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# Feral Hogs Management at Merritt Island National Wildlife Refuge: Analysis of Current Management Program

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**August 2002**

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**August 2002**



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## Summary

This report summarizes a two-month project on feral hog management in Merritt Island National Wildlife Refuge (MINWR). In this project I marked and recaptured feral hogs, with the help of local trappers, to estimate population size and habitat preferences. Habitat covers (obtained from Dynamac Corporation at Kennedy Space Center) included vegetation cover and Light Detection and Ranging (LIDAR) data for MINWR. In addition, an analysis was done of hunting records compiled by the refuge, and hog-car accidents compiled by KSC security.

Feral hogs arrived at Merritt Island with the settlers of the 1800s. Until 1960s when NASA purchased Merritt Island and established KSC, hogs were raised in open pastures. When the farmers left the island some of the hogs remained and formed the basis for the hog population on Merritt Island. Using capture recapture method I estimated the hog population in the KSC security zone in MINWR to be about 3000 hogs, with an average density of  $13.36 \pm 6.15$  hogs per  $\text{km}^2$  (summer 2002). Sex and age ratios might suggest a declining population of hogs.

Habitat preference analysis showed that the two factors determining habitat selection are the availability of food, especially citrus, and the ability of the vegetation to provide shelter as represented by the density of the vegetation canopy. Hogs estimated density was higher in and around citrus groves. In areas where groves were scarce or not available hogs preferred dense vegetation of native hammocks. The LIDAR data enabled me to conduct a three-dimensional study of the vegetation in MINWR and showed that hogs preferred dense vegetation, while vegetation height was not an important factor in deciding on habitat.

The importance of citrus groves for the hogs was also mirrored in the accidents reports, which showed that most of the accidents occurred at night and early morning, along the main roads, State Road (S.R.) and S.R. 402, and near citrus groves. Hunting records showed that more hogs were captured during winter than summer. Similar pattern was found in the accident reports. These differences between winter and summer were probably caused by hogs movement between different parts of the refuge. In fall and winter hogs moved to the oak hammocks to forage for mast and to the citrus groves to feed on citrus. In summer they moved to the marshes. The main roads in MINWR are near the oak hammocks and the citrus groves. Those areas are also more accessible to trappers and hunters. The combination of habitat and accessibility can explain the seasonal differences and the similar patterns of hunting records and accident reports. Analysis of hunting records for the years 1998 through 2001 did not show significant differences between the years. Analysis of accident reports showed a decline in number of accidents on the main roads after 1995 when a new management program for hogs hunting was implemented in the refuge.

Recommendations for future management plans include: improvement of accessibility for hunters to the remote parts of the refuge. Segregation of management activities – different management methods have different requirements from the environment in which they are activated. Therefore using several methods in the same area might degrade their performances. Increase the effort in removing young hogs. Young hogs are not hunted, today, relatively to their part in the population. Increasing the removal of young hogs will expedite the decline of the population. Another way to reduce hogs population in MINWR is to reduce the suitable habitat

especially citrus groves, which are an important food source for the hogs. Assign a person to manage and administrate the program. Obtain funding for a long-term program. Improve data collection from trappers and hunters in order to have a better understanding of the changing population.

Further research is necessary to evaluate the role of the hogs in the ecosystem of MINWR and to determine their impact on both vegetation and wildlife in the refuge.



# 1 INTRODUCTION

This report is the summary of a two-month internship in Kennedy Space Center and Merritt Island National Wildlife Refuge (MINWR). The study project analyzed current data available on feral hogs on refuge grounds, estimated feral hog population and gave recommendations for improving management programs.

## 1.1 History of Hog Populations at MINWR

Hogs first arrived at Merritt Island with the Spanish occupation in the 16th century. Few hogs were brought with the Spanish ships as part of their livestock to be used as food source for the Spanish soldiers and settlers. When settlers occupied Merritt Island they brought hogs with them. Hogs were raised in open range free roaming in the forests and marshes these hogs were brand marked on their ears (John Tanner, personal communication), and herded for meat.

When NASA bought the island from its occupants, in the early 1960s they were told to remove their property. Not all the hogs were removed; branded hogs were still trapped in the early 1980s. From these accounts it is apparent that the origin of feral hogs on the refuge is from domesticated hogs reared on Merritt Island for the past 200 years.

## 1.2 Feral Hog Biology

Hogs, feral hogs, and wild boar are all of the same specie — *Sus scrofa*. The difference between wild boars and hogs is that wild boars are animals that were never domesticated nor were any of its ancestors ever domesticated. Whereas hogs and feral hogs are domesticated animals or their ancestors were domesticated. All of the hogs in MINWR are feral hogs.

### 1.2.1 Habitat Preference and Movement

Wild boars are found in a variety of habitats, from lowlands to 2000-meter-high mountains. They can survive in snow if they can walk through it. They thrive in tropical climate, but can survive in semi-arid conditions as long as there is shade and drinking water (Brooks et al. 1986; Leaper et al., 1999). During the heat of the day, boars hide in dense vegetation in habitats like forest, dense bush, swamps and even agricultural fields such as corn. They prefer streamside vegetation and oak forests over pine or mixed forests. In these habitats they find shelter, water, and food. The denser the vegetation, the better the chances are that there will be boars around (Brooks et al. 1986; Boitani et al. 1994). Although they show preference for certain types of vegetation, a more important factor is the density of the vegetation (Rosenfeld 1998).

Hogs show marked preference for certain habitats. The factors that influence their habitat selection are food availability and shelter from climate conditions (mainly heat) and hunting. Hogs on MINWR showed preference for pineless flatwoods and palm-oak-wax myrtle. They preferred cooler, shaded habitats in the warmer months, and tended to stay at the same place as long as food supply was adequate (Poffenberger 1979). Antonelli (1979), on the other hand, found that pineless flatwoods habitats were used less than other habitats. Both studies found that palm-oak-wax myrtle, citrus groves, grass swales, and grass ponds were the most preferred habitats. The difference between the two studies is probably due to different data collection techniques. Antonelli used tracks and signs left by the hogs, which showed mostly activity of



feeding and rooting, whereas Poffenberger used radio-telemetry, which collected data throughout the day and showed the location of hogs without describing their activity. Another point to consider is that Poffenberger only tagged three hogs, which might create a bias in the results. The difference between the findings may be explained by the hogs' behavior and the ability of the researcher to collect data on them. It is possible that for Poffenberger, the finding of high usage of pineless flatwoods represents resting habitat of the hogs were they spent a relatively long time but left few tracks.

The wild boar's home range size measured around the world is between 5 km<sup>2</sup> and 50 km<sup>2</sup> (1.9 mile<sup>2</sup> to 19.3 mile<sup>2</sup>). Home range size is affected by factors such as food distribution and abundance, sex, age, and physiological condition of the animal, population density, and habitat quality (Leaper et al. 1999). Studies have shown that they will remain within the same home range as long as there is enough food and shelter and there are no disturbances such as hunting or other human activities (Brooks et al. 1986; Boitani et al. 1994). Some studies in Europe showed that the wild boar annual home range is 16 km<sup>2</sup> to 26 km<sup>2</sup> (6.18 mile<sup>2</sup> to 10 mile<sup>2</sup>), with a monthly core of 1 km<sup>2</sup> to 2 km<sup>2</sup> (0.38 mile<sup>2</sup> to 0.77 mile<sup>2</sup>). Other studies found that the home range is less than 15 km<sup>2</sup> (5.79 mile<sup>2</sup>). Females near farrowing further reduce movement and home range (Leaper et al. 1999).

Hogs at MINWR have small home ranges of about 1.2 km<sup>2</sup> (0.5 mile<sup>2</sup>) (Poffenberger 1979). This home range size is smaller than other places around the globe, and is probably due to the heterogonous habitat on MINWR that can supply the hogs all there food, water, and shelter year round and within short distances.

### 1.2.2 Density

In 1979 the hog density on MINWR was estimated as 8.1 hogs per km<sup>2</sup>. This estimate was derived from a population size estimate of 201 hogs for 28.7 km<sup>2</sup> around the shuttle landing facility (Antonelli 1979). This density estimate is similar to wild boar density estimates from Israel, and in the Mediterranean forest habitat where there is hunting, the numbers are 7.8 for Alona hills (Rosenfeld 1998) and 7.5 for Mt. Merone (Cnaany 1972). This estimate is lower than the wild boar estimate for an area without hunting (12 for Ramat hanadiv) (Rosenfeld). A minimum density of 12.8 boars per km<sup>2</sup> was estimated in Italy (Massei et al. 1996). A density of 6.2 hogs km<sup>2</sup> was found in southern Texas (Harveson et al. 2000).

It is interesting to note that these three countries are at latitudes of 28 to 40 degrees north of the equator. Northern countries have lower boar/hog density. For example, in Poland the average density was 4 to 5 boars per km<sup>2</sup> (Andrzejewski and Jezierski 1978).

### 1.2.3 Reproduction

Boars around the world produce on average of five piglets per litter (the range was 2 to 13) (Brooks et al. 1986). The percentage of females lactating is dependent upon body fat conditions, which depends on food availability (Massei et al. 1996), especially mast production. If mast production is poor, boars, which live in areas near human populations can find supplementary food, and thus maintain body fat levels and reproduce (Groot Bruinderink 1994). In general, wild boars that are of European origin produce one litter per year, with estrus in fall and parturition in



spring, whereas wild boars of Asian origin, domestic pigs, and feral pigs produce two litters a year (Brooks et al. 1986). Piglet survival depends mostly on food availability, for milk production, and weather conditions (Groot Bruinderink 1994). In cold weather and low mast production piglet mortality, in the first year of life, can be as high as 90% (Groot Bruinderink 1994; Jezierski 1977).

Studies on Merritt Island showed that the average number of piglets per litter is 4.6 to 6.7, but not all the piglets survive the first year. Females examined had an average of 1.8 litters per year. Main farrowing season was between February and May, and another smaller peak in November and December (Strand 1980).

In the Great Smoky Mountain National Park, the average litter size was 4.4. Between March and May, 41% of the piglets were born, and few of the females (5%) gave two litters per year. Sexual maturity was achieved at the age of 7 or 8 month, but was dependent on food availability (Peine and Farmer 1990).

The gestation period is about four months long, and lactation continues for up to three months after the litter is born. Generally the female will not come into estrus as long as she is lactating. Therefore, the time between litters is not constant and is influenced by behavioral and biological factors as well as by environmental factors (Strand 1980).

#### **1.2.4 Diet**

Wild boars are omnivores that consume mainly vegetative matter. Studies around the world showed that their diet contains 86% to 95% vegetative matter and the rest is of animal or litter origin (Massei et al. 1996; Groot Bruinderink 1994; Cnaany 1972). Wild boars have a simple stomach, therefore, they cannot digest cellulose, and so leaves are not a food source.

In a Mediterranean habitat, they eat acorns, olives, pine seeds, and different species of Graminoids (Massei et al. 1996). Animal matter included invertebrates of different species, and also rodents and reptiles (Massei et al. 1996). In the marshes of the Camargue (southern France), wild boars also eat snails and fish (Daraillon 1987). Analysis of seasonal changes in diet showed a negative correlation between Graminoids and mast, which suggested that Graminoids were discarded when other food was available. Pine-seeds and fruits were consumed mainly in summer, although they were available through most of the year (Massei et al. 1996). Wild boar selected energy-rich foods such as acorns, olives, and pine-seeds (Massei et al. 1996; Peck 1978). When eating grass they do not digest the leaves and stems. They clip and chew the grass, sucking the sugar and protein rich liquids and spit the chewed grass in mouth-size clumps (Cnaany 1972; Rosenfeld 1998). Such clumps were also seen on MINWR (Arie Rosenfeld, personal observation).

Analysis of manure pellets collected on MINWR showed that hogs preferred vegetation species with high energy content and high carbohydrate content versus high protein or high lipid content. Pellets samples were collected in February, April, and June (Peck 1978), which might influence results by creating a seasonal bias.



Since hogs have simple stomachs and cannot digest cellulose, they might also have difficulties digesting vegetative proteins and lipids, which would explain their lack of preference for plants with high protein or lipid values (Peck 1978).

Rooting activity is common at MINWR and was done mainly along roads and dikes. Hogs rooted up stems of Bahia grass, red root, and bracken fern rhizomes. In the canals, the hogs were after aquatic and emergent vegetation (Antonelli 1979; Peck 1978).

## **2 ANALYSIS OF HUNTING RECORDS**

### **2.1 Introduction**

This section analyzes data from hunting records submitted by licensed trappers under contract at MINWR. The first data set is of hunting records for the month of July for the years 1984 through 2001, and the second data set include summary of hunting records for the years 1998 through 2001.

### **2.2 Method**

Two methods of hunting are used on MINWR grounds. One is trapping (see Section 4 on capture-recapture for detailed description of the method), and the other is “dogging,” capturing hogs with hunting dogs. When dogging, the hunter and another helper or two travel with two or more dogs on a vehicle along the roads and unpaved roads of the refuge. When spotting a hog along the road or crossing the road, they release the dogs and the chase begins. When the dogs catch the hog, the hunter or one of the helpers grabs the hog by its hind legs flips it and ties it down. The hog is then carried to the truck and placed in a cage for transportation off the refuge.

Records of each hog captured on the refuge during the month of July for the years 1984 through 2001 were totaled up by sex for each hunting day. Hunter success was estimated by dividing the total number of hogs captured (harvested) per month by the number of hunt days per month. This provided an estimate of harvest success based on effort. Changes in average monthly hunting success were examined through the years. Differences in hunting success were examined using Kruskal-Wallis ANOVA, which is a general nonparametric test for comparing two or more independent samples.

Sex ratio was calculated from the total number of males and females hunted per month. Hunting records submitted by the hunters did not include details on the method used.

The hunting records for the years 1998 through 2001 included only a summary of hogs hunted per month. This data set was examined for differences in the average number of hogs hunted between the years and the months within the years. Data analyzed include only hunting records from within NASA’s security zone. Differences were examined using two-way ANOVA without replications, and Scheffé test for homogeneous groups.

### **2.3 Results**

The average number of hogs captured on the month of July for the years 1984 through 2001 was  $113.9 \pm 52.6$ . The minimum was 58 and the maximum was 216. To capture more than 100 hogs

per month, John Tanner and his trapping crew had to spend more than 20 days on the refuge (Fig. 1). On average, Tanner and his crew spent  $19.4 \pm 4.7$  days a month on the refuge hunting feral hogs.

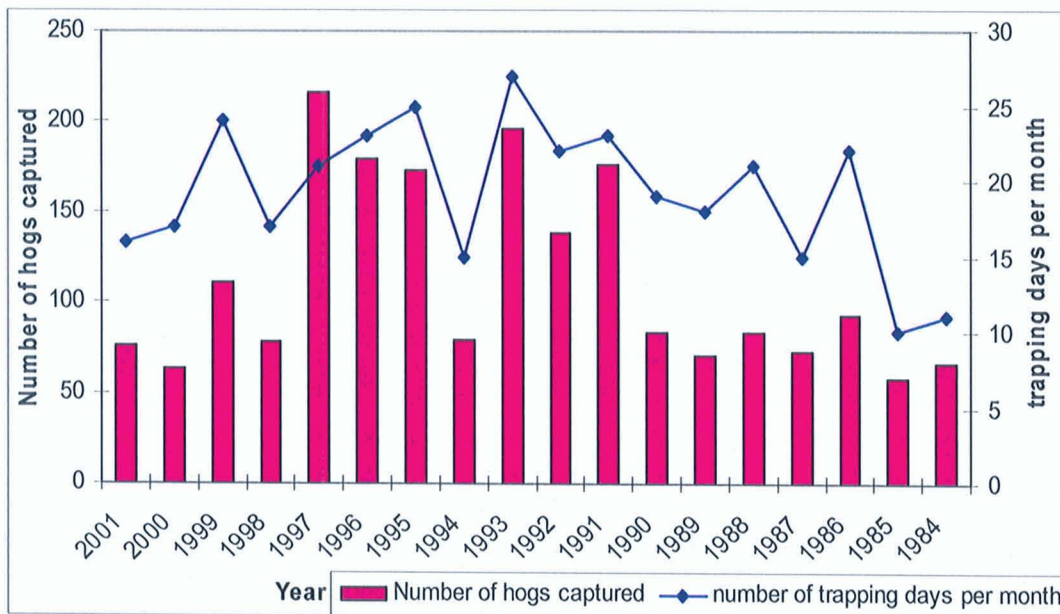
Average hunting success was  $5.7 \pm 1.57$  hogs per day for the month of July. The minimum was 3.7 hogs per day in 2000 and the maximum was 10.3 hogs per day in 1997 (Fig. 2). Kruskal-Wallis ANOVA showed that hunting successes differed between the years ( $\chi^2 = 51.35$ ;  $df = 17$ ;  $p < 0.0001$ ); however, the Steel-Dwass test did not show any pair wise differences between the years.

Hunting success in the years 1991 to 1997 was significantly higher than in the other years (1984–1990 and 1998–2001) ( $F = 22.72$ ;  $df = 16$ ;  $p < 0.0005$ ).

Several factors can attribute to the change in hunting success among the years.

1. Change in hog population size — If population size increased, then the density of hogs increased and it would be easier to hunt them either with traps or with dogs. A smaller population would be harder to capture.
2. Changes in hunter’s efforts — If the hunter increased his efforts, i.e., increased the number of traps or the number of dogs used per day, his success per day would increase.

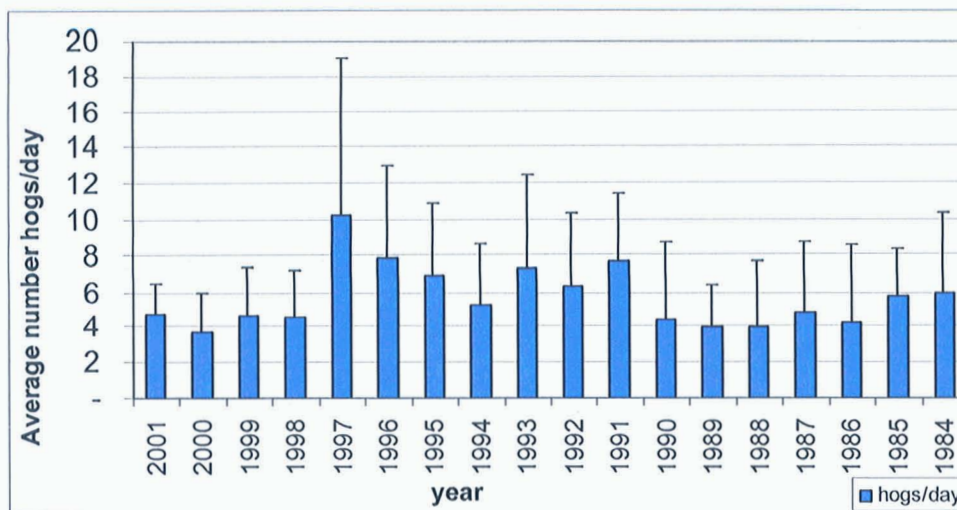
If the high hunting success continued all year (especially in July of 1996 and 1997), then that could mean a reduction of the hog population.



**Figure 1. Total number of hogs hunted each July from 1984 to 2001**

Generally 10 to 15 traps are set each night (Tanner, pers. comm.). This would result in an average of 0.38 to 0.57 captures per trap per night (assuming for the discussion that all hogs hunted were trapped). This rate of success is higher than the rate of 0.0062 to 0.033 captures per trap reported for the Great Smoky Mountain National Park (Peine and Farmer 1990).





**Figure 2. Hunting success – hogs/hunting day, for the month of July**

One of the main problems with assessing hunting efficiency is assessing the area the hunters can actually cover. A Geographic Information System (GIS) was used to estimate how much of the security zone and the refuge as a whole could be accessed by the hunters. Using ARC/VIEW 3.2, a 200-meter-wide buffer was created around the roads and dirt roads in the refuge (Map 2.1 in Appendix A) (road coverage was created by J. Vehrs of MINWR). This is generally the maximum distance a hunter would walk from the road to carry a hog (caught by the dogs) back to his truck. Carrying even a 30 lb hog in the brush and dense vegetation is a laborious task (A. Rosenfeld, pers. exp.).

From Map 2.1 (in Appendix A) it is apparent that large areas in the security zone are virtually inaccessible to the hunters. This lowers the hunting efficiency because the hunters have to wait for the hogs to come to them near the roads instead of going after the hogs wherever they are.

**2.3.1 Monthly Hunting Records: 1998 through 2001**

Total number of hogs hunted on the security zone in the years 1998 to 2001 were: 1734, 1607, 1774, and 1502 respectively (Table 1). No significant differences were found in the average number of hogs hunted per month between the years.

**Table 1. Total number of feral hogs hunted on the security zone 1998–2001**

Year	Total	Average per Month	Standard Deviation
1998	1734	144.50	83.28
1999	1607	133.92	65.38
2000	1774	147.83	78.14
2001	1502	125.17	50.72



Two-ways ANOVA for the number of hogs hunted in the security zone in the years 1998 through 2001 found significant differences between the months ( $F = 8.81$ ;  $df = 11$ ;  $p < 0.0001$ ), but not between the years.

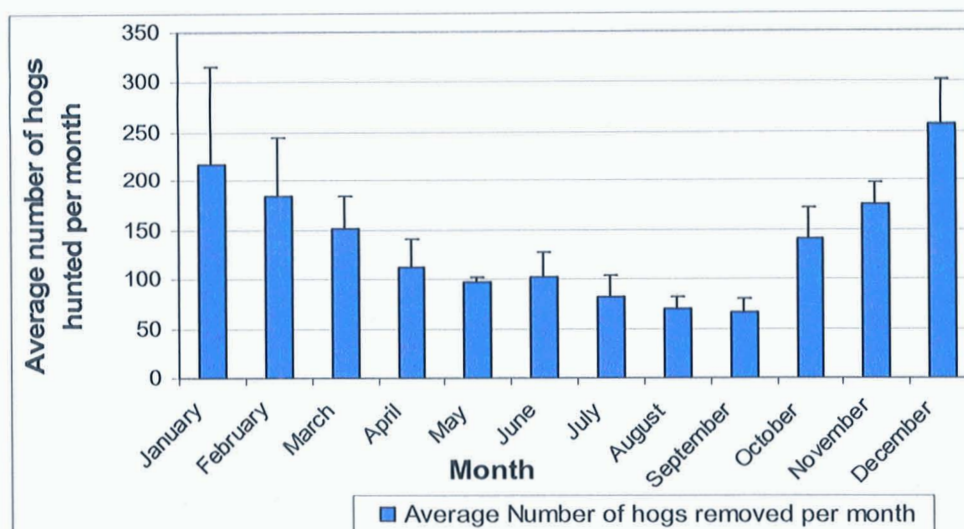
Average number of hogs hunted was highest during December ( $256 \pm 45.7$ ) (Fig. 3), declined during spring and summer to its lowest point in September ( $65.5 \pm 14.5$ ), and increased again during fall. A Scheffé test showed that the average number of hogs hunted in August and September was significantly lower than the numbers hunted in December and January (Table 2).

