Technical Report No. 120

SNAKES AND LIZARDS OF THE PAWNEE SITE

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GRASSLAND BIOME

U. S. International Biological Program

September 1971

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ABSTRACT

Some 167 snakes were marked and released on the intensive study site during the study period of 1970. The four most numerous species present were:

i. the prairie garter snake, (*Thamnophis radix*), 140 specimens;

ii. the gopher (bull) snake, (*Pituophis catenifer*), 13 specimens;

iii. the prairie rattlesnake, (*Crotalus viridis*), 8 specimens; and

iv. the western hog-nosed snake, (*Heterodon nasicus*), 6 specimens.

In addition to these, 27 prairie rattlesnakes (*C. viridis*) were collected near the intensive study site for egg counts, fat body weights, dry weights, and ash weights. Continuous trapping by using drift fence-funnel traps was the most effective collecting method for snakes. However, most garter snakes were caught by hand. Snake populations on the intensive site, except immediately around Cottonwood Pond, were low according to the methods used. Initial data indicates a standing crop of between 100 and 300 g of snake per hectare over most of the site. The standing crop around the only permanent water at the site (Cottonwood Pond) was calculated to be nearly 8 kg/ha. Sex ratios of trapped and captured snakes were nearly equal for all four species. In the spring of 1970 the prairie rattle snakes (*C. viridis*) and the plains garter snakes (*T. radix*) emerged from dens between May 1 and May 4. No snakes were collected after October 20, 1970. The plains garter snake (*T. radix*) began breeding between May 18 and May 24. The prairie rattlesnake (*C. viridis*) was shown to have mature appearing eggs present in the body in both May and October, 1970. Two recaptures of plains garter snakes (*T. radix*) occurred over a long enough period to show weight increases. Egg counts varied from 9 to 37 eggs per female.

Growth curves of all four species have been presented in the data section. Length was plotted against weight for snakes collected during the summer of 1970. Coefficient of correlation of length to weight was +.82 on the plains garter snakes (*T. radix*), and coefficient of correlation of length to weight on prairie rattlesnakes (*C. viridis*) was +.85. Numbers of individuals of the other two species were so low as to not warrant correlation coefficients. There was great variation in the amount of stored fat in both emerging and denning snakes. No significant difference was found in the amount of fat per body weight in the spring collected snakes, when compared to fall collected snakes. This study is the initial phase of a two year investigation concerning the role of snakes on the Grassland Biome.

METHODS AND MATERIALS

Snake Study Methods

Field work at the intensive site began on January 20, 1970, with the initial selection of study areas and the construction of traps. Regular sampling began on April 4, 1970, to determine the time of emergence of wintering snakes from their dens. Beginning on May 3, 1970, each study plot was surveyed three times a week until October 12, 1970, at which time most snakes were back in their dens.

STUDY AREA ON THE PAWNEE INTENSIVE SITE

Reptiles were studied on three selected plots on the intensive site. Study plot number one (the ridge section) was composed of sandy soils, with major plant forms being *Aristida longiseta*, *Atriplex canescens*, and *Opuntia polycantha*. This study plot was located approximately 700 m north of Cottonwood Pond in section 11. This plot was purposely selected to minimize human influence on reptile activities. Nearby ravines had an abundance of small animal burrows which provided potential denning and residence sites for snakes.

The second study plot (the dog town section) was located in section 22, about 900 m northeast of the Pawnee Site headquarters. It was located about 200 m east of a frequently traveled road. The plot was located on the edge of an active blacktailed prairie dog town and also had many mammal burrows for potential denning and residence sites for snakes. *Bouteloua gracilis* and *Opuntia polycantha* were the main vegetation on this study plot. Human influence on this study plot was an important factor. In past years this area had been subjected to both small mammal and snake hunting, and more recently, to small mammal population studies.

The third study plot (Cottonwood Pond section) was located on the edge of the only permanent water on the Pawnee Site. Vegetation on this plot mainly consisted of cattails (*Typha angustifolia*), and reed grasses. On moist years much of this study plot is subjected to commercial haying operations, and cattle are frequently present in the area during the summer months.

Each of the study plots was marked off as a square having an area of 2.5 ha. The sides of each plot were further subdivided into 10 m intervals which were designated by white markers placed at ground level. The markers served as a grid to accurately locate captures.

Study areas for destructive sampling were located on the Pawnee Grasslands within 10 miles of the intensive site. Snakes were collected from these known denning locations at intervals for fat body studies, egg counts, dry weights, ash weights, and other measurements.

SNAKE COLLECTING PROCEDURES

Method 1

Snakes were collected on each of the study plots three days per week from May 3 until October 12, 1970. Each study area was surveyed by slowly walking back and forth between 10 m markers (modified Degenhardt method). This put the observer at a maximum distance of 5 m from any reptile, a close visible or audible distance in the shortgrass prairie. Nearly 40 minutes was required to survey each plot, providing no tagging had to be done. The time of day for observations varied with the season. During June, July, and August, most observations took place in late afternoon and into the crepuscular period.

Method 2

The most successful snake trapping method was continuous trapping using drift fences and funnel traps. Drift fences were constructed of rust-proof metal strips that were 15 m long and 20 m high. This barrier was supported by metal stakes every 2 m and was positioned flush with the ground. Funnel traps were placed at the ends of each drift fence. Each trap employed a cone shaped wire mesh to funnel animals moving around the barrier from either side into a cylindrical hardware cloth trap. The funnel cone was held flush to the ground by galvanized nails.

The opening of the funnel trap was constructed so that fine wires extended into the trap at the narrow opening. The wires did not interfere with the entrance of small animals into the trap, but prevented their escape. Field tests were conducted on this trap, and no snakes were able to escape. A door was placed at the rear of the trap for quick removal of specimens, and a sun shade was constructed for each trap. Snakes, lizards, insects, and small mammals, confronted with the drift fence barrier, were diverted into the traps.

Each study plot had four drift fences with traps. Two drift fences were placed at the Cottonwood Pond plot. They became ineffective in early June because vegetation became so tall and dense that fences would no longer divert animals to the traps.

Method 3

Night lighting for nocturnal species was done on June 17, June 19, July 26, and August 4. On each occasion a group of observers walked the study areas and surrounding hills after dark using headlamps, flashlights, and Coleman lanterns. Red filters were placed over the

lights on July 26 and August 4. At least four hours were spent on each of these occasions.

