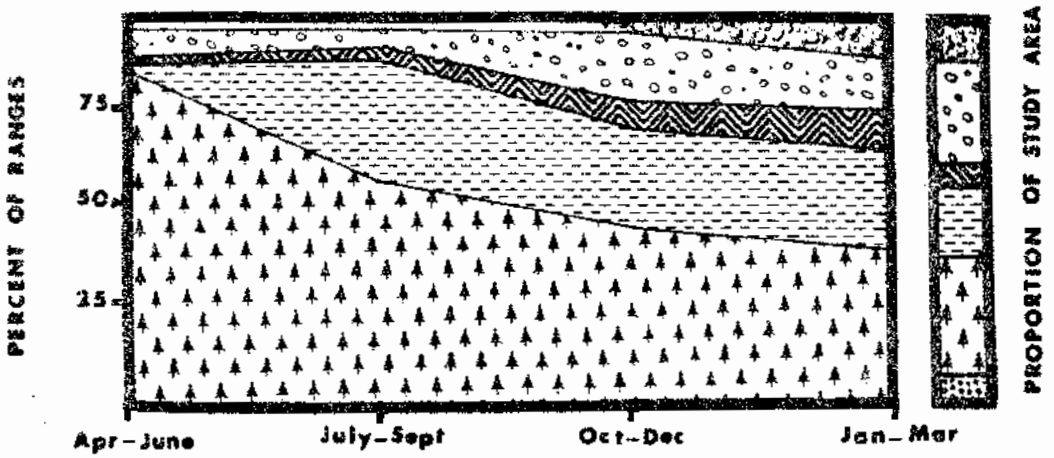


Figure 24. Plant community composition, in percent, of the mean monthly ranges of six female fawn Key deer compared to that available, Key Deer National Wildlife Refuge, Monroe Co., Florida, 1969-1972. Habitat types from top to bottom are mangrove, buttonwood, hardwood, open-developed areas, pineland and hammock.

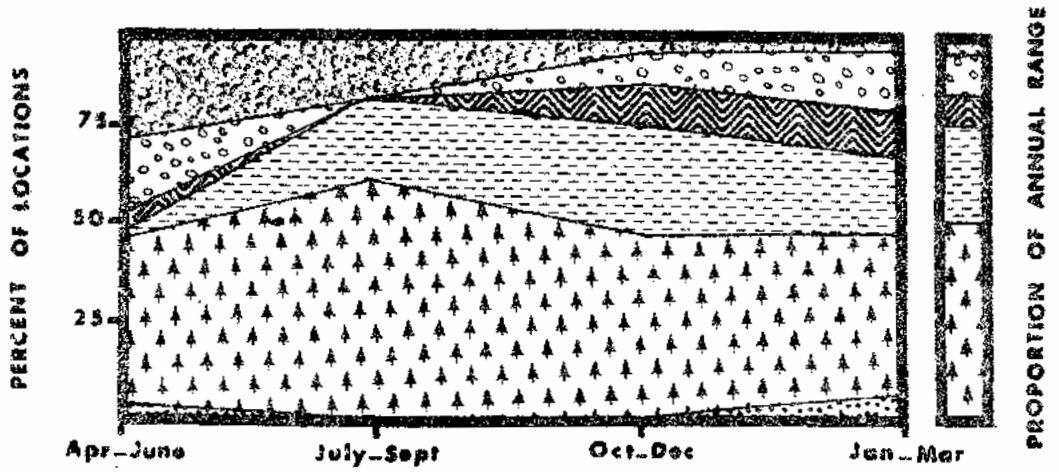


Figure 25. Plant community composition, in percent, of radio locations for 14 female fawn Key deer compared to that available, Key Deer National Wildlife Refuge, Monroe Co., Florida, 1969-1972. Habitat types from top to bottom are mangrove, buttonwood, hardwood, open-developed areas, pineland and hammock.

Table 22. Plant community composition, in percent, of radio locations during day and night hours for 81 Key deer radio-tracked, Key Deer National Wildlife Refuge, Monroe Co., Florida, 1969-1972.

Period	Daylight*	Open**	Pine	Butt	Hard	Mang	Hamm	Number of Locations
Winter	Day	02	27	31	15	14	12	1,162
	Night	21	26	27	10	08	08	1,256
Spring	Day	05	36	28	14	10	07	1,832
	Night	21	34	24	09	08	04	1,308
Summer	Day	05	37	21	18	10	08	1,597
	Night	23	36	17	11	10	03	1,302
Fall	Day	04	41	20	16	11	08	1,268
	Night	24	37	17	13	06	02	1,528
Year	Day	04	35	25	16	11	09	5,859
	Night	22	33	21	11	08	04	5,394

*Day equal period between sunrise and sunset and night equal all other time periods

**Habitat type: Open = open-developed areas, Pine = pineland, Butt = buttonwood, Hard = hardwood, Mang = mangrove, Hamm = hammock

night (Table 22). Mangrove and hammock also appeared to be used greater during the day. All these areas offered escape cover and cool bedding and loafing areas during the day. Buttonwood and pineland were used almost equally during day and night. Jeter and Marchinton (1964:148) in northwestern Florida, also observed deer in wooded portions of their range during daylight and in open range at night.

Rainfall

Telemetry locations revealed that deer avoided open-developed areas and utilized hardwood areas greater when rainfall was over 0.25 inches per day (Table 23). This difference was significant on an annual basis; seasonally, it was significant only in spring, when more data were available to compare the effects of heavy and light rain on deer behavior. During some of the heaviest rains, some deer invariably bedded or fed in open-developed areas. But, during the spring fawning season, adult does remained with fawns in heavy cover.

Temperature

No significant correlation was detected between either daily maximum or minimum temperatures and deer use of habitat as judged by telemetry. Because of this, the interaction between maximum and minimum temperatures was analyzed. Deer locations obtained on days when the minimum temperature was 40 degrees were grouped with those obtained on days when the minimum temperature was 70 degrees or above and tested against locations obtained on days when the minimum temperature was 50-60 degrees (Table 24). A Chi-square test indicated a significant difference, showing that greater use was made of open-developed areas during periods when temperatures were either low or hight, but pinelands and buttonwood less.

Table 23. Plant community composition, in percent, of radio locations by rainfall greater than 0.25 inch (I) and less than 0.26 inch (II) for 81 Key deer radio-tracked, Key Deer National Wildlife Refuge, Monroe Co., Florida, 1969-1972.

Period	Rainfall	Open*	Pine	Butt	Hard	Mang	Hamm	Number of Locations
Winter	I	15	27	27	12	10	08	226
	II	11	25	29	12	11	10	2,082
Spring	I	09	30	26	19	09	07	192
	II	12	35	27	11	09	05	2,714
Summer	I	10	36	19	16	11	07	712
	II	14	37	19	15	10	06	2,187
Fall	I	19	40	13	13	07	07	188
	II	15	38	19	15	09	05	2,607
Year	I	12	34	21	15	09	07	1,318
	II	13	34	24	13	09	06	9,590

*Habitat type: Open = open-developed areas, Pine = pineland, Butt = buttonwood, Hard = hardwood, Mang = mangrove, Hamm = hammock

Table 24. Plant community composition of radio locations by various combinations of daily minimum and maximum temperatures for 81 Key deer radio-tracked, Key Deer National Wildlife Refuge, Monroe Co., Florida, 1969-1972.

Temp Min.-Max.	Open*	Pine	Butt	Hard	Mang	Hamm	Totals
40 - 50	17(22)**	19(25)	15(19)	9(12)	9(12)	9(12)	78(100)
40 - 60	15(20)	29(39)	13(17)	11(15)	6(08)	3(04)	77(100)
40 - 70	7(08)	25(30)	24(29)	9(11)	15(18)	4(05)	84(100)
50 - 60	40(10)	103(26)	106(26)	58(15)	51(13)	41(10)	399(100)
50 - 70	146(15)	276(29)	251(26)	125(13)	82(09)	78(08)	958(100)
50 - 80	6(04)	57(36)	40(25)	24(15)	21(13)	10(06)	158(100)
60 - 60	0(00)	2(33)	4(67)	0(00)	0(00)	0(00)	6(100)
60 - 70	120(12)	324(32)	265(26)	125(12)	102(10)	78(08)	1,014(100)
60 - 80	94(06)	588(35)	431(26)	249(15)	197(12)	115(07)	1,674(100)
60 - 90	3(07)	22(51)	2(05)	12(28)	2(05)	2(05)	43(100)
70 - 70	0(00)	13(41)	7(41)	5(16)	5(16)	2(06)	32(100)
70 - 80	303(11)	1,093(38)	658(23)	380(13)	277(10)	163(06)	2,874(100)
70 - 90	85(04)	977(40)	589(24)	379(16)	227(09)	167(07)	2,424(100)
80 - 80	1(05)	7(37)	2(11)	5(26)	2(11)	2(11)	19(100)
80 - 90	24(21)	39(34)	23(20)	13(11)	11(09)	6(05)	116(100)
Totals	907(09)	3,671(36)	2,506(24)	1,442(14)	1,052(10)	700(07)	10,279(100)

*Habitat type: Open = open-developed areas, Pine = pineland, Butt = buttonwood, Hard = hardwood, Mang = mangrove, Hamm = hammock

**Percentage of total

Because of the subtropical climate in the Florida Keys, one might expect that temperature effects on deer use of habitat would be minimal. The highest temperature recorded between 1969-1973, was 96 degrees (F), the lowest 39 degrees; the mean annual temperature was approximately 75 degrees (Ralph Higgs, Big Pine Key area weather station).

When temperatures are either low or high, deer are known to utilize dense areas for protection from cold and heat, respectively (Severinghaus 1947, Robinson 1960, Ozoga 1968, Verme 1968 and Loveless 1964). This may be the reason Key deer utilized pinelands and buttonwood areas less under low temperatures; except for the open-developed areas, these were the most open of the six habitats. However, this does not explain utilization of open-developed areas during low temperatures more even though they were least protected.

An explanation lies in Moen's (1968) work on surface temperatures and radiant heat loss from deer. He (1968:343) noted that deer in the agricultural habitat of western Minnesota did not always seek heavier cover during cold winter weather. He observed that when air temperatures did not rise above -18 degrees (C) for an entire week, deer continued to bed in open fields and fed on corn, soybeans and dry sweet clover. He showed that this was possible from an energetic standpoint, because the diet supplied an adequate quantity of metabolizable energy. He emphasized that thermal energy emanating from the cover could only serve to reduce heat loss; but, sufficient food had to be available for basal energy requirements and for activities. Key deer may have utilized open-developed areas more during cold periods as a ready source of food to replace heat loss. Moen (1968:343) emphasized that the quantity of heat lost by an animal must be balanced against the heat produced by metabolic processes.

