J. Entomol. Res. Soc., 15(2): 37-50, 2013 *ISSN:1302-0250*

Ethology of *Stichopogon trifasciatus* (Say, 1823) (Diptera: Asilidae) in Northeastern Florida, U.S.A.

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ABSTRACT

Stichopogon trifasciatus (Say, 1823) foraged from the ground, and rocks and small sticks on the ground. Most prey were captured and immobilized in flight. Prey came from the orders Araneae (1.4%), Coleoptera (1.4%), Diptera (26.1%), Hymenoptera (2.9%), Lepidoptera (1.4%), and Orthoptera (66.7%). Mating was generally preceded by male courtship and occurred in the male over female position. Eggs were laid in the soil. The daily rhythm of activity consisted of peaks for both mating and feeding in the morning and afternoon, although after the morning peak these behaviors steadily decreased. Grooming behavior was similar to that described for other species of Asilidae. Habitat, resting behavior, and predators and parasites also are discussed.

Key words: Behavior, robber flies, prey.

INTRODUCTION

In the United States of America (U.S.A.) there are 10 valid species of robber flies in the genus *Stichopogon* (Barnes, 2013). The ethology of only *S. trifasciatus* (Lavigne and Holland, 1969; Rogers and Lavigne, 1972; Weeks and Hespenheide, 1985) and *S. catulus* Osten-Sacken, 1887 (Weeks and Hespenheide, 1985) have been described in some detail, with other publications containing primarily observations on habitat and/or prey (*S. trifasciatus* in Back, 1909; Baker and Fischer, 1975; Blanton, 1939; Bromley, 1931, 1934, 1946, 1950; Dennis *et al*., 2010, 2012; Hull, 1962, as *Neopogon;* James 1938, 1941; Lavigne, 2002; McAtee and Banks, 1920). Similar information on habitat and/or prey has been published for, *S. abdominalis* Back, 1909 (Back, 1909; Hull, 1962); *S. arenicola* Wilcox, 1936 (Hull, 1962); *S. argenteus* (Say, 1823) (Back, 1909; Baker and Fischer, 1975; Bromley, 1946; Hull, 1962; James, 1938; Lavigne, 2002; McAtee and Banks, 1920; Rogers and Lavigne, 1972); *S. californica* Barnes, 2013 (Barnes, 2013); *S. colei* Bromley, 1934 (Hull, 1962 as *S. colei* and *S. pritchardi*); *S. coquilletti* (Bezzi, 1910) (Barnes, 2013; Hull, 1962, as *Neopogon*); *S. fragilis* Back, 1909 (Hull, 1962; Weeks and Hespenheide, 1985; Wilcox, 1936); *S. pritchardi* Bromley, 1951 (Hull, 1962); *S. salinus* (Melander, 1924) (Hull, 1962, as *Neopogon*); *S*. spp. (Dennis *et al*., 2009, 2010, 2012; Hull, 1962); and *S. venturiensis* Barnes, 2010 (Barnes, 2010, 2013). This paper provides detailed information on the ethology of *S. trifasciatus* in the Moses Creek Conservation Area (MCCA) in St. Augustine, Florida, U.S.A.

MATERIALS AND METHODS

Stichopogon trifasciatus is a small fly (approximately 8-16 mm, excluding antennae) and widely distributed in Florida and, depending on location, generally occurs from March into October. Most observations were made in the MCCA from 13 May to 4 July 2011.

The study began with the author sitting or lying on the ground and observing single flies for as long as possible in order to collect information on their various behaviors and diurnal activities. When sufficient data were gathered on their behavior, the activities of many flies were observed by the author walking around the study area. This also allowed for the collection of prey and the observation of mating pairs.

Collected prey was placed in glass vials with the following information: sex of predator (if observed), date, time, and location. Prey that the author could not identify were sent for identification to the U.S. Department of Agriculture, Agricultural Research Service, Systematic Entomology Laboratory, Beltsville, Maryland, U.S.A. Prior to shipment, prey were measured with a clear, plastic ruler to the nearest 0.5 mm.

Temperature and wind are important environmental variables that determine the activities in which adult asilids engage. A hand held Taylor thermometer was used to take air, and surface and subsurface ground temperatures. Wind speed was measured with a Dwyer Hand-Held Wind Meter.

RESULTS AND DISCUSSION

Habitat

Stichopogon trifasciatus occurs in the MCCA primarily on sand/dirt roads where there is little, if any vegetation. Only one individual was in a small open area surrounded by scrub oak (*Quercus* spp.), approximately 13 m from the nearest road.

The main study area was a 15 m long, 3 to 4 m wide part of a road immediately south of and in the floodplain of Moses Creek (Fig. 1). The dominant vegetation on either side of the road was 30 to 60 cm high danglepod [*Sesbania herbacea* (Mill.) McVaugh], bladderpod [*Sesbania vesicaria* (Jacq.) Elliott], and then forest with pond cypress (*Taxodium ascendens* Brongn.), sweetgum (*Liquidambar styraciflua* L.), live oak (*Quercus virginiana* L.), oak shrubs (*Quercus* spp.), and saw palmetto [*Serenoa repens* (W. Bartram) Small]. On the road were a large number of 2 1/2 to 5 cm diameter limestone rocks and some unidentified immature sedge (family Cyperaceae) that was 6 to 8 cm high.

Stichopogon trifasciatus also occurs on other roads located in mesic flatwoods and scrub communities of the MCCA. The vegetation near the roads in the mesic flatwoods community includes saw palmetto, rusty lyonia [*Lyonia ferruginea* (Walter) Nutt.], rusty staggerbush or coastal plain staggerbush [*Lyonia fruticosa* (Michx.) G.S. Torr.], gallberry [*Ilex glabra* (L.) A. Gray], tarflower (*Bejaria racemosa* Vent.), oak shrubs, longleaf pine (*Pinus palustris* Mill.), and slash pine (*Pinus elliottii* Engelm.);

whereas, vegetation along the roads in the scrub community includes saw palmetto, rusty lyonia, rusty staggerbush or coastal plain staggerbush, gall barry, and oak shrubs.

