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Seasonal activity and road mortality of the snakes of the Pa-Hay-Okee wetlands of Everglades National Park

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SEASONAL ACTIVITY AND ROAD MORTALITY
OF THE SNAKES OF THE PA-HAY-OKEE WETLANDS
OF EVERGLADES NATIONAL PARK

by

FRANK S. BERNARDINO, JR.

A thesis submitted in partial fulfillment of the

requirements for a degree of

MASTER OF SCIENCE

in

BIOLOGICAL SCIENCES

at

FLORIDA INTERNATIONAL UNIVERSITY

1990

ABSTRACT

SEASONAL ACTIVITY AND ROAD MORTALITY OF THE SNAKES OF THE PA-HAY-OKEE WETLANDS OF EVERGLADES NATIONAL PARK

by

Frank S. Bernardino, Jr.

The current study describes the composition and activity of the snake community of the Pa-hay-okee wetlands of Everglades National Park. The study was conducted from January 1987 to January 1989. Sixteen species were observed, with Thamnophis sauritus, Thamnophis sirtalis, Nerodia fasciata pictiventris, and Agkistrodon piscivorus representing 90.2% of the total sample. The seasonal distribution and activity of the snakes were closely related to fluctuations in the water table. Most activity occurred in the winter months as snakes migrated west following the drying water edge of Shark River Slough. Seventy percent of all snakes observed during this study were either injured or dead on the road. Over 50% of annual mortality occurred during migration. The impact that road mortality is having on the local snake community cannot be ignored. Management options are provided to minimize loss. A comparison is made to the snake community of the Long Pine Key Region of Everglades National Park.

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Committee in charge:

Dr. George H. Dalrymple Chairperson

Dr. William B. Robertson, Jr.

Dr. J. Eric Juterbock

July 1990

To Dr. George H. Dalrymple

Dr. William B. Robertson, Jr.

Dr. J. Eric Juterbock

This thesis, having been approved in respect to form and mechanical execution, is referred to you for judgement upon its substantial merit.

Dean James A. Mau

College of Arts and Sciences

The thesis of Frank S. Bernardino, Jr. is approved.

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Date of Examination: July 23, 1990

PROPOSAL FOR RESEARCH THESIS

MASTER OF SCIENCE DEGREE

FLORIDA INTERNATIONAL UNIVERSITY

COLLEGE OF ARTS AND SCIENCES

BIOLOGICAL SCIENCES

Frank S. Bernardino, Jr.

I propose to the Guidance Committee a study of the following topic to be conducted in partial fulfillment of the requirements for the degree of Master of Science: SEASONAL ACTIVITY AND ROAD MORTALITY OF THE SNAKES OF THE PA-HAY-OKEE WETLANDS OF EVERGLADES NATIONAL PARK.

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INTRODUCTION

Dalrymple (1986) and Dalrymple, Steiner, et al, (In press) described the overall seasonal activity of snakes of Long Pine Key (LPK), the major upland area of Everglades National Park (ENP), as a modified temperate zone pattern. They noted a prolonged period of annual activity due to subtropical temperatures. Most activity occurred at the beginning of the wet season in May and June and prior to the beginning of the dry season in October and November.

Preliminary surveys of the Pa-hay-okee wetlands in 1986 revealed that snakes remained more active there than in LPK during winter months, a period characterized by declining water levels throughout the region. The increased winter activity coincided with the period of greatest vehicular activity in ENP resulting in significant mortality, with 144 (93%) of the 155 snakes observed on the Main Park Road found dead or injured (Dalrymple, unpublished data).

The main objectives of this study were to determine the composition of the snake community of the Pa-hay-okee wetlands, evaluate the pattern of seasonal activity as it relates to changes in hydrology and temperature, evaluate road mortality and propose management alternatives to reduce it. This study showed that a significant difference existed between the patterns of seasonal activity of the upland and the wetland snakes of ENP. Snake activity within the Pa-hay-okee wetlands was closely related to fluctuations in the water table, and this relationship can be used to predict migratory behavior and enact management to reduce road mortality.

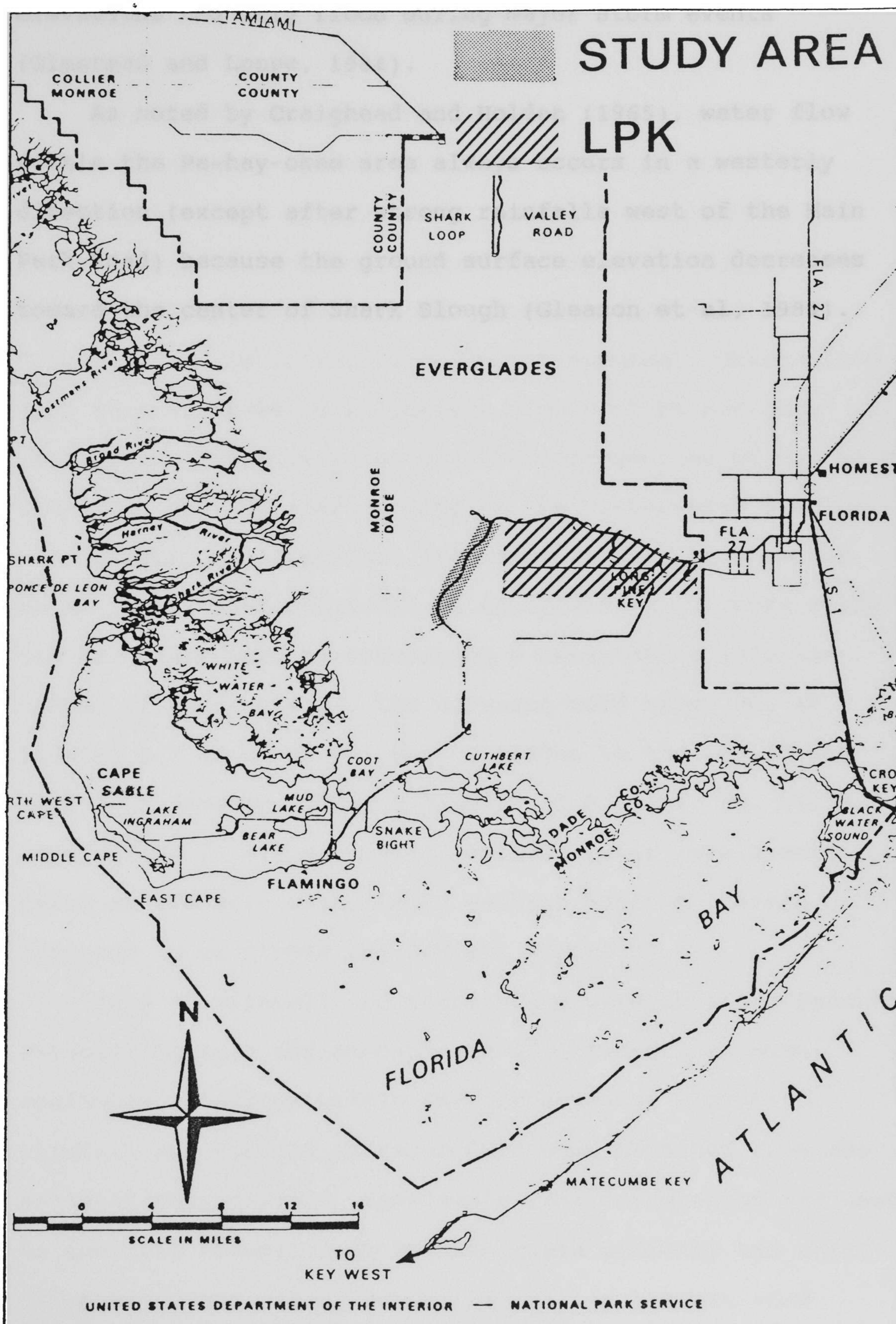
STUDY AREA

The Pa-hay-okee wetlands lie between 21.4 km and 32.9 km west of the Everglades National Park main entrance, along the Main Park Road (U.S.G.S., 1964). The northern portion of the area lies within the Shark River Slough basin (Figure 1). The Shark River Slough is the primary freshwater feature in ENP, flowing from the north to the southwest and draining into Florida Bay. Seasonally inundated cypress flats with interspersed cypress domes and mixed hardwood forests dominate the northern 4.8 km of the area. The cypress community floods six to nine months of the year and is the last to dry down within the study area at the begining of each dry season.