**Table 2. Scheffé comparison of means**

Variable	Homogeneous	
	Mean	Groups
December	256.00	I
January	218.25	II
February	208.75	III
November	175.00	IIII
March	152.00	IIII
October	141.75	IIII
April	112.50	III
June	101.25	III
May	96.250	III
July	82.250	III
August	69.750	II
September	65.500	I

Based on 18 years of data (Fig. 1) provided by trapper John Tanner on hunting during the month of July, he and his trapping crew spent an average of more than 19 days each month hunting in the security zone. Therefore, it is probable that the difference in number of hogs hunted per month during the years 1998 through 2001, did not originate from lower hunting pressure during the months of July to September. It appears that differences in number of hogs hunted were due to differences in the hog's behavior. These differences can be changes in attitude toward the traps and the bait placed in them, or changes in the hogs' distribution across the security zone. The bait placed in the traps is corn. It is possible that hogs are more attracted to this bait during late fall and winter, but prefer other food sources in summer. However, this is unlikely because, as will be shown later, summer is probably the hardest season for the hogs since there is less food available. The end of fall and beginning of winter are the most plentiful seasons with many food sources available. Therefore, the most likely explanation to changes in number of hogs trapped each month is assumed to be changes in the distribution of feral hogs across the security zone. Traps are placed along unpaved roads, and hunters can effectively range about 100 meters to 200 meters (328 feet to 656 feet) away from the roads while hunting with dogs. This leaves large tracts of land inaccessible to the hunters (Map 2.1). It is possible that the hogs move to those areas during summer and this causes the decline in hog trapping in summer. On the other

hand in fall and winter the hogs move to areas more accessible to the hunters, and therefore numbers of hunted hogs increase in winter. Further discussion of hog movement is covered in Section 4.



**Figure 3. Average number of feral hogs hunted per month 1998–2001 within the KSC security zone**

### 3 ANALYSIS OF HOG — CAR ACCIDENTS DATA

#### 3.1 Introduction

This section analyzes data on hog-car accidents and hog road kills reported on MINWR. In their movement in search for food and other activities, hogs cross the roads and cars hit many of them. These accidents can cause up to \$3000 worth of damage to the cars, but generally the damage is several hundreds of dollars (KSC security reports).

#### 3.2 Methods

Data analyzed in this section included data from KSC security accidents reports from the years 1995–1997, 2001, and 2002 (until June 2002). Data from 1998 to 2000 was not available. The reports are for car accidents from within the refuge boundary.

Another data set includes records of road-kills observed by Dynamac Corporation personnel on refuge main roads in the years 1992 through 1995. Data were analyzed to determine changes in car accident frequency between years, months, and time of day. When analyzing the influence of the time of day on the frequency of car accidents, the day (24-hour period) was divided into four time periods:

- Morning: 04:00 to 08:00
- Day: 08:00 to 16:00
- Evening: 16:00 to 20:00
- Night: 20:00 to 04:00



Chi-square test was used to determine whether the distribution of the accidents was even between the time periods of the day. Observed data was the number of accidents at each time period. The expected data was calculated as the total number of accidents (75) multiplied by the relative duration of each time period (see Table 3).

To determine influence of time of day and month on frequency of accidents, data from all the years available was combined, due to low number of reported accidents in the years, following 1995. Road-kill data were also examined for changes in the number of road kills between years and months. To examine the influence of month on the number of accidents, the average number of road kills per month was calculated.

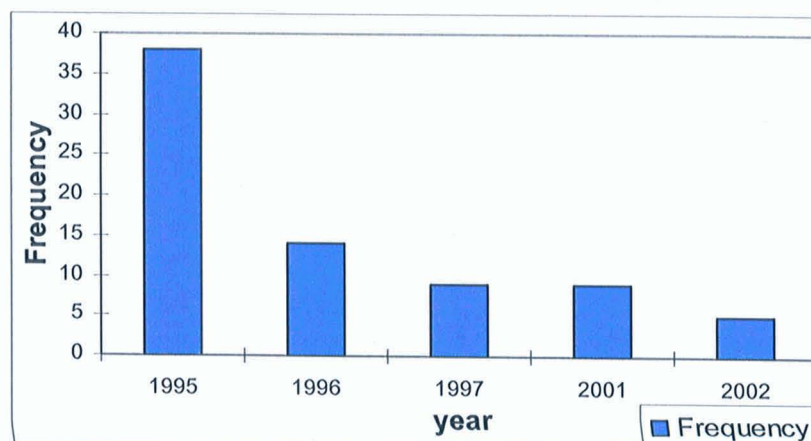
Distribution of road kills and accidents were examined with GIS to determine on which roads most of the accidents happened and to examine the influence of surrounding habitat on accident frequency. Accident location was digitized with ARC/VIEW 8.1 according to description given in KSC security accident report, with road cover (created by J. Vehrs) as a background (Map 3.1 in Appendix A). Paved roads were extracted from the main road cover to create a new cover.

Chi-square test was used to determine whether the percentage of accidents on the main roads (where most accidents occurred) was similar to the percentage of these roads from the total length of paved roads in the refuge, or not. The number of accidents reported on the main roads was used as observed data. Expected numbers were calculated by multiplying the total number of accidents (75) by the percentage of length of the main roads from all of the paved roads.

### 3.3 Results and Discussion

#### 3.3.1 Yearly Changes in Hog-Car Accident Frequency

During the 4.5 years of data available from KSC security reports, there were 75 accidents. There were 38 accidents in 1995 and after that there were about 10 accidents per year (see Fig. 4).



**Figure 4. Frequency of hog-car accidents per year**

Changes in accident frequency between the years could arise from several reasons that include the following two.

1. Reduction of hog population. In 1995 the refuge administration changed its hog management program. Prior to 1995, the entire refuge was under one management unit; the only one hunter and his team of helpers worked over the entire area. In 1995, the refuge was divided to three management zones, and three hunters and their helpers started working on the refuge. This increased the number of hogs hunted in the refuge. This decline in hog population might be the reason for the reduction in hog-car accidents.
2. Changes in habitat and vegetation might have influenced the pattern of hog movement and, therefore, they were not as active near the roads as they were in 1995, resulting in a decline in accident numbers. Changes in vegetation can include a reduction in grove production (the importance of groves as a food source are explained in the following sections), or changes in natural vegetation caused by fire. Burning of oak forests will cease its mast production for a few years. This will force the hogs to look for acorns in other oak forests. If an oak forest near the road was burned, then hogs may not come to this hammock until it started producing acorns.

### 3.3.2 Changes in Car Accident Frequency Throughout the Day

Looking at the distribution of car accidents throughout the day it is apparent that most accidents happened at night or early morning, 64 of 75 accidents (see Table 3). Chi-square test showed that the number of accidents in the different time periods was significantly different from the number expected by their relative duration (Chi = 24.41; df = 3; p < 0.0001).

**Table 3. Distribution of car accidents throughout the day**

Time	No. Hours	Frequency	Relative Length	Expected No.
Morning	4	30	17%	12.5
Day	8	5	33%	25.0
Evening	4	6	17%	12.5
Night	8	34	33%	25.0
Total	24	75		

The chi-square test showed that during morning and night there were significantly more accidents than expected, and during day and evening, significantly less. This can be explained by:

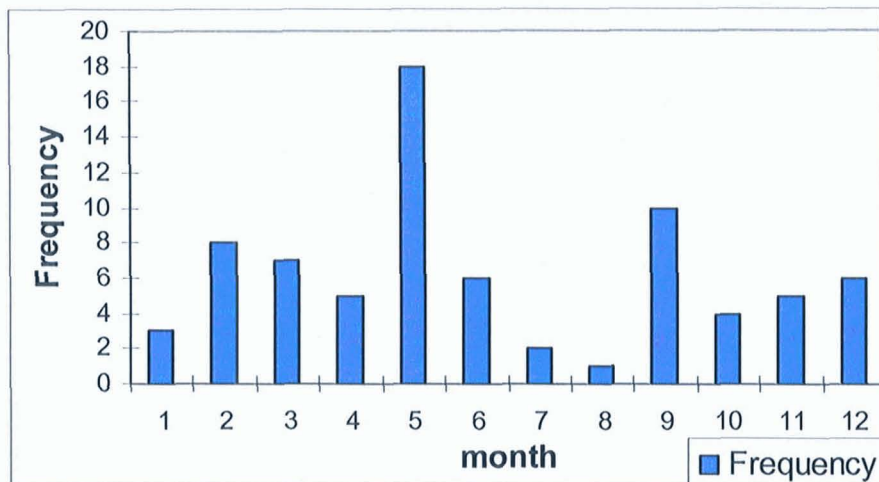
1. Hog activity. Hogs like boars do not have sweat glands. Therefore they have trouble regulating their body temperature in hot weather. To compensate for that they stay in the shade and are less active during the hot hours of the day, and forage for food at night and early morning (Brooks et al. 1986; Singer et al. 1981; Andrzejewski and Jezierski 1978). The lowered activity of the boars during the hot hours of the day can explain the low number of accidents during those hours, whereas high activity during the cool hours of the day (dawn and night) can contribute to the high number of accidents in those time periods.



2. Traffic activity. Morning is the traffic rush hour at KSC. This can attribute to high number of accidents, in that time period. During the day there is good visibility and drivers can avoid hitting hogs. At night and dawn the visibility is poorer and it is harder to spot hogs on the roads, especially those with dark fur, which add to their susceptibility to accidents.

### 3.3.3 Monthly Changes in Car Accident Frequency

Frequency of accidents is relatively high in December and February, declining during the months of spring and summer, and rising again in fall (Fig. 5). This trend is broken by a high frequency of accidents in May through June, and September.



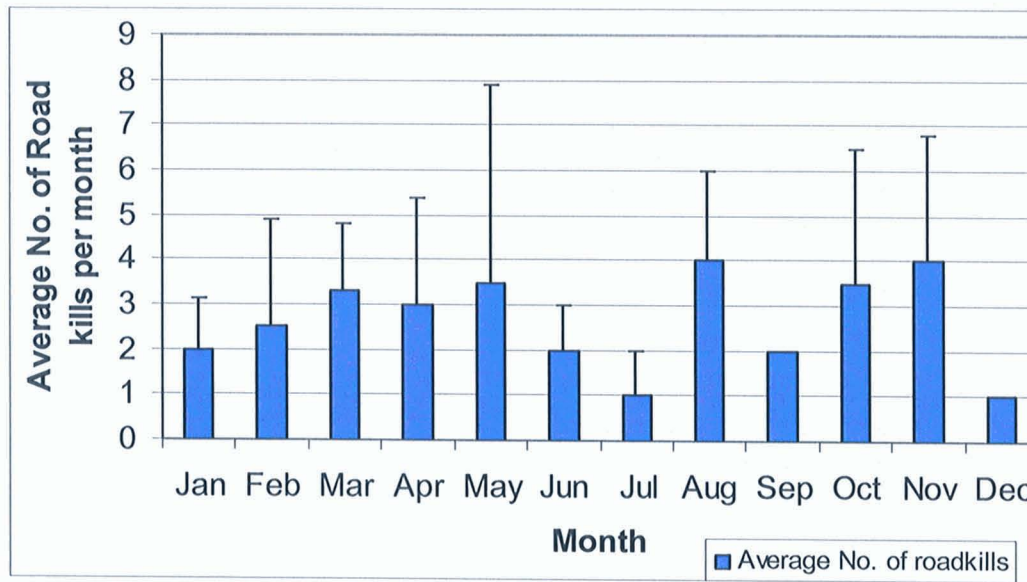
**Figure 5. Monthly frequency of accidents at MINWR  
(Total of all KSC reports years combined)**

As shown above two main factors influence this trend in accident frequency. One is human activity and the other is hog activity.

1. Human activity can influence the frequency of accidents per month by the mere amount of traffic on the roads. The more traffic there is, the higher the chances of accident. However, no data on traffic at the refuge was available and therefore in the following analysis we assume that the average number of cars traveling the roads, per month, is constant.
2. Hog activity. Two attributes of hog activity interplay in the frequency of accidents on the roads at MINWR. The first is the search for food. It is probable that the distribution of food sources on the refuge is not homogenous, which causes the hogs to move from one part of the refuge to another. Thus when a seasonal food source is near the roads, more hogs will travel to that location to feed, and there will be more accidents. When that food source is depleted, the hogs will move in search of other food sources and will be further away from the roads. Thus the chances of accidents and accident frequency will decline. (Analysis of food source distribution is elaborated in Section 4 on habitat selection.)

3. The second activity is connected with hog reproduction. The main mating season of boars and hogs is at fall (Brooks et al. 1986; Leaper et al. 1999). This will cause the adult males to travel more for food and mating. These movements may explain the increase in frequency of accidents in September. The increase of accidents in May and June might be attributed to juvenile activity. Most births occur from February to May (Strand 1980). Thus young juveniles, who are weaned by May, will start to be more independently active. They may be more prone to accidents than adults, which might explain the relatively high number of accidents in May.
4. Another factor that might influence accident frequency is weather conditions that degrade visibility. Rain is probably not a cause for increase in accidents because the rainiest month is August and that is also the month with the lowest number of accidents. But other conditions like fog, which hamper visibility, may well cause an increase in accidents.

Monthly changes in average number of road kills showed similar trend to changes in hog-car accidents (Fig. 6). Lowest numbers of accidents were in summer. But peaks were in spring and autumn and not winter. A peak in May and another peak in August again broke the yearly trend. The causes for the changes in average number of accidents per month were discussed above. Although there appears to be a trend in monthly changes in road-kill numbers, no significant differences were found in the average number of road-kills between the months (Kruskal-Wallis ANOVA  $P > 0.05$ ).



**Figure 6. Average number of road kills per month**

Only one year (1995) had data for both road kills and hog-car accident reports. Comparing data from road kills and data from accident reports for 1995 it became apparent that not all the accidents were reported to KSC security. In 1995 there were 38 accidents reported to KSC security. In that year, Dynamac personnel sighted 34 dead hogs, but only 16 dead hogs were both sighted by Dynamac personnel and were involved in an accident reported to KSC security



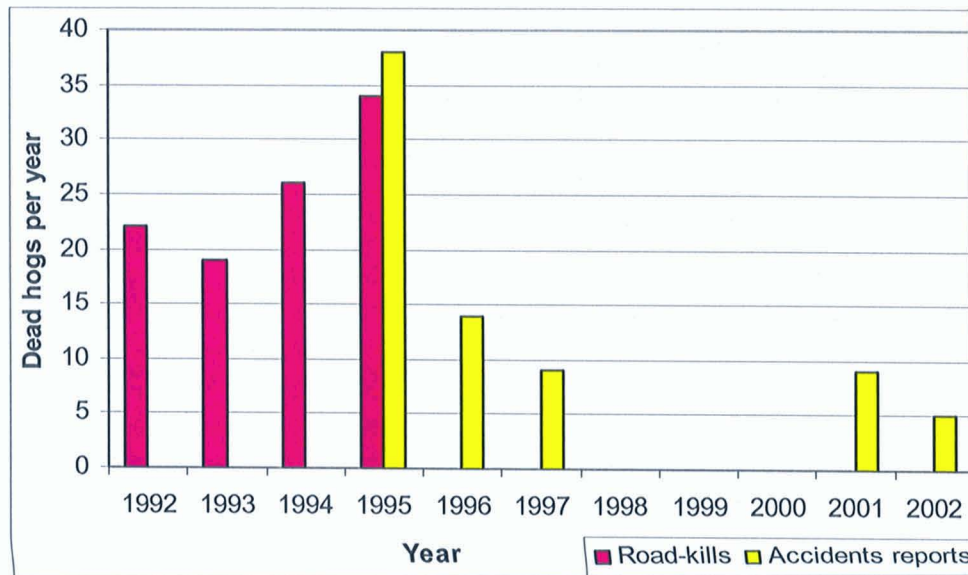
(Map 3.2 in Appendix A). This leaves 18 hogs that died on the roads, probably in collision with cars, and were not reported.

These numbers increase the total number of hog accidents on the refuge in 1995 from 38 to 56. It is possible that there were even more accidents that were not sighted and not reported.

Limited data prevented an accurate interpolation of the total number of accidents for the period from 1992 to 2002, but since the total number of accidents for 1995 in both data sets was similar, we combined the two to get the trend of accidents frequency per year.

Looking at the information from the two data sets combined, it appears that the number of accidents per year increased from 1992 to 1995 and then declined rapidly (Fig. 7). The decline in the number of accidents was discussed earlier in this section, and can probably be attributed to the increase in hunting pressure on the refuge grounds. The increase in road kills observed from 1992 to 1995 can arise from several reasons:

1. Increase in hog population on the refuge, which increased the number of hogs crossing the roads — and the number of accidents.
2. Changes in habitat — changes in habitat near the roads might increase hogs activity near the roads and thus increase the number of accidents.
3. Observer proficiency — the ability of the personnel, which collected the road kill data, has improved with the years.
4. Changes in road infrastructure — improvements of roads on the refuge allow drivers to drive faster and thus increase the chances of accident.



**Figure 7. Trend in the frequency of hog death on roads at MINWR**

Distribution of hog accidents and road kills was examined with GIS. Most accidents happened along S.R. 3 and S.R. 402 (Maps 3.1 and 3.2 in Appendix A). These two roads are among the

most active roads on the refuge grounds. Of the 75 accidents reported to KSC security, 58 were on S.R. 3 and S.R. 402. The rest were on other paved roads of the refuge (Table 4). The total length of paved roads on the refuge is about 190,376 meters (118.8 miles). The total length of these two roads is about 71,208 meters (44.4 miles) (37.4%) (GIS cover prepared by J. Vehrs). Chi-square test showed that the number of reported accidents on S.R. 3 and S.R. 402 differed significantly from the expected numbers ( $\text{Chi} = 23.81$ ;  $\text{df} = 1$ ;  $p < 0.00$ ). This means that accidents occur more frequently than expected on these two roads.

**Table 4. Total number of accidents on the roads at MINWR**

	No. of accidents	Road Length %	Expected No.
S.R. 3 + S.R. 402	58	37.4%	28.05
Other roads	17	62.6%	46.95

Several factors may attribute to the higher number of accidents on these two roads:

1. Traffic volume — as previously mentioned, these two roads are among the most active roads on the refuge. These roads are used by the general public accessing the refuge and by KSC's employees.
2. Speed — people driving along these roads drive faster than on the other smaller roads in the refuge.
3. Surrounding habitat — S.R. 3 divides the refuge into two parts, east and west. Hogs traveling between these two parts would have to cross that road, and thus the potential of their being hit by a car increases. Preferred habitat along the road would also increase the potential for accidents. (Influence of citrus groves and other habitats is discussed in the section on habitat selection).

Another active road, S.R. 405, had no accidents. This might be because there are deep canals on both sides of the road (Map 3.3 in Appendix A). These canals are inhabited by alligators and the hogs probably prefer not to cross them, and so they have less access to this section of road. It is important to note that hogs were seen along this section of road, but the numbers are less than in other sections.

A good estimate for the number of road-killed hogs on the refuge, per year, exists only for 1995; in this year there were 56 accidents. This results in an average of 0.3 road-killed hogs per kilometer per year, on all the refuge paved roads. In that year, 39 hogs were killed on the two main roads S.R. 3 and S.R. 402, with an average of 0.55 hogs killed per kilometer per year. This accident rate is lower than one armadillo killed per kilometer per year reported on the Florida Turnpike (Inbar and Mayer 1999), but is much higher than the rate of 0.006 mammals killed per kilometer per year in the central valley of California (Caro et al. 2000). We have not found data on road-kills of hog related species from other places around the world to compare to the data collected from the refuge.



## 4 ANALYSIS OF CAPTURE-RECAPTURE DATA

### 4.1 Introduction

One of the main purposes of this project was to try and estimate the hog population at MINWR. Working with the licensed trapper at MINWR, we used capture-recapture methods to try to estimate hog population on the refuge.

### 4.2 Methods

For the capture-recapture study hogs were trapped in cage traps. Each trap was about  $3 \times 3$  meter area and the side fence 1.6 meter (5.25 feet) tall. The traps had a trip mechanism to close the door behind the hogs. Traps were baited with corn, which was spread on the ground both in the trap and outside in a trail leading to the trap. Two types of trapping mechanism were used. The first was a flapping door with the hinges at the top. The door was held open with a stick that the hogs accidentally pushed when they went into the trap, and the door closed behind them. The other mechanism consisted of a heavy plywood door, which was held up by a rope connected to a peg at the far side of the trap. When the hogs went into the trap and rooted for corn seeds in the ground near the peg they flipped the rope and the door fell down behind them closing the trap.

We used 16 traps. We used only traps that were known by the trapper to capture hogs at this time of year. All traps were located within the KSC security area. The traps were distributed along unpaved roads with easy access to a vehicle (for location of traps, see Map 4.1 in Appendix A). After the first trapping night we stopped using traps 6, 7, and 12 due to human disturbance, therefore only 13 traps were used for the calculations. Trap locations were digitized to create GIS cover using ARC/VIEW 8.1. NAD83 datum was used for mapping.

Hogs were marked with numbered ear tags and released after tagging at the trap where they were captured. For each hog, we determined sex and J. Tanner estimated age and weight. Only the trapper's estimates of age and weight were used to ensure relative consistency of estimates. From July 6 to August 3 we had 11 trapping nights. Each time the traps were baited for two nights before the door was set. On August 13–15, we made three removal trappings, with the hogs captured in the traps and removed from the refuge.

Each captured hog was given a unique ID number. This allowed us to study hog movements between traps. For this analysis we combined data of capturing locations from both the capture-recapture phase of the study and the capture-removal phase. Distances (in meters) between capturing locations were measured with ARC/VIEW 3.2.

Several methods were used to estimate population size. For most of the calculations, we used only data from the capture-recapture phase of the study. For the purpose of population estimates it is assumed that the average home range of hogs is  $1 \text{ km}^2$ , and therefore the effective trapping area of each trap is also  $1 \text{ km}^2$ .

1. The total number of different hogs caught in each trap was counted and an average was calculated. This is considered as the minimum density of hogs per  $\text{km}^2$  in the security area.

