RELATIONSHIPS BETWEEN SOME ACTIVITY VARIABLES AND CENSUS IN THE BLACK-HEADED GULL (*LARUS RIDIBUNDUS*) IN REGARD TO CERTAIN METEOROLOGICAL PARAMETERS

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The census, orientation, preening, rest and wing-flapping of a Black-headed gulls club were sistematically observed during 82.5 hours. Multiple regression analysis was used and possible relations with meteorological parameters were explored. A strong relationship is found between club census and solar elevation. In a year with fine weather and high temperatures, the number of subjects decreases since the gulls return elsewhere for the night, which agrees with the observations of Delius (1970, as reported by GALUSHA & AMLANER, 1978). A weaker inverse relation was found between club size and wind speed. Orientation is directly related to wind direction (again in agreement with the findings of Bales, 1919 and Austin, 1929, reported in GOCHFELD, 1978) and solar elevation, and less markedly, to the number of subjects. When the wind blows from the sun position, a direct relation between the orientation of the subjects and the direction of the wind is observed. No environmental influences on the ethological variables of rest, preening and wing-flapping are found.

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INTRODUCTION

The descriptive study, as well as the causality of the Black-headed Gull (*Larus ridibundus*) behaviour patterns has been carried out extensively and in detail by TINBERGEN (1959). Nevertheless, the possible relationship between these behaviour patterns and the most conspicuous meteorological parameters has hardly been dealt with.

Regarding the latter, GALUSHA & AMLANER (1978) pointed out that some of the animal's activity models show daily endogenous rhythms while others are related to environmental changes such as temperature and humidity.

The present work focuses on this last point, using SCHREIBER's definition of a club (1967) as a basis for this research. This type of association allowed us to study the following variables:

a) Preening and rest (defined by GALUSHA & AMLANER, 1978).
b) Wing-flapping. This activity was recorded every time the gull flapped its wings without moving from the place where it was perched.
c) Orientation. Taking the sun as reference, the number of individuals that perched themselves facing the sun or otherwise was recorded.
d) Daily census of individual subjects present in the study area.

Multivariate statistical methods have been used for the statistical handling of data; this represents a different approach with respect to studies dealing with the same subject, such as those carried out by GIROUX (1977), COOKE & ROSS (1972), KRANTZ & GAUTHREAUX (1975), etc.

MATHERIAL AND METHODS

1. Description of the study area

The study area consisted of a large perch site located in the "African fauna" section of the Barcelona Zoo, which formerly housed a group of monkeys and was vacant during the study period (fig. 1).

It should be pointed out that, although this project was carried out at the above mentioned Zoo, the presence of the group of gulls being studied was completely spontaneous, and that they enjoyed total freedom. Their presence must be attributed to their easy access to food which was provided for other animals in captivity.

This area was considered a suitable place for sampling, and its sorroundings made a good habitat for the black-headed gull. (On December 29, 1976. 1675 specimens were counted, according to unpublished censuses taken by Lascurain).

2. Methodology

a) Collection of data

From 1978 to 1981, periodic observations were made from October to April. This is the period during which the black-headed gull is present in Barcelona (as well as along most of the Catalan coast). These observations were made from 14.30 to 16.00 hours (G.M.T.), totalling 82.5 hours.

The methodology used in noting both the ethological variables and the census, consisted of a sweeping look at the perch; during this "sweep", notes were taken on the number of gulls that were preening, resting or flapping their wings. The orientation of the gulls that were sunbathing was also noted.

Although the time spent on each sweep was of five minutes, these intervals have been grouped into longer 15-minute periods as a more representative sample for the calculations. For the same reason, relative frequencies rather than absolute frequencies have been used.

The following meteorological parameters have been taken into account in the present study:

- Wind speed (m/s).
- Direction of the wind, taken as the point on the compass (in degrees) from which the wind blows.
- Relative humidity (percentage).
- Atmospheric pressure (millibars).
- Temperature (degrees Celsius).
- Global solar radiation (W/m^2).
- Solar elevation (degrees).

