September 2002

The influence of light intensity of the moon on the calling behavior of the common pauraque (Nyctidromus albicollis) during moonlit and twilight hours

Kristin Bondo

The influence of light intensity of the moon on the calling behavior of the Common Pauraque *(Nyctidromus albicollis)* during moonlit and twilight hours

Kristin Bondo

Department of Forestry and Natural Resources, Purdue University, West Lafayette, IN

ABSTRACT

A study of the Common Pauraque *(Nyctidromus albicollis)* was conducted in an area of Costa Rica that has a pronounced dry season. The mean frequency of calls per minute, number of consecutive minutes of calls, and starting times of vocalizations at dusk were recorded. The mean frequency of Common Pauraque calls per minute, number of consecutive minutes of calls, and maximum number of calls per minute were not direct functions of percent moon face illumination, (Regression, $R^2 = 0.064$, $p = 0.1366$; Regression, $R^2 = 0.257$, $p = 0.0269$; Regression, $R^2 = 0.095$, $p = 0.2286$) respectively. This suggests that weather, breeding, and insect populations may be involved, in relation with the moon, in influencing vocalizational patterns of the Common Pauraque. The number of consecutive calls was greatest on nights where the rising of the moon overlapped with dusk. The lengthening of time during which these birds could call, especially near the equator where dusk lasts at most for 39 minutes, may explain why early accounts have related calling with the phase and brightness of the moon.

RESUMEN

Se hizo un estudio del Cuyeo *(Nyctidromus albicollis)* en una área de Costa Rica que tiene una estación seca pronunciada. El promedio de la frecuencia de las llamadas durante un minuto, el número de llamadas consecutivas y los tiempos cuando las vocalizaciones empezaron fueron anotados. El promedio de la frecuencia de llamadas del Cuyeo durante un minuto, el número de llamadas consecutivas y el número máximo de llamadas durante un minuto no fueron funciones directas del porcentaje de la iluminación de la cara de la luna, (Regression, $R^2 = 0.064$, $p = 0.1366$; Regression, $R^2 = 0.257$, $p = 0.0269$; Regression, $R^2 = 0.095$, $P = 0.2286$) respectivamente). Esto sugiere que el tiempo, la crianza y las poblaciones de insectos pueden ser involucrados, en relación con la luna, en la predicción de la vocalización del Cuyeo. El número de llamadas consecutivas fue mayor durante las noches donde la salida de la luna coincidió con el atardecer. El

prolongamiento del tiempo durante lo cual estas aves pueden llamar, especialmente cerca del ecuador donde el atardecer dura un máximo de 39 minutos, puede explicar porque desuipinones previas han relacionada las llamadas con la fase y la iluminación de la luna.

INTRODUCTION

The Common Pauraque *(Nyctidromus albicollis)* is a crepuscular and nocturnal bird of the Caprimulgidae family (Latta and Howell 1999) found from southern Texas to northwest Peru and northern Argentina (Stiles and Skutch 1989). It makes vocalizations at dawn, dusk and after dark (Latta and Howell 1999), and the calling and persistence of these calls have been associated with the phases and brightness of the moon. Vocalizations have been said to increase as the moon waxes, during bright moonlit nights, and on favorable nights when the moon is full or nearly full (Edwards 1983, Latta and Howell 1999). Common Pauraques were calling in great numbers in Mexico during the bright moonlit nights of April 1-5 (Edwards 1983). The loud and persistent calling occurring in Guanacaste, Costa Rica in mid-April reported by Edwards (1983) may have been related to the moon as well.

Light intensity may be an important factor in the ecology of Caprimulgids because their eyes contain numerous rods, as well as a tapetum lucidium, a reflective structure on the choroid that reflects light back to the eye (Mills 1986, Latta and Howell 1999). The presence of these structures suggests that Caprimulgid eyes are extremely light sensitive (Mills 1986) and that they detect prey by silhouetting it against the sky (Latta and Howell 1999). If light affects the vision of Caprimulgids, patterns of lunarphilia may be strongest near the equator because the crepuscular hours near the equator are much shorter than that of the temperate zone (Mills 1986). Unlike the temperate zone, where crepuscular twilight can last as long as eighty-four minutes, in areas near the equator it lasts for at most 39 minutes (Mills 1986).

The observation of increased calling in relation to the phase and light intensity of the moon has been little studied, especially in the tropics. In the temperate zone, it has been shown that Whip-por Will *(Caprimulgis vociferus)* singing is a function of percent moon face illumination (%MFI), the amount of light that the moon gives off during the course of its 29.5 day cycle (Mills 1986). The light intensity of the moon is influenced by both moon height and percent moon face illumination (Mills 1986). Percent moon face illumination is lowest at the start of the new moon and at its maximum on the night of the full moon.