2. The abundance of hogs was calculated for the whole security area and also per trap. We used the Lincoln-Peterson index corrected by Chapman:

$$\text{Equation 1: } N = \frac{(n_1 + 1)(n_2 + 1)}{(m_2 + 1)} \quad (\text{Nichols and Dickman 1996})$$

Where  $N$  is estimated population size,  $n_1$  is number of individuals trapped at first trapping,  $n_2$  is the number of individuals trapped in the second trapping,  $m_2$  is the number of individuals trapped on first trapping and retrapped on the second trapping. This equation is suitable for close population where the population size does not change during the trapping period. Because the trapping was done in a short period of time, it is assumed that the population did not change and therefore it is applicable to use Equation 1. From the third trapping,  $n_1$  was calculated as the sum of the number of different individual hogs trapped so far. The term  $n_2$  was the number of hogs trapped at the recent trapping. Variance for the population estimate was calculated as:

$$\text{Equation 2: } V(N) = \frac{(n_1 + 1)(n_2 + 1)(n_1 - m_2)(n_2 - m_2)}{(m_2 + 1)^2(m_2 + 2)} \quad (\text{Nichols and Dickman 1996}).$$

The highest population estimate was used as the final estimate for the population. This highest estimate provided the most conservative approach for determining trap success and future management options.

Hog abundance, survival, and recapture rates were estimated using program MARK 3.0. Since the trapping session continued for a short period of time — one month — we used close population model type for the analysis. We ran the model on data collected throughout the month (11 trapping nights and 97 different hogs captured), and also on the first half of the month (8 trapping nights and 88 hogs trapped). We also ran both data sets through the recapture model to examine survivability, which is estimated as one in closed population models. In order to compare estimation results generated by MARK, we used t-test:

$$\text{Equation 3: } t_{\alpha[\infty]} = \frac{x_1 - x_2}{\sqrt{S_1^2 + S_2^2}} \quad (\text{Sokal and Rohlf 1995}).$$

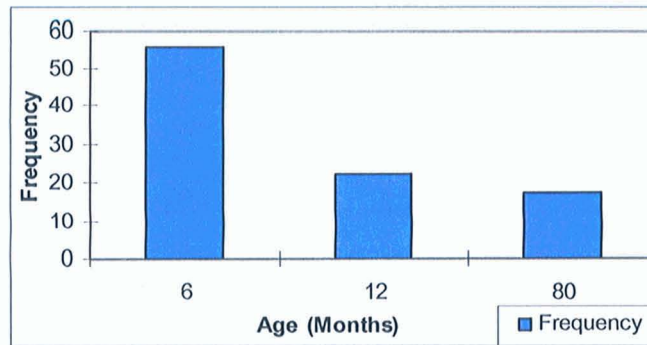
Where  $x$  is a population estimate generated by MARK for each of the data sets, and  $S^2$  is the variance.

## 4.3 Results and Discussion

### 4.3.1 Population Dynamics

During the capture-recapture phase of the study, 95 hogs were tagged. Of these hogs, 42 (43%) were males and 53 (57%) were females. Of the total 95 hogs, 78 (82%) were less than one year old (Fig. 8).





**Figure 8. Age distribution in tagged hogs population**

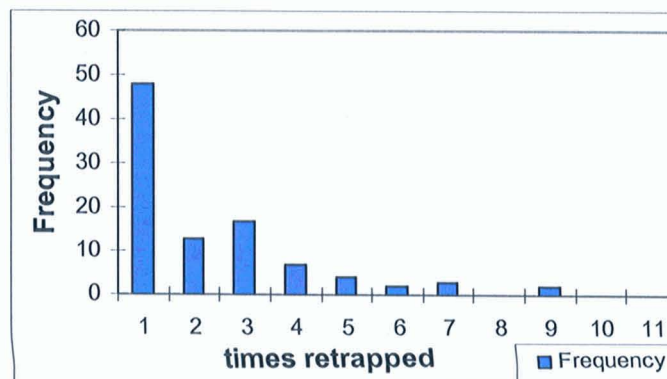
This ratio differs from the ratio of 60% young (less than 1 year) and 40% adults (more than one year) found in the refuge in the past (Antonelli 1975) ( $\chi^2 = 11.51$ ;  $df = 1$ ;  $p < 0.0007$ ).

This ratio of 82% young 18% old can arise from several sources:

1. Rising population with lots of piglets.
2. Heavily hunted and declining population with few adults.

The time of year of this study, July and August, is right after the main birthing season, which is February to May (Strand 1980). This can be the reason for the high percentage of young and especially the young piglets, and can explain the biased age ratio. Hog hunters prefer to hunt bigger, older hogs (J. Tanner, pers. comm.). This can also cause a change in age ratio that is based on hunt-captured hogs. The trapping period had only lasted less than a month. This is not a sufficient time to accurately assess the age structure of the population.

During the capture-recapture phase, there were 227 recaptures of the 95 hogs tagged. Fifty percent of those hogs were only caught once, but the rest were caught more than once, and two of them were caught as many as nine times (Fig. 9). This shows the high heterogeneity in the hog population with some of them trap-happy and some trap-shy.



**Figure 9. Frequency of retrapping hogs July 2002**

### 4.3.2 Hog Movement

Combining data from the two phases of the study increased the number of hogs caught to 100. Of these, 56 were caught more than once. Of these 56 hogs, only 8 (14.3%) were caught in more than one trap. Of these 8 hogs, 5 moved back and forth between traps 3 and 5 (a distance of 800 meters), another hog was caught once at trap No. 9 and once at trap No. 15 — a distance of 400 meters. One hog moved from trap 14 to 4 — a distance of 2650 meters (1.65 miles) and another one from trap 9 to 11 a distance of 7690 meter (4.8 miles).

These findings are evidence of only 2 hogs (3.5%) moving a distance greater than 1000 meters during the study period. These findings indicate that the hogs in general stay at the same location (at least for this time of year). These findings are also in agreement with the finding of Poffenberger (1979) that hogs home range is about 1 km<sup>2</sup>. Since the traps were not randomly distributed and were spread over a large area, it is possible that more hogs moved distances greater than 1000 meters, but at present, there is no data to support this.

### 4.3.3 Population Estimates

The average number of different hogs per trap was  $7.25 \pm 2.63$  hogs (see Map 4.2 in Appendix A). If we assume that the trapping area for each trap is 1 km<sup>2</sup>, then that is also the estimated minimum density for the month of July 2002. The area of the security zone is 234.3 km<sup>2</sup>. Thus the estimated minimum hog population in the security zone is 1699 hogs.

Using Lincoln-Peterson index, we estimated population size as  $128 \pm 24$  hogs for the trapping area (Table 5). Assuming again that the effective trapping area of each trap is 1 km<sup>2</sup>, and then we receive a density estimate of 9.85 hogs per km<sup>2</sup>.

As trapping progressed through July, population estimates increased. This is probably because more of the hogs that were trapped near the traps had not been trapped on the initial trapping night. The lower estimates at the beginning of August might be just an artifact as a result of calculations (as happened with population estimates in July 13, 2002) or might represent an opening of the population and beginning of hog movement across the refuge and away from current traps locations.

Using the same area estimate of 234.3 km<sup>2</sup> for the security zone, we estimated population size at NASA security zone as 2307 hogs.

**Table 5. Capture data and population estimation**

	N1	N2	M2	N	Standard Deviation (N)
July 7, 2002	25	15	4	82.20	25.31
July 9, 2002	36	19	11	60.67	8.89
July 11, 2002	44	22	9	102.50	20.69
July 13, 2002	57	18	11	90.83	13.77



	N1	N2	M2	N	Standard Deviation (N)
July 18, 2002	65	24	15	102.13	13.06
July 20, 2002	74	25	18	101.63	10.29
July 23, 2002	80	25	16	122.88	15.27
July 30, 2002	89	9	6	127.57	23.91
August 1, 2002	91	26	22	107.00	7.35
August 3, 2002	95	19	17	105.67	6.98

Using the Lincoln-Peterson index, we have found that the average hog population per trap was  $13.36 \pm 6.15$  (Map 4.3 in Appendix A). This brings us to an estimated population of 3130 hogs in the security zone. Using the standard deviation estimates above, the hog population estimated is between 1689 and 4334. This lower limit is very similar to the lower limits estimated above with total number of individual hogs captured in each trap.

#### 4.3.4 MARK Analysis

Using program MARK, we first used closed population models to estimate parameters of capture probability ( $p$ ), recapture probability ( $c$ ), and population size ( $N$ ). First we examined whether parameters  $p$  and  $c$  had changed over time – changed between trapping nights or were constant over time. The comparison between models showed that the one in which  $p$  and  $c$  were constant over time provided the best fit to the data (Delta AIC = 0.000; AICc weight = 0.53; Model Likelihood = 1.0). Further, using program CAPTURE in MARK, we examined the influence of heterogeneity between hogs ( $h$ ), behavioral changes ( $b$ ), and time ( $t$ ) on capture and recapture estimate. Results showed that there was a high heterogeneity between hogs in susceptibility to trapping ( $\chi^2 = 40.24$ ;  $df = 3$ ;  $p < 0.0001$ ). Continuous trapping probably did not cause changes in hog behavior ( $p > 0.5$ ), which meant that hogs probably did not change their behavior toward the traps during the study. Capture and recapture probabilities changed over time ( $\chi^2 = 26.5$ ;  $df = 10$ ;  $p < 0.003$ ). This might indicate that the population was not closed during the study period and changes had occurred in the population size. Of all the combinations of  $h$ ,  $b$ , and  $t$ , the model that included both heterogeneity and change over time ( $th$ ), provided the best fit to the data.

According to this model population size is estimated at 161 hogs with a standard error of 20.6. Confidence intervals (95%) are 132 and 215 hogs. From this estimate of hog numbers for the traps derive an average estimate of 12.4 hogs per  $\text{km}^2$ , and the estimated population for the security zone is 2900 hogs, with 95% confidence intervals of 2380 to 3875 hogs. These estimates are within the boundaries of estimate calculated using the Lincoln-Peterson index per trap. Trapping probability changed between trapping nights and was between 0.05 and 0.16.

Using data from the first eight trapping nights (July 6–23, 2002) in which 88 individual hogs were captured, showed that the model providing the best fit to the data was the model in which both capture ( $p$ ) and recapture ( $c$ ) probabilities were constant through time (Delta AIC = 0.000; AICc weight = 0.67; Model Likelihood = 1.0). Further, using program CAPTURE in MARK, we examined the influence of heterogeneity between hogs ( $h$ ), behavioral changes ( $b$ ), and time ( $t$ ) on captures and recaptures estimates. The results from CAPTURE showed that there is heterogeneity between hogs in susceptibility to trapping ( $\chi^2 = 19.15$ ;  $df = 2$ ;  $p < 0.0001$ ).



Continuous trapping probably did not cause changes in hog behavior ( $p > 0.05$ ). Capture and recapture probabilities did not change over time ( $p > 0.05$ ). This fact indicates that there was probably no change in the population size during this shorter time period. This result indicates that there was no migration, immigration, deaths, or births during this time.

Of all the combinations of  $h$ ,  $b$ , and  $t$ , a model that included only heterogeneity ( $h$ ) provided the best fit to the data. According to this model population size is estimated at 153 hogs with a standard error of 18.3. Confidence intervals (95%) are 127 and 200 hogs. From this we derive an average estimate of 11.77 hogs per  $\text{km}^2$ , and the estimated population for the security zone is 2757 hogs, with 95% confidence intervals of 2289 to 3604 hogs. These estimates are within the boundaries of estimate calculated using the Lincoln-Peterson index per trap. We used Equation 3 to compare the results of MARK population size estimates (161 and 153 hogs). The t-test indicated that there is no significant difference between the two estimates ( $t = 0.29$ ;  $df = 1$ ;  $p > 0.2$ ).

In addition to analysis with closed population models, we used MARK to analyze the data in open (recapture) population models. Open population models estimate survival probability ( $\phi$ ), recapture probability ( $p$ ), and examine the probability of change over time. Analyzing the data from the whole month showed that the model best fitting the data was one with constant survival probability and constant recapture probability. Survival probability was estimated as 0.89, and recapture probability as 0.32. Estimates for the first two weeks of the study were similar (0.88 and 0.33 respectively). These estimates challenged the basic assumption of the closed population model, i.e., there is no change in the population, and survivability is 1. The survivability rate found indicates that there was either death or migration in the population during the study period. Migration is probably low at this time of year since the important food sources of acorns and other mast have not yet ripened. Death can occur from either biological factors such as predation by alligators or disease, or from human factors like car accidents and hunting. Hunting with dogs continued during the study period and hunters trapped some hogs in the study area (Tanner, pers. comm.). At least two accidents happened during the study period, in the study area, in which 7 hogs were killed (A. Rosenfeld, pers. obs.).

In our opinion the best feral hogs population estimate for KSC security zone for the month of July 2002 is the estimate calculated using program MARK with the full study data, which is 2900 hogs with confidence intervals of 2380 to 3874 hogs.

The average density estimate of 12.4 hogs per  $\text{km}^2$  is similar to other studies done in Mediterranean climate, where population density was estimated as 12 boars per  $\text{km}^2$  (Rosenfeld 1998; Massei et al. 1996). The difference between those studies and the present study is that they were done in conservation areas with no hunting, whereas an intensive trapping program is established in the KSC security zone. This trapping resulted in removing some 1700 hogs per year.



## **5 HABITAT PREFERENCE ESTIMATES**

### **5.1 Introduction**

Two major factors influence habitat selection by the feral hogs. The first is availability of shelter. Hogs, like boars, need shelter from the heat and from predators – mainly hunters. The other factor is availability of food. A third important factor is water, which is used both for drinking and wallowing in to cool down in the heat. But water is not a problem on the refuge.

The preferred habitat would be one that can provide a good shelter with ample supply of food nearby. Shelter is the crucial factor because hogs, like boars, can probably travel a couple of miles a night in search of food. But without shelter they will not be able to survive the day in the same area.

### **5.2 Methods**

We used remote sensing and GIS to describe the habitats on the refuge. This description includes location of vegetation types, which are probable food sources. Food items were not examined in stomach content or feces content. Description of habitat also includes analysis of vegetation for density and its ability to provide shelter for the hogs.

#### **5.2.1 Data Sources**

- a. Vegetation map prepared by Dynamac Corporation in 1989.
- b. Mr. SID images of the refuge taken in May 2000. Ground surface resolution is 0.5m. These images include three channels: green, red, and infrared.
- c. LIDAR image of the refuge. These images were taken in April and June 1999, and September 2000. Spatial resolution 10 meters (32.8 feet) (Schaub 2002).

All data sources were registered to NAD83 datum.

#### **5.2.2 Analysis of Food Availability**

Hogs and boars eat mainly vegetative matter. Since they cannot digest cellulose, they feed mainly on fruits, bulbs, and roots. We used the 1989 vegetation map to find the main vegetation species on the refuge and their location. With the help of Dr. Paul Schmalzer, Dynamac Corp., a table was prepared that identified the season of fruiting for the different vegetation types in the 1989 vegetation map (Table 4). Using ARC/VIEW 3.2, that table was then joined with the vegetation coverage and created seasonal “Feral hogs food maps.”

#### **5.2.3 Analysis of Vegetation Cover**

The ability of the vegetation on the refuge to serve as shelter for hogs was analyzed using Light Detection and Ranging (LIDAR) data. LIDAR is a laser system used to measure topographic relief. Such instruments are used for high-resolution topographic mapping. LIDAR data on KSC was collected in spatial resolution of 2 m (Neuenschwander and Crawford 2001).



From the LIDAR data and ground measurements, a Digital Terrain Model (DEM) was created (Schaub 2002). Surface elevation estimates (derived from DEM) were subtracted from LIDAR data to create cover layers, which include vegetation, buildings, and other man-made objects. This cover presents the height of the laser beam reflector. Reflector can be ground surface, tree canopy or building roof. This layer of surface cover height was in spatial resolution of 2 m, which mean the grid pixels were 2 m × 2 m wide. In this resolution, there was one-height measurement per pixel. This high resolution created a very large data set. In order to reduce the size of the files, resolution was reduced to 10 m. This was done by calculating the maximum height measured in grid pixels of 5 × 5 former pixels. In this resolution there were 25 height measurements for each 10 m × 10 m pixel. In addition to maximum cover elevation for 10 m pixels, layers of cover average height, standard deviation of height, and range of height were calculated (Schaub, pers. comm.)

Analysis of vegetation was done using ARC/VIEW 3.2 with Spatial Analyst. Most of the analysis was done using grid coverage. Two factors are important when estimating the vegetation ability to serve as shelter for hogs: (1) the height of the vegetation above the ground, and (2) density. When looking at vegetation height, we assumed that every pixel with maximum height of more than 2 m was suitable for hogs cover. Vegetation density (*dns*) was calculated as:

$$\text{Equation 4: } dns = \frac{(avg + std) - (avg - std)}{\max}$$

Where *avg* is the average vegetation height for a 10 m × 10 m pixel; *std* is the standard deviation for the same pixel; and *max* is the maximum height for the pixel. This density index first calculates the range of about 2/3 of the height samples in each pixel (vegetation amplitude). By dividing this range with the maximum height for the pixel one can estimate relative density.

Acceptable values were between 0 and 1. The smaller the relative density, the denser the vegetation will be. This index shows more clearly the closeness of the canopy than the actual density of the entire vegetation column, but we assumed this to be a good indication of vegetation density.

This index is based on the fact that the laser beams of the LIDAR system are reflected from any surface they encounter, whether it is soil or leaf. In areas with sparse vegetation the laser beams are reflected from surfaces with different heights, such as soil or vegetation canopy. Therefore, the variance and standard deviations are large and as a result the vegetation amplitude is large and close to the vegetation maximum height. Therefore the density index value is large. In areas with dense vegetation, the laser beams do not penetrate the canopy and are reflected from the leaves. As a result the height amplitude is small and the density index is small.

In areas with flat terrain like road or rooftop all the beams are reflected from surface with the same elevation and therefore the variance and standard deviations are small and as a result the index value is small. We arbitrarily chose an index value of 0.5 as the division point between areas with vegetation dense enough to provide shelter for the hogs and areas that do not provide suitable shelter for the hogs.



A grid of vegetation height greater than 2 m and a grid with density values of less than 0.5 were created then were added using the spatial analysis to locate grid cells with both attributes. The combined grid was converted to a shape file and the area of each polygon was calculated. Polygons with an area of less than 1000 m<sup>2</sup> (10,800 ft<sup>2</sup>) were eliminated.

#### **5.2.4 Influence of Habitat Parameters on Number of Hogs Trapped Per Trap**

After creating covers for the different factors, we investigated the relationship between the environmental factors and the estimated hog population per trap. For that, we have created a buffer layer of 200 meters around the traps and intersected it with the different the vegetation cover, the density index grid, the average height and maximum height grids. We chose to create a 200-meter buffer because this was the largest buffer width that did not create overlapping buffers between the traps.

After intersecting covers, we calculated the percentage cover of the different vegetation types for the buffer around each trap. We calculated the average density index, the average for average height, and the average for maximum height. Vegetation types that covered less the 1% area on average for the 13 traps were removed from further analysis. We combined all the hammock types to a single factor and all the grass types.

A Pearson correlation was then done between all of the independent and the dependent factor to discover co-linearity, and factors that had a correlation coefficient of more than 0.8 were removed. The factors that remained were divided into categories and placed in ANOVA. Division into different categories was based on detecting natural breaks. Each factor was ordered in ascending fashion and the slope between consecutive traps was calculated. The factor was divided to categories when a steep slope was detected.

### **5.3 Results and Discussion**

#### **5.3.1 Food Availability**

Analysis of available food items in the security zone showed that there is available food throughout the year but it is not evenly distributed (Maps 5.1 through 5.4 in Appendix A).

The food items maps show potential food available for the hogs, not necessarily what they actually eat on the refuge. For example some of the plant species under “fruit” are Brazilian pepper, which hogs probably do not eat (Tanner, pers. comm.), or pine seeds in “seeds” category. If the pine species on the security zone produce only small seeds, then the hogs probably do not eat them, but the hogs would eat seeds that are large and energy-rich.

Analyzing the vegetation map and food availability data, it is apparent that all food items are either spatially or temporally localized, which means that either they are not available all over the area or not throughout the year (Table 6; Maps 5.1 through 5.4 in Appendix A). This means that the hogs will have to move from place to place around the security zone throughout the year in search of food.

The richest season for food availability is fall when oak mast and palm berries are available. The poorest season is summer. At this season it appears that the highest quantities of food are



available in the marshes where there are roots and bulbs of different grasses and herbaceous vegetation. These grasses are mostly perennial grasses and therefore are available throughout the year. They have rhizomes and other bulbous underground parts, which are good food sources for hogs. Hogs will be able to easily root those underground parts in the soft sandy soil of MINWR. They will also look for roots under water (in water that is less than 10 cm deep).

**Table 6. Available food items in different habitats in different seasons**

<b>Description</b>	<b>Winter</b>	<b>Spring</b>	<b>Summer</b>	<b>Fall</b>
Black Mangrove				Fruit
Brazilian Pepper	Fruit			
Brazilian Pepper/Cabbage Palm Disturbed	Fruit			
Cabbage Palm Hammock			Berries	
Cabbage Palm Savanna			Berries	
Cabbage Palm/Red Cedar Hammock			Berries	Mast
Cattail	Root	Root	Root	Root
Citrus Grove	Citrus	Citrus		Mast
Coastal Live Oak Woods				
Coastal Strand	Berries			Berries
Disturbed Slash Pine Light Canopy	Seeds			Seeds
Hardwood Swamp		Maple	Elm	Mast
Live Oak Hammock				Mast
Live Oak/Cabbage Palm Hammock				Mast
Live Oak/Cabbage Palm/Red Cedar Hammock				Mast
Live Oak/Hickory Hammock				Mast
Mixed Cabbage Palm/Unid Shrubs			Berries	
Mixed Cedar/Brazilian Pepper	Fruit			Mast
Mixed Graminoid Marsh/Slash Pine	Seeds			Seeds
Mixed Mangrove/Shrubs				Fruit
Mixed Oak/Saw Palmetto				Mast
Mixed Oak/Slash Pine Hammock				Mast
Mixed Salt Marsh	Root	Root	Root	Root
Mixed Saltwort/Glasswort-Salt Tolerant Grasses	Root	Root	Root	Root
Mixed Saltwort/Glasswort-Stg-Mangrove	Root	Root	Root	Root
Mixed Sane Cordgrass/Salt Tolerant Grasses	Root	Root	Root	Root
Mixed Wax Myrtle/Cabbage Palm	Fruit		Berries	Fruit
Mixed Willow/Wax Myrtle	Fruit			Fruit
Open Scrub/Slash Pine Disturbed	Seeds			Seeds
Salt Tolerant Grasses (Stg)	Root	Root	Root	Root
Saltwort/Glasswort	Root	Root	Root	Root
Scruboak/Cedar				Mast
Slash Pine (Dense Canopy)	Seeds			Seeds
Slash Pine (Moderate Canopy)	Seeds			Seeds
Slash Pine (Open Canopy)	Seeds			Seeds
Slash Pine Dense Canopy Disturbed	Seeds			Seeds
Smooth Cordgrass/Mangrove				Fruit
Southern Red Cedar/Live Oak Hammock				Mast
Southern Red Cedar Hammock				Mast
Wax Myrtle	Fruit			Fruit



The refuge terrestrial land area (excluding open water) is 321.9 km<sup>2</sup>. Of which 181.94 km<sup>2</sup> (57%) are covered with edible food at least part of the year (Table 7). As was mentioned above the poorest season is probably summer, with less than 50 km<sup>2</sup> covered by vegetation considered a good food source and the richest season is fall with more than half the refuge covered with edible vegetation.