Method 4

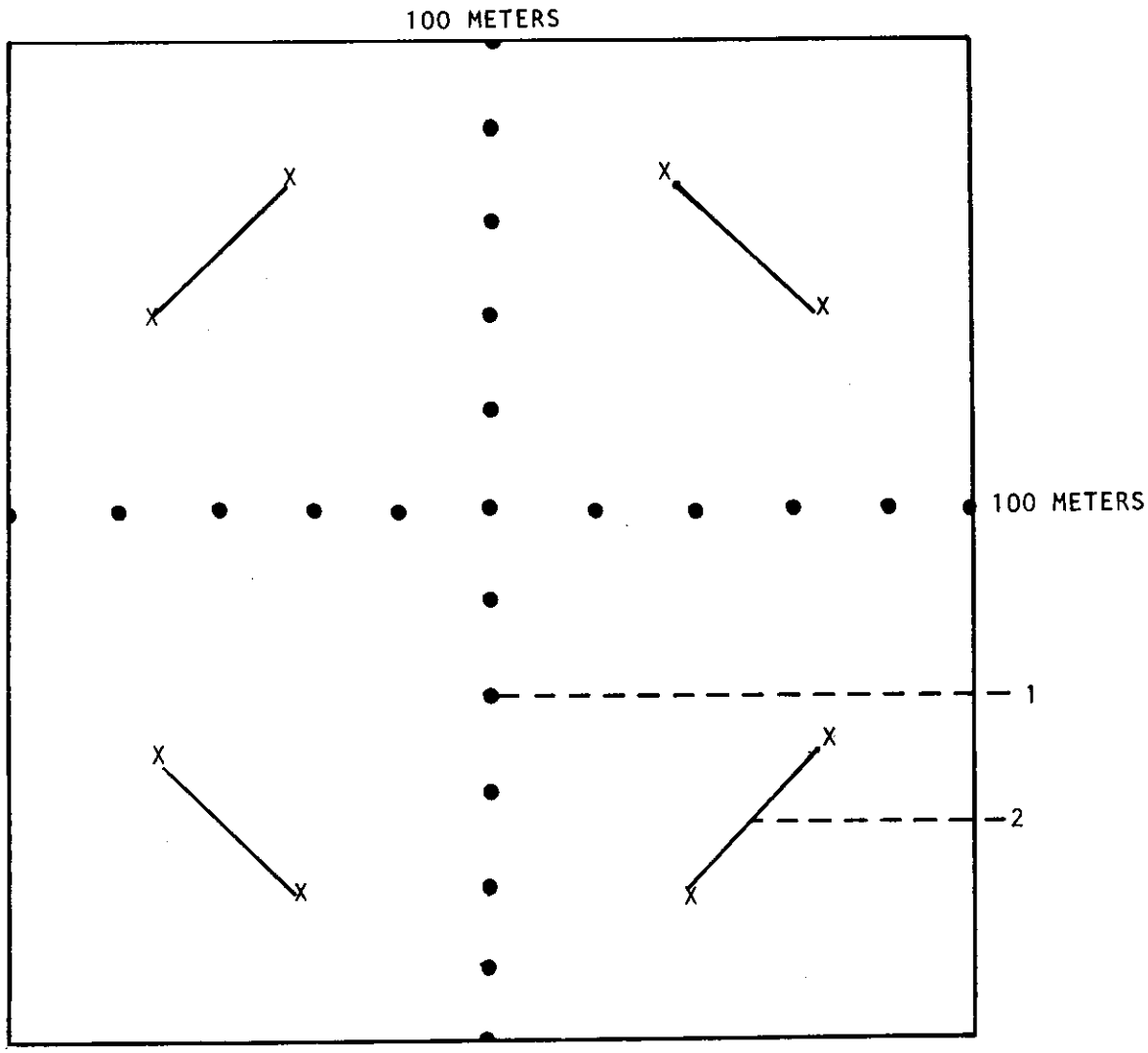
Nearly three hours per week were spent driving the intensive site roads and the surrounding gravel and asphalt roads observing snakes at dusk. Reptiles have been shown to move onto such roads in spring and fall to control body temperature. The two mile stretch of seldom used asphalt highway southeast of the intensive site was regularly checked for snakes throughout the summer.

Method 5

Pits 60 cm deep and 25 cm wide were drilled into the ridge and dog town study plots on September 16, 1970, by the use of a power fence post digger. Twenty pit traps, placed 10 m apart and arranged in an equal cross, were placed on each study plot. A rust-proof metal sleeve 20 cm deep was placed in each hole at ground level to prevent animals from escaping. The outside holes of the cross shaped series of pit traps had short drift fences, 2 m by 15 cm (Fig. 1).

Method 6

Snakes were collected from these permanent study grids on the intensive site. Other U.S. IBP research teams that found snakes in the course of their work were requested to capture them, when possible to place them in bags in the shade, and leave a note on the main chalkboard. The response to this request was excellent, and consequently, some of the snakes were collected by other investigators.



1. Pit traps spaced 10 m apart.
2. Drift fences with funnel traps at the ends (X).

Fig. 1. Diagram of drift fence and pit trap locations on study plot number one and number two.

SNAKE MARKING TECHNIQUES

Sex Determination

All snakes were weighed, measured, sexed, marked, and immediately released (Table 1). Males were recognized by probing caudally behind the vent with a moistened probe, a deep pocket signifying the presence of inverted hemipenises.

Clip Methods

All snakes were marked by the standard scale clip method. In this method the enlarged belly scute covering the vent was given the number zero. Moving anteriorly, the next scale was number 1, the next number 2, and so on. The tenth belly scute was number 10, the eleventh was number 20, the twentieth was number 100, the twenty-first was number 200, etc. By this numbering system, many snakes can be marked in one area. A small triangular section was cut into the dermal layer of each scute, leaving a scar. The scar has been shown to remain as long as three years if properly cut, but clips were renewed with each recapture to counteract any new growth.

The prairie rattlesnake (*Crotalus viridis*) was also marked by a second method. A number was cut from a telephone book and sealed onto the newest rattle nearest the head with a heavy coating of clear enamel. This mark was readily identifiable to other investigators in the field who did not know the scale clip code. A special holding device was constructed, using a soft plastic tube and circular clamps, to enable a single investigator to mark and measure snakes.

Table 1. Snake field data, summer 1970.

Species	Number	Length(mm)	Weight (g)	Sex	Location	Date Collected
Crotalus viridis	1	264	9.3	F	Dog section	5/10/70
	2	257	9.0	F	Ridge section	5/18/70
	3	464	47.0	M	2 miles E of Headquarters	5/27/70
	4	921	398.8	M	½ mile W of Headquarters	6/02/70
	5	807	144.4	F	Buffalo Pen Road	6/19/70
	6	349	20.1	M	Hill ½ mile N of Headquarters	7/07/70
	7	660	160.2	M	450 m SW of trailer in section 26	9/24/70
	8	444	92.0	F	Ridge, W trap of E-W center fence	9/24/70
Pituophis catenifer	1	1276	501.9	M	Post near dog town	5/27/70
	2	1324	682.4	M	2 miles E of Headquarters	5/27/70
	3	337	6.9	M	E of Headquarters house	6/02/70
	4	343	10.5	F	Headquarters garage	6/17/70
	5	838	143.0	M	SE trap ridge	6/25/70
	6	1346	-	M	¼ mile E of Headquarters	7/20/70
	7	470	30.0	F	Ridge N fence W trap	7/27/70

Table 1. (Continued)

Species	Number	Length (mm)	Weight (g)	Sex	Location	Date Collected
Pituophis catenifer (continued)	8	1245	442.0	M	SE corner irrigated	8/04/70
	9	not used	-	-	Field W of Headquarters	-
	10	959	358.1	M	Ridge N fence W trap	7/31/70
	11	356	11.45	F	Road to ridge ¼ mile past first gate	10/01/70
	12	686	106.7	M	¼ mile E of irrigated on the road	10/06/70
Heterodon nasicus	1	445	41.4	M	100 yards W. in irrigated	5/21/70
	2	637	164.6	M	Lynn Lake	5/27/70
	3	489	69.7	F	¼ mile W of dog town	5/27/70
	4	495	70.2	M	½ mile N on Dogtown Road	7/08/70
	5	470	75.5	F	N fence W trap ridge	7/21/70
	6	406	43.3	F	500 yd SW of trailer in section 26	7/24/70
Thamnophis radix	1	648	140.0	F	Restricted to Cottonwood Pond	5/24/70
	2	521	-	F	"	5/24/70
	3	705	52.5	M	"	5/26/70
	4	356	-	F	"	5/26/70

Table 1. (Continued)

Species	Number	Length (mm)	Weight (g)	Sex	Location	Date Collected
Thamnophis radix (continued)	5	451	-	M	Cottonwood Pond	5/26/70
	6	460	-	F	"	"
	7	445	-	M	"	"
	8	384	-	F	"	"
	9	578	74.8	F	"	"
	10	368	-	M	"	"
	11	518	-	F	"	"
	12	343	-	F	"	"
	13	527	-	M	"	"
	14	400	14.9	F	"	"
	15	686	102.3	F	"	5/27/70
	16	445	31.9	F	"	"
	17	813	119.0	M	"	"
	18	438	17.7	M	"	"
	19	502	22.5	F	"	"
	20	362	11.4	F	"	"

Table 1. (Continued)