The southern portion of the Pa-hay-okee area is dominated by sawgrass prairie. Mixed hardwood tree islands are isolated on slightly elevated substrate within the prairie (Olmstead and Loope, 1984). Due to higher moisture levels in the interior of the tree islands their cores are seldom affected by fires, and provide refugia for wildlife. The sawgrass prairie is characterized by three to six month hydroperiods. The herbaceous vegetation in this area tends to be denser and of greater diversity than in cypress flats (Steward, 1984).

Pinelands border the entire study area to the east and only contact the Main Park Road at the southern end of the segment of road surveyed. Pinelands occur on higher

Figure 1. Map of Everglades National Park delineating the Long Pine Key Region and the current study area (after a Department of Interior Map of ENP).


STUDY AREA
LPK
TAMIAMI
COLLIER
MONROE
COUNTY
COUNTY
COUNTY
COUNTY
SHARK
LOOP
VALLEY
ROAD
FLA 27
EVERGLADES
Lostmans River
Broad River
Harney River
Shark River
MONROE
DADE
HOMEST
FLORIDA
FLA
27
LONG PINE KEY
U.S. 1
SHARK PT
PONCE DE LEON
BAY
WHITE
WATER
BAY
CAPE
SABLE
COOT
BAY
CUTHBERT
LAKE
MUD
LAKE
LAKE
INGRAHAM
BEAR
LAKE
SNAKE
BIGHT
DADE
MONROE
CO
CO
CRO
KEY
BLACK
WATER
SOUND
MIDDLE CAPE
FLAMINGO
EAST CAPE
BAY
N
FLORIDA
ATLANTIC
MATECUMBE KEY
0
4
8
12
16
SCALE IN MILES
TO
KEY WEST
UNITED STATES DEPARTMENT OF THE INTERIOR — NATIONAL PARK SERVICE

elevations and only flood during major storm events (Olmstead and Loope, 1984).

As noted by Craighead and Holden (1965), water flow within the Pa-hay-okee area always occurs in a westerly direction (except after strong rainfalls west of the Main Park Road) because the ground surface elevation decreases toward the center of Shark Slough (Gleason et al, 1984).

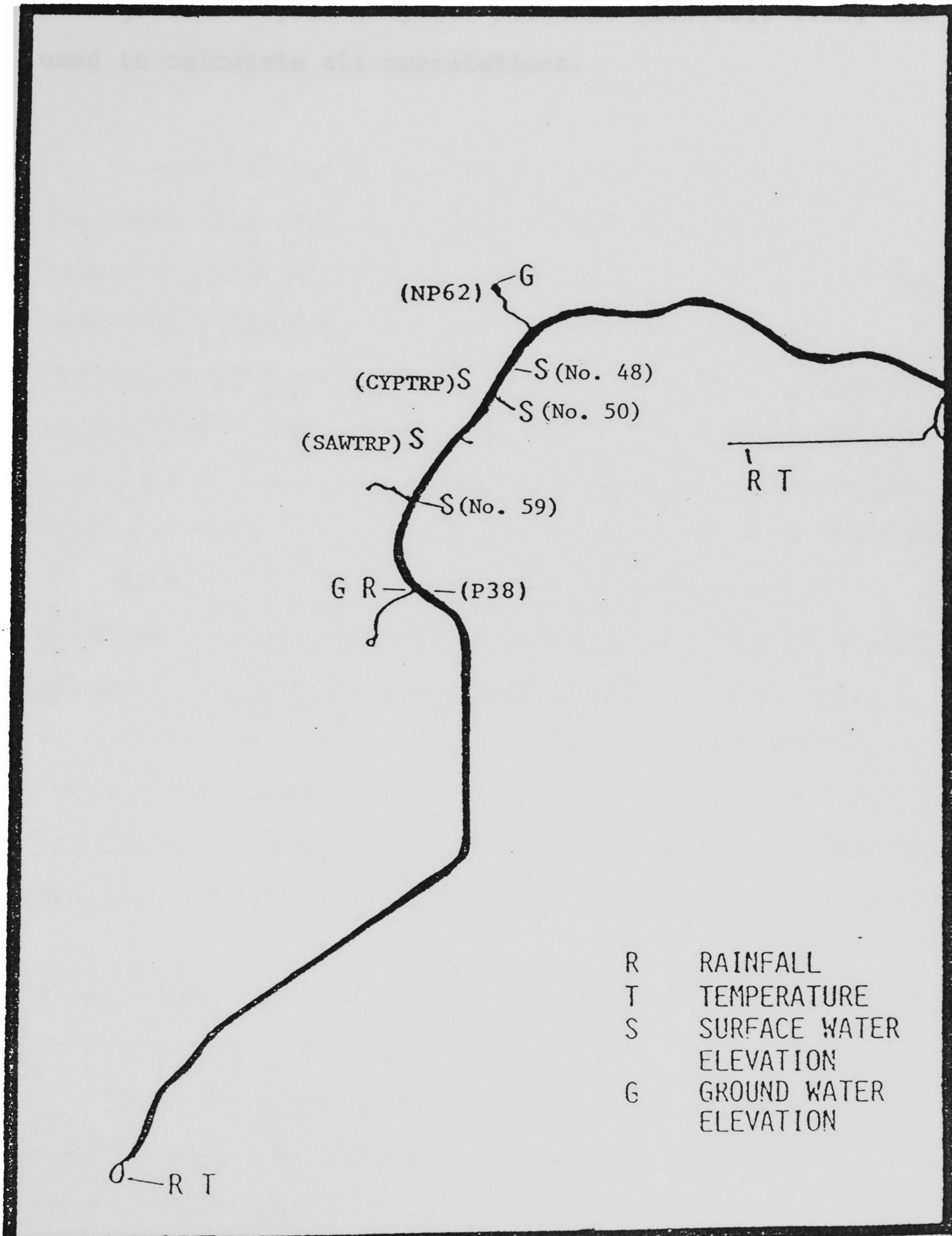
METHODS

Most data were collected through road cruising once a week beginning at sundown and ending at midnight, from February 1987 to January 1989. Information collected for snakes included: time of collection, species, age (adult, juvenile, young of year), sex, status (live, dead or injured), and if alive, direction of movement. Observation data were recorded as kilometers "South of Pa-hay-okee" (S. of P.); the starting point was the intersection of the Main Park Road and the road leading to the Pa-hay-okee overlook.

Starting in September 1987 measurements on standing water levels were collected in the field at culverts along the Main Park Road by submerging a meter stick into the center of each culvert. The culverts used were: No. 48, located 1.7 km S. of P.; No. 50 (added to the monitoring system in January 1988), 2.3 km S. of P.; and, No. 59, 8.1 km S. of P. (U.S.G.S., 1964). Surface water levels were taken at one site within each wetland habitat (herein referred to as CYPTRP and SAWTRP; Figure 2).

Data on rainfall and temperature were obtained from the National Oceanic and Atmospheric Administration (NOAA) monitoring stations within ENP. Groundwater elevation, rainfall and vehicle entrance data were obtained from the National Park Service. Spearman's rank correlation was used to evaluate associations between snake activity and rain, temperature and water levels, as well as between road

Figure 2. Sites where data on temperature, rainfall, surface and groundwater elevations were gathered.



(NP62) G
S (No. 48)
(CYPTRP) S
S (No. 50)
(SAWTRP) S
R T
S (No. 59)
G R
(P38)
R T
R RAINFALL
T TEMPERATURE
S SURFACE WATER ELEVATION
G GROUND WATER ELEVATION

mortality and auto traffic (McClave and Dietrich, 1985). The Ecological Analysis computer software (Eckblad, 1986) was used to calculate all correlations.

RESULTS

1. Snake Community Composition

A total of 1,018 specimens of 16 taxa were recorded in the study area (Table 1). Nine of the 16 taxa were viviparous and collectively represented 99% of all of the individuals captured. The most common species were: Thamnophis sauritus (N = 299, 29.4% of total), Thamnophis sirtalis (N = 258, 25.3%), Nerodia fasciata pictiventris (N = 233, 22.9%) and Agkistrodon piscivorus (N = 128, 12.6%; Table 2). These four species represented 90.2% of the total.