**Table 7. Area covered by different vegetation types serving as food source for hogs (area in km<sup>2</sup>)**

	Winter	Spring	Summer	Fall
Berries	—	—	0.77	—
Citrus	12.44	12.44	—	—
Elm	—	—	4.13	—
Fruit	6.61	—	—	11.62
Maple	—	4.13	—	—
Mast	—	—	—	107.31
Root	40.72	40.72	40.72	40.72
Seeds	22.29	—	—	22.29
Sum	82.06	57.29	45.62	181.94

In winter and spring the citrus groves are probably an important food source, which attract hogs from relatively large distances. Using data from the car-accidents report, it was possible understand the importance of the citrus groves to the hogs. Roads S.R. 402 and S.R. 3 are two of the main roads in the refuge. Their total length is 71208 m (44.5 miles app.). Of these, 27,393 m (approx. 17.12 miles) (38.5%) are within 1000 meters of a citrus grove. On these two roads there were 58 accidents recorded by KSC security in the years 1995–1997 and 2001–2002. Of these 58 accidents, 33 (57%) were within 1000 m of a citrus grove (Map 5.5 in Appendix A). We used a chi-square test to determine whether accidents occurred near citrus groves more than expected by their relative road length (Table 8). Chi test showed that there were significantly more accidents within 1000 m of citrus groves than further away from them (Chi = 3.86; df = 1; p = 0.0495). The buffer distance of 1000 m was chosen, because this was found to be the seasonal home range size for hogs on the refuge (Poffenberger 1979).

**Table 8. Accidents near citrus groves**

	Observed No. of Accidents	Percent Road Length	Expected No. of Accidents
Near Citrus Groves	33	38.5%	22.33
Away from Citrus Groves	25	61.5%	35.67

Food distribution influences hog movement and home range size (Leaper et al., 1999; Singer et al., 1981; Brooks et al., 1986). At MINWR food availability is not constant throughout the year (Table 7, Maps 5.1 through 5.4 in Appendix A). Therefore changes in food availability probably effect hog movements. By comparing hog-car accident and hogs road kill with food distribution shows the probable influence of food availability on hog movements.



Winter and spring food availability maps (5.1 and 5.2 in Appendix A) show food resources along the main roads. These food items are mainly citrus groves but also maple trees (spring) and possibly pine seeds (winter). During these seasons, there was a high number of accidents and road kill. In summer there is hardly any food source near the main roads and most of the foods available are grasses on the marshes — away from the roads (Map 5.3 in Appendix A). The KSC security and road kill records show low average number of accidents per month during summer. In fall the mast (acorns and other fruits) is available throughout the security zone (Map 5.4 in Appendix A) and near the roads. The average number of accidents per month increased during fall.

### 5.3.2 Vegetation Cover

Using LIDAR data, the vegetation cover was examined to view its ability to provide cover for the hogs. Maps 5.6 through Map 5.11 (in Appendix A) show the process of vegetation structure analysis. First, Map 5.6 shows vegetation maximum height on the refuge with an inset to the center of the refuge. The following maps show vegetation amplitude (Map 5.7 in Appendix A), density index (Map 5.8), suitable vegetation height (maximum height more than 2 meter) (Map 5.9 in Appendix A), suitable vegetation density (density index below 0.5) (Map 5.10 in Appendix A), and finally areas with vegetation that can provide suitable shelter for the hogs (Map 5.11 in Appendix A).

Vegetative cover provides suitable shelter for the hogs in the security zone 74 km<sup>2</sup> (31%), 14.5 km<sup>2</sup> (20%) in Zone 2, and 11.23 km<sup>2</sup> (24%) in Zone 1.

### 5.3.3 Influence of Habitat Parameters on Number of Hogs Trapped Per Trap

The result of intersecting the 200 m buffer cover with the vegetation cover and the different grids resulted in six factors describing the habitat: (1) average of maximum height around the trap; (2) average of average height; (3) average density; (4) percent cover of citrus groves; (5) percent cover of native hammocks and (6) percent cover of grasses (Table 9). The dependent factor was the hog population as estimated by the Lincoln-Peterson index (7).

A high negative correlation was found between citrus groves cover and native hammock cover ( $R^2 = -0.854$ ;  $N = 13$ ;  $p < 0.0001$ ). Native hammock cover was removed from further analysis. Positive correlation was found between average of maximum height and average of average height ( $R^2 = 0.962$ ;  $N = 13$ ;  $p < 0.0001$ ). Average of average height was removed from further analysis. Other correlations did not produce an  $R^2$  higher than 0.8.

The remaining factors were divided to categories in order to use them in ANOVA. Citrus grove cover was divided to 4 categories; Grass cover to 3; Average density to 5; and Average of Maximum height to 4 categories.

ANOVA of estimated number of hogs per trap explained a high percentage of the variance (adj.  $R^2 = 0.891$ ). The ANOVA was significant ( $F = 17.33$ ;  $df = 12$ ;  $p < 0.001$ ). Citrus cover and average density were both significant ( $p < 0.005$ ). Grass cover and Average of Maximum height were not significant. There were not enough degrees of freedom to examine the interaction between Citrus cover and average density.

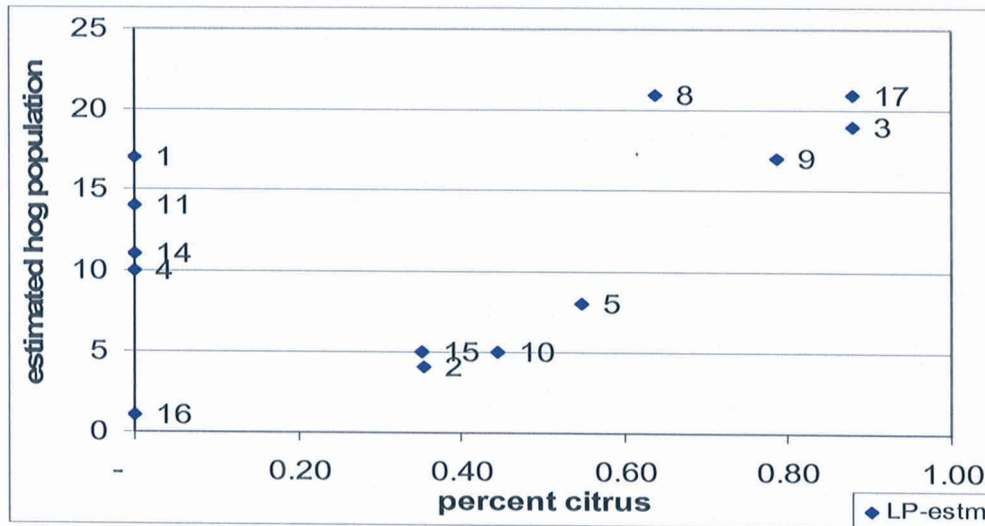


Hog population increased as the percent of citrus groves area increased inside the buffers. But this trend was not linear and did not include all traps (Fig. 10). Other vegetation types did not show any clear influence on hog population.

**Table 9. Habitat factors around different traps**

Trap No.	Citrus <sup>4</sup>	Native Hammock <sup>5</sup>	Grass <sup>6</sup>	Avg-Dns <sup>3</sup>	Avg-Max <sup>1</sup>	Avg-Hgt <sup>2</sup>	LP-Estm <sup>7</sup>
1	0	62	25	.40	9.19	5.44	17
2	35	27	19	.49	8.22	4.80	4
3	88	2	2	.54	4.49	1.80	19
4	0	47	28	.44	4.86	2.55	10
5	55	0	43	.45	6.23	3.22	8
8	64	30	5	.49	8.56	4.98	21
9	79	4	0	.53	4.36	1.49	17
10	45	34	21	.44	6.17	3.38	5
11	0	52	14	.42	2.33	1.09	14
14	0	30	40	.41	6.00	3.84	11
15	35	36	0	.50	8.91	4.47	5
16	0	62	4	.78	4.05	2.23	1
17	88	12	0	.53	5.60	2.56	21

Numbers correspond to factor numbers in text.



**Figure 10. Influence of citrus groves area on hog population**

Numbers denote trap number.

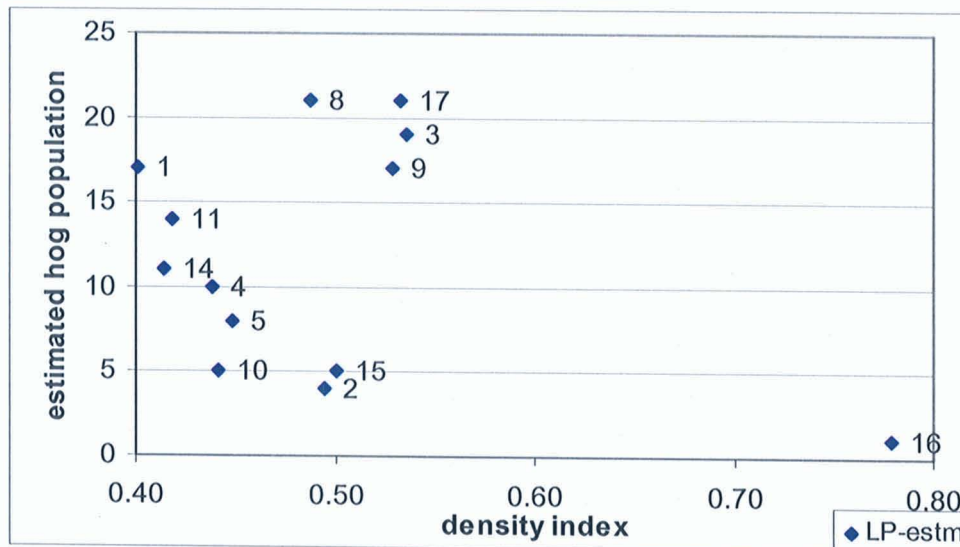
Figure 10 shows that the traps can be divided to groups.

Group 1 (traps 3, 8, 9, and 17) had an average estimated population of  $19.5 \pm 1.9$  hogs per  $\text{km}^2$ . Group 2 (traps 2, 5, 10, and 15) had an average estimated population of  $5.5 \pm 1.73$  hogs per  $\text{km}^2$ . Group 3 (traps 1, 4, 11, and 14) had an average estimated population of  $13 \pm 3.16$  hogs per  $\text{km}^2$ .

Trap 16 had only 1 hog per  $\text{km}^2$ . Kruskal-Wallis ANOVA found significant difference in average estimated hog population between the three groups ( $\chi^2 = 9.64$ ;  $df = 2$ ;  $p < 0.009$ ). Steel-Dwass test for pair wise comparison of means did not find any significant differences between the groups.

Group 1 had a high percentage of citrus grooves and could sustain a relatively high population of hogs. This indicates the importance of the citrus grooves to the hogs even when there is relatively little fruit to be found in the grooves. For the same reason, Group 2 had a low percentage of grooves, and could sustain a relatively low population of hogs. Group 3 had no citrus groves around its traps and had a relatively high percentage of native hammocks (Table 9), which support the hog population.

Average vegetation density values for most trap buffers were between 0.4 and 0.6 with the exception of trap 16, which had a density value of 0.78. As explained above, density index is an inverted one, the lower the index value – the denser the vegetation. Hog population in Groups 3 and 2 increased as vegetation density increased (Fig. 11), whereas Group 1 did not. This shows the importance of dense habitat especially in native hammocks, which are dominant in Group 3, and compose a large percentage of Group 2. In contrast, Group 1 is composed mainly from citrus grooves, which sustain the hogs, and the important factor there is probably availability of fruit in the grooves. Trap 16 emphasizes the general trend, shown in Groups 2 and 3, of the importance of vegetation density on habitat preferences of hogs.



**Figure 11. Influence of vegetation density on hog populations**

Numbers denote trap number.



This study showed that two main factors influence hogs habitat selection: availability of food and availability of shelter. Food seems to be the most important factor, which is apparent from the high estimated population. In areas with low or no citrus groves, the important factor is availability of shelter, which, when combined with a high cover of native hammocks provide the hogs both shelter and food. Trap 16 emphasize these results – there are no citrus groves around it, there is a high percentage of native hammock cover around it, but the vegetation density is low and cannot provide good shelter. All these factors combine to create a habitat that can support only a small hog population.

Some notes on the habitat preference analysis:

1. Data collection in this study continued for less than 2 month, and therefore results might not apply to other periods of the year.
2. The study used only 13 traps, which are not sufficient to cover all the habitat types present on the refuge.
3. Some of the data sources are relatively old—especially the vegetation cover, which is from 1989, and some changes might have occurred in the time since its creation.

These notes taken into account we believe that the main conclusions on the importance of food sources availability and shelter are valid for feral hogs in MINWR as they are valid for *Sus scrofa* around the world.

## 6 RECOMMENDATION FOR THE FUTURE

This section discusses recommendations important both for management of feral hog population at MINWR and understanding their biology and ecology.

### 6.1 The Need for Management

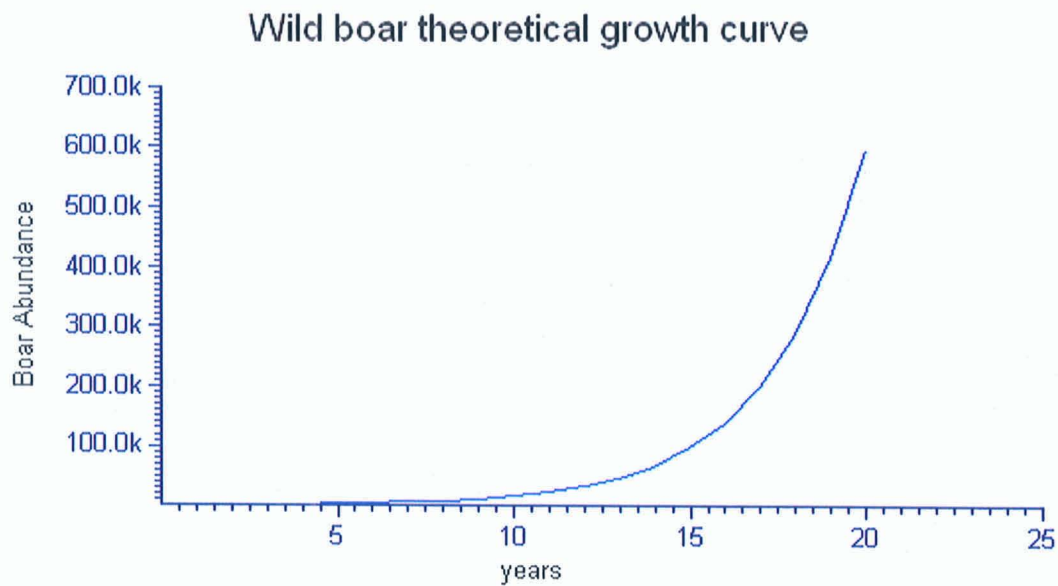
Like boars, feral hogs have a tremendous ability to reproduce in good habitat conditions (Fig. 12). Whereas most hoofed mammals produce just one offspring per year, boars produce on average 5 and may produce as many as 13. The situation is amplified with feral hogs, which may produce even twice a year (Strand 1980).

Boar population growth was simulated with RAMAS EcoLab 2 (Fig. 12). Model and stage parameters were for wild boar in Czechoslovakia (Leaper et al. 1999) (Table 10). Boar population for the simulation was started with 100 boars at the age of 3–4 years. Simulation showed that out of those 100 boars, the population could theoretically grow to more than 500,000 boars in 20 years. Growth curves for feral hogs in MINWR are probably sharper because they can produce twice a year.

Obviously there are some limiting factors that inhibit the boars from reaching such numbers. Possible natural limiting factors that might exist on MINWR are food and its seasonal availability, available shelter, and diseases. We do not know for certain what the limiting factors are that regulate the hog population, or what the thresholds are.

Feral hogs are considered both a nuisance and as exotic animals on National Refuge and Parks lands. They have an ability to affect the native habitats and some studies described their ability to damage vegetation and small animals (Leaper et al. 1999; Peine and Farmer 1990).

In Europe, it has been shown that wild boars have considerable potential to alter the ecological character of their environment. Rooting can have a strong effect on the structure and nutrient status of the soil, which can hinder tree growth and other vegetation, and affect soil biota. Rooting also decreases vegetative cover and species diversity (Leaper et al. 1999; Peine and Farmer 1990) and damages seedlings of longleaf pine (Lipscomb 1989).



**Figure 12. Boar population increase in time**

**Table 10. Life history parameters for wild boar in Czechoslovakia**

Age Class	Fecundity	Survival
0-1	0.0	0.580
1-2	2.5	0.219
2-3	3.0	0.586
3-4	6.0	0.626
4-5	7.0	0.367
5-6	7.0	0.273
6-7	5.0	0.334
7-8	4.0	0.001

Wild hogs root the ground looking for soil invertebrate and other food items. This has led to an estimated 80% reduction in micro invertebrate in the soil of some areas of the Great Smoky Mountain National Park. Other species affected include red-back voles (*Clethrionomys gapperi*) and short-tailed shrews (*Blarina brevicauda*), snails, and salamanders (Peine and Farmer 1990).



They are suspected at predation of ground nesting birds like scale quails (Rollins and Carroll 2001). Nest predation is probably more likely to happen in hammocks and wetlands habitats than in pine flatwoods (Babbitt and Lincer 1993). They might also be in competition over food and space with many species of mammals (Peine and Farmer 1990).

On the other hand, some studies have found them beneficial to the habitat. Rooting activity turns the soil and may accelerate and improve decomposition of organic matter, which will increase nutrient cycling (Leaper et al. 1999). A study in an impounded floodplain marsh in central Florida showed that although feral hog rooting decreased vegetation cover in the marsh, it increased species richness and microhabitat diversity (Arrington et al. 1999). Although most of their diet is of vegetative matter, diet overlap with large native herbivores in the southern Texas plains was moderate and competition of hogs with these species may be restricted to times of resource scarcity. Direct negative impact on threatened and endangered plants and animals within the southern Texas plains was considered minimal (Taylor and Hellgren 1997). In California it was found that although their rooting can cover large tracts of land and destroy the grassy vegetation on them, it appears that this does not lower either native or non-native species richness (Kotanen 1995).

Feral hogs are also food source for large predators as the mountain lion (*Puma concolor*) and Florida panther (*Felis concolor coryi*) (Harveson et al. 2000).

Another consideration is the fact that at present feral hogs are the only abundant large herbivore mammals at MINWR. As such they probably have an ecological role in shaping vegetation around the refuge, in seed dispersal, and other ecological processes.

## 6.2 Ecological Research

Ecological research of feral hogs should concentrate on three main subjects:

1. A better understanding of hog population— population size and reproduction.
2. Understanding habitat use and movement of feral hogs at MINWR and beyond.
3. Examination of the effects of feral hogs on the different habitats of the refuge and its multitude of residents.

The first two research goals will help guide the management program and follow its application and effectiveness. The third goal will help establish management goals and targets.

Study methods for the first two subjects should allow researchers to follow and locate hogs in the refuge. This can be done using several methods:

1. Trapping and tagging as was done in this study.
2. Radio telemetry tagging of feral hogs.
3. Observing and recording road kills and hog-car accidents.

Each of the first two methods has its pros and cons. Earmark tagging will enable collecting data on a large number of hogs but relatively small amount of data for each hog. Radio tagging will



enable collection of data on a small number of feral hogs but for each hog a lot of data can be collected.

### **6.2.1 Mark-Recapture Program**

The purpose of a mark-recapture program should be to estimate population size, but with correct distribution of traps, trapping and marking individual hogs can also assist in studying habitat preferences of feral hogs. Mark-recapture program cannot be executed continuously throughout the year because it demands a lot of work-hours and resources. It will also hamper management and removal programs. Analysis of data with program MARK also requires data be collected in distinctive studying period.

We suggest that mark-recapture program will concentrate on two-week long sessions with periods of 6 to 8 nights were trapping is done. As noted earlier, the population is quite stable – close, on a two-week period. MARK analysis in this study showed that during the first two weeks the survivability estimate was higher than during the entire study period. This might indicate that during the first two weeks there were fewer changes in the population than during the longer period of the entire study. We recommend that a two-week session be conducted every two month. This will enable an accurate population estimate and enable studying of seasonal changes in population abundance. If the program cannot be done so intensively (a trapping session every two months), a marking session at least once a year is imperative and will give the refuge management a tool to follow population changes in the long term.

Trapping session should consist of 20 to 30 traps baited each trapping day. These will optimally be distributed in a grid formation encompassing the security zone with a distance of approximately 2000 m between traps distributed across the security zone. This distance is a compromise between the preferred distance of 1000 m between traps since this is the home range size for feral hogs on the refuge, and the number of traps, which is feasible to handle per day.

### **6.2.2 Radio-Telemetry Studies**

Radio telemetry study should help answer questions of feral hog movement and habitat preference. To answer these questions, at least 20 hogs should be marked with radio tags. Radio tags, in my opinion, should be GPS tags with automatic data collection. Such a system will enable collection of a large amount of data with minimal expenditure after tagging. This kind of tags will also enable collection of data at all times of day.

