Can Sun and Moon Charts Predict Wildlife Activity?

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Abstract: Systems claiming to predict fish and wildlife activity based on solar and lunar gravitational forces are popular among sportsmen. If valid, these could have implications for wildlife management. Two such systems, the Solunar Tables® and Fish and Game Forecaster™, were evaluated using data from free-ranging and captive birds and mammals. Neither system accurately or consistently predicted activity, although some data sets revealed suggestive relationships.

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Free-ranging vertebrates engage in a variety of activities. The proportion of time devoted to each varies seasonally and with factors such as age, social status, and reproductive condition. Within this framework, many terrestrial species exhibit daily rhythms that are correlated within the 24-hour light-dark cycle. Even in the absence of obvious external cues, most species maintain "free-running" activity rhythms that deviate only slighly from 24 hours (Bunning 1973). There are 2 principal schools of thought regarding the underlying basis for this "biological clock." One is timing by an autonomous, endogenous mechanism, possibly biochemical (Cloudsley-Thompson 1961; Ashcoff 1965, 1967; Palmer 1976). The other is external control, possibly by subtle geophysical forces (Brown 1960, 1965*a,b;* Brown et al. 1970; Terracini and Brown 1962).

Outdoorsmen can sometimes broadly predict animal activity based on season, time of day, and prevailing or impending weather. There are, however, occasions when fish and wildlife seem unusually active at "odd" times; conversely, fish and wildlife are sometimes noticeably inactive during apparently favorable periods. Several commercial, popular publications claim to predict such periods based on the gravitational forces of the moon and sun. First was the Solunar Tables® developed in the mid 1930s (Knight 1942). This system identifies 2 "major" and 2 "minor" periods each day which purportedly indicate the most probable times of animal activity. Major Solunar Periods last about 2 hours, and minor periods about 1 hour. The times follow a lunar day and thus occur about 50 minutes later each solar day.

A second system is the Fish and Game Forecaster(TM) (formerly Actiongraph) by DataSport, Inc. (Schara 1975). This system, too, is based primarily on the moon and sun's gravitational effects. However, it also considers daily and seasonal photoperiods and "biological research studies performed by colleges, universities, and government agencies regarding the movement habits of fish and game" (DataSport, Inc. 1984). Output is a continuous curve for each diel period. The area under the curve at any point in time corresponds to the expected level of animal activity. The Forecaster thus provides a continuous, quantitative prediction of diel activity as opposed to the Solunar Tables' ordinal classification of major, minor, and non-periods. To facilitate interpretation, the ordinate of the Forecaster graph is divided into "fair," "good," and "excellent" zones. Both systems normally predict 2 major and 2 lesser activity peaks per day with general temporal alignment; however, major Solunar Periods usually coincide with the beginning of a peak Forecaster phase and persist for a shorter duration. Developers of both systems contend that response of higher vertebrates to the indicated gravitational forces may lag somewhat behind ($\approx$30 minutes) that of lower forms. Both systems also acknowledge that weather may moderate or override predicted effects.

Although these and similar systems claim to predict activity of birds and mammals as well as fish, interest has centered primarily on sport fishing (Carter 1978, Rogers 1984). If valid, sun and moon charts also have potential applications for research and management in terms of impacting harvests and enhancing efficiency and/or avoiding biases in data collections. We tested the hypothesis that daily activity patterns of selected wildlife could be predicted by Solunar Tables and/or the Fish and Game Forecaster against the alternative that they could not be predicted. We utilized 5 data sets representing free-ranging white-tailed deer (*Odocoileus virginianus*) and songbirds, semi-captive cottontail rabbits (*Sylvilagus floridanus*), and caged Mongolian gerbils (*Meriones ungiculatus*).

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Methods

Diurnal Activity of Deer

Systematic observations of free-ranging white-tailed deer were made from an elevated blind on Crab Orchard National Wildlife Refuge (NWR), Williamson County, Illinois. A 30-ha area of high-density deer habitat was scanned with binoculars at 15-minute intervals from 0900 to 1500 hours to record the number of active (non-bedded) deer. Observations were conducted for 5 to 6 consecutive days during each of 9 weeks that coincided with the occurrence of a major Solunar Period during study hours. A total of 1,200 separate counts was obtained during 48 days from November 1982 through February 1983. Crepuscular activity was avoided by analyzing only observations made between 0930 and 1430 hours. Deer sightings per 15-minute interval were expressed as: (1) absolute number seen, (2) percentage of daily total, and (3) deer seen or not seen (irrespective of number). Height of the Forecaster curve (measured to nearest 0.05 mm with a dial caliper) and presence or absence of a major or minor Solunar Period were determined retrospectively for each observational period. The Mann-Whitney U test was used to detect differences in absolute and relative numbers of deer seen during favorable and unfavorable Solunar and Forecaster periods. Fisher's exact probability test was used to compare frequency of sightings, while Spearman's rank correlation was used to compare numbers of deer seen with absolute height of the Forecaster curve. Unless noted otherwise, similar procedures were used for all data. To coincide with the claims made for these products, all tests assumed a directional alternative hypothesis in which the only possibilities considered were that the systems did or did not predict activity. Alpha was set at 0.10. Because of possible lag effects in the predicted response of higher vertebrates, all tests were repeated with data sets which incorporated a 30 minute lag in Solunar Periods and Forecaster curve heights. Results are presented for whichever treatment (lagged or unlagged) proved most favorable to the predictors.