Species	Number	Length (mm)	Weight (g)	Sex	Location	Date Collected
Thamnophis radix (continued)	21	618	61.8	F	Cottonwood Pond	5/27/70
	22	483	16.6	M	"	"
	23	400	12.0	M	"	"
	24	435	17.5	M	"	"
	25	362	7.0	M	"	"
	26	578	31.9	M	"	5/31/70
	27	654	58.0	F	"	"
	28	610	38.3	M	"	"
	29	584	39.8	M	"	"
	30	648	161.3	M	"	6/02/70
	31	559	39.0	F	"	"
	32	495	121.9	F	"	"
	33	508	28.3	F	"	6/04/70
	34	559	35.0	F	"	"
	35	542	35.6	F	"	"
	36	807	165.2	F	"	"

Table 1. (Continued)

Species	Number	Length (mm)	Weight (g)	Sex	Location	Date Collected
Thamnophis radix (continued)	37	286	5.8	M	Cottonwood Pond	6/04/70
	38	514	25.0	M	"	"
	39	553	33.5	M	"	"
	40	330	8.2	F	"	"
	41	470	23.1	F	"	"
	42	540	30.2	F	"	"
	43	324	8.1	F	"	"
	44	508	37.9	F	"	"
	45	419	19.6	F	"	"
	46	356	12.2	F	"	"
	47	324	8.5	M	"	"
	48	394	14.3	F	"	"
	49	368	10.8	M	"	"
	50	292	11.2	F	"	"
	51	413	13.0	M	"	"
	52	254	3.6	M	"	"

Table 1. (Continued)

Species	Number	Length (mm)	Weight (g)	Sex	Location	Date Collected
Thamnophis radix (continued)	53	394	23.2	M	Cottonwood Pond	6/04/70
	54	318	10.9	F	"	"
	55	457	26.4	F	"	"
	56	273	4.2	F	"	"
	57	476	27.6	F	"	"
	58	362	11.0	M	"	"
	59	241	3.5	F	"	"
	60	305	7.3	M	"	"
	61	349	-	F	"	6/15/70
	62	413	-	F	"	"
	63	406	-	M	"	"
	64	368	-	F	"	"
	65	330	-	F	"	"
	66	406	-	F	"	"
	67	330	-	F	"	6/22/70
	68	584	-	F	"	"

Table 1. (Continued)

Species	Number	Length (mm)	Weight (g)	Sex	Location	Date Collected
Thamnophis radix (continued)	69	553	27.0	M	Cottonwood Pond	6/25/70
	70	533	33.0	F	"	"
	71	495	21.1	M	"	"
	72	432	14.3	F	"	"
	73	533	30.0	F	"	"
	74	419	19.0	F	"	"
	75	318	10.0	F	"	"
	76	394	30.1	F	"	"
	77	445	18.5	F	"	"
	78	686	53.2	F	"	"
	79	279	5.0	F	"	"
	80	572	42.2	F	"	"
	81	559	33.0	M	"	"
	82	381	12.0	F	"	"
	83	572	48.0	F	"	"
	84	521	46.0	F	"	"

Table 1. (Continued)

Species	Number	Length (mm)	Weight (g)	Sex	Location	Date Collected
Thamnophis radix (continued)	85	356	8.5	F	Cottonwood Pond	6/25/70
	86	673	58.0	M	"	"
	87	559	36.0	F	"	"
	88	292	4.0	F	"	"
	89	457	20.0	M	"	"
	90	826	141.0	F	"	"
	91	508	26.0	M	"	"
	92	483	27.0	F	"	"
	93	699	71.0	F	"	"
	94	559	37.0	F	"	"
	95	495	22.0	M	"	"
	96	610	52.0	M	"	"
	97	495	21.0	F	"	"
	98	343	9.0	F	"	"
	99	457	20.0	M	"	"
	100	483	20.0	F	"	"

Table 1. (Continued)

Species	Number	Length (mm)	Weight (g)	Sex	Location	Date Collected
Thamnophis radix (continued)	101	432	18.0	F	Cottonwood Pond	6/25/70
	102	495	22.5	F	"	"
	103	406	13.0	F	"	"
	104	381	17.0	M	"	"
	105	711	94.0	F	"	"
	106	483	22.0	F	"	"
	107	470	24.0	F	"	"
	108	559	28.0	M	"	"
	109	356	10.0	F	"	"
	110	381	9.0	F	"	"
	111	533	31.0	F	"	"
	112	330	5.0	M	"	"
	113	356	4.0	F	"	"
	114	292	3.0	M	"	"
	115	368	7.0	M	"	"
	116	483	26.0	M	"	"

Table 1. (Continued)

Species	Number	Length (mm)	Weight (g)	Sex	Location	Date Collected
Thamnophis radix (continued)	117	559	61.0	F	Cottonwood Pond	6/25/70
	118	533	27.0	M	"	"
	119	419	15.0	M	"	"
	120	381	9.0	F	"	"
	121	610	45.0	F	"	"
	122	445	25.0	M	"	"
	123	495	34.0	F	"	"
	124	584	40.0	M	"	"
	125	356	11.0	M	"	"
	126	305	5.0	M	"	"
	127	343	9.0	F	"	"
	128	406	10.0	F	"	"
	129	368	8.0	M	"	"
	130	356	7.0	F	"	"
	131	381	10.0	F	"	"
	132	489	19.7	M	"	8/13/70

Table 1. (Continued)

Species	Number	Length (mm)	Weight (g)	Sex	Location	Date Collected
Thamnophis radix (continued)	133	394	12.9	F	Cottonwood Pond	8/13/70
	134	483	24.5	M	"	"
	135	413	25.8	F	"	"
	136	279	3.8	F	"	"
	137	419	11.6	M	"	"
	138	318	7.9	M	"	"
	139	318	6.7	F	"	"
	140	800	97.2	F	"	9/01/70

DESTRUCTIVE SAMPLING TECHNIQUES ON VALIDATION SITES

Twenty-seven specimens of the prairie rattlesnake (*Crotalus viridis*) were collected from two denning sites on the Pawnee Grasslands. These snakes were frozen on capture and later dissected. Fat bodies and eggs were weighed and counted (Table 2). Snakes were dried at 100°C until they lost no more weight, and then ash weights were determined for each specimen. Snakes were collected both in the spring and fall for this purpose in order to compare fat storage, egg counts, and growth for this period of time.

AN ALTERED TECHNIQUE

The plains garter snake (*Thamnophis radix*) required different techniques early in the summer. By May 29, these were present in such numbers that after 100 snakes were marked, it was deemed necessary to reduce sampling to once every three weeks. Twenty University of Northern Colorado students participated in collecting these snakes at Cottonwood Pond on June 25 and August 13. Groups of students spread out 1 m apart and walked slowly through the study area capturing snakes by hand or net. After July, the dense vegetation greatly hampered all collecting efforts in the Cottonwood Pond area.

LIZARD COLLECTING PROCEDURES

Field work took place on the same plots used for the snake study. Lizards were collected, measured, sexed, marked, and released at the same observation periods used for snakes. Lizards were captured by drift fence-funnel trap, pit trap, and by hand or net as they were sighted by investigators. Weight, total length, snout-vent length, and sex were recorded for each specimen.

Table 2. Data for 27 prairie rattlesnakes (*C. viridis*) collected near the intensive study area.

