

Diets, Nutrition, and Reproduction of Feral Hogs on Cumberland Island, Georgia

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Abstract: Detailed knowledge of a species' biology and ecology is required before site-specific management programs can be implemented. Therefore, we examined seasonal changes in food habits, nutritional status, and reproduction in a sample of 54 feral hogs (*Sus scrofa*) collected over a 2-year period from Cumberland Island National Seashore, Georgia. Seasonal variations in food habits probably were related to changes in food availability. Differences in seasonal rainfall patterns between years appeared to be related to dietary changes. No significant seasonal changes in body mass, fat indices, or crude protein in stomach contents were evident, which indicated that hogs on this subtropical island may not undergo pronounced seasonal variations in nutritional status. An exception occurred in May/June 1986 when greater ($P < 0.05$) kidney fat levels were observed coincident with a unique predominance (54.2%) of grape (*Vitis* sp.) leaves in the diet and a mean ovulation rate (14.8 corpora lutea/sow) that was double any other collection month. Reproduction in feral hogs may be highly responsive to short-term dietary changes, as is the case in domestic swine.

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Feral hogs occur in many areas of the southeastern United States (Wood and Lynn 1977, Wood and Barrett 1979). Several of these areas are managed by the National Park Service (NPS), where there is concern about the adverse effects of feral hogs on native plant and animal communities (Bratton 1974, 1975; Wood and Barrett 1979).

Feral hogs have occurred on most of Georgia's coastal islands for several hundred years since their release by Spanish explorers and periodic replenishment by escape from farms (Hanson and Karstad 1959). Wood and Barrett (1979) identified Cumberland Island as being 1 of the areas in the southeastern United States where significant damage to natural plant communities is attributable to feral hogs.

1. Deceased.

Diet, nutritional status, and reproductive characteristics of a feral hog population are important in assessing its potential ecological effects. Previous work has determined the food habits of feral hogs in southeastern Coastal Plain sites (Wood and Roark 1980, Belden and Frankenberger 1990), and diet, nutrition, and conception of hogs on a California coastal island (Baber and Coblentz 1987); however, no literature exists on the nutritional ecology of feral hogs on southeastern coastal barrier islands. Furthermore, only 1 study (Baber and Coblentz 1987) has characterized feral hog diets by microhistological techniques. Microhistological techniques can identify dietary items that are too finely digested for identification macrohistologically. Thus, our objectives were to determine the seasonal diets of feral hogs on Cumberland Island, Georgia, with microhistological techniques, and to relate diets to seasonal variations in nutritional status and reproduction.

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Methods

Our study was conducted on 9,400-ha Cumberland Island, the largest and most southerly of Georgia's coastal islands. It is located about 2 km east of the mainland. Most of the island is contained in the Cumberland Island National Seashore (CINS), which is administered by NPS. The climate was classified as humid subtropical, with annual averages of 305 frost-free days and 137 cm of precipitation (Johnson et al. 1974). Principal plant communities on the island included dune (about 9% of the island), interdune flats (6%), salt marsh (37%), fresh water (8%), and upland forests (39%) (Hillestad et al. 1975).

The NPS reduced the feral hog population to minimize ecological effects of hogs on Cumberland Island. Records from a live-trapping and removal program conducted from 1975–1983, and from public hunts conducted during the 1983–84 hunting season document a reduction in the feral hog population of $\geq 1,527$ individuals (K. O. Morgan, Superintendent, CINS, pers. commun.) before we began our study. Thus, the hogs collected during our study were from a population of relatively low numbers.

Sample Collection

We collected 54 feral hogs (≥ 1 year old) by shooting and from hunters at 2- to 3-month intervals from October 1984 to June 1986. Hogs were obtained primarily from the northern portion of Cumberland Island. Hogs were grouped into discrete collection months (Oct/Nov, Dec/Jan, Mar, May/June, and Sep). Collections were grouped into 2 study years—1984/85 included October 1984 through September 1985; 1985/86 included October 1985 through June 1986.

We weighed hogs, determined total length, and removed viscera. We aged hogs based on weight and length criteria for adult hogs on Ossabaw Island, Georgia

(Brisbin et al. 1977). We mixed the stomach contents thoroughly and took 2 samples—1 in ethanol for food habits analysis and 1 frozen for nitrogen analysis. We removed and froze the kidneys with attached perirenal fat and the right femur. Female reproductive tracts were preserved in formalin. We removed fetuses present from the uterus and preserved them separately in formalin.