The mean value of the meteorological parameters for every 15-minute interval was obtained. It must be pointed out that solar radiation is expressed as a fraction of the solar constant, thus compensating for the effect of the excentricity of the earth's orbit. On the other hand, it may be noted that, as the hours of observation were fixed, inclusion of the solar elevation gives an idea of the photoperiod.

b) Analysis of data

In the present work, multiple regression analysis (M.R.A., SSP Fortran IV and M.R.A. SPSS) was used to determine the quantitative differences in the relationships between the ethological and the meteorological variables. In keeping with required conditions previous to the application of this analysis (DRAPER & SMITH, 1966), a series of tests were carried out before applying the M.R.A.

First, the Kolmogorov-Smirnov test for verification of the normality of the variables was performed, and it was concluded that the majority of the variables did not show a normal distribution ($\alpha = 0.05$). Therefore, it was necessary to apply normalizing transformations. The most appropiate transformation was selected by applying a test of assymmetry and kurtosis to determine the skewness of the distribution curve (RICHARDSON, 1974). Next, a change in scale was affected through a number of transformations to normalize the above-mentioned variables (SOKAL & ROHLF, 1979). The variances of the variables were also homogenized by multiplying or dividing the transformation by a constant (the square root of a power of ten).

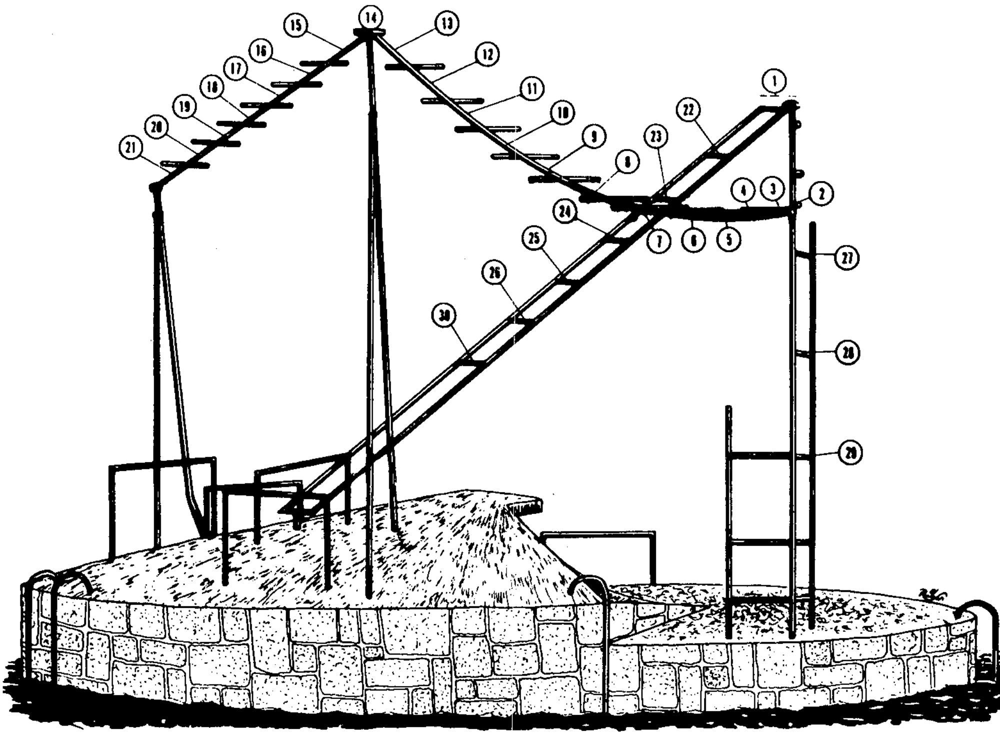

Fig. 1. Site where the observations were taken. The places where the gulls perched are marked with figures (a total of 30).

Upon complexion of this process, most of the variables used in the M.R.A. showed a normal distribution and their variances were homogeneous. After having conducted the M.R.A., the residuals were examined to confirm the appropiateness of the model (DRAPER & SMITH, 1966). In effect, it is not necessary for each variable to have a normal distribution and fulfill the homoscedasticity of variances, but rather, it is the residuals which must comply with these conditions (Richardson, pers. comm.).

Since in our multiple regression analysis certain meteorological parameters (such as temperature and atmospheric pressure) do not show great fluctuations during short periods of time (e.g., 15 minutes) (variables of the first type) while others do or may, such as the wind speed and direction (variables of the second type), 15-minutes time-interval were used as the unit of the M.R.A. data series in order to take the above-mentioned variability into account.

