

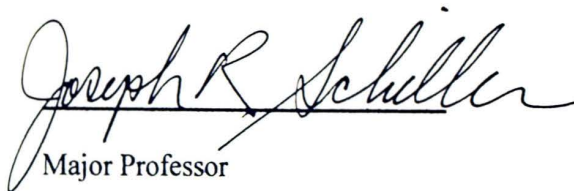
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A COMPARATIVE STUDY OF CAPTURE METHODOLOGIES, EFFECTS
OF TAIL AUTOTOMY ON BEHAVIOR AND PHEROMONE
COMMUNICATION OF THE FIVE-LINED SKINK, EUMECES FASCIATUS



THEODORE T. IVES, JR.

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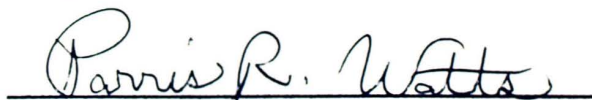
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**A Comparative Study of Capture Methodologies, Effects
of Tail Autotomy on Behavior and Pheromone
Communication of the Five-Lined Skink, *Eumeces fasciatus***

A Thesis

Presented for the

Master of Science

Degree

Austin Peay State University

Theodore T. Ives, Jr.

August 2002

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ABSTRACT

The hypothesis that pitfall traps, glue traps and funnel traps do not differ in capture efficiency for *Eumeces fasciatus*, the Five-Lined skink, was tested over a two year period. Glue traps were most efficient on a time of effort basis during monitoring, but pitfall traps were a safer capture technique that required less time for monitoring. Reducing the sticky surface on the glue trap and constant monitoring eliminated glue trap mortalities. Although capture efficiency of glue and pitfall traps did not significantly differ on a time of effort basis in 2001, this may be due to decreased adhesion of glue traps used in early 2001 and a change of glue trap style used later in 2001. Funnel traps failed to capture *E. fasciatus*, but fabrication of funnel traps from a coarser meshed material may improve their performance.

I also tested the hypothesis that dominance relationships between male *E. fasciatus* are not altered by tail autotomy. Neither this study (n=16) nor previous unpublished data collected by Schiller (n=10) observed dominance reversal as a result of tail autotomy. These results suggest that tail autotomy does not cause discernable reduction in social dominance among male *E. fasciatus*.

The incidences of four social behaviors, i.e. tongue flicks, tail wags, grapples, and bites were evaluated in dominance contests, but no relationship among dominance classification and behavior was detected. Difference in intensity of behaviors was observed between years. This difference may result from differences in lab conditions where the experiments were conducted in 2001 (~ 16 °C) compared to 2000 (~ 22 °C).

In dominance contests in which fighting was not observed, males sometimes did not interact as evaluated by observation, or one animal immediately retreated. This

suggests that some of the males may have established dominance relationships prior to capture. Since this would be more likely of animals captured in proximity to each other, I tested the relationship between capture proximity and probability of antagonistic interaction using the Wilcoxon Rank Sum test. No relationship of capture distance to the likelihood of aggressive interactions among male *E. fasciatus* was detected. However, very few of the male *E. fasciatus* were captured in close proximity, thus it is likely all of the contests involved lizards that had not previously interacted.

The third hypothesis tested was that male *E. fasciatus* do not utilize pheromones to recognize dominant/submissive conspecifics. I used the Wilcoxon Rank Sum test to test for a relationship of tongue flicks to pheromones using cloacal swabs obtained from lizards that had been ranked based on the outcome of the dominance contests. There was a significant difference in the number of tongue flicks between pheromone (self, a positive control or conspecific) and no pheromone (distilled water, a negative control) indicating the animals did detect the pheromone. However, there was no relationship of tongue flicks to “self pheromone” versus “conspecific pheromone” among dominance classes. There was no difference in the number of tongue flicks to pheromones among dominance classes. The dominance classifications assigned in dominance contests agreed with those assigned in pheromone tests.

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CHAPTER I

Overview of Previous Research on *Eumeces*

fasciatus and Relevance to this Study

Basic Ecology and Life History

The Genus *Eumeces* is comprised of approximately 50 species in Central America, North America, Southern Asia and North Africa. Fitch (1954) conducted the first comprehensive study of the life history and biology of the most widespread North American species in the Genus, the Five-Lined skink, *Eumeces fasciatus*. Fitch (1954) captured *E. fasciatus* using pitfall traps and screen funnels. Baited lizard pole, i.e. angling (Schiller, personal communication), and hand capture (Downes and Borges, 1998; Schiller, personal communication; Zani, 1996) are other trapping techniques that have been used to capture *E. fasciatus*. One of my objectives was to evaluate the relative efficiency of three different trapping techniques for *E. fasciatus*. I tested the hypothesis that pitfall traps, glue traps and funnel traps do not differ in capture efficiency.

The range of *E. fasciatus* correlates closely with the Deciduous Forest Biome of eastern North America. *Eumeces fasciatus* is usually most abundant in cutover forest, old rock piles, or near deserted sawmills. In the south, *Eumeces fasciatus* may inhabit heavily wooded terrain, and in the north it is found mostly in open areas. *Eumeces fasciatus* prey mainly upon invertebrates but also may eat small vertebrates.

Fitch (1954) determined the optimal body temperature for *E. fasciatus* was near 34°C. Using thermoregulatory behavior, *E. fasciatus* are able to maintain their body temperature near the optimal over a broad range of environmental temperatures. When ambient temperature approaches freezing, *E. fasciatus* become torpid and hibernate. Usually *E. fasciatus* emerge from hibernation in northern Tennessee around the middle of March (Schiller, personal communication); however, they may return to torpidity if a period of cold weather occurs. *Eumeces fasciatus* are very active for a period of weeks immediately following emergence and are commonly observed foraging and basking on live and dead trees, and rocks.

Within a few weeks of emerging, adult *E. fasciatus* come into breeding condition (Fitch, 1954). *Eumeces fasciatus* males develop a salmon red suffusion on the face and neck during breeding season. The intensity of the red suffusion is more pronounced in older males. This head coloration is controlled by gonadal androgens (Edgren, 1959). A red suffusion is observed also in males of many other *Eumeces* species, such as *E. egregius baird*, and *E. laticeps*. Male *E. fasciatus* follow a reproductive female and grip loose skin at or behind her shoulders with their jaws until copulation is completed, usually in about five minutes. Within a few days of insemination females become hostile towards males (Fitch, 1954). Gravid female *E. fasciatus* become secretive and dig nest burrows in moisture-laden soil under level rocks, or in decomposing wood of rotting logs or stumps. The annual clutch of *E. fasciatus* in Kansas is approximately nine eggs, with bigger and older females producing more than nine eggs and smaller and younger females laying less than nine eggs (Cagle, 1940; and Fitch, 1954).

Female *E. fasciatus* brood their eggs for approximately a month (Fitch, 1954).

Eumeces fasciatus eggs usually double in weight during incubation indicating accumulation of water by the developing embryos (Fitch and Fitch, 1967). Temperature tolerances for *E. fasciatus* eggs range from 0° to 42 °C (Fitch and Fitch, 1967). Preferred temperature for *E. fasciatus* eggs is 20.9 °C (Hecnar, 1994). While brooding, the female may dampen the burrow in times of drought with dew gathered from the outside the nest (Fitch, 1954). Mortality of *E. fasciatus* eggs is probably lowest at moderate moisture levels (Hecnar, 1994). At low moisture levels eggs may dry out, and at high moisture levels eggs may become infected with microbes or gas exchange through the eggshell may be interrupted (Fitch, 1954; and Fitch and Fitch, 1967). Females adjust their brooding positions to regulate moisture levels near the eggs. When moisture levels are low females increase body to egg contact. In contrast, when moisture levels are high females decrease body to egg contact (Hecnar, 1994). Females may also rotate their eggs in response to low moisture levels (Fitch, 1954). She will also keep the cavity of the burrow clear of debris, keep the eggs from becoming attached to the floor and sides of the burrow, and ward off predators (Fitch, 1954). Females may change nest sites after disturbance or a change in environmental conditions (Fitch, 1954; and Vitt and Cooper, 1989). Females may brood their hatchlings for a short period of time after hatching (Vitt and Cooper, 1989). Once *E. fasciatus* hatchlings leave the nest they do not return (Fitch, 1954).

Two to five females may aggregate in burrows to share brooding responsibilities and to increase their ability to defend the nest (Cagle 1940; Fitch, 1954; Cooper et al.,

1983; Hecnar, 1994; and Seburn, 1993). Females may also aggregate if optimal nest sites are scarce (Cooper et al., 1983). Additionally, *E. fasciatus* aggregate in hibernacula in the ground or decayed logs during the winter (Fitch, 1954). Cooper and Garstka (1987) found that *E. laticeps* also hibernate in winter groupings in the ground. If females do not disperse far from winter hibernacula prior to breeding and egg laying, aggregate brooding would be facilitated. Female *E. fasciatus* and *E. laticeps* are congeneric brooders (Vitt and Cooper, 1989).

Effect of Tail Autotomy on Social Status

Predators of *E. fasciatus* include birds, mammals, and snakes. A common name for many species of *Eumeces* is “blue-tailed skink.” Fitch (1954) hypothesized that the blue tail of immature *E. fasciatus* is an adaptation for predator avoidance by directing the predator to an expendable part of the body. Clark and Hall (1970) suggested the blue tail serves an intraspecific social function, i.e. inhibiting attack by breeding males.

Arguments by Clark and Hall (1970) which support a social role of the blue tail include:

(1) a cryptically colored tail decreases the chance of predator detection, (2) predation does not account for the loss of the blue tail color at maturity, (3) tail loss decreases body weight and energy storage, and (4) predation does not explain the marked contrast between the bright blue tails of juveniles compared to the bright red jaws of breeding males. Adult male *E. fasciatus* commonly fight viciously among themselves during breeding season and the blue tail of juvenile skinks might serve to signal their nonreproductive status. Juvenile *E. fasciatus* frequently undulate their tails in a pronounced sinusoidal wave (tail wags). Adult *E. fasciatus* are observed to perform this

behavior, but usually only when highly excited as during combat. If the tail is used as an important social signal, then tail autotomy could have social costs, including loss of social status by breeding males. Many studies have shown a reduction in social status due to tail autotomy (Cooper and Vitt, 1987; Cooper and Vitt, 1993; Martin and Salvador, 1993; Salvador et al., 1995; Salvador et al., 1996). I also explored the possibility that tail loss might affect male dominance relationships in the experiments described in Chapter III. Specifically, I tested the hypothesis that dominance relationships between male *E. fasciatus* were not altered by tail autotomy.

Pheromone Studies in Lizards

Pheromones have been revealed to communicate species membership, sex, and reproductive state in the closely related *E. laticeps* (Cooper and Vitt, 1986a; Cooper, 1995; Mason, 1992), but this ability has not been studied in *E. fasciatus*. Male *E. laticeps* can distinguish familiar versus unfamiliar conspecific males by pheromones from their skin and cloaca (Cooper and Vitt, 1984a; Cooper, 1996) and have the ability to trail females by scent (Cooper and Vitt, 1986b). *Eumeces fasciatus* males also track females by scent (Fitch, 1954). Given the importance of pheromones in social communication in *E. laticeps*, I tested a third hypothesis: male *E. fasciatus* do not utilize pheromones to recognize dominant/submissive conspecifics.

Review of Problems Encountered

Throughout this study unforeseen problems occurred and were corrected as encountered when possible. Using the whole sticky surface of the glue trap caused two male *E. fasciatus* deaths. I corrected this problem early in 2000 by reducing the area of

exposed glue surface by two thirds. This eliminated trapping mortality on glue traps. When I tried to reuse the glue traps from 2000 in 2001, I concluded that they were not as efficient due to lessened stickiness resulting from collection of debris and prolonged exposure to sunlight and air. I was unable to purchase the same traps as used in 2000 and I had to use a different size and type of glue trap in 2001. When I conducted dominance trials in 2000, in order to prompt captive males to engage in physical contests, I had to capture a female in breeding condition, which took longer than expected. The differences I observed between years in dominance trials and pheromone test results may be due to low temperature conditions in the lab where the experiments were conducted in 2001 (~ 16 °C) compared to 2000 (~ 22 °C). Another problem that occurred in the McCord building was an air conditioning failure that lead to extreme temperatures in the lab that were higher than optimal temperature conditions for *E. fasciatus*. As a result, two second year females died in late July of 2001.

