A MODEL OF THE BLACK EAGLE (*AQUILA VERREAUXII*) POPULATION IN THE MATOBO NATIONAL PARK AND SURROUNDING AREA.

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A research report submitted in partial fulfilment of the degree of Master of Science in Quantitative Conservation Biology to the Faculty of Science, University of the Witwatersrand, Johannesburg.

DECLARATION

I declare that this research report is my own, unaided work. It is being submitted for the degree of Master of Science in the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination in any other University.

Michael J.C. Bailey

28th February 1993.

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Introduction.

Black Eagles occur in the Matobo Hills in such numbers that this population is known as being one of the highest concentrations of large raptors anywhere in the world. The area provides suitable habitat for these birds with numerous cliffs for nest sites and hyrax for food.

Being territorial, and because they often use the same nest site from year to year, they lend themselves well to long term population studies. Black Eagle nests sites in the area have been known since 1912 and since 1959 continuous records of site occupation have been kept. A considerable amount of information on the Black Eagle population, their numbers and breeding success has been collected over the last 28 years, and during this time there was a decline evident in the number of Black Eagles breeding successfully from 1974 - 1979 and again in 1980 - 1984. These observations have prompted many questions as to what factors might be limiting the population, and what the future holds for these bird with human activity becoming more and more evident in the areas around the National Park.

My initial aim was to use the information collected by the Black Eagle Survey team, and in particular by Valerie Gargett, and attempt to design and construct a model which might aid understanding of fluctuations in the Black Eagle population. However, on closer inspection of the data, it was found to be lacking essential information required for developing a useful working model; Black Eagle longevity, survival rates for birds of different ages and a measure of immigration and emigration were not available.

As an alternative, an attempt was made to identify some of the environmental factors which may be limiting the Black Eagle population by comparing numbers and breeding success of resident eagle pairs in three different land-use areas in the Matobo Hills, National

Park, farmland and communal land.

This manuscript is written in the form of a scientific paper and has been prepared with future publication in mind. The format follows that set out by the South African Journal of Wildlife Research and is entitled:

"An analysis of the changes in the Black Eagle (*Aquila verreauxii*) population of the Matobo Hills, Zimbabwe".

An Analysis of Changes in the Black Eagle (*Aquila verreauxii*) population of the Matobo Hills, Zimbabwe.

Abstract.

Data on the Black Eagle population in the Matobo Hills, Zimbabwe has been collected for 28 years (1964 - 1991). These data were used to compare fluctuations in the percentage of occupied territories, breeding attempts and success in three different land-use areas within the Matobo Hills. A correlation between these parameters and rainfall was also investigated. The percentage of occupied territories in the three areas was significantly correlated but breeding attempts and success were not. There was little correlation with rainfall. Overall environmental influences have a limiting effect on the percentage of occupied territories but their effect on breeding attempts and success is buffered or accentuated by local conditions in each of the land-use areas.

Introduction.

The Matobo Hills provide ideal habitat for Black Eagles (*Aquila verreauxii*) with many cliff sites for nests and hyrax for food. The area now comprises a National Park, commercial farmland (hereafter referred to as farmland) and communal lands. Nest sites in the Hills have been recorded since 1912, and continuous records of territory occupation have been kept from 1959 (Gargett 1990).

There was a decline in the percentage of Black Eagles breeding successfully during 1974 - 1979, and to a greater extent during 1980 - 1984 (Gargett 1990). This observation has prompted questions on what factors might be limiting the Black Eagle population in the Matobo Hills.

In his paper on population limitation in raptors, Newton (1991) states that raptor populations are normally regulated, rather than fluctuating at random. In a habitat where nest sites are freely available, breeding density is limited by food supply, while in other areas, breeding density may be restricted by a shortage of nest sites to a lower level than would normally occur with the available food supply. Hence, in any one region of suitable habitat, breeding density is naturally limited by food supply or nest sites, whichever is most restricting. In the absence of human intervention, regulation in many species is the result of competition for breeding space, with surplus adults only forming new pairs and attempting to breed when one of an existing resident pair dies or a territory becomes vacant.