Sample Analyses

Food habits analyses were conducted at the Composition Analysis Laboratory, Department of Range Science, Colorado State University, using microhistological techniques described by Johnson et al. (1983). Stomach contents were washed over a 200-mesh (0.1 mm) screen, dried, and ground in a Wiley mill through a 20-mesh (1 mm) screen. We prepared 2 microscope slides from these fragments for each hog. Twenty fields with identifiable fragments were read for each slide under a 100X binocular microscope. We identified fragments based on epidermal tissue characteristics using reference slides prepared from plants collected on Cumberland Island and processed as described above. All identifiable plant fragments in the 40 fields of view were counted for each hog. These data were used in the statistical analysis (below) and to calculate relative frequencies (the number of fragments of a given food item divided by the total number of all fragments in all hogs within a particular sex, month, or year classification). Relative frequency reflects dry weight of species in the diet (Holechek and Gross 1982).

We thawed and rinsed stomach contents through a series of 4 sieves (U.S. Standard sieves; 5.60, 3.35, 1.41, and 0.43 mm, in order). The material remaining in the top 3 sieves was combined, oven-dried at 60 C for 2–3 days, and ground in a Wiley mill through a 20-mesh screen. The fourth sieve usually contained only sand, which was discarded. Crude protein (CP) of stomach contents was calculated after determination of nitrogen by the micro-Kjeldahl technique using procedures described for the Kjeltach Auto Analyzer (Tecator Inc., 1981).

We thawed kidneys and femurs, and determined the kidney fat index (KFI; Riney 1955) and femur marrow fat (FMF; Warren and Kirkpatrick 1978). We weighed ovaries and examined them macroscopically for corpora lutea (CL) and follicles (≥ 1 mm) as described by Harder and Kirkpatrick (1994). We weighed fetuses, took crown-rump measurements, and estimated conception and parturition dates based on mean fetal length and a gestation period of 115 days (Ullrey et al. 1965).

Data Analyses

We conducted statistical analyses of diets based on the number of fragments observed according to food class, month, year, and sex. Data on relative frequency of individual plant species could not be analyzed statistically because all plant species did not occur in all hogs. We pooled data into food classes and used individual hogs as replicates. A factorial analysis of variance (SAS Inst., Inc. 1985) was used to determine the significance of main effects (food class, sex, month, and year) and their interactions. If month effects were non-significant ($P > 0.05$), then we pooled collections into cool season (Oct/Nov, Dec/Jan, and Mar) or warm season (May/June and

Sep) and reanalyzed the data with a season main effect. If any main effect and its interaction terms were non-significant, then we eliminated that main effect from the model and reanalyzed the data. In cases where the interaction terms were significant in our statistical analyses, we reanalyzed the data separately by *t*-test to examine specific main effects. We analyzed nutritional and ovarian data as described previously except food class was eliminated as a main effect. An F_{\max} test (Sokal and Rohlf 1969) was used to test for homogeneity of variances. In cases of heterogeneous variances, data were transformed logarithmically ($\log 10$) and reanalyzed.

Results and Discussion

Diets

The occurrence of individual food items in the diet of feral hogs on Cumberland Island varied among collection months and between years (Table 1). The sex main effect and all its interaction terms were not significant in the analysis (Table 2), so data were pooled across gender. The dietary variation observed was likely the result of seasonal and annual changes in food item availability and vegetative phenology on the island rather than feeding preferences of hogs. Unfortunately, we did not determine food item availability, which is required to estimate preference.

Other researchers (Henry and Conley 1972, Scott and Pelton 1975, Barrett 1978, Everitt and Alaniz 1980, Wood and Roark 1980, Belden and Frankenberger 1990) have studied feral hog food habits in North America and have concluded that hogs are opportunistic and primarily herbivorous feeders. However, these studies determined food habits using macrohistological analysis of stomach contents, which is less likely to detect small, finely masticated, or highly digestible food items than microhistological analysis. For example, Wood and Roark (1980), working in habitats in coastal South Carolina very similar to those on Cumberland Island, were unable to identify any of the grass, marsh, and aquatic plants, browse, or forbs we observed. In the only other study that used microhistological techniques, Baber and Coblenz (1987) found that feral hogs also readily consumed grass, forbs, and browse. Baber and Coblenz (1987) also determined plant availability in their study and thus were able to calculate a dietary preference rating. They determined that fruits and seeds were the most preferred foods for feral hogs on Santa Catalina Island, California.