Less common were Coluber constrictor, Nerodia cyclopion, Nerodia fasciata compressicauda, Regina alleni, Sistrurus miliarius and Storeria dekayi, collectively representing 8.8% of the total. The six rarest species, Cemophora coccinea, Diadophis punctatus, Farancia abacura, Lampropeltis getulus, Lampropeltis triangulum and Opheodrys aestivus, collectively represented 1.0% of the total sample.

2. Activity

Snake activity within the study area was most significantly affected by seasonal fluctuations of surface water levels (Figure 3). There was a significant negative correlation between monthly changes in water levels at Culvert No. 50 and the number of snakes observed on the MPR

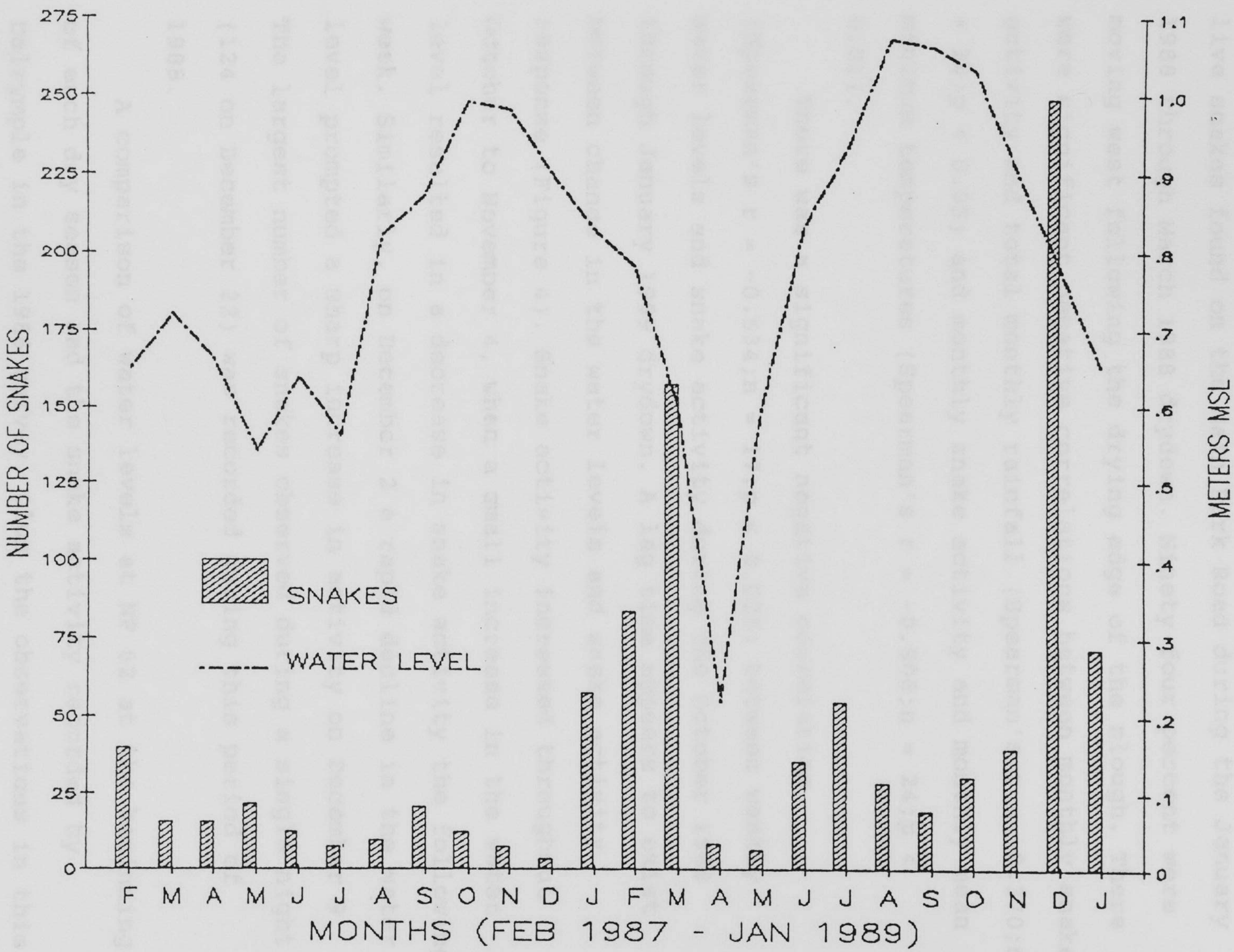
Table 1. Species recorded in the Pa-hay-okee Wetlands of Everglades National Park, Dade County, Florida.

TAXA	COMMON NAME
Agkistrodon piscivorus	Cottonmouth
Cemophora coccinea	Scarlet Snake
Coluber constrictor	Black Racer
Diadophis punctatus	Ringneck Snake
Farancia abacura	Mud Snake
Lampropeltis getulus	Kingsnake
Lampropeltis triangulum	Scarlet Kingsnake
Nerodia cyclopion	Green Water Snake
Nerodia fasciata compressicauda	Mangrove Water Snake
Nerodia fasciata pictiventris	Banded Water Snake
Opheodrys aestivus	Rough Green Snake
Regina alleni	Crayfish Snake
Sistrurus miliarius	Pygmy Rattlesnake
Storeria dekayi	Brown Snake
Thamnophis sauritus	Ribbon Snake
Thamnophis sirtalis	Garter Snake

Table 2. Total and number of each species per month in the study area between February 1987 and January 1989.

MONTHS	SPECIES																TOTAL
	Agk	Cem	Col	Dia	Far	Lge	Ltr	Ncy	Nfc	Nfp	Oph	Ral	Sis	Sto	Tsa	Tsi	
FEB 87	8	0	1	0	0	0	0	0	0	7	0	0	0	1	12	11	40
MAR "	3	0	0	0	0	0	0	0	0	1	1	0	1	1	6	3	16
APR "	3	0	0	0	0	0	0	0	0	4	0	0	0	1	5	3	16
MAY "	6	0	0	0	0	1	0	0	0	1	0	0	1	2	4	7	22
JUN "	2	2	0	0	0	0	0	0	0	2	0	0	0	1	3	2	13
JUL "	1	0	1	0	0	0	0	0	0	0	0	0	1	0	3	1	7
AUG "	1	0	1	0	0	0	1	0	0	2	0	0	1	0	0	4	10
SEP "	8	0	1	0	0	0	0	0	0	4	0	0	1	2	3	3	21
OCT "	4	0	0	0	0	0	0	0	1	5	0	0	0	0	2	1	13
NOV "	0	0	0	0	0	0	0	0	0	4	0	0	2	1	1	0	8
DEC "	1	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	4
JAN 88	8	0	0	0	0	0	0	2	0	13	0	0	2	0	18	15	58
FEB "	4	0	0	0	0	0	0	2	1	7	0	0	3	5	19	43	84
MAR "	17	0	0	0	0	0	0	2	0	9	0	1	1	6	52	70	158
APR "	2	0	0	0	0	0	0	0	0	1	0	1	0	0	2	3	9
MAY "	5	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	7
JUN "	13	1	0	0	1	0	0	0	0	6	0	1	0	1	9	4	36
JUL "	14	0	0	0	0	0	0	1	1	18	0	0	2	6	13	0	55
AUG "	6	0	0	0	0	0	0	2	0	17	0	0	0	0	4	0	29
SEP "	8	0	0	0	0	0	0	0	0	8	0	1	2	0	0	0	19
OCT "	5	0	0	0	0	0	0	5	2	7	0	2	3	0	5	2	31
NOV "	2	0	0	0	0	0	0	3	1	23	0	0	0	0	10	1	40
DEC "	3	0	1	1	0	1	0	3	1	76	0	0	3	0	101	59	250
JAN 89	4	0	0	0	0	0	0	0	1	17	0	0	1	0	24	25	72
TOTAL	128	3	5	1	1	2	1	20	8	233	1	6	24	27	299	258	1,018

Figure 3. Monthly number of snakes and surface water levels at NP 62 between February 1987 and January 1989.