He also noted that food must be considered the basic requirement, and cover becomes physiologically important only when its presence is necessary to maintain a positive energy balance. Because of their small size and large surface to volume ratio, Key deer may be similarly affected by less extreme temperatures than their counterparts on the mainland. Key deer may find it more efficient to replenish heat energy loss by utilizing a habitat with abundant food and less cover than to use one with greater cover and less food.

During periods of high temperatures, Key deer may have utilized open-developed areas more because of the lower amount of thermal energy present which would in effect be cooler at night than would be the other habitats.

Wind

There was no apparent effect of wind direction on deer use of habitat (Table 25). However, wind speed exceeding 15 mph (Table 26), resulted in some significant differences in habitat utilization. These differences were on an annual basis and during winter and spring. When wind speeds exceeded 15 mph, open-developed areas were used more during spring and summer and used less in winter. Buttonwood tended to be used more during all seasons when wind speed exceeded 15 mph.

Such utilization of open-developed and buttonwood areas (the two less dense habitats) during summer was expected; for, with greater wind speed, more effective cooling of deer occurred. In contrast, during periods of low wind speed, cooling would be more effective in shaded cover. Deer may also have used these open areas to escape attacks by mosquitoes. During the summer rainy season, mosquitoes were numerous in the dense habitats. By bedding in more exposed areas, Key deer could take advantage of the high wind speed which hampered flight of mosquitoes. Just why deer

Table 25. Plant community composition, in percent, of radio locations by wind direction for 81 Key deer radio-tracked, Key Deer National Wildlife Refuge, Monroe Co., Florida, 1969-1972.

Wind Direction	Open*	Pine	Butt	Hard	Mang	Hamm	Number of Locations
North	13	30	27	11	11	08	1,334
Northeast	15	33	24	14	08	06	2,591
East	12	34	25	15	08	06	1,576
Southeast	13	35	21	16	10	05	3,012
South	13	38	21	12	10	06	1,264
Southwest	09	33	20	14	16	08	210
West	08	31	30	08	13	10	103
Northwest	11	34	23	14	11	07	443

*Habitat type: Open = open-developed areas, Pine = pineland, Butt = buttonwood, Hard = hardwood, Mang = margrove, Hamm = hammock

Table 26. Plant community composition, in percent, of radio locations by wind speed between 0-15 mph and between 15-30 mph for 81 Key deer radio-tracked, Key Deer National Wildlife Refuge, Monroe Co., Florida, 1969-1972.

Period	Wind Speed (mph)	Open*	Pine	Butt	Hard	Mang	Hamm	Number of Locations
Winter	15-30	06	27	29	16	11	10	280
	0-15	13	26	29	12	11	10	2,114
Spring	15-30	16	35	28	13	10	04	297
	0-15	12	34	21	12	09	05	2,562
Summer	15-30	16	37	23	15	08	04	158
	0-15	13	39	18	15	10	06	2,423
Fall	15-30	12	36	20	12	12	09	139
	0-15	15	39	18	15	08	05	2,587
Year	15-30	12	33	24	14	10	07	874
	0-15	13	35	23	13	10	06	9,686

*Habitat type: Open = open-developed areas, Pine = pineland, Butt = buttonwood, Hard = hardwood, Mang = mangrove, Hamm = hammock

utilized buttonwood areas greater in winter when wind speed exceeded 15 mph was not clear. The buttonwood habitat provided some shelter from wind and also allowed sufficient exposure to solar radiation to help maintain body loss during these cooler periods.

Moonlight

In the summer, buttonwood was used significantly more during periods of a three-quarter moon than during other moon phases (Table 27). At present I cannot offer an explanation for this difference nor can I be sure that the difference is real; the effects of moonlight may have been masked by other variables.

Cloud Cover

No significant difference could be detected between light, medium nor heavy cloud cover on deer use of habitats (Table 28). Either the effects of cloud cover were masked by other variables or were non-existent.

Habitat Change

During January 1969 through June 1973, land clearing on Big Pine Key averaged about 115 acres per year (Table 2). Of the 3,640 acres of undeveloped land, approximately 1,500 acres are owned by the National Audubon Society and the U.S. Government (Jack Watson, personal communication). If the above rate of development continues unchecked, all non-developed, privately-owned land could be developed in less than 20 years. It is inevitable that the Key deer population will decrease due to conflicts with human populations and reduction in habitat.

Land cleared and developed represented approximately 90 percent pineland, hardwood and mangrove habitats (Table 2). The importance of these

Table 27. Plant community composition, in percent, of radio locations by three-quarter moon (I) and all other combined moon phases (II), for 81 Key deer radio-tracked, Key Deer National Wildlife Refuge, Monroe Co., Florida, 1969-1972.

Period	Moonphase	Open*	Pine	Butt	Hard	Mang	Hamm	Number of Locations
Winter	I	19	24	32	10	08	08	113
	II	21	26	27	10	08	08	1,143
Spring	I	19	37	41	03	00	00	32
	II	21	34	24	09	08	04	1,276
Summer	I	14	41	25	09	05	05	99
	II	23	36	16	11	10	03	1,203
Fall	I	21	48	17	12	02	00	58
	II	24	36	17	13	06	03	1,470
Year	I	17	36	28	09	05	05	302
	II	23	33	21	11	08	04	5,092

*Habitat type: Open = open-developed areas, Pine = pineland, Butt = buttonwood, Hard = hardwood, Mang = mangrove, Hamm = hammock

Table 28. Plant community composition, in percent, of radio locations by cloud cover for 81 Key deer radio-tracked, Key Deer National Wildlife Refuge, Monroe Co., Florida, 1969-1972.

Period	Cloud Cover	Open*	Pine	Butt	Hard	Mang	Hamm	Number of Locations
Winter	Light	12	26	30	11	10	11	1,625
	Medium	09	27	27	17	12	08	607
	Heavy	26	21	27	08	13	06	162
Spring	Light	14	33	27	11	10	05	2,011
	Medium	08	36	28	12	09	06	601
	Heavy	09	34	27	18	07	04	247
Summer	Light	13	38	18	14	10	06	1,571
	Medium	12	38	20	15	10	06	778
	Heavy	14	38	19	13	09	06	244
Fall	Light	14	39	19	14	09	05	2,203
	Medium	20	37	18	14	06	05	407
	Heavy	09	44	10	25	03	09	116
Year	Light	14	34	23	13	10	06	7,410
	Medium	12	35	23	15	09	06	2,393
	Heavy	14	34	22	15	08	06	769

*Habitat type: Open = open-developed areas, Pine = pineland, Butt = buttonwood, Hard = hardwood, Mang = mangrove, Hamm = hammock

habitats was established by this study. The use of open-developed areas by deer was below the percent availability; and, with 115 acres being cleared yearly, the percent deer use of open-developed areas can only decrease.

Harlow (1959) evaluating white-tailed deer habitat in Florida, indicated that pine-oak upland, sand pine-scrub oak and hammock habitats could support more deer per acre than most other types in the State. And, as pointed out by Halls and Crawford (1960), a greater number of deer in a declining habitat will soon lead to a deer herd exceeding its carrying capacity. With continued overbrowsing seriously reducing forage, only a decline of the herd can be expected.

Big Pine Key has more than 100 miles of mosquito ditching. These ditches as well as firetrails have opened new travel routes and allowed freer deer movement through thick areas of hardwood-hammock habitats. The "new land" created by the marl extraction from mosquito ditching has made available an "edge" (open) habitat extending into and through all major habitats. Heavy deer use was made of these openings and of the herbaceous, woody and grassy plants that invaded. Because some of these ditches created contained suitable water, deer use was possible even during drought. Concentrations of deer activities around water supplies created by ditching was evident. These ditches probably enhanced the deer carrying capacity and affected herd distribution. However, the presence of ditches in some areas did result in fawn mortality (Hardin 1974).

Vegetation in the lower Keys has been greatly influenced by fires, as have plant communities in all south Florida for the past 2,000 to 3,000 years (Klukas 1973). Absence of fires from the normally open pinewoods resulted in replacement of pines by dense hardwood hammocks (Dickson 1955).

As a result, most low growing species were eliminated and the dense hardwood species had few, low side branches available to deer. During this study, new woody and herbaceous plant growth following fires, immediately attracted deer; and, extensive movements to such areas occurred for up to 6-9 months. Use then declined and was drastically reduced after about 18 months. Deer attraction was also noted following fire or mowing in open, grassy areas. Such changes in habitat greatly affected deer movements and utilization of given areas.

Population Density of Deer on Big Pine Key

In estimating population densities, fawns were not included until October of the year of birth because few fawns were active at night prior to the fall season. Because of this, population estimates exhibited an increase starting in fall each year. Therefore, annual estimates were begun with the October census data of 1968. Monthly estimates were made from January 1969 on and quarterly estimates from summer 1968 on.

Road Census Estimates of Deer Densities Within Refuge

Combining quarterly census data (Table 29) to determine annual estimates yielded 61 deer in 1969 (October 1968-September 1969), 83 in 1970, 120 in 1971 and 110 in 1972 (October 1971-June 1972). From January 1969 through June 1973, monthly estimates of deer density based on the standard 10-mile census varied from 37 deer in July and October 1969 to 177 in February 1972 (Table 30). Estimates by quarters (Table 29) showed an increase in the number of deer from January 1969 (67 deer) until winter 1971 (156 deer). Following this, the population seemed to decrease; however, the apparent decline throughout 1971 and 1972 may have been caused by deer moving from other Keys onto Big Pine Key (see later section)

Table 29. Quarterly estimates of population size by age and sex based on nightly 10-mile censuses on Big Pine Key, Key Deer National Wildlife Refuge, Monroe Co., Florida, October 1968-June 1972.