Food items that occurred in the highest ($\geq 10\%$) relative frequencies during ≥ 1 collection month in our study were *Panicum* sp., *Bromus* sp., *Setaria* sp., *Carex* sp., *Spartina* sp., *Vitis* sp., *Opuntia* sp., *Rhus* sp., forb seeds, acorns, fungi, and invertebrates/arthropods (Table 1). More ($P < 0.05$) grass occurred in the March diet of 1984/85 compared to 1985/86 (Tables 1, 2). *Carex* sp. and *Spartina* sp. also appeared to occur more frequently in the March diet of 1984/85 than 1985/86 (Table 1), but number of fragments of marsh and aquatic plants did not differ between years (Table 2). Browse consumption did not differ between years (Table 2). However, it was apparent that hogs shifted browse use from *Opuntia* sp. in 1984/85 to *Vitis* sp. in 1985/86 (Table 1). More ($P < 0.001$) seeds and fruit occurred in the December/January diet of 1984/85 than 1985/86 (Table 2), which probably resulted from the greater

Table 1. Relative frequencies (%) for foods comprising >0.5% of the seasonal diet of feral hogs collected during different months from 1984–85 to 1985–86 on Cumberland Island, Georgia.

Food class and species	Oct/Nov		Dec/Jan		Mar		May/June		Sep
	1984/85 ^a (N = 8)	1985/86 ^a (N = 3)	1984/85 (N = 8)	1985/86 (N = 7)	1984/85 (N = 5)	1985/86 (N = 3)	1984/85 (N = 5)	1985/86 (N = 7)	1984/85 (N = 6)
Grass:									
<i>Panicum</i> sp.	7.3		3.1	1.2	10.6		1.9	0.9	1.0
<i>Bromus</i> sp.	4.9		7.5	1.5	12.2	4.3	3.0	1.5	0.3
<i>Sporobolus</i> sp.	0.2				0.8		3.7		
<i>Paspalum</i> sp.							2.6		
<i>Setaria</i> sp.			2.2	2.7	12.5		16.3		0.7
<i>Andropogon</i> sp.								7.9	
Total grass ^b	12.4		12.8	5.4	36.1	4.3	27.5	10.3	2.0
Marsh and aquatic grass and plants:									
<i>Carex</i> sp.	0.5			1.2	11.8	1.4	3.7	1.5	
<i>Spartina</i> sp.	8.7		7.7	0.9	20.9	8.6	2.6	9.7	1.0
<i>Eleocharis</i> sp.					2.7				
<i>Salicornia</i> sp.					1.1			0.3	
Total marsh and aquatic ^b	9.2		7.7	2.1	36.5	10.0	6.3	11.5	1.0
Browse:									
<i>Vitis</i> sp.	4.9	25.2		25.0		35.3	0.7	54.2	19.7
<i>Opuntia</i> sp.	0.5		9.2	2.1	16.0		32.2	6.4	2.4
<i>Rhus</i> sp.	4.7	15.4	3.1	0.3	0.8	1.4		0.3	
<i>Quercus</i> sp.	2.1	1.4	0.4	1.2	1.1		0.7	0.6	5.2
<i>Myrica</i> sp.	0.2		0.7		0.8	4.3			1.0
<i>Salix</i> sp.			6.4						
<i>Ilex</i> sp.				0.6					
Total browse ^b	12.4	42.0	20.8	29.5	18.7	41.0	34.0	61.5	28.3
Forbs:									
Fern	2.1		0.2	6.0			0.7	0.9	
<i>Argemone</i> sp.					1.1				
Unknown forb					0.8			0.6	
Total forbs ^b	2.1		0.2	6.0	1.9		0.7	1.5	
Seeds and fruit:									
Forb seeds ^c	26.6	20.3	20.4	5.7	0.4	25.9	4.4	3.3	6.9
Acorns	22.4	4.9	15.4	0.3		0.7		0.9	3.5
Flowers	4.0				0.4				
Pods	7.3								
Total seeds and fruit ^b	60.5	25.2	35.8	6.0	0.8	26.6	4.4	4.2	10.4
Fungi									
	1.2	9.1	9.4	25.6	1.5	14.4	11.9	9.1	6.2
Roots and bark									
		1.4	6.6		0.4				1.7
Arthropods									
	2.4	21.6	6.6	25.6	4.2	3.6	10.4	1.8	43.9
Bone									
							4.8		6.2

a. 1984/85 included Oct 1984–Sep 1985; 1985/86 included Oct 1985–June 1986.

b. Total may include species for which the seasonal relative frequencies were <0.5%.

c. Includes 6 different, but unidentified species.

Table 2. Mean (\pm SE) number of food item fragments according to food class, month, and year in the diet of feral hogs collected during different months from 1984–85 to 1985–86 on Cumberland Island, Georgia.