Stepwise regression analysis (S.R.A.) ($p < 0.05$) were also used to identify the minimun number of variables necessary to account for a high proportion of the dependent variable. In this way, the number of variables included in the multiple regression equation was reduced, as was, therefore, the possibility of difficulties arising as a result of multicollinearity.

Five M.R.A. and five S.R.A. were conducted for each of the three years of observation. In the first analysis, the number of gulls present was taken as the dependent variable and all the above-mentioned meteorological parameters were taken as independent variables. In the second, third and fourth analyses (where the preening, resting and

Table 1. Multiple and stepwise regression analysis for the census of individual subjects as related to meteorological parameters in 1978-79. The statistical significances is indicated by asterisks; * = P < 0.05, ** = P < 0.01, *** = P < 0.001.

Weather factors	M.R.A. Regression coefficient	R Correlation coefficient	S.R.A. Regression coefficient
Wind speed	–0.23	–0.12	
Wind direction	–0.02	0.05	
Relative humidity	–0.012	–0.30	
Atmospheric pressure	–0.054	–0.22	
Temperature	–0.80***	–0.56	–0.073***
Solar radiation	–0.22	–0.33	–0.34***
Solar elevation	–0.16	–0.16	
Multiple correlation coefficient	0.73		0.70
Intercept	45.61		10.56
F for analysis of variance of R	11.98**		37.6**
d.f. of F (n_2)	71		76

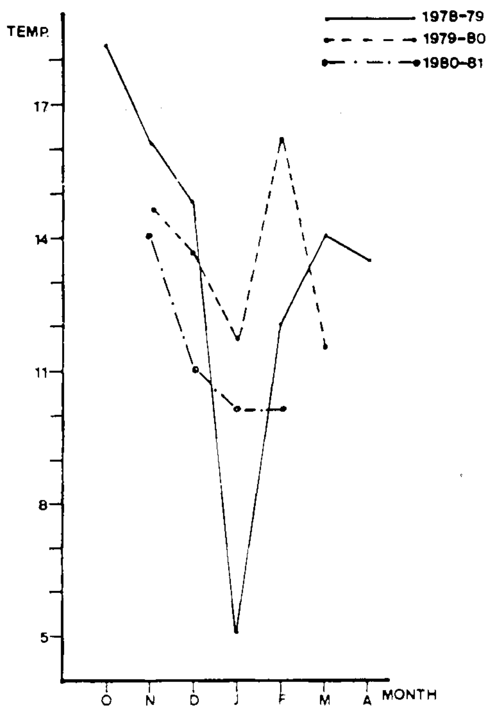

Fig. 2. Montly means of temperature (at the times of observations i.e. 14.30 to 16.00 G.M.T.) for the six to seven-month periods of study covering the years 1978-79, 1979-80 and 1980-81.

wing-flapping patterns were taken, respectively, as the dependent variables) the solar elevation was discarded, including instead the number of gulls present at the perch site (within the independent variables), since we believed this change to be more appropiate and realistic.

Finally, in the analysis in which orientation was the dependent variable, wind speed and direction, solar elevation and frequency of subjects present at the perch site, were chosen as independant variables since they were considered to be of greatest interest.

RESULTS

The perch site seemed to have no effect on the gull's activities. The same can be said of influence of the daily observation period on their behaviour patterns, and of the influence of the prenuptial and post-reproductive periods on the development of those patterns.

Regarding the census of individuals present at the perch, during the first year of study, a high multiple correlation coefficient (R) is observed (table 1), the meteorological parameters selected by the S.R.A. being tem-

Table 2. Multiple and stepwise regression analysis for the frequency of individual subjects facing the sun as related to meteorological parameters in 1978-79.

Weather factors	M.R.A. Regression coefficient	R Correlation coefficient	S.R.A. Regression coefficient
Wind speed	0.17	0.53	
Wind direction	0.83***	0.67	0.93***
Solar elevation	0.18	0.19	0.29*
Frequency of individual subjects present	0.16	0.08	
Multiple correlation coefficient	0.74		0.71
Intercept	−3.04		−5.27
F for analysis of variance of R	20.54**		36.68**
d.f. of F (n_2)	67		68

Table 3. Multiple and stepwise regression analysis for the census of individual subjects as related to meteorological parameters in 1979-80.