NUMBER OF SNAKES
METERS MSL
SNAKES
WATER LEVEL
F M A M J J A S O N D J F M A M J J A S O N D J
MONTHS (FEB 1987 - JAN 1989)

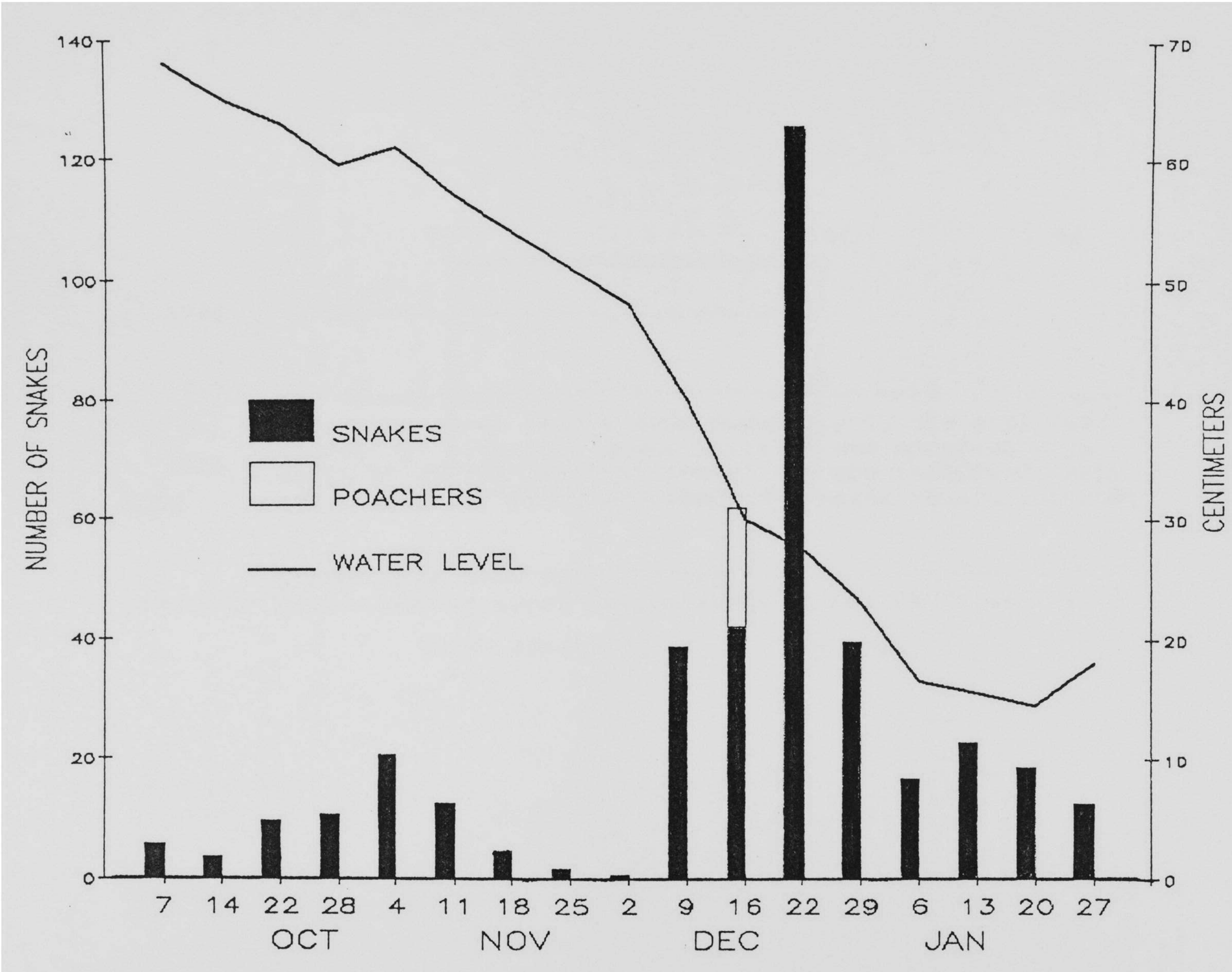
(Spearman's $r = -0.678; n = 12; p < 0.05$). Data on the direction of snake movement were recorded for 89% of the live snakes found on the Main Park Road during the January 1988 through March 1988 drydown. Ninety four percent were moving west following the drying edge of the slough. There were significant negative correlations between monthly snake activity and total monthly rainfall (Spearman's $r = -0.370; n = 24; p < 0.05$) and monthly snake activity and monthly mean minimum temperatures (Spearman's $r = -0.500; n = 24; p < 0.01$).

There was a significant negative correlation (Spearman's $r = -0.534; n = 17; p < 0.025$) between weekly water levels and snake activity during the October 1988 through January 1989 drydown. A lag time appears to exist between change in the water levels and snake activity response (Figure 4). Snake activity increased throughout October to November 4, when a small increase in the water level resulted in a decrease in snake activity the following week. Similarly, on December 2 a rapid decline in the water level prompted a sharp increase in activity on December 9. The largest number of snakes observed during a single night (124 on December 22) was recorded during this period of 1988.

A comparison of water levels at NP 62 at the beginning of each dry season and the snake activity recorded by Dalrymple in the 1986 survey, plus the observations in this study (Figure 5) reveal that the earliest snake migratory

Figure 4. Number of snakes per trip and weekly water levels at culvert No. 48 during the October 1988 through January 1989 drydown.

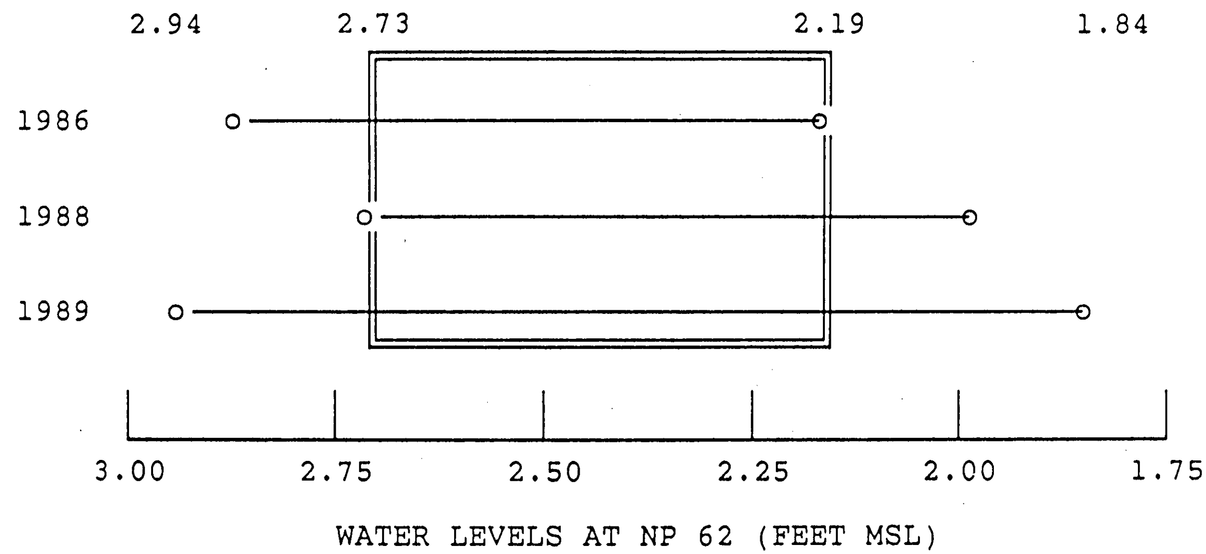
NOTE On December 16, 1989 snake collectors illegaly removed all snakes from the northern three miles of the road transect. Under questioning by Park rangers the poachers admitted to removing over 20 snakes off of the Main Park Road. This information has been added here to properly illustrate the increase in snake activity that would have been recorded if not for the unfortunate incident.



NUMBER OF SNAKES
140
120
100
80
60
40
20
0
CENTIMETERS
70
60
50
40
30
20
10
0
SNAKES
POACHERS
WATER LEVEL
7 14 22 28 4 11 18 25 2 9 16 22 29 6 13 20 27
OCT
NOV
DEC
JAN

Figure 5. Comparison of water levels at NP 62 during three drydowns between 1986 and 1989.