Bromley (1931, 1934, 1946, 1950) said that *S. trifasciatus* occurs on bare, sandy or gravelly areas. James (1938) found this species on exposed rock, windblown areas, and the sides of streams in Colorado. Lavigne and Holland (1969) studied *S. trifasciatus* at two different locations along streams in Wyoming, one a slow moving stream and the other an ephemeral stream. McAtee and Banks (1920) reported that *S. trifasciatus* occurs on sand and rocks in the District of Columbia and Maryland. Fisher (2009) indicated that in Central America, *Stichopogon* are always found on the ground, often on sandy soil, including beaches.

Stichopogon trifasciatus was very active and moved frequently and quickly. They only rested when the ground surface temperature was below 30.6 ºC or above 38.9ºC, the sun was obscured by clouds, their habitat was in shade from surrounding vegetation, or the wind at their level on the ground was gusting to at least 6 km/hr. During these periods they would flatten themselves against the substrate that they were on and remain in this position for up to 30 minutes. Weeks and Hespenheide (1985) observed similar behavior for *S. catulus*.

In the early morning most asilids rested on or foraged from the ground. When the ground temperature reached 35.6 to 36.7°C they began to move onto the limestone rocks where the temperature was generally slightly lower (34.4 to 35°C). Also, when the ground and rock temperatures exceeded 38.3°C, many asilids moved to the moist ground and rocks along Moses Creek. There the moist soil and rock temperatures were less than 32.2°C and 34.4°C, respectively. A few asilids also moved to a log and pieces of concrete in the Creek.

Dennis and Lavigne (1975), and Lavigne and Holland (1969) observed that asilids on the ground apparently maintain their body temperature by changing their position and flattening themselves against the ground. Many asilids are also known to maintain their body temperature by turning so that one of their sides faces and is elevated to the sun. However, *S. trifasciatus* did not exhibit these behaviors.

When resting and feeding, a few individuals expelled a drop of white liquid from their anus. Lehr (1958c) indicated that the expulsion of liquid from the anal opening is quite common.

Foraging and Feeding Behavior

Stichopogon trifasciatus foraged from the ground, and rocks and sticks on the ground, frequently with two asilids on a rock or stick at the same time. They never foraged from vegetation on the sides of or in roads. Lavigne and Holland (1969) also observed that *S. trifasciatus* only forages from the ground or objects on the ground. Weeks and Hespenheide (1985) commented on similar foraging behavior for *S. catulus*.

While foraging individuals of *S. trifasciatus* had their bodies parallel to the surface that they were on. Unlike many other asilids and *S. catulus* (Weeks and Hespenheide, 1985), they did not routinely face the sun, presumably to backlight prey.

While foraging, *S. trifasciatus* frequently changed their location or position on the substrate that they were on. The latter was accomplished by a few wing beats or with quick movements of their legs. Even while feeding, individuals typically changed their position every 2 to 40 seconds. When the sun was obscured by clouds, they would either flatten themselves against the ground or remain standing still for up to 4 minutes.

Depending on the species, asilids forage from one location for variable periods of time or frequently move to a new location. A number of researchers have commented on asilids moving to new foraging locations to increase the probability of finding prey (Lavigne and Holland, 1969; Lavigne, 1992; Hespenheide and Rubke, 1977; Scarbrough, 1979, 1981a; Scarbrough and Sraver, 1979).

Foraging *S. trifasciatus* made investigatory flights without making contact with potential prey. These flights were for distances of 15 to 30 cm from the asilid's original foraging location and 4 to 5 cm above the ground, and often with prey still on the asilid's proboscis. Following investigatory flights, the asilids would return to their original foraging location or land at a new location within 10 to 15 cm of the original location.

Dennis and Lavigne (1975) referred to short flights around a foraging location without pursuing potential prey as, orientation flights. *Stichopogon trifasciatus* made orientation flights 3 cm above the ground and within 60 cm from their foraging location or moved to a new nearby location up to 1.5 m away.

A few asilids captured potential prey and released them while still in-flight or after they had contact with prey on the ground. Dennis and Lavigne (1975) commented that some species might capture and release prey because the asilids use both visual and other stimuli to select prey.

Stichopogon trifasciatus individuals captured most of their prey in the air when the prey were within 30 cm in front of or slightly to the side of the asilids foraging position and 1 to 8 cm above the ground. Only two prey were successfully captured on the ground [pygmy mole cricket, *Ellipes minutus minutus* (Scudder, 1892) and red imported fire ant, *Solenopsis invicta* Buren, 1972] and one on a grass blade (long legged fly, *Chrysotus* sp. near *longimanus* Loew, 1861). Lavigne and Holland (1969) observed *S. trifasciatus* capturing prey on the ground. Weeks and Hespenheide (1985) reported *S. catalus* capturing prey in the air and on a stream's water surface (first and second instar nymphal water striders, *Gerris* sp.).

Having captured prey, *S. trifasciatus* would generally hold onto it with all six tarsi, often in a hover, and insert its proboscis. During feeding *S. trifasciatus* hovered and manipulated prey approximately 2 1/2 to 3 cm above the feeding site. Small prey (e.g., *Ellipes minutus minutus* nymphs (Fig. 2)) were generally not manipulated or were manipulated only once while feeding. Larger prey (e.g., house fly, *Musca domestica* Linnaeus, 1758) was manipulated up to three times. Lavigne and Holland (1969), and Rogers and Lavigne (1972) also reported that *S. trifasciatus* manipulated prey during a hover above its feeding site.