Specimen #	Date Collected	Sex	Total Length (mm)	Tail Length (mm)	Live Weight (g)	Dry Weight (g)	Ash Weight (g)	Fat Body Weight (g)	Eggs No. and Weight	Location Collected[a/]
1	10/12/70	F	797	42	263.8	72.89	9.67	22.68	12-13.1g	1
2	5/10/70	M	767	54	159.5	65.51	10.40	10.26	-	1
3	6/06/70	M	631	49	88.19	24.59	4.07	2.51	-	1
4	10/12/70	M	744	58	207.33	51.87	8.62	5.88	-	1
5	5/02/70	M	884	67	356.64	102.03	18.36	15.55	-	2
6	5/17/70	M	645	47	119.51	58.32	4.56	3.73	-	1
7	5/17/70	F	711	43	157.36	47.65	6.05	15.95	-	2
8	5/17/70	M	809	57	220.74	50.20	3.29	2.85	-	2
9	5/17/70	M	828	62	280.60	73.58	10.82	19.33	-	2
10	5/17/70	M	931	73	349.30	94.84	20.60	8.00	-	2
11	5/05/70	M	714	51	152.01	38.15	6.78	4.83	-	1
12	10/12/70	F	763	45	163.45	37.91	7.37	3.17	-	1
13	5/05/70	F	482	26	45.24	10.12	1.70	1.63	-	2
14	10/12/70	F	707	23	131.35	7.36	2.68	1.26	-	1
15	6/06/70	M	278	21	9.49	2.05	.39	.27	-	1
16	5/10/70	M	275	16	6.88	1.55	.24	.10	-	1
17	10/12/70	F	263	11	7.78	1.64	.22	.02	-	1
18	10/12/70	F	738	42	199.89	55.64	6.98	17.23	37-0.1g	1
19	10/12/70	M	644	45	106.29	26.03	4.08	4.68	-	1
20	10/12/70	M	681	54	124.64	30.21	4.70	2.28	-	1
21	10/12/70	F	312	16	14.39	3.30	.46	.06	-	1
22	10/12/70	F	744	35	254.25	76.26	8.79	19.49	-	1
23	10/12/70	F	588	31	69.81	14.41	1.08	1.01	9- 0.2g	1
24	10/12/70	M	598	42	82.96	18.67	10.05	1.70	-	1
25	10/12/70	M	690	49	147.49	36.02	5.59	2.43	-	1
26	10/12/70	F	729	42	150.11	31.60	5.85	.92	-	1
27	10/12/70	F	291	17	11.40	2.60	.38	.32	-	1

[a/] Location: 1. 12 miles northeast of Ault, Colorado on the Pawnee Grasslands.
2. 6 miles northeast of the Intensive Site Headquarters for the Pawnee Site.

Marking was by the standard toe clip method. The outside right rear toe was designated number one, the right rear foot potentially having numbers one through nine. The inside left rear toe was number 10, the next toe 20, and so on. The presence of breeding colors in lesser earless lizard females (*Holbrookia maculata*) was recorded. Blue-tail color in juvenile skinks (*Eumeces multivirigatus*) was also noted. Date of hatching of eggs of lizards was determined by the sudden appearance of extremely small individuals of each species.

RESULTS -- SNAKE STUDY

1. One hundred sixty-seven snakes were marked and released on the intensive study site during the study period of 1970. The four most numerous species present were:

i. the plains garter snake (*Thamnophis radix*), 140 specimens (Fig. 2).

ii. the gopher (bull) snake (*Pituophis catenifer*), 13 specimens (Fig. 3).

iii. the prairie rattlesnake (*Crotalus viridis*), 8 specimens (Fig. 4).

iv. the western hog-nosed snake (*Heterodon nasicus*), 6 specimens (Fig. 5).

In addition to these, 27 prairie rattlesnakes (*C. viridis*) were collected near the intensive study site for egg counts, fat body weights, dry weights, and ash weights.

2. Continuous trapping by using drift fence-funnel traps was the most effective collecting method for snakes. Most garter snakes were caught by hand, however.

3. Snake populations on the intensive site, except immediately around Cottonwood Pond, were low according to the methods used.

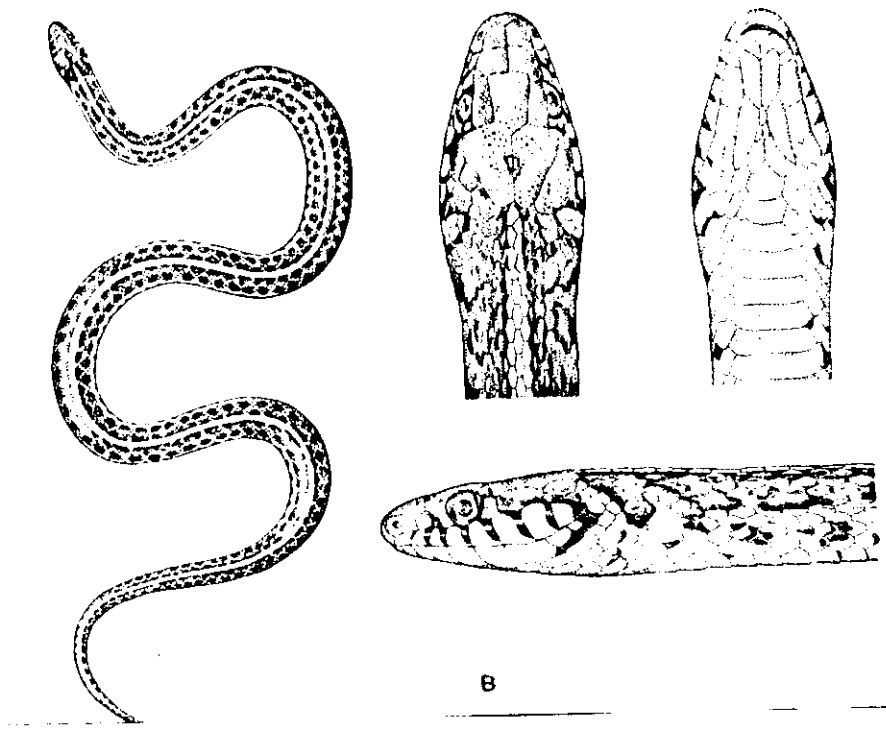


Fig. 2. *Thamnophis radix*, the plains garter snake (Line drawing from: Stebbins, R. D. 1954. Amphibians and Reptiles of Western North America).

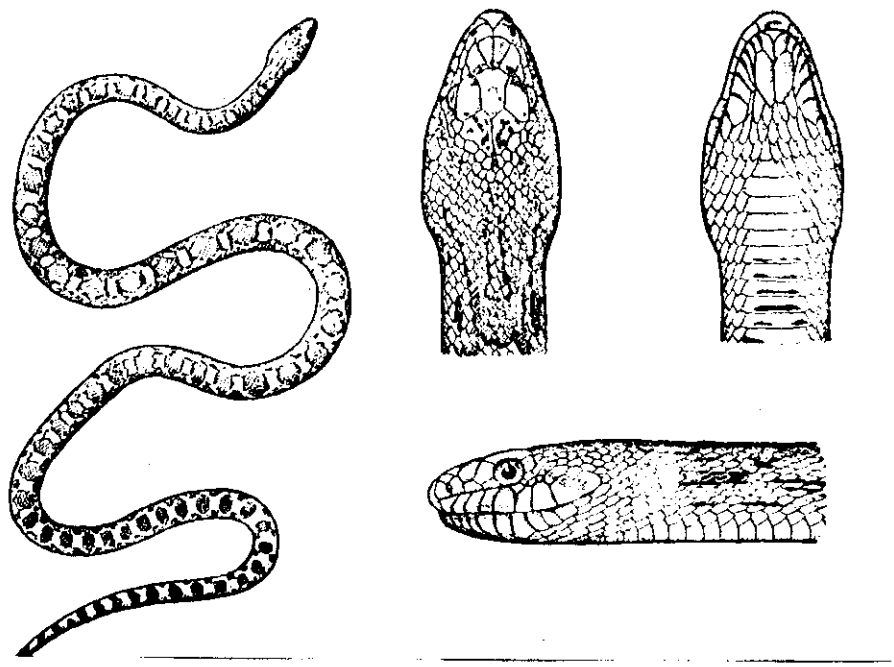


Fig. 3. *Pituophis catenifer*, the gopher (bull) snake (Line drawing from: Stebbins, R. C. 1954. Amphibians and Reptiles of Western North America).