The purpose of this study was to compare the frequencies and total calls of Common Pauraque vocalizations during twilight and moonlit hours in a seasonal area near the equator in order to see how the moon influences the calling patterns of this bird.

METHODS

Study Site

This study was conducted from April 13 to May 6, 2002 in two pastures currently grazed by cattle at 1100 meters within a premontane wet forest life zone (Haber et. al

2000) of the Upper San Luis Valley, Puntarenas Province, Costa Rica (10'N, 84' 0"). The dry season occurs from February to April and is characterized by moderate trade winds, stratus clouds or clear sky conditions and wind driven mist and cloud water, particularly during the night. The San Luis Valley receives little amounts of wind-driven precipitation and minimal cloud immersion during the dry season (Clark et. al 2000), however, during the period of May 1 through May 6, an atypical amount of rain and mist was deposited on the Upper San Luis Valley.

Lunar, Solar, and Meteorological Conditions

Percent moonlight illumination (%MFI), phase of the moon, time of moon rise, moon set, sunrise, and sunset for Costa Rica (10'N, 84' 0") were obtained from Starry Night (2000) (Appendix 1). The periods of moonlight influence were distinguished from the periods of twilight influence, periods of subdued light just after sunset and just before sunrise, by listening to when the last call was made at dusk on moonless nights and to when the first call was made on moonless mornings. Since 18:35 was the last time that a bird call was heard at dusk, the crepuscular hours at dusk were defined as being the period between the first call, usually five minutes before sunset, to 18:35. Any activity after 18:35 was considered to be influenced by the moon. Likewise, since the first call at dawn was heard at 4:38, the twilight hours at dawn were defined as being from 4:38 to the timing of sunrise. Any calls made before 4:38 were considered to be influenced by the moon.

Vocal Activity

The time of the first call, number of vocalizations per minute per bird, and number of consecutive minutes of calls, defined as being the number of minutes a bird called without stopping for one hour, were recorded at dawn, dusk, and moonlight conditions in two pastures throughout a 23 day period, starting the first day after the new moon and stopping two days after the last quarter moon. At dawn and dusk, observations were started half an hour before sunrise and sunset and were stopped after not hearing any calls for one hour. On moonlit nights, after not hearing any calls for at least an hour, additional moonlight data were collected at random times throughout the night. Due to the amount of rain occurring on all nights and mornings between May 1 and May 6 when the moon rose very late at night, no data were collected.

Although at least four different calls were heard for the Common Pauraques, only two were included in this analysis because they were the most common and could be heard from far away. The two calls that were recorded in this study were the loud "cuyeer" (Stiles and Skutch 1989), which was the most frequently heard call, and the "hip-hip hip-hip hip-hip-hooray" (Latta and Howell 1999), the second most frequently heard call. Two other calls that were infrequent and not recorded due to the faintness of the calls were frog-like growling noises (Latta and Howell 1999) observed once and the "which" or "whip" calls (Stiles and Skutch 1989) that were often associated when the bird would take flight or sally for insects.

Monitoring of the pastures was alternated throughout the study period. Pasture 1 contained one calling male bird, and on all nights except one, he was the only bird that could be heard. Pasture 2, on the other hand, contained at least three calling birds that could be heard at a time, but the sexes could not be determined because of the abundance of birds and their frequent switching of locations. Pasture 1 was monitored two times at dawn and pasture 2 was monitored four times at dawn. Starting at dusk, pasture 1 was monitored 13 times and pasture 2 was monitored eight times. During the full moon night and two nights following the full moon, only pasture 2 was monitored for the night data because more birds could be heard in that pasture than pasture 1, increasing the amount of data that could be recorded.

Data Analysis

For each day, the average number of calls per minute per bird as well as the maximum number of calls per minute per bird were calculated for each half hour interval for both dusk and moonlight hours. The total number of crepuscular calls per minute for all birds heard was also calculated for each day. To account for the difference in numbers of individuals in both pastures, the number of calls per minute was kept separate for each bird, so that frequencies would not be falsely high due to more birds being present on a given site. However, for total number of crepuscular calls, this includes all calls for all birds because this observation is taking into account that during brighter periods, more individual birds may be calling.

Regression analyses were run for mean number of calls, total number of calls at dusk, and total number of minutes of consecutive song as a function of %MFI. Consecutive song is defined as the number of minutes a bird called, starting at dusk, without taking a break of a half an hour or more.

Analyses were made with percent moon face illumination rather than moon height because moon face illumination is a better predictor of the light intensity of the moon. Moons with high percent moon face illumination are just as likely to be high in the sky as they are low, and all high moons have high %MFI (Mills 1986).