Quarter	Population Estimates													
	All Deer		Adult Does		Adult Bucks		Yearlings						Fawns	
							Bucks		Does		Both			
	N	C.L.*	N	C.L.	N	C.L.	N	C.L.	N	C.L.	N	C.L.	N	C.L.
Oct-Dec 68	242	140	---**		---		---		---		---		20	12
Jan-Mar 69	61	9	19	5	12	7	---		---		---		21	5
Apr-June 69	70	13	29	6	7	2	14	20	8	1	25	6	---***	
July-Sept 69	42	7	24	7	9	4	7	2	4	0	10	2	---	
Oct-Dec 69	67	12	15	3	---		8	4	---		21	12	19	5
Jan-Mar 70	67	5	33	5	5	2	9	3	4	0	12	3	17	2
Apr-June 70	98	10	56	5	10	1	9	3	10	0	21	4	---	
July-Sept 70	83	8	44	4	12	2	17	10	10	2	23	6	---	
Oct-Dec 70	127	12	59	8	17	5	10	3	12	5	20	5	21	4
Jan-Mar 71	156	11	55	5	23	9	26	9	13	5	42	12	49	11
Apr-June 71	117	5	61	2	23	3	15	5	14	2	31	6	---	
July-Sept 71	97	3	57	3	20	3	13	3	10	0	21	2	---	
Oct-Dec 71	118	5	48	2	20	6	9	2	13	2	23	3	25	3
Jan-Mar 72	114	12	49	7	---		10	5	7	0	17	3	14	1
Apr-June 72	101	10	47	4	18	3	---		15	4	39	15	---	

*Plus and minus ninety-five percent confidence limit.

**Insufficient data for population estimate.

***Insufficient data and fawns not counted for population estimates during these periods.

Table 30. Monthly estimates of population size based on weekly 10-mile censuses on Big Pine Key, Key Deer National Wildlife Refuge, Monroe Co., Florida, January 1969-June 1972.

Month	Population Estimates							
	1969		1970		1971		1972	
	N	C.L.*	N	C.L.	N	C.L.	N	C. L.
Jan	57	8	72	13	176	26	90	12
Feb	151	95	68	8	141	10	177	7
Mar	43	4	61	8	157	26	113	17
Apr	75	9	89	17	135	6	106	18
May	58	18	131	13	108	3	100	6
June	108	53	83	7	101	9	68	12
July	37	6	86	16	102	5		
Aug	40	11	79	10	93	11		
Sept	83	65	79	13	89	8		
Oct	37	9	110	26	123	11		
Nov	41	5	138	35	106	9		
Dec	92	27	126	8	119	2		

*Plus and minus ninety-five percent confidence limit.

during a drought from October 1970 through May 1971 increasing estimates during winter 1971 (156 deer) and spring 1971 (117 deer). Estimates prior to the drought, in spring 1970, and those following the drought in spring 1972, were 98 and 101 deer, respectively. The apparent decline in population size noted in all years during summer was caused by the fawn crop not being included in the estimates.

Road Census Estimates of Deer Densities on Big Pine Key

Application of the Schumacher-Eschmeyer technique to data from sunrise-sunset censuses (Tables 31 & 32), revealed a population of 177 animals for Big Pine Key. The sunrise census yielded a significantly higher population estimate (213) than the sunset census (165); the proportion of marked to unmarked deer seen during the sunrise census was significantly less than that for the sunset census.

Behavior of radio-tagged animals indicated that at sunset certain animals moved into open areas to feed. Because most were marked due to ease in capturing, such animals were more readily seen during the sunset census. In contrast, seldom was any deer observed in open-developed areas during the sunrise census; deer were usually observed crossing roads at this time. Therefore, the more random mix of marked to unmarked deer would have been during the sunrise census. For this reason the sunrise census was considered best for population estimation.

The number of deer seen per mile along the 10-mile census route was correlated with the Schumacher-Eschmeyer estimate of population size to determine if these data show population trends. The Schumacher-Eschmeyer estimate (based on marked-unmarked deer) and the number of deer seen per mile are independent indications of the herd increase or decrease during a given year. Of the two methods, the latter is much easier to apply and

Table 31. Results of sunrise census conducted for all of Big Pine Key, Key Deer National Wildlife Refuge, Monroe Co., Florida, January 1971-December 1971.

Month	Number of Censuses	Number of Deer				Buck:Doe:Fawn Ratio	Marked Deer	Non-Marked Deer	Total Number Observed	Number Per Mile
		Buck	Doe	Fawn	Unidentified					
Jan	2	8	9	7	4	.89:1:.77	5	23	28	.32
Feb	2	3	11	10	3	.27:1:.91	5	19	24	.27
Mar	2	3	8	6	1	.38:1:.75	8	10	18	.20
Apr	2	8	32	0	4	.25:1:.00	21	23	44	.50
May	2	17	26	1	3	.65:1:.04	19	27	47	.53
June	2	10	19	1	1	.52:1:.05	17	13	31	.35
July	2	12	33	5	2	.36:1:.15	26	26	52	.59
Aug	2	3	14	5	3	.21:1:.36	10	12	25	.29
Sept	3	2	15	6	0	.13:1:.40	9	14	23	.17
Oct	2	6	7	6	1	.86:1:.86	9	11	20	.23
Nov	2	3	12	8	0	.25:1:.66	6	17	23	.26
Dec	2	8	6	3	0	1.33:1:.50	6	11	17	.19
Total	25	83	192	58	22	.43:1:.30	141	206	352	.32

Table 32. Results of sunset census conducted for all of Big Pine Key, Key Deer National Wildlife Refuge, Monroe Co., Florida, January 1971-December 1971.

Month	Number of Censuses	Number of Deer				Buck:Doe:Fawn Ratio	Marked Deer	Non-Marked Deer	Total Number Observed	Number Per Mile
		Buck	Doe	Fawn	Unidentified					
Jan	2	9	23	15	4	.39:1:.65	14	37	51	.58
Feb	2	13	17	7	3	.76:1:.41	20	20	40	.45
Mar	2	13	21	10	9	.14:1:.48	19	24	43	.49
Apr	2	14	34	0	3	.41:1:.00	23	28	51	.58
May	2	17	27	0	0	.63:1:.00	26	18	44	.50
June	2	8	9	0	0	.89:1:.00	13	4	17	.19
July	2	9	17	2	2	.53:1:.12	19	11	30	.34
Aug	2	6	8	0	0	.75:1:.00	11	3	14	.16
Sept	3	4	8	0	2	.50:1:.00	11	3	14	.11
Oct	2*	3	6	11	0	.50:1:.17	9	1	10	.11
Nov	2	6	4	3	2	1.50:1:.75	4	11	15	.17
Dec	2	4	11	3	4	.36:1:.27	11	11	22	.25
Total	25	96	185	41	29	.52:1:.22	180	171	351	.32

*On one census no deer were seen.

it provides a comparable estimate ($r = 0.746$ when the two methods are compared).

It will be impractical for refuge personnel to devote the time and energy necessary to mark deer for use in obtaining population estimates, but a road census would be practical. Censuses should be conducted during December-May or June-November when deer are most readily seen along the census route (Table 33); because of these monthly variations, only observations for the same months should be compared.

During 1969 and 1970 the number of deer seen per mile averaged 0.65, whereas during 1971 and 1972 the average was 1.11 and 1.14 deer, respectively (Table 34). The increase in the number of deer sighted between the second and third years of the study seemed due to a stable population increase, because during the third and fourth years the number remained high. Further, the percent of bucks, does, and fawns seen during these years indicated stabilization. The percent of fawns decreased, whereas adult bucks and does increased (Table 34), further evidence of stabilization (Dasmann 1964:92).

The use of sex ratios and age ratios to evaluate herd productivity should be done with caution. Such ratios vary depending upon the methods used to determine them. Based on all recorded observations of Key deer, the apparent composition of the herd varied by year, month and time of day (Hardin 1974). These variations were due to seasonal changes in behavior of deer and were reflected in the probability of seeing marked deer along the 10-mile census route (Table 35). The probability of seeing marked deer along this route varied by month. Adults and yearlings of both sexes were observed almost equally during April; however, newborn fawns were not seen at night during this period. Hence, April was best for obtaining

Table 33. Results of weekly censuses along 10-mile route, Big Pine Key, Key Deer National Wildlife Refuge, Monroe Co., Florida, July 1968-June 1972.

Month & Year	Number of Censuses	Total No. Deer Observed	Number Deer/Mile
July 68	4	18	0.45
Aug 68	5	24	0.48
Sept 68	4	23	0.57
Oct 68	5	18	0.36
Nov 68	4	26	0.65
Dec 68	4	29	0.73
Jan 69	5	42	0.84
Feb 69	4	26	0.65
Mar 69	4	27	0.68
Apr 69	4	37	0.93
May 69	5	55	1.10
June 69	4	26	0.65
July 69	5	22	0.44
Aug 69	4	16	0.40
Sept 69	4	14	0.35
Oct 69	5	10	0.20
Nov 69	4	16	0.40
Dec 69	4	35	0.88
Jan 70	5	43	0.86
Feb 70	4	35	0.88
Mar 70	4	24	0.60
Apr 70	5	54	1.08
May 70	4	36	0.90
June 70	4	23	0.58
July 70	5	25	0.50
Aug 70	4	21	0.52
Sept 70	4	16	0.40
Oct 70	5	16	0.32
Nov 70	4	35	0.70
Dec 70	5	48	0.96
Jan 71	4	66	1.65
Feb 71	4	68	1.70
Mar 71	4	55	1.38

Table 33. Continued.

Month & Year	Number of Censuses	Total No. Deer Observed	Number Deer/Mile
Apr 71	4	78	1.91
May 71	4	63	1.51
June 71	4	23	0.51
July 71	5	62	1.24
Aug 71	4	23	0.58
Sept 71	5	45	0.90
Oct 71	4	51	1.28
Nov 71	4	61	1.55
Dec 71	4	85	2.13
Jan 72	4	27	0.68
Feb 72	2	20	1.00
Mar 72	5	55	1.20
Apr 72	4	43	1.08
May 72	4	40	1.00
June 72	3	9	0.30

Table 34. Summation of road census data from October 1968-June 1972, Key Deer National Wildlife Refuge, Monroe Co., Florida.

Year*	% Bucks	% Does	% Fawns	Deer/Mile
1969	15	46	39	0.65
1970	9	48	43	0.65
1971	12	55	33	1.11
1972	19	54	27	1.14

*Data to obtain percentages were from October of preceding year through March of year listed, as few fawns were active during April-September at night.

Table 35. The probability of observing marked deer along a 10-mile census route, Big Pine Key, Key Deer National Wildlife Refuge, Monroe Co., Florida, based on actual observations of marked deer from June 1968-June 1972.