### **6.2.3 Road Kills and Hog-Car Accidents**

Road kill and hog-car accidents data seems to be an important data source for changes in hog population through the years, and movement around the refuge. Road-kill surveys are used to monitor populations of mammals like raccoon (*Procyon lotor*) (Gehrt 2002) and armadillo (Inbar and Mayer 1999). The refuge should continue collecting road kill and hog-car accidents data. Collection efforts should concentrate on S.R. 3 for all its length and S.R. 402 from the entrance to the refuge to the junction with S.R. 3. Surveyors should drive slowly along these two roads and look for road-kills on both sides of road shoulders. Optimally data will be collected every day, but a minimum of once every 3 days might be enough. A period longer than 3 days between surveys is not recommended because it takes the vultures just 3 to 4 days to consume an average



hog (Rosenfeld, pers. obs.). Collection of road-kill data once a day, in the morning, should be sufficient to create a viable database. Preferably for each road kill observed, data on location, age and sex will be recorded (Table 11). In this form a record is given to every road kill encountered. Coordinates denote for coordinates obtained using a GPS receiver. Locations should be collected in NAD83 datum, in which most of the refuge GIS data is georeferenced. Age should be categorized to two or three groups. Sexual status should denote whether a female is lactating.

KSC security hog-car accidents reports are also an important data source and should be collected and maintained by the refuge. The same form (Table 11) can be given to KSC security personal for data collection.

**Table 11. Suggested form for collecting road kill data**

Date	Time	Location (description of location)	Coordinates	Age	Sex	Sexual status

**6.2.4 Impact Studies**

The aim of impact studies is to assess the impact of feral hogs on the different habitats of the refuge.

Two main methods are available for these studies:

1. Enclosures.
2. Analysis of stomach contents.

Enclosures studies can be conducted in two ways. The first is intended to keep hogs out of the enclosures. In these fenced enclosures one can study the development of vegetation, invertebrate and small vertebrate with out the presence of hogs, and compare it to their development in the presence of hogs. These enclosures can be relatively small, about 20 m × 20 m. Distinguishing differences between treatments will take relatively long time (probably a couple of years), and will depend mostly on regeneration rate of vegetation and other organisms on the refuge.

The other method to use enclosures is just the opposite. Build relatively large enclosures of about 100 m × 100 m. These enclosures should be made of sturdy fences and in them put feral hogs in different densities, for different time period. Using this method one should sample important index species in the enclosure before hogs are placed in the enclosure and then sample them again after the hogs are removed. This method will generate results in a relatively short time period (weeks to months). Using this method one can assess the influence of hog density on hog impact. This will also help the refuge management to determine hog density and the population level, which the refuge habitat can support with acceptable impact.

The other method of analyzing stomach content can help assess species, which are directly consumed by feral hogs. This can serve as another method, which will complement the enclosures studies.



### 6.3 Recommendations for Control Program

Looking at the ability of feral hogs to reproduce (Fig. 12), there is no doubt about the need for control program in MINWR. The question remains is what should be the target of the control/management program. Total eradication of hogs from the refuge grounds is probably not a feasible target since hogs are very well adapted to survival in the kind of dense vegetation habitats dominating the refuge, and will be able to hide and avoid hunters in this kind of habitat.

Therefore refuge management has to decide on its program target, which can be estimated either as number of hogs removed per year or as amount of impact monitored on the habitat. If the refuge management is pleased with the current numbers of hogs removed per year from the refuge – then no further recommendations are necessary. If on the other hand refuge management wishes to increase the number of hogs removed then several things can be done to increase hunting efficiency, but all of them would require investment of resources.

Appoint a person in charge of the management program. This person will be in charge of coordinating work with hunters, and managing the research program suggested above (Peine and Farmer 1990).

Create a long term 15 to 20 years, management program with dedicated funding and personnel. Whether the removal number is maintained at current, or hog removal from the refuge, is increased. In any case continuation of removal program is necessary because in a few years, of good mast crop and in weather conditions as prevailing at MINWR, the population can double and even quadruple.

Maintain unpaved roads on the refuge. As seen on Map 2.1 (in Appendix A) large areas of the security zone are inaccessible to trappers, hunters, or management staff. If unpaved roads are not maintained, larger areas will be inaccessible and the hogs will have larger areas with no disturbance, in which they could reproduce and from which they could emerge to other areas of the security zone. (Specific recommendations about roads follow).

Set a target number of hog removal that is feasible (workforce plus funding). Based on refuge data, hunters in the security zone must operate traps and hunt with dogs more than 20 days a month to remove more than 100 hogs (for the month of July), which is almost a full months work.

Theoretically if hunting pressure could be doubled or quadrupled, then hog populations would decline rapidly for the first couple of years, but then hogs will be harder to find and removal will decline. Eventually it would come to a phase were hogs are very hard to find. If at that point hunting pressure would decline then the hogs population will rise back in a few years. Currently hunters pay for the privilege to hunt on refuge grounds. These are dedicated hunters who invest a lot of time and money to remove hogs from refuge grounds. In return they sell the hogs. If refuge management decides to increase hunting pressure, with the current system of bidding and paying for hunting rights, eventually hog population numbers would decline. Hunters would have to invest more time and money to catch the same amount of hogs they hunt currently. At this point, refuge management would have to consider supporting the hunters by assistance with purchase of corn, constructing traps, and paying for gas. At a later phase, hogs might become so scarce



that hunters would not want to come to the refuge – at this point the refuge management might have to pay for hunters to come and maintaining the hunting pressure. Because without maintaining the hunting pressure, hog population numbers would rise again, and all the effort put to reduce the population would go to waste.

Currently, at least for the month of July, the most cost-effective method to hunt hogs is traps. In order for a trap to be effective, it’s surrounding must not be disturbed. Therefore, we suggest some form of segregation between the hunting methods utilized on the refuge: trapping, dogging, and shooting. We suggest that shooting will be used mainly along the main roads like S.R. 3 and S.R. 402, where there is relatively wide field of view on both sides of the roads. Areas further into the bush are better left to other methods of hunting. Another advantage of shooting along the roads is that hogs would probably learn the danger and might reduce their activity near the roads (Rosenfeld 1998), which might further reduce the amount of traffic accidents.

Another method to reduce hog population is to reduce the carrying capacity of the habitat. As was seen above the citrus grooves are an important food source for the hogs. Reducing citrus grooves on the refuge might eventually reduce the hog population, but in the time period between reductions of this food source to reduction in population, the hogs will put more strain on other habitats and might cause more damage to them. Opening dense hammock will also reduce their suitability for the hogs but might also reduce their suitability for other species.

Improve data collection from the hunters. Currently, hunters only report the number of hogs caught with no additional data. Location and method of capture is important. Location of capture is important for understanding habitat preferences and hog movements around the refuge. Knowledge of capture method and, more importantly, effort is an important tool in understanding the impact of hunting on the hog population. Table 12 is a proposed hunting report form. Each record in the form is for a different hog caught. The columns are Date – date of capture; Number of people – number of hunters hunting that day; Number of Dogs – number of dogs who came to hunt that day; Number of traps – number of traps set for that day; Time on the refuge – number of hours spent on the refuge hunting; Method - the method by which each hog was hunted (trap or dogs); sex, weight and age of each hog; Location – location in which each hog was captured.

**Table 12. Suggestion for feral hogs hunting report**

Report on feral hogs hunted for the month of \_\_\_\_\_ in zone \_\_\_\_\_  
 Date: \_\_\_\_\_  
 Name: \_\_\_\_\_

ID	Date	No. of people	No. of dogs	No. of traps	Time on refuge	Method	Sex	Weight	Age (month)	Location
1										
2										
3										

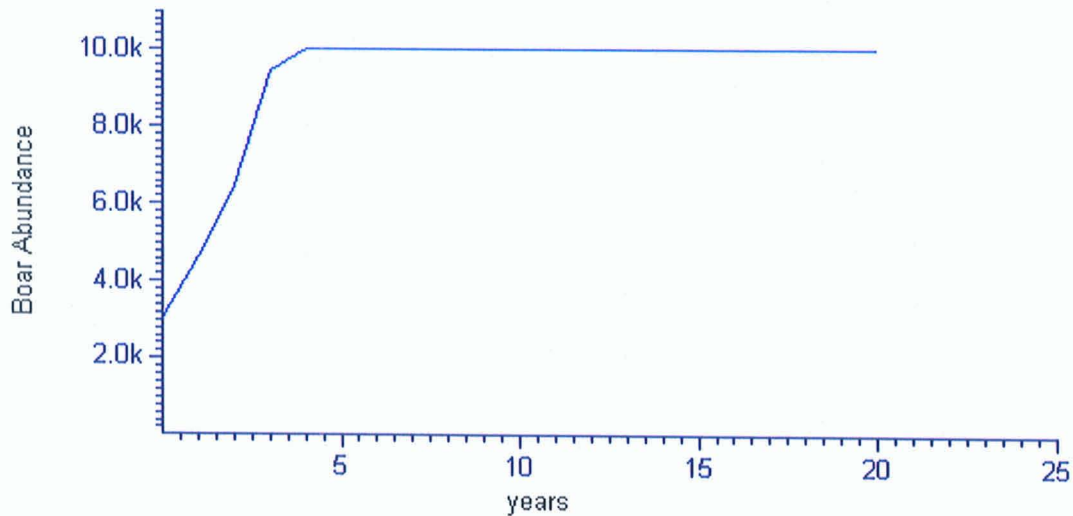
### 6.3.1 Influence of Hunting on the Population

This paragraph presents simulations of different hunting schemes on a population of wild boars. (Life History Parameters, Table 10). Simulated population started with 3000 individuals:

Age	Number
0-1	2000
1-2	800
2-3	100
3-4	80
4-5	20
5-6	20
Total	3000

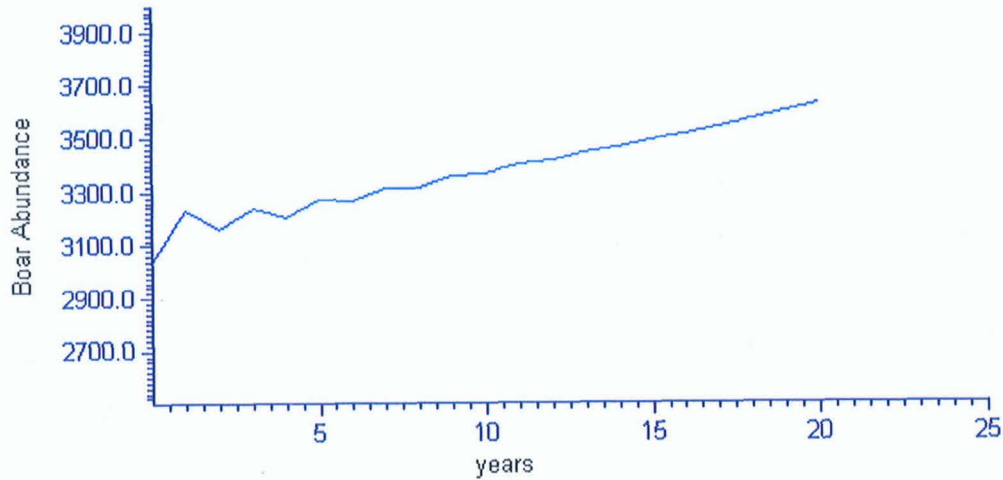
A carrying capacity of 10,000 was placed on the population. Hogs population without hunting reached 10,000 in less than 5 years (Fig. 13). It is more important to look at the trend and not the actual numbers, because the data is of wild boars and not feral hogs, which probably have steeper growth curves.

In order to really slow the population growth, more than 30% of each age class must be removed from the refuge (Fig. 14). Removing less than 30% of the population would not prevent the population from reaching the threshold of 10,000 boars.



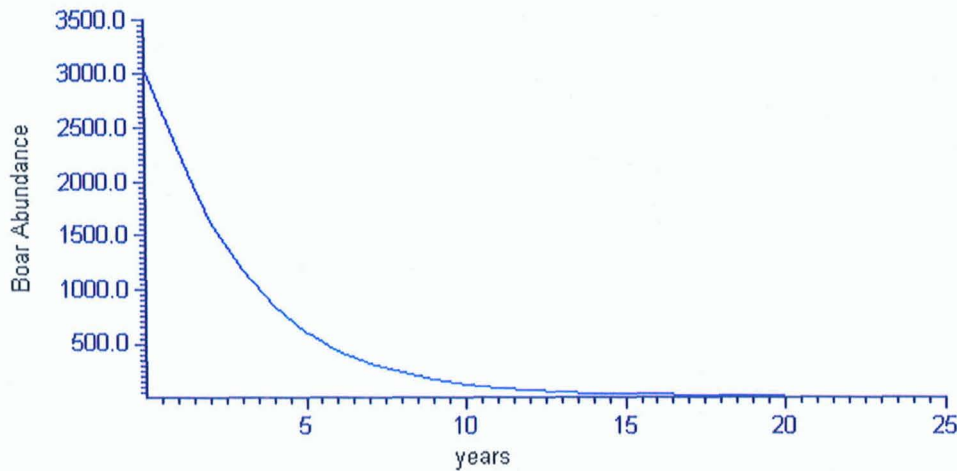
**Figure 13. Wild boar abundance (without hunting)**





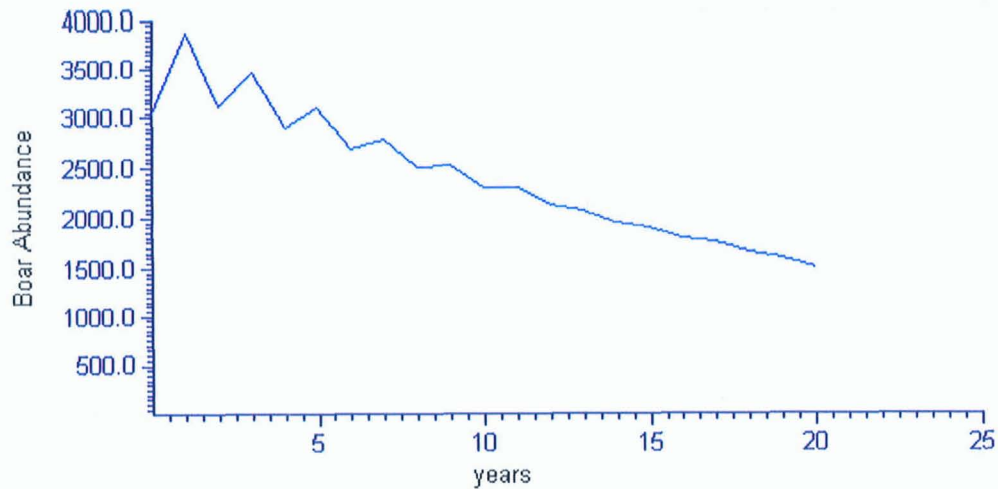
**Figure 14. Effect on population growth curve by removing 30% of the population**

Removing 50% of the population each year might eventually cause eradication of wild boar population (Fig. 15). But the problem of hunting boars would start at the sixth or seventh year when boars will be difficult to find. With hogs on MINWR there might be some differences and numbers would dwindle after the ninth or tenth year.



**Figure 15. Effect on population growth curve by removing 50% of the population**

Hunting 50% of only the adult, more than one year old, portion of the population will cause a slower decline of the population (Fig. 16). Population will not be eradicated after 20 years.



**Figure 16. Effect on population growth curve by removing 50% of the adult population**

After 20 years of hunting only adults (>1 year old), the population would have declined from 3000 to 1500. Population structure would be biased toward young individuals (73.5%), < 1 year old. This ratio is not different from the one found for trapped hogs in the security zone – Chi-square test (Chi = 0.32; df = 1;  $p < 0.057$ ). These calculations suggest that the refuge should insist on removing younger hogs than those currently being removed from the refuge.

The best time to concentrate effort at young hogs is the summer months between June and August. These months are shortly after the end of the farrowing season with the young hogs concentrated near their mothers, which would aid in trapping groups of young. But the problem in hunting at this time is access to where the hogs are concentrated. In order to improve accessibility of hunters to the hogs the refuge should maintain the unpaved roads clear and passable.

Road clearing, in our opinion, should be based on seasonal changes and selected according to hog movements. Earlier we showed that food availability was probably the cause for hog movement across the refuge. Now we suggest using data on the available food for hogs in order to determine what roads should be cleared and when. Map 6.1 (in Appendix A) provides suggestions for clearing of roads and when they should be cleared. Blue colored roads should be cleared before winter, green colored before spring, red colored before summer, and brown colored before fall. Clearing of roads includes mowing grasses and trimming the branches above the roads.



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APPENDIX A. MAPS

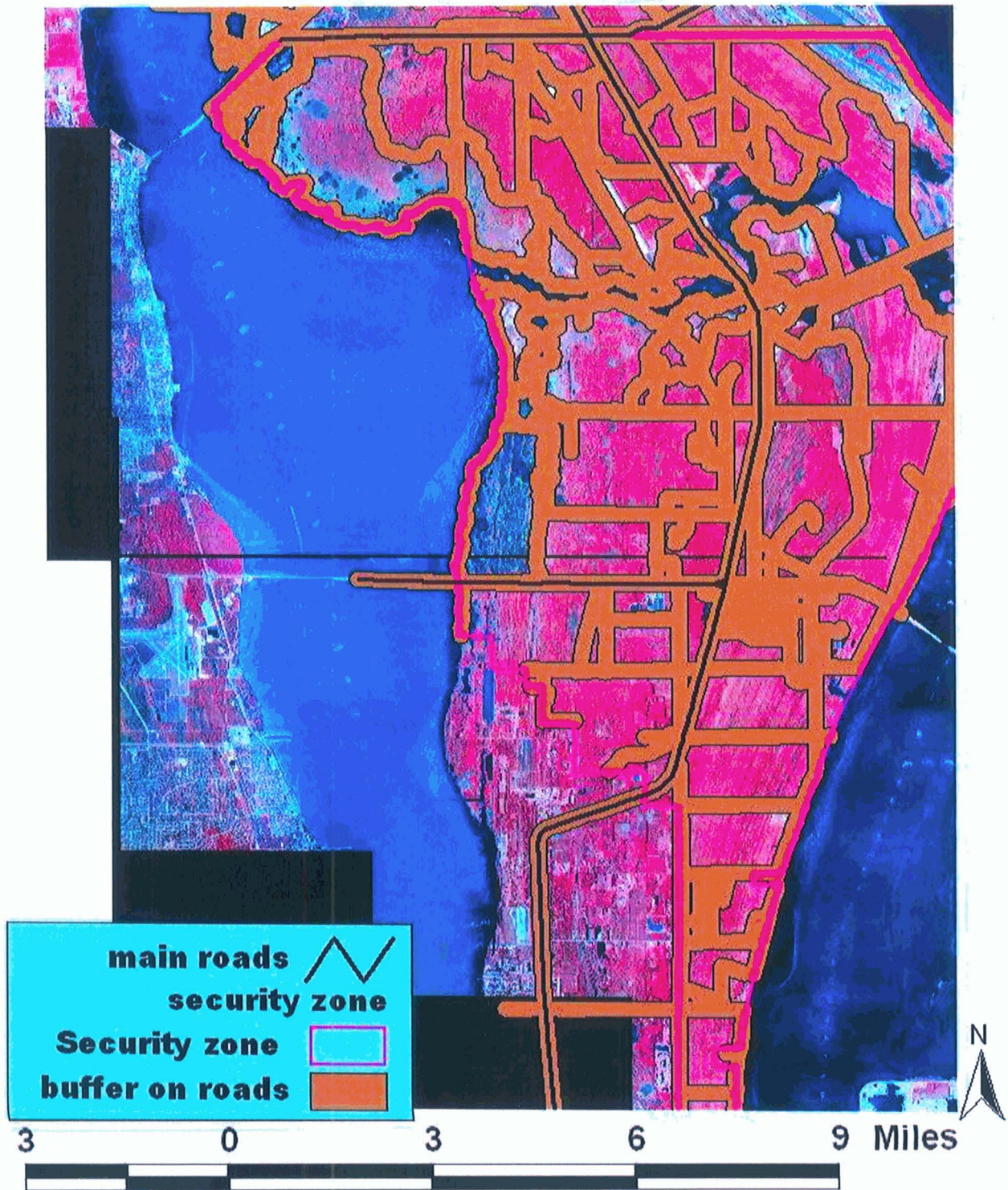


Figure 17. Map 2.1, Actual hunting areas (within 200 m from roads)