A regression analysis between total number of calls at dusk and time of the first call was also run. To see if the bird in pasture 1 called more per minute than individual birds in pasture 2, a t-test was run between the mean number of calls per minute per bird in pastures 1 and 2. A t-test was also used to determine if the number of calls per minute at dusk were different from the number of calls per minute of the bright moonlit nights (94.78% MFI to 99.89 %MFI).

RESULTS

The total number of minutes of consecutive song ranged from 7 minutes on April 16 to 166 minutes on April 26, the night of the full moon (Figure 1). There was no significant relationship between the number of consecutive minutes of calls and %MFI (Regression, $R^2 = 0.142$, $p = 0.1336$). No data were collected on April 19, May 1, and May 4, and no calls were heard on May 2 and May 3 (Figure 1).

There was no significant relationship between the mean number of calls per minute and % MFI (Regression, $R^2 = 0.064$, $p = 0.1366$). The mean number of calls per minute time remained fairly constant throughout each half hour time period, regardless of the day and the phase and stage of the moon (Figures l, 2a and 2b). However, the mean number of calls per minute at dusk, 9.2 +/- 6.8 calls/minute (N = 301), and the mean number of calls for moonlit nights 94.78% MFI or greater, 12.0 +/- 7.6 calls/minute (N = 770), were significantly different (t-test, F = 30.14, $p < 0.0001$). (Figure 3).

The maximum number of calls per minute per bird ranged from two calls per minute to 28 calls per minute. (Figures 4a and 4b). There was no significant relationship between the maximum number of calls per minute per bird and %MFI (Regression, R^2 = 0.095, p = 0.2286).

The total number of calls at dusk ranged from 27 to 306 calls (Figure 5). There was no significant relationship between the total number of crepuscular calls and %MFI (Regression, R^2= 0.171, p = 0.0986). During the twilight hours of dusk, the total number of calls was greatest on April 22 with 349 calls, followed by April 21 with 306 calls and April 27 with 271 calls. The total number of calls was lowest on April 16 with a total of 27 calls (Figure 5). However, the frequencies at which the bird in pasture 1 and the individual birds in pasture 2 called during dusk were significantly different (t-test, F = 27.45, p = 0.0026). The mean number of times per minute the bird in Pasture 1 called was 10.6 +/- 7.2 (N = 140), whereas the mean number of calls per minute per bird for pasture 2 was 8.2 +/- 6.5 (N = 174) (Figure 6).

DISCUSSION

Lunarphilia in Common Pauraques

These results indicate that other factors besides the percent moon face illumination of the moon may be involved in Common Pauraque vocalizations. The lack of relationship between the mean number of calls per minute (Figures 2a and 2b), maximum number of calls per minute (Figures 4a and 4b), and total number of calls at dusk (Figure 5) as a function of %MFI may have been caused by rain, cloud cover, and mist. Calling has been reported to decrease with cloud cover, cold, rain, and wind (Latta and Howell 1999). During the wet seasons of Central America, Common Pauraque vocalizations have been reported to decrease even on the brightest moonlit nights. Figure 1 shows the total amount of consecutive minutes of calling. Consecutive minutes of calling was similar for both April 20, which had an MFI of 55.32%, and for April 26 and 27, which had an MFI of 98.66% and 99.89%, respectively (Figure 1). This may been caused by clear skies because unlike many of the nights where there was much cloud cover and mist, April 20 was particularly clear.

The lack of relationship between mean number of total calls per minute (Figures 2a and 2b), maximum number of calls per minute (Figures 4a and 4b), and total number of calls at dusk (Figure 5) as a function of %MFI contradicts Mills (1986) study that singing is a function of %MFI. Although Mills found that clouds did not influence movement of the birds, he did not test cloudiness with vocal behavior. Since seasons in the tropics are defined by the characteristics of clouds and by the amount of rainfall (Clark et. al 2000), the types of clouds may also be an important factor in singing and comparing analyses between temperate and tropical zones.

Another factor that may have influenced why total number of calls at dusk was not significantly correlated with %MFI is that two different pastures were sampled. The variation in Figure 5 shows that the total number of calls changes very abruptly from April 21 and 22 to April 23. This variation might be explained since the bird in Pasture 1 called at a significantly different frequency per minute than individual Pasture 2 birds. (Figure 6).