Suggestions for Further Research

The results of this research suggest new ways in which future research may be carried out more effectively. First, more research needs to be done on the design of funnel traps. My results suggest that traps constructed of a sturdier material that has larger mesh size so lizards can observe prey items inside would likely be more effective. Additionally, further research is needed on the effect of tail autotomy on male dominance by conducting more trials to confirm the results of this study. In 16 of 16 trials I conducted, dominance was unaffected by tail autotomy. Similarly, Schiller (unpublished data) obtained the same results in 10 of 10 trials, i.e. no affect of tail autotomy on

dominance. I did not use a double blind experimental design in the pheromone study conducted in 2000. I started using a double blind method in 2001, acting upon advice offered when I presented preliminary results at the Ninth Symposium on the Natural History of Lower Tennessee and Cumberland River Valleys (2001). This method assures a random pheromone test where neither the observer nor collector knew the treatment being administered. Similarly, in order to see if male *E. fasciatus* responded to the swab itself versus the pheromone on the swab I used dH₂O swabs as a negative control during the pheromone tests only in 2001.

CHAPTER II

Comparative Efficiency of Glue, Pitfall, and Funnel Traps in Capturing the Five-Lined Skink, *Eumeces fasciatus*

List of Previous Research for Capture Techniques

Capture techniques for *E. fasciatus* include pitfall traps (Fitch, 1954) screen funnel traps (Fitch, 1954), baited lizard pole (Schiller, personal communication), and hand capture (Schiller, personal communication; Zani, 1996). Baited lizard poles are used successfully for other lizard species (Strong et al., 1993). Capture techniques for other lizard species that may be successful for *E. fasciatus* include baited glue traps (Downes and Borges 1998, Whiting, 1998, Vargas et al. 2000, Glor et al. 2000), and pole with attached glue pad (Durtsche, 1996).

Research Plan and Methods

Comparison of Capture Techniques

The following trap types were used to capture *E. fasciatus* in this study in Montgomery County, TN (36.52 N, 87.35 W):

(1) Glue traps (Fig. 2.1): Victor® 13 X 21 cm (used in 2000) and 13 X 17 cm (used in 2001) manufactured by Woodstream, AN EKCO Group Company, Lititz, PA 17543, USA. Traps were baited by sticking a cricket to its center.

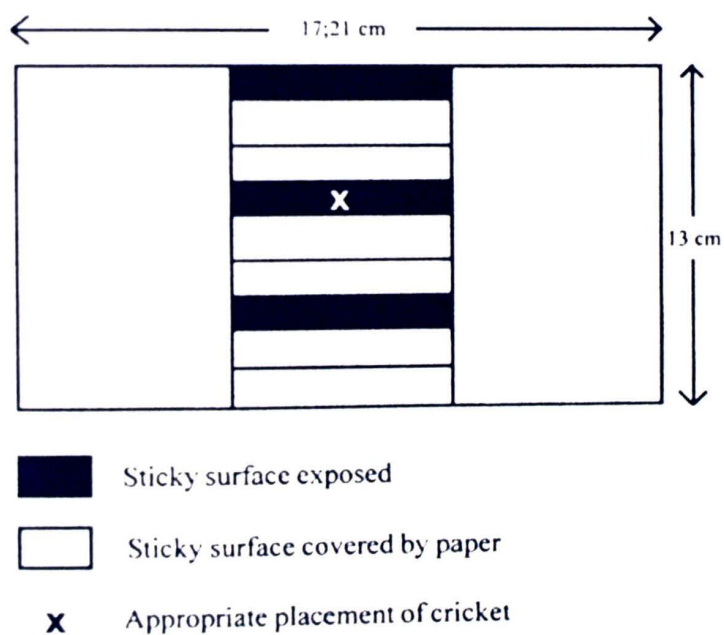
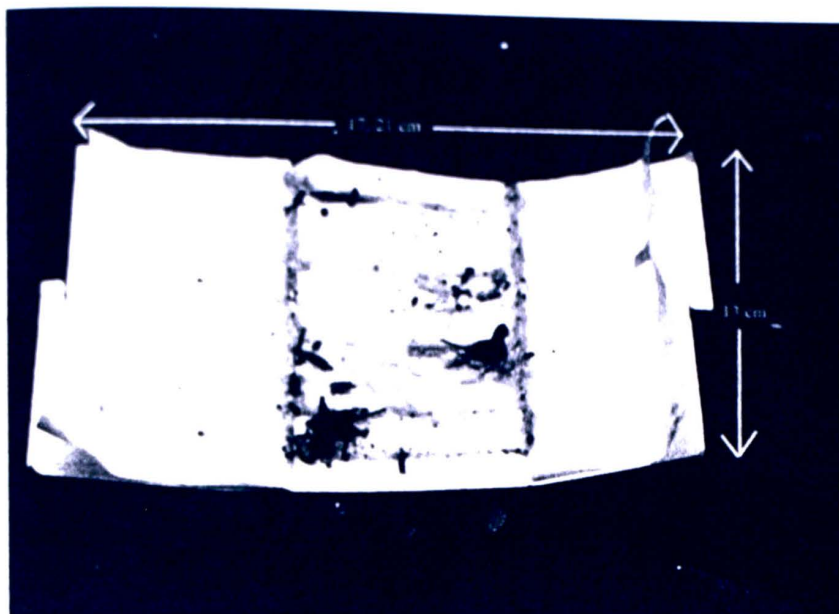


Fig. 2.1. Glue trap: one-third of the one-centimeter strips of paper cover removed and prey item (i.e., a cricket) attached to exposed glue surface (13 X 21 cm (used in 2000) and 13 X 17 cm (used in 2001)).

(2) Pitfall trap (Fig. 2.2): a No. 10 food can placed within a rock outcrop or large woody debris baited with a cricket (the cricket's hind legs were removed to prevent them from jumping out of the trap) to help attract *E. fasciatus* (Fitch, 1954; Schiller, unpublished research). Large rocks and woody debris were arranged so as to provide lizards access to the rim of the cans.

(3) Funnel trap (Fig. 2.3): plastic mesh commonly sold in department stores as "shelf liner material" was fabricated into cylinders about 29 cm long and 12 cm in diameter with a funnel opening into each side (Fitch, 1954; Schiller, unpublished data). This material was used because of economy and ease of fabrication. These traps were used only in 2000.

Trios of these trap types were set together in areas judged to be "good" skink habitat. Sometimes pitfall traps were patrolled without setting glue traps when there was inadequate time to do both. Pitfall and funnel traps were checked daily whenever environmental conditions allowed lizards to be active (at least 18 °C air temperature and sunny) from 15 April to 6 May 2000 and from 6 April to 27 August 2001. Pitfall traps were patrolled a total of 14 days in 2000 and 42 days in 2001. Screen funnel traps were not used in 2001 due to their inability to capture *E. fasciatus* in 2000. Glue traps were deployed only when they could be patrolled continuously because of the risk of injury or possible death of captured animals on unattended glue traps. Glue traps were patrolled a total of 14 days in 2000 and 33 days in 2001.

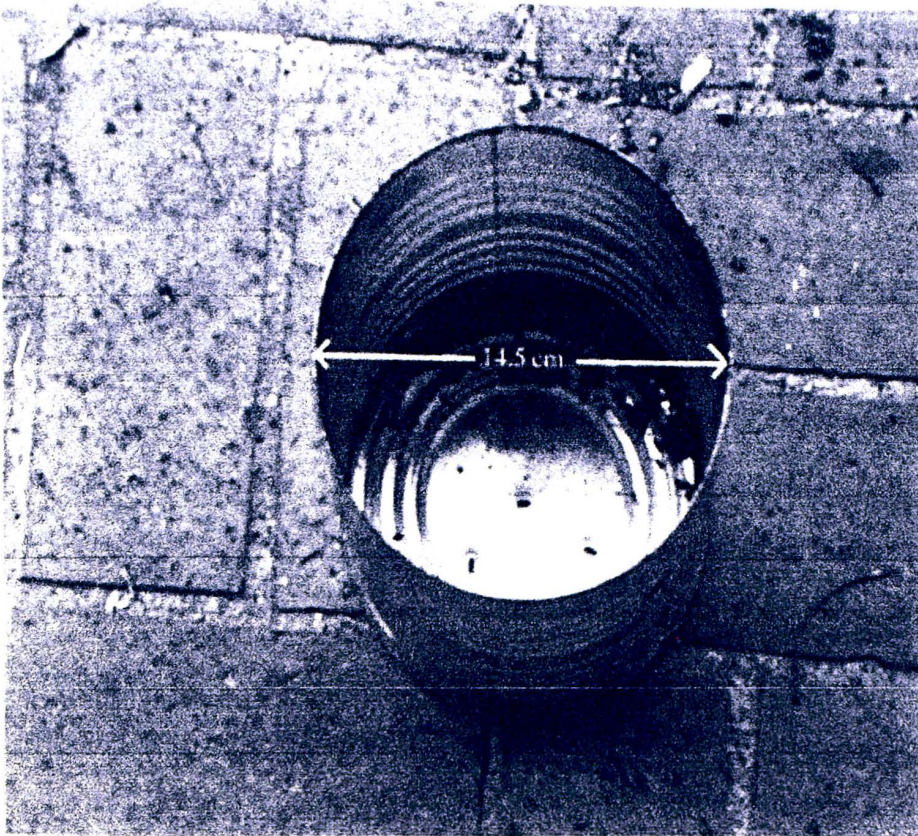
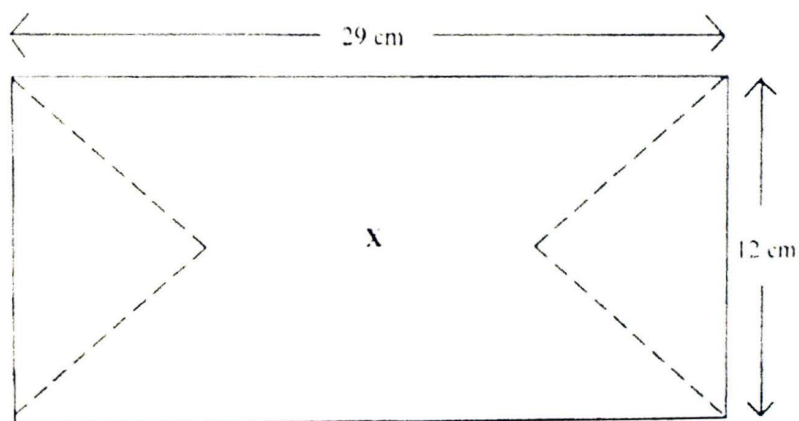
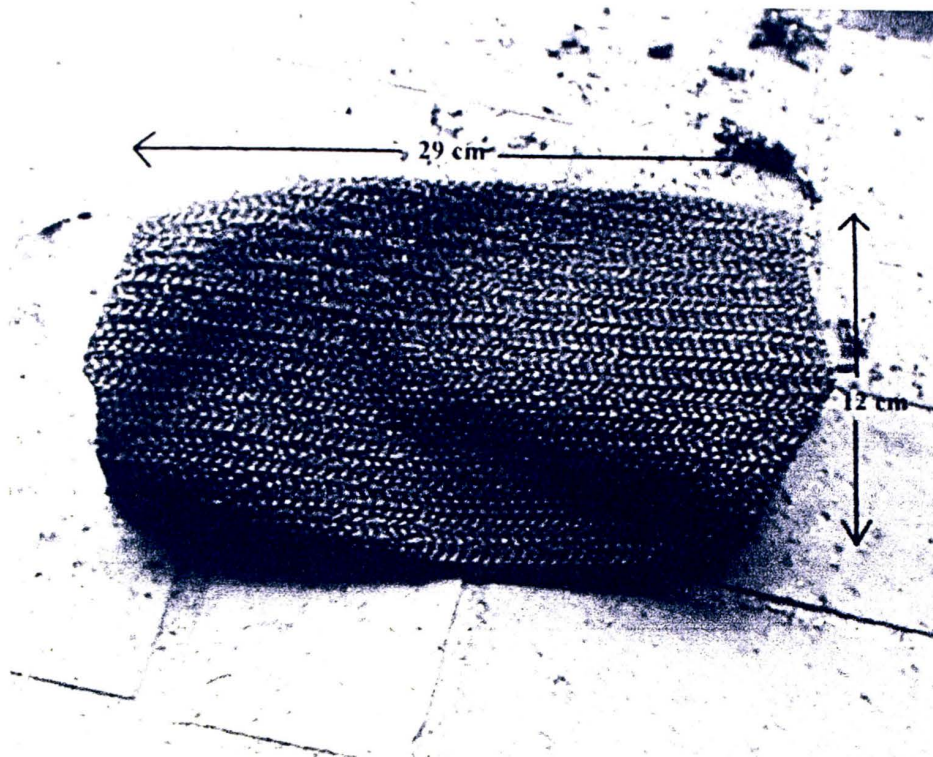


Fig. 2.2. Pitfall trap: a No. 10 food can with prey item (i.e., a cricket) inside.