When *S. trifasciatus* were feeding, prey hung free from their proboscises without support by the tarsi.

As researchers have observed for other species of robber flies, the time spent feeding usually depended on prey length (Dennis and Lavigne, 1975; Lavigne and Dennis, 1975). Prey with an average length of 1.5 mm, were fed on for 11 minutes. Larger prey that had an average length of 3.4 mm, were fed on for 12.3 minutes. The length of time that *S. trifasciatus* spent feeding on individual prey varied from 6 to 16 minutes, with an average of 11.6 minutes.

Female *S. trifasciatus* captured prey that averaged longer than those captured by males. The mean prey length for females was 3.3 mm (n = 19) with a range from 1.5 to 6.0 mm; whereas, males had a mean prey length of 2.5 mm (n = 14) with a range from 1.0 to 5.5 mm. The overall mean prey length was 2.9 mm with a predator to prey ratio of 4.1 (n = 10 males and 10 females). Mean predator to prey ratios for other species of robber flies have ranged from 0.9 to 8.4 with a mean of 2.9 (Dennis, 1979, 2012; Dennis and Lavigne, 1975, 1976a and b, 1979; Hespenheide, 1978; Lavigne, 1979, 1984, 1992; Lavigne and Bullington, 1984, 1999; Lavigne and Dennis, 1975, 1985; Lavigne *et al*., 1983, 1993; Lavigne and Holland, 1969; Lehr, 1958c, 1971; Scarbrough, 1978, 1979, 1981a, 1982; Scarbrough and Sraver, 1979; Shelly and Pearson, 1980).

At the completion of feeding, most prey were discarded by *S. trifasciatus* individuals pushing them off their proboscises with their fore tarsi while still at the feeding site. Some prey also were allowed to drop-off the asilid's proboscis at the feeding site and a few prey were dropped in flight as the asilid moved to a new location. Lavigne and Holland (1969) only observed *S. trifasciatus* complete feeding by pushing prey off its proboscis at the feeding site.

The time between feedings (interfeeding time) varied between 0 and 17 minutes, with an average of 5.4 minutes. Interfeeding times diminished for one male and two females that dropped their prey in flight and immediately captured another prey.

One can calculate the theoretical number of prey an individual *S. trifasciatus* could feed on in one day if we assume that, (1) an asilid continually forages and feeds between 9:00 AM and 4:00 PM (the observed period of foraging and feeding activity), and (2) an asilid captures and feeds on prey every 17 minutes (based on the average feeding and interfeeding times). Thus, over a seven hour period an individual asilid could feed on approximately 24 to 25 prey. Other investigators have estimated that asilids feed on from 1 to 35 prey per day (Baker and Fischer, 1975; Dennis, 2012, Dennis and Lavigne, 1975, 1976a and b; Joern and Rudd, 1982; Lavigne and Dennis, 1975; Lavigne *et al*.,1978; Lavigne and Pfadt, 1966; Lehr, 1958a, 1964, 1961).

Prey

Stichopogon trifasciatus individuals were selective in their choice of prey with Orthoptera making up 66.7% of the 69 identified prey (Table 1). Diptera and Hymenoptera made up 26.1% and 2.9%, respectively; and Araneae, Coleoptera and Lepidoptera each made up 1.4%. The Orthoptera consisted of pygmy mole crickets (Tridactylidae, 95.7%) and pygmy grasshoppers (Tetrigidae, 4.3%). The latter insects are not common prey of robber flies based on the list of prey species in the asilid predator-prey data base (Lavigne, 2003).

Lavigne and Holland (1969) indicated that *S. trifasciatus* fed on Diptera (80%), Homoptera (10%), Hymenoptera (5%), and Araneae (5%). Bromley (1931, 1934, 1946,1950) said that they prey on small Diptera and Orthoptera, and spiders including the black widow [Theridiidae: *Latrodectus mactans* (Fabricius, 1775)]. Rogers and Lavigne (1972) reported this species preying on Homoptera.

Table 1. Number and percent composition of orders of prey captured by *Stichopogon trifasciatus.*

	Male		Female		Unknown Sex		Total	
Order	Number	Percent	Number	Percent	Number	Percent	Number	Percent
Araneae	0	0	0	0	1	4.5	1	1.4
Coleoptera	0	0	1	3.7	0	0	1	1.4
Diptera	4	20.0	7	25.9	7	31.8	18	26.1
Hymenoptera	1	5.0	1	3.7	0	0	2	2.9
Lepidoptera	0	0	0	0	1	4.5	1	1.4
Orthoptera	15	75.0	18	66.7	13	59.1	46	66.7
Totals	20	100.0	27	100.0	22	99.9	69	99.9

Note: Percent of prey may not total 100.0% because of rounding.

Both male and female *S. trifasciatus* preyed primarily on Diptera, Hymenoptera and Orthoptera. However, more females were captured with prey than males. Numerous other investigators also have reported collecting more female than male asilids with prey (Dennis, 1979; Dennis and Lavigne, 1975, 1976a and b, 1979; Dennis *et al*., 1986; Hobby, 1931a and b, 1935; Lavigne, 1970a, 1979, 1984, 1992; Lavigne and Dennis, 1985; Lavigne *et al*., 1976, 1983; Lavigne and Pogue, 2009; Lehr, 1958a and b; Londt, 1991; Poulton, 1906; Weeks and Hespenheide, 1985).

The following is a list of prey taken by *S. trifasciatus*. All prey were collected between May 19 and June 23, 2011. The number and sex (if known) of the predator is indicated following the prey record.