The lack of relationship between mean number of calls per minute, maximum number of calls per minute, and total number of calls at dusk as a function of %MFI also contradicts the observations of increased vocalizations in the spring as the moon waxes and during bright moon-lit nights (Latta and Howell 1999). Since calling frequency remained constant as a function of %MFI (Figures 1, 2a, and 2b), observations made by Latta and Howell (1999) and Edwards (1983) may have been the result of the moon overlapping with the crepuscular hour. Figure 1 shows that on the nights of April 26 and April 27, when the moon rose at 17:30 and 18:30 respectively, that the number of minutes of consecutive calls was greatest. The observations may have been the result of the moon lengthening the amount of time that the birds could be active, thus increasing the chances that they would be noticed, especially in areas near the equator where dusk lasts at most for 39 minutes (Mills 1986).

The loud and persistent vocalizations in Guanacaste, Costa Rica in mid-April as well as the large number of birds calling in Mexico on the bright moonlit nights of April 1-5 (Edwards 1983) could have been a response to insect abundance or breeding season events rather than the moon. High densities of birds have been associated with the sudden onset of the wet season and large concentrations of insects (Latta and Howell 1999). Latta and Howell (1999) report that Common Pauraque vocalizations are often associated with breeding season events because during the non-breeding season when the birds are molting, they are particularly silent. Since the Common Pauraque's breeding season in Costa Rica is from February through April (Stiles and Skutch 1989), the increase in calls could have been a combination of many factors, including the moon.

Future research needs to be done to better understand how moonlight in relation to weather, insect abundance, and breeding season events affects the vocalizations of the Common Pauraque. Understanding when Common Pauraques lay their eggs in relation to the phase of the moon may provide important insights as well. Mills (1986) found that Whip-por-wills usually synchronize their reproductive cycles with the lunar cycle by having hatching occur during young waxing moons. Although no nests were found during the course of this study, one fledgling was seen on April 20. According to records of time of fledging, the bird would have been about 23 days old (Latta and Howell 1999). If the bird were about 23 days old, it would not have hatched during the young waxing moons as did the birds in Mills (1986) study. More research, however, needs to be done in this area.

The influence of cloud cover and clear skies on Common Pauraque calling as well as foraging behavior is an important question to answer, especially with the theories of global warming. According to Pounds et al (1999), recent warming has caused changes in species distribution and abundance, suggesting that atmospheric warming has raised the average altitude of the orographic cloud bank, as predicted by the lifting cloud hypothesis. This would create an increase in the amount of dry days and clear skies as clouds are replaced by non-precipitating clouds (Pounds et. al 1999). The relation between Common Pauraque calling, feeding, and behavioral activity in relation to percent cloud cover, types of clouds, and percent moon phase illumination, could possibly yield some important insights of not only bird behavior but climate change as well.

ACKNOWLEDGMENTS

I would like to thank Mauricio Garcia for being enthusiastic and encouraging me to continue with this project and Karen Masters for introducing me into the world of the Common Pauraque. I would like to give much thanks to Andrew Rodstrom for being an excellent, dependable, and awesome TA as well as field assistant in helping with the collection of data and field techniques. Much thanks to Will Wieder for offering to help with the project and for his constructive comments and to Liz McCarren for help with the translating this into Spanish. I would also like to thank Alex Shelton for the collection of written materials and mailing of them to Costa Rica, Alan Masters for his support, the Villalobos and Leitón families for use of their land, and their dog who kept me company on some of those long nights in the field.

LITERATURE CITED

Clark, K., Lawton, R., and P. Butler. 2000. "The Physical Environment". Pages 15-38 in *Monteverde: Ecology and Conservation of a Tropical Cloud Forest.* N.M. Nadkami and NT Wheelwright (eds). Oxford University Press, New York.

Edwards, E.P. 1983. *"'Nyctidromus albicollis* (Common Pauraque)". Pages 590-591 in *Costa Rican Natural History.* D. H. Janzen (ed). The University of Chicago Press, Chicago.

Haber, W, Zuchowski, W, and E. Bello. 2000. *An Introduction to Cloud Forest Trees Monteverde, Costa Rica.* Mountain Gem Publications, Costa Rica. pp. 4-6.

Latta S.C. and C.A. Howell. 1999. *Common Pauraque. The Birds of North America,* No. 429.

Mills, A. M. 1986. The Influence of Moonlight on the Behavior of of Goatsuckers (Caprimulgidae). *The Auk.* 103: 370-378.

Pounds, J. A., M. P. L. Fogden, and J. H. Campbell. 1999. Biological response to climate change on a tropical mountain. *Nature.* 398: 611 - 615.

—-. *Starry Night* 2000. Version 3.1. Canada Inc.

Stiles, F. G. and A. F. Skutch 1989. *A Guide to the Birds of Costa Rica,* Cornell University Press, New York. pp. 200-201.