NOTE The horizontal lines represent the water levels recorded at NP 62 at the begining (left) and end (right) of each migration. Migratory snake activity was observed each year when water levels were between 2.73 and 2.19 feet MSL (boxed area).


2.94
2.73
2.19
1.84
1986
1988
1989
3.00
2.75
2.50
2.25
2.00
1.75
WATER LEVELS AT NP 62 (FEET MSL)

activity in response to a decline in the water table occurred in 1989 when the water level at NP 62 was 2.94 feet MSL (approximately 23.0 cm standing water at CYPTRP). The most delayed response occurred in 1988 when the water level at the same station was 2.73 feet MSL (approximately 14 cm in the cypress flats). Snake migratory activity was observed in all the years after water levels fell below 2.73 feet MSL at NP 62 and ceased after water levels had fallen below ground elevation at the CYPTRP site (approximately 2.25 feet MSL at NP 62).

When the section of road surveyed was subdivided into half kilometer segments, two portions of the road stood out as being most used by snakes (Figure 6). Twenty eight percent of the snakes were observed in the northernmost two kilometers of the study area moving between cypress flats. Thirty one percent were recorded between the sixth and ninth kilometers S. of P. moving in sawgrass prairies.

3. Mortality

The number of vehicles entering ENP begins to increase in November and peaks in February with approximately 20,000+ autos using the Main Park Road (Figure 7). The least auto traffic occurs in June (approximately 7,000 vehicles). Over 70% of all snakes found on the Main Park Road between February 1987 and January 1989 were either dead or injured (DOR). Although there was a significant correlation between

Figure 6. Number of snakes observed South of Pa-hay-okee between February 1987 and January 1989 in half kilometer intervals.

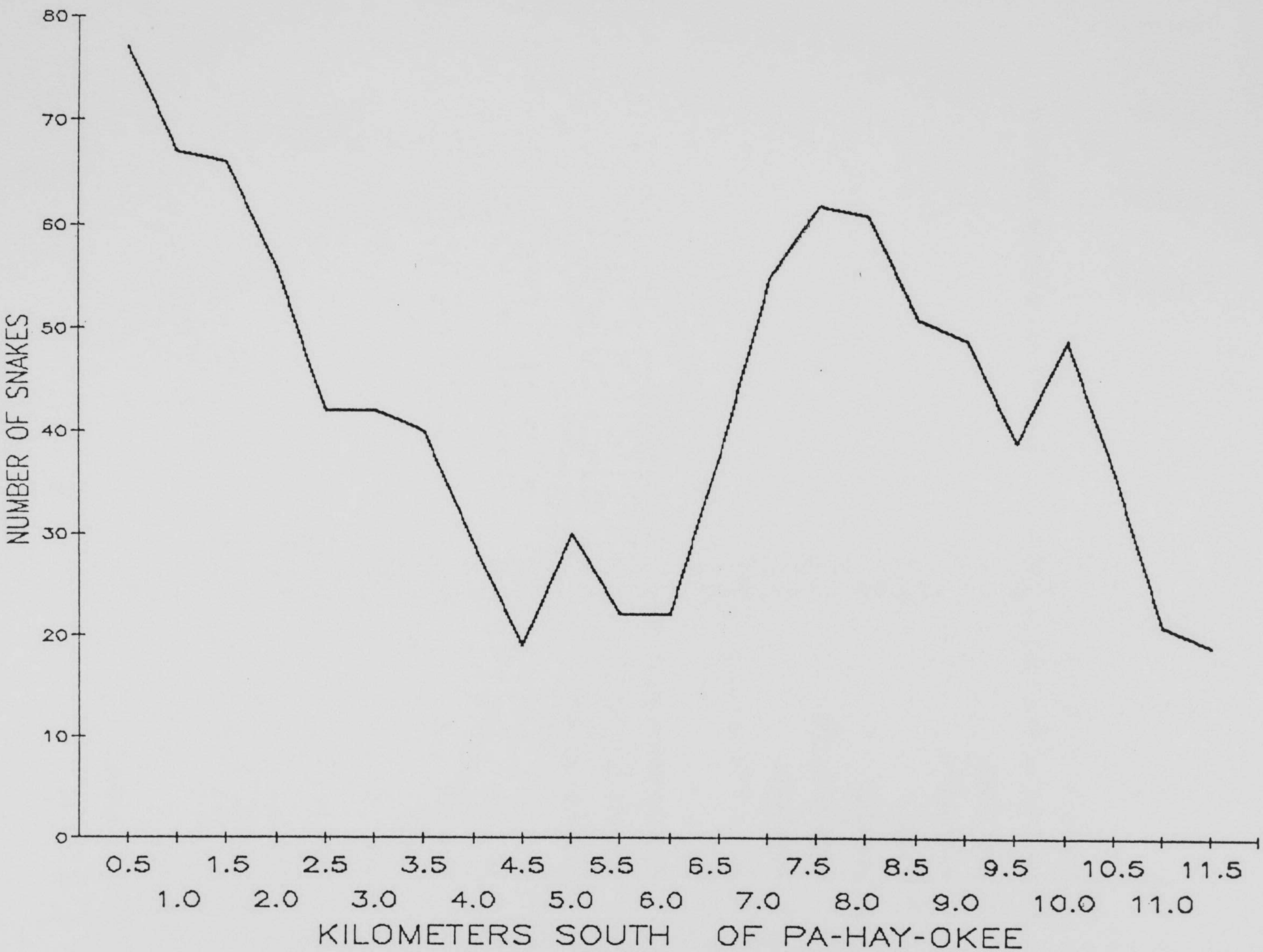
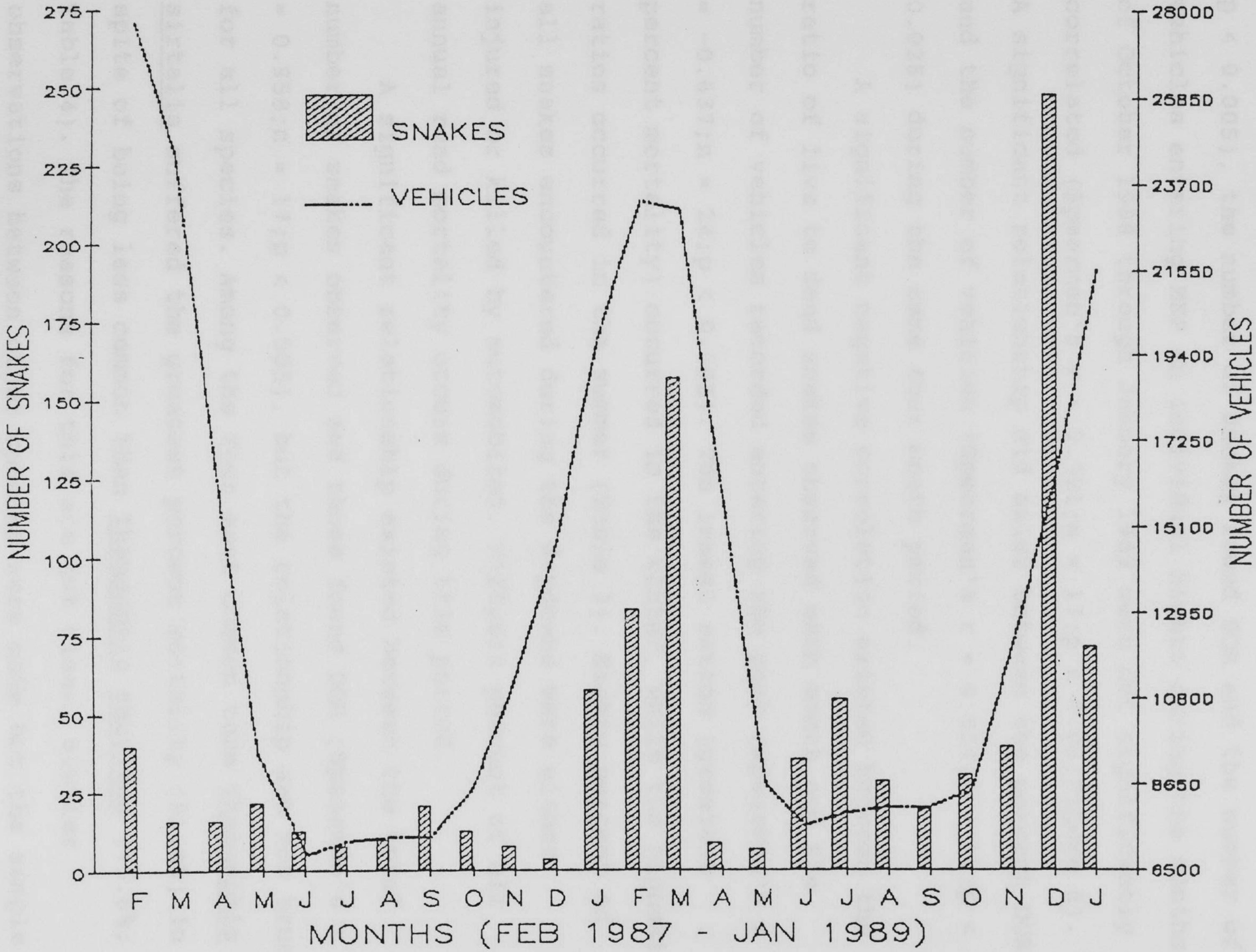

