THE DIURNAL ETHOLOGY OF THE ADULT GREEN STINK BUG, *ACROSTERNUM HILARE*, IN SENESCING SOYBEANS

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ABSTRACT

A preliminary behavioral catalogue of the adult green stink bug, *Acrosternum hilare* (Say), was developed from observations taken in a field of senescing soybeans. A total of 20 behaviors were described, and the effects of sex and time of day on these behaviors were quantified. Behaviors were categorized as resting, componential movements, grooming, feeding, excretion, positional orientation, and locomotion. Sex significantly influenced the duration of time spent in lifted and tilted postures and resting both on pods and with conspecifics and the proportion of time spent in a lifted posture, resting on all substrates, antennal waving, shifting, and walking. Time of day significantly influenced the duration of time spent in a tilted posture, basking, and walking and the proportion of time spent in a lifted posture, resting on all substrates, antennal waving and quivering, shifting, walking, and flying. The functions of the behaviors were either implicit or inferred from current understanding of pentatomid biology.

Key Words: Behavior, pentatomidae, ethogram.

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INTRODUCTION

The green stink bug, *Acrosternum hilare* (Say), is a serious pest of numerous crops including peaches (Woodside 1946), soybeans (Yeargan 1977) and lima beans (Wingard 1925), however, virtually nothing is known about its behavior. As the pentatomids are ethologically versatile and include several major agricultural pests, the compilation of a behavioral catalogue for the *A. hilare* is a logical and necessary step towards an understanding of these insects. Research on the behavior of insect pests has largely been directed at either the behavior of a population in the field or the behavior of an individual in the laboratory. There has been little consideration of the ethology of the individual in its natural habitat. Eibl-Eibesfeldt (1975) and Lehner (1979) state that the development of a behavioral catalogue is a necessary starting point for the understanding of an organism's behavior. In turn, the understanding of an insect's behavior is a prerequisite to the development of integrated pest management systems. This study addresses the need for both basic and applied information through the development of a behavioral catalogue for *A. hilare* which documents its behavioral repertoire and assesses the effects of sex and time of day on the duration and frequency of the behaviors.

MATERIALS AND METHODS

Aerosternum hilare adults were observed in a soybean field at the Burden Research Center, Baton Rouge, Louisiana between October 10 and 27, 1983. Data were collected using focal animal sampling (Lehner 1979) by an observer during three time blocks: morning (0700 - 1100h), noon (1100 - 1500h), and afternoon (1500 - 1900h). Both males and females (6 - 8 individuals of each sex) were observed during each time block.

Subjects were located in the field at a distance of several meters to avoid eliciting escape or alarm behavior. The observer slowly approached the insect to a distance of ca. 0.5 m and observed its behavior for a period of 30 minutes or until the insect flew far enough away that it could not be located. Each behavior and its duration were recorded; these observations provided measures of both the frequency and duration of each behavior. The only case in which a behavior was not recorded due to the simultaneous occurrence of another behavior was antennal movements which were not recorded during locomotion. In addition to the duration of each behavior, the subject's location with respect to sunlight/shade was recorded when sunlight was available.

The mean frequency of a behavior was defined as the proportion of individuals which engaged in the behavior. The mean duration of behavior was defined as the mean number of minutes the given behavior lasted in all instances in which it occurred. The proportion of time spent by a behavior was calculated by dividing the total time engaged in the behavior by the total observation time. Fagen and Goldman (1977) developed an index of sample coverage, $\hat{\theta} = 1 - (N_1/I)$, where $\hat{\theta}$ is the estimated degree of sample coverage (0 = no coverage, 1 = complete coverage), N_1 is the number of behaviors seen only once, and I is the total number of different behaviors seen. This index was used to estimate the degree of completeness of the behavioral catalog. For each behavior accounting for more than 0.5% of the total observation time, the effects of sex, time of day, and their interaction on the duration and proportion of time spent engaged in the behavior were assesed by analysis of variance. The frequency of these behaviors with respect to sex and time of day were analyzed using the chi-square test. Behaviors not meeting the criterion of occupying more than 0.5% of the total observation time were too uncommon to be meaningfully analyzed. The proportions of time spent basking during each time block were compared using the chi-square test. Variables were considered significantly different at $P < 0.05$.