ARANEAE, Unidentified, 31-V-11. COLEOPTERA, Unidentified, 20-V-11 (♀). DIPTERA, Agromyzidae: poss. *Calycomyza* sp., 27-V-11; Dolichopodidae: *Chrysotus* sp., 24-V-11 (♀), *Chrysotus* sp. near *longimanus* Loew, 1861, 20-V-11 (♀), 24-V-11, 31-V-11 (♀), *Condylostylus* sp. poss. *tonsus* Aldrich, 1901, 25-V-11 (♀), *Diaphonus* sp., 25-V-11 (♂, unknown); Unknown, 23-V-11 (2♀♀), 24-V-11 (♂); Ephydridae, *Hydrochasma leucoproctum* Loew, 1861, 25-V-11, 27-V-11 (♂), *Paralimna decipiens* Loew, 1878, 24-V-11 (♀), *Scatella tenuicosta* Collin, 1930, 23-V-11, 27-V-11; Muscidae: *Musca domestica* Linnaeus, 1758, 20-V-11 (♀); Sarcophagidae: *Senotainia trilineata* (Wulp, 1890), 24-V-11; Unidentified: 23-V-11 (2♀♀, unknown), 24-V-11 (2♂♂). HYMENOPTERA, Formicidae: *Solenopsis invicta* Buren, 1972 (workers), 24-V-11 (♂), 31-V-11 (♀); LEPIDOPTERA, Unidentified, 27-V-11; ORTHOPTERA, Tetrigidae, *Tetrix* sp. (2 nymphs), 19-V-11 (♀), 23-V-11 (♀); Tridactylidae, *Ellipes minutus minutus* (Scudder, 1892) (39 nymphs, 6 adults), 13-V-11 (♂), 19-V-11 (5♀♀, 7♂♂), 20-V-11 (2♀♀), 23-V-11 (4♀♀, 6♂♂), 24-V-11 (2♀♀), 25-V-11 (♀), 27-V-11 (♂), 31-V-11 (4♀♀).

Courtship and Mating Behavior

Males searched for receptive females with which to mate by flying from one asilid (both males and females) to the next and then attempting to mate in the male over

female position either with or without courtship hovering in front of the other asilid. Only three of the 24 complete matings occurred without the male courtship hover. All seven matings observed by Lavigne and Holland (1969) were preceded by a male courtship hover after the male had initially landed on the female. Weeks and Hespenheide (1985) did not observe a male courtship display for *S. catulus*.

Courting males generally hovered within about 2 1/2 cm, in an approximate 120° arc, in front of other asilids. Hovering lasted up to 5 to 10 seconds and involved the male quickly oscillating from side to side 3 to 14 times before landing on an asilid's back and trying to grasp their genitalia. Lavigne and Holland (1969) observed courting males hovering 6 mm in front of other asilids in an approximate 35° arc. Weeks and Hespenheide (1985) saw *S. trifasciatus* males oscillating 2 to 8 times in front of other asilids at a distance of 2/3 to 3/4 of a body length.

Males often courted and attempted to mate up to three to four times, with non-receptive asilids before flying to another asilid and repeating the courtship display. Males would attempt to mate with up to six different asilids before flying away. Lavigne and Holland (1969) also observed *S. trifasciatus* males attempting to mate with up to six other asilids.

When males and females were not receptive to mating they would often raise one or both fore legs and "push" at the courting male. If this was ignored and the male still landed on the other asilid, the non-receptive asilid would often repeatedly curve and flex or bend its abdomen down so that the courting male could not grasp the genitalia. Some males and females held onto prey with their proboscises while mating, and they also often bent their abdomens down in order to avoid having males try to mate with them. Lavigne and Holland (1969) reported that a non-receptive female would raise the tip of her abdomen.

If a female was receptive to mating, the male's abdomen curved to the right or the left of the female's abdomen and grasped her genitalia from below. In the male over female position the male's fore tarsi rested on the female's eyes or the anterior part of her thorax. If on the eyes, the male would often rub the female's eyes with his fore tarsi during mating. Matings were generally terminated when the female began pushing on or rubbing her abdomen with her hind tarsi and flexing her abdomen down.

Matings lasted from 35 to 96 seconds, with an average of 50.2 seconds. These times are very close to those reported by Lavigne and Holland (1969) who observed matings that lasted from 45 to 72 seconds, with an average of 56.3 seconds. Weeks and Hespenheide (1985) said that one mating for *S. trifasciatus* lasted 30 to 60 seconds, and S*. catulus* mated from less than 1 to 16 minutes, with most matings lasting less than a minute.

Stichopogon trifasciatus matings occurred when air temperatures at the height of the mated pair ranged from 28.3º to 36.7ºC. The temperatures of the rocks and sand that the asilids were on ranged from 27.8° to 37.8°C.

During matings, other males often landed on top of the mating male. Also, while a female was being courted by a male, another male would land on the female and

mate with her. Lavigne and Holland (1969) commented that this "…may account for the immediate mounting which is so characteristic of the searching males."

Oviposition

One oviposition was observed at 11:03 AM when a female crawled on the ground into the shade of the author's shoe. There she dug into the soil with her ovipositor, after 30 seconds withdrew her ovipositor, and briefly brushed the soil surface with its tip before flying away. Eggs were not recovered.

The temperature on and below the ground surface at the oviposition location was 33.9˚C.

Lavigne and Holland (1969) did not observe ovipostion for this species. However, they commented that female ovipositors have acanthophorites and this indicates that they oviposit in the soil or sand. Londt (1994) commented that species of Afrotropical Asilidae that forage from the ground surface oviposit in ground or soil and he noted that females in the subfamily Stichopogoninae have "…cerci with strong setae (acanthophorites), suggesting adaptation for oviposition in sand."

Lavigne and Holland (1969) found *S. trifasciatus* near natural drainages in Wyoming and suggested that the larvae of this species may need a moist habitat for development. Londt (1979) also suggested this for *Stichopogon* spp. in the Afrotropical Region. The occurrence of *S. trifasciatus* on dry sand roads in the MCCA may indicate that this species does not need to oviposit near moist or damp surface areas for larval development, in particular in areas with a humid climate such as Florida.