NUMBER OF SNAKES
0
10
20
30
40
50
60
70
80
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5
6.0
6.5
7.0
7.5
8.0
8.5
9.0
9.5
10.0
10.5
11.0
11.5
KILOMETERS SOUTH OF PA-HAY-OKEE

Figure 7. Monthly number of snakes and monthly number of vehicles recorded at Flamingo between February 1987 and January 1989.



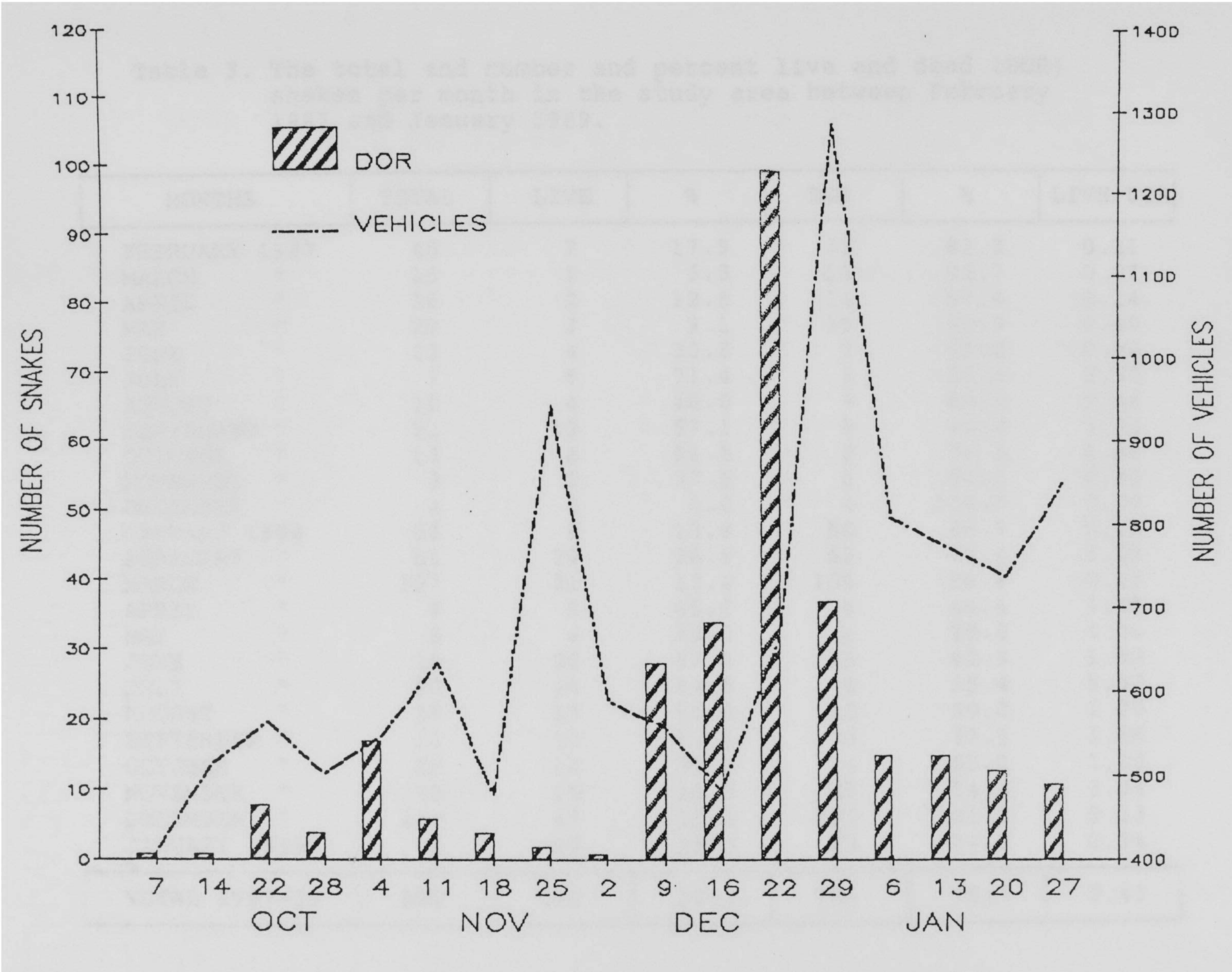
SNAKES
VEHICLES
NUMBER OF SNAKES
275
250
225
200
175
150
125
100
75
50
25
0
NUMBER OF VEHICLES
28000
25850
23700
21550
19400
17250
15100
12950
10800
8650
6500
F M A M J J A S O N D J F M A M J J A S O N D J
MONTHS (FEB 1987 - JAN 1989)

the monthly number of vehicles entering ENP and the monthly number of snakes found DOR (Spearman's $r = 0.550; n = 24; p < 0.005$), the number of snakes found DOR and the number of vehicles entering ENP on individual nights during the months of October 1988 through January 1989 were not significantly correlated (Spearman's $r = 0.321; n = 17; p < 0.05$; Figure 8). A significant relationship did exist between the percent DOR and the number of vehicles (Spearman's $r = 0.534; n = 17; p < 0.025$) during the same four month period.

A significant negative correlation existed between the ratio of live to dead snakes observed each month and the number of vehicles recorded entering the park (Spearman's $r = -0.637; n = 24; p < 0.005$). The lowest ratios (greatest percent mortality) occurred in the winter, while the highest ratios occurred in the summer (Table 3). Eighty percent of all snakes encountered during the drydowns were either injured or killed by automobiles. Fiftysix percent of all annual road mortality occurs during this period.

A significant relationship existed between the total number of snakes observed and those found DOR (Spearman's $r = 0.958; n = 17; p < 0.005$), but the relationship was not true for all species. Among the four most common taxa *Thamnophis sirtalis* suffered the greatest percent mortality (81.4%) in spite of being less common than *Thamnophis sauritus* (75.6%; Table 4). The reasons for this are not clear. Similar observations between other species were made but the sample sizes were too small to draw any significant conclusions.

Figure 8. Number of dead or injured snakes per trip and the number of vehicles entering ENP on the same day between October 1988 and January 1989.



DOR
VEHICLES
NUMBER OF SNAKES
NUMBER OF VEHICLES
0
10
20
30
40
50
60
70
80
90
100
110
120
400
500
600
700
800
900
1000
1100
1200
1300
1400
7 14 22 28 4 11 18 25 2 9 16 22 29 6 13 20 27
OCT NOV DEC JAN

Table 3. The total and number and percent live and dead (DOR) snakes per month in the study area between February 1987 and January 1989.