The density of Black Eagles in the Matobo Hills can be as high as one pair/10.3 km^2 (Gargett 1990), with contiguous territories covering almost all the National Park area. This suggests that nest sites may be the limiting factor on eagle breeding density. However, it has been also suggested that hyrax (the Black Eagle's main prey) were not as abundant in the 1980's as during the 1970's (Gargett 1990) and that food might be the limiting factor. The hyrax population is dependant on vegetation for food which, in turn, is limited by rainfall (Skinner & Smithers 1990). As well as natural factors, the hyrax population is also affected by human intervention through hunting and poaching, destruction of the vegetation through deliberate fires and overgrazing by domestic animals (Gargett 1990). Low hyrax numbers would have an adverse effect on the Black Eagle population and its breeding (Figure 1). Human activity in the Matobo Hills and its effect on the eagles is of great concern to ornithologists and conservationists alike. However, the extent to which these accentuating factors affect the eagle numbers and breeding in the three different land-use areas has never been carefully examined.

The first objective of this study was to compare population fluctuations in the farmland and communal lands with those in the protected area of the National Park. Assuming that environmental factors affect all three equally, any asynchronous fluctuations might indicate that human intervention is having an impact on the Black Eagle population.

The second objective was to analyze changes in the Black Eagle population and breeding success related to rainfall.

The Matobo Hills.

The Matobo Hills are in the Matabeleland province of Zimbabwe between 20°25´ and 20°45´ South and 28°15´ and 28°45´ East, extending 80 kilometres east-west and 32 kilometres north-south. The survey area consisted of 620 km^2, 65% in the Matobo Hills National Park, 25% in communal lands (Kumalo to the south and Gulati to the north-east), and 10% farmland in the north-west corner.

The area is a granite batholith protruding from older surrounding areas and is tilted to the south. The batholith has been eroded along rectangular jointing, resulting in many low hills covered with trees and dotted with large and often precariously balanced granite boulders. There are also many bare rock-faces, especially on "dwalas" (smooth round bald hills) (Tredgold 1956, Vernon 1965).

Plant cover in this diverse topography ranges from thick forest and dense woodland to open grassland and bare rock. The characteristic mixed vegetation of the hills is of open woodland with a shrub layer or medium to tall grasses in between, including stretches of ... associated with former areas of cultivation (Gargett 1990).

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Most rain falls in summer (December to March) with occasional thunder storms in October and November and light showers in April and May. For the 28-year period analyzed in this study, 1964 - 1991, the average annual rainfall (July - June) measured at four local meteorological stations (Matobo Sandveld, Matobo National Park, Matobo Nursery and Matobo Park) was 592 mm (range 324 mm to 1043 mm) (Table 1).

Above average rainfall improves the grass cover, maintains vleis, replenishes the nine dams built between 1942 and 1956, and keeps the six main rivers flowing during the dry season of April to October (Gargett 1990). In years of below average rainfall grass cover becomes sparse and dams and rivers sometimes dry out; however vegetation at the base of outcrops and hills is little affected due to the gutter effect around the bare rock surfaces.

Fires usually occur before the rains and burn fiercely through flat wood- and grassland. The dense growth on and at the base of rocky outcrops is less susceptible to burning and fires seldom reach far up the sides of the hills (Gargett 1990).

The Black Eagle.

Adult Black Eagles are generally found in pairs. The pair bond is strong, with birds presumably remaining together for life; should a bird lose a mate it is soon replaced from the reserve population of unpaired adults.

The Black Eagle is extremely prey specific and in the Matobo Hills they feed almost exclusively (98 % by numbers, Gargett 1990) on two species of hyrax or dassie, the Rock Hyrax (*Procavia capensis*) and the Yellow-spotted Hyrax (*Heterohyrax brucei*).

Adult pairs are resident and territorial. They establish and defend a territory which allows them access to a dassie population large enough to support themselves and any offspring they may raise throughout the year. A pair of eagles and their eaglet account for approximately 400 hyrax in a year (Steyn 1982).

An adult pair will build or re-build a nest in a preferred site during the breeding season, although alternative sites within a territory are occasionally used. Two eggs are usually laid during April - June, although one egg clutches are sometimes observed (15%, Gargett 1990). The first egg hatches after an incubation period of about 45 days and four to five days later the second-laid egg will hatch. By this stage the first chick has already developed its strength and co-ordination and a period of relentless sibling aggression follows until the second chick dies from a combination of its injuries and starvation. This phenomenon is referred to as the "Cain and Abel struggle" (Gargett 1990).

