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The Long-term Effect of Precipitation on the Breeding Success of Golden Eagles *Aquila chrysaetos homeyeri* in the Judean and Negev Deserts, Israel

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INTRODUCTION

Raptor nesting success is dependent on different factors including food availability, weather, predation, human disturbance, diseases and others (Newton 1979). Food quantity and availability play a major role in raptor breeding success, which is in certain cases correlated to the fluctuations in the prey populations (Newton 1979).

Fluctuations in prey populations may be generated by weather changes, which might also have an impact on the breeding success of raptors, as extreme cold or heat may cause starvation of adult birds, direct mortality of young, or have an indirect effect due to their impact on prey availability (Gargett 1977; Kochert 1972; Newton 1979; Newton & Marquiss 1986).

In Israel, a total population of 41 breeding pairs of Golden Eagles was investigated between 1985-1990. This population is located mostly in the semi-arid and arid parts of Israel, in the Judean and Negev Deserts (Bahat 1989).

In the present study, the effect of weather on their breeding success in the Judean and Negev Deserts was investigated, focusing on the following questions:

1. Which weather factors, if any, significantly affect the breeding success?
2. Is there a difference in the breeding success of Golden Eagles in different climatic zones of the Israeli deserts?
3. Is there a difference in the breeding success of Golden Eagles in direct response to weather changes from year to year?

MATERIALS AND METHODS

The breeding success of Golden Eagles in the Judean and Negev Deserts was determined by the number of chicks reaching fledging state. A nesting success survey was carried out between 1972-1989, covering 19 different nesting sites, and including a total of 119 nesting attempts. In all of the examined events, no human disturbance or any other artificial interference that might affect the nesting success were recorded.

The different sites were divided into three different climatic subgroups:

1. Judean Desert: This area covers the slopes of the Judean moutains, east of Jerusalem, and further south along the Dead Sea. In this area, the multi-year rain average is 179.1 mm (± 134.4), and the average number of annual rainy days (of 0.1 mm rain or more) is 39.3 (± 11.3). In the Judean Desert, a total of 39 nesting events were recorded.

2. Irrigated Negev Desert: This area is located south of the Judean desert in the north of the Negev desert. All eagle nests in this area are located near settlements with irrigated fields, where the birds are able to forage. In this area, the multi-year rain average is 85.2 mm (± 40.3), and the average number of annual rainy days (of 0.1 mm rain or more) is 25.5 (± 9.7). The artificial irrigation of the fields increases water availability and enables vegetation to grow throughout the year (Bahat 1989). In the irrigated Negev Desert, a total of 32 nesting events were recorded.

3. Arid Negev Desert: This area is located south of the Irrigated Negev Desert and down to Eilat. All eagle nests in this area are located far from settlements, and the birds forage in the natural arid land. The multi-year rain average is 74.8 mm (± 45.6), and the average number of annual rainy days (of 0.1 mm rain or more) is 21.6 (± 10.1). In the arid Negev desert, a total of 48 nesting events were recorded.

The climatic factors that were examined in correlation to the nesting success are:

1. Precipitation (in mm.) during the nesting year.

2. Precipitation (in mm.) during the year prior to the nesting year.

3. Number of rainy days (in which 0.1 mm rain or more are recorded) during the nesting year.

4. Number of rainy days (in which 0.1 mm rain or more are recorded) during the year prior to the nesting year.

5. Precipitation during the nesting year, expressed as a percentage of the multi-year rain average.

6. Precipitation during the year prior to the nesting year, expressed as a percentage of the multi-year rain average.

The climatological data used for each nesting site were collected at the nearest meteorological station by the Isaeli Meteorological Services.

RESULTS

A mean of 1.26 chicks per pair (range 0-3) reached the fledging state for the whole sample (Table 1).

The precipitation (mm.) in the year prior to breeding is positively correlated to the number of chicks fledged (Spearman correlation, $r = 0.42$, $P < 0.0001$). The number of rainy days in the previous year is also positively correlated ($r = 0.35$, $P < 0.0001$). The mutual impact of these two factors on the number of chicks fledged is demonstrated in Figure 1.

Table 1. Average numbers of fledglings per Golden Eagle pair and precipitation values for the whole sample (119 nesting attempts).