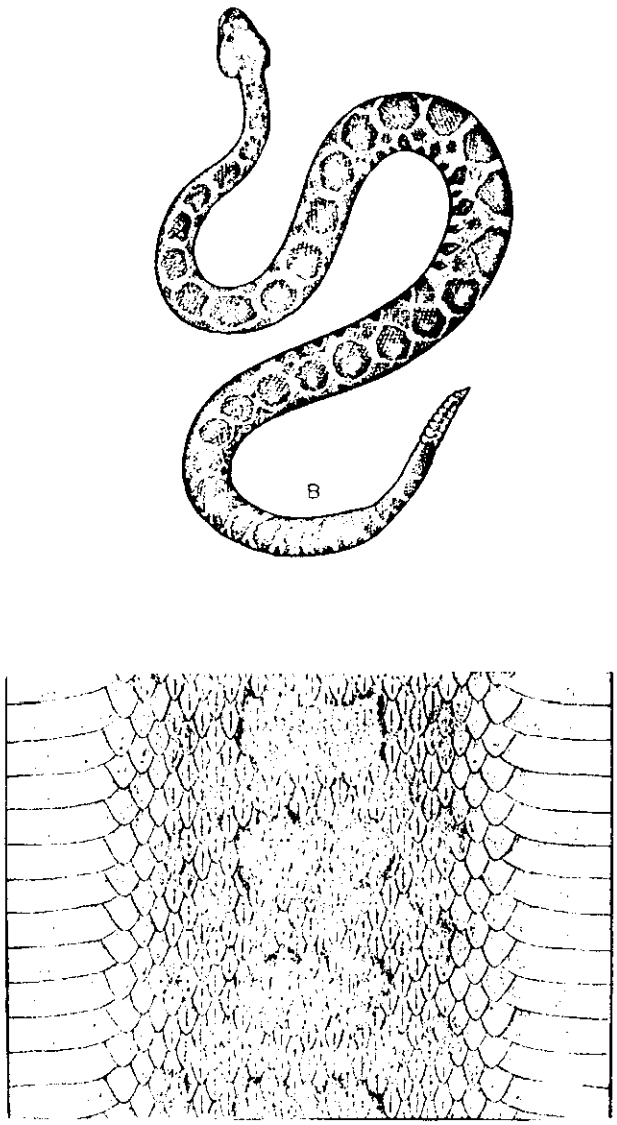


Fig. 4. *Crotalus viridis*, the prairie rattlesnake (Line drawings from: Stebbins, R. C. 1954. Amphibians and Reptiles of Western North America).

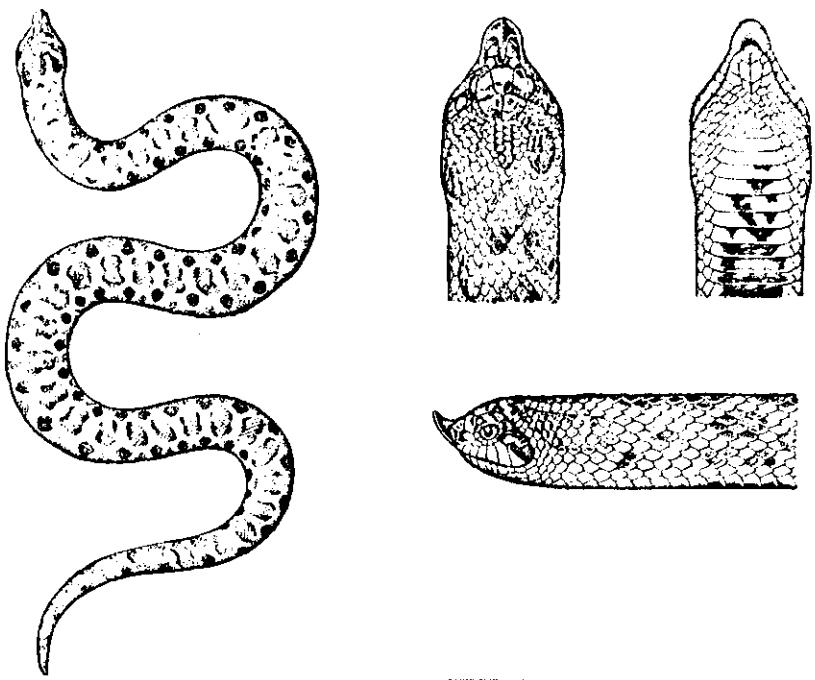


Fig. 5. *Heterodon nasicus*, the western hog-nosed snake (Line drawing from: Stebbins, R. C. 1954. Amphibians and Reptiles of Western North America).

4. Sex ratios of trapped and captured snakes were nearly equal for all four species (Table 1).

5. In the spring of 1970, the prairie rattlesnakes (*C. viridis*) and the plains garter snakes (*T. radix*) emerged from dens between May 1 and May 4.

6. The plains garter snake (*T. radix*) began breeding between May 18 and May 24. Breeding continued for nearly two weeks. This was determined from sperm released during the sexing procedure. Copulation was observed on May 24, 1970.

7. A juvenile (34 mm) gopher snake marked on June 2, 1970, may indicate recent hatching.

8. Individual plains garter snakes (*T. radix*) do not appear to be restricted in their range around Cottonwood Pond. On June 4, one specimen was recaptured over 500 m from its original capture a week before. Another was recaptured more than 200 m from the point of original release. Although these distances would not seem large in other circumstances, in the limited "moist" area around Cottonwood Pond in the summer, this represents nearly all the available territory.

9. Due to vegetation growth and collecting techniques, there were 10 recaptures out of 140 plains garter snakes (*T. radix*) on the Cottonwood Pond plot. Using the Lincoln Index on two consecutive capturing dates, the population was determined to consist of approximately 800 snakes per 2.5 ha.

10. Of the 140 plains garter snakes (*T. radix*) collected, the mean total length was 463 mm (18.23 inches). One standard deviation from this mean length was 124 mm (4.88 inches). The mean weight of this group was 28.75 g with one standard deviation being 29.31 g.

11. Two recaptures of plains garter snakes (*T. radix*) occurred over a long enough period to show weight increases. Snake number 94 weighed 37.0 g on June 25 and increased to 58.5 g by August 13, a gain of 21.5 g. Snake number 22 increased from 16.6 g. on May 23 to 28.4 g on August 13, a gain of 11.8 g. In both instances, these snakes were not filled with food at the time of measurement.

12. The prairie rattlesnake (*C. viridis*) was shown to have mature appearing eggs present in the body in both May and October of 1970 (Table 2). This tends to support Rahn (1942), who presented evidence for a two-year reproductive cycle for prairie rattlesnakes in their northern range. This would also tend to explain why many mature females used for egg counts did not contain eggs. Rahn (1942) indicated that spermatozoa may survive in the vaginal region over the winter, awaiting a spring ovulation. Of those specimens collected which had eggs, there was great variation in number. Egg counts varied from 9 to 37 eggs per female. Females with few eggs had large mature ones, while in cases where females had large numbers of eggs, they were all small. This is evidence for a large initial number of eggs starting to develop from which only a fraction eventually reach maturity. Six females with eggs were collected which were not included in Table 2. These had been killed with a shotgun by residents near the intensive site, and could not be used for any other purpose but egg counts. Table 3 shows the size relationship of eggs with the total egg count.

13. Growth curves of all four species were calculated (Fig. 6, 7, 8, 9). Length was plotted against weight for snakes collected during the summer of 1970. Coefficient of correlation of length to weight was +.82 on the plains garter snakes (*T. radix*). Coefficient

Table 3. Egg counts from six prairie rattlesnakes (*C. viridis*) collected two miles east of the intensive site.

