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Time Budgets of the Gray Squirrel (*Sciurus carolinensis*)

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Abstract

Time budgeting accounts for how an animal spends its time, and the percentage of time spent in particular life sustaining activities. The time budgeting of gray squirrels in Brandon Park, Williamsport, PA, were studied and grouped into the following behavioral categories: inactive, feeding, locomotion, and social. Observations varied according to season, time of day, wind speed, cloud cover and temperature. Data was statistically analyzed using ANOVA, ANCOVA, procedure General Linear Model for simple factorial and repeated measures with weighted variables. Results showed variation between behavioral categories: most time was spent feeding (34.0%) while the least time was spent inactive (14.3%). A significant interaction occurred between season and time of day for both locomotion and social behaviors. Social behavior differed between time of day while significant differences occurred between seasons for inactive, feeding and locomotion behaviors, but not for social behavior. In fall, the greatest mean behavior was feeding (71.47) while inactivity was lowest (1.45). In winter, locomotion was greatest (57.43) and feeding was lowest (34.69). Gray squirrels were more inactive in the winter, fed more in the fall, and engaged in locomotion more in winter. Generally, weather conditions had little influence on behavior, however, temperature showed the greatest effect, significantly influencing inactive, feeding and social behaviors. Findings of this study were compared to previous studies, and similarities as well as differences are discussed.

The concept of time budgeting accounts for how an animal spends its time and what percent of the time that animal engages in particular life sustaining activities (Pratt 1987). External pressures influence an animal's time budget. The effects of predation (Lima 1987), seasons of the year (Verner 1965), and solitary vs. gregarious existence (Barnard 1980) on time budgeting have been studied and results indicate that trade-offs are created in an attempt to maximize efficiency. All species utilize some form of time budgeting, while not all of them spend the same amount of time in any specific activity.

According to Grzimek's Encyclopedia of Mammals (1990), gray squirrels (*Sciurus carolinensis*) are primarily tree dwellers, visiting the ground only to gather food, bury or dig nuts, etc.. Three peak activity times occur for these squirrels: the most intense being from 6 a.m. to 9 a.m., another from 11 a.m. to 1 p.m., and the third between 6 p.m. and 7 p.m. (Hicks 1949). They are a non-territorial species which forage widely and independently for food, while maintaining a "social contract" with neighboring squirrels either directly or by scent marking trees. Competition is minimal and they are widely distributed over available resources. Because of their independent nature, gray squirrels lack the advantage of mutually cooperative food searching and protection against predators.

While previous studies have been conducted on the time budgets of several avian species, including blackbirds, wrens, and sparrows, this study is directed toward the time budgets of gray squirrels. Jodice and Humphrey (1992) conducted a study on the activity and diet of an urban population of Big Cypress Fox Squirrels (*Sciurus niger avicennia*). In general, they found that Big Cypress Fox Squirrels spend the majority of their time foraging while the least amount of time is spent in social behaviors. However, these data do differ depending on the season.

In addition, Jodice and Humphrey incorporated external factors, including weather

conditions such as temperature and wind speed, but found that they had little effect on squirrel behavior. Similar results were anticipated at the conclusion of this study. However, since time budgeting behaviors can differ, one objective was to compare and contrast how two different species of squirrel budget their time.

Methods and Materials

Brandon Park, in Williamsport, PA, served as the study area for gray squirrel data collection. This park covers approximately 40 acres of land, about half of which was forested while the other half was more open fields. All observations in this study were recorded from the forested section of the park. This park is commonly utilized for recreational purposes and the squirrels were well adjusted to man's presence, including being fed by man. Observations of the squirrel's behavior began approximately three weeks before the first actual recorded date, in an attempt to get familiar with squirrel activities. Data were collected on an average 2.5 days/week for a total of 13 weeks from October 1997 continuing through February 1998. Since time of day, wind speed, cloud cover and temperature have been shown to influence behaviors, observations varied through the hours of the day to incorporate the three peak activity times, (as well as other less active times) and they incorporated a mixture of these other conditions (Hicks 1949). At the start of each observation period, the date, time, wind speed, temperature, cloud cover and general weather conditions were recorded. Time of day was recorded in hours and divided into three periods to test for daily activity changes: morning included 7 a.m. to 11:30 a.m., afternoon 11:35 a.m. to 3 p.m., and evening 3:05 p.m. to 5:30 p.m.. Wind speeds were assigned a Beaufort number, ranging from 0 (calm) to 6 (strong), and temperature was recorded in degrees F. Cloud cover was categorized by dividing the sky into ten equal parts and determining how many tenths of the sky were clouded: (0-.4) sunny, (.5-.8) partly cloudy, (.9-1.0) cloudy. Based on the time