Food class	Oct/Nov				Dec/Jan				Mar				May/June				Sep	
	1984/85 (N = 8)		1985/86 (N = 3)		1984/85 (N = 8)		1985/86 (N = 7)		1984/85 (N = 5)		1985/86 (N = 3)		1984/85 (N = 5)		1985/86 (N = 7)		1984/85 (N = 6)	
	\bar{x}	SE	\bar{x}	SE	\bar{x}	SE	\bar{x}	SE	\bar{x}	SE	\bar{x}	SE	\bar{x}	SE	\bar{x}	SE	\bar{x}	SE
Grass	6.8	4.6			7.1	3.0	2.6	1.2	19.6 ^b	5.1	2.0 ^b	2.0	14.4	3.4	4.9	3.2	1.0	0.3
Marsh and aquatic plants	4.8	3.2			4.4	4.1	1.0	0.4	18.8	4.7	4.7	4.7	3.8	1.7	5.4	2.8	0.5	0.3
Browse	6.6	2.7	20.3	14.2	12.0	5.3	14.1	5.2	9.8	5.1	19.0	10.1	18.4	7.7	29.3	4.9	13.7	5.5
Forbs	1.1	1.1			1.1	1.0	2.9	2.9	1.4	1.0			0.2	0.2	0.7	0.4		
Seeds and fruit	29.5	6.6	12.0	6.1	20.5 ^c	8.5	2.9 ^c	1.1	0.4	0.4	12.3	8.9	2.4	1.7	2.3	0.8	5.3	2.0
Fungi	0.6	0.3	4.3	4.3	4.4 ^d	1.9	12.3 ^d	4.7	0.8	0.6	6.7	6.7	6.6	3.8	4.3	2.7	3.0	2.2
Arthropods and animal matter	1.3 ^d	1.0	10.3 ^d	2.6	3.8 ^d	3.5	12.3 ^d	4.4	2.2	1.0	1.7	1.7	8.2	6.5	0.9	0.5	24.2	4.3
Other			0.7	0.7	3.8	3.8			0.2	0.2							0.8	0.5

a. Sex, month, and year main effects, and all interaction terms including sex were nonsignificant ($P > 0.05$). Significant variation occurred for food class main effect ($P < 0.001$), and for year \times food class ($P < 0.05$) and month \times year \times food class ($P < 0.05$) interaction terms.

b. $P < 0.05$; 1984/85 vs. 1985/86 within collection months (t -test).

c. $P < 0.001$; 1984/85 vs. 1985/86 within collection months (t -test).

d. $P < 0.01$; 1984/85 vs. 1985/86 within collection months (t -test).

use of forb seeds and acorns (Table 1). Consumption of fungi was greater ($P < 0.01$) in 1985/86 than 1984/85 (Tables 1 and 2). Invertebrates, arthropods, and animal matters occurred more frequently ($P < 0.01$) in the October/November and December/January diets of 1985/86 than 1984/85 (Tables 1 and 2).

Dietary shifts may have reflected differences in food availability caused by differences in rainfall between years. Data collected from a weather station on CINS (NPS, unpubl. data) documented more rainfall from October through June for 1985/86 (78.4 cm) than 1984/85 (54.1 cm). Rainfall may have influenced the availability of food items by affecting vegetative growth, and thus may have caused some of the dietary differences observed between years (Tables 1, 2). More rainfall in 1985/86 may have increased availability of browse (especially *Vitis* sp.), fungi, and arthropods compared to 1984/85. The drier conditions that prevailed on the island during 1984/85 may have provided hogs access to areas that otherwise might have been too wet, and thus may have accounted for the greater occurrence of grass and marsh and aquatic plants in 1984/85 than in 1985/86 (Tables 1, 2). Some of the dietary shifts also may have been caused by feeding preferences. For example, in years of acorn abundance, feral hogs (Henry and Conley 1972) and white-tailed deer (*Odocoileus virginianus*; Harlow et al. 1975) consume lower amounts of herbaceous plants than in years of mast failure or scarcity.

Nutrition

Body mass varied significantly ($P < 0.01$) between sexes; males weighed more (57.4 ± 4.4 kg [$x \pm SE$], $N = 30$) than females (40.1 ± 1.9 kg, $N = 24$). This dimorphism has been reported previously in European wild hogs in Tennessee (Henry 1970), but was not observed in 2 populations of feral hogs in South Carolina or on Ossabaw Island, Georgia (Brisbin et al. 1977). Significant differences in body mass were not detected among months, nor between seasons or years. Thus, body mass did not reveal any variations in nutritional status during our study.