MONTHS	TOTAL	LIVE	%	DOR	%	LIVE/DOR
FEBRUARY 1987	40	7	17.5	33	82.5	0.21
MARCH "	16	1	6.3	15	93.7	0.07
APRIL "	16	2	12.6	14	87.4	0.14
MAY "	22	3	9.1	19	90.9	0.10
JUNE "	13	4	30.8	9	69.2	0.44
JULY "	7	5	71.4	2	28.6	2.50
AUGUST "	10	4	40.0	6	60.0	0.66
SEPTEMBER "	21	12	57.1	9	42.9	1.33
OCTOBER "	13	8	61.5	5	38.5	1.60
NOVEMBER "	8	3	37.5	5	62.5	0.60
DECEMBER "	4	0	0.0	4	100.0	0.00
JANUARY 1988	58	8	13.8	50	86.2	0.16
FEBRUARY "	84	19	22.6	65	77.4	0.29
MARCH "	157	21	13.4	136	86.6	0.15
APRIL "	9	5	65.6	4	44.4	1.25
MAY "	5	4	80.0	1	20.0	4.00
JUNE "	35	20	57.1	15	42.9	1.33
JULY "	52	44	84.6	8	15.4	5.50
AUGUST "	26	13	50.0	13	50.0	1.00
SEPTEMBER "	16	10	62.5	6	37.5	1.66
OCTOBER "	28	14	50.0	14	50.0	1.00
NOVEMBER "	39	10	25.6	29	74.4	0.34
DECEMBER "	248	47	19.0	201	81.0	0.23
JANUARY 1989	71	18	25.3	53	74.7	0.34
TOTAL 1987-89	998	292	29.3	706	70.7	0.41

Table 4. The total and number and percent live and dead (DOR) snakes per species in the study area between February 1987 and January 1989.

TAXA	TOTAL	LIVE	%	DOR	%
Agkistrodon	120	52	43.3	68	56.7
Cemophora	3	2	66.6	1	33.4
Coluber	5	0	0.0	5	100.0
Farancia	1	1	100.0	0	0.0
L. getulus	2	0	0.0	2	100.0
L. triangulum	1	1	100.0	0	0.0
N. cyclopion	17	6	35.3	11	64.7
N. fasciata p.	230	80	34.2	150	65.8
N. fasciata c.	7	3	42.9	4	57.1
Opheodrys	1	0	0.0	1	100.0
R. alleni	5	4	80.0	1	20.0
Sistrurus	23	10	43.5	13	56.5
Stoteria	27	14	51.9	13	48.1
T. sauritus	298	72	24.2	226	75.8
T. sirtalis	258	47	18.2	211	81.8
TOTAL	998*	292	29.3	706	70.7

* NOTE A single Diadophis was found on the road inside the stomach contents of an L. getulus and therefore was not included in these calculations.

DISCUSSION

1. Species List

Fourteen of the 20 species listed for the Long Pine Key region of ENP (Dalrymple, Bernardino, et al, In press) occurred in the Pa-hay-okee wetlands. The LPK species not observed in the Pa-hay-okee area were: Nerodia taxispilota, Drymarchon corais, Crotalus adamanteus, Micrurus fulvius, Elaphe guttata and Elaphe obsoleta. The two species found in the Pa-hay-okee wetlands that do not occur in LPK were Nerodia fasciata compressicauda and Nerodia cyclopion.

N. cyclopion is most commonly associated with habitats having longer hydroperiods than those found in LPK. Ashton and Ashton (1981) describe N. f. compressicauda as restricted to black and red mangrove swamps, canals and brackish swamps. This species was collected as far north on the Main Park Road as 5.6 km S. of P., approximately 0.8 km south of Sisal Hammock, in a sawgrass prairie. This is the northernmost record for the species within Everglades National Park. Its distribution within the Everglades therefore remains unclear. The only species expected but not observed within the study area was Seminatrix pygaea. This species is described by Ashton and Ashton (1981) as preferring cypress swamps suggesting it may require longer hydroperiods than those in the Pa-hay-okee wetlands.

2. Relative Abundance and Dominance

On LPK the species with the greatest relative abundance were Thamnophis sirtalis, Sistrurus miliarius, Thamnophis sauritus, and Coluber constrictor. The most common was T. sirtalis with a relative abundance of 15.66% (Dalrymple, 1986). In the Pa-hay-okee wetlands, the most common species, T. sauritus, represented 29.4% of the total. T. sirtalis (25.3%) and N. fasciata pictiventris (22.9%) also had relative abundance values greater than the most common species on LPK. Collectively T. sirtalis, T. sauritus, and N. f. pictiventris represented 77.6% of the total in the Pa-hay-okee area. The three most common species on LPK made up only 42.7% of the upland community.

Habitat diversity is an important variable influencing the composition of snake communities in the Everglades (Means and Simberloff, 1987 and Dalrymple, Bernardino, et al, In press). As the percentage of upland area diminishes, the percentage of the community represented by those species that require those habitats to fulfill some part of their life cycle also declines. Of the 20 species listed for LPK 11 are oviparous and nine are viviparous. Collectively all of the individuals of the oviparous species represented 43% of the sample collected in LPK (Dalrymple, Bernardino, et al, In press). In Pa-hay-okee nine of the 16 taxa were viviparous and the individuals of those taxa represented 98.6% of the total sample. The relative increase in percent area that is seasonally inundated is reflected in the dominance of those taxa that do not require the limited moist upland soils for their reproduction.