of the year, the months of observation were grouped into two seasons: fall (Oct.-Dec.) and winter (Jan.-Feb.).

Squirrel behaviors were observed on foot, with the occasional use of binoculars. Through instantaneous (or scan) sampling (Altmann 1974), an individual squirrel was chosen at random and monitored for 5 minutes, while a classification of its behavior was assigned at 5 second intervals. Records of individual squirrels were not maintained due to the similarity between individuals and the inability to identify them consistently. The following general behavioral categories were recorded: inactive, feeding, locomotion, and social behaviors. For the purposes of this study, the following definitions or subcategories were utilized for further specification:

- Inactivity includes any resting state, and grooming/maintenance behavior.

- Feeding behavior includes searching, digging, consuming, carrying, or hoarding/caching a food source.

- Locomotion is that movement from one point to another which does not involve any immediate feeding behavior (ie. carrying), nor social interaction (ie. chasing).

- Social behavior is any intraspecific behavior; includes tail flicking, vocalizations, chases, alert behavior (that behavior where normal, continuous activity ceases, and the squirrel assumes an attentive posture - may include pause with head up, up on hind legs, or paused on a tree).

The data were analyzed utilizing two-way ANOVA, two-way ANCOVA, procedure General Linear Model (GLM) for simple factorial and repeated measures with weighted variables. Means that differed at $P < 0.05$ were considered significant. These data were analyzed for variations within behavioral categories among both seasons and time of day, and pairwise comparison was used to determine significant differences between behavioral categories.

Results

Time budgeting varied between the general behavior categories. Overall, gray squirrels spent most of their time feeding (34.0%), while social and locomotion behaviors (both 25.8%) were the next most common. Squirrels spent the least amount of time in an inactive state (14.3%) (Figure 1).

Differences between behaviors themselves were illustrated through pairwise comparison. Significant differences were found between mean inactive behavior and each of the other three categories: feeding, locomotion, and social. In addition, feeding behavior was significantly different from both locomotion and social behaviors (Table 2). The greatest mean difference in behaviors occurred between inactivity and feeding (33.02) while the least difference was between locomotion and social behaviors (2.66). No significant difference was found between locomotion and social behaviors ($P=0.319$).

When the data were analyzed within behavioral categories among both seasons and the time of day, only social behavior showed a significant difference between times of day. The mean amount of social behavior in the afternoon (55.30) was significantly different from the morning (35.64) or evening (33.52) mean social behavior (Table 1). No other behavioral categories showed any significant differences between time of day. The mean maximum behavior for any one time of day was feeding (76.86), which occurred during the afternoon in the fall season. The mean minimum behavioral category for any one time of day was inactivity (0.62), which occurred during the evening of the fall season (Table 1).

Significant differences did occur within inactive, feeding, and locomotion behaviors between seasons, but not for social behaviors. The largest seasonal change occurred between mean inactivity: 1.45 in fall and 43.07 in winter (Table 1). In general, during the fall season, the

greatest mean behavior was feeding (71.47) while inactivity was the lowest (1.45), and in the winter, locomotion was greatest (57.43) and feeding was lowest (34.69). Mean feeding behaviors in the fall (71.47) were significantly different than those in the winter (34.69), and locomotion behavior significantly differed between fall and winter, 26.64 and 57.43, respectively. No significant difference was found between the mean amount of time engaged in social behavior in the fall (42.96) and winter (44.81).