Period	AM* (1,480)**	AF (4,985)	YM (1,184)	YF (781)	FM (769)	FF (312)	ALL DEER (9,511)
Apr	.13	.11	.10	.10	.00	.00	.11
May	.08	.12	.13	.12	.00	.00	.11
June	.05	.06	.01	.07	.00	.00	.05
Spring	.09	.09	.08	.10	.00	.00	.09
July	.08	.10	.11	.10	.00	.00	.09
Aug	.07	.04	.14	.06	.00	.13	.06
Sept	.04	.06	.06	.04	.00	.00	.05
Summer	.06	.07	.10	.08	.00	.03	.07
Oct	.04	.06	.04	.05	.10	.06	.06
Nov	.06	.09	.07	.11	.16	.15	.10
Dec	.08	.10	.07	.12	.13	.27	.11
Fall	.06	.08	.06	.09	.13	.19	.09
Jan	.04	.06	.07	.14	.12	.25	.09
Feb	.05	.10	.07	.06	.11	.20	.09
Mar	.02	.08	.11	.05	.07	.11	.08
Winter	.03	.08	.08	.08	.10	.18	.08
Year	.07	.08	.08	.09	.08	.15	.08

*Sex and age classes: AM = adult males, AF = adult females, YM = yearling males, YF = yearling females, FM = fawn males, FF = fawn females

**Number of censuses times number of marked deer

pre-fawning sex ratios. Using April data, the buck:doe ratio was 0.41 to 1.00. Harlow and Jones (1965:63) indicated an adult male:female ratio prior to fawning as 0.43 to 1.00 for the mainland of Florida. Taber and Dasmann (1957) noted that the population structure of black-tailed deer in California was best determined in July and December when all age and sex classes were equally visible. Although, July was also a good month to determine population structure for Key deer, December was not (Table 35). Taber and Dasmann (1957) considered December favorable as the rut had subsided and bucks had returned to normal levels of mobility prior to the shed of antlers. In contrast, female Key deer fawns were active in December as they were being pursued by bucks during the late rut; this greatly increased the probability of sighting these fawns along the census route. Michael (1970:53) also observed that seasonal sex ratio variation of Texas deer was due to reproductive behavior.

The use of open-developed areas along the 10-mile census route varied by year and month (Figure 26) and by time of day (Figure 27). From January through December 1971, an average of 1.36 deer were seen per mile; while, the same route during sunrise and sunset censuses yielded only 0.83 and 0.93 deer per mile, respectively. This indicated that the number of deer seen per mile varied with time of day. Therefore, in estimating population size on Big Pine Key from road censuses, censuses should be scheduled during April or July on set days and preferably between 2200 and 0100 hours when traffic has subsided (except on weekends) and deer activity is "normal". By keeping the month, time of month, time of day and census route constant, census data could be compared between years to reflect trends in population densities.

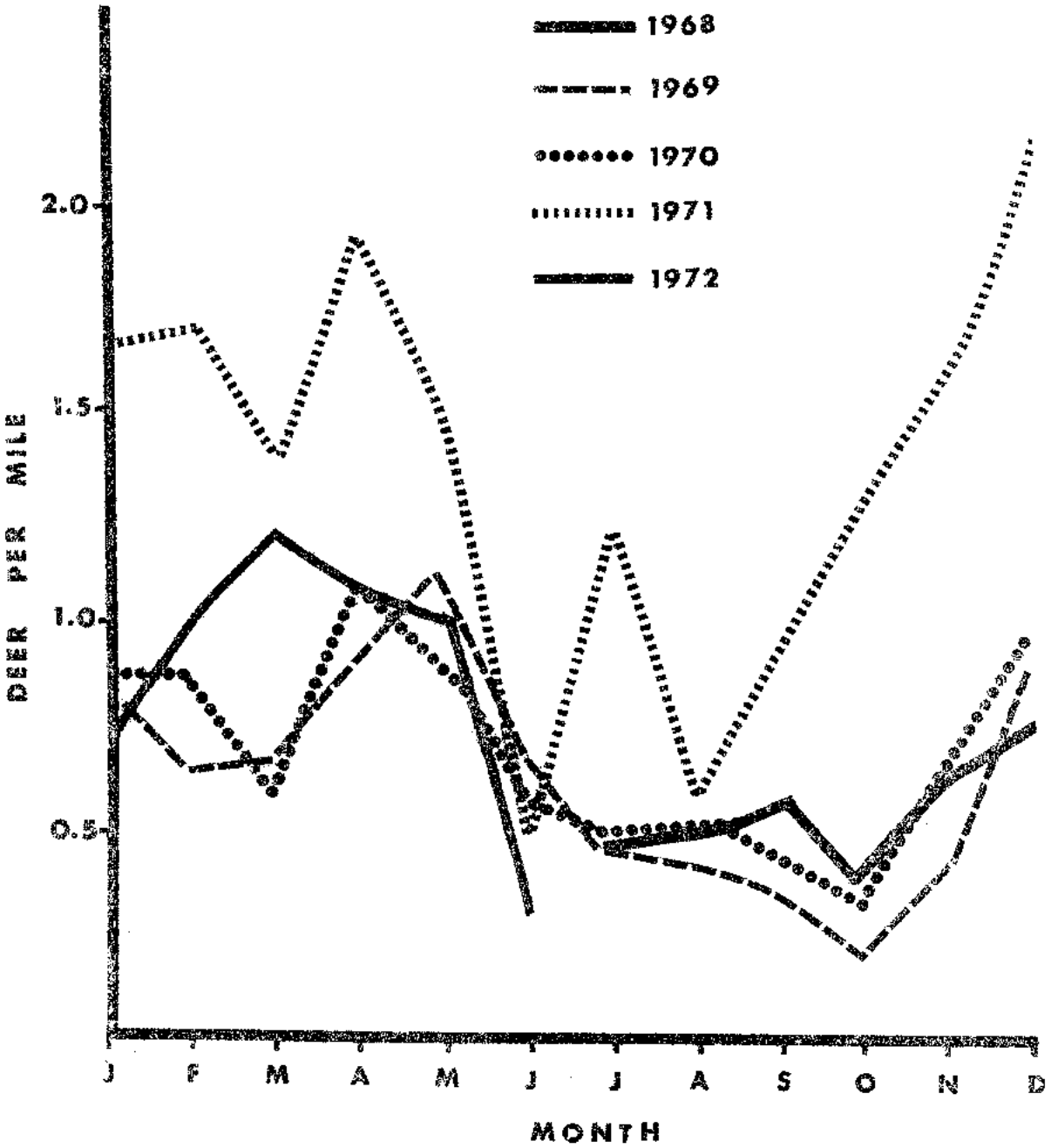


Figure 26. Number of deer observed per mile along the 10-mile census route by month and year, Big Pine Key, Key Deer National Wildlife Refuge, Monroe Co., Florida, July 1968-1972.

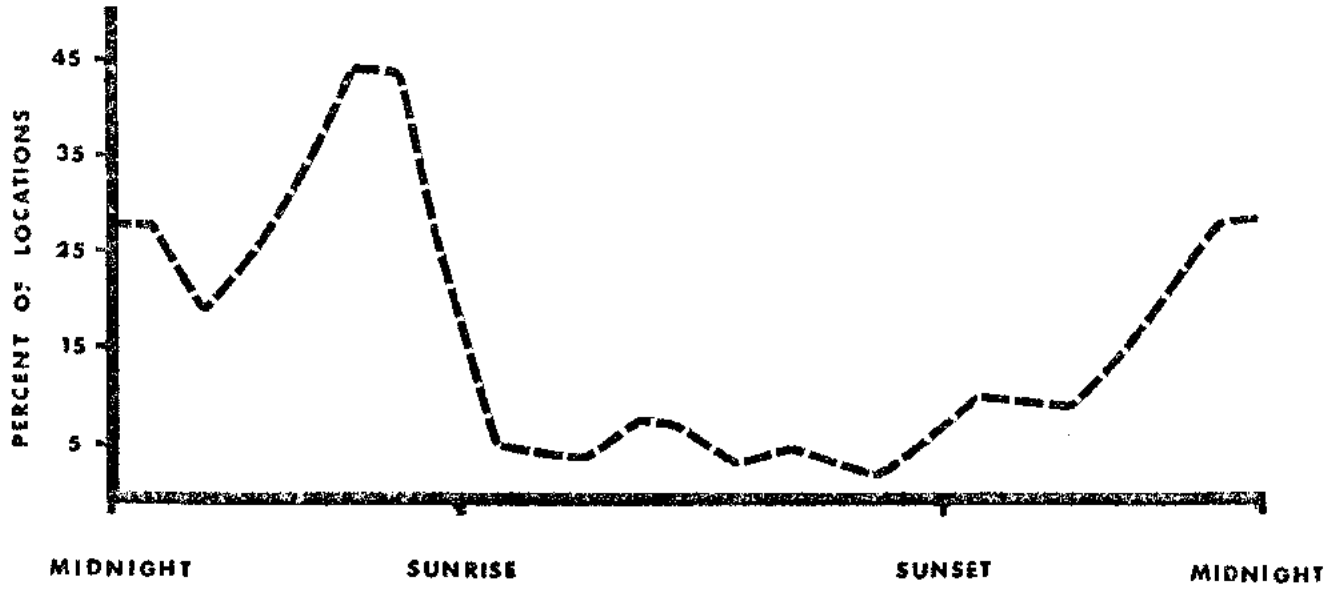


Figure 27. Time of day useage pattern of open-developed habitat by Key deer, Key Deer National Wildlife Refuge, Monroe Co., Florida, 1969-1972.

Pellet Transect Data Related to Population Density

The pellet transects established on refuge land during 1969, were run during May and August 1969 (Table 36). However, because of apparent problems in the application of data from pellet transects to estimates of deer numbers, transects were discontinued after 6 months. Thick vegetation, periodic shifts in centers of deer activity, porosity of the oolitic limestone, and behavioral characteristics of the deer seemed to negate the usefulness of such data on Big Pine Key.

A transect located in Watson Hammock, an area heavily used by deer, produced all but 1 of the 22 pellet groups found. Twenty-one of these 22 groups were found along the east half of this transect, which had been burned. Key deer characteristically are attracted to burned areas after the appearance of new grasses (Klimstra 1974).

Neff (1968), in a review of the use of pellet transects, noted they were unreliable at times because of rapid loss of pellets by insect attack, heavy rains and extremely dense vegetation. Eberhardt and VanEtten (1956:74) found the method subject to serious errors from either natural causes, observer error, or both.

Number of Roadkills Related to Population Density

Population estimates (Schumacher-Eschmeyer) based on accidental deer mortalities yielded 212 animals in 1968 to 639 animals in 1973 for Big Pine Key. Mortality data from the area covered by the standard 10-mile census gave estimates ranging from 97 animals in 1968 to 333 animals in 1973. These estimates were higher than those obtained by other methods. The use of our roadkill data to estimate population density was subject to limitations.