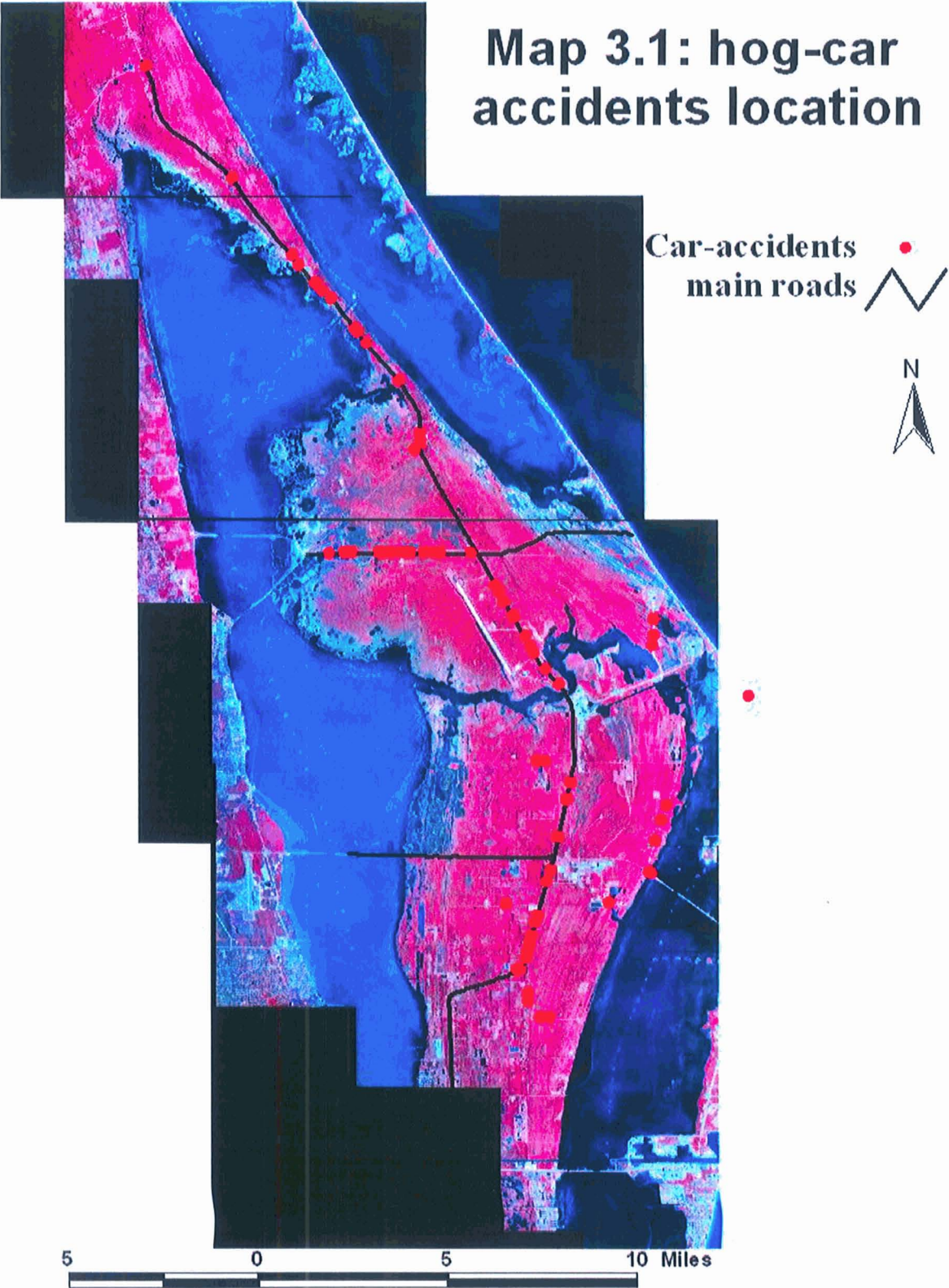


Figure 18. Map 3.1, Hog-car accidents location



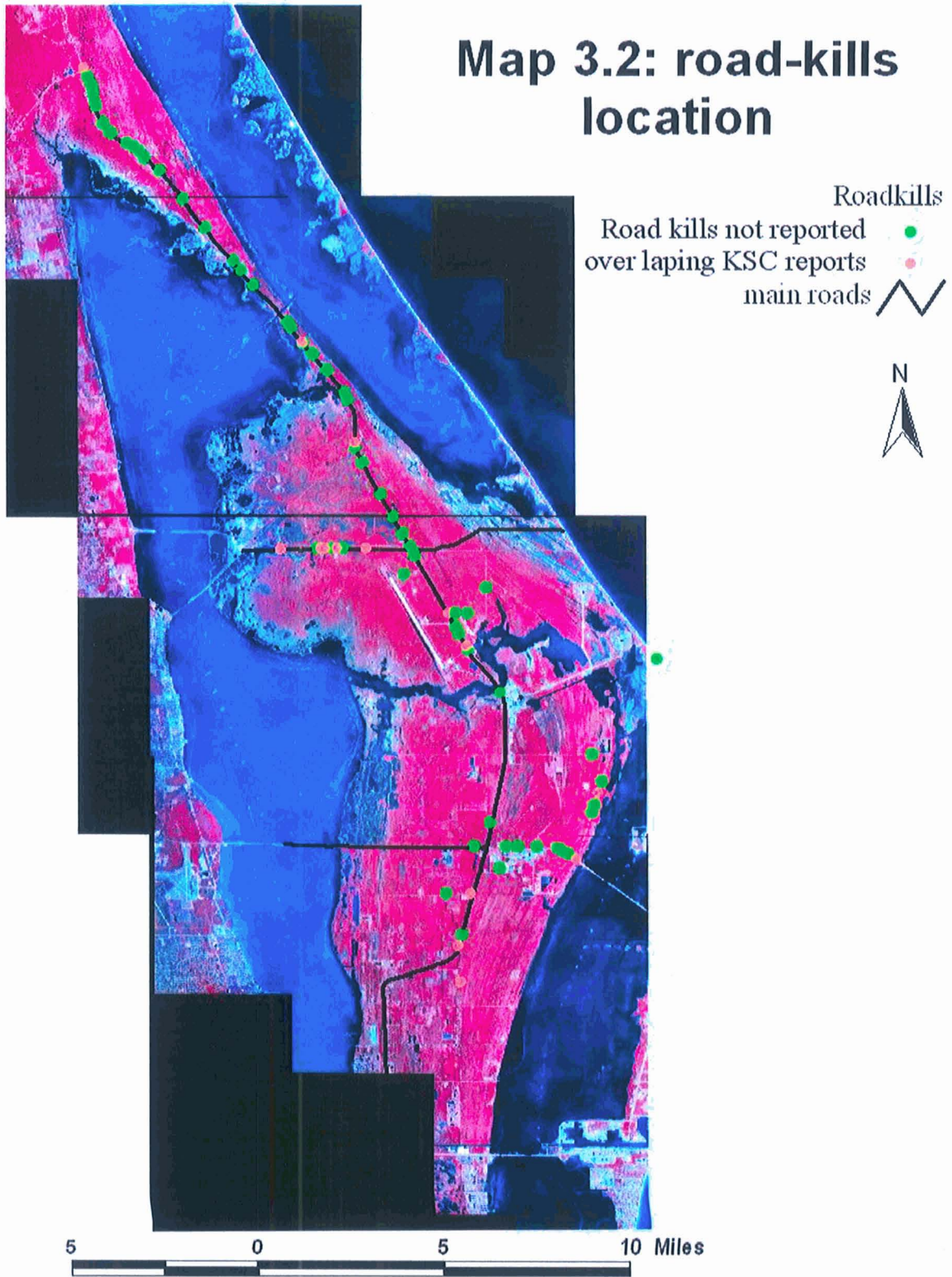


Figure 19. Map 3.2, Road-kills location



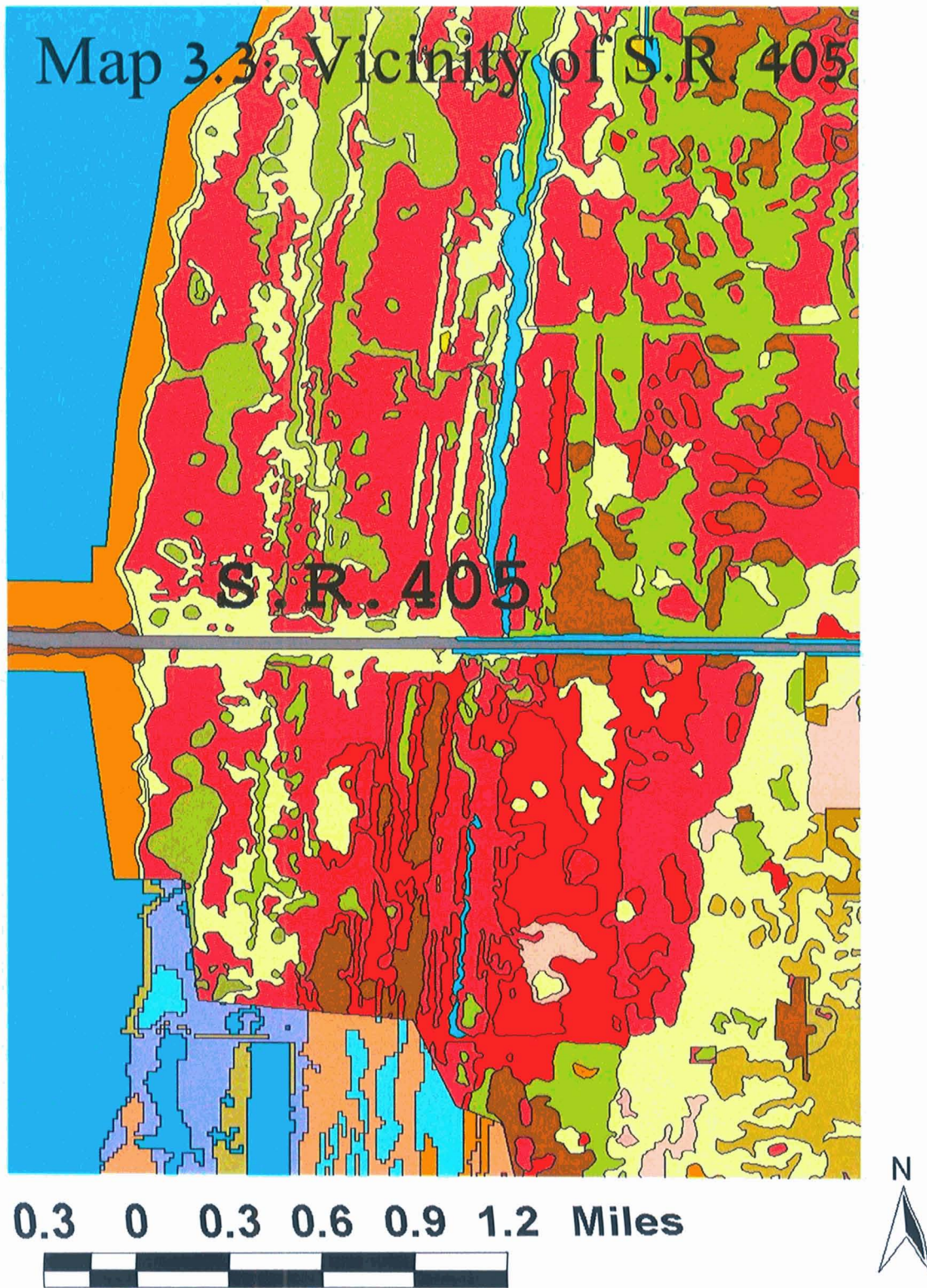


Figure 20. Map 3.3, Vicinity of S.R. 405



# Map 4.1: traps location

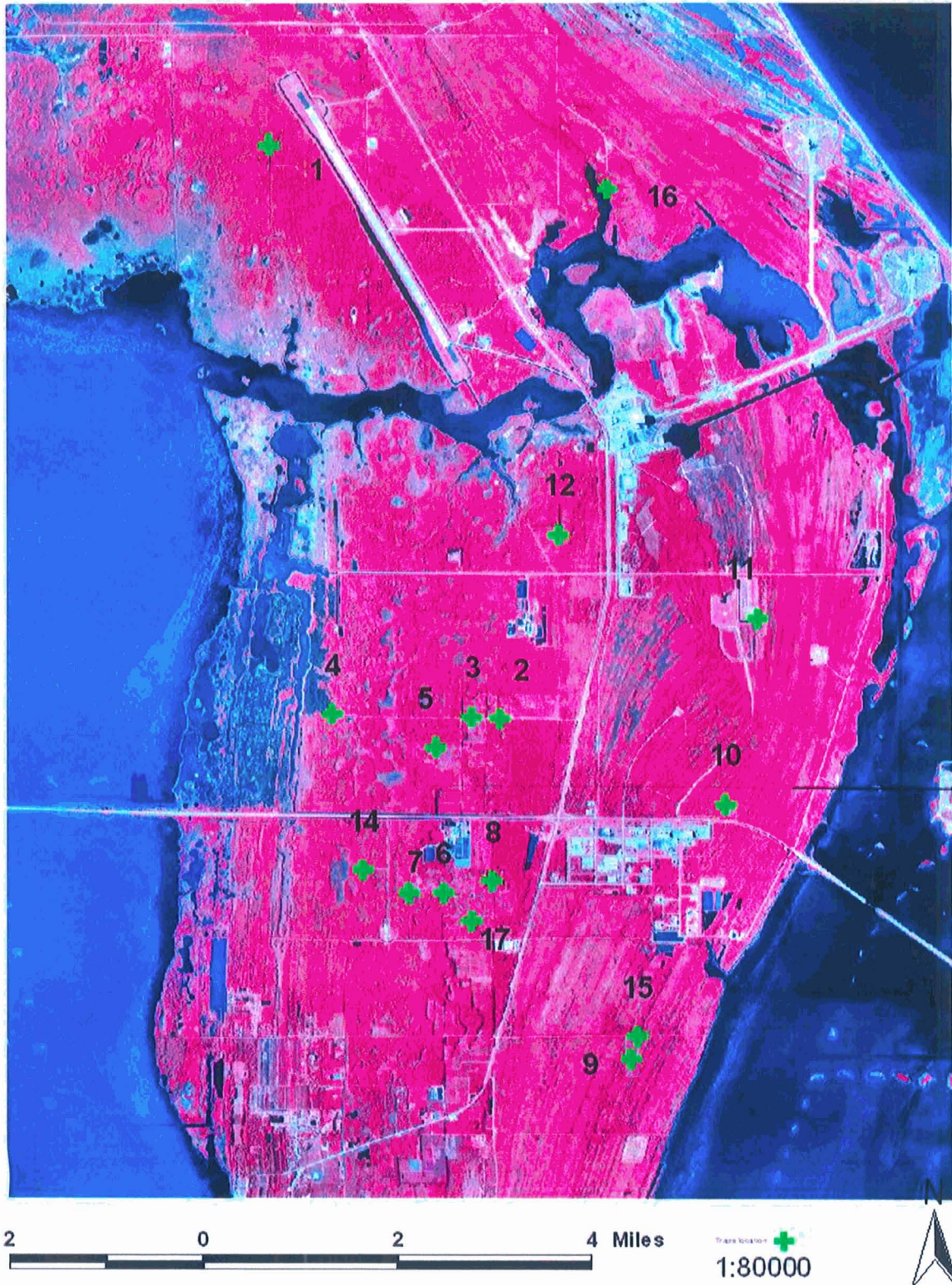


Figure 21. Map 4.1, Location of traps



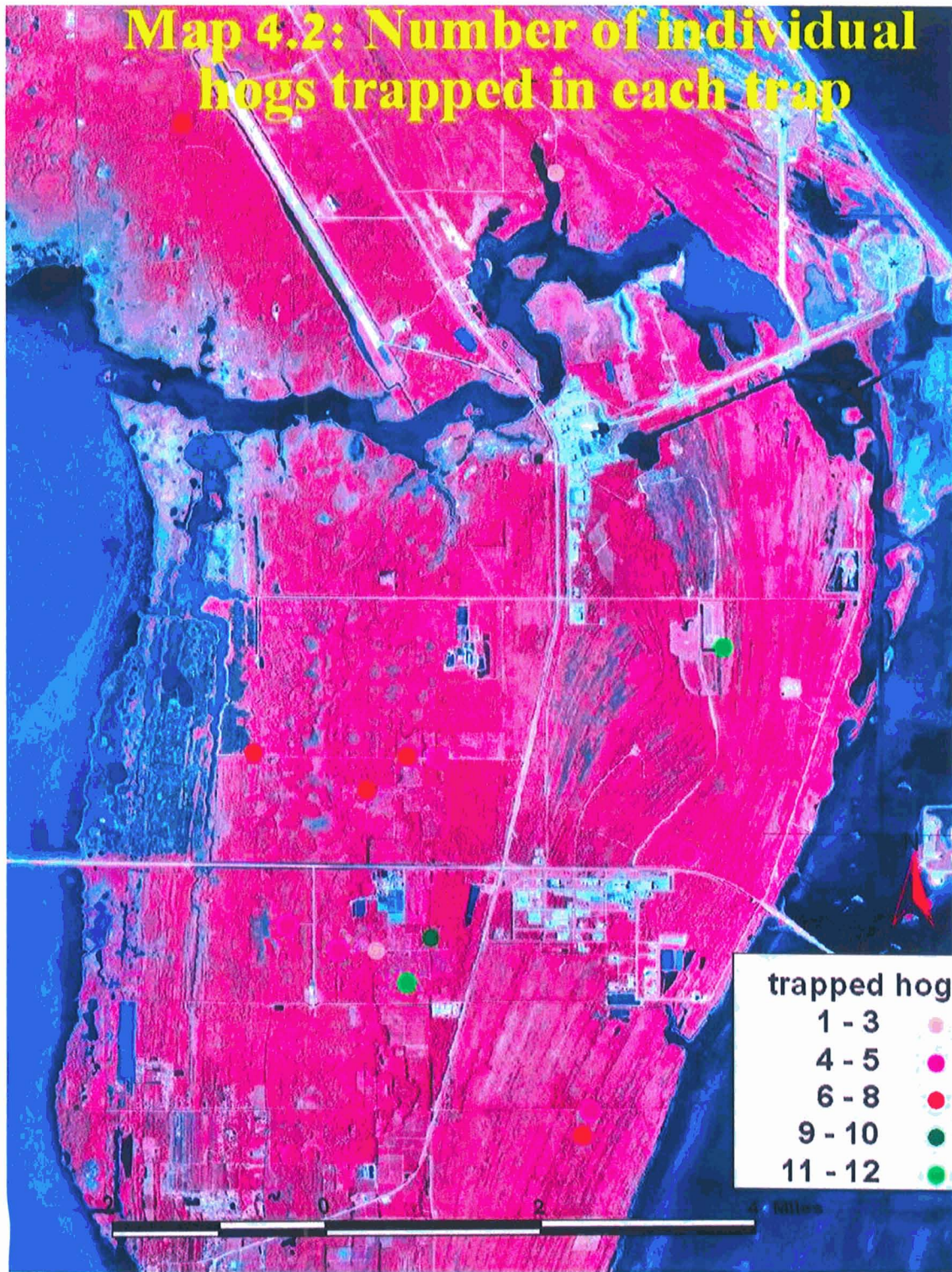


Figure 22. Map 4.2, Number of individual hogs trapped in each trap



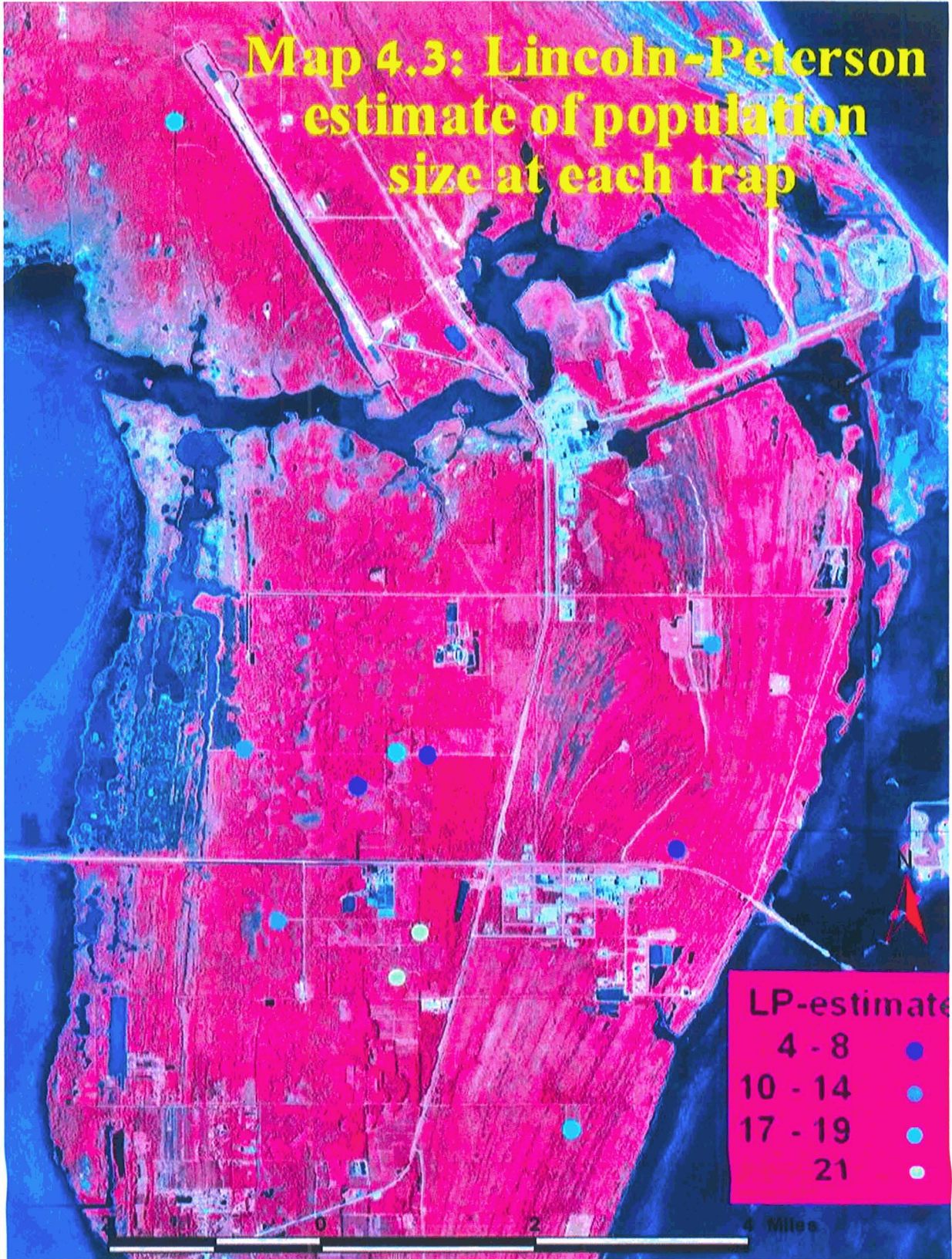


Figure 23. Map 4.3, Lincoln-Peterson estimate of population size at each trap



## Map 5.1: Food items available in Winter

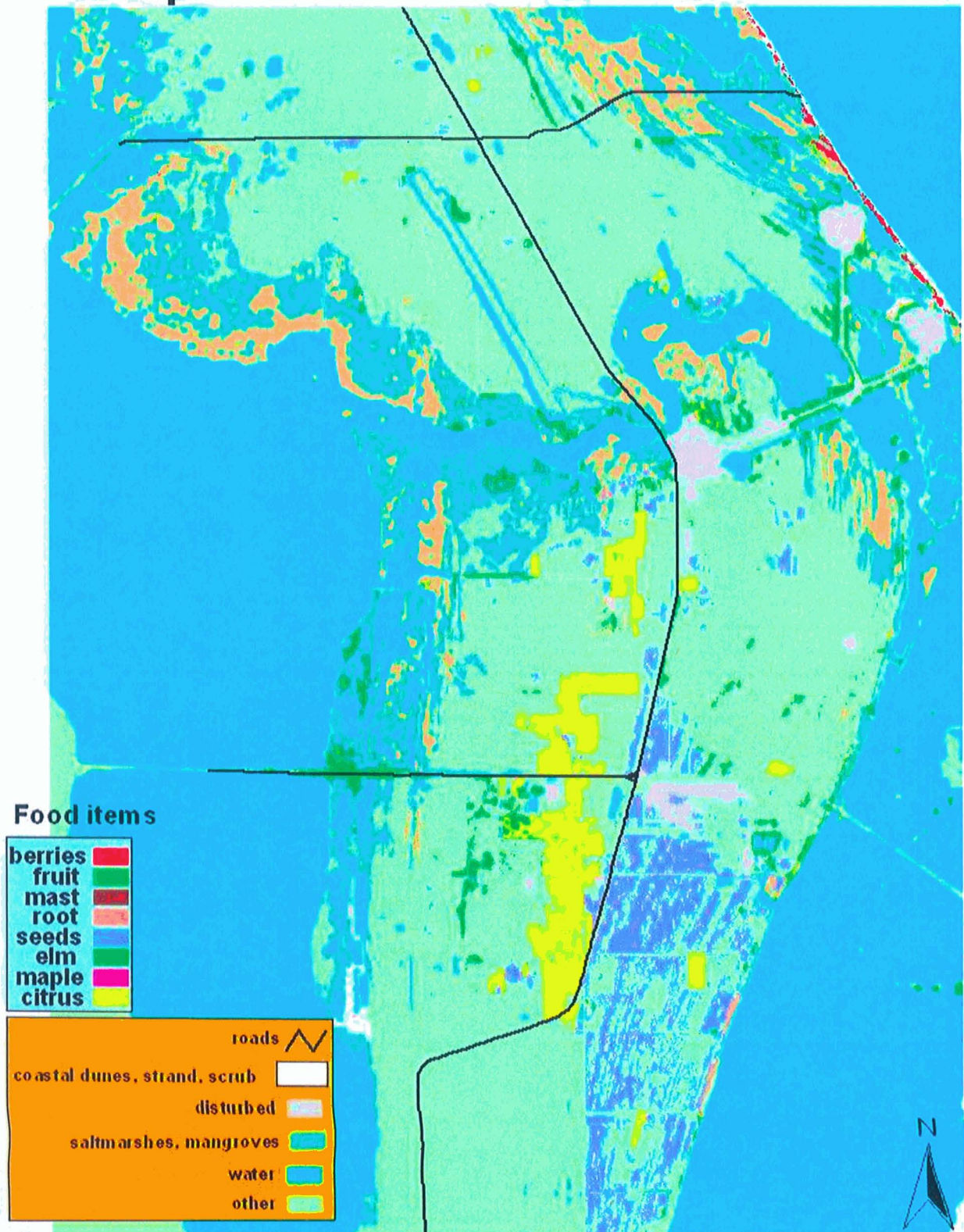


Figure 24. Map 5.1, Food items available in winter



### Map 5.2: Food items available in Spring

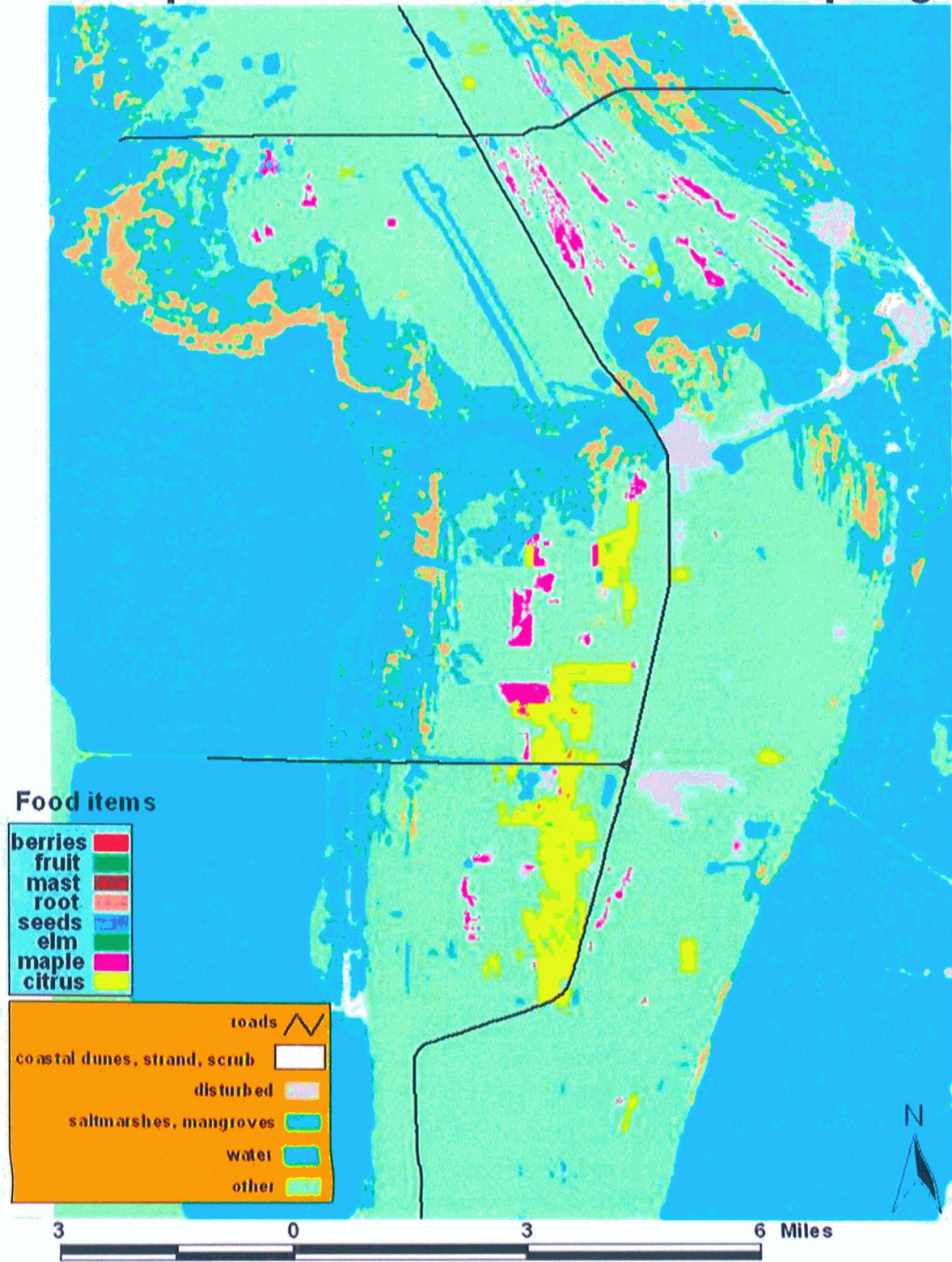


Figure 25. Map 5.2, Food items available in spring