X Placement of Prey Item

Fig. 2.3. Funnel trap: plastic mesh cylinder with prey item (i.e., a cricket) inside.

Captured *E. fasciatus* were returned to the lab, measured, weighed, and marked both by toe clipping and painting dots on different parts of the lizard's body. The painted dots, though temporary, allowed easy field identification at a distance so to distinguish recently captured animals from others. I used toe clipping for permanent marking; but toe clipping only allows identification of recaptured lizards. Captured animals were assigned to age/sex class based on subjective comparison of Snout-Vent Length (mm), weight (g), time of year captured, blueness of tail, redness of head and neck, broadness of head and body, and brightness of light longitudinal lines. Sexually mature male *E. fasciatus* were returned to the lab in separate holding containers and used in dominance contests and pheromone tests.

Results and Discussion

Comparison of Capture Techniques

Table 2.1 describes captures and mortality of *E. fasciatus* in this study. During the 22-day study (15 April to 6 May) in 2000, 16 *E. fasciatus* were captured. Lizards captured with modified glue traps (N=9) experienced 22.2% mortality rate (2 deaths) during the capture phase. Lizards (N=7) captured in pitfalls traps had 0% mortality. During the five-month study in 2001 (6 April to 27 August), 46 *E. fasciatus* were captured. Lizards captured on modified glue traps (N=2) experienced 0% mortality, but one hatchling lost its tail when being removed from the trap. Downes and Borges (1998) reported that a few skinks lost portions of their tail (around 3-5%) using traps of double-sided packing tape.

Table 2.1. Captures and mortality of the Five-Lined skink, *Eumeces fasciatus*.

Year	Trap Type	Captured (n)	Died (n)	Mortality (%)
2000	Glue	9	2	22.2
2000	Pitfall	7	0	0
2001	Glue	2	0	0
2001	Pitfall	44	0	0
	Total	62	2	3.2

Both deaths on glue traps in 2000 were of small, second-year, male *E. fasciatus* prior to modifying the glue traps to reduce the area of exposed sticky surface. In an attempt to eliminate trapping mortality, I removed one-centimeter strips of the paper cover on the sticky surface of the glue traps so that only 1/3 of its surface area was active. This decreased the amount of lizard to glue contact while still capturing skinks efficiently, and effectively eliminated trap mortality. As the glue on the exposed portion became unusable I removed another one cm strip to maintain the 1/3 active surface area. This increased the longevity of the trap by three fold. One of the two trapping deaths appeared to result from the simultaneous capture of a subordinate second year male on the same glue trap with an adult male. The adult male apparently killed the juvenile male which could not retreat as evidenced by the blood flowing from fresh wounds on the juvenile. As a result of this incident, I patrolled the glue traps more frequently. No captures were made with the funnel traps. Schiller (personal communication) captured a Five-Lined skink in a 1999 pilot study using a funnel trap. A possible explanation for the failure of funnel traps to capture *E. fasciatus* in this study may be the coarser mesh of the trap used by Schiller (personal communication). The plastic coated “shelf liner” fabric used in this study was selected for economy and ease of fabrication, but was not effective in capturing *E. fasciatus*.

Mortality was defined as the percentage of deaths that occurred within 24 hours of capture (Vargas et. Al, 2000; Whiting and Alexander, 2001). There was 0% mortality during confinement of *E. fasciatus* for both years of this study (except for unforeseen events such as air conditioning failure that led to the death of two second year females

from heat stress) (Table 2.1). Whiting and Alexander (2001) reported 0% mortality for *Platysaurus broadleyi* and *P. intermedius wilhelmi* when kept in confinement after capture with glue traps. Conversely, Vargas et. al (2000) reported 47.6% mortality to *Anolis carolinensis* during their confinement period. This could be due to the hardier integument of *E. fasciatus* or damage from glue to the dewlap of *A. carolinensis* not detected by the naked eye. Perhaps the use of cooking oil to remove *A. carolinensis* from glue traps, a technique I did not resort to, contributed to the difference in mortality between the two studies. Lizards captured with pitfall traps (N=45) experienced 0% mortality. Note, that all captured animals were returned to the lab, weighed, measured, marked, and held for at least 24 hours, so the definition of trap mortality used here is quite conservative, since animals were actually exposed to many stressors in addition to trapping.

Capture efficiency is defined as number of *E. fasciatus* captured per trap adjusted for differences in the amount of time each trap type was deployed. Table 2.2 describes total captures by year (2000 and 2001) of *E. fasciatus*. A Chi square test was used to assess for difference in capture rate among trap type. The expected number of captures adjusted to the number of hours each was active in the field was derived for this test (Fig. 2.4). I observed nine glue and seven pitfall trap captures compared to the expected 3.43 glue and 12.57 pitfall trap captures when adjusted to the number of hours each was active, a highly significant difference ($\chi^2=11.52$, $df=1$, $p=0.0007$) in 2000. I observed two glue and 44 pitfall trap captures compared to the expected 2.84 glue and 43.16 pitfall trap captures adjusted to the number of hours each was active, a nonsignificant difference

Table 2.2. Total captures and expected captures adjusted to the number of hours each trap type was active by year (2000 and 2001) of the Five-Lined skink, *Eumeces fasciatus*.

Year	Trap Type	Total Captures	Expected Captures
2000	Glue	9	3.43
	Pitfall	7	12.57
2001	Glue	2	2.84
	Pitfall	44	43.16

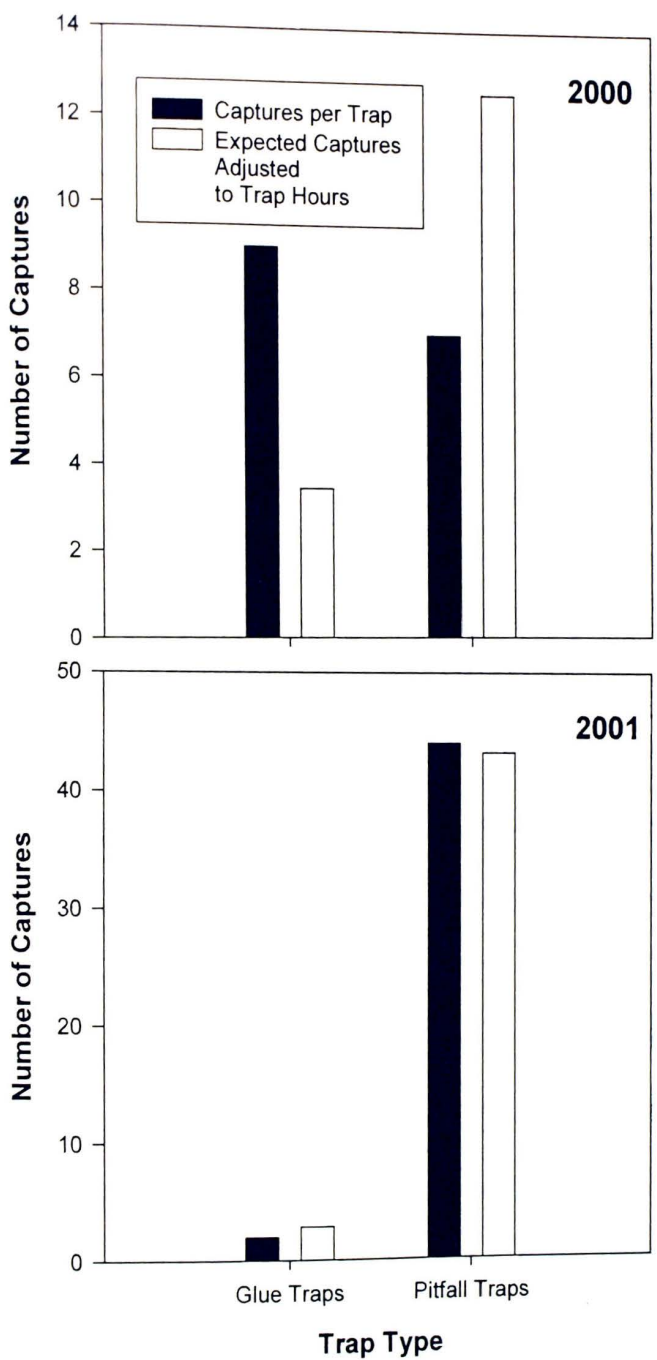


Fig. 2.4. Captures of *Eumeces fasciatus* by glue and pitfall traps in Montgomery County, Tennessee.

($\chi^2=0.30$, $df=1$, $0.90 < p < 0.50$) in 2001. I purchased new glue traps in 2001 because of decreased adhesiveness of the glue traps used in 2000; however, the exact same trap type as was used in 2000 was not available. Since I did not use glue traps after 6 May 2000, the failure to capture more animals on the new glue traps that were purchased and deployed on 15 May 2001 is difficult to evaluate because the new glue traps were not used during a comparable time period to those used in 2000. The difference in glue trap effectiveness in 2001 can be estimated by the ratio of glue trap captures to pitfall trap captures in 2000 compared to 2001 as follows:

$$a/b=c/d$$

where:

a = expected number of glue trap captures in 2001

b = number of pitfall trap captures adjusted to the number of hours active in 2001

c = number of glue trap captures adjusted to the number of hours active in 2000

d = number of pitfall trap captures adjusted to the number of hours active in 2000

$$a/2.90 = 3.43/12.57$$

$$a = 148.04/12.57 = 11.78$$

This analysis reveals that if the assumption that the trapping effectiveness of glue and pitfall traps is unchanged from 2000 to 2001, then the expected number of glue trap captures in 2001 ($a = 11.78$) should have occurred. Instead, only 2.84 captures (adjusted for time of deployment) was made. This is probably due to decreased adhesive ability of the glue to capture lizards in 2001 and/or the change of glue trap style (Victor® 13 X 21 cm (used in 2000) and 13 X 17 cm (used in 2001)).

Assignment of captured *E. fasciatus* to age/sex class

In general, longitudinal lines in *E. fasciatus* are bright yellow on a dark brown background in juveniles and they, along with the trunk color fade with age (Fitch, 1954). However, this fading occurs more slowly in females (Fitch, 1954). Another sexual dimorphism includes the red color of the head of second year and mature males (Fitch, 1954). Based on size, color, and sex specific differences captured animals were classified to age/sex class as follows:

Hatchlings—these animals were captured later in the year than juveniles (July and August), with very short snout-vent lengths (SVLs) ranging from 25 to 52 mm, and weighing between 0.40 to 1.85 g. By late summer some hatchlings may overlap in size with juveniles captured early in the summer. The hatchlings may be distinguished from the juveniles by the fact that they were captured late in the year, while small juveniles were captured early in the year and weighed a lot less than second year lizards captured at that time.

Juvenile—these animals hatched late in the previous summer and have grown almost to adult size during this, their first complete summer. Juveniles with very short SVLs were captured too early in the season to be hatchlings (captured in April), but weighed a lot less than second year lizards.

Second year male—these animals will achieve adult size by the end of this year their second full summer. At least some of these animals had red suffusion on their head and neck during breeding season, but had distinctly smaller SVLs and weights than adult males, and retained longitudinal stripes and some blue color in the tail.

Second year female—these animals had smaller SVLs and weights than adult females, and retained their five longitudinal lines and some blue color in tail.

Adult male—animals of mature size with a red suffusion on head and neck during breeding season, faded five longitudinal lines, and no blue tail color.

Adult female—animals of mature size, with five longitudinal lines present but subdued, and no blue tail color.

In an effort to independently affirm the assignment of captured lizards to age/sex classes, I plotted the SVLs of all captured animals (Fig. 2.5, and Table 2.3). Breaks in the frequency distribution at 25-52 mm (hatchlings, and juveniles), 53-66 mm (second year males and females), and 67-80 mm (adult males and females), seem to correspond, at least approximately, to the age/sex classifications I used. These SVL frequency distributions provide empirical support for the age/sex class assignments that were made on the basis of qualitative characteristics described above.