The nestling stage lasts for 90 - 98 days, during August - October, while the post-fledgling stage is estimated at 4 - 5 months, usually September - February and exceptionally to March. Juveniles then leave the parental territory and are chased out of every other territory into which they wander (Gargett 1990). These juveniles, along with other unattached sub-adults, must find unoccupied areas of land in which to survive until they reach adulthood at around five years old. Even then, they can only take up residence in a territory that has been vacated or that has lost one of its pair (Newton 1979).

Methods.

The Black Eagle Survey in the Matobo Hills.

Observations of 35 Black Eagle eyries in the Rhodes Matopos National Park were first complied by Ron Thomson in 1959 and 1960. These were extended by Carl Vernon who, by 1964, had located another 18 pairs (Gargett 1990).

In 1964 it was decided to use Thomson's and Vernon's work as a basis for a survey of the Black Eagle in the Matobo Hills. The aim of the survey was to establish the total population, population density, breeding frequency and success, factors regulating numbers, and a complete life history of the eagles within a selected area of the Matobo Hills (Vernon 1965). Originally this work was made possible by the co-operation of members of the Matabeleland sub-branch of the Rhodesian Ornithological Society (now the Ornithological Association of Zimbabwe).

In 1965, with a greater number of members participating in observations, the size of the survey area was increased to 620 km^2, of which 440 km^2 consisted of National Park. By 1970 an additional 600 km^2 was being monitored. However, during the liberation war (1974 - 1980) and dissident incursions (1984/85) observations were curtailed for security reasons, and after 1974 it was not even possible to monitor the original 620 km^2 as thoroughly as in the first eleven years (Gargett 1990).

Sources of data on the Black Eagles of the Matobo Hills.

All information on territory boundaries, nest sites, resident pairs, breeding attempts and breeding success was obtained from:

1) individual records made by members of the Black Eagle Survey team and stored at the Natural History Museum, Bulawayo, Zimbabwe. All field observation procedures were carefully outlined and discussed to ensure credibility and uniformity. Each report was further scrutinised by the survey leaders before inclusion into the records (Gargett 1990).

2) the annual Black Eagle Breeding Reports (1984 - 1991) written and compiled by George Banfield, Breeding Report Organiser.

3) Valerie Gargett's book on the study of the Black Eagle (1990).

Records used in analyses.

A total of 121 separate eagle territories were identified during the Black Eagle survey. It was assumed that each territory was occupied by a monogamous pair. Eighty-seven eagle territories were selected for analysis in this study, all being territories in the 620 km^2 core area described above. Although breeding records for some of these territories were recorded before 1964, only records from the start of the full survey in 1964 were used in this study.

To observe population trends in areas of varying land use, each territory selected for analysis was noted as residing in National Park, farmland or communal lands. A territory was defined as being occupied when two adult birds were observed flying within its boundaries, territories being secured and intruding eagles chased out by February each year. A territory was not considered occupied if only one adult was seen.

A resident pair was considered to have attempted to breed if they were observed building a new nest, repairing an old one, if a nest was lined with fresh leaves, if they were seen mating or if there were eggs or a chick in the nest. A breeding success was registered when a chick survived to fledgling stage, was seen leaving the nest or was seen later and presumed to have flown from the nest.

Analyses undertaken.

Because of the variable sample sizes in the three areas, (National Park 26 - 44 occupied territories, farmland 2 - 8, communal lands 0 - 10) the following indices of occupied territories, breeding attempts and success were calculated and used for comparison:

1) Occupied territories - expressed as a percentage of territories examined.

2) Breeding attempts - expressed as a percentage of occupied territories

3) Breeding success - expressed as a percentage of a) occupied territories and b) attempts.

4) Rainfall - correlated with 1), 2) & 3).

5) Nesting density - to examine effects of density on breeding success, the location of each active nest was mapped for each year of the study. The distance from every active nest site to its three nearest neighbours was determined. An index of density was calculated as the mean of the three nearest neighbour distances. Some nests, particularly those close to the boundary of the survey area, had only two realistic nearest neighbours. In these situations the mean of two measured distances was used as the third distance and any distance over

7.0 kms. was not regarded as a neighbour, being more than the diameter the largest territory and considered too far away to have any effect on another nest.

Results.