Evening Activity of Deer

As part of a long-term study of white-tailed deer on Crab Orchard NWR, weekly counts along a standardized 32-km survey route were recorded annually from 1966 through 1980 and during fall and winter thereafter. Counts were made 1 to 2 hours before sunset by 2 persons riding in a vehicle moving 32 kph. Efforts were suspended during strong winds or heavy rains. Utilized for the present analysis were 125 counts from mid-September to mid-November 1975 through 1985 and 105 counts during January and February 1976 through 1986. To adjust for annual variation in deer density, weekly counts were expressed as Z-scores standardized to the mean and variance of their respective years and season.

Diurnal Activity of Songbirds

A total of 925 separate counts of feeding songbirds was made concurrently with the diurnal deer observations. A "house-type" feeder filled with cracked corn, wheat, and sunflower seeds was hung in a tree 20 m from the deer blind. Number and species of birds at the feeder were recorded immediately prior to each scheduled deer count.

Diel Activity of Cottontail Rabbits

Activity of 8 cottontail rabbits (2 adult, 6 juvenile) maintained under seminatural conditions in a 1.5-ha enclosure was recorded from 18 September through 17 October 1984. Rabbits were neck-collared with an activity sensing transmitter and monitored for 4 minutes every hour by an automatic system consisting of a scanning receiver, a digital data processor, and a dual channel chart recorder. Individuals were classified as active if 3 or more period changes occurred during the scanning interval; signal amplitude was used for verification. An index of total activity was obtained for each hour by dividing number of rabbits active by total number scanned.

Diel Activity of Gerbils

Six male Mongolian gerbils were housed individually in Wahmann activity cages under a long-day (18L:6D) photoperiod. Continuous 24-hour locomotor activity of each gerbil was recorded from September 1980 through March 1982 using an Esterline Angus recorder (Natalini 1982). Four months, representing high, low, and average levels of activity, were selected for analysis.

Results

Diurnal Activity of Deer

Deer were observed during 32% of the 1,008 counts; 1,450 sightings were recorded. There was no difference in numbers of deer seen nor in the frequency of sightings between Solunar and nonsolunar periods (Table 1). Deer were seen more often and in greater numbers during "good/excellent" than during "fair" Forecaster periods; however, this tendency was evident only for the first half of the study. Data from the last 4 weeks of observation did not indicate any relationship between Forecaster predictions and either absolute or relative numbers of deer seen (Table 1).

Evening Activity of Deer

A total of 22,951 deer sightings was recorded during 230 standardized roadside surveys. Evening counts that coincided with Solunar Periods were relatively higher than those conducted during nonperiods in winter but not in autumn. Conversely, autumn counts were higher during favorable than during unfavorable Forecaster periods, but winter counts were not (Table 2).

Diurnal Activity of Songbirds

Sightings of 612 individuals, representing 10 species, were recorded during 925 counts. There was no difference in mean number or frequency of birds seen during Solunar and nonsolunar periods (Table 3). Overall, birds were seen more often and in greater numbers during "good/excellent" Forecaster times as compared to "fair" periods. However, there was essentially no predictive ability during early weeks. Furthermore, relative numbers of birds seen (in relation to daily total) did not vary between Forecaster periods, and the slight correlation between absolute number of visitations and Forecaster curve height (Table 3) was not considered biologically important.

Table 1. Diurnal observations of white-tailed deer, Crab Orchard NWR, 1982–1983.