Table 2.4 describes observed and expected captures by trap type (modified glue and pitfall traps) of the different age/sex class of *E. fasciatus*. The expected captures are adjusted for the number of hours each trap type was active. I used Chi Square to test for difference in age/sex class captures between trap types. No significant difference ($\chi^2=6.12$, $df=5$, $0.90 < p < 0.50$) was found in age/sex class captures between trap types.

Table 2.5 describes observed and expected captures by year (2000 and 2001) of the different age/sex class of *E. fasciatus*. I also used Chi-square to test for difference in age/sex class captures between years. A significant difference ($\chi^2=18.09$, $df=5$,

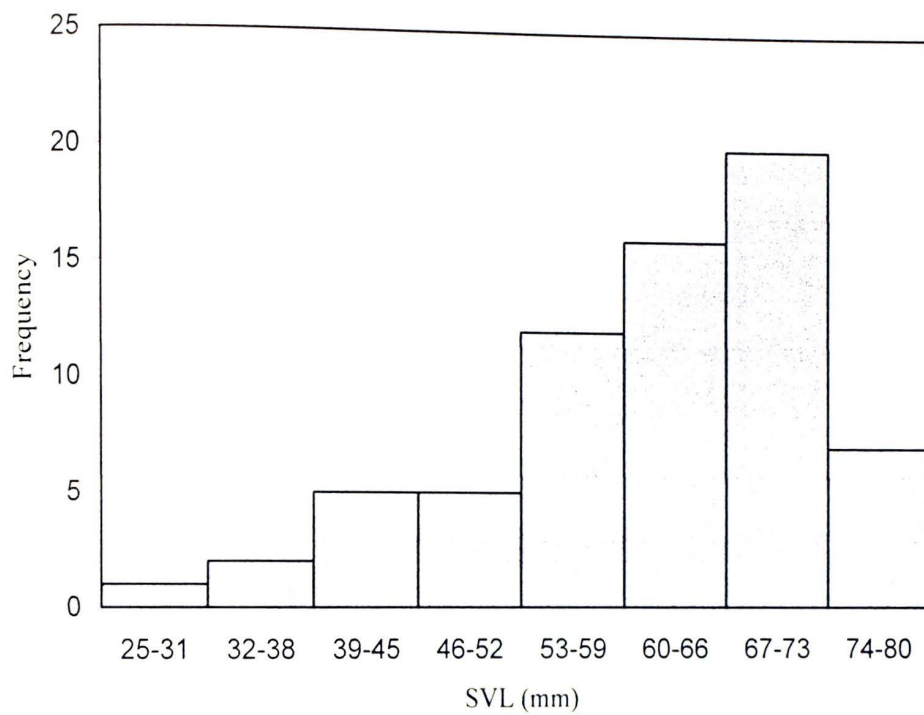


Fig. 2.5. Frequency of *Eumeces fasciatus* snout-vent lengths (SVL) captured in 2000 and 2001.

Table 2.3. Capture descriptions of the Five-Lined skink, *Eumeces fasciatus* (GLT = glue trap, PFT = pitfall trap; SVL = snout-vent length; HAT = hatchling, JUV = juvenile, 2YRM = second year male, 2YRF = second year female, AM = adult male, and AF = adult female).

Day/Month	Year	Trap Type	Age/Sex Class	SVL (mm)	Weight (g)
15-Apr	1	GLT	2YRM	*	*
16-Apr	1	GLT	2YRM	4.59	59
16-Apr	1	GLT	AM	9.60	73
16-Apr	1	GLT	AM	9.86	70
16-Apr	1	GLT	2YRM	5.90	56
16-Apr	1	GLT	AM	10.20	75
16-Apr	1	GLT	AM	9.58	68
22-Apr	1	PFT	2YRM	4.85	62
29-Apr	1	PFT	AM	8.93	68
30-Apr	1	PFT	AM	8.12	65
29-Apr	1	PFT	2YRM	4.32	56
6-May	1	PFT	AM	10.81	74
6-May	1	GLT	AM	10.07	72
6-May	1	PFT	2YRM	3.68	50
6-May	1	GLT	2YRM	4.19	57
6-May	1	PFT	2YRM	4.58	57
8-Apr	2	PFT	AM	8.33	68
13-Apr	2	PFT	AM	9.90	66
13-Apr	2	GLT	AM	6.79	68
23-Apr	2	PFT	AM	7.28	65
25-Apr	2	PFT	AF	6.52	66
29-Apr	2	PFT	JUV	2.00	45
29-Apr	2	PFT	AM	4.82	57
2-May	2	PFT	AM	9.53	71
2-May	2	PFT	AF	8.23	70
5-May	2	PFT	AM	7.43	71
5-May	2	PFT	2YRM	3.01	55
5-May	2	PFT	AF	11.23	69
5-May	2	PFT	AM	6.39	63
10-May	2	PFT	AF	4.98	56
10-May	2	PFT	2YRM	2.96	47
14-May	2	PFT	AF	8.91	58
15-May	2	PFT	AM	7.25	77
15-May	2	PFT	AM	9.50	80
17-May	2	PFT	AM	8.16	72
17-May	2	PFT	2YRM	5.09	61
28-May	2	PFT	AM	9.82	78
5-Jun	2	PFT	AM	7.32	73
5-Jun	2	PFT	2YRM	4.61	60
16-Jun	2	PFT	2YRF	4.47	58
18-Jun	2	PFT	AM	7.25	77
22-Jun	2	PFT	2YRF	3.87	65
22-Jun	2	PFT	2YRF	4.27	66
29-Jun	2	PFT	2YRF	4.02	52
9-Jul	2	PFT	2YRF	5.15	56
9-Jul	2	PFT	2YRF	6.25	61

9-Jul	2	PFT	AM	7.34	60
9-Jul	2	PFT	HAT	0.40	25
13-Jul	2	PFT	2YRF	4.78	67
20-Jul	2	PFT	2YRF	4.45	63
20-Jul	2	PFT	AM	7.25	77
20-Jul	2	PFT	2YRF	5.26	61
20-Jul	2	PFT	AM	10.93	73
14-Aug	2	PFT	HAT	0.84	37
15-Aug	2	GLT	HAT	0.91	38
23-Aug	2	PFT	HAT	1.55	42
23-Aug	2	PFT	2YRF	7.17	65
23-Aug	2	PFT	HAT	3.30	51
24-Aug	2	PFT	HAT	1.32	42
24-Aug	2	PFT	HAT	1.85	46
27-Aug	2	PFT	HAT	1.36	43
27-Aug	2	PFT	2YRF	7.32	63

* Not Reported due to not being able to remove the lizard from glue trap

Table 2.4. Total observed (x_n) and expected captures adjusted for the number of hours each trap type was active (y_n) of age/sex classes of the Five-Lined skink, *Eumeces fasciatus* by trap type.

Age/Sex Class	Trap Type			
	Glue		Pitfall	
	x_n	y_n	x_n	y_n
Hatchling	1	4	7	4
Juvenile	0	0.5	1	0.5
Second Year Male	4	6	8	6
Second Year Female	0	5.5	11	5.5
Adult Male	9	12.5	19	12.5
Adult Female	0	2.5	5	2.5

Table 2.5. Total observed (x_n) and expected captures adjusted for the number of hours each trap type was active (y_n) of age/sex classes of the Five-Lined skink, *Eumeces fasciatus* by year.

Age/Sex Class	Year			
	2000		2001	
	x_n	y_n	x_n	y_n
Hatchling	0	4	8	4
Juvenile	0	0.5	1	0.5
Second Year Male	8	6	4	6
Second Year Female	0	5.5	11	5.5
Adult Male	8	12.5	17	12.5
Adult Female	0	2.5	5	2.5

0.005 < p < 0.001) was observed in age/sex class captures between years. This was probably due to my attempt to use the same glue traps in 2001 that I used in 2000.

Capture frequencies of these age/sex classes most likely indicate that their habitat preferences differ over time (Fig. 2.6, Table 2.3). Most adult and second year males and adult females were captured in the early months (April to May) of the study. This may have been due to their having increased activity during the breeding season compared to other age/sex classes. High capture rate of males in spring may reflect territory patrolling, mate searching, and foraging. Home ranges for adult and second year males, juveniles, and hatchlings were approximately 27.3 m across compared to 9.1 m across for adult and second year females (Fitch, 1954). In 2000, I captured eight adult and eight second year males and no other age/sex classes. In contrast, in 2001 I captured 17 adult and four second year males, one juvenile, and eight hatchlings compared to five captures of adult and 11 second year females. The age/sex class capture data for 2001 (6 April to 27 August) is probably the better comparison due to a longer and more complete study of the *E. fasciatus* activity cycle compared to 2000 (15 April to 6 May). A presumably smaller home range for adult and second year females may explain why they were captured less frequently, although the ratio of female to male captures is less than observed by Fitch (1954). Fitch and Von Achen (1977) also observed that during the breeding season male *E. fasciatus* home range shifted an average daily distance of 17.7 m, but home range shifted very little after the completion of breeding season. This would explain the reduced captures of adult males later in the season. Additionally, Eifler and Eifler (1999) speculated that Grand skink (*Oligosoma grande*) males increase their home range to

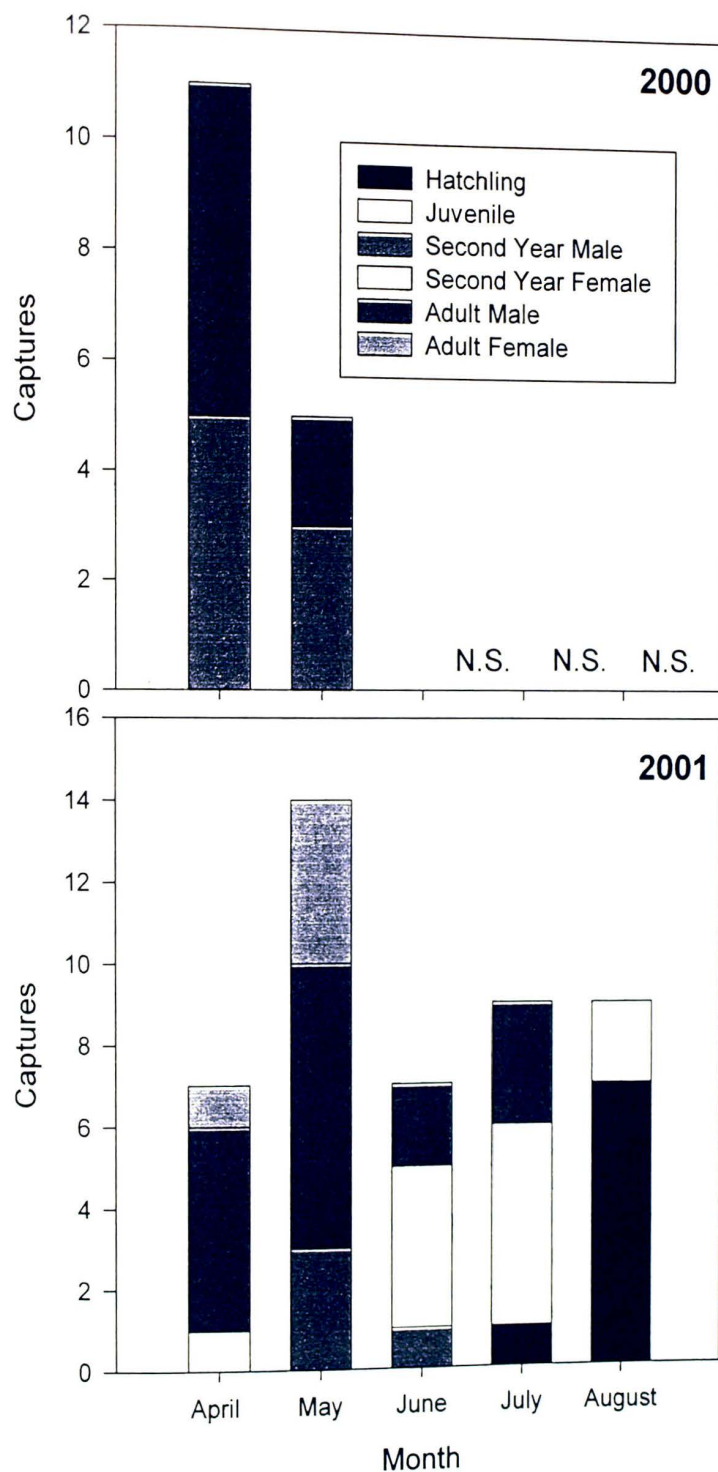


Fig. 2.6. Captures of *Eumeces fasciatus* by age/sex class. (N.S. = Not Sampled)

associate with females. As would be expected, hatchlings were captured in traps only after hatching in July to August. Also, second year females were captured in larger numbers in the later months of the study, perhaps due to increased foraging to increase their body size for the next breeding season. Only one juvenile was captured during the two years (April 2001) of this study. Juveniles may not be as catchable, or they may not be as abundant in the trapping areas compared to other age/sex classes. Also, I may have misclassified some juveniles as second year lizards. Access to traps may be more difficult for juveniles than adults because of their smaller size relative to the size of the trap. However, the capture of even smaller hatchlings in significant numbers in the later part of the summer, coupled with the assumption of a stable population size supports the hypothesis that possible habitat partitioning among *E. fasciatus* age/sex classes is occurring. The ultimate test of this hypothesis may only be made by the use of telemetry to more closely monitor movements of individuals in different age/sex classes.