Differential behavior of deer greatly influenced the sex and age

Table 36. Pellet groups located along ten, 1/10-mile transects during May and August 1969, Key Deer National Wildlife Refuge, Monroe Co., Florida.

Transect	Vegetation Type	Number of Groups May	Number of Groups August	Average Number/Group	Range Number/Group
1	Hardwood	1	0	112	------
2	Hardwood	0	0	---	------
3	Hammock	16	6	77	36-188*
4	Hammock	0	0	---	------
5	Buttonwood	0	0	---	------
6	Buttonwood	0	0	---	------
7	Pineland	0	0	---	------
8	Pineland	0	0	---	------
9	Mangrove	0	0	---	------
10	Mangrove	0	0	---	------

*This group of 188 pellets may have been two groups, but as no size difference was apparent, they were included as one group.

groups roadkilled (Hardin 1974). The ratio of adult and yearling males to females killed (1.74:1.00 males to females) reflected greater male activity (Hardin 1974) and movements in areas of heavy traffic, especially during the rut. In addition, more adult and yearling females were marked than males of these age classes (Table 1), and they were marked mostly in the refuge area away from the Overseas Highway. Thus, the probability of marked does being killed on this highway was much less, as they moved less than unmarked bucks, which tended to disperse to that area. These limitations biased mortality estimates by overestimating the population.

The use of total roadkills per year to determine population trends may be unreliable, reflecting density along the highways rather than on the Key as a whole. Total roadkills on Big Pine Key (Table 37) fluctuated from 1 year to the next. This may have resulted from a delay in repopulating the area around the Overseas Highway following a year of heavy losses. Movements caused by drought or resulting from displacement of animals in response to extensive habitat changes also may have affected the number of animals roadkilled. Further, the differing amount of automobile traffic on Big Pine Key from year to year may have increased roadkills. McCaffery (1973:213) has noted that increased volume of traffic increased the number of roadkills in Pennsylvania.

Effects of Drought on Estimates of Population Density

Drought appeared to affect population estimates in the following ways: (1) During the drought, non-marked animals from other areas of Big Pine Key as well as from other keys probably moved to the censused area while some marked animals moved out; this activity resulted in a higher ratio of unmarked deer seen. (2) The capture of these deer from remote areas would have essentially "increased" the area being censused. (3) The

Table 37. Locations of highway mortalities of Key deer listed by calendar year, Key Deer National Wildlife Refuge, Monroe Co., Florida, January 1968-June 1973.

Location	Year						
	1968	1969	1970	1971	1972	1973*	Total
Big Pine Key							
Overseas Highway	15(58)**	21(50)	10(33)	18(35)	14(48)	16(70)	94(47)
State Route 940	5(19)	8(19)	12(40)	19(37)	7(24)	6(26)	57(28)
Other	6(23)	13(31)	8(27)	14(33)	8(28)	1(4)	50(25)
Total	26	42	30	51	29	23	201
Other Keys							
No Name Key	0	0	0	4	2	4	10
Little Torch Key	1	1	0	3	3	0	8
Middle Torch Key	0	0	1	0	0	0	1
Big Torch Key	0	1	0	0	0	0	1
Ramrod Key	1	1	0	4	2	0	8
Cudjoe Key	0	1	0	0	0	1	2
Total	2	4	1	11	7	5	30
Total killed on all keys	28(93)	46(91)	31(97)	62(82)	36(81)	28(82)	231(87)

*Data includes deer killed up through June 1973

**Numbers in parentheses represent the percent of the deer lost on Big Pine Key for the year at the designated location

greater and differential use of open areas increased the area being censused.

Key deer increased their movement and ranges during the drought (Tables 4 & 5). Although, mean movement indices and mean ranges for deer during the drought and non-drought years were not significant, all but 6 of the 80 individual ranges and movement indices were larger during the drought than during similar non-drought periods; this trend was significant (Wilcoxon matched-pairs sign test, Siegel 1956). This increased activity probably resulted in some non-marked deer from remote areas being observed in the censused area. Because deer in the censused area (most were marked) also showed greater range and movement during drought, they were less likely to be observed along the census route. As a result of the increased activity, a higher ratio of unmarked deer was observed, resulting in an increase in population estimates.

During the drought only eight animals caught outside the censused area were marked; five made trips into the censused area during the drought. If additional non-marked deer behaved as these did, the ratio of non-marked animals would have increased even more. Nine of approximately 80 marked animals from the censused portion of the Key were observed at least once outside the censused area during the drought.

During the drought almost 40 percent of the roadkilled deer were found on State Route 940, whereas prior to and following the drought, road mortality on that highway ranged from 19.0-26.1 percent (Table 37). This suggested that animals may have moved from the vicinity of the Overseas Highway into areas to the north, where the census area was located and there was a better water supply.

The capture of 54 previously unmarked animals during the drought in

areas along the census route, where most animals prior to the drought had been marked, indicated movement of deer into the census area. The majority of these animals were observed later, by telemetry or collar, to have ranges in remote non-censused areas (i.e., the northend and Watson Hammock). These captures essentially extended the area being censused, resulting in higher population estimates.

Recent reports that habitat utilization by white-tailed deer (Michael 1967:54) and mule deer (Wood et al. 1970:21) was related to the availability of permanent water, supports the view that drought may influence distribution of Key deer. Accessible fresh water was more available in areas near the census route than in others (Figure 28). Michael (1967:57) noted that in Texas, the concentration of deer near surface water could have a "significant effect" on deer censuses. He (1967:51) also observed that pregnant does drank more frequently than did non-pregnant ones. Because Key deer were pregnant during the drought, increased activity from this cause may have affected census results.

Rainfall fluctuations on Big Pine Key correlated with population estimates yielded negative correlations of -0.298 and -0.620 for monthly and quarterly comparisons, respectively. The R^2's, indicated rainfall accounted for slightly less than 9 percent of the variance for monthly population estimates and about 38 percent for quarterly estimates. Because fawns were included in population estimates only during the fall and winter, the quarterly estimates did not represent actual sequence of population change. A bias, due to the addition of fawns to the estimates during quarters of high rainfall, tended to increase the apparent correlation between rainfall and population size.

The Key deer population on Big Pine Key was thought to increase as

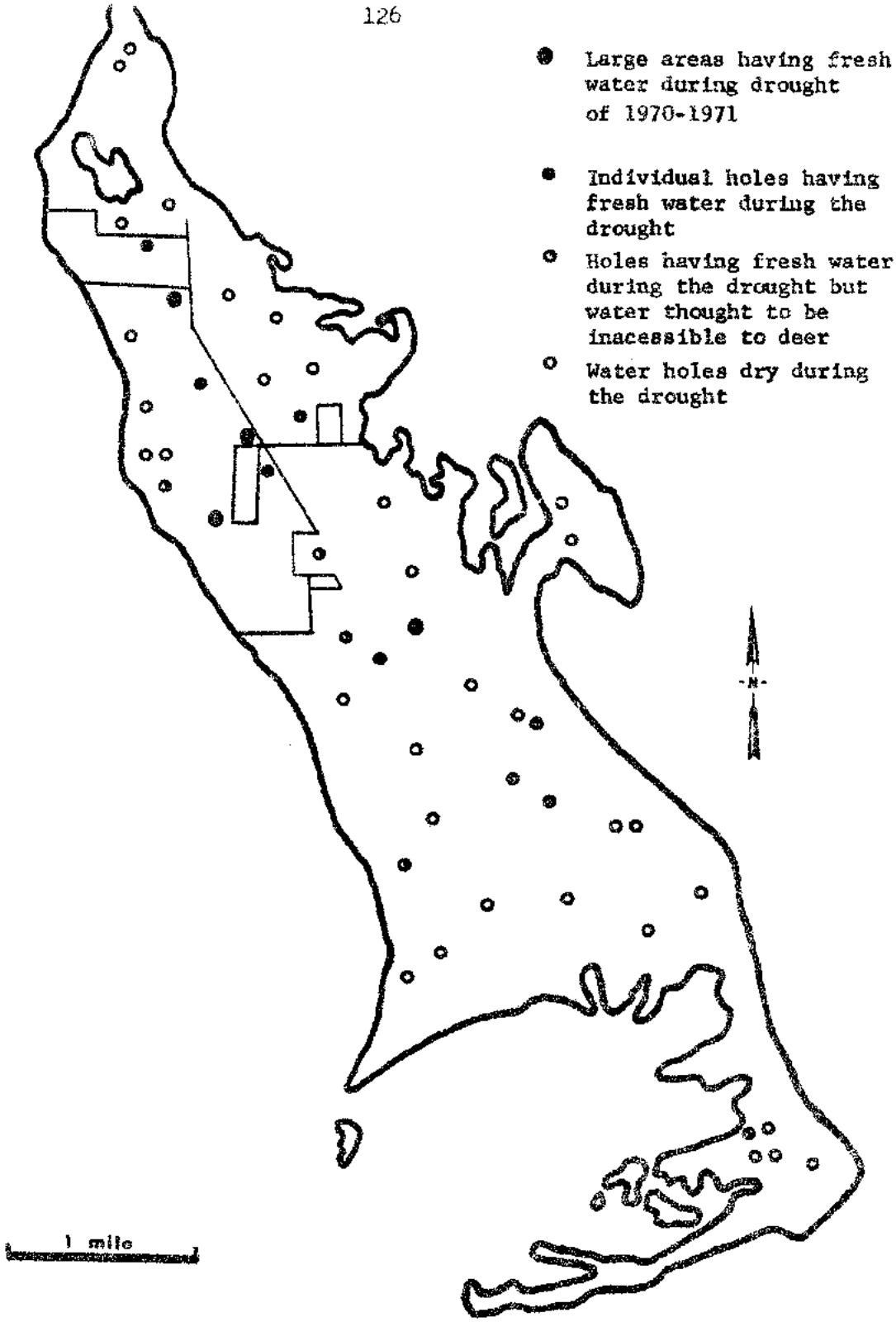


Figure 28. Outline map of Big Pine Key showing roads traversed during the 10-mile census and available water for Key deer during the 1970-1971 drought, Key Deer National Wildlife Refuge, Monroe Co., Florida.

water supplies diminished on outlying keys (Allen 1952:80). Dickson (1955:85) noted that deer moved to Big Pine Key during March and April when the dry season was at its peak; however, he also noted that tracks were always found on the other keys which deer inhabited; this was substantiated in my study. Deer movement to and from Big Pine Key may be an annual occurrence of dry and wet seasons. However, population estimates of 15 deer for keys adjacent to Big Pine (Howe, Annette, Porpoise, Mayo, Cutoe and the Newfound Harbor keys) would not explain the 89 animal increase on Big Pine Key during the drought; nor would it explain the 42 animal decrease following the drought if these 15 deer returned to adjacent keys.