Sex, month, and season main effects and their interaction terms were non-significant in the analysis of CP and FMF data. Crude protein of stomach contents was lower in 1985/86 ($8.5 \pm 0.6\%$, $N = 13$) than in 1984/85 ($11.7 \pm 1.1\%$, $N = 28$). Levels of FMF were higher ($P < 0.05$) in 1985/86 ($97.8 \pm 0.4\%$, $N = 20$) than in 1984/85 ($94.9 \pm 0.9\%$, $N = 25$). Femur marrow fat reserves in white-tailed deer primarily indicate long-term energy intake (Warren and Kirkpatrick 1982). The difference in FMF between years probably has little ecological significance because FMF levels observed in both years ($>90\%$) were indicative of excellent nutritional status. Perhaps the intensive population reduction program conducted by the NPS from 1975–1984 lowered the hog population numbers on Cumberland Island to the extent that even in years of lowered nutritional quality, the individuals in the population still exist in excellent nutritional status. The lack of monthly or seasonal variations in FMF of feral hogs on Cumberland Island is contrary to data published for feral hogs in California (Baber and Coblentz 1987), collared peccaries (*Tayassu tajacu*) in Texas (Corn and Warren 1985), and white-tailed deer in numerous regions of the United States (Finger

et al. 1981, Kie et al. 1983, Johns et al. 1984, Waid and Warren 1984). However, total body fat indices of feral hogs collected on Ossabaw Island, Georgia, and on the Savannah River Plant near Aiken, South Carolina, also failed to demonstrate pronounced seasonal variations (Stribling et al. 1984).

Although seasonally high rates of fat deposition are an obligatory physiological event in some northern, temperate ungulates (Verme and Ozoga 1980b), excessively high levels of fat reserves may actually be detrimental in southern, tropical ungulates (Smith 1970). It is possible that the subtropical environment on Cumberland Island does not require feral hogs to deposit seasonally high levels of fat. However, white-tailed deer on Cumberland Island demonstrate pronounced seasonal variations in humerus marrow fat reserves (ranging from 4.4% to 99.8% among different seasons; R. J. Warren, unpubl. data).

A significant month-by-year interaction occurred for KFI (Table 3), indicating that the trends in KFI levels observed between years varied among months. The month-by-year interaction resulted primarily from the higher KFI levels observed in the March and May/June collections of 1985/86 compared to 1984/85 (Table 3). These higher KFI levels reflect a greater level of nutritional quality (primarily energy) in the hogs' diets at that time. Fat deposition in mammals occurs primarily in response to dietary energy intake (Harder and Kirkpatrick 1994).

Limited data exist in wild and feral species on the responses of specific fat indices to controlled nutritional intake for specified times. However, previous work has shown that KFI is more responsive to short-term energy intake than FMF (Verme and Ozoga 1980a, Warren and Kirkpatrick 1982). Therefore, the greater KFI levels observed in March and May/June 1985/86 were probably the result of a relatively short-term increase in the dietary energy intake of these hogs. During these collection months, the hogs consumed substantially more *Vitis* sp. browse than in any other collection month (Table 1). *Vitis* sp. leaves at that time of year may have been high in energy content. Sugar content of leaves and succulent green shoots of *Vitis rotundifolia* (Pickett and Cowart 1941) and *V. vinifera* (Winkler and Williams 1945) are highest during spring prior to the beginning of fruit maturation.

Table 3. Kidney fat indices (KFI) and perirenal fat (PF) for male and female feral hogs collected during different months from 1984–85 to 1985–86 on Cumberland Island, Georgia.

Collection month	Year	N	KFI (%) ^a		PF (g)	
			\bar{x}	SE	\bar{x}	SE
Oct/Nov	1984/85	7	24.5	5.1	15.9	3.8
	1985/86	3	24.0	9.6	17.8	8.6
Dec/Jan	1984/85	8	27.0	3.4	17.7	3.8
	1985/86	7	26.9	4.7	18.4	4.0
Mar	1984/85	4	26.9	9.3	21.2	9.1
	1985/86	3	56.3	25.9	51.0	35.8
May/Jun	1984/85	4	17.1	3.3	12.2	3.5
	1985/86	7	50.1	10.3	35.7	7.3
Sep	1984/85	6	24.0	3.7	28.9	7.5

a. $P < 0.05$; month \times year interaction.