In conclusion, the results of the 2000 field season suggest glue traps were more efficient than pitfall traps on a time of effort basis, but pitfall traps were a safer capture technique that required less researcher time for monitoring. The glue trap mortalities that occurred early in 2000 were eliminated by trap and procedural modifications. The results of the 2001 field season indicated that glue and pitfall traps were equally efficient on a time of effort basis, but this may be due to decreased adhesion of glue traps used in early 2001 and the change of glue trap style later in 2001. A possible reason for the failure of funnel traps to capture *E. fasciatus* in this study may be due to fabrication of funnel traps from plastic coated "shelf liner" fabric instead of a coarser meshed material. The failure

of funnel traps may be because the lizard could not see the prey item inside the funnel trap, the openings in the funnels could be too small for the lizard to enter, or too large allowing the lizard escape.

CHAPTER III

Effect of Tail Autotomy upon Social Status of Adult Male *Eumeces fasciatus*

Review of Previous Research

Social Interactions during Breeding Season

Male *E. fasciatus* in breeding condition are aggressive to other mature males and may fight upon sight and in confined spaces might even maim or kill one another (Fitch, 1954). The mortality of a second year male captured on the same glue trap with an adult male in this study seems to confirm Fitch's speculation. Fighting between reproductive males has been observed in many other lizards, such as *Sceloporus undulatus consobrinus* (Vinegar, 1975), *Gonatodes vittatus* (Demeter and Marcellini, 1981), *Eumeces laticeps* (Cooper and Vitt, 1987), *Gambusia sila* (Germano and Williams, 1993), and *Scincella lateralis* (Akin, 1998). The aggregation of female *E. fasciatus* at brood sites may explain why breeding males are so hostile towards each other (Fitch, 1954; Cooper et al., 1983; Hecnar, 1994; and Seburn, 1993). That male *E. fasciatus* seem to frequently engage in violent, physical contests rather than using display behavior to resolve territorial disputes may be explained by the possibility of a large fitness reward accruing to males who attain a territory containing communal brooding sites. If females congregate in the locality of these communal brooding sites before mating then male lizards that control these areas might achieve very high reproductive success similar to

that achieved by harem forming mammals such as sea lion or elk. After the spring breeding season males lose their salmon red suffusion and their activity decreases (Fitch, 1954).

Tail Autotomy

The self-induced breaking off of the tail from its attachment point, tail autotomy, is a mechanism to help lizards escape predation (Bellairs and Bryant, 1985; Arnold, 1988; Castilla et al., 1999). Tail autotomy has not been widely studied in *E. fasciatus*. The benefits and costs of tail autotomy have been shown to differ among lizard species (Vitt et al., 1977; Fox et al., 1994) or among age classes in the same species (Niewiarowski et al., 1997). Lizards with complete tails can save themselves more efficiently than lizards with incomplete tails (Congdon et al., 1974; Dial and Fitzpatrick, 1984; Vitt and Cooper, 1986). Consequently, there are survival costs to tail autotomy in lizards such as *Uta stansburiana* (Fox et al., 1998). Compared with tailed lizards, lizards without tails may run less effectively (Ballinger et al., 1979; Punzo, 1982; Formanowicz et al., 1990; Daniels, 1983; Brown et al., 1995) and exhibit decreased somatic growth (Ballinger and Tinkle, 1979; Smith, 1996; Niewiarowski et al., 1997; Vitt and Cooper, 1986; Althoff and Thompson, 1994). Tail autotomy may reduce fitness by reducing energy reserves for mating activity and/or yolking eggs (Smyth, 1974; Dial and Fitzpatrick, 1981). Tailless lizards may have lower social status resulting in reduced reproductive success. For example, female *E. laticeps* prefer larger males with tails (Cooper and Vitt, 1987; Cooper and Vitt, 1993). Reduced social status may result in a condensed home-range size for males and reduced access to females (Martin and Salvador, 1993; Salvador et al., 1996).

Salvador et al. (1995) speculate that large male *Psammmodronus algerus* with autotomized tails may maintain their dominance but limit their activity and reduce the area of their home range thereby achieving less reproductive success.

The fights among male *E. fasciatus* seem sufficiently violent to possibly cause tail autotomy of the combatants unless the animals have some ability to regulate autotomy in a context specific manner. Fighting males often bite each other at the base of the tail and exert much force in attempts to gain mechanical advantage. I refer to this fighting maneuver as the behavior “grapple” in this study. The potential aggregation of unbred females in brooding locales, and the very high potential reproductive success accruing to males that control these territories could provide the impetus for their violent fighting as well as the selective pressure for the evolution of context specific ability to regulate tail autotomy. If tail autotomy reduced fighting ability or attractiveness to females, there would be strong selective pressure to avoid tail autotomy while fighting. Given the demonstrated social costs of tail autotomy in *Uta stansburiana* and *E. laticeps* (Fox and Rostker, 1982; and Copper and Vitt, 1987), I hypothesized that tail autotomy could be an important factor determining social status in male *E. fasciatus*. Therefore, I designed an experiment to test the hypothesis that tail autotomy has no effect on social status of male *E. fasciatus*. If tail autotomy does reduce social status, then it would be more likely that tail autotomy is regulated in a context specific manner.

Research Plan and Methods

Testing the Effect of Autotomy on Dominance

I conducted dominance contests that are a variation of those employed by Fox and Rostker (1982) to study the effect of tail autotomy on social status of *Uta stansburiana*. They scored aggressive behaviors in order to assign dominance rankings to each member of a pair of juvenile *U. stansburiana* (Fox and Rostker, 1982). They shortened the tail of the dominant lizard by thirds, checking for a change in dominance after each removal (Fox and Rostker, 1982). If, after a third of the tail was removed from the dominant juvenile male the previously submissive juvenile male became dominant, then the new dominant juvenile male had a third of his tail removed. Tail autotomy by thirds was repeated until complete autotomy was achieved. These tests demonstrated a considerable effect of tail loss on dominance in juvenile *U. stansburiana*.

In this study I tested dominance only in adult *E. fasciatus* males. I simplified the experiment performed by Fox and Rostker (1982) because *E. fasciatus* males are usually completely indifferent or intolerant of each other during the breeding season. When males are intolerant one either retreats immediately or they will battle until one retreats. Thus, retreat is a reliable and unambiguous indicator of submissiveness. Retreat is further validated by Akin's (1998) study of dominance relationships in *Scincella lateralis* in competition for food. Although I used a female as stimulus for competition instead of food, the experimental design is similar. Akin (1998) observed male *S. lateralis* establishing dominance through biting and chasing the other male similar to the behaviors observed in my experiment. I recorded the duration of the contest, i. e., time until one of

the males retreats, as well as other behaviors displayed during the contest including orientation towards or away, tongue flicks, tail wags, approach, grappling (i.e. fighting males often bite each other in the tail and exert much force in attempts to gain mechanical advantage), and bites. A mature reproductive female was present in the contest arena throughout the trial to provide visual and pheromonal stimulus for male aggression (Fig. 3.1). A second variation I made to Fox and Rostker's experimental protocol was the use of complete rather than partial tail autotomy of the dominant male as the treatment.

I attempted to evaluate all possible pair-wise comparisons of captured males to determine initial dominance relationships. Thus, the number of contests could exceed the number of males captured. The number of possible contests is described by the formula for combinations: $(n!/r!(n-r)!)$ where n =number of distinct things, i.e. male *E. fasciatus* taken "r" at a time. Since I am observing pairs, "r" is always 2 in this case. For example, 10 male lizards could be matched in $(10!)/2!(10-2)!$ combinations, or

$$(10)(9)(8)(7)(6)(5)(4)(3)(2)(1)/(2)(1)*(8)(7)(6)(5)(4)(3)(2)(1) =$$

$$(10)(9)/2 = 90/2 = 45 \text{ combinations.}$$

For the males I captured ($n=37$) there were 647 possible contests. However, since I was not able to hold all captured males simultaneously, the actual number of contests ($n = 64$) was less than what was theoretically possible. Sometimes two males paired in a contest seem to display indifference to each other. I analyzed the frequency and/or duration of fighting in males captured from sites in "close proximity" versus those captured from distant sites i.e. "within versus between the same population". I hypothesized males from the same population may have already established dominance relationship prior to their capture

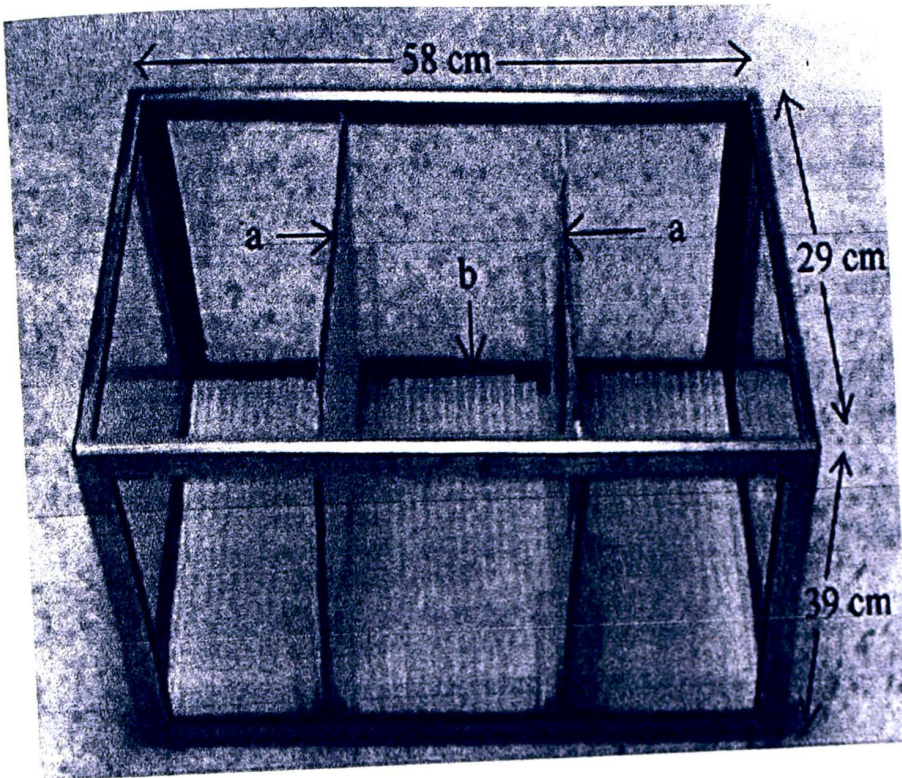


Fig. 3.1. Contest arena for dominance contests between adult male *Eumeces fasciatus*, the Five-Lined skink. a. removable cardboard partitions. b. shelf liner covering glass bottom.

whereas males from two distinct populations certainly have not established dominance relationship prior to capture. Contests in which dominance relationship could be assigned, i.e. one animal clearly retreated, were repeated after complete autotomy of the dominant animal to assess the effect of tail autotomy on its dominance.

Because the behavioral data did not meet the normality assumptions of ANOVA, the contests data were analyzed by the nonparametric Wilcoxon Rank Sum test to test the hypothesis of no effect of tail autotomy on dominance. Similarly, the trap distance data did not meet the normality assumptions of ANOVA, so I used Wilcoxon Rank Sum test to determine if males fought differently with each other among years, and to test the subsidiary hypothesis that some dominance relationships may have been established prior to the time the males were captured. I reasoned that males captured in close proximity were more likely to have established a dominance relationship prior to capture than those captured at distant sites. I chose to analyze the contest in this manner because of previous observations that males seem to fight very hard, or not at all (Schiller, personal communication). When no fighting occurs there is either what appears to be complete indifference between two males or immediate retreat by the submissive male, possibly, but not necessarily, because dominance has already been established prior to the contest.