Grooming

Stichopogon trifasciatus groomed themselves in much the same way as other asilids (Dennis, 1979, 2012; Dennis and Lavigne, 1975, 1976a, 1979; Johnson, 1976; Lavigne and Pogue, 2009; Lehr, 1958c). They always used the fore legs to groom their heads, and the hind legs for grooming their wings, abdomen and genitalia. Grooming of the head was usually preceded and followed by rubbing together of the fore tarsi while the fore legs were extended and slightly elevated. The asilid moved its fore tarsi back and forth along their long axis and then rubbed the dorsolateral part of its head with the inside of either one or both front femora.

Stichopogon trifasciatus rubbed their hind tarsi together before grooming the abdomen, genitalia and wings. They turned the hind tarsi inward and used them to groom the abdomen and genitalia, and tops and bottoms of the posterior part of the wings (Fig. 2). Grooming of the abdomen and wings was always from anterior to posterior as observed by Lehr (1958c).

Grooming was common between foraging flights. Also, grooming of the face was particularly common after feeding, as was grooming of the abdomen and genitalia after mating.

Daily Rhythm of Activity

Stichopogon trifasciatus exhibited peak periods for both mating and feeding in the morning and afternoon (Fig. 3). The peak periods for mating were from 10:00 to

11:00 AM, and 1:00 to 2:00 PM. The number of feeding asilids initially peaked from about 10:00 AM to 12:00 noon, and then like mating, peaked again between 1:00 to 2:00 PM. Both mating and feeding steadily declined after their peaks in the morning. Weeks and Hespenheide (1985) observed that *S. calutus* had a peak foraging period in the morning and mating in the afternoon.

The main road that *S. trifasciatus* was studied on had upland mixed forest that was approximately 10 to 20 m away to both the east and west. Thus, the road was mostly in shade until about 9:00 AM and after 3:30 PM. This may be why the asilids quickly began mating and feeding by 10:00 AM and these activities tapered off in the afternoon with another peak between 1:00 to 2:00 PM as the area began to be covered by shade.

As the sun set in the evening, the asilids moved into surrounding vegetation on the western side of the road. The sunlight would shine there earliest in the morning and as most of the road became exposed to the sun, the asilids moved further east into the road. The movement into an area during the day and out again at dusk or under changing light conditions has been observed for a number of asilid species (Adamovic, 1963; Dennis, 2012, Hespenheide and Rubke, 1977; Lavigne, 1970b; Lavigne and Holland, 1969; Musso, 1972; Scarbrough, 1981b; Scarbrough and Norden, 1977).

Because of the thickness of vegetation around the basin, the nocturnal resting position for *S. trifasciatus* was not observed.

Predators and Parasites

Asilids of the same species are often observed to prey on each other (Lavigne *et al*., 1978). However, cannibalism was not observed for *S. trifasciatus* during this study or by Lavigne and Holland (1969).

A male *Proctacanthus brevipennis* (Wiedemann, 1828) captured a *S. trifasciatus*, but released it after a brief hover above the ground and manipulation with all six tarsi.

There were a number of ants (primarily fire ants, *Solenopsis invicta*) in the same habitats as *S. trifasciatus*. When the ants crawled on the asilids' tarsi, the asilids would shake their tarsi and then usually fly to a new location.

Asilids are often observed with mites on their bodies, in particular on the thorax. However, no mites were observed on the bodies of *S. trifasciatus*.

Conclusions

While some information is available on the ethology of 2 (*S. catulus* and *S. trifrasciatus*) of 10 species of robber flies in the genus *Stichopogon* in the United States, there is little information, other than habitat and prey, on the other 8 species. This paper provides more detailed information on the behavior of *S. trifasciatus*. The individuals studied rested on the ground or limestone rocks on the ground, depending on temperature. *Stichopogon trifasciatus* did not adjust their position to maintain their body temperature, such as flattening against the ground or turning so that one side was to the sun. Foraging was from the ground and rocks and sticks on the ground during which the asilids frequently changed their location and position. Most prey

were captured in flight and consisted of Araneae, Coloeptera, Diptera, Hymenoptera, Lepidoptera, and Orthoptera. During feeding, *S. trifasciatus* manipulated prey with all six tarsi while intermittently hovering above its feeding site. Males searched for receptive females with which to mate by flying from one individual to the next. Males courted females by hovering in front of them prior to landing on a their backs and attempting to grasp their genitalia. Mating occurred in the male over female position with the male's fore tarsi resting on the female's eyes or the anterior part of her thorax. One female oviposited in the soil. Peak periods for feeding were from 10:00 AM to 12:00 noon and 1:00 to 2:00 PM, and mating was from 10:00 to 11:00 AM and also 1:00 to 2:00 PM. Grooming was in much the same was as other species of asilids.

Fig. 1-2. 1. Road habitat of *Stichopogon trifasciatus* south of Moses Creek.Resting Behavior. 2. *Stichopogon trifasciatus* with *Ellipes minutus minutus* as prey and grooming wings with hind tarsi.

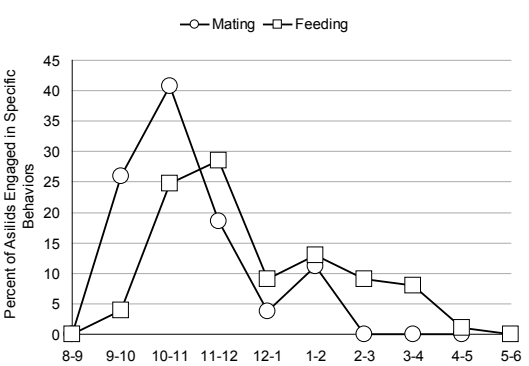

Fig. 3. Diurnal rhythm of activity for *Stichopogon trifasciatus* based on 27 and 77 observations for mating and feeding, respectively.