Levels of PF did not vary significantly among months, seasons, or years (Table 3). However, PF levels were greater ($P < 0.01$) in males (32.3 ± 5.9 g) than females (16.6 ± 1.8 g). Perirenal fat and KFI were highly correlated ($r = 0.91$, $P < 0.0001$, $N = 49$), which indicated that variations in KFI levels observed were largely the result of changes in PF levels and not likely because of changes in kidney weights. Some investigators have questioned the use of KFI in some ungulates, because significant variation in kidney weights can distort the KFI (Dauphine 1975). In summary, our observations on CP, FMF, and KFI indicate that the hogs probably consumed diets lower in protein and higher in energy content in 1985/86 than 1984/85.

Reproduction

Ovarian weights did not reflect a trend that indicated a distinct, synchronous breeding season (Table 4). However, sows demonstrated greatest ovarian follicular activity during the September, October/November, and December/January collection months (Table 4). Measurable fetuses were obtained from only 4 of 27 adult females, providing estimated conception dates ranging from 18 September 1984 to 19 June 1985. Extended periods of reproduction in feral hog populations have been reported in South Carolina (Sweeney et al. 1979) and Florida (Belden and Frankenberger 1990). Conversely, Baber and Coblentz (1986, 1987) reported a greater degree of synchrony in breeding for feral hogs on Santa Catalina Island, California. Coblentz and Baber (1987) observed an apparent lack of seasonality in conceptions by feral hogs on Isla Santiago, Galapagos, Ecuador, which they attributed to an absence of seasonal variations in photoperiod and abundant forage available throughout most of the year.

The number of CL per female we observed was similar to that reported for other feral hog populations across the United States (Baber and Coblentz 1986). A significant month-by-year interaction occurred for the number of CL per female and was

Table 4. Ovarian weights, number of ovarian follicles (≥ 1 mm), and number of corpora lutea (CL) for adult female feral hogs collected during different months from 1984–85 to 1985–86 on Cumberland Island, Georgia. All females had CLs.

Collection Month	Year	N	Ovarian weight (g) ^a		N follicles ^b		N CL ^{b,c}	
			\bar{x}	SE	\bar{x}	SE	\bar{x}	SE
Oct/Nov	1984/85	2	3.1	0.5	23.5	2.5	7.5	0.5
	1985/86	0						
Dec/Jan	1984/85	6	2.1	0.3	17.7	5.6	4.8	0.8
	1985/86	6	2.2	0.3	17.0	3.5	4.5	1.1
Mar	1984/85	2	5.2	2.1	3.5	3.5	6.0	2.0
	1985/86	1	3.4		0.0		5.0	
May/Jun	1984/85	3	3.2	0.5	1.0	0.6	7.0	1.5
	1985/86	4	4.9	1.1	2.3	1.4	14.8	1.9
Sep	1984/85	3	4.8	1.1	10.3	1.9	7.0	2.0

a. $P < 0.05$; significant month main effect.
 b. $P < 0.01$; significant month main effect.
 c. $P < 0.05$; significant month \times year interaction term.

manifest in greater ovulation rates observed for sows in the May/June 1985/86 collection month (Table 4). This particular collection month also was characterized by greater KFI levels in both males and females (Table 3), and substantially higher amounts of *Vitis* sp. leaves in the diet (Table 1). An analysis of the KFI data from females separately in May/June 1985/86 also revealed greater ($P < 0.05$, $t = 3.08$) KFI levels ($37.4 \pm 5.8\%$, $N = 4$) than in May/June 1984/85 ($14.7 \pm 3.2\%$, $N = 3$).

An increase in dietary energy intake of 25% for a period as short as 6 days, or supplementation of basal swine rations with only 1% glucose (body weight basis) for 2 weeks, can significantly increase the number of ova shed in domestic swine (i.e., "flush"; Zimmerman et al. 1960). The importance of nutritional intake on reproductive performance also is well documented in wild swine. Reductions or failures in oak mast production have been related to delayed breeding and fewer conceptions in feral hogs in Tennessee (Matschke 1964) and California (Baber and Coblenz 1987). Thus, it appeared that reproductive performance (ovulation rates) in the feral hogs on Cumberland Island was greatly influenced by short-term changes in nutritional status (fat indices).

Management Implications

In many areas of the southeastern United States, feral hogs are considered a pest because of their effect on timber regeneration sites and natural plant communities. Feral hogs on Cumberland Island appeared to be primarily opportunistic in their diets, feeding heavily on seeds and fruit, fungi, and arthropods. Therefore, they affect the island's vegetation by altering plant regeneration (seeds and fruits), and soil fertility by possibly interfering with litter decomposition and nutrient recycling (fungi and invertebrates/arthropods).