Results and Discussion

Effects of Social Status on Behavior

I recorded the number of tongue flicks, tail wags, grapples, and bites observed during male dominance contests (Fig. 3.2, Table A). I classified males that retreated as submissive and males that did not retreat as dominant. Males that did not interact were

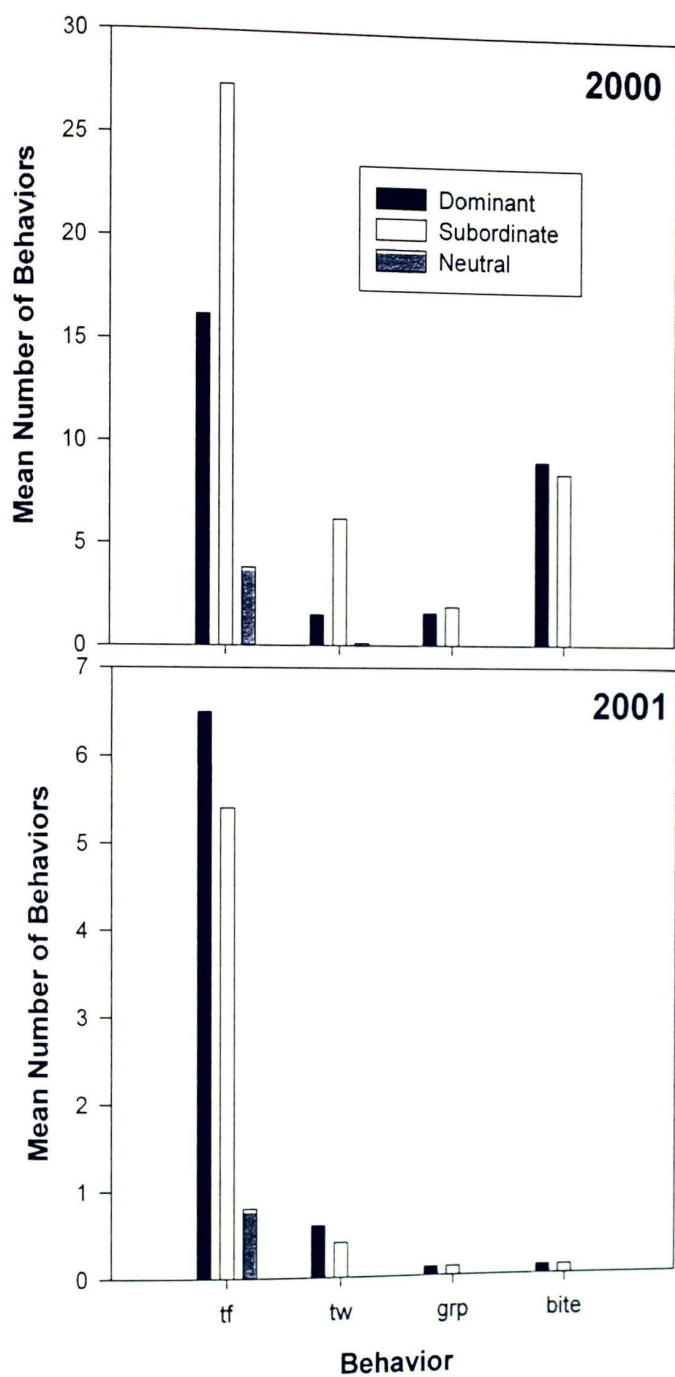


Fig. 3.2. Mean number of behaviors (tf = tongue flicks, tw = tail wags, grp = grapples, and bite = bites) of adult male *Eumeces fasciatus* in dominance contests.

classified as “neutral”. The mean number differed between years for all of the studied behaviors based upon the results of the t-test shown in table 3.1. The t-tests show intensity of each behavior differed between years. Therefore, subsequent analyses will be made on each year separately. The difference in behaviors between years may be due to the low temperature conditions in the lab where the experiments were conducted in 2001 (~ 16 °C) compared to 2000 (~ 22 °C). I did not regulate temperatures because the temperatures of the thermostats were set by Austin Peay State University in Clarksville, TN. Therefore, the 2001 data must be considered suspect because the male lizards were less active due to the low temperature.

In order to test for an effect of social status on behavior, I analyzed each behavior using the Wilcoxon Rank Sum test (Table 3.2) where:

Behavior = the number of each of the behaviors counted during the contest,

Dominance classification = dominant, neutral, or subordinate as determined by the outcome of the contest

Because all of the behaviors were measured in each contest and therefore cannot be considered independently observed, the Bonferonni adjustment was applied to correct for experimentwise error. The Bonferonni correction for significance $\alpha'' = \alpha/k$, where $\alpha = 0.05$ and k = the number of dependent significant tests. Thus, $\alpha'' = 0.05/4 = 0.013$ is the appropriate significance level.

Therefore, all the behaviors among dominance classes for each year were not significant, and thus, I could not detect any relationship of the behaviors to dominance classification.

Table 3.1. T-tests comparing the mean number of *Eumeces fasciatus* behaviors (tongue flicks, tail wags, grapples, and bites) between years (2000 and 2001) (df = degrees of freedom).

Behavior	2000 Mean	2001 Mean	t-value	df	p-value
Tongue flicks	16.40	3.52	2.80	94	0.006
Tail Wags	3.03	0.26	2.06	94	0.042
Grapples	1.23	0.05	2.91	94	0.005
Bites	5.50	0.06	2.62	94	0.010

Table 3.2. Wilcoxon Rank Sum tests of *Eumeces fasciatus* behaviors (tongue flicks, tail wags, grapples, and bites) among dominance classes (dominant, neutral, and subordinate) for 2000 and 2001 "behavior = dominance classification" (df = degrees of freedom).

Behavior	Year					
	2000			2001		
	Chi-square	df	p-value	Chi-square	df	p-value
Tongue flicks	3.01	2	0.222	6.47	2	0.039
Tail wags	3.11	2	0.211	5.72	2	0.057
Grapples	4.90	2	0.086	3.69	2	0.158
Bites	6.50	2	0.039	3.69	2	0.158

Capture distance, distance in meters between the traps in which the two lizards in each contest were captured was recorded. Almost all of the contests were between male lizards that were captured far away (> 50 m) from each other. Fight was defined as physical contact (i.e. a bite and/or grapple occurred and was followed by a retreat by one male *E. fasciatus* during the contest) or the immediate retreat of one animal in response to an advance by the other and the latter situation possibly indicating a previously established dominance relationship. No fighting was defined as retreat or indifference.

The capture distance data was analyzed to test for the possibility that animals captured in close proximity may have already established dominance relationships. This hypothesis would be supported if a significant positive relationship were found between capture distance and fighting. I used a t-test to see if capture distances differed among years ($t=1.25$, $df=62$, $p=0.216$). These results show there was no difference between years; therefore, data for both years were considered together.

The Wilcoxon Rank Sum test was used to determine if males fought with each other differently among trap distances, where:

Fight = "Yes" if physical contact occurs or if one animal advances and the other immediately retreats or "No: if both retreat or display indifference

The Wilcoxon Rank Sum test for the model "trap distance = fight" ($\chi^2=0.46$, $df=1$, $p=0.496$) showed no significant relationship of capture distance to likelihood of fighting. However, given that very few of the male *E. fasciatus* were captured in closely spaced traps it is likely they had virgin interactions in the dominance contests.

Behavior data was compared from dominance contests before and after tail autotomy when there was a fight to see if the length of the contest and/or number of behaviors (tongue flicks, tail wags, grapples, and bites) differed as a result of autotomy. The duration of the contests before autotomy, 14 min ($n = 48$) differed from the duration of the contests after autotomy, 13 min ($n = 16$), ($t = -4.39$, $df = 62$, $p < 0.0001$).

Because all of the behaviors were measured in each contest and therefore cannot be considered independently observed, the Bonferonni adjustment was applied to correct for experimentwise error. The Bonferonni correction for significance $\alpha'' = \alpha/k$, where $\alpha = 0.05$ and k = the number of related significant tests. Thus, $\alpha'' = 0.05/4 = 0.013$ is the appropriate significance level. The results for the t-test comparing each behavior before and after tail autotomy are shown in table 3.3. The mean number of tongue flicks before tail autotomy, 26.2, did not differ from those after tail autotomy, 15.3. Since there were no tail wags, grapples, or bites in the postautotomy contests compared to an average of 5.1 tail wags, 1.8 grapples, and 8.0 bites before autotomy; there were more of these behaviors exhibited before tail autotomy compared to after. After dominance has been established the subordinate lizard backed down from the advances of the dominant lizard even though the dominant lizard's tail had been autotomized. Even if the submissive lizard had challenged the dominant lizard, the submissive male would have a harder time biting dominant's tail, so that the number of bites and grapples that potentially could have occurred would have been reduced. If these behaviors tend to be reciprocal, then tail wags would be reduced also.

Table 3.3. T-tests comparing each *Eumeces fasciatus* behavior (tongue flicks, tail wags, grapples, and bites) before and after tail autotomy (df = degrees of freedom).

Behavior	t-value	df	p-value
Tongue flicks	-0.93	62	0.354
Tail Wags	-1.04	62	0.302
Grapples	-1.01	62	0.317
Bites	-0.83	62	0.409

Neither this study (n=16) nor previous data (Schiller, unpublished data) (n=10) showed dominance reversal as a result of tail autotomy. These results strongly suggest that tail autotomy causes no discernable reduction in social dominance among male *E. fasciatus*. I did not assess its possible effect on female preference. Although tail autotomy does not seem to affect social dominance among male *E. fasciatus* it may yet prove important to female *E. fasciatus*. Further, it almost certainly reduces fitness by impairing escape from predators and diverting energy from growth and activity to tail growth.

Fox and Rostker's (1982) dominance contest experiments used juvenile *Uta stansburiana*, which is an iguanid that communicates at a distance with displays (i.e., headbobbing, body push-ups, enlarging the throat, open mouth displays, and curling their tail (this latter display would obviously not be possible after tail autotomy, and may explain the loss dominance in autotomized *U. stansburiana*)). In contrast, *E. fasciatus* is a fossorial species and would not be expected to be as visually oriented. *Eumeces fasciatus* might rely more on olfactory communication to establish and/or communicate dominance, and, therefore is less affected by tail autotomy than *U. stansburiana*.

CHAPTER IV

Pheromone Communication of Social Status

of Adult Male *Eumeces fasciatus*

Communication among individuals in a population by odor, i.e. pheromones, is important in social interactions in many reptiles (Mason, 1992). Although, not widely studied in *Eumeces fasciatus*, pheromones have been shown to communicate species membership, sex, and reproductive state in the closely related *Eumeces laticeps* (Cooper and Vitt, 1986a; Cooper, 1995; Mason, 1992). Male *E. laticeps* can recognize pheromones from the skin and cloaca of females (Cooper and Vitt, 1984b) and have the ability to track females by scent (Cooper and Vitt, 1986b). *Eumeces fasciatus* males also locate females by odor (Fitch, 1954). Additionally, *E. laticeps* males use odor to identify familiar versus unfamiliar males (Cooper and Vitt, 1984a). Given the demonstrated significance of pheromone communication in *E. laticeps*, I reasoned that pheromones may be used to communicate social status in male *E. fasciatus*. Therefore, I designed the experiment described here to test the hypothesis: male *E. fasciatus* do not utilize pheromones to recognize social status (i.e. dominance or subordination) of conspecifics.