	Period[a]		Deer seen		Percent of daily total		Frequency of sightings		Correlation[b]	
Season	Type	N	Mean	P	Mean	P	Percent	P	r_S	P
Autumn[c]	Nonsolunar	295	1.45	>0.10	5.04	>0.10	34.6	>0.10		
	Solunar	167	1.12		4.26		34.1			
	Fair forecast	298	1.06	<0.01	3.96	<0.01	26.2	<0.01	+0.25	<0.01
	Good/exc forecast	164	1.81		6.22		49.4			
Winter[d]	Nonsolunar	349	1.46	>0.10	5.25	>0.10	31.3	>0.10		
	Solunar	197	1.65		3.88		29.3			
	Fair forecast	256	1.69	>0.10	5.34	>0.10	31.3	>0.10	−0.03	>0.10
	Good/exc forecast	164	1.72		3.78		26.8			
Total	Nonsolunar	644	1.45	>0.10	5.15	>0.10	32.8	>0.10		
	Solunar	364	1.41		4.07		31.5			
	Fair forecast	554	1.35	<0.01	4.55	<0.01	28.5	<0.01	+0.12	<0.01
	Good/exc forecast	328	1.77		5.13		38.1			

[a]30 minute lag.
[b]With absolute height of Forecaster curve.
[c]31 October–18 December.
[d]28 December–1 March (11–16 January omitted from Forecaster analysis because only 2 of 126 periods were "favorable").

Table 2. Roadside counts of white-tailed deer, Crab Orchard NWR, 1975–1986.

	Period		Standardized count[a]		Number of counts relative to mean			Correlation[b]	
Season	Type	N	Mean	P	Above	Below	P	r_S	P
Autumn[c]	Nonsolunar	68	−0.07	>0.10	33	35	>0.10		
	Solunar	57	+0.04		27	30			
	Fair forecast	81	−0.10	0.09	35	46	0.09	+0.11	>0.10
	Good/exc forecast	34	+0.17		20	14			
Winter[d]	Nonsolunar	53	−0.10	0.08	20	33	0.03		
	Solunar	46	+0.16		27	19			
	Fair forecast	59	+0.03	>0.10	31	28	>0.10	−0.01	>0.10
	Good/exc forecast	40	+0.01		16	24			
Total	Nonsolunar	121	−0.08	0.08	53	68	>0.10		
	Solunar	103	+0.09		54	49			
	Fair forecast	140	−0.04	>0.10	66	74	>0.10	+0.04	>0.10
	Good/exc forecast	74	+0.08		36	38			

[a]Z-score; means compared using Student's t-test.
[b]With absolute height of Forecaster curve.
[c]September, October, November (Forecaster analysis excludes 1976).
[d]January, February (Solunar analysis excludes 1981; Forecaster analysis excludes 1982).

Table 3. Observations of songbirds, Crab Orchard NWR, 1982–1983.

	Period[a]		Birds seen		Percent of daily total		Frequency of sightings		Correlation[b]	
Season	Type	*N*	Mean	*P*	Mean	*P*	Percent	*P*	r_S	*P*
Autumn[c]	Nonsolunar	271	0.24	>0.10	4.00	>0.10	17.7	>0.10		
	Solunar	129	0.20		3.92		14.7			
	Fair forecast	272	0.20	0.09	4.14	>0.10	15.1	>0.10	+0.02	>0.10
	Good/exc forecast	128	0.29		3.61		20.3			
Winter[d]	Nonsolunar	353	1.01	>0.10	4.17	>0.10	52.6	>0.10		
	Solunar	172	0.99		3.77		54.7			
	Fair forecast	226	0.92	0.06	3.76	0.08	45.6	0.03	+0.04	>0.10
	Good/exc forecast	149	1.13		4.48		55.7			
Total	Nonsolunar	624	0.67	>0.10	4.09	>0.10	37.4	>0.10		
	Solunar	301	0.65		3.83		37.5			
	Fair forecast	498	0.53	<0.01	3.96	>0.10	28.9	<0.01	+0.06	0.06
	Good/exc forecast	277	0.74		4.09		39.4			

[a] 30 minute lag.
[b] With absolute height of Forecaster curve.
[c] 29 November–1 January.
[d] 11 January–1 March (11–16 January omitted from Forecaster analysis).

Table 4. Activity of cottontail rabbits, September–October 1984, Carbondale, Illinois.

	Period[a]		Percent of rabbits active	
Time	Type	*N*	Mean	*P*
Diurnal[b]	Nonsolunar	120	32.08	>0.10
	Solunar	81	29.74	
	Fair forecast	129	31.99	>0.10
	Good/exc forecast	73	29.63	
Crepuscular[c]	Nonsolunar	128	49.00	>0.10
	Solunar	81	48.45	
	Fair forecast	129	48.69	>0.10
	Good/exc forecast	80	48.94	
Nocturnal[d]	Nonsolunar	133	52.81	>0.10
	Solunar	88	53.12	
	Fair forecast	139	52.15	>0.10
	Good/exc forecast	82	54.26	
Diel	Nonsolunar	381	45.00	>0.10
	Solunar	250	44.03	
	Fair forecast	396	44.51	>0.10
	Good/exc forecast	235	44.80	

[a]30 minute lag for Solunar Tables.
[b]0900–1659 Central Standard Time (CST).
[c]0500–0859 and 1700–2059 CST.
[d]2100–0459 CST.