Value	*Average ± SD*	*Min. value*	*Max. value*
No. of chicks fledging	1.26 ± 1.02	0	3
Previous year's rain (mm.)	111.6 ± 92.5	7.0	833.4
Previous year's no. of rainy days	28.21 ± 2.8	3	61
Previous year's rain (mm.) as % of multi-year average	100.5 ± 43.1	21.4	233.0

Precipitation values were grouped into four quarters, and the number of chicks fledging in each quarter was examined. The results of a one-way Anova test show that the nesting success of eagle pairs nesting in areas where the former year's precipitation is the upper quarter, is higher ($P < 0.0001$) than the other groups (Figure 2).

Figure 1. A smoothing interpolation representation of the number of fledglings (A axis) by previous year. Rain (mm). (X axis) and the number of previous year rainy days (Y axis).

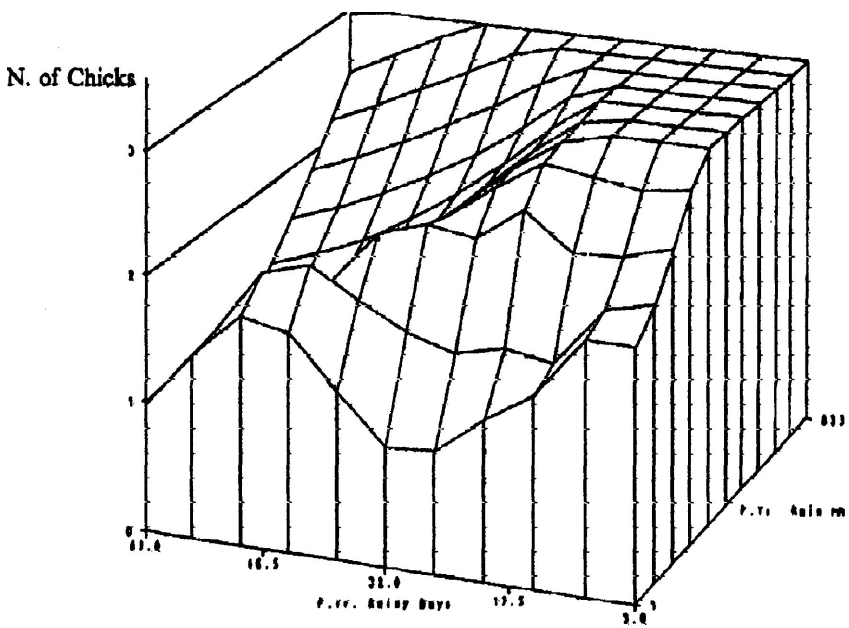
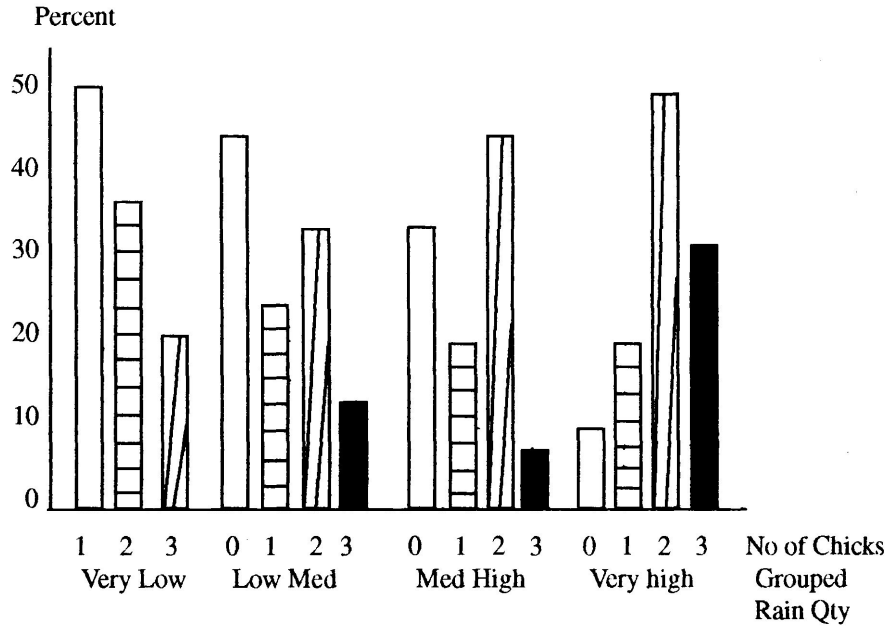


Figure 2. Impact of previous year rain (as % of annual average precipitation, divided into four groups from very low to very high) on the number of fledglings. The number of fledglings which corresponds to the upper rain group is the highest.