ACKNOWLEDGMENTS

The author would like to thank the staff of the St. Johns River Water Management District for the issuance of the Special Use Authorization that allows him to study robber flies in the Moses Creek Conservation Area (MCCA).

With gratitude the author acknowledges the following Research Entomologists with the Systematic Entomology Laboratory (SEL), Agricultural Research Service U. S. Department of Agriculture, for their prompt identification of prey: Matthew Buffington (Formicidae, Sphecidae); Wayne Mathis (Ephydridae); David A. Nickle (Tetrigidae, Tridactylidae); Allen L. Norrbom (Muscidae); Geoffrey B. White (Chironomidae); Norman E. Woodley (Dolichopodidae, Muscidae, Sarcophagidae). The SEL's Geoffrey B. White also is thanked for his handling of the prey and prompt Identification Reports.

Thank you, also, to the anonymous reviewers for your constructive comments on the manuscript.

REFERENCES

Adamovic, Z. R., 1963, Ecology of some asilid-species (Asilidae, Diptera) and their relation to honey bee (*Apis mellifica* L.). *Museum d'Histoire Naturelle de Beograd*, Hors serie 30: 1- 102. (In Serbian, English summary)

Back, E. A., 1909, The robber-flies of America, north of Mexico, belonging to the subfamilies Leptogastrinae and Dasypogoninae. *Transactions of the American Entomological Society*, 35: 137-400.

Baker, N. T., Fischer, R. L., 1975, A taxonomic and ecologic study of the Asilidae of Michigan. *Great Lakes Entomologist*, 8: 31-91.

Barnes, J. K., 2010, Revision of Nearctic *Stichopogon* species (Diptera: Asilidae) with white-banded abdomens, including description of *Stichopogon venturiensis*, new species, from coastal California. *Proceedings of the Entomological Society of Washington,* 112: 367-380.

Barnes, J. K., 2013, The genus *Stichopogon* Loew (Diptera: Asilidae) in America North of Mexico. *Proceedings of the Entomological Society of Washington*, 115: 9-36.

Blanton, F. S, 1939, Collecting notes on the family Asilidae (Diptera). *Bulletin of the Brooklyn Entomological Society*, 34: 229-235.

Bromley, S. W., 1931, A preliminary annotated list of the robber flies of Ohio. *Ohio State Museum Science Bulletin*, 1: 1-18.

Bromley, S. W., 1934, The robber flies of Texas (Diptera, Asilidae). *Annals of the Entomological Society of America,* 27: 74-113.

Bromley, S. W., 1946, Guide to the insects of Connecticut. Part VI. The Diptera or true flies of Connecticut. Third Fascicle. Asilidae. *Connecticut State Geological and Natural History Survey Bulletin* 69: 1-48.

Bromley, S. W., 1950, Florida Asilidae (Diptera) with description of one new species. *Annals of the Entomological Society of America*, 43: 227-239.

Dennis, D. S., 1979, Ethology of *Holcocephala fusca* in Virginia (Diptera: Asilidae). *Proceedings of the Entomological Society of Washington,* 81: 366-378.

Dennis, D. S., Lavigne. R. J., 1975, Comparative behavior of Wyoming robber flies II (Diptera: Asilidae). *Agricultural Experiment Station University of Wyoming-Laramie Science Monograph*, 30: 68 pp.

Dennis, D. S., Lavigne, R. J., 1976a, Ethology of *Efferia varipes* with comments on species coexistence (Diptera: Asilidae). *Journal of the Kansas Entomological Society,* 49: 48-62.

Dennis, D. S., Lavigne, R. J., 1976b, Ethology of *Leptogaster parvoclava* in Wyoming (Diptera: Asilidae). *Proceedings of the Entomological Society of Washington,* 78: 208-222.

Dennis, D. S., Lavigne, R. J., 1979, Ethology of *Machimus callidus* with incidental observations on *M. occidentalis* in Wyoming (Diptera: Asilidae). *Pan-Pacific Entomologist* 55: 208-221.

Dennis, D. S., 2012, Ethology of *Proctacanthus brevipennis* (Wiedemann, 1828) (Diptera: Asilidae) in Northeastern Florida, U.S.A. *Journal of the Entomological Research Society*, 14: 91-109.

Dennis, D. S., Lavigne, R. J., Bullington, S. W., 1986, Ethology of Efferia cressoni with a review of the comparative ethology of the genus (Diptera: Asilidae). Proceedings of the Entomological Society of Washington, 88: 42-55.

Dennis, D. S., Lavigne, R. J., Dennis, J. G., 2009. Lepidoptera as prey of robber flies (Diptera: Asilidae) with unpublished records. *Journal of the Entomological Research Society,* 11: 71-84.

Dennis, D. S., Lavigne, R. J., Dennis, J. G., 2010, Hemiptera (Heteroptera/Homoptera) as prey of robber flies (Diptera: Asilidae) with unpublished records. *Journal of the Entomological Research Society,* 12: 27 - 47.

Dennis, D. S., Lavigne, R. J., Dennis, J. G., 2012, Spiders (Araneae) as prey of robber flies (Diptera: Asilidae). *Journal of the Entomological Research Society,* 14: 65-76.

Fisher, E. M., 2009, Asilidae (robber flies, assassin flies, moscas cazadoras, moscas ladronas). *In* Brown, B. V., Borkent, A., Cumming, J. M., Wood, D. M., Woodley, N. E., Zumbado, M. (Editors). *Manual of Central American Diptera*, Volume 1. National Research Council Press, Ottawa. pp. 585-632.