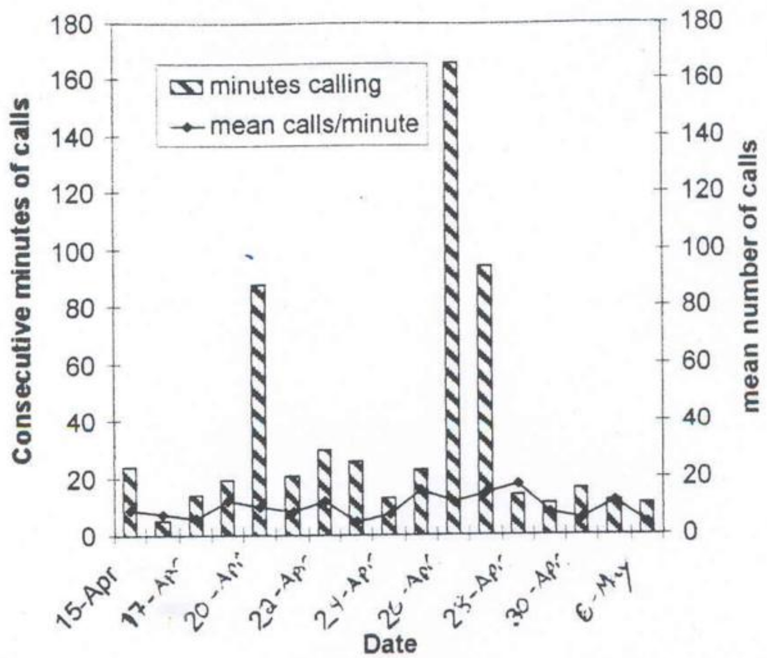

Figure 1: Unlike the mean number of calls per minute, the number of consecutive minutes of song, defined as the number of minutes without stopping for an hour, was more variable, ranging from 7 minutes on April 16 to 166 minutes on April 26, the night of the full moon. On April 20, the night was very clear, possibly allowing the birds to devote more time to calling.

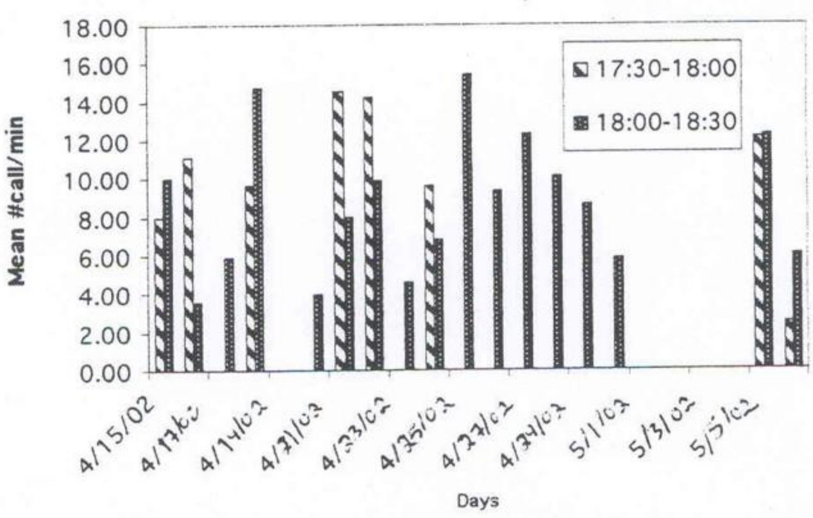

Figure 2a. The mean frequency of calls per minute appears fairly constant throughout time and does not change as a function of %MFI for each day (Regression, $R^2 = 0.064$, $p = 0.1366$). However, the mean number of calls/minute between 17:30-18:30 was significantly different than the mean number of calls/minute at night (18:30 – 2:30) (Figures 2b and 3). The lack of patterns in some categories represents gaps in the data and is not meant to indicate that birds did not call during those times.