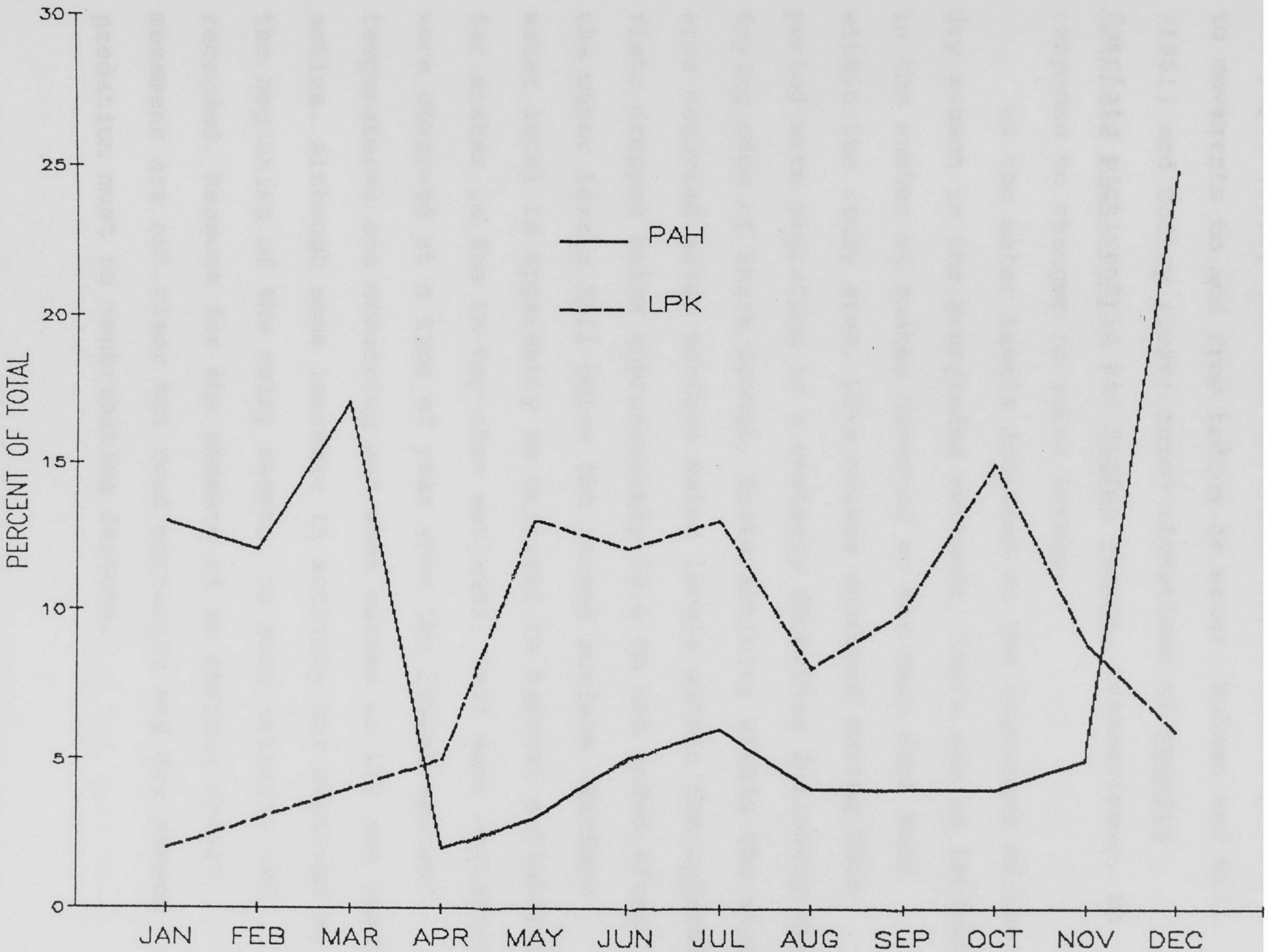
3. Activity

The activity of the snakes of the Pa-hay-okee wetlands varies significantly from that of LPK (Figure 9). Dalrymple (1986) and Dalrymple, Steiner, et al, (In press) describe the snake community of LPK as having a bimodal activity pattern. The first peak occurs between May and July and includes activity associated with spring emergence and mating. The second occurs between September and November and includes activity associated with fall breeding and recruitment. The greatest difference in activity between the two communities in ENP occurs in the winter. In LPK winter is characterized by a significant reduction in activity, whereas in the Pa-hay-okee wetlands this period coincides with a large migration associated with declining water levels.

4. Migration

Gregory, MaCartney and Larsen (1987,p.375) define migration as "the seasonal movements of snakes between habitats." Dunson and Freda (1985), Fitch (1965), Gannon

Figure 9. Percent of total annual snake activity per month in LPK (Dalrymple et al, In press) and in the Pa-hay-okee wetlands.



30
25
20
15
10
5
0
PERCENT OF TOTAL
PAH
LPK
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC

and Secoy (1985), Larsen (1987), and Reichenbach and Dalrymple (1986) have all described snake activity related to movements to and from bodies of water. Holman and Hill (1961) and Godley (1980) noted migrations of *Nerodia fasciata pictiventris* and *Regina alleni*, respectively, in response to changes in water levels.

As the water levels declined at the beginning of the dry season in the Everglades wetlands, there was an increase in the number of snakes observed on the Main Park Road within the study area. Live snakes observed during this period were migrating in a westerly direction following the drying edge of Shark Slough. Snake activity within the study area occurred after surface water levels within the cypress flats dropped below approximately 20.0 cm and ended after the water levels fell below the ground surface. Surface water level is apparently so critical to habitat suitability for snakes in the Pa-hay-okee wetlands, that mass migrations were observed at a time of year when the lowest ambient temperatures are occurring and when snakes on LPK are least active. Although some increase in activity was observed at the beginning of the rainy season, no mass activity was recorded. Reasons for the absence of an obvious return movement are not clear but road mortality and dry season predation must be contributing factors.

5. Mortality

Without absolute density estimates it is difficult to determine the impact that auto mortality may be having on the Pa-hay-okee snake community. Auto mortality may be a serious problem and is worthy of further study. The loss to such an unnatural cause within a National Park is unacceptable and probably avoidable. The mortality may be having an impact on the predator-prey interactions (Langston, 1989). Scavenging birds and mammals may stand to benefit from or may have even become dependent on an event that may be as old as the road itself, 30 years.

Options are available to minimize the impact the road mortality may be having on the snake community. In a recent conference (Langston, 1989) on amphibian road mortality in Europe and North America, several methods were discussed to avoid or reduce the loss:

1) construction of habitat capable of substituting for that sought by the migrating organisms (i.e. open bodies of water);
2) construction of wildlife underpasses;
3) closing the road on the main migratory nights;
4) installation of temporary speed zones; and
5) hand transportation of organisms across the road to insure survival (Podloucky, 1989).

The first option is clearly not acceptable within Everglades National Park where the alteration of natural processes by the creation of artificial habitats is against policy. During migration the portion of Main Park Road between the Pa-hay-okee side-road and the road leading to Mahogany Hammock could be temporarily closed, beginning approximately one half hour before dusk and ending two to three hours after sundown. A temporary "speed zone" could be created. Lower speeds may enable drivers to better avoid hitting the snakes. "Snake Crossing" signs could be posted to increase the awareness of drivers traveling through the area. These options would require many man hours and inconvenience tourists. The transportation of animals by hand across the Main Park Road is also an unsatisfactory option given a better than one in ten chance that the animal encountered could be venomous and that the work must occur on a road with a 89 kmph speed limit.

The best option is the construction of wildlife underpasses along the entire 11.3 km road segment. At a minimum the technique could be used along the first two km of the Main Park Road S. of P. and between 6.0 to 9.0 km S. of P.. Both areas were identified as heavily used by snakes. Although no long term studies have been completed verifying the effectiveness of wildlife underpasses preliminary results are encouraging. A common type of wildlife underpass is manufactured by the ACO Polymer Products, Ltd. (Langston, 1989). The technique requires plastic drift fencing to direct the animals into a funnel that leads to the excavated underpass. The underpass' upper surface has slots that allow for near ambient temperature and light penetration (Brehm, 1989).

Among the many benefits attributed to this system are: it effectively moves reptiles and amphibians through without trapping them; animals that accidentally find their way on to the road can easily move off it; the fence is easily installed, requires minimum maintenance and is not dangerous to vehicles or visitors (Brehm, 1989). The disadvantages are the possible washing of materials into the underpasses and the noise from the wheels of the vehicles as they pass overhead which may disturb the animals. The first is resolved through periodic cleaning of the underpasses by removing parts of the cover and clearing the passageway of all obstructions or waste. The second pales in comparison with the alternative of being run over by a car. Further study is necessary to determine how this method could be used within Everglades National Park.

CONCLUSIONS

1. The snake community of the Pa-hay-okee wetlands of Everglades National Park includes 16 taxa of which *Thamnophis sauritus*, *Thamnophis sirtalis*, *Nerodia fasciata pictiventris* and *Agkistrodon piscivorus* are the most common; collectively representing 90.2% of the total sample. The two taxa recorded in the Pa-hay-okee wetlands that did not occur on LPK were *Nerodia cyclopion* and *Nerodia fasciata compressicauda*. The major difference between the wetlands snake community and that of LPK was the absence of some species that prefer upland habitats and the increased relative abundance of aquatic and semi-aquatic species. The percent of the community composition that was represented by oviparous species declined from 55% on LPK to 44% in Pa-hay-okee. The percent of the total number of individuals observed comprised by viviparous species increased from 57% on LPK to 99% in Pa-hay-okee.
2. The activity pattern of snakes in the Pa-hay-okee wetlands varied seasonally. A significant negative correlation existed between changes in water levels and number of snakes observed. Most snakes were observed on the Main Park Road during winter months migrating in a westerly direction following the drying edge towards Shark Slough. The earliest snake activity associated

with a migration was recorded in October 1988 when water levels fell bellow 23 cm in the cypress flats. Reasons for the absence of return activity at the beginning of the wet season were not clear but road mortality and dry season predation may have been among the contributing factors.

3. Mortality was found to be significant; 70% of all snakes encountered were injured or dead on the road. The winter snake migration coincided with the period of greatest vehicular activity within ENP. Fifty-six percent of the annual mortality is associated with the winter migration when approximately 80% of all of the snakes observed are killed or injured by auto traffic. The impact of this mortality on the snake community and dependent predator-prey interactions may be significant. Given the predictable nature of the migratory activity and available management alternatives, the continued loss of this resource within a national park without an attempt to alleviate it is unacceptable. Ongoing studies in Europe and the United States suggest that the installation of wildlife tunnels are an effective means of reducing if not eliminating road induced mortality on populations of amphibians and reptiles. I feel this is the best option available to managers within the National Park. Any option chosen to address this situation should be monitored to evaluate its effectiveness.

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- Dalrymple, G.H., F.S. Bernardino Jr., T.M. Steiner and R. Nodell. In press. Patterns of species diversity of snake community assemblages, with data on two Everglades' snake assemblages. Copeia.
- Dalrymple, G.H., T.M. Steiner, R. Nodell and F.S. Bernardino, Jr. In press. Seasonal Activity of the Snakes of Long Pine Key, Everglades National Park. Copeia.

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