Hespenheide, H. A., 1978, Prey, predatory and courtship behavior of *Nannocyrtopogon neoculatus* Wilcox and Martin (Diptera: Asilidae). *Journal of the Kansas Entomological Society*, 51: 449-456.

Hespenheide, H. A., Rubke, M. A., 1977, Prey, predatory behavior, and the daily cycle of *Holopogon wilcoxi* Martin (Diptera: Asilidae). *Pan-Pacific Entomologist*, 53: 277-285.

Hobby, B. M., 1931a, The British species of Asilidae (Diptera) and their prey. *Transactions of the Entomological Society of South England,* 6: 1-42.

Hobby, B. M., 1931b, The relationship between courtship and predaceous habits in *Dioctria rufipes* De. G. and *D. atricapilla* Meig. (Dipt., Asilidae). *Proceedings of the Entomological Society of London* (Ser. A), 6: 74-75.

Hobby, B. M., 1935, Rhodesian Asilidae (Diptera) and their prey collected by Mr. C. F. M. Swinnerton. *Journal of Animal Ecology,* 4: 90-112.

Hull, F. M., 1962, Robber flies of the world. The genera of the family Asilidae. *Smithsonian Institution, U. S. National Museum Bulletin,* 224(1,2): 907 pp.

James, M. T., 1938, A systematic and ecological study of the robber flies (Asilidae) of Colorado. *In* O. C. Lester, O. C. (Editor). *Abstracts of Theses and Reports for Higher Degrees*, *1938. University of Colorado Studies*, General Series (A), 26: 70-74.

James, M. T., 1941, The robber flies of Colorado (Diptera: Asilidae). *Journal of the Kansas Entomological Society,* 14: 27-53.

Joern, A., Rudd, N. T., 1982, Impact of predation by the robber fly *Proctacanthus milbertii* (Diptera: Asilidae) on grasshopper (Orthoptera: Acrididae) populations. *Oecologia*, 52: 42-46.

Johnson, P. E., 1976, *A preliminary investigation of the behavior of adult Holcocephala abdominalis (Say) (Diptera: Asilidae) in Putnam County, Indiana; with a description of the larvae and eggs*. Unpublished M. S. Thesis, DePauw University, Greencastle, Indiana, 108 pp

Lavigne, R. J, 1970a, Courtship and predatory behavior of *Cyrtopogon auratus* and *C. glarealis* (Diptera: Asilidae). *Journal of the Kansas Entomological Society,* 43: 163-171.

Lavigne, R. J., 1970b, Courtship and predation behavior of *Heteropogon maculinervis* (Diptera: Asilidae). *Journal of the Kansas Entomological Society,* 43: 270-273.

Lavigne, R. J., 1979, Notes on the ethology of *Efferia argyrogaster* (Diptera: Asilidae) in Mexico. *Proceedings of the Entomological Society of Washington,* 81: 544-551.

Lavigne, R. J., 1984, Ethology of *Neocerdistus acutangulatus* (Diptera: Asilidae) in south Australia. *Proceedings of the Entomological Society of Washington,* 86: 422-431.

Lavigne, R. J., 1992, Ethology of *Neoaratus abludo* Daniels (Diptera: Asilidae) in South Australia, with notes on *N. pelago* (Walker) and *N. rufiventris* (Macquart). *Proceedings of the Entomological Society of Washington,* 94: 253-262.

Lavigne, R. J., 2002., Evolution of courtship behavior among the Asilidae (Diptera), with a review of courtship and mating. *Studia Dipterologica,* 9: 703-742.

Lavigne, R. J., 2003, Predator-prey database for the family Asilidae (Hexapoda: Asilidae). Modified 2005. Available from: http://www.geller-grimm.de/catalog/lavigne.htm (accessed 03 December 2011).

Lavigne, R. J., Bullington, S. W., 1984, Ethology of *Laphria fernaldi* (Back) (Diptera: Asilidae) in southeast Wyoming. *Proceedings of Entomological Society of Washington*, 86: 326-336.

Lavigne, R. J., Bullington, S. W., 1999, Ethology of *Heteropogon paurosomus* Pritchard (Diptera: Asilidae) in Mexico. *Journal of the Entomological Research Society,* 1: 9-19.

Lavigne, R. J., Bullington, S. W., Stephens, G., 1993, Ethology of *Holopogon seniculus* (Diptera: Asilidae). *Annals of the Entomological Society of America*, 86: 91-95.

Lavigne, R. J., Dennis, D. S., 1975, Ethology of *Efferia frewingi* (Diptera: Asilidae). *Annals of the Entomological Society of America,* 68: 992-996.

Lavigne, R. J., Dennis, D. S., 1985, Ethology of three coexisting species of *Efferia* (Diptera: Asilidae) in Mexico. *Proceedings of the Entomological Society of Washington,* 87: 146-160.

Lavigne, R. J., Dennis, D. S., Gowen, J. A., 1978, Asilid literature update 1956-1976 including a brief review of robber fly biology (Diptera: Asilidae). Agricultural Experiment Station *University of Wyoming Science Monograph* 36: 134 pp.

Lavigne, R. J., Holland, F. R., 1969, Comparative behavior of eleven species of Wyoming robber flies (Diptera: Asilidae). *Agricultural Experiment Station University of Wyoming Laramie Science Monograph* 18: 61 pp.

Lavigne, R. J., Pfadt, R. E., 1966, Parasites and predators or Wyoming rangeland grasshoppers. University of Wyoming Agricultural Experiment Station Science Monograph 3: 31 pp.

Lavigne, R. J., Pogue, M. G., 2009, Ethology of *Omninablautus nigronotum* (Wilcox) (Diptera: Asilidae) in Wyoming. *Proceedings of the Entomological Society of Washington,* 111: 1-6.

Lavigne, R. J., Pogue, M., Johnson, P., 1983, Ethology of *Laphystia rufofasciata* Curran (Diptera: Asilidae) in Wyoming. *Proceedings of the Entomological Society of Washington,* 85: 121-127.