A comparison between the three geographical subgroups was carried out, in order to investigate the effect of precipitation on the breeding success in each area (Table 2): The number of chicks fledging per pair is highest in the Judean desert, lower in the irrigated Negev, and lowest in the arid Negev. The difference between the subgroups is significant (Scheffe test, $F = 5.36$, $P < 0.01$).

No significant correlation was found between the climatic factors and the nesting success of Golden Eagles in the Judean desert and the irrigated Negev. In contrast, in the arid Negev, nesting success is positively correlated to precipitation during the previous year expressed as a percentage of the multi-year rain average (Spearman correlation, $r = 0.55$, $P < 0.0001$).

DISCUSSION

The major climatic factor that affects the number of Golden Eagle fledglings in the Judean and Negev deserts is rainfall during the year prior to the nesting year.

Table 2. Average numbers of fledglings per Golden Eagle pair and precipitation values for each of the three geographical sub-regions (Judean, irrigated Negev and dry Negev Deserts, a total of 119 nesting attempts).

Value	*Area*	*Average ± SD*	*Min.*	*Max*
No. of fledging chicks	Judean Des.	1.67 ± 0.87	0	3
	Irr. Negev	1.19 ± 0.97	0	3
	Arid Negev	0.98 ± 1.08	0	3
Average annual rainfall (mm)	Judean Des.	179.1 ± 134.4	54.4	833.4
	Irr.Negev	85.2 ± 40.3	32.5	165.9
	Arid Negev	74.8 ± 45.6	7.0	201.8
Average No. of rainy days (> 0.1 mm)	Judean Des.	39.3 ± 11.3	13	61
	Irr. Negev	25.5 ± 9.7	8	41
	Arid Negev	21.6 ± 10.1	3	47
Rain (mm) as % of multi-year average	Judean Des.	103.6 ± 37.1	43.1	177.9
	Irr. Negev	99.0 ± 34.5	49.2	170.8
	Arid Negev	91.2 ± 45.0	21.4	233.0

In general, the more arid the nesting area, the greater the positive effect of rainfallon the nesting success. In a more arid area, the average number of fledglings is smaller. The effect of rain is significant, and there is a shift of one year between rain peaks and high nesting successes.

Newton (1979) emphasised the importance of food supply, prior to the nesting season, for the improvement of the physical and physiological condition of the female. This enables her to produce larger clutches and to conserve fat, an essential energy resource for maintaining stable body temperature during incubation, and later while brooding. When food is scarce, the female may eat some of the chicks' food herself, or leave the nest to hunt, exposing the eggs or chicks for long periods and thus reducing breeding success.

In the Judean and Negev deserts, rain quantity has a direct affect on the growth of annual plants, and their density, in turn, has a direct effect on the breeding performance of herbivores, including species which form the main prey items of Golden Eagles. In a good rainy season, there is a marked increase in the breeding of herbivores, mainly hares *Lepus capensis* and Chukars *Alectoris chukar* (Mendelssohn & Yom-Tov 1987). We propose here that the increase in these herbivores, including high numbers of young, results in better hunting success for the Golden Eagles. Consequently, the

female's physiological condition improves and she produces a larger clutch. At a later stage, the still high numbers of herbivores enable the eagles to obtain enough food for their young and increase their chances of fledging.

A relation between the breeding success of Golden Eagles and the numbers of hares probably plays a very important role in the arid Negev desert. The number of hares in this area, and their breeding performance, is largely dependent on rainfall. Their dispersion varies from one per 1 km in the dry Negev Desert, to 10 in the irrigated fields in the same area (Mendelssohn & Yom-Tov 1987). The more arid the nesting area, the greater the proportion of hares in eagles' diet (Bahat 1989). This explains the positive correlation between rainfall and the eagles' breeding success in the arid Negev.

An exception in the present study is represented by two pairs of eagles which nested in the Eilat Mountains (southern Negev), and were observed between 1972-1988 (Bahat 1989): the breeding success of these eagles was not correlated to the previous year's rainfall, despite this being the most arid part of the entire study area. This is explained by the fact that the eagles' main prey in this area (89.0%) is the Spiny-tailed Lizard *Uromastix aegyptius*, whose numbers are only slightly affected by the recent amount of rain, since it is mostly dependent on plant species not greatly affected by rainfall, and its numbers thus remain quite stable.

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