Number	Egg Size		Total Count
	Large = 15 mm +	Small = 15 mm -	
1	4	11	15
2	11	22	33
3	8	14	22
4	7	15	22
5	16	16	32
6	7	19	26

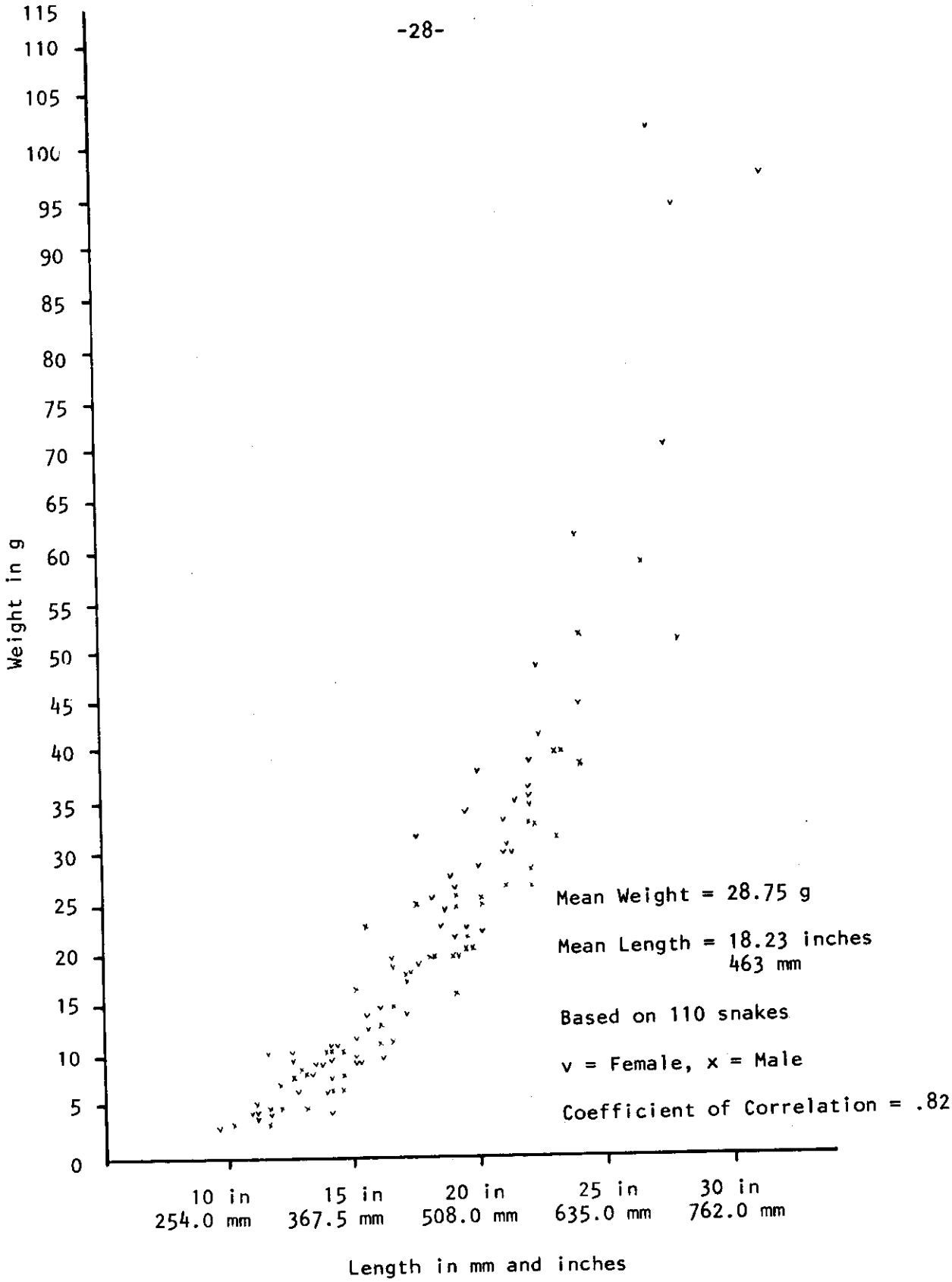


Fig. 6. Growth curve of *Thamnophis radix*, length vs. weight of 1970 data.

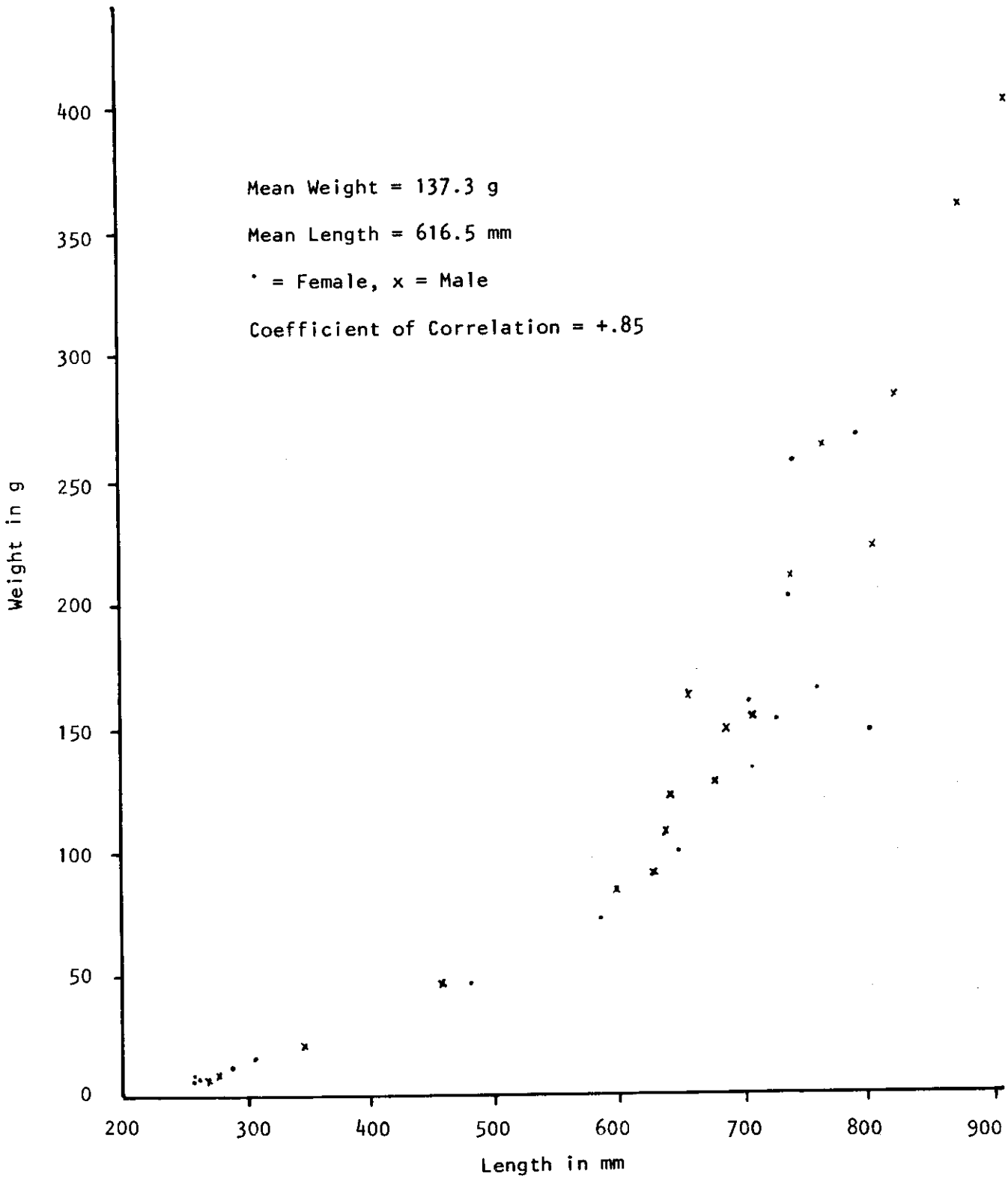


Fig. 7. Growth curve of weight vs. length of 34 prairie rattlesnakes (*C. viridis*) collected on or near the intensive site during the summer of 1970.