Weather factors	M.R.A. Regression coefficient	R Correlation coefficient	S.R.A. Regression coefficient
Wind speed	−0.25	−0.24	
Wind direction	−0.20	−0.13	
Relative humidity	−0.19	−0.08	
Atmospheric pressure	0.009	0.11	
Temperature	0.001	0.06	
Solar radiation	0.33	0.11	
Solar elevation	−0.33	−0.27	−0.28**
Multiple correlation coefficient	0.45		0.27
Intercept	−16.67		3.76
F for analysis of variance of R	2.98**		7.18**
d.f. of F (n_2)	82		88

Table 4. Multiple and stepwise regression analysis for the frequency of individual subjects facing the sun as related to meteorological parameters in 1979-80.

Weather factors	M.R.A. Regression coefficient	R Correlation coefficient	S.R.A. Regression coefficient
Wind speed	0.34**	0.46	0.45***
Wind direction	0.28	0.41	
Solar elevation	0.18	0.17	
Frequency of individual subjects present	––	––	−0.37**
Multiple correlation coefficient	0.55		0.54
Intercept	−1.18		1.96
F for analysis of variance of R	10.27**		15.66**
d.f. of F (n_2)	72		73

Table 5. Multiple and stepwise regression analysis for the census of individual subjects as related to meteorological parameters in 1980-81.

Weather factors	M.R.A. Regression coefficient	R Correlation coefficient	S.R.A. Regression coefficient
Wind speed	−0.09	−0.33	
Wind direction	−0.07	−0.02	
Relative humidity	−0.03	0.22	
Atmospheric pressure	0.38	0.38	0.377***
Temperature	0.42	0.29	
Solar radiation	−0.41	−0.05	
Solar elevation	−0.56***	−0.54	−0.66*
Multiple correlation coefficient	0.73		0.62
Intercept	−50.09		−36.72
F for analysis of variance of R	7.18**		16.42**
d.f. of F (n_2)	44		49

Tabla 6. Multiple and stepwise regression analysis for the frequency of individual subjects facing the sun as related to meteorological parameters in 1980-81.

Weather factors	M.R.A. Regression coefficient	R Correlation coefficient	S.R.A. Regression coefficient
Wind speed	0.20	0.20	
Wind direction	0.48***	0.54	0.47***
Solar elevation	0.44**	0.29	0.25
Frequency of individual subjects present	0.35	−0.01	
Multiple correlation coefficient	0.67		0.58
Intercept	−3.05		0.95
F for analysis of variance of R	7.82**		10.83**
d.f. of F (n_2)	38		40

perature and solar radiation. For the second year (table 3), the M.R.A. shows a lower R, the only variable selected being solar elevation. On the third year (table 5) solar elevation was again chosen together with atmospheric pressure, R being high.

In figure 2 the mean monthly temperatures are plotted for the three years of the study. Note that the temperature was higher on the first year.

Regarding solar radiation, which was selected by the S.R.A. only in the first year, a rather strong multicollinearity was seen to exist between this variable and solar elevation ($r = 0.76$) as figures 3 and 4 show. In order to ascertain the fictitious nature of the relationship found with solar radiation, another regression analysis was performed in which this variable was excluded. The variable selected by the S.R.A. was then the solar elevation.

Concerning orientation, it may be seen from tables 2 and 6 that the results were very similar for the first and third year, both in R and in the variables selected by the S.R.A. Considerable deviations, however, arise in the second year of study (table 4). Such deviations will be discussed later on.