RESULTS

The sample coverage was 0.90 for males and 0.89 for females, indicating fairly complete sample coverage. Twenty behaviors were documented and classified into seven categories: resting, componential movements, grooming, feeding, excretion, positional orientation, and locomotion. Table 1 shows the proportion of time occupied with respect to sex and time of day for each of these categories. The mean durations and frequencies of behaviors which occupied more than 0.5% of the total observation time are shown with respect to sex and time of day in Table 2.

Table 1. Proportion of time spent in each behavioral category by *A. hilare* with respect to sex and time of day.

Behavioral Category	% of total time spent				
	Male	Female	Morning	Noon	Afternoon
Resting	83.6	84.5	83.9	84.6	82.9
Componential Movements	1.9	2.0	1.4	2.2	1.9
Grooming	0.2	0.1	0.3	0.2	0.1
Feeding	1.8	0.1	0.6	1.7	0.1
Excretion	0.1	0.1	0.1	0.2	0.1
Positional Orientation	4.8	4.4	6.0	3.2	4.9
Locomotion	7.7	8.9	7.6	7.8	9.9

Table 2. Durations and frequencies of behaviors occupying more than 0.5% of the time of *A. hilare* with respect to sex and time of day.

Behavior	Duration ($\bar{x}$ sec) [Frequency (% exhibiting)]									
	Male		Female		Morning		Noon		Afternoon	
Rest (leaf)	138	[90]	117	[80]	126	[80]	132	[93]	122	[92]
Rest (stem)	61	[28]	84	[43]	52	[47]	90	[40]	70	[17]
Rest (pod)	45	[14]	204	[28]	157	[40]	130	[13]	26	[8]
Antennal wave	5.4	[76]	6.0	[86]	4.8	[93]	6.9	[73]	5.3	[75]
Shuffle	3.6	[76]	4.3	[76]	3.5	[73]	4.0	[87]	4.2	[53]
Excretion	4.5	[28]	3.8	[38]	3.5	[27]	4.3	[47]	4.2	[25]
Shift	4.2	[86]	3.4	[86]	3.7	[93]	4.3	[73]	3.2	[92]
Lift	112	[33]	53	[24]	80	[53]	11	[7]	79	[25]
Walk (forwards)	29	[90]	25	[81]	22	[80]	22	[93]	41	[83]
Flight	22	[33]	8	[24]	11	[33]	23	[40]	11	[8]

Resting was characterized by a state of immobility in which all body parts remained motionless and the ventral body surface was held close to the substrate. All individuals displayed this behavior. Resting was classified according to the substrate the subject was in contact with: leaf, stem, pod, or conspecific. The influence of sex and time on the resting behavior of *A. hilare* was not consistent across all plant parts. Males spent a significantly greater portion of their time resting on leaves than females. The afternoon block had a significantly greater portion of time spent resting on leaves than the noon block which in turn was significantly greater than the morning block. Females spent a significantly greater portion of their time resting on stems than males. The noon block had a significantly greater portion of time spent resting on stems than did the morning block, and the morning block had a significantly greater portion than the afternoon block. Females rested significantly longer and spent a significantly greater portion of their time on pods than males. Resting on pods occupied a significantly greater portion of the morning block than the noon block, while the noon block had a significantly greater proportion of time spent resting on pods than the afternoon block. This behavior was also significantly more frequent during the morning block than the noon or afternoon blocks. While the duration of resting in contact with conspecifics was significantly greater in females than males, males spent a

significantly greater proportion of their time resting with conspecifics. Resting in contact with a conspecific occupied a significantly greater portion of the noon block than the morning or afternoon blocks.