Deer mortalities recorded on Big Johnson, Howe and Big Munson keys during the drought indicated that not all deer moved to keys where fresh water remained. In fact, these deaths represented nearly a third of the estimated population for these keys. Because no intensive searches for drought mortalities were made, definitive deductions cannot be made on drought related deer losses.

Not only did some animals return to Big Pine Key, but some were observed to leave during the drought. Two adult bucks left Big Pine for No Name Key during the drought and two adult does, originally radio-tracked on Big Pine Key prior to the drought, were observed on No Name after the drought. As acceptable water and food were present on both keys, these deer did not leave Big Pine Key for lack of food or fresh water. The adult males may have left in response to aggressive female behavior during the fawning season; and, the does may have left because a major portion of their ranges was cleared during late 1971 and early 1972.

The large number of deer estimated during the drought may have

resulted from an increased use of open-developed areas as a food source. Vegetation around residental homes may have attracted deer from the more remote areas of Big Pine Key when lack of rain during the drought left natural vegetation scarce. Michael (1967:57) noted that concentrations of deer due to attraction of green vegetation in Texas could "significantly affect" deer censuses.

Differental use of open areas during drought and non-drought periods affected population estimates. Deer activity almost ceased during night hours when mosquitoes were abundant and wind velocity was low, whereas, mid-day activity increased (Hardin 1974). Deer used open areas where the wind apparently reduced harassment by mosquitoes. Mosquitoes were few during the drought as breeding areas were limited; however, following the drought, mosquitoes increased greatly and deer were observed less along the census route. In addition, nightly fogging operations by county mosquito control personnel also reduced deer activity along the route.

Population Densities of Deer on Other Keys

By assuming the ratio of animals killed on the Overseas Highway (U.S. 1) and the estimated population of Big Pine Key were equal to a proportional ratio of those killed on other keys (Little Torch, Ramrod and Cudjoe) crossed by this highway, a population for these keys was estimated. Because of the few mortalities (Table 36) on these keys, an average of all roadkills during the study was used in the ratio. An average population of 200 deer was assumed to be present on Big Pine Key during 1968 through June 1973. Adjustments were made to accommodate the difference in total highway mileage and land areas for Big Pine and the other Keys.

The estimated population obtained for Little Torch Key was two animals, for Ramrod Key two animals and, for Cudjoe Key two animals. However, if kills on Ramrod and Little Torch keys were assumed to represent animals dispersing from Big and Middle Torch keys, an estimate of 23 animals was obtained for this total complex. As 14 of the 16 animals roadkilled on the highway on both Ramrod and Little Torch keys were males (males being the sex class most likely to disperse), this estimate may be valid. Deer-crossing points were visable between Big, Middle and Little Torch keys and the distance between Middle Torch and Ramrod keys was narrow (Figure 13), with shallow water, land being exposed at low tides.

No Name Key Population

Only on Big Pine Key did the population of deer surpass that of No Name Key. Five deer were trapped and marked and three adult bucks were transplanted to No Name Key during the study; one returned to Big Pine Key. Ten deer (4 adult males, 1 adult female, 2 yearling males, 2 yearling females, and 1 male fawn) were killed on the roads of this key.

Deer were seen almost daily on No Name Key, which was privately owned and recently subjected to a rapid rate of development. Approximately 17 percent of the Key was cleared during this study and subdivisions with dredged canals were under construction. The fate of the deer population will be determined in the next few years as development continues. Adequate acceptable fresh water was available during the entire drought of 1970-1971. Annual reproduction was evidenced by numerous observations of fawns. This Key contained all major habitat types and offered considerable habitat variety. In 1973, a Lincoln Index estimate of 34 deer was obtained for this Key.

Little Pine Key Complex Population

The Little Pine Key Complex (Little Pine, Big and Little Johnson and Grassy keys) represented outlying islands (Figure 13). Deer were observed on both Little Pine and Big Johnson keys and fresh tracks were observed on Little Johnson and Grassy keys. Both Johnson keys yielded considerable deer sign as evidenced by current trails, pellets, and browsed plants. These two keys had a network of open areas and an interior of near-hammock and hardwood "islands" of cover with considerable usable deer habitat. Variety of plants was lacking, as well as abundance of given kinds except for the mangrove. Little Pine Key contained all major vegetation types and offered considerable habitat and food for deer support. Numerous deer were sighted on this Key and fawn tracks indicated reproduction had occurred. Grassy Key had vegetation similar to the Johnson keys; but, also had a sizeable, typical hammock area.

A trip to Big Johnson Key during the height of the 1970-1971 drought found all water holes dry except one. A deer was sighted near this hole and heavy deer use was apparent. This site yielded little exposed surface water, as most of the stored water was in a large cistern-like cavity in the side of the basin. This allowed for minimum evaporation and probably accounted for the presence of water following the dry season. In December of 1972, this water hole was found to be brackish due to high fall tides. Water holes on Grassy and Little Johnson keys were believed dry during the height of the drought; Little Pine probably provided some acceptable water during the entire drought. Deer possibly returned periodically or regularly to Little Pine when water holes on Grassy and Little and Big Johnson keys went dry or became brackish.

It was difficult to make an estimate of deer numbers on this complex

because of the dense vegetation and because the deer were on any one key at different times. However, 30 animals for the whole complex, with the majority being on Little Pine Key, seemed a reasonable prediction.

Big Pine Key Complex (excluding Big Pine Key) Population

In addition to Big Pine Key, this complex included Howe, Annette, Mayo, Cutoe, Porpoise and the Newfound Harbor keys (Figure 13). Deer or deer sign were seen on all keys with the exception of Cutoe and the smallest of the three Newfound Harbor Keys. During the drought, no recent deer sign or fresh water was recorded on Mayo, Porpoise and Annette keys. An adult animal was jumped on Annette at the end of the drought; however, sign indicated this deer had been on the island for only a short time. Deer were seen regularly on Howe Key. Following the drought, two deer skeletons were found on Howe; one a 3-year-old doe and the other could not be sexed or aged. These were possible victims of the drought, as all were near or at water holes which were dry or contained a high salt content. The skeleton of an adult doe was found in a dry water hole on Big Munson Key (the largest of the Newfound Harbor keys) after the drought. As many as three deer (all adults) were seen on Big Munson at one time; however, no permanent water supply existed. Mayo Key evidenced sign prior to the drought but no deer were believed there since. During the drought an adult doe gave birth to a fawn on Porpoise Key. But, she swam to Big Pine Key almost daily except following periods of rain. No deer sign had been seen on Porpoise Key prior to or after the above doe left the Key.

At various periods, deer or deer sign were located on all the above keys with the exception of Cutoe and the smallest of the Newfound Harbor Keys. It appeared that deer utilizing Annette, Howe, Mayo, Porpoise, and

the Newfound Harbor keys obtained acceptable water on Big Pine Key during drought. The population estimated for Big Pine during the drought may have included some of these animals; however, probably a few animals were resident on Howe Key during this period, moving to Big Pine only long enough to obtain fresh water. Even with an artificial water supply it is doubtful that these islands could support a permanent deer population. They were not high enough above sea level to provide the variety of vegetation that seemed necessary to support a resident deer population. The other keys of this complex yielded a limited variety of deer habitat with the exception of the smallest of the three Newfound Harbor keys and Cutoe Key. Much of Cutoe Key was subjected to tidal inundation during spring and fall tides; hence, it was of little use to deer.

Torch Key Complex Population

The Torch Key Complex included Big, Middle and Little Torch, Ramrod and Water keys, plus a small island off the southeast end of Ramrod Key (Figure 13). Numerous deer were sighted on Big and Middle Torch keys; and, early in this study, deer were regularly seen on Little Torch; however, with increased development, fewer deer were recorded. As many as three deer were seen on Water Key at one time; but, these animals seemed transitory and probably were part of the Big Torch Key population. A male fawn was caught while swimming from Water Key to Big Torch in February 1969. Ramrod Key, subject to extensive development, yielded few observations of deer. Old tracks of a single deer were located twice on the small island southeast of Ramrod Key.

Except for Water Key and a small island off the southeast end of Ramrod Key, the Torch Key Complex had fair to good deer habitat. A permanent supply of acceptable water was available only on Big Torch Key

during periods of extreme drought. Big Torch, the largest key in this complex, was comprised of extensive areas of hammock and hardwood with many buttonwood or mangrove encroachments. Two housing subdivisions were being developed and poaching seemed to be limiting deer numbers. Middle Torch Key contained an interior of hardwoods separated by a strip of buttonwood from mangroves which formed the shore vegetation. Part of the Key was being developed and Little Torch Key was over half developed. Deer using Little Torch Key may be animals dispersing from Middle and Big Torch keys. Water Key consisted of an extensive marl prairie with a shoreline of large mangroves. A small hardwood area was located in the center of the key; and no permanent fresh water was available. Ramrod Key was composed of hardwood growth over a large portion of the key. North of the Overseas Highway, was a large buttonwood slough with available fresh water. Mangrove surrounded most of the key. Much of the hardwood areas have been cleared and no permanent fresh water was found during the 1970-1971 drought.

Eight (5 adult males, 1 adult female and 2 yearling males) deer were killed on the roads of Ramrod Key, eight (3 adult males, 1 adult female, 2 yearling males and 2 male fawns) on Little Torch Key, one adult male on Big Torch Key, and a male fawn on Middle Torch Key. All but two animals of this complex were killed on Little Torch and Ramrod; however, these were the only keys of the complex crossed by the Overseas Highway. Many of these animals may have represented dispersals from other keys as all but two were males, the sex class most likely to disperse. An estimated 30 to 40 animals probably comprised the total deer population of this complex.

Cudjoe Key Complex Population

Cudjoe, Sugarloaf, Big and Little Knockemdown, Summerland, Toptree Hammock and Wahoo keys made up the Cudjoe Key Complex (Figure 13). Two roadkills were noted on Cudjoe Key, an adult female and a deer of unknown sex and age. Early in this study deer sign was widely evident on Cudjoe; however, by 1973 this was greatly reduced. Evidence of deer was noted on all keys except Little Knockemdown Key. During 1970, an adult male was seen on Sugarloaf Key by Jack Watson, Refuge Manager. This was the first recorded sighting on this Key, although tracks were seen earlier. A trip to Cudjoe in March 1970 yielded some sign of deer browsing but no fresh tracks or pellets. Deer using Wahoo, Toptree Hammock, and Big and Little Knockemdown keys must either return to Cudjoe Key or Summerland Key for the nearest acceptable water during dry periods. The estimated population for this complex was between 15 and 20 deer with resident animals probably occurring only on Cudjoe, Summerland, Big Knockemdown and Sugarloaf keys. Toptree Hammock and Wahoo keys were visited occasionally by deer from Summerland Key.