Lavigne, R. J., Rogers, L., Lavigne, F., 1976, Ethology of *Efferia benedicti* (Diptera: Asilidae) in Wyoming. *Proceedings of the Entomological Society of Washington,* 78: 145-153.

Lehr, P. A., 1958a, The biology of a robber fly feeding on locusts. *Doklady Kazakhstan Akademii selskokhoz*. Nauk, Alma-Ata, 3: 16 -23. (In Russian)

Lehr, P. A., 1958b, Information on the biology of *Promachus leontochlaenus* Loew (Diptera- Asilidae). *Trudy nauchno-issledovaniya Instituta Zaschti Rasteniy, KazASKhN (Proceedings of the Scientific Research Institutee of Protection of Plants, Kazakhstan)*, Alma-Ata, 4: 210-224. (In Russian)

Lehr, P. A., 1958c, On the biology and behavior of robber flies (Asilidae-Diptera). *Trudy* Instituta *Zoologii, Akademiya Nauk Kazakhstan. SSR*, 8: 173-196. (In Russian)

Lehr, P. A., 1961, The robber fly *Stenopogon heteroneurus* Macquart (Diptera: Asilidae), its behavior and feeding. *Trudy nauchno-issledovaniya Instituta Zaschti Rasteniy, KazASKhN (Proceedings of the Scientific Research Institute for Protection of Plants, Kazakhstan)*, Alma- Ata, 6: 96-130. (In Russian)

Lehr, P. A., 1964, On the nutrition and significance of Asilidae. *Trudy nauchno-issledovaniya Instituta Zaschti Rasteniy, KazASKhN (Proceedings of the Scientific Research Institute for Protection of Plants, Kazakhstan)*, Alma-Ata, 8: 213-244. (In Russian)

Lehr, P. A., 1971, Review of life style and significance of *Machimus rusticus* Meig. (Diptera: Asilidae) and closely related species of robber flies. *Biological Sciences, Kazakhstan State University*, Alma-Ata, 3: 203-213. (In Russian)

Londt, J. G. H., 1979, Afrotropical Asilidae (Diptera) 3. The tribe Stichopogonini. *Annals of the Natal Museum,* 23: 833-854.

Londt, J. G. H., 1991, Afrotropical Asilidae (Diptera) 21. Observations on the biology and immature stages of *Damalis femoralis* Ricardo, 1925 (Trigonomiminae). *Annals of the Natal Museum*, 32: 149-162.

Londt, J. G. H., 1994, Afrotropical Asilidae (Diptera) 26. Ethological observations, and a possible ecological classification based on habitats. *Annals of the Natal Museum,* 35: 97-122.

McAtee, W. L., Banks, N., 1920, District of Columbia Diptera: Asilidae. *Proceedings of the Entomological Society of Washington*, 22: 13-33.

Musso, J. J., 1972, Étude des migrations journalières d'*Andrenosoma bayardi* Seguy (Diptera-Asilidae). *Bulletin de la Société Zoologique de France*, 97: 45-53.

Poulton, E. B., 1906, Predaceous insects and their prey. *Transactions of the Royal Entomological Society of London,* 1906: 323-409.

Rogers, L. E., Lavigne, R., 1972, Asilidae of the Pawnee National Grasslands in northeastern Colorado. *Agricultural Experiment Station University of Wyoming-Laramie Science* Monograph 25: 35 pp.

Scarbrough, A. G., 1978, Ethology of *Cerotainia albipilosa* Curran (Diptera: Asilidae) in Maryland: predatory behavior. *Proceedings of the Entomological Society of Washington,* 80: 113-127.

Scarbrough, A. G., 1979, Predatory behavior and prey of *Diogmites missouriensis* Bromley in Arkansas (Diptera: Asilidae). *Proceedings of the Entomological Society of Washington,* 81: 391-400.

Scarbrough, A. G., 1981a, Ethology of *Eudioctria tibialis* Banks (Diptera: Asilidae) in Maryland: prey, predator behavior, and enemies. *Proceedings of the Entomological Society of Washington*, 83: 258-268.

Scarbrough, A. G., 1981b, Ethology of *Eudioctria tibialis* Banks (Diptera: Asilidae) in Maryland: seasonal distribution, abundance, diurnal movements, and behaviors. *Proceedings of the Entomological Society of Washington,* 83: 245-257.

Scarbrough, A.G., 1982, Coexistence in two species of *Holcocephala* (Diptera: Asilidae) in Maryland habitat: predatory behavior. *Proceedings of the Entomological Society of Washington*, 84: 349-365.

Scarbrough, A.G., Norden, A., 1977, Ethology of *Cerotainia albipilosa* Curran (Diptera: Asilidae) in Maryland: diurnal activity rhythm and seasonal distribution. *Proceedings of the Entomological Society of Washington*, 79: 538-554.

Scarbrough , A. G., Sraver. B. E., 1979, Predatory behavior and prey of *Atomosia puella* (Diptera: Asilidae). *Proceedings of the Entomological Society of Washington*, 81: 630-639.

Shelly, T. E., Pearson, D. L., 1980, Predatory behavior of *Proctacanthella leucopogon* (Diptera: Asilidae): prey recognition and prey records. *Environmental Entomology,* 9: 7-9.

Weeks, L., Hespenheide, H. A., 1985, Predatory and mating behavior of *Stichopogon* (Diptera: Asilidae) in Arizona. *Pan-Pacific Entomologist*, 61: 95-104.

Wilcox, J., 1936, Asilidae new and otherwise, from the Southwest, with a key to the genus *Stichopogon*. *Pan-Pacific Entomologist*, 12: 201-212.

Received: May 31, 2012 *Accepted: May 21, 2013*