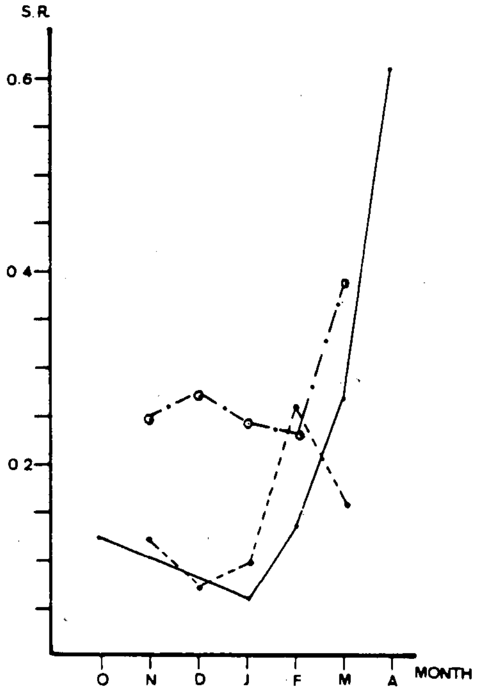

Fig. 3. Montly means of global solar radiation. The time and the period covered are the same as in fig. 2.

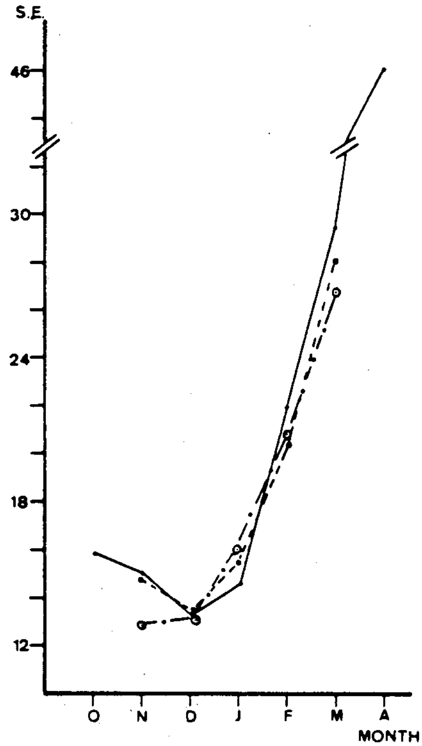

Fig. 4. Montly means of solar elevation. The time and the period covered are the same as in fig. 2.

Finally, results concerning the remaining activities studied (rest, preening and wing-flapping) were much alike for the three years. The R's obtained did not significantly differ from zero. It should be remarked, nevertheless, that the S.R.A. for the second year (in which the frequencies of individuals preening or resting were taken as dependent variables) shows an R significantly different from zero, the frequency of individuals present on the perch being the variable selected by the S.R.A.

DISCUSSION

As mentioned in the foregoing paragraph, when performing the multiple regression analyses, it was found convenient to distinguish between two kinds of meteorological parameters which are termed here: variables of the first type and variables of the second type.

This nature of the analysis forced us to interprete the results from two points of view:

1. Seasonal relationship (throughout the whole study period) when the variable selected belonged to the first type (without great fluctuations).

2. Daily relationship (throughout each day of the study period) when the selected variable belonged to the second type (with great fluctuations).

Thus, a careful interpretation of the results was necessary, always keeping this double point of view in mind.

As regards the census of individuals present at the perch site, it may be seen that solar elevation was selected in the three

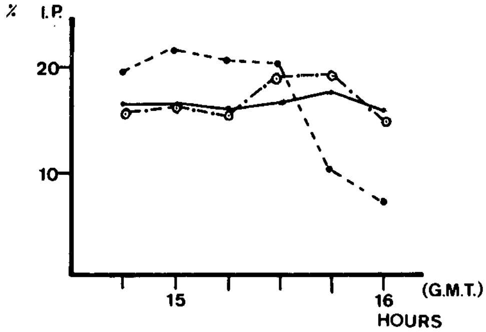

Fig. 5. Percentage frequency of individual subjects on the perch during the time of observation for the same years as in fig. 2.

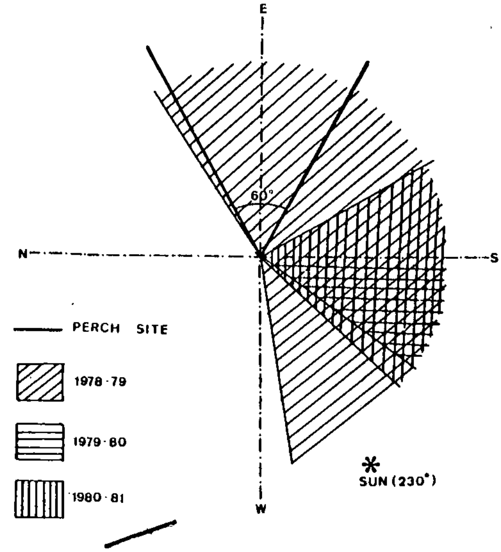

Fig. 6. Range of values of wind direction during the period of observation. Perch orientation and mean azimuth of the sun at the time of observations are also shown.

years of study. The false selection of solar radiation in the first year has already been discussed.