According to NPS policy, feral hogs are an exotic species and should be eradicated. However, the prospect of completely eradicating hogs on Cumberland Island, much of which is a federally designated wilderness area, is not good. The intensive program of hog removal that was conducted until 1983, before the island was a wilderness area, reduced the population significantly, however, and may have reduced damage to vegetation of the island. The population reduction appeared to improve the nutritional condition of remaining individuals. A related study on endoparasites of the hogs collected in our study, when compared to similar data from hogs on the island in 1979–80, revealed that the population reduction also seemed to improve hog health (Pence et al. 1988). The reproductive potential of feral hogs is well known. Intensive population control measures are necessary to maintain reduced population numbers. Novel techniques, such as the use of radio-telemetry in the eradication of remnant feral goats (Taylor and Katahira 1988), should be considered to increase and maintain control over the hog population on Cumberland Island.

Literature Cited

- Baber, D. W. and B. E. Coblenz. 1986. Density, home range, habitat use, and reproduction in feral pigs on Santa Catalina Island. *J. Mammal.* 67:512–525.

- and ———. 1987. Diet, nutrition, and conception in feral pigs on Santa Catalina Island. *J. Wildl. Manage.* 51:306–307.
- Barrett, R. H. 1978. The feral hog at Dye Creek Ranch, California. *Hilgardia* 46:283–355.
- Belden, R. C. and W. B. Frankenberger. 1990. Biology of a feral hog population in south central Florida. *Proc. Annu. Conf. Southeast. Assoc. Fish and Wildl. Agencies* 44:231–242.
- Bratton, S. P. 1974. The effect of the European wild boar (*Sus scrofa*) on the high elevation vernal flora in Great Smoky Mountains National Park. *Bull. Torrey Bot. Club* 101:198–206.
- . 1975. The effect of the European wild boar, *Sus scrofa*, on gray beech forest in the Great Smoky Mountains. *Ecology* 56:1356–1366.
- Brisbin, I. L., Jr., R. A. Geiger, H. B. Graves, J. E. Pinder, III, J. M. Sweeney, and J. R. Sweeney. 1977. Morphological characterizations of two populations of feral swine. *Acta Theriol.* 22:75–85.
- Coblentz, B. E. and D. W. Baber. 1987. Biology and control of feral pigs on Isla Santiago, Galapagos, Ecuador. *J. Appl. Ecol.* 24:403–418.
- Corn, J. L. and R. J. Warren. 1985. Seasonal variation in nutritional indices of collared peccaries in South Texas. *J. Wildl. Manage.* 49:57–65.
- Dauphine, J. C. 1975. Kidney weight fluctuations affecting the kidney fat index in caribou. *J. Wildl. Manage.* 39:379–386.
- Everitt, J. H. and M. A. Alaniz. 1980. Fall and winter diets of feral pigs in South Texas. *J. Range Manage.* 33:126–129.
- Finger, S. E., I. L. Brisbin, Jr., and M. H. Smith. 1981. Kidney fat as a predictor of body condition in white-tailed deer. *J. Wildl. Manage.* 45:964–968.
- Hanson, R. P. and L. Karstad. 1959. Feral swine in the southeastern United States. *J. Wildl. Manage.* 23:64–74.
- Harder, J. D. and R. L. Kirkpatrick. 1994. Physiological methods in wildlife research. Pages 275–306 in T. A. Bookhout, ed. *Research and management techniques for wildlife and habitats*. 5th ed. The Wildl. Soc., Washington, D. C.
- Harlow, R. F., J. B. Whelan, H. S. Crawford, and J. E. Skeen. 1975. Deer foods during years of oak mast abundance and scarcity. *J. Wildl. Manage.* 39:330–336.
- Henry, V. G. 1970. Weights and body measurements of European wild hogs in Tennessee. *J. Tenn. Acad. Sci.* 45:20–23.
- and R. H. Conley. 1972. Fall foods of European wild hogs in the southern Appalachians. *J. Wildl. Manage.* 36:854–860.
- Hillestad, H. O., J. R. Bozeman, A. S. Johnson, C. W. Berisford, and J. I. Richardson. 1975. The ecology of the Cumberland Island National Seashore, Camden County, Georgia. *Tech. Rep. Ser. No. 75–5*, Ga. Mar. Sci. Center, Skidaway Island, Ga. 299pp.
- Holechek, J. L. and B. D. Gross. 1982. Evaluation of different calculation procedures for microhistological analysis. *J. Range Manage.* 35:721–723.
- Johns, P. E., M. H. Smith, and R. K. Chesser. 1984. Annual cycles of the kidney fat index in a southeastern white-tailed deer herd. *J. Wildl. Manage.* 48:969–973.
- Johnson, M. K., H. Wofford, and H. A. Pearson. 1983. Microhistological techniques for food habits analyses. U.S. Dep. Agric., For. Serv. South. For. Exp. Sta. Res. Paper SO-199, New Orleans, La. 40pp.
- Johnson, A. S., H. O. Hillestad, S. F. Shanholtzer, and G. F. Stanholtzer. 1974. An ecological survey of the coastal region of Georgia. U.S. Dep. Int., Nat. Park Serv. Sci. Monogr. Ser. No. 3, Washington, D.C. 233pp.
- Kie, J. G., M. White, and D. L. Drawe. 1983. Condition parameters of white-tailed deer in Texas. *J. Wildl. Manage.* 47:583–594.