Research Plan and Methods

The experimental protocol for the pheromone study mirrored that for dominance contests in that pheromone swabs were obtained from every pair of lizards observed in a dominance contest and used in a corresponding pheromone test. At the conclusion of

each dominance contest a pheromone sample was collected from each male by wiping the cloacal region with a cotton swab. Cloacal swabs were kept frozen in individual plastic bags until the pheromone tests were conducted, usually within two days of the dominance contests. Each male *E. fasciatus* was presented with a cloacal swab from itself and from its opponent in the dominance contest, as well as a swab with distilled water. The pheromone swabs presented were classified as dominant, subordinate, or neutral pheromone as determined by the outcomes of the earlier dominance trial between the two males. That is the pheromone swab obtained from a lizard classified as "dominant" in a dominance contest was classified as "dominant" for the pheromone test and so on. Distilled water swabs were only used in 2001 because the need for this control was not recognized until after the pheromone tests conducted in 2000 had been completed. The pheromone swabs were presented in a double blind method where the experimenter presenting the swabs to the lizards knew neither the social status of the animal from which the swab was collected nor the social status of the animal to which the swab was presented. The pheromone swab was presented to each lizard for 60 seconds or until the lizard displayed one of these behaviors: stands ground, or retreat, or bite the swab. I classified the response of male lizards to cloacal swabs presented to them as neutral if they responded with tongue flicks and/or "stands ground", submissive if they retreated, and dominant if they bit it. I recorded the number of tongue flicks a lizard made in response to a cloacal swab. The results of all tongue flick data from the pheromone tests were recorded and analyzed by the nonparametric ANOVA analog the Wilcoxon Rank Sum test to test the hypothesis of no effect of tongue flicks on dominance. I did not use

ANOVA because the data did not satisfy normality assumptions. Then the dominance classifications from the dominance contests were compared to the dominance classifications from the pheromone tests. I used contingency table analyses to see if the response of male lizards to pheromone swabs was consistent with their response to the male lizard from which the pheromone swab was obtained.

Results and Discussion

The number of tongue flicks observed during the pheromone tests are presented in (Fig. 4.1, and Tables B and C). The mean number of tongue flicks during the pheromone tests differed between years for both self ($t=5.00$, $df=98$, $p<0.0001$) and conspecific pheromone ($t=3.07$, $df=102$, $p=0.003$). The difference in tongue flicks between years may be due to the less than optimal temperature conditions in the lab where the experiments were conducted in 2001 ($\sim 16^\circ\text{C}$) compared to 2000 ($\sim 22^\circ\text{C}$). Given that the relationship between tongue flicks, dominance class, and pheromone source differed between years the analyses of tongue flick data relative to dominance classification and pheromone source are considered separately for each year. Additionally, the effect of dominance classification and the effect of pheromone source on tongue flicks were analyzed separately because the Wilcoxon Rank Sum test is limited to a one level model. I analyzed the following models "tongue flicks = dominance class" and "tongue flicks = pheromone source" using the Wilcoxon Rank Sum test where:

Dominance classes = swab from a dominant, neutral, or subordinate

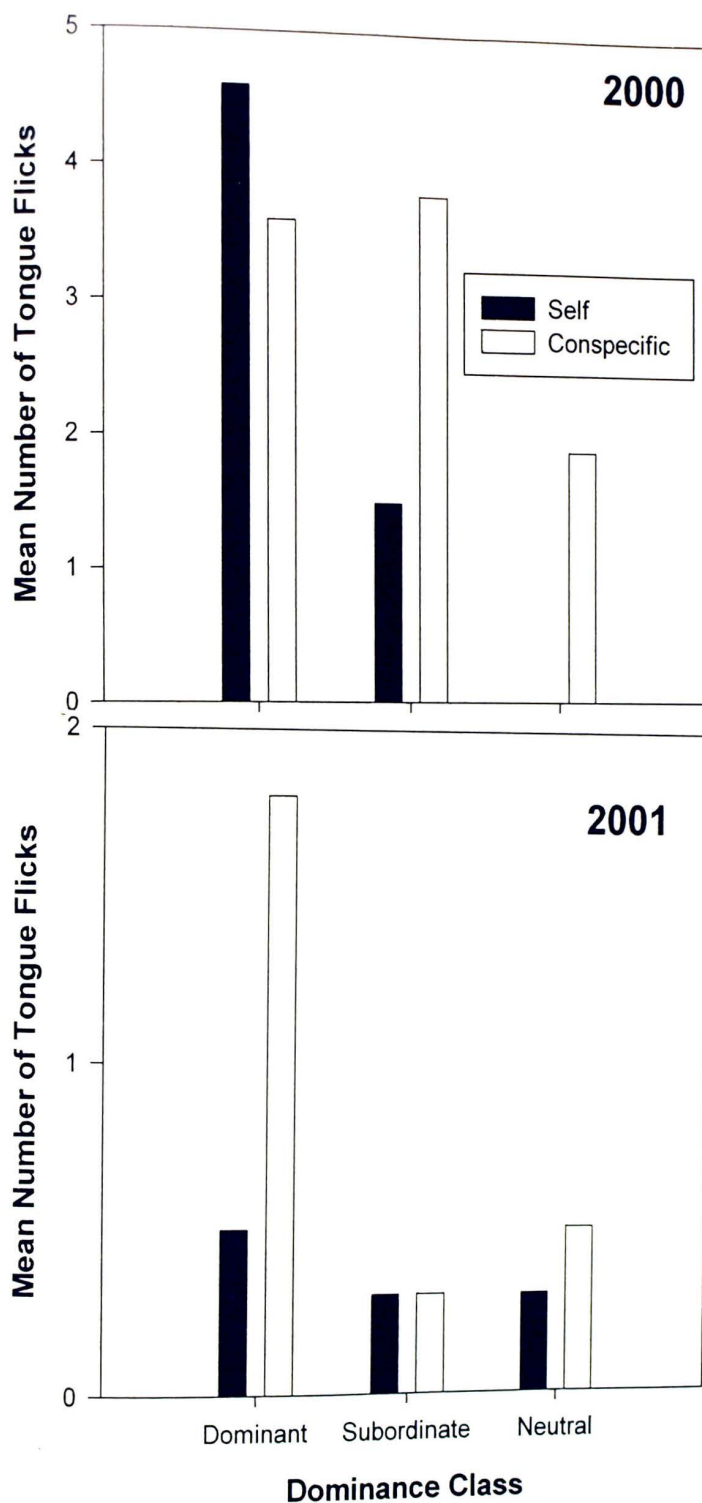


Fig. 4.1. Mean number of tongue flicks exhibited by adult male *Eumeces fasciatus* in pheromone tests.

The results for the Wilcoxon Rank Sum test of tongue flicks as a function of dominance classes and pheromone source for 2000 are as follows:

Dominance class: ($\chi^2=3.91$, $df=2$, $p=0.142$)

Pheromone source: ($\chi^2=0.08$, $df=1$, $p=0.776$)

The results for the Wilcoxon Rank Sum test of tongue flicks as a function of dominance classes and pheromone source for 2001 are as follows:

Dominance class: ($\chi^2=0.72$, $df=2$, $p=0.699$)

Pheromone source: ($\chi^2=0.45$, $df=1$, $p=0.500$)

I obtained no significant results for tongue flicks, i.e. animals did not tongue flick differently to “self pheromone” versus “conspecific pheromone” or to dominant versus neutral versus subordinate pheromone. In a similar study, Bofill and Lewis (1999) found no significant difference in tongue flicks in the Teiid lizard, *Ameiva exsul*, to “unfamiliar male pheromone” versus “distilled water blank”. In a study with *E. laticeps*, Cooper (1996) presented animals with pheromone swabs from familiar versus unfamiliar conspecifics, in which he observed a difference. In this study, I did not present the lizards with pheromones from unfamiliar conspecifics.

I used contingency table analyses to see if the response of animals to pheromone swabs was consistent with their response to the male lizard from which the pheromone swab was obtained. That is, if the lizard had responded submissively to another lizard in a dominance contest, did it then respond submissively to the pheromone swab obtained from that animal? Because number of tongue flicks per pheromone test were shown to

differ between years, a separate contingency analysis was performed for each year. I tested the hypothesis: dominance classification determined by dominance contests is not different from dominance classification determined by pheromone tests. All the contingency tables performed produced a warning that the Chi Square statistic is suspect because 20% of the contingency table cells have expected counts of less than five. Table 4.1 presents the contingency table of the response of the lizards to “Conspecific pheromone” in 2000. Although the likelihood ratio Chi Square is marginally significant, given the unreliability of the test on a table with cells containing expected values less than five, and the insignificant Pearson Chi Square, I conclude that there was no significant difference in dominance classifications between experiments, i.e. dominance classification based on 16 observations (Table B) of reaction to pheromone swabs was similar to dominance classification as determined by contest data (Likelihood Ratio: $\chi^2=10.65$, $df=4$, $p=0.031$; Pearson: $\chi^2=9.18$, $df=4$, $p=0.057$).

Table 4.1 presents the contingency table analysis of 88 observations of response (Table C) of *E. fasciatus* males to “Conspecific pheromone” in 2001. There was no significant difference in dominance classifications (dominant, subordinate, neutral) between experiments, i.e. contests versus pheromone tests (Likelihood Ratio: $\chi^2=5.50$, $df=4$, $p=0.240$; Pearson: $\chi^2=5.21$, $df=4$, $p=0.267$). I failed to reject the hypothesis that dominance classification as determined in actual contests was a reliable predictor of dominance classification as determined in pheromone tests. However, this may be due to low temperatures (~ 16 °C) in 2001 in the lab where the experiments were conducted

Count Total % Col % Row %	D	N	S	2000
D	2 12.50 100.00 40.00	2 12.50 66.67 40.00	1 6.25 9.09 20.00	5 31.25
N	0 0.00 0.00 0.00	0 0.00 0.00 0.00	5 31.25 45.45 100.00	5 31.25
S	0 0.00 0.00 0.00	1 6.25 33.33 16.67	5 31.25 45.45 83.33	6 37.50
	2 12.50	3 18.75	11 68.75	16

Count Total % Col % Row %	D	N	S	2001
D	5 5.68 29.41 21.74	6 6.82 16.22 26.09	12 13.64 35.29 52.17	23 26.14
N	7 7.95 41.18 16.28	19 21.59 51.35 44.19	17 19.32 50.00 39.53	43 48.86
S	5 5.68 29.41 22.73	12 13.64 32.43 54.55	5 5.68 14.71 22.73	22 25.00
	17 19.32	37 42.05	34 38.64	88

Table 4.1. Contingency tables of dominance classifications (dominant, subordinate, neutral) from dominance contests versus pheromone tests of adult male *Eumeces fasciatus*.

because the overall intensity of the observed behaviors decreased when compared to 2000.

Analysis of 12 observations of response (Table B) of *E. fasciatus* males to “Self pheromone” in 2000 showed a subordinate response to all the swabs. Therefore, there is nothing to compare in a contingency table analysis. Although, if for example I change two subordinate results to one dominant and one neutral I get a highly significant result (Likelihood Ratio: $\chi^2=4.03$, $df=4$, $p=0.403$; Pearson: $\chi^2=3.89$, $df=4$, $p=0.422$). The point of this exercise being to demonstrate that the inability to perform the statistical analysis is only computational. In fact, the data suggests strongly that a significant difference exists. However, these conclusions consequently may not hold much significance due to the small sample resulting from the small number of male lizards captured in 2000.

Table 4.2 presents the contingency table analysis of 88 observations of response (Table C) of *E. fasciatus* males to “Self pheromone” in 2001. There was no significant difference in dominance classifications (dominant, subordinate, neutral) between experiments, i.e. contests versus pheromone tests (Likelihood Ratio: $\chi^2=2.89$, $df=4$, $p=0.576$; Pearson: $\chi^2=2.67$, $df=4$, $p=0.612$). Therefore, I failed to reject the hypothesis that dominance classification as determined in actual contests was a reliable predictor of dominance classification as determined in pheromone tests. Although, the dominance classifications from dominance contests compared to those from pheromone tests were in agreement for both 2000 and 2001. In retrospect, I should have maintained experimental temperatures at a higher level in 2001. In addition, it would have been good idea to

Count Total % Col % Row %	D	N	S	
D	2 2.27 20.00 8.70	1 1.14 10.00 4.35	20 22.73 29.41 86.96	23 26.14
N	5 5.68 50.00 11.63	7 7.95 70.00 16.28	31 35.23 45.59 72.09	43 48.86
S	3 3.41 30.00 13.64	2 2.27 20.00 9.09	17 19.32 25.00 77.27	22 25.00
	10 11.36	10 11.36	68 77.27	88

Table 4.2. Contingency table for 2001 of dominance classifications (dominant, subordinate, neutral) from dominance contests versus pheromone tests of adult male *Eumeces fasciatus*.

collect cloacal swabs of male *E. fasciatus* before the dominance contests so they could have been compared to the cloacal swabs taken after the contests. This might have revealed the existence of prior established dominance relationships among the male lizards and helped explain some of the contest and pheromone test results. However, it would not have changed the outcome of the contingency table analysis reported here.