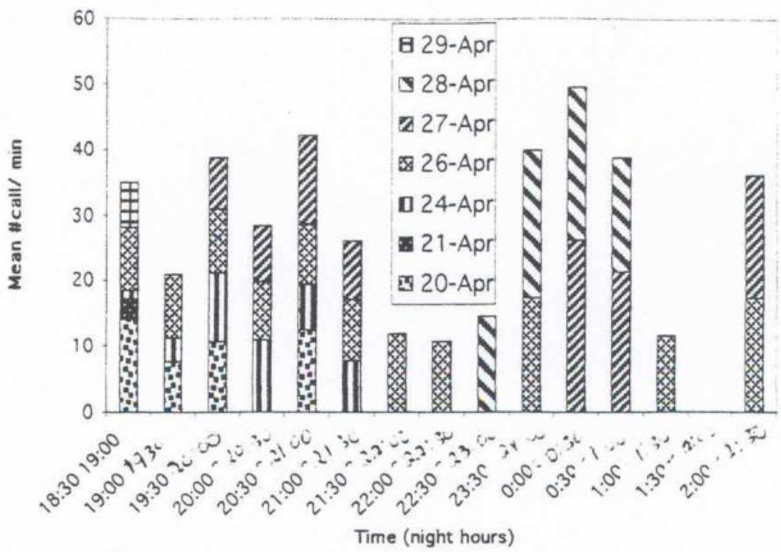

Figure 2b. The mean frequency of calls per minute appears fairly constant throughout time and does not change as a function of %MFI for each day (Regression, $R^2 = 0.064$, $p = 0.1366$). However, the mean number of calls at dusk (17:30-18:30) (Figure 2a) was significantly different than the mean number of calls at night (6:30 p.m. – 2:30 a.m.) (Figure 3). The lack of patterns in some categories represents gaps in the data and is not meant to indicate that birds did not call during those times.

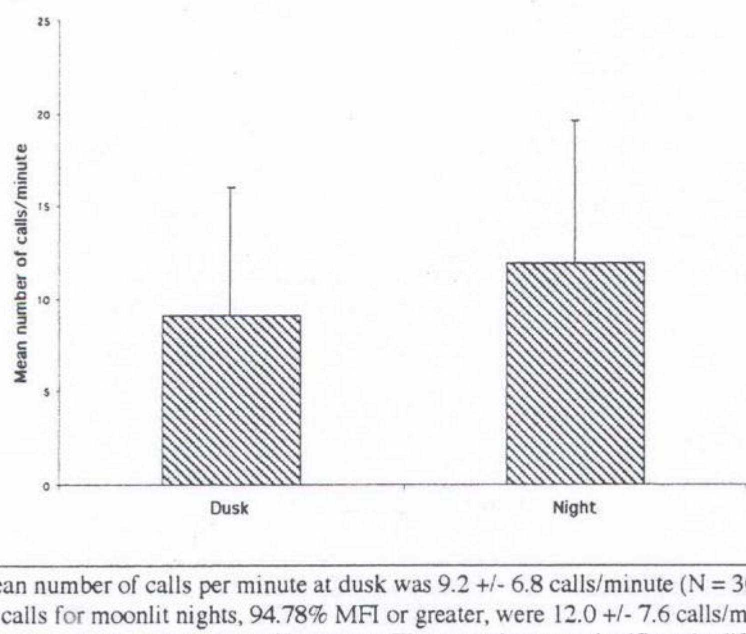

Figure 3. The mean number of calls per minute at dusk was 9.2 +/- 6.8 calls/minute (N = 301), and the mean number of calls for moonlit nights, 94.78% MFI or greater, were 12.0 +/- 7.6 calls/minute (N = 770). The bars represent one standard deviation of the mean. These results were significantly different (t-test, $F = 30.41$, $p < 0.0001$).

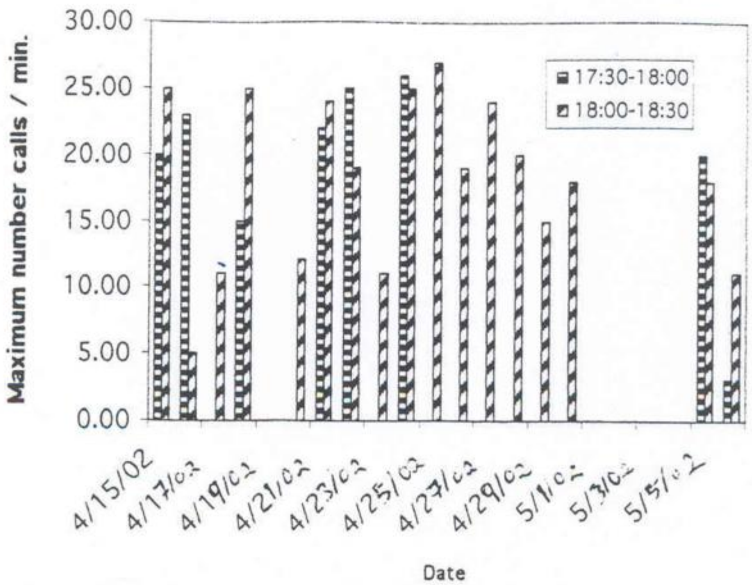

Figure 4a: The maximum number of calls per minute ranged from 2 calls on April 24 from 17:30 – 18:00 to 28 calls on April 24 and 25 from 19:30 – 20:00, April 26 from 20:00 – 20:30, April 28 from 23:30 – 0:00, and 0:00 – 0:30, and April 27 from 0:30 – 1:00 (Figure 4b). The lack of patterns in some categories represents gaps in the data and is not meant to indicate that birds did not call during those times.