- Matschke, G. H. 1964. The influence of oak mast on European wild hog reproduction. Proc. Annu. Conf. Southeast. Assoc. Game and Fish Comm. 18:35-39.
- Pence, D. B., R. J. Warren, and C. R. Ford. 1988. Visceral helminth communities of an insular population of feral swine. J. Wildl. Dis. 24:105-112.
- Pickett, T. A. and F. F. Cowart. 1941. Carbohydrate changes in muscadine grape shoots during the growing season. Proc. Am. Soc. Hort. Sci. 38:393-396.
- Riney, T. 1955. Evaluating condition of free-ranging red deer (*Cervus elaphus*) with special reference to New Zealand. New Zealand J. Sci. Tech. 36B:429-463.
- SAS Institute, Inc. 1985. SAS/STAT guide for personal computers, version 6 ed. SAS Inst., Inc., Cary, N.C. 378pp.
- Scott, C. D. and M. R. Pelton. 1975. Seasonal food habits of the European wild hog in the Great Smoky Mountains National Park. Proc. Annu. Conf. Southeast. Assoc. Game and Fish Comm. 29:585-593.
- Smith, N. S. 1970. Appraisal of condition estimation methods for East African ungulates. East Afr. Wildl. J. 8:123-129.
- Sokal, R. R. and F. J. Rohlf. 1969. Biometry. W. H. Freeman and Co., San Francisco, Calif. 776pp.
- Stribling, H. L., I. L. Brisbin, Jr., J. R. Sweeney, and L. A. Stribling. 1984. Body fat reserves and their prediction in two populations of feral swine. J. Wildl. Manage. 48:635-639.
- Sweeney, J. M., J. R. Sweeney, and E. E. Provost. 1979. Reproductive biology of a feral hog population. J. Wildl. Manage. 43:555-559.
- Taylor, D. and L. Katahira. 1988. Radio telemetry as an aid in eradicating remnant feral goats. Wildl. Soc. Bull. 16:297-299.
- Tecator, Inc. 1981. Determination of Kjeldahl nitrogen content with Kjeltach Auto Systems I, II, III, and IV. Application Note No. 30/81, Tecator, Inc., Herndon, Va. 5pp.
- Ullrey, D. E., J. I. Sprague, D. E. Becker, and E. R. Miller. 1965. Growth of the swine fetus. J. Anim. Sci. 24:711-717.
- Verme, L. J. and J. J. Ozoga. 1980a. Influence of protein-energy intake on deer fawns in autumn. J. Wildl. Manage. 44:305-314.
- and ———. 1980b. Effects of diet on growth and lipogenesis in deer fawns. J. Wildl. Manage. 44:315-324.
- Waid, D. D. and R. J. Warren. 1984. Seasonal variations in physiological indices of adult female white-tailed deer in Texas. J. Wildl. Dis. 20:212-219.
- Warren, R. J. and R. L. Kirkpatrick. 1978. Indices of nutritional status in cottontail rabbits fed controlled diets. J. Wildl. Manage. 42:154-158.
- and ———. 1982. Evaluating nutritional status of white-tailed deer using fat indices. Proc. Annu. Conf. Southeast. Assoc. Fish and Wildl. Agencies 36:463-472.
- Winkler, A. J. and W. O. Williams. 1945. Starch and sugars of *Vitis vinifera*. Plant Physiol. 20:412-432.
- Wood, G. W. and R. H. Barrett. 1979. Status of wild pigs in the United States. Wildl. Soc. Bull. 7:237-246.
- and T. E. Lynn, Jr. 1977. Wild hogs in southern forests. South. J. Appl. For. 1:12-17.
- and D. N. Roark. 1980. Food habits of feral hogs in coastal South Carolina. J. Wildl. Manage. 44:506-511.
- Zimmerman, D. R., H. G. Spies, H. L. Self, and L. E. Casida. 1960. Ovulation rate in swine as affected by increased energy intake just prior to ovulation. J. Anim. Sci. 19:295-301.