Componential movements were characterized by an insect moving a portion of its body without changing its overall orientation or location. Behaviors consisted of antennal waving, antennal quivering, shuffling, and wing buzzing. Antennal waving involved the slow, asynchronous movement of the antennae through a wide arc. Females spent a significantly greater portion of their time in this behavior than males. A significantly greater portion of the noon bock was spent in antennal waving than the morning or afternoon blocks. Antennal quivering was characterized by the rapid, simultaneous movement of the antennae through a narrow arc. This behavior occupied a significantly greater portion of the afternoon than the morning or noon blocks. Shuffling was defined as the lifting of the middle and fore legs in succession, giving the impression that the insect was walking in place. Wing buzzing was characterized by the lifting of the hemelytra and the rapid and audible beating of the hind wings without the insect leaving the plant. This behavior did not precede flight.

Grooming included those behaviors which involved the movement of one body part against another, usually several times in rapid succession. Antennal grooming involved the insect placing the proximal end of the tibia around the base of an antenna and then pulling the tarsal segments down over the antenna 3 to 5 times. Abdominal grooming was characterized by 3 to 6 rapid longitudinal strokes of the ventral abdomen with either the hind or middle legs and was occasionally followed by a brief rubbing together of the hind tarsi. Fore leg grooming consisted of the rapid rubbing together of the tarsi of the fore legs and often followed antennal grooming.

Feeding was characterized by a series of rarely observed behaviors consisting of stylet extension, spittle secretion and stylet insertion. Stylet insertion did not always immediately follow the other two behaviors. Stylet extension involved the unfolding of the mouthparts away from the body. Spittle secretion was seen in a single male which produced and maintained a drop of clear liquid at the tip of its stylet. Stylet insertion was characterized by the stylet piercing the substrate. This behavior was observed in two males, one of which fed during the morning block on a leaf vein and the other during the noon block on a pod.

Excretion was a common behavior characterized by the insect raising the posterior portion of the abdomen and releasing 1 to 3 drops of excrement. Males took significantly longer in excretion than females.

Positional orientation was characterized by a change in position of the body without a change in location of the bug. These behaviors consisted of shifting, jerking, tilting, and lifting. Shifting was a common behavior in which an insect slowly changed its horizontal orientation by rotating its body within a plane, without releasing hold of the substrate. Males spent a significantly greater portion of their time shifting than females. Jerking was observed in a single male which engaged in rapid changes in its horizontal orientation by sudden lateral movements, without releasing the substrate. Tilting was characterized by an individual slowly changing its vertical orientation by raising one side of its body. The titled posture was maintained significantly longer in females and occupied a significantly greater portion of their time than males. Tilting lasted for significantly longer durations in the noon block than in the afternoon or morning blocks. Lifting was characterized

by the insect straightening its legs so as to raise its body away from the substrate. The lifting posture lasted significantly longer and occupied a significantly greater portion of time in males than in females. Lifting was significantly more frequent and occupied a significantly greater portion of the morning block than the afternoon block, which differed similarly from the noon block.

Locomotion was characterized by movements which changed the location of the entire insect. Locomotion included walking, both backwards and forwards, and flying. Walking backwards was typified by the insect slowly crawling caudad, and often preceded excretion. Walking forward was characterized by crawling anteriad. Females spent a significantly greater portion of their time walking forward than males. Time of day significantly affected the duration of this behavior, with the most extended walks occurring during the afternoon block. In addition, a significantly greater portion of the afternoon block was spent walking than the morning or afternoon blocks. Flight involved an individual lifting its elytra and immediately taking off, usually from the edge of a horizontal surface. The duration of flight was variable and individuals were observed to fly from less than 0.5 m to more than 50 m. A significantly greater portion of the noon block than the morning or afternoon blocks was occupied by flight.

Basking behavior was defined as any behavior which occurred in direct sunlight, providing direct sunlight was available. In the morning block, 57.3% of the time was spent basking, which was significantly greater than the 48.9% of time spent basking during the noon block, which in turn was significantly greater than the 45.6% of the time spent basking in the afternoon block. Thus, *A. hilare* spent a decreasing proportion of its time in direct sunlight as the day progressed, and only during the morning block did it spend the majority of available time basking.