Good deer habitat was evident on Cudjoe and Sugarloaf keys; both provided areas of pines and sources of permanent acceptable water. These keys were extensively developed and about 50 percent of the best deer habitat was destroyed. Late in this study, the last area of major pines on Cudjoe Key was under development. Also, Sugarloaf Key had about 100 horses which competed with the few remaining deer; and, the possibility of domestic disease spreading to the deer herd seemed important. Big Knockemdown had a small stand of pines; whereas, Summerland, Toptree Hammock, and Wahoo keys had limited deer habitat. None of these had permanent acceptable water. Little Knockemdown provided little more than

dense stands of inundated red mangrove.

Other outlying keys visited during this study were Crawl, Content, East and West Bahia Honda, Horseshoe, Mud, and Raccoon keys. None of these keys showed deer sign or permanent acceptable water.

Population Change

During the course of this study, deer seemed to have increased on both Big Pine and No Name keys. Populations on Cudjoe, Sugarloaf, Big, Little, and Middle Torch, Howe and Big Johnson keys appeared to have decreased. Populations on Little Pine, Summerland, and Ramrod keys may have remained stable during this period. Deer increases on Big Pine were probably due to natural reproduction and/or deer returning to Big Pine from outlying keys during the drought. On No Name, increases may have resulted from increased reproduction as deer responded to development and a recent fire. Development of Cudjoe, Sugarloaf and Little Torch keys may have resulted in the declines on these keys. Population decline on Howe and Big Johnson keys appeared related to a lack of acceptable water during the drought. The possibility that poaching affected deer numbers on given keys should not be negated. With low population levels, a few illegal kills can prevent growth of the population or cause it to decline. Harlow and Jones (1965:117) observed that even light illegal hunting was effective in preventing expected herd increases where reproductive rates were low such as noted for Florida deer herds. Walls (1974:152) using computer simulation, noted that poaching was a critical process affecting herd stability.

Carrying Capacity of Key Deer Range

The Schumacher-Eschmeyer population estimate for the sunrise census indicated an average population of 213 deer for Big Pine Key during 1971. A conservative estimate of 200 deer for the pre-fawning population of Big Pine would represent approximately one deer per 30 acres. The probability of finding a deer in a particular habitat type on Big Pine Key was determined with daily radio locations. These data and the total acreages for each habitat type indicated 1 deer per 42 acres of open-developed areas, 1 per 17 acres of hammock, 1 per 35 acres of buttonwood, 1 per 32 acres of mangrove, 1 per 28 acres of hardwood and 1 per 23 acres of pineland. The density of deer in most habitat types on Big Pine Key was much higher than recorded (Harlow and Jones 1965:59) for the mainland of Florida. Their estimates ranged from 1 deer per 34 acres in pine-oak uplands and sand pine-scrub oak to 1 deer per 300 acres in swamp habitat.

Historically, Big Pine Key has been the main island for the Key deer population (Barbour and Allen 1922). Most of the other keys within the present Key deer range will not support a resident deer population equal to that of Big Pine Key because many lack permanent fresh water or a sufficient variety of habitat types. The U.S. Government has indicated theoretical carrying capacity for the major keys within the Key deer range (1939-1967 Narrative Reports, USF&WS) at around 1,000 animals and over. If Big Pine Key is assumed to be at carrying capacity as my study indicated, and the estimated 1 deer per 30 acres is the upper limit for all other keys, then an estimate for the other keys within the present Key deer range can be made. If an average acre of land on the other keys is assumed to support the same density of deer as on Big Pine Key, then the 21 major keys now supporting or having transient Key deer (19,601 total

acres; Dickson 1955) would support only 653 animals. This overestimates the current carrying capacity of these keys. For example, Cutoe Key which is inundated by high tides would never support even one deer on its 175 acres. Therefore, even the theoretical estimate must be below 653 animals.

Population Simulation

The Florida Key deer is in an especially precarious situation in that it is a product of a very restrictive insular environment. In response to the habitat of the islands, it has evolved unique characteristics. Under pressure from hunting, hurricanes and habitat destruction, the deer decreased to less than an estimated 50 animals by 1949 (USF&WS Narrative Reports 1939-1967). Since being afforded protection, the population has increased to around 350 animals. The increase, however, appeared slower than that characteristic of other white-tailed deer populations that were afforded similar protection and opportunity for increment (Hardin 1974 and Klimstra 1974).

To determine whether the Key deer population had evolved an unique method of population control, a theoretical population was simulated by computer. Starting with a population of 350 animals during the period prior to the fawning season in 1973, and composed of 73 adult bucks, 189 adult does, 46 male fawns and 42 female fawns (Table 38), the model reflected a 1950 pre-fawning season population of 51 animals (11 adult males, 28 adult females, 7 male fawns and 6 female fawns from census data. Data from the model indicated an 8 percent increase in herd size per year.

The age specific sex ratios of fawns at birth utilized to model the population were based on sex ratios obtained from fetuses of roadkilled

Table 38. Simulated theoretical population for Key deer, Key Deer National Wildlife Refuge, Monroe Co., Florida, 1973-1950.

	Population after Fawning Season					Population prior to Fawning Season					
Year	Total	Bucks	Does	Male Fawns	Female Fawns	Total	Bucks	Does	Male Fawns	Female Fawns	Annual Loss
1973						350	73	189	46	42	
1972	554	110	213	138	93	322	67	174	42	39	232
1971	510	101	196	127	86	296	62	159	39	36	214
1970	469	93	180	117	79	273	57	147	36	33	196
1969	431	86	166	107	72	251	52	135	33	30	180
1968	397	79	153	99	67	231	48	125	30	28	166
1967	365	72	140	91	61	212	44	115	28	25	153
1966	336	67	129	84	56	195	41	105	26	23	141
1965	309	61	119	77	52	180	37	97	24	22	129
1964	284	56	109	71	48	165	34	89	22	20	120
1963	262	52	101	65	44	152	32	82	20	18	113
1962	241	48	93	60	41	140	29	76	18	17	101
1961	221	44	85	55	38	129	27	69	17	15	92
1960	204	40	78	51	35	118	27	64	16	14	86

Table 38. Continued.

Year	Population after Fawning Season					Population prior to Fawning Season					Annual Loss
	Total	Bucks	Does	Male Fawns	Female Fawns	Total	Bucks	Does	Male Fawns	Female Fawns	
1959	187	37	72	47	32	109	23	59	14	12	78
1958	172	34	66	43	29	100	21	54	13	12	72
1957	159	31	61	40	27	92	19	50	12	11	67
1956	146	29	56	36	25	85	18	46	11	10	61
1955	134	26	52	33	23	78	16	42	10	9	59
1954	124	24	47	31	21	72	15	39	9	9	52
1953	114	22	44	28	19	66	14	36	9	8	48
1952	105	21	40	26	18	61	13	33	8	7	44
1951	96	19	37	24	16	56	12	30	7	7	40
1950	88	17	34	22	15	51	11	28	7	6	37

*Numbers rounded to the nearest whole animal

does (Table 39). Harlow and Jones (1965:109) using data for 121 pregnant Florida does having 130 fetuses, found the prenatal sex ratio to be 1.95 males to 1 female. This was higher than sex ratio differences for this study. Illige (1951:420) in an analysis of reproductive patterns of white-tailed deer in south Texas observed a primary sex ratio of 1.36 males to 1 female for 33 fawns examined. McDowell (1961) presented data for 1,697 white-tailed does from the northeastern region of the U.S. and Canada (1.13:1) and for 230 does from outside this region (1.11:1) and found males outnumbered female fawns. Taber (1953:96) summarizing the literature, noted that 1.20 males to 1 female fawn would probably be a good approximation of prenatal sex ratios. He found that sex ratios varied from 1.20:1 to 1.42:1 for the literature surveyed. Taylor (1956) noted that for 2,096 embryos there was a ratio of 1.17 males per female fawn. From the literature, the observed 1.45 males per Key deer doe fawn appears in line with those found during other studies. In this respect the Key deer population was not unique.

For the simulated population, female fawns of the year were assumed not to breed. Illige (1951:421) found no evidence that fawns bred during their first winter in south Texas. However, most other studies assumed that fawns did or were capable of breeding but added only small numbers to the overall production of the herd. Data from roadkilled animals during the present study indicated female fawns did not breed and yearling females produced an average of 0.82 fawns per doe while older does produced 1.21 fawns per doe (Table 38). Harlow and Jones (1965:116) observed the reproductive rate for 134 Florida deer was 1.15 fetuses per doe. Rates, however, were noted to vary between herds. Barron and Harwell (1973:181) found 1.59 fetuses per mature doe and 1.32 per yearling doe in a south

Table 39. Reproductive data gathered from female Key deer during November-June, beginning January 1968-June 1973, Key Deer National Wildlife Refuge, Monroe Co., Florida (after Klimstra 1974).

Age of Doe	Total Number of Does Examined	Number Pregnant	Number Lactating	Single Fetuses M*	Single Fetuses F	Single Fetuses UK	Twin Fetuses M	Twin Fetuses F	Twin Fetuses UK	Total Fetuses	Fetal Sex Ratio M:F	Fetuses Per Doe	Fawns Produced Per Doe
½-1 yr.	6	0	0	0	0	0	0	0	0	0	---	0.00	0.00
1-2 yrs.	8	0	0	0	0	0	0	0	0	0	---	0.00	0.00
2-3 yrs.	11	7	1	4	0	2	0	2	0	8	4:2	0.73	0.82
3-4 yrs.	8	7	1	2	2	2	0	2	0	8	2:4	1.00	1.12
4-5 yrs.	4	3	1	2	0	0	2	0	0	4	4:0	1.00	1.25
5-6 yrs.	4	3	1	1	2	0	0	0	0	3	1:2	0.75	1.00
6-7 yrs.	0	0	0	0	0	0	0	0	0	0	---	----	----
7-8 yrs.	1	0	1	0	0	0	0	0	0	0	___	0.00	1.00
Adults (age unknown)	7	6	0	2	0	0	3	3	2	10	5:3	1.43	1.43
Totals	49	26	5	11	4	4	5	7	2	33	16:11	0.67	0.78

*M = male, F = female, UK = sex unknown

Texas deer herd. Roseberry and Klimstra (1970:25) also noted yearling does produced fewer fetuses than did adult does in Illinois. They concluded there was no apparent relationship between age and productivity among does older than yearlings. Olmstead (1970:5) found deer aged 3 and older at parturition, produced statistically the same number of corpora lutea per dam; yearlings fewer and fawns even fewer, statistically. It appeared that Key deer productivity fell within ranges observed for other populations of white-tailed deer.