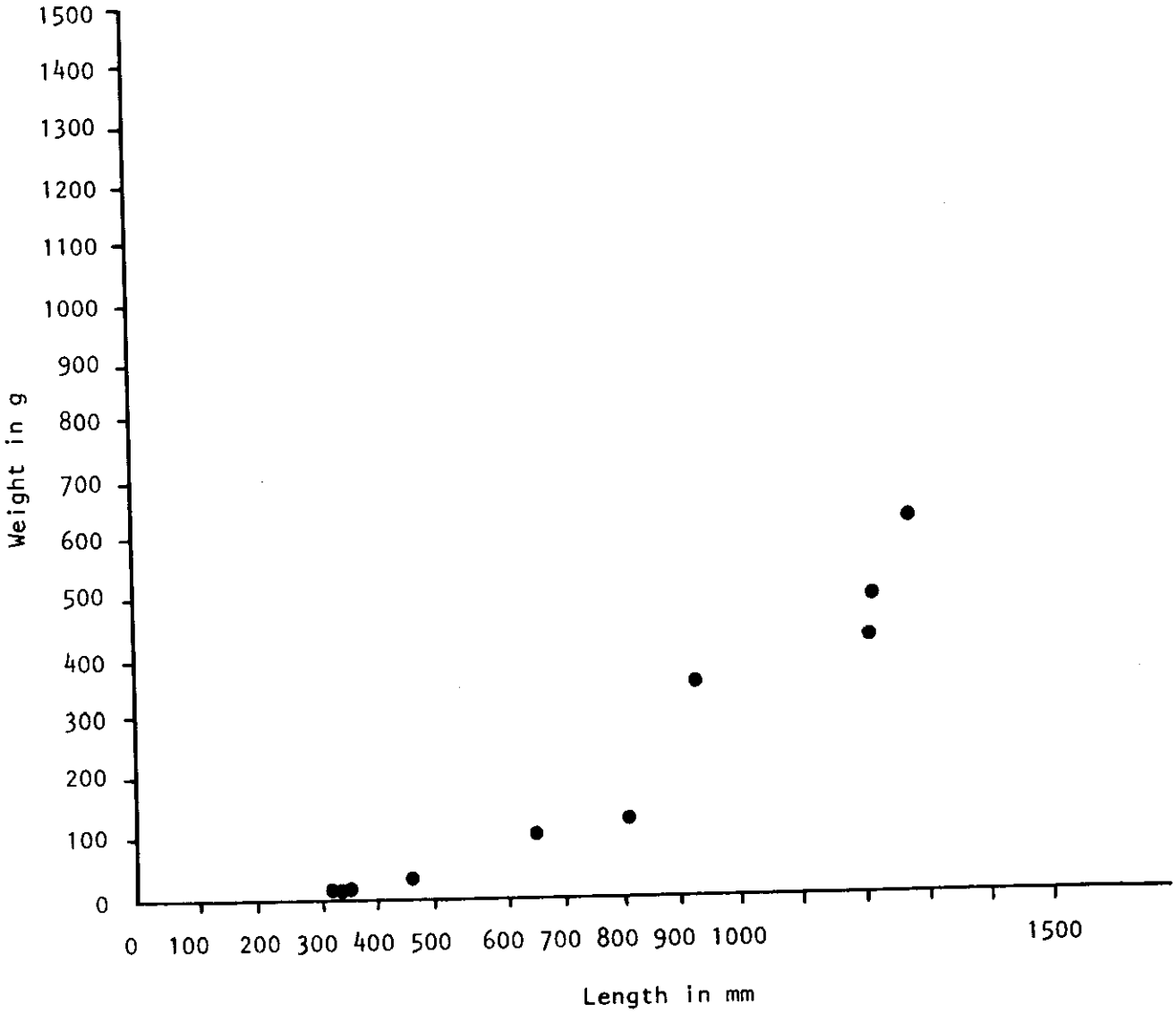


Fig. 9. Growth curve of weight vs. length of 10 specimens of the gopher (bull) snake (*Pituophis catenifer*) marked and released on the intensive study area.

of correlation of length to weight on prairie rattlesnakes (*C. viridis*) was +.85. Numbers of individuals of the other two species were so low as to not warrant correlation coefficients.

14. Fat bodies were weighed on 27 specimens of the prairie rattlesnake (*C. viridis*) collected for the egg count survey. Fat bodies from individuals collected in early May were compared with the amount of fat present in snakes collected in October. There was great variation in the amount of stored fat in both emerging and denning snakes. No significant difference was found in the amount of fat per body weight in the spring collected snakes when compared to fall collected snakes.

Snakes are opportunistic feeders; the well fed snakes had much fat, but results show that those which had experienced a lean summer went into dormancy in the fall with little or no fat reserves. Thus, there was much difference in the amount of fat present when comparing spring to fall. If very large numbers of snakes could have been collected, the average weight of body fat going into dormancy would perhaps be greater than for snakes coming out of dormancy. Unfortunately, to measure body fat present, the snakes must be sacrificed. This cannot be done on the intensive site, and this investigator was not able to locate a denning site which was (1) close enough to the intensive site to be within the same vegetational component so that results would be valid if extrapolated for the site itself; and (2) of a size so that a large number of each size range and sex could be killed in the fall and again in the spring. To be significant, the number sacrificed would have to be very high.

LIZARD RESULTS

Lizard results are presented in Tables 4, 5, and 6.

DISCUSSION

In most closed community ecosystems, each trophic level will have a biomass production per unit time of about one order of magnitude less than the trophic level upon which it feeds. Population numbers of snakes encountered in this study appear to reflect the numbers of small mammals reported on the intensive site, small mammals being a major food source for snakes (Table 7).

It is assumed that the snakes marked and released on each study plot were residents. The calculation of standing crop data can be determined. Study plot number one was found to have a standing crop of 708 g (of snake) per 2.5 ha. This was calculated from the two rattlesnakes (*C. viridis*), three gopher snakes (*P. catenifer*), and one hog-nosed snake (*H. nasicus*) marked and released on this plot. Study plot number two was found to have a standing crop of 511 g (of snake) per 2.5 ha. This figure was calculated from one rattlesnake (*C. viridis*) and one large gopher snake (*P. catenifer*). Study plot number three had a standing crop of 23,200 g per 2.5 ha. This figure was taken from population numbers of prairie garter snakes (*T. radix*) projected by a Lincoln Index, using a mean weight of 29 g per snake from 120 individuals measured on the intensive site.

It is important to distinguish assessments of standing crop from those of biomass production. Biomass production is a rate measure expressed in terms of grams on increase per unit time. If bioproductivity is to be determined accurately for each trophic level snakes

Table 4. Short horned lizard *Phrynosoma douglassi.*

Number	Total Length (mm)	Snout-Vent Length (mm)	Sex	Weight (g)	Date (1970)	Capture Location
1	76	54	F	8.4	21 May	Stake at curve on road to ridge
2	95	60	M	19.4	21 May	Stake on flat to windmill
3	92	64	M	17.5	21 May	Funnel trap ridge section
4	89	57	M	17.1	24 May	Funnel trap ridge section
5	45	32	too small	1.2	26 May	Funnel trap ridge section
6	78	51	M	8.54	14 July	Funnel trap ridge section
7	98	65	F	15.7	31 Aug.	Flat toward windmill
8	41	29	too small	1.3	31 Aug.	Ditch SW of windmill
9	38	27	"	1.2	3 Sept.	100 yd S of #10 Hollrookia
10	45	32	"	1.4	6 Sept.	30 yd from second gate to ridge
11	95	67	F	20.5	16 Sept.	Lynn Lake to Ridge Top Road
12	45	32	too small	2.3	24 Sept.	Lynn Lake to Ridge Top Road
13	98	70	M	20.9	24 Sept.	Lynn Lake to Ridge Top Road

Table 5. Lesser earless lizard *Holbrookia maculata*.