Since solar elevation and the census of individual subjects exhibit a negative regression coefficient (B) in all three years, we conclude that as solar elevation decreases (daily) the census of individual subjects increases, up to the point at which they leave the perch site (we have not registered this particular point due to the chosen sampling period) (fig. 5).

In the first year of study, the temperature was selected by the S.R.A. together with solar elevation. The mean temperature for this year was higher than for the other two. On the other hand, it is important to point out the fact that temperature shows a negative B which is keeping with Deliu's observations (1970, cited in GALUSHA & AMLANER, 1978) that a direct relationship exists between the highest daily temperature and the mean percentage of sleeping *Larus fuscus.* This leads us to believe that an increase in temperature resutls in the Black-headed gull leaving the perch site to go to its night area.

In the third year, the S.R.A. selected atmospheric pressure in addition to solar elevation. This is a difficult factor to interpret. Nevertheless, COOKE & ROSS (1972), after observing a garbage dump used by the gulls as a feeding area, describe the same conditions that we have observed and state that "a decrease in temperature combined with an increase in the atmospheric pressure tended to produce a decrease in the number of gulls present".

Another aspect to take into consideration is that by lowering the selection criterion in the S.R.A. ($p < 0.1$), the wind speed appears as a significant variable for all three years, with a negative B. This could be expected since when the wind blows at high speed, the individuals tend to leave the area in search of a better shelter.

We can, therefore, conclude that the census of individual subjects is closely related to solar elevation and, that depending on the conditions, it also bears a relation to temperature and atmospheric pressure.

Concerning orientation, the results for the first and third year are quite similar, both in connection with the R and with the variables selected by the S.R.A. (wind direction and solar elevation). However, considerable differences appear in the second year, although they can be accounted for.

It is known that birds have a tendency to

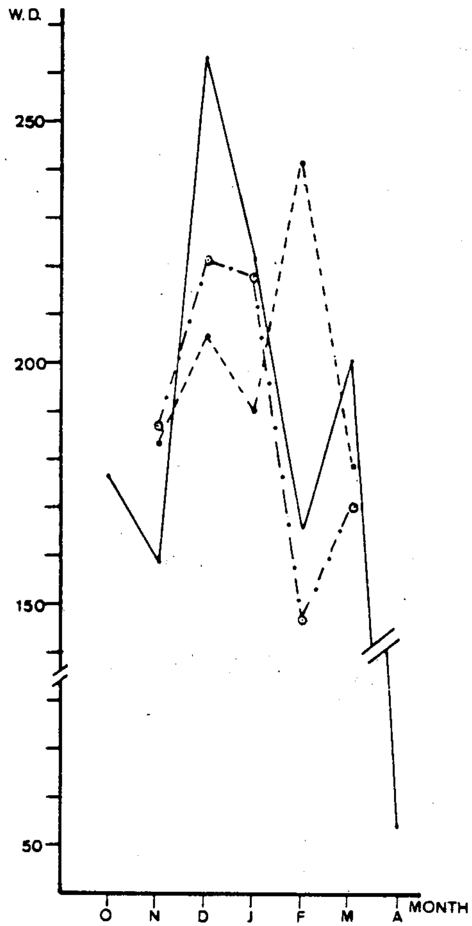

Fig. 7. Montly means of wind direction. The time and the period covered are the same as in fig. 2.