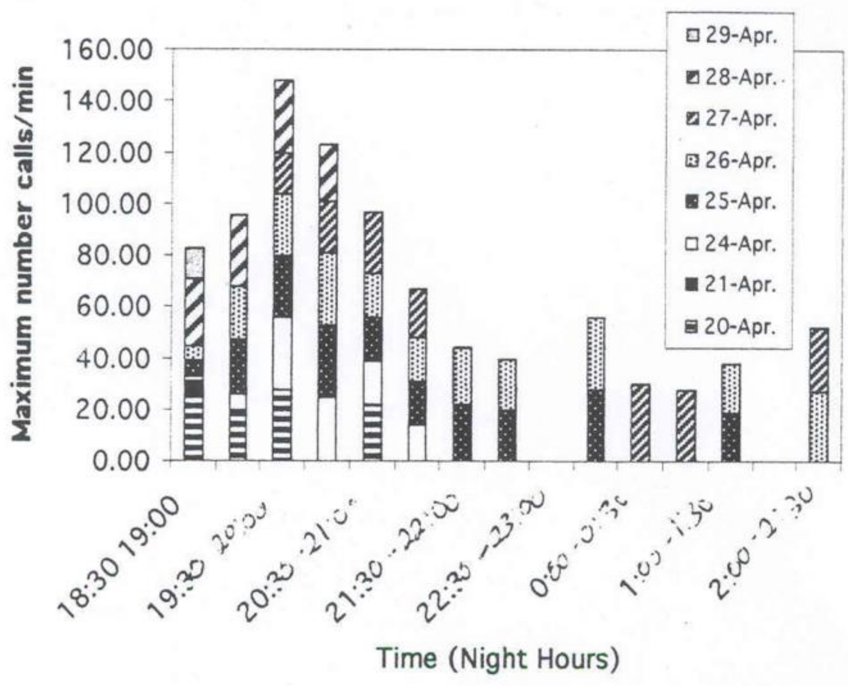

Figure 4b: The maximum number of calls per minute ranged from 2 calls on April 24 from 17:30 – 18:00 (Figure 4a) to 28 calls on April 24 and 25 from 19:30 – 20:00, April 26 from 20:00 – 20:30, April 28 from 23:30 – 0:00, and 0:00 – 0:30, and April 27 from 0:30 – 1:00. The lack of patterns in some categories represents gaps in the data and is not meant to indicate that birds did not call during those times.

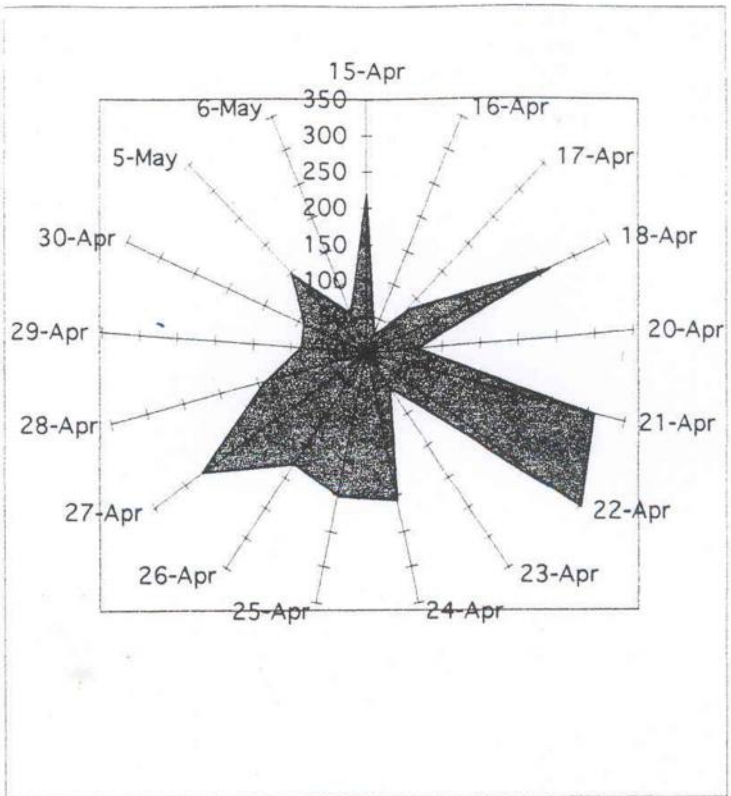

Figure 5: The total number of calls at dusk ranged from 27 to 306 calls. One possible explanation for why the maximum number of dusk calls was so great on April 22 and 21 and then dropped so abruptly on the 23 was because two different pastures were sampled and pasture 1 bird called at a significantly different frequency/min than Pasture 2 birds (Figure 6). Pasture 1 represents April 15, 16, 18, 21, 22, 24, 25, 29 and May 5 and 6. Pasture 2 represents April 20, 23, 26, 27, 28 and 30.