Interaction between season and time of day was found for both locomotion and social behaviors. Locomotion behavior was shown to be significantly greater in winter, but even more specifically, the most difference in mean locomotion behaviors between seasons occurs in the afternoon hours (Fig. 3). The least difference of mean social behaviors between fall and winter occurred during the morning hours, as compared to the afternoon and evening (Fig. 4). However, these interactions between season and time of day may be due to the fact that in winter months the amount of daylight hours is less than in the fall.

In general, weather had very little effect of the time budgets of the gray squirrel. When the covariates wind, temperature, and cloud cover were analyzed within behavioral categories among both seasons and three times of day, temperature showed the greatest effect, significantly influencing inactive ($P=0.000$), feeding ($P=0.034$), and social ($P=0.036$) behaviors. In addition, wind speed showed a significant effect on feeding ($P=0.000$) while cloud cover significantly influenced social behavior ($P=0.006$). The covariates, however, showed no effect on any of the four behaviors when analyzed using GLM repeated measures.

Discussion

The trends of time budgeting found in this study are comparable to some previous studies, although differences do exist. Hicks (1949) reports different activity levels with differing wind

conditions, cloud cover, and time of day, and the results of this study found some significant differences between these factors as well. In addition, several studies have indicated activity differences between seasons, and the results of this study are in agreement with these previous findings (Hicks 1949, Jodice and Humphrey 1992).

Gray squirrels are significantly more inactive in winter than in the fall (Figure 2). In addition, temperature was shown to have an effect on inactive behavior. This indicates that squirrels are significantly less active in colder temperatures during winter than the somewhat warmer fall temperatures. Feeding behaviors were significantly influenced by temperature, suggesting that gray squirrels feed more in the fall when the temperatures are more mild as opposed to the colder winter temperatures. This characteristic could be attributed to the idea that gray squirrels store up food caches for use in winter months. Also, temperature significantly effected social behavior. Significantly more social behavior occurred during the afternoon as opposed to the morning or evening time periods. This suggests that gray squirrels engage in social behavior more during the afternoon when temperatures typically reach their peak rather than during the morning or evening hours when temperatures are usually cooler.

Although some differences exist, Jodice and Humphrey (1992) conducted an activity study of the fox squirrel which is comparable to this study. Their study had four seasons: early wet, from June to August; late wet, from September through November (which is similar to "fall"); early dry, from December to February (which is similar to "winter"); and late dry, from March to May. Also, their behavioral categories were: inactive, foraging (similar to "feeding"), traveling (similar to "locomote"), other active and social interactions (when grouped, are similar to "social").

In both studies, maximum foraging/feeding behavior, and minimum inactivity occurred in

the fall. However, Jodice and Humphrey found that foraging behavior was greater than inactivity in both late wet (fall) and early dry (winter) seasons, whereas in this study, foraging/feeding behavior was greater than inactivity in the fall, but inactivity was greater than feeding in the winter. Of the four behavioral categories, in the winter season feeding behavior occurred the least, whereas in Jodice and Humphrey's study, foraging behavior was always greater than the other active categories. Jodice and Humphrey found mean inactivity greater than traveling, other active, and social in all seasons except for late wet (fall). In contrast, this study found that locomotion was greater than inactivity in the winter season. Both studies did suggest that temperature had the greatest effect on behavior, however, in general, weather had little relation to the squirrel's behavior.

It is difficult to suggest any conclusive evidence on the differences between this study and previous findings due to the fact that, although similar, many variables do differ. Category definitions, time of day and season criteria, location, etc. differ between studies and are not an exact match. Also, sample sizes may vary between studies which can influence the results. However, it is useful to compare the differences and analyze the results in an attempt to accurately portray squirrel time budgets. For example, the fox squirrel Jodice and Humphrey (1992) studied are endangered, and the results of their work aid in the attempt to preserve the species. The more information known about animal behaviors, the more that can be done to help preserve and extend their existence during a time when biological diversity is threatened.