### Map 5.3: Food items available in Summer

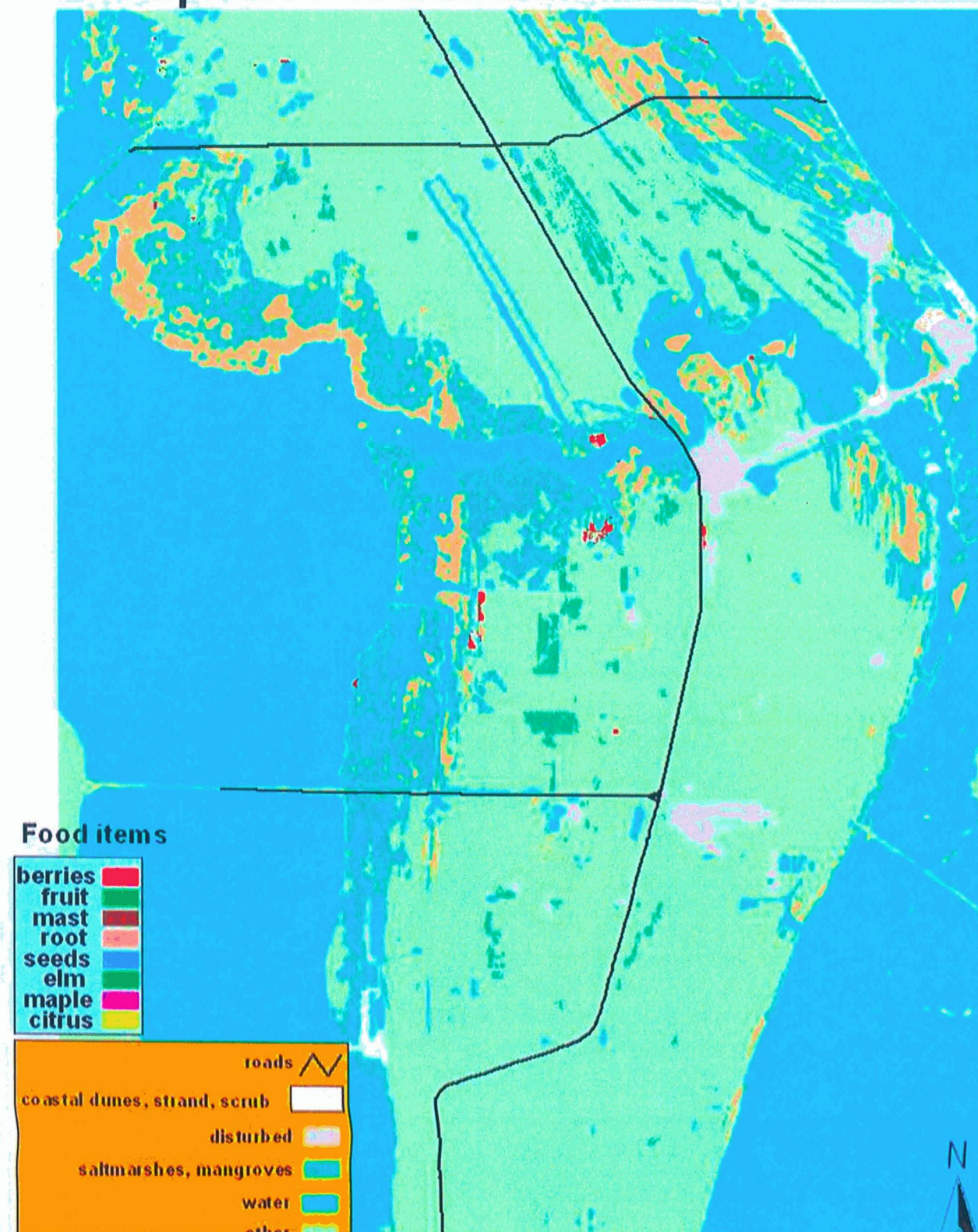


Figure 26. Map 5.3, Food items available in summer



# Map 5.4: Food items available in Fall

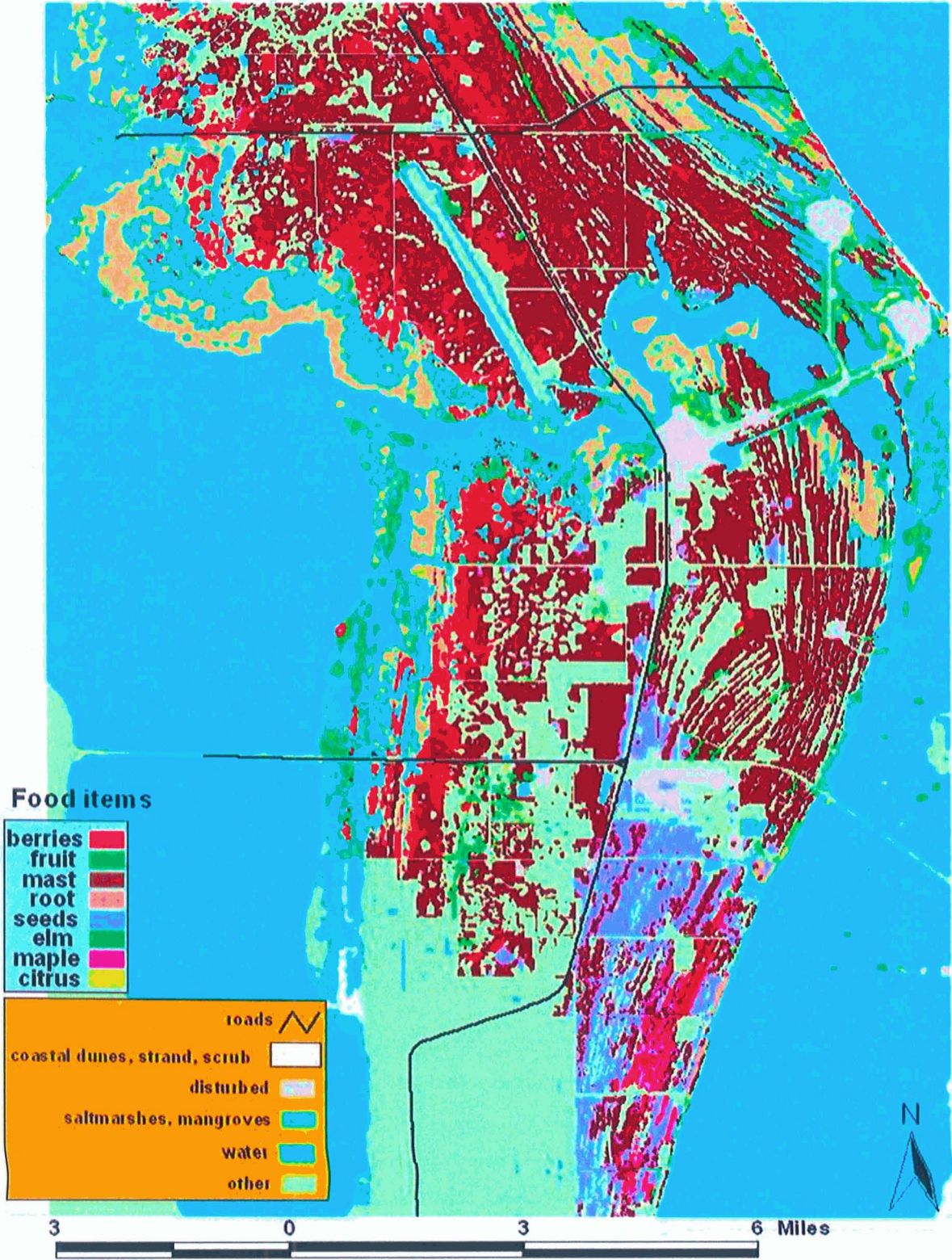


Figure 27. Map 5.4, Food items available in fall



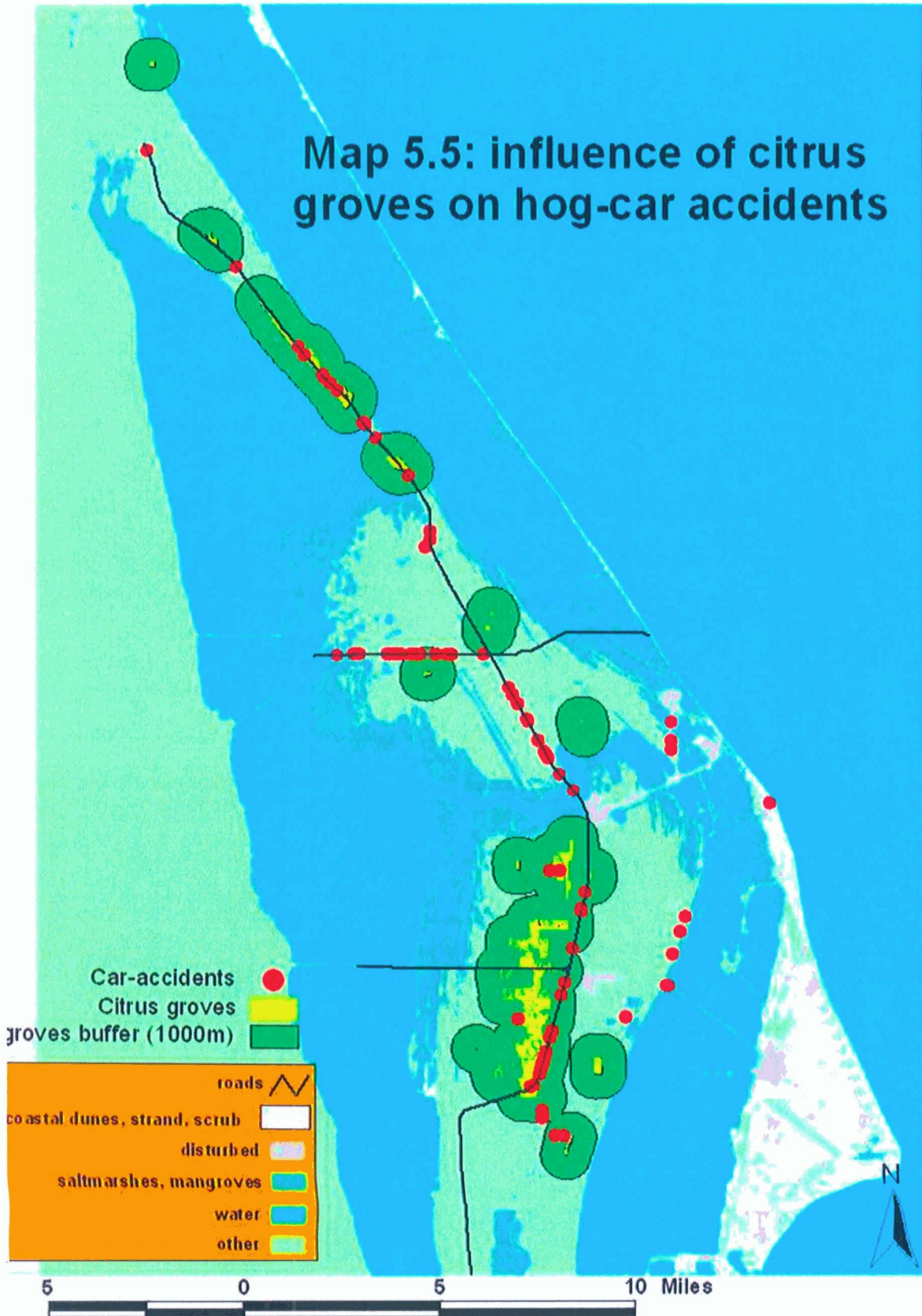


Figure 28. Map 5.5, Influence of citrus groves on hog-car accidents



# Map 5.6: vegetation maximum height

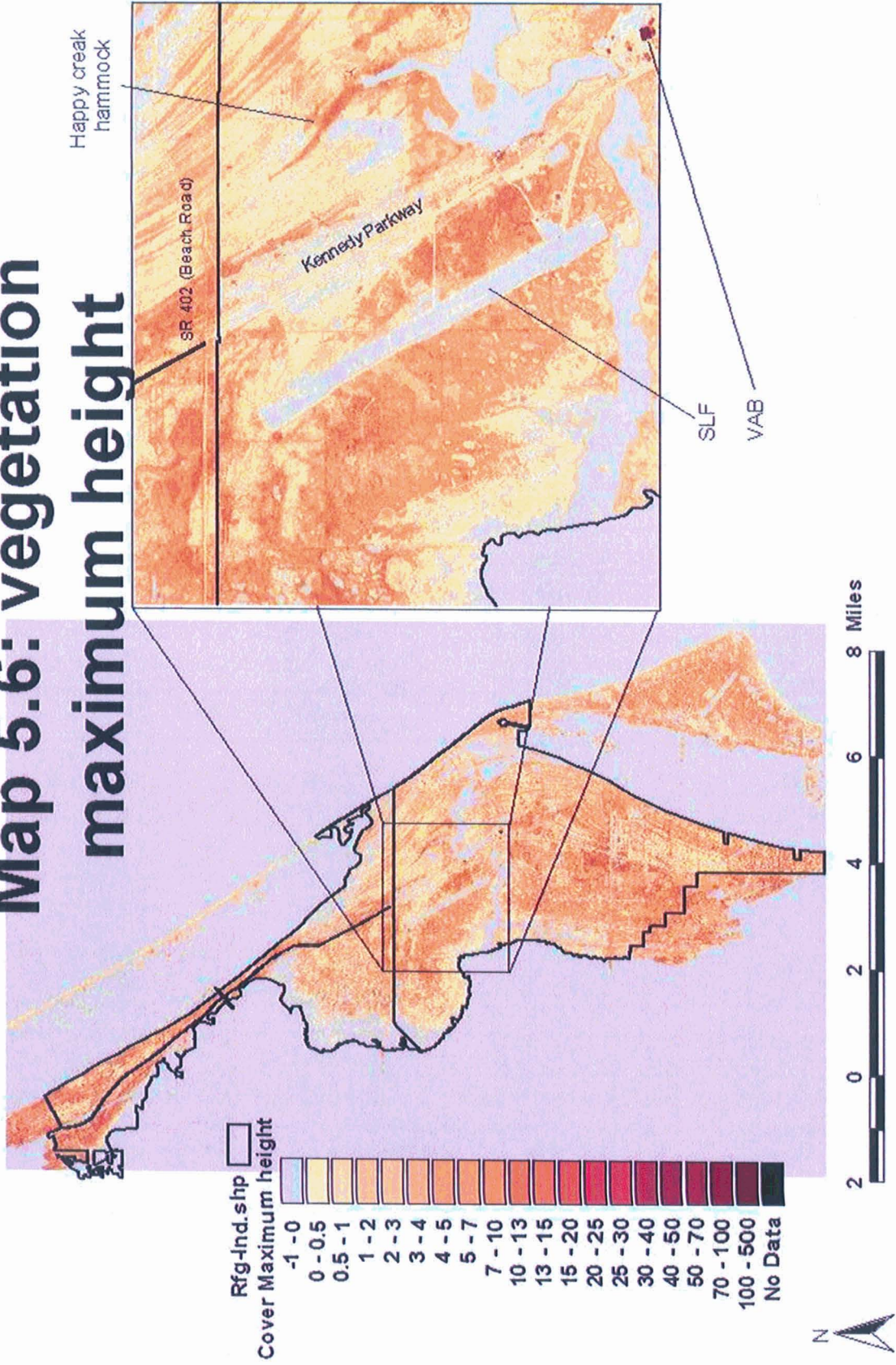


Figure 29. Map 5.6, Vegetation maximum height



# Map 5.7: vegetation amplitude height

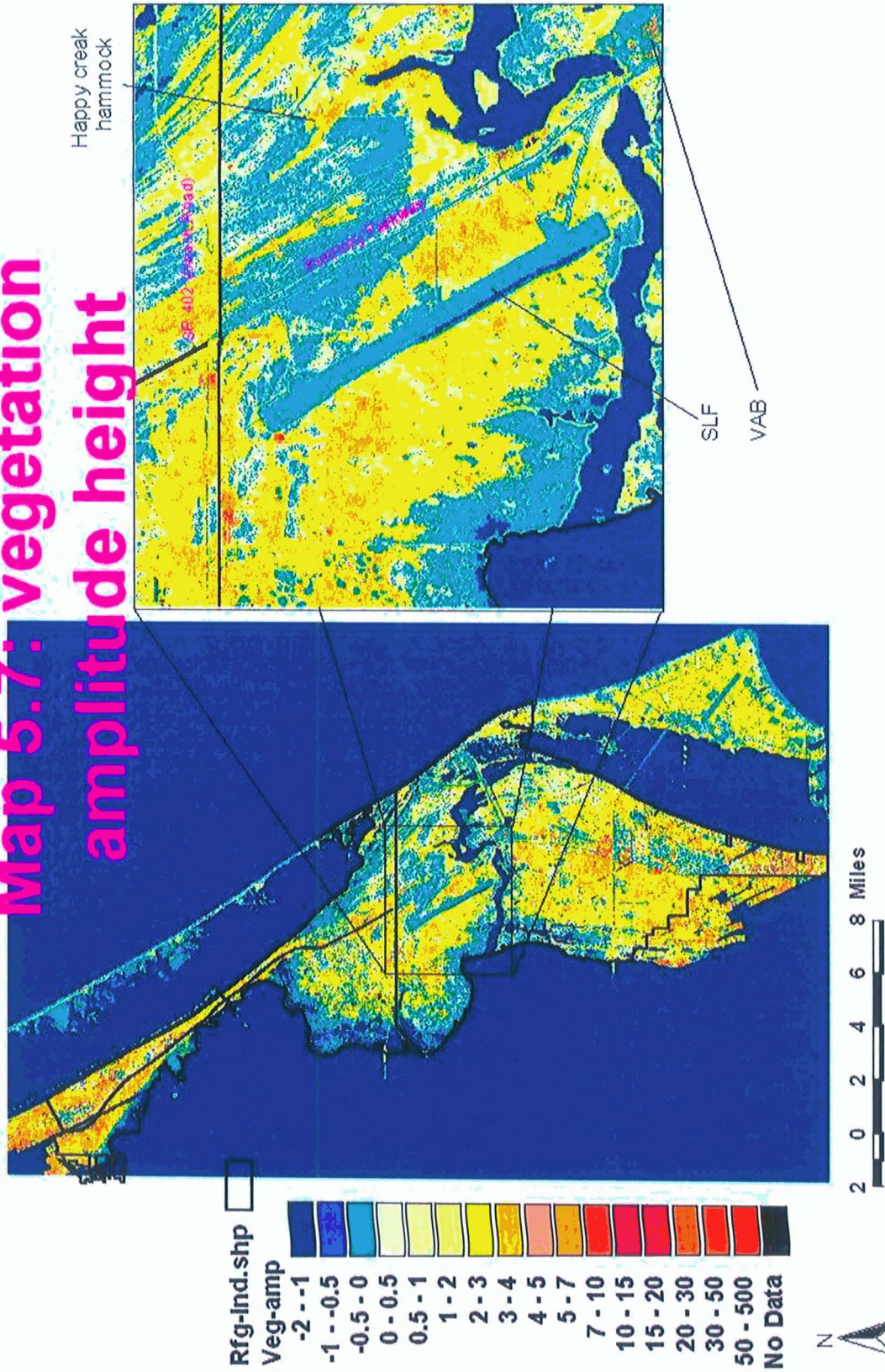


Figure 30. Map 5.7, Vegetation amplitude height



# Map 5.8: vegetation density index

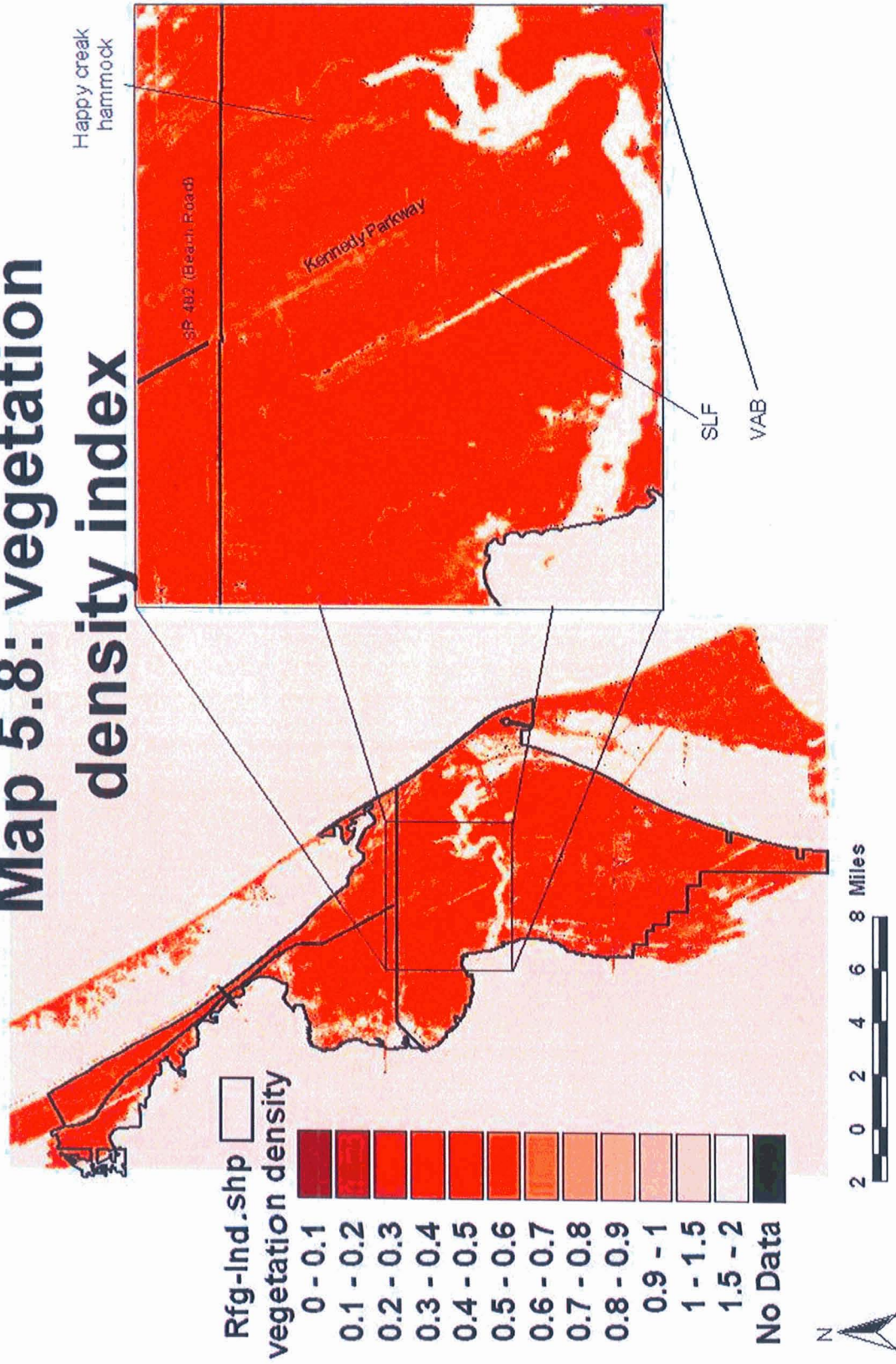


Figure 31. Map 5.8, Vegetation density index

# Map 5.9: Suitable vegetation height

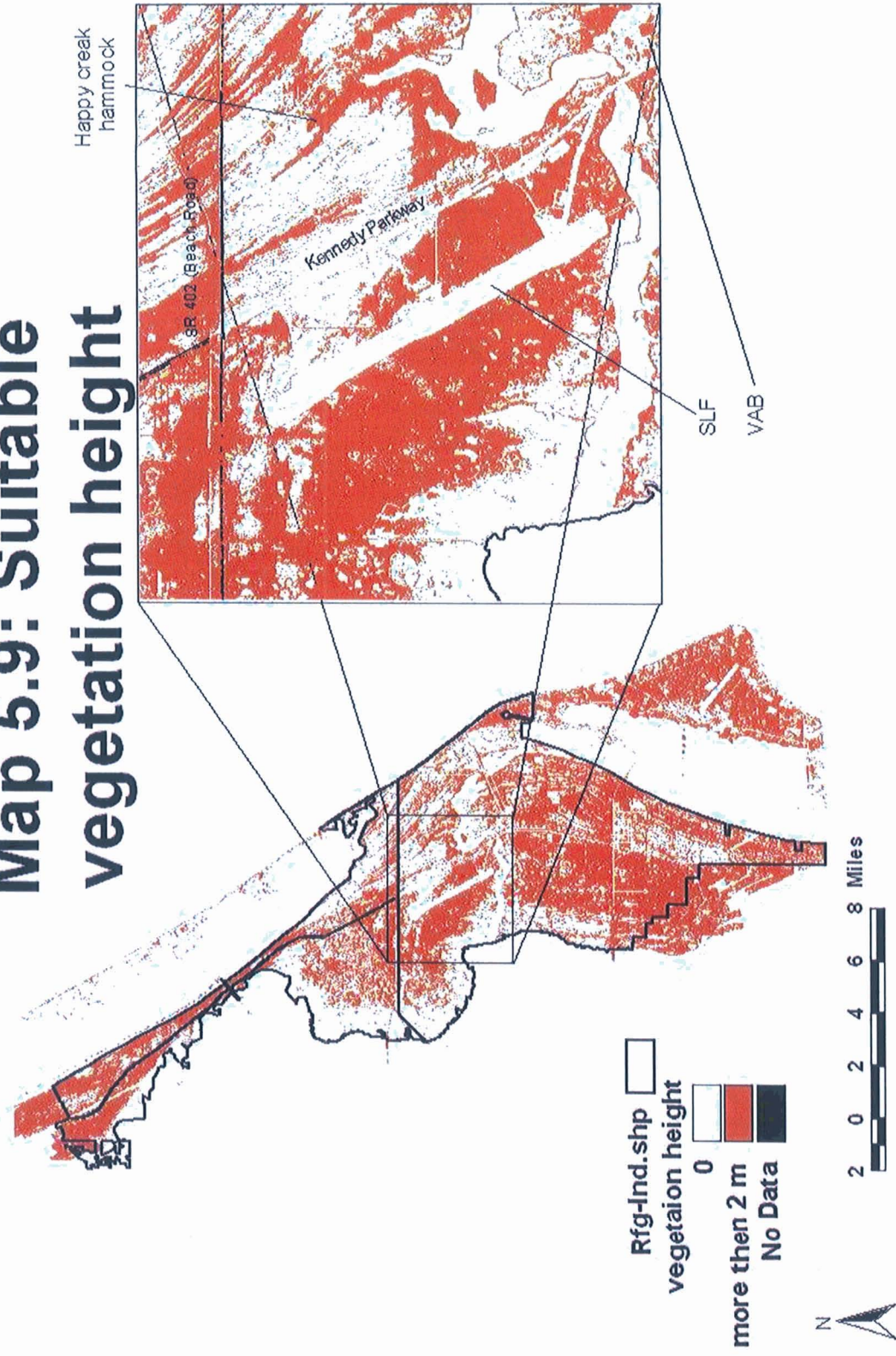


Figure 32. Map 5.9, Suitable vegetation height



# Map 5.10: Suitable vegetation density

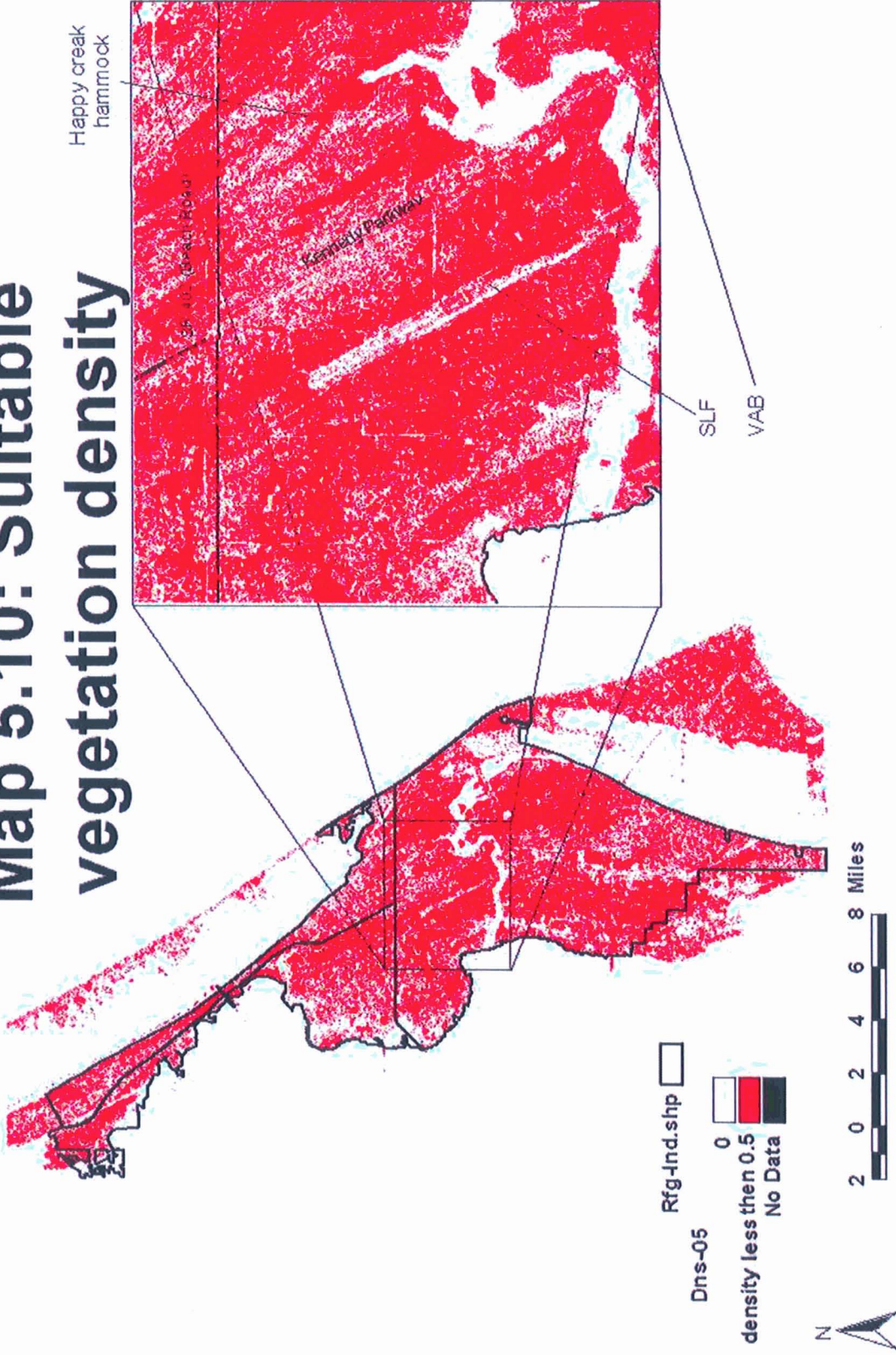