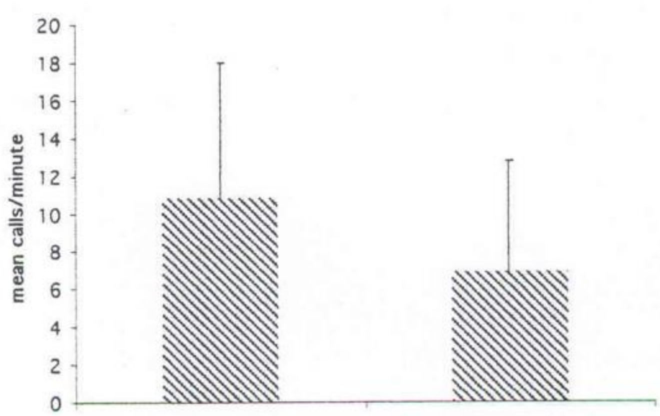

Figure 6: The mean number of calls per minute for the bird in pasture 1 was 10.8 +/- 7.2, (N = 162) and the mean number of calls per minute for birds in pasture 2 was 6.9 +/- 6.0, (N = 143). The bars represent one standard deviation of the mean. They were significantly different (t-test, F = 27.45, $p < 0.0001$).

APPENDIX

Lunar and solar information for Costa Rica (10’ N, 84’ 0’’) from April 13, 2002 to May 7, 2002. (Starry Night 2000)

Date	6:00p.m. (%MFI)	Sun Rise (A.M.)	Sunset (A.M.)	Moon Rise	Moon set	Phase
13-Apr	1.24	5:28	5:45	6:07 A.M.	5:53P.M.	Waxing Crescent
14-Apr	4.23	5:27	5:45	6:46 A.M.	6:38P.M.	Waxing Crescent
15-Apr	9.08	5:27	5:45	7:27 A.M.	7:26 P.M.	Waxing Crescent
16-Apr	15.71	5:26	5:45	8:13 A.M.	8:16 P.M.	Waxing Crescent
17-Apr	23.93	5:26	5:45	9:03 A.M.	9:08 P.M.	Waxing Crescent
18-Apr	35.52	5:25	5:45	9:56 A.M.	10:03 P.M.	Waxing Crescent
19-Apr	44.13	5:25	5:45	10:53A.M.	10:59 P.M.	1st Quarter
20-Apr	55.32	5:24	5:45	11:51A.M.	11:55 P.M.	Waxing Gibbous
21-Apr	66.54	5:24	5:45	12:51P.M.	12:56 A.M.	Waxing Gibbous
22-Apr	77.14	5:23	5:45	1:49P.M.	1: 42 A.M.	Waxing Gibbous
23-Apr	86.38	5: 23	5:45	2:48P.M.	2:33 A.M.	Waxing Gibbous
24-Apr	93.59	5: 22	5:45	3:45P.M.	3:21 A.M.	Waxing Gibbous
25-Apr	98.2	5:22	5:45	4:41P.M.	4:09 A.M.	Waxing Gibbous
26-Apr	99.89	5:22	5:45	5:40P.M.	5:46 A.M.	Full
27-Apr	98.66	5:21	5:45	6:39P.M.	6:38 A.M.	Waning Gibbous
28-Apr	94.78	5:21	5:46	7:39P.M.	7:31 A.M.	Waning Gibbous
29-Apr	88.69	5:20	5:46	8:37P.M.	8:26 A.M.	Waning Gibbous
30-Apr	80.96	5:20	5:46	9:36P.M.	9:23 A.M.	Waning Gibbous
1-May	72.14	5:20	5:46	10:32P.M.	10:17 A.M.	Waning Gibbous
2-May	62.68	5:20	5:46	11:24P.M.	11:12 A.M.	Waning Gibbous
3-May	No info	5:18	5:47	No info	No info	Waning Gibbous
4-May	43.44	5:18	5:47	12:13A.M.	12:02 P.M.	Last Quarter
5-May	24.26	5:18	5:47	12:57A.M.	12: 50P.M.	Waning Crescent
6-May	25.76	5:18	5:47	1:37A.M.	1:37 P.M.	Waning Crescent
7-May	18.02	5:18	5:47	2: 15A.M.	2:21 A.M.	Waning Crescent