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Time Budgeting Analysis

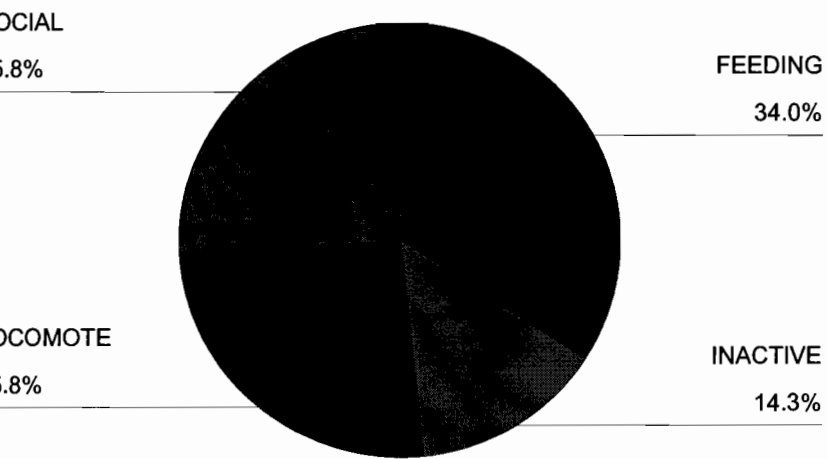


Fig 1. Time budget of gray squirrels in Brandon Park.

Seasonal Activity Patterns

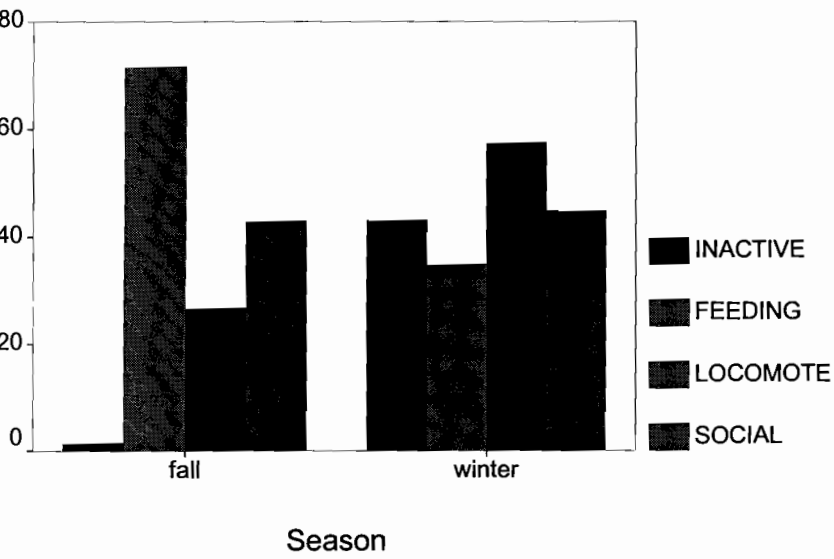


Fig 2. Comparison of mean behavior categories between fall and winter.

Asterisks (*) indicate significant differences ($P > 0.05$).

Interaction Plot of Locomotion Behavior

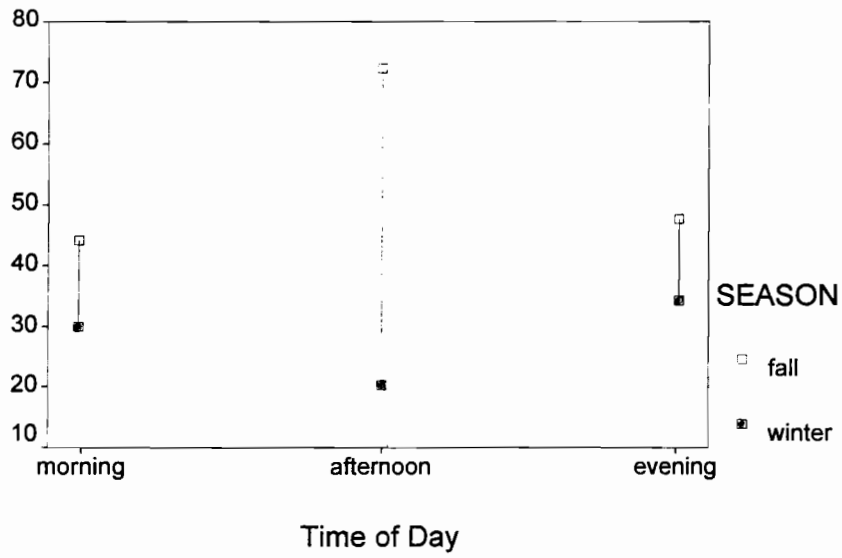


Fig 3. Interaction between season and time of day for locomotion behavior.