Figure 33. Map 5.10, Suitable vegetation density

# Map 5.11: Suitable vegetation cover

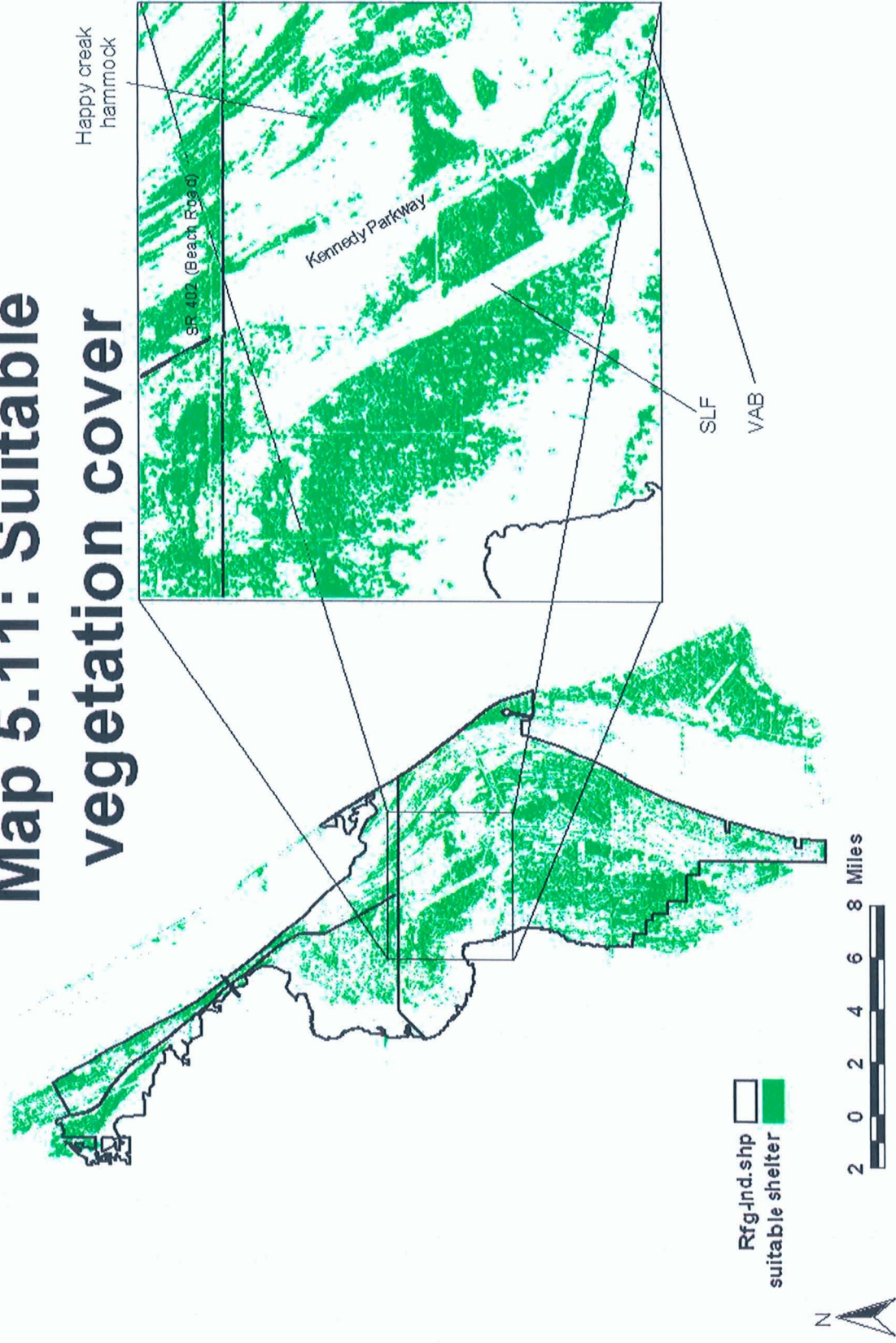


Figure 34. Map 5.11, Suitable vegetation cover



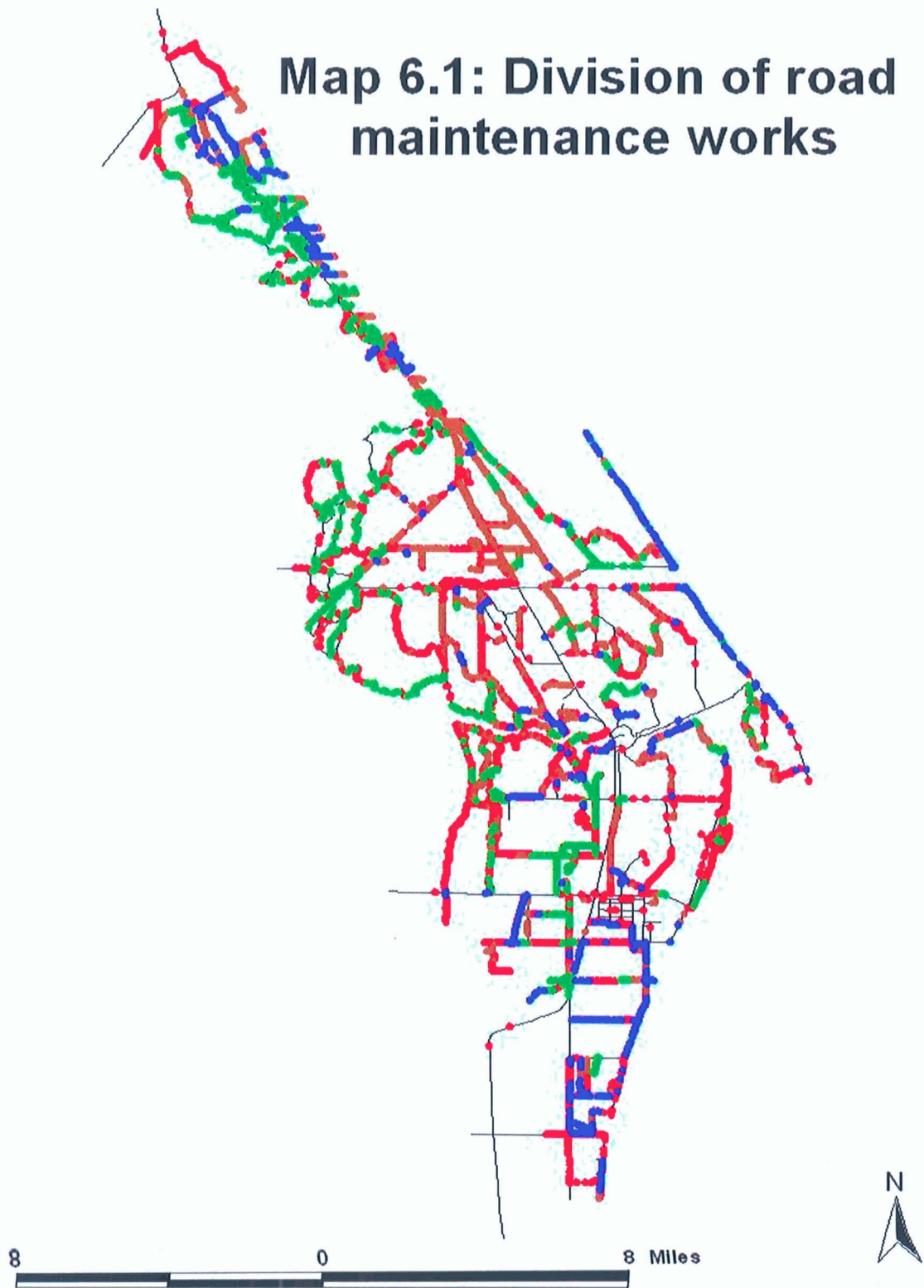


Figure 35. Map 6.1, Division of road maintenance works

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14. ABSTRACT This STI Technical Memorandum (TM) summarizes a two-month project on feral hog management in Merritt Island National Wildlife Refuge (MINWR). For this project, feral hogs were marked and recaptured, with the help of local trappers, to estimate population size and habitat preferences. Habitat covers included vegetation cover and Light Detection and Ranging (LIDAR) data for MINWR. In addition, an analysis was done of hunting records compiled by the Refuge and hog-car accidents compiled by KSC Security.					
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