In all pheromone tests conducted in 2001, I used a swab with distilled water as a negative control to see if the response of the lizard was to the swab or the pheromone. All lizards responded to the distilled water swab in the same manner, i.e. the lizard stood its ground and never tongue flicked to the distilled water swab. Although, lizards did tongue flick to "self" pheromone swabs in 36.0 % of the tests (0.7 tongue flicks per pheromone test) and to "conspecific" pheromone swabs in 36.7% of the tests (1.2 tongue flicks per pheromone test) pheromones, this difference was not significant in the Wilcoxon Rank Sum test. I can speculate that lizards had no interest (i.e., no dominant or subordinate behaviors exhibited) in the distilled water swab. This confirms that pheromones probably can be detected and assessed on the cloacal swab (i.e., self and conspecific's pheromones) presented to the lizards but there is no evidence for a difference in reaction to swabs from different dominance classes. Additionally, this supports the classification of "standing ground" as being a neutral behavior since this was how all animals responded to the distilled water control.

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Appendices

Table A. Dominance contest behaviors exhibited by the Five-Lined skink, *Eumeces fasciatus* (D = dominant, N = neutral, and S = subordinate).

Year	Dominance Class	Tongue Flicks	Tail Wags	Grapples	Bites
2000	N	2	0	0	0
2000	N	7	0	0	0
2000	D	22	6	0	1
2000	S	4	22	6	26
2000	S	30	0	0	0
2000	S	84	2	4	7
2000	S	12	0	0	0
2000	D	1	0	0	0
2000	S	53	62	16	83
2000	S	106	0	0	0
2000	S	0	0	0	0
2000	D	5	0	0	0
2000	D	30	0	0	0
2000	D	2	0	0	0
2000	D	4	1	1	3
2000	N	7	0	0	0
2000	N	0	0	0	0
2000	N	1	0	0	0
2000	N	0	0	0	0
2000	S	0	0	0	0
2000	N	12	0	0	0
2000	N	6	1	0	0
2000	S	9	0	0	2
2000	D	5	4	6	31
2000	D	15	0	0	0
2000	D	15	0	4	3
2000	D	99	0	0	0
2000	S	4	0	0	0
2000	D	21	10	11	63
2000	D	4	0	0	0
2000	D	4	0	0	0
2000	S	0	0	0	0
2000	S	2	0	0	0
2000	S	0	0	0	0
2000	S	80	13	1	1
2000	N	8	0	0	0
2000	N	2	0	0	0
2000	N	0	0	0	0
2000	N	0	0	0	0
2000	D	0	0	1	0
2001	D	0	0	0	0
2001	D	50	0		

2001	N	0	0	0	0
2001	D	0	0	0	0
2001	N	0	0	0	0
2001	N	0	0	0	0
2001	S	2	0	0	0
2001	N	1	0	0	0
2001	N	0	0	0	0
2001	D	1	0	0	0
2001	S	38	7	1	0
2001	D	2	0	0	1
2001	D	0	0	0	0
2001	N	0	0	0	0
2001	N	0	0	0	0
2001	D	1	0	0	0
2001	D	13	2	0	0
2001	N	12	0	0	1
2001	D	2	0	0	0
2001	S	0	1	0	0
2001	N	0	0	0	0
2001	N	2	0	0	0
2001	S	8	0	0	0
2001	D	0	0	0	0
2001	N	0	0	0	0
2001	D	0	0	0	0
2001	D	1	0	0	0
2001	D	4	0	0	0
2001	D	2	0	0	0
2001	N	1	0	0	0
2001	N	0	0	0	0
2001	D	3	0	0	0
2001	D	8	0	0	0
2001	N	6	0	0	0
2001	N	3	0	0	0
2001	D	2	0	0	0
2001	N	0	0	0	0
2001	N	0	0	0	0
2001	N	3	0	0	0
2001	S	0	0	0	0
2001	D	0	0	0	0
2001	N	0	0	0	0
2001	N	0	0	0	0
2001	N	0	0	0	0
2001	S	25	0	1	1
2001	S	0	0	0	0
2001	N	17	0	0	0
2001	S	0	0	0	0
2001	N	0	0	0	0
2001	N	0	0	0	0
2001	D	37	1	0	0
2001	N	0	0	0	0

2001	N	0	0	0	0
2001	S	0	0	0	0
2001	D	16	0	0	0
2001	S	24	11	1	0
2001	S	6	0	0	0
2001	N	0	1	0	0
2001	N	0	0	0	0
2001	S	0	0	0	0
2001	S	5	0	0	0
2001	N	1	0	0	0
2001	S	0	0	0	0
2001	D	0	0	0	0
2001	N	0	0	0	0
2001	N	0	0	0	0
2001	D	7	0	0	0
2001	S	0	0	0	2
2001	N	0	0	0	0
2001	S	2	0	0	0
2001	S	0	0	0	0
2001	S	0	0	0	0
2001	S	0	0	0	0
2001	N	0	0	0	0
2001	N	2	0	0	0
2001	S	0	0	0	0
2001	S	0	0	0	0
2001	N	0	0	0	0
2001	N	3	0	0	0
2001	S	0	0	0	0
2001	N	0	0	0	0
2001	N	0	0	0	0
2001	N	0	0	0	0
2001	D	0	0	0	0
2001	S	0	0	0	0
2001	N	0	0	0	0
2001	N	0	0	0	0
2001	N	0	0	0	0

Table B. Dominance classification of the Five-Lined skink, *Eumeces fasciatus*, from dominance contests, self pheromone tests, and number of tongue flicks exhibited during self pheromone tests (D = dominance, N = neutral, and S = subordinate).

Pheromone Test	Year	Dominance classification of Lizard in Dominance Contests	Dominance classification of Lizard in Dominance Contests	Tongue Flicks
1	2000	D	S	14
2	2000	S	S	2
3	2000	D	S	3
4	2000	D	S	6
5	2000	D	S	0
6	2000	N	S	0
7	2000	S	S	1
8	2000	D	S	1
9	2000	D	S	5
10	2000	D	S	3
11	2000	N	S	0
12	2000	N	S	0
13	2001	D	S	4
14	2001	D	S	2
15	2001	N	S	0
16	2001	D	S	2
17	2001	N	S	0
18	2001	N	S	2
19	2001	N	S	1
20	2001	N	S	1
21	2001	N	N	1
22	2001	D	S	0
23	2001	S	S	1
24	2001	D	S	3
25	2001	D	D	0
26	2001	N	S	0
27	2001	N	S	0
28	2001	D	S	5
29	2001	D	S	0
30	2001	N	S	0
31	2001	D	S	0
32	2001	S	S	0
33	2001	N	N	0
34	2001	N	S	1
35	2001	S	S	0
36	2001	D	S	0
37	2001	N	D	0
38	2001	D	S	0
39	2001	D	S	0

40	2001	D			69
41	2001	S	S		1
42	2001	S	S		0
43	2001	N	S		0
44	2001	S	S		1
45	2001	N	S		0
46	2001	N	S		0
47	2001	D	S		1
48	2001	N	S		0
49	2001	N	N		0
50	2001	S	S		0
51	2001	D	S		0
52	2001	S	S		1
53	2001	S	S		0
54	2001	N	S		0
55	2001	N	S		0
56	2001	S	S		0
57	2001	S	S		0
58	2001	N	N		1
59	2001	S	N		1
60	2001	D	N		0
61	2001	N	N		0
62	2001	N	S		0
63	2001	D	S		0
64	2001	S	D		0
65	2001	N	S		0
66	2001	S	S		0
67	2001	S	S		2
68	2001	S	D		0
69	2001	D	S		0
70	2001	N	S		0
71	2001	N	S		0
72	2001	D	S		1
73	2001	D	D		2
74	2001	N	D		0
75	2001	N	S		0
76	2001	D	S		0
77	2001	N	S		0
78	2001	N	S		0
79	2001	N	S		0
80	2001	S	N		0
81	2001	D	S		0
82	2001	N	N		0
83	2001	N	S		0
84	2001	N	S		0
85	2001	S	D		0
86	2001	N	S		2
87	2001	N	D		0
88	2001	S	S		0
89	2001	S	S		1

90	2001	N			70
91	2001	N	S		2
92	2001	S	N		0
93	2001	N	S		0
94	2001	N	S		0
95	2001	N	D		0
96	2001	D	S		0
97	2001	S	S		0
98	2001	N	S		0
99	2001	N	S		0
100	2001	N	D		0
			S		0

Table C. Dominance classification of the Five-Lined skink, *Eumeces fasciatus*, from dominance contests, conspecific pheromone tests, and number of tongue flicks exhibited during conspecific pheromone tests (D = dominance, N = neutral, and S = subordinate).

Pheromone Test	Year	Dominance classification of Lizard in Dominance Contests	Dominance classification of Lizard in Dominance Contests	Tongue Flicks
1	2000	D	D	5
2	2000	S	N	2
3	2000	N	S	9
4	2000	S	S	12
5	2000	S	S	2
6	2000	S	S	0
7	2000	S	S	0
8	2000	D	S	5
9	2000	D	N	7
10	2000	D	D	2
11	2000	D	N	0
12	2000	N	S	0
13	2000	N	S	0
14	2000	N	S	1
15	2000	N	S	6
16	2000	S	S	1
17	2000	S	S	0
18	2000	D	D	12
19	2000	N	S	1
20	2000	D	D	4
21	2000	D	S	0
22	2000	D	N	3
23	2000	D	S	2
24	2000	S	N	22
25	2000	S	S	0
26	2000	S	S	1
27	2000	S	S	0
28	2000	N	S	0
29	2000	N	S	1
30	2000	N	S	1
31	2000	N	S	2
32	2000	D	N	0
33	2001	D	S	2
34	2001	D	N	1
35	2001	N	S	1
36	2001	D	N	0
37	2001	N	S	0
38	2001	N	S	0
39	2001	N	N	

40	2001	N			
41	2001	N	S		1
42	2001	D	N		1
43	2001	S	S		0
44	2001	D	D		4
45	2001	D	S		0
46	2001	N	S		2
47	2001	N	S		0
48	2001	D	D		1
49	2001	D	S		1
50	2001	N	N		0
51	2001	D	N		0
52	2001	S	D		0
53	2001	N	D		0
54	2001	N	N		0
55	2001	S	N		0
56	2001	D	N		0
57	2001	N	S		0
58	2001	D	D		0
59	2001	D	S		2
60	2001	D	S		0
61	2001	S	D		0
62	2001	S	S		0
63	2001	N	S		0
64	2001	S	N		0
65	2001	N	N		0
66	2001	N	S		1
67	2001	D	S		0
68	2001	N	N		0
69	2001	N	N		4
70	2001	S	N		24
71	2001	D	S		0
72	2001	S	N		1
73	2001	S	D		0
74	2001	N	N		0
75	2001	N	S		0
76	2001	S	N		6
77	2001	S	S		1
78	2001	N	S		0
79	2001	S	D		0
80	2001	D	N		0
81	2001	N	D		0
82	2001	N	N		6
83	2001	D	N		0
84	2001	S	N		0
85	2001	N	N		0
86	2001	S	N		0
87	2001	S	N		0
88	2001	S	N		0
89	2001	D	N		0

90	2001	N	S	0
91	2001	N	N	0
92	2001	D	S	0
93	2001	D	D	0
94	2001	N	S	0
95	2001	N	N	2
96	2001	D	D	0
97	2001	N	S	0
98	2001	N	D	0
99	2001	N	D	0
100	2001	S	S	0
101	2001	D	S	0
102	2001	N	S	0
103	2001	N	N	0
104	2001	N	S	0
105	2001	S	N	1
106	2001	N	N	1
107	2001	N	S	0
108	2001	S	N	2
109	2001	S	D	0
110	2001	N	D	1
111	2001	N	N	1
112	2001	S	N	2
113	2001	N	N	0
114	2001	N	S	0
115	2001	N	S	0
116	2001	D	D	0
117	2001	S	S	0
118	2001	N	D	1
119	2001	N	N	1
120	2001	N	N	1

Theodore T. Ives Jr. was born in Rochester, New York on May 12, 1977. He attended elementary school at Saint Margaret Mary in Rochester, New York and graduated from Irondequoit High School in Rochester, New York in June, 1995. The following September he entered Barry University in Miami Shores, Florida and in December, 1998 received the degree of Bachelor of Science in Biology.

He presently attends Austin Peay State University in Clarksville, Tennessee working towards his Master of Biology degree.