Diel Activity of Cottontail Rabbits

Activity indices averaged 31%, 49%, and 53% for diurnal, crepuscular, and nocturnal periods, respectively, and were unrelated to either the Solunar Tables or the Forecaster (Table 4).

Diel Activity of Gerbils

Total hourly gerbil activity and mean number of gerbils active were slightly higher during favorable Forecaster periods for months of average activity (August, September), but not for months of high or low activity (November, January) (Table 5). Similar results were obtained when data were analyzed by individual month and separately for light and dark times of day. Solunar Tables did not predict gerbil activity during any period (Table 5).

Discussion

We were unable (with 1 exception) to demonstrate any association between recorded indices of activity and occurrence of Solunar Periods. Results of tests involving the Fish and Game Forecaster were somewhat more ambiguous. Absolute height of the Forecaster curve was not a useful predictor of corresponding levels of wildlife activity; however, when the Forecaster chart was divided into good/excellent and fair zones, there was a tendency in some cases for activity to be higher during the favorable times, although inconsistencies existed both within and among species. For example, autumn deer counts (diurnal and evening) differed according

Table 5. Activity of caged gerbils,[a] 1980–1982, Quincy, Illinois.

	Period[b]		Total activity (%)				Number active			
Months	Type	*N*	Mean	*P*	r_S[c]	*P*	Mean	*P*	r_S[c]	*P*
August, September	Nonsolunar	903	20.77	>0.10			2.96	>0.10		
	Solunar	561	20.69				2.95			
	Fair forecast	642	19.47	<0.01	+0.12	<0.01	2.81	<0.01	+0.12	<0.01
	Good/exc forecast	822	21.88				3.07			
November, January	Nonsolunar	892	20.95	>0.10			3.07	>0.10		
	Solunar	572	18.72				2.91			
	Fair forecast	823	21.78	>0.10	−0.15	>0.10	3.12	>0.10	−0.10	>0.10
	Good/exc forecast	641	17.94				2.86			
Total	Nonsolunar	1,795	20.86	>0.10			3.01	>0.10		
	Solunar	1,133	19.75				2.94			
	Fair forecast	1,465	20.78	>0.10	−0.02	>0.10	2.99	>0.10	+0.01	>0.10
	Good/exc forecast	1,463	20.12				2.98			

[a]Gerbil data courtesy J. J. Natalini.
[b]30 minute lag.
[c]Correlation with absolute height of Forecaster curve.

to Forecaster periods, but winter counts did not; the reverse was true for songbirds. Gerbil activity was also positively related to the Forecaster during some months but not others. Cottontail activity was independent of the Forecaster during the 1 month of monitoring.

Although the various experimental designs and methods of recording and interpreting activity might explain some of the variation among species, they should not have contributed to conflicting results for the same species over time. The relative frequency of favorable and unfavorable Forecaster times during a particular period was unrelated to the system's ability to predict activity. The fact that activity coincided, albeit slightly, with the Forecaster during some months but not others suggests the possibility of a seasonal factor, either biological or geophysical or both, that is not adequately represented by the predictor system. Deer observations recorded prior to and during the rut differed by Forecaster period, whereas those recorded after rut were independent of the system; the significance of this, if any, is unclear. Deer behavior varies between fall and winter, especially among sex-age groups; however, non-yarding southern Illinois herds do not exhibit drastic weather-related changes in overall levels of activity. Furthermore, knowledge of daily weather did not improve Forecaster predictive ability nor explain inconsistencies (Roseberry and Woolf 1985).

Gerbil data used in our study came from a larger data set that showed evidence of a circannual rhythm (Natalini 1982). It may or may not be relevant that Forecaster effects were positive only during months of "average" activity; months reflecting near maxima or minima produced negative results. Stutz (1974) reported a seasonally variable lunar-day cycle in caged gerbils with maximum activity coinciding with upper and lower transits. This pattern would tend to produce negative effects for the predictors as their favorable times correspond primarily to upper and lower lunar transits. Taylor (1985) speculated that fish and wildlife activity may respond to the "moon up" but not the "moon down" phase. Our diurnal deer observations, however, alternately represented each condition with no discernable difference in the systems' predictive capabilities.

Our results indicate that neither the Solunar Table nor the Fish and Game Forecaster is an accurate or consistant predictor of wildlife activity, although certain suggestive evidence precludes unequivocal dismissal of the systems or their underlying premise. While further study may be indicated, these products do not presently appear to warrant consideration in the planning and/or interpretation of research or management activities.

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