DISCUSSION

The behavioral catalogue developed in this study is a good approximation of the repertoire of the behaviors of adult *A. hilare.* However, it is necessary to consider these findings in the context in which they were taken and not to extrapolate beyond the spatial and temporal conditions of this study. It has been shown that stink bug behavior may change with respect to development (Brennan et al. 1977), time (Miner 1966), and location (Mitchell and Mau 1971; Harris and Todd 1980). The behaviors documented for *A. hilare* can not be readily compared to those of other stink bugs as there are no other behavioral catalogues available from the family Pentatomidae or the order Hemiptera. Considerable work has been done on the bionomics of *A. hilare* and related pests (Jensen and Newsom 1972; Todd and Turnipseed 1974), but in this context behavior is considered in terms of ecological, population parameters (Miner 1966) or host damage tendencies (Yeargen 1977). However, specific behaviors of some pentatomids, in particular *Nezara viridula* (L.), have been studied and provide some basis for comparison and functional interpretation. The functions of the behaviors of *A. hilare* were either implicit or inferred, although the difference was not always well defined.

Behaviors with implicit functions have a purpose inherent in their description. These actions include feeding, excretion, locomotion, resting, and basking. The feeding behaviors of *A. hilare* appeared to involve the testing of a potential food source by stylet contact and possibly spittle secretion prior to acceptance and stylet insertion. The frequency of excretion indicated that some feeding may not

have been observed; perhaps *A. hilare* was more cryptic while feeding than while resting or often fed outside of the times of observation. Excretion often followed or preceded a change in location; it may be that excrement provides a kairomonal cue, although no predator or parasite interactions were observed. Locomotory behaviors were common, as might be expected, although flight was more frequent than that reported for *N. viridula* (Nishida 1966). *Acrosternum hilare* spent a great deal of time resting in a dorsoventrally flattened posture. This position is characteristically adopted for camouflage (Matthews and Matthews 1978), thus crypsis is implicated as a function of the resting posture. Basking apparently had a thermoregulatory function (Waite 1980) which is supported by the tendency to bask in the mornings and prefer shade later in the day. Mating behaviors were not observed, as may be expected since *A. hilare* do not mate during the time at which this study was conducted (Miner 1966).

The behaviors with inferred functions have a purpose that is rationalized from their description and the insect's biology. These actions include componential movements, grooming, and positional orientation. The various componential movements may have served different functions. Antennal movements were probably related to sensation of chemical stimuli and functioned to increase the amount of air sampled by the insect. Wing buzzing, also observed in *N. viridula* (J. A. Lockwood, unpublished), may be functionally related to the dissemination of a pheromone from a pair of exocrine glands located on the dorsal abdomen of related pentatomids (Aldrich et al. 1978). Shuffling, although very frequent, did not lend itself to functional interpretation. Like componential movements, grooming behaviors may not share a common function. The grooming of antennae and the tarsi of the fore legs probably functioned to clear the related sensory organs of debris. Abdominal grooming, however, did not appear to serve a cleaning role, but this stroking action did allow contact with a series of possible exocrine glands. Ventral abdominal exocrine glands are thought to be present in *N. viridula* (Harris, personal communication). Thus, grooming in *A. hilare* may have hygienic and communicative functions, both of which have been described by Wilson (1971) in context of social insects. Positional orientation behaviors may have a number of functions including chemokinesis and anemokinesis. Orientation changes may also have allowed greater exposure of a body surface for thermoregulation for chemical dissemination.

Differences in durations and frequencies of behaviors are difficult to interpret without adequate knowledge of the biology of *A. hilare* and the functions of documented behaviors. Sexual differences indicate that even under nonreproductive conditions, the behavioral responses to ecological demands differ for males and females. Both sexual and temporal differences may help elucidate the function of a behavior. This study demonstrates that both sex and time of day influence *A. hilare* behavior. Management strategies for this pest should consider the impact of these behavioral changes since they may influence many components of a management system, including sampling efficiency and the effectiveness of control measures.

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