Number	Total Length (mm)	Snout-Vent Length (mm)	Sex	Weight (g)	Date (1970)	Capture Location
1	92	51	F	3.8	21 May	Funnel trap on dog town study area NE
2	108	64	F	5.5	24 May	"
3	89	51	F	4.9	2 June	"
4	95	54	F	5.0	6 June	"
5	102	51	M	4.0	4 May	"
6	105	51	M	4.1	13 May	"
7	105	54	M	3.8	13 May	"
8	102	51	M	3.5	13 May	"
9	92	48	M	3.9	11 June	"
10	105	52	M	5.0	4 Aug.	"
11	105	57	M	5.3	4 Aug.	"
12	57	3.5	too small	.8	31 Aug.	Find right turn on road to ridge
13	57	3.8	F	1.3	31 Aug.	N for left circle top
14	54	3.5	too small	.6	31 Aug.	Lynn Lake Road NW top
15	57	3.2	F	2.2	16 Sept.	Funnel trap on dog town area NE
16	102	4.8	M	4.1	11 June	"

Table 6. Skink *Eumeces multivarigatus*.

Number	Total Length (mm)	Snout-Vent Length (mm)	Sex	Weight (g)	Date (1970)	Capture Location
1	83	38	too small	.6	31 Aug.	W center dog town study area
2	89	41	too small	.8	31 Aug.	½ mile SW of Headquarters
3	146	57	M	4.1	31 Aug.	½ mile SW of Headquarters
4	114	57	F	4.4	31 Aug.	½ road to Buffalo pens
5	89	32	too small	2.0	16 Sept.	E center irrigated section

Table 7. A summary of some of the known food items in the diet of snakes.

	Birds	Bird Eggs	Carrion	Earthworms	Fish	Frogs	Insects	Lizards	Reptile Eggs	Small Mammals	Mollusks	Salamanders	Snakes	Tadpoles	Toads	Leeches
Crotalus viridis	K	K				K		K		K						
															D	
										S						
	G							G		G					G	
Heterodon nasicus								P	P	P			P			
	G					G		G	G	G		G			G	
	E					E		E		E					E	
						H		H				H			H	
	A									A					A	
Pituophis catenifer	S	S								S						
	G	G						G		G						
	C	C								C						
	A	A								A						
Thamnophis radix			H	H	H	H	H								H	H
			S	S	S	S	S								S	

Key to the authority cited:
A -- Anderson 1965, C -- Conant 1958, E -- Edgren 1955, K -- Klauber 1956,
P -- Platt 1966, S -- Schmidt and Davis 1941, D -- Stabler 1948,
G -- Stebbins 1954, H -- Stebbins 1966.

occupy, the population dynamics of these species must be determined. Recapture and remeasurement of individuals after one year will provide this data.

One purpose of assessments of biomass is to provide estimates of stored energy in organic materials in the individual reptiles, or in the species. Energy values can be computed from these measures of biomass. Such caloric values can also be determined empirically by the use of a bomb calorimeter, for comparison.

The weight plotted against length data (Fig. 6 through 9), presented in this first season's study, may have great potential value. If snakes captured in 1970 are recaptured in 1971 and their growth increases are measured, then more than bioproductivity data will be available. Yearly growth rates for individuals of various sizes, and thus an "age" scale, could be determined for each species.

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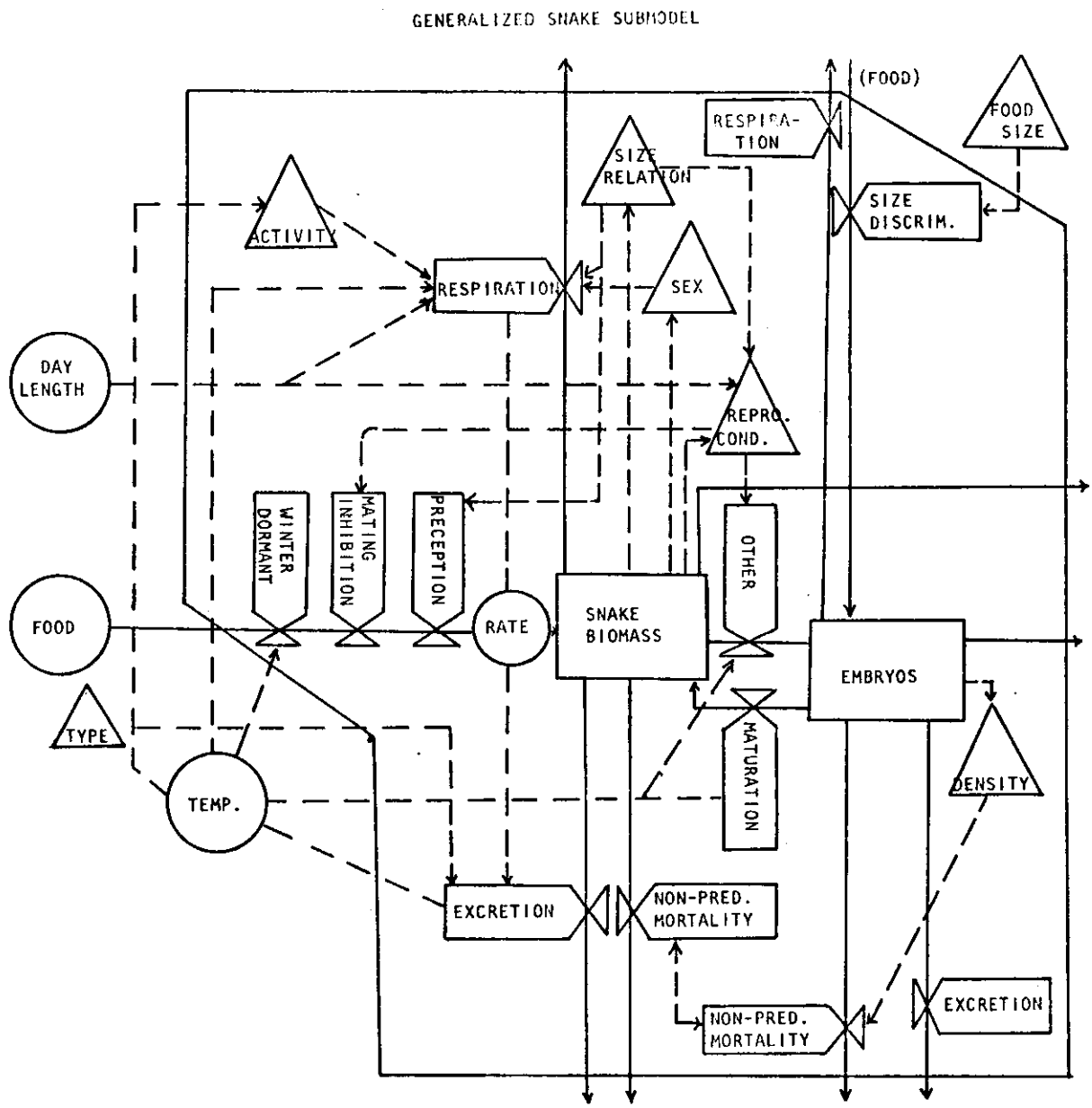
APPENDIX I

MODEL DESIGN



APPENDIX II

SNAKE GROWTH

Snakes continue to grow throughout their lives. Adapting a widely used model of von Bertalanffy's (Dickie 1968) to snake growth:

$$l_t = L_{oo}\left(1 - e^{-k(t-t_o)}\right)$$

where L_{oo} = maximum size toward which snake is tending

k = the rate at which length approaches L_{oo}

t_o = a parameter indicating the hypothetical time at which snake would have been zero size.

The Bertalanffy growth equation can also be written in terms of weight, assuming that weight is proportional to the third power of length as the growth curves indicate (Tables 4 and 5).

$$w_t = W_{oo}\left(1 - e^{-k(t-t_o)}\right)$$

This curve is sigmoid in form with the inflection point at $0.296W_{oo}$ (see Beverton and Holt 1957 for a complete discussion and derivation).

Ricker's exponential model, as adapted from Kramer (1970), has been used as an approximation of growth rate over a short time interval:

$$w_t = w_o e^{gt}$$

where w_t = weight at the end of time period t

w_o = weight at the start of time period t

g = instantaneous rate of growth. $g = (\log_e w_t - \log_e w_o)\ t$