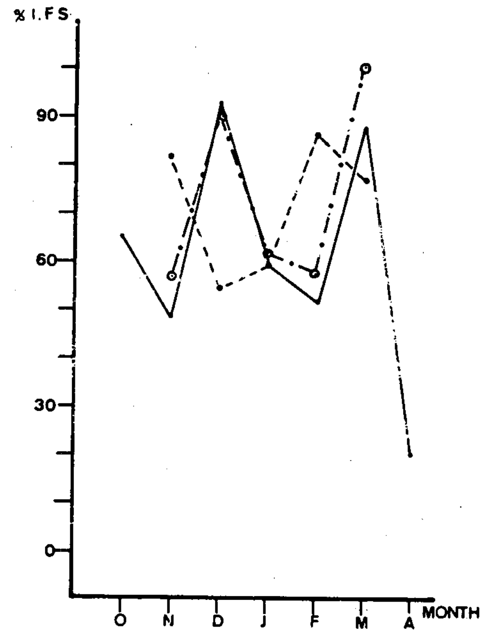

Fig. 8. Percent of individual subjects facing the sun during the six to seven-months period of observation along the three years.

face the wind. Bales (1919, cited in GOCHFELD, 1978) and Austin (1929, cited in GOCHFELD, 1978) have reported that birds tent to orientate themselves facing the wind in order to avoid the ruffling of their feathers, which would result in an increase in the consumption of energy necessary to mantain body temperature. Another aspect, not yet confirmed, is that turbulence might be reduced with the heads directly oriented towards the wind and therefore, the probability of feeling an uneven air pressure in both ears would be reduced (GOCHFELD, 1978).

In our particular case we found, during the three years of study, a positive B between wind direction and the frequency of individual subjects facing the sun. If we take into account the mean solar position in relation to the perch site (fig. 6) and the range of values of wind direction (fig. 7), these results agree with the above discussion.

On the other hand, solar elevation shows a positive B for the three years of observation, since whenever the sun is at a low elevation it hinders the vision of those subjects facing the sun.

This correlation could be interpret either seasonally or daily (see the beginning of discussion). Since no seasonal relationship has been observed between the tendency of the solar elevation to increase and the seasonal orientation of the individual subjects (fig. 8), we have to think that this association occurs in each observation day because the solar elevation continues to decrease throughout the hour and a half of daily observation.

For the second year of study the range of values of wind direction is small and very close to the solar position. For this reason, if the subjects tend to avoid facing the sun when it is at a low elevation, they will only face it in spite of its low elevation when the wind speed is strong enough to disturb them, or they will go away. We conclude, therefore, that there is a direct relationship between wind speed and the frequency of individual subjects in facing the sun, since the sun's direction is fairly constant.

In summary, wind direction, solar elevation and the frequency of gulls present at the perch site have an influence (in that order) in the orientation of the individual subjects. If the wind blows from the direction of the sun's position, wind speed is then the important variable.

Regarding the remaining activities studied (rest, preening and wing-flapping), the results show that these bear no relationship with meteorological parameters. We must point out that the M.R.A. in which wing-flapping was the dependent variable should be taken with certain reservations as the examination of residuals showed a strong bias. This is due to the fact that in this analysis there was a great deal of data with nought value and the prediction equation provided a distorted estimate.

On the other hand, we should look for other causes, perhaps social ones (as the M.R.A. conducted in the second year suggested) such as club size, distance between individual subjects, and so on.

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RESUMEN

Se da cuenta de los resultados obtenidos en una serie de 82.5 horas de observación sistemática del censo, orientación, espulgamiento, reposo y aleteo de un "club" de Gaviotas Reidoras (*Larus ridibundus*).

Se analizan estadísticamente los datos por medio del análisis de regresión múltiple y se investiga su posible relación con ciertas variables meteorológicas.

Se concluye que existe una marcada relación entre el censo de individuos que componen el club y la altura solar. Asimismo, existe una relación con la temperatura cuando el año es bonancible; si ésta es elevada, se produce una disminución del número de individuos en la zona de estudio, al retirarse a las zonas donde pasan la noche. También, si bien su efecto no es muy importante, se ha encontrado una relación inversa entre el tamaño del club y la velocidad del viento.

Con respecto a la orientación, se observa una relación directa entre ésta y la dirección del viento y la altura solar; también existe una relación menor con la frecuencia del número de individuos presentes en la zona de estudio. Si la dirección del viento es próxima a la posición del sol, la velocidad del viento es la variable decisiva en la orientación de los individuos, guardando una relación directa.

Las variables etológicas de descanso, espulgamiento y aleteo no están sometidas a influencias de tipo ambiental. Se apuntan, no obstante, influencias de tipo social.

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