Key deer age specific sex ratios at birth and herd productivity were not different from those of other Florida white-tailed deer populations. If the growth of the herd from 1950 to present was slower than that characteristic of other white-tailed deer populations, the difference in growth rate may be a result of sex and age specific survival. Sex-age specific data showed a greater survival of female fawns after the first 6 months of life (Klimstra 1974). Female survival was greater than that of males thereafter. Males 1 year or older had an average observed mortality of 24.2 percent annually, whereas females in the same age group had only a 13.4 percent annual observed mortality. Highway mortalities accounted for 76 percent of the known Key deer losses (Table 37). Harlow and Jones (1965:63) reported that natural winter and spring mortality for deer on the Florida mainland was 0.4 percent for roadkills and 14.7 percent from all other causes. Miscellaneous mortality was assumed to be 14.7 percent of the pre-hunt population. Totaled, this yielded a yearly loss of 29.8 percent. In addition, they reported an average 9 percent to crippling loss. Hawkins et al. (1971) in Illinois noted a differential mortality associated with different sex and age classes.

The above variables were held constant throughout the simulation.

The projected population closely approximated the estimated population of 25-50 animals for 1950 (USF&WS Narrative Reports 1939-1967). Therefore, the present rate of increase closely represented the average increase during the modeled period. Obviously, the rate of increase varied through this period; however, these data indicated that even if it had not, the present rate of increase could have accounted for the current population. If the current rate of increase accounted for the present population, it stands that if the Key deer population did increase at a slower rate than other white-tailed deer populations, this rate of increase must be the unique characteristic.

If the population growth rates of Key deer are unique, this uniqueness is due to the deer's greater susceptibility to roadkill deaths. This uniqueness is more probably a characteristic of the environment than of the population. It is here suggested that this high mortality rate was due to continued and extensive land development and other human disturbances causing change in areas used. Data by Reilly and Green (1974) suggested that disturbances in habitat used by deer, increased car-deer mortality. Currently, roadkills serve to benefit the Key deer population as they contribute to population control; however, such accidents are undesirable due to property damage and potential human losses.

As housing developments increased on the Keys, the newly created open areas may have stimulated reproduction because of a possible increase in food associated with these areas. However, increased subdivision development also led to a patch-type habitat where not all deer requirements were met in a single area; therefore, deer movements and roadkill mortality increased.

With increased development of the Keys, deer will gradually be

confined to refuge lands. Even though available habitat in small blocks may lie outside refuge boundaries, roadkills will reduce deer and damage in these areas. However, dispersal of excess animals into these areas from refuge lands and damage of private property next to refuge areas will increase as deer are confined to the refuge. This problem is compounded on Big Pine and Big Torch keys where there are four and two major private developments, respectively, within the refuge. These subdivisions will receive heavy use by animals residing on adjacent refuge lands.

Simply an increase in numbers (such as 50 to 350) of an endangered population cannot be interpreted as being saved from extinction. The fate of any animal, especially the Key deer, is directly related to those factors which effect changes in the habitat of which it is a product. In the Florida Keys, it is the habitat that is currently endangered, but as the habitat changes, so will the deer and other native wildlife. The long-term effects of these changes must be considered, and management to insure the future existence of the deer must be planned to provide adequate and acceptable habitat in the future.

SUMMARY

Population density, movements and habitat utilization of the Florida Key deer were studied from December 1968 through December 1971, and during six periods of 2 weeks each in 1972 and 1973. The study was conducted on Big Pine Key and adjacent islands in Monroe County, Florida. Most of the 233 deer captured and subsequently marked provided basic information.

Animals were captured by trail traps, drugs, hands and portable drive nets, the latter taking the most animals. Deer were individually marked by bells, plastic collars, numbered ear tags, streamers and ear tattoos. Eighty-one radio-tagged deer were located at least once each day at random hours. Data recorded for each marked deer included location, associated animals, date, time, vegetation type, weather and behavior. Data were also gathered from road censuses and highway mortalities.

On the basis of radio-tracking, 470 monthly movement indices were obtained; 110 for adult males, 165 for adult females, 48 for yearling males, 39 for yearling females, 75 for male fawns and 34 for female fawns. Movement indices of adult males were significantly larger than those of other sex and age groups. Most deer made trips out of their "normal" ranges; extreme movements during 1970-1971 were caused by a drought. Most yearling males dispersed from their areas of birth. Data from the transplant of eight deer to other islands indicated that some deer relocated to new areas returned to original ranges. None of 119 radio-tagged deer originally marked on Big Pine Key were found off the Key, indicating limited egress.

Four hundred and twenty-one monthly ranges were determined for 58 deer radio-tracked; 99 ranges were for adult males, 165 for adult females, 42 for yearling males, 37 for yearling females, 57 for fawn males and 26

for fawn females. The average monthly range for an adult male was 315 acres, adult female 135 acres, yearling male 288 acres, yearling female 155 acres, male fawn 140 acres and female fawn 109 acres. During the first 6 months of life, the ranges (average 123 acres) were significantly smaller than during the following 6 months (average 140 acres). Ranges for adult male and female deer radio-tracked during 1969 and 1970 were dynamic; in all cases the 1970 ranges showed additions to the 1969 ranges.

The average monthly range for the combined sex and age classes was made up of 4 percent hammock, 40 percent pineland, 18 percent open-developed areas, 10 percent hardwood, 5 percent mangrove and 26 percent buttonwood. Proportions of most habitat types within monthly ranges differed significantly from those available in the study area. Ranges contained a greater percentage of pineland and hardwood and less mangrove and buttonwood than would be expected on the basis of random distribution. Both hammock and open-developed areas were used in the same proportion as that available in the study area.

Radio-tagged deer were located significantly less in open-developed areas during daylight hours than during dark hours, and more often than expected in buttonwood, hardwood, mangrove and hammock areas. Deer avoided open-developed areas and were found in hardwood areas more when rainfall was over 0.25 inches per day. Deer were found more in open-developed areas and less in pineland and buttonwood when minimum temperatures were either 40, 70 or 80 degrees. Wind direction did not effect habitat use except that, when wind speed exceeded 15 mph, deer were found more often than expected in open-developed areas during spring and summer and less in winter. Deer were found more often than expected in buttonwood during each season when wind speed exceeded 15 mph. During periods of

three-quarter moon, deer were also found more often than expected in buttonwood areas. No significant differences were detected between deer locations and amount of cloud cover.

On Big Pine Key, an average of 115 acres of land was being cleared annually, decreasing available deer habitat. This conflict with the human population and the reduction in habitat will probably result in a smaller deer population.

Quarterly estimates of deer densities based on a 10-mile road census showed an increase in the Big Pine Key population from spring 1969 (70 deer) to spring 1972 (101 deer). A drought from October 1970 through May 1971 appeared to have caused an abnormally large population estimate for fall 1970 (127 deer), winter 1971 (156 deer) and spring 1971 (117 deer). A positive correlation ($r = 0.746$) existed between the Schumacher-Eschmeyer estimate of population size and the number of deer seen per mile of census route. Deer were more often seen during December-May than during June-November. Because of this differential probability of seeing deer along the census route, only data for the same months of the year should be used when comparing the number of deer seen per mile during different years.

Sunrise and sunset censuses suggest a population of approximately 200 deer on Big Pine Key. Populations of deer on Little Pine, Summerland, and Ramrod keys appeared stable in number; deer increased in number on Big Pine and No Name keys. Populations on Cudjoe, Sugarloaf, Big Torch, Little Torch, Middle Torch, Howe and Big Johnson keys decreased.

The reproductive output of Key deer (1.21 fawns per doe) was similar to deer populations on the Florida mainland (1.15 fawns per doe). Seventy-eight percent of Key deer mortality was caused by automobiles.

In the Florida Keys, deer habitat is currently endangered. Habitat protection is essential to save the deer population from extinction.

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POPULATION DENSITY, MOVEMENTS, AND HABITAT UTILIZATION OF KEY DEER, *ODOCOILEUS VIRGINIANUS CLAVIUM*

by

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A Dissertation Submitted in Partial
Fulfillment of the Requirements
for the Degree of
Doctor of Philosophy

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AN ABSTRACT OF THE DISSERTATION OF

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TITLE: POPULATION DENSITY, MOVEMENTS, AND HABITAT UTILIZATION OF KEY DEER, ODOCOILEUS VIRGINIANUS CLAVIUM

Major Professor: Dr. W. D. Klimstra

The population density, movements and habitat utilization of the Florida Key deer (Odocoileus virginianus clavium) were investigated from December 1968 through December 1971, and during six periods of 2 weeks each in 1972 and 1973. Most of the 233 captured and subsequently 119 radio-tagged deer provided basic information.

Movement by adult males was significantly larger than that for the other sex and age classes. Most deer made long trips from their normal range. Some extreme movements were thought caused by a drought. Most yearling males dispersed from their areas of birth. Eight deer transplants to other islands, suggested that some deer relocated to new areas would return to original ranges. There was limited dispersal from Big Pine Key.

The average monthly range for a Key deer was 193 acres with adult males showing larger ranges than other sex and age classes. Ranges were dynamic as in all cases radio-tagged adult male and female ranges during 1970 showed additions to 1969 ranges.

The average monthly range for all combined sex and age classes was made up of approximately 4 percent hammock, 40 percent pineland, 18 percent open-developed areas, 10 percent hardwood, 5 percent mangrove and 26 percent buttonwood. There was a significant difference between habitat

types found within monthly ranges and the availability of habitat types in the study area. Seasonal differences in habitat use were noted for all sex and age classes.

Time of year, time of day, rainfall, wind speed, moonlight and temperatures affected deer use of habitat. No effects of wind direction and cloud cover were detected.

Population estimates of deer density based on road censuses indicated approximately 200 deer on Big Pine Key. A drought appeared to have affected the number and the sex and age ratios of deer seen along the census routes. The reproductive output of Key deer was similar to deer on the Florida mainland. High roadkill mortality, appeared to have stabilized the Key deer population on Big Pine Key.

In the Florida Keys, the habitat is endangered; as the habitat changes, so will the deer. Protection of preferred Key deer habitat from continued development is essential to save the deer from extinction.

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