Interaction Plot for Social Behavior

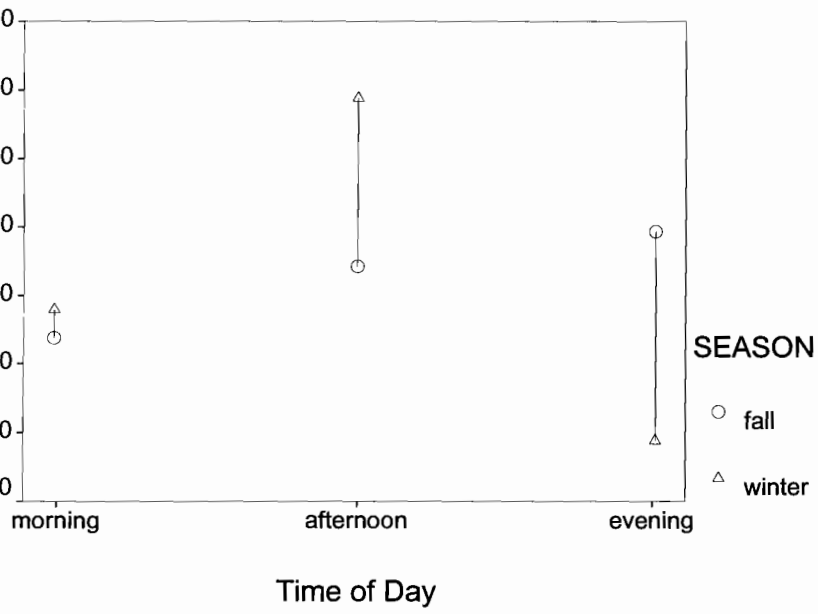


Fig 4. Interaction between season and time of day for social behavior.

INACTIVE	Morning	Afternoon	Evening	Total
Fall	2.25	1.50	0.62	1.45 *
Winter	34.70	47.61	43.21	43.07 *
Totals	17.00	22.25	22.70	21.09

FEEDING	Morning	Afternoon	Evening	Totals
Fall	59.42	76.86	73.46	71.47 *
Winter	35.60	41.39	25.43	34.69 *
Totals	48.59	60.90	48.56	54.11

LOCOMOTE	Morning	Afternoon	Evening	Totals
Fall	30.00	20.27	34.31	26.64 *
Winter	44.20	72.33	47.71	57.43 *
Totals	36.45	43.70	41.26	41.17

SOCIAL	Morning	Afternoon	Evening	Totals
Fall	33.75	44.23	49.31	42.96
Winter	37.90	68.83	18.86	44.81
Totals	35.64 *	55.30 *	33.52 *	43.83

Table 1. Mean behaviors of gray squirrel time budget within behavioral categories between season and time of day. Asterisks (*) indicates significant differences ($P > 0.05$).

Behavior		Mean Difference	Standard Error	Significance
1	2	-33.02*	5.956	.000
	3	-20.08*	2.624	.000
	4	-22.74*	4.063	.000
2	3	12.94*	5.488	.021
	4	10.28*	4.658	.030
	1	33.02*	5.956	.000
3	2	-12.94*	5.488	.021
	4	-2.66	2.656	.319
	1	20.08*	2.624	.000
4	2	-10.28*	4.658	.030
	3	2.66	2.656	.319
	1	22.74*	4.063	.000

Table 2. Pairwise comparison of mean behaviors where (1) inactive, (2) feeding, (3) locomote, (4) social. Asterisks (*) indicates significant differences ($P > 0.05$).