The actual number of territories checked, resident pairs observed, breeding attempts and success in each land-use area are available for the breeding seasons 1964 - 1991 (Table 2 - 4).

Occupied territories.

The percentage of occupied territories in eaci. area remained fairly stable from 1965 to 1976 (Figure 2. National Park and farmland >97 %, communal lands around 80 %). Farmland and communal lands experienced a decline in occupied territories in 1976 and 1975 respectively, then recovered in 1977, but after 1978 all areas had reduced occupancy. A further decline was seen in all areas in 1982, most obviously in the communal lands which contained no occupied territories by 1984. Occupancy in farmland was only 40 % in 1985 but recovered to 80 % by 1991. Lowest occupancy in the National Park was in 1989 (69 %), recovering by 1991 to 77.5 % but still below levels prior to 1984.

A Pearson correlation analysis (SYSTAT, Wilkinson 1990) on all 28 years of data showed a significant correlation in the number of occupied territories in the National Park and farmland (0.549 $p < 0.03$). Correlations with communal lands were performed on 20 years of data (1964 - 1983) and were also significant (National Park & communal lands, 0.658, $p < 0.01$; farmland & communal lands, 0.743, $p < 0.01$).

Breeding attempts.

Breeding attempts were expressed as a percentage of the number of resident pairs (Table 3) and fluctuated throughout the study period (Figure 3).

In the National Park, breeding attempts declined from 1980 (67.5 %) to 1985 (36.7 %), but then seemed to show a slight recovery towards the end of the study, with the average for whole study period being 76.0 %). Farmland pairs showed no distinct trends but the two years in which breeding attempts were lowest in 1978 (42.9 %) and 1982 (40.0 %) were well below the average of 75.3 %. From 1964 - 1976 breeding attempts in the communal lands averaged 62.6 %, but dropped from 71.4 % (5 attempts from 7 resident pairs) in 1976 to 0 % (0 from 2) in 1977. No pairs attempted to breed in 1980 (0 from 3) and by 1984 resident pairs were absent from the area. Pearson correlation analysis between each land-use showed no significant correlations.

Breeding success.

Breeding success as a percentage of attempts in all areas fluctuated within similar ranges from 1964 - 1973 (Figure 4a), but subsequent years produced greater and more varied differences.

Breeding success as a percentage of occupied teritories (Figure 4b) in the National Park declined from a high in 1968 (78.8 %) to the lowest level in 1985 (16.7 %) and then rose to 32.3 % by 1991, rather below the average of 47.2 % (1964 - 1991). Breeding success in the farmland averaged 46.2 %, similar to the National Park, also with lower success during 1980 - 1985 when there were three years without a chick raised. The average success rate in the communal lands was 38.8 % (from 1964 - 1983), >10 % below the National Park and farmland averages, with the first noticeable decline in breeding success in 1974.

Breeding success as a percentage of occupied territories (Figure 4b) followed a similar trend to that of attempts (Figure 4a).

Pearson correlation analysis showed no significant correlations between the breeding success in the three land-use areas.

Correlations with rainfall.

Pearson correlation analysis for occupied territories, breeding attempts and success in the three land-use areas were compared with rainfall for;

1) rainfall closest to the Black Eagle winter breeding season (summer rainfall season July - June, breeding period April - February),

2) rainfall of the previous year and,

3) rainfall from two years previously.

The percentage occupied territories showed no significant correlation with any of the rainfall patterns (Table 5). Percentage breeding attempts and rainfall produced two significant correlations; 1) attempts in farmland with rainfall from 2 years previously (0.415, $p < 0.05$), 2) attempts in communal land and rainfall of the previous year (-0.509, $p < 0.05$), and 3) attempts in communal land and rainfall from 2 years previously (0..426, $p < 0.05$).

Significant correlations were also observed between breeding success in the communal land with rainfall of the previous year (-0.465, $p < 0.05$) and in the National Park with rainfall of that year (-0.530 $p < 0.05$). Although most of the correlations were not significant, there was a trend in the figures showing a negative correlation with rainfall of that year (Table 5).

Change in correlations.

Correlations in breeding attempts and then in success in the three land-use areas were identified at different years through the study. Pearson correlations were performed on the first five years of data, 1964 - 1968 and then on the remaining 23 years 1969 - 1991. This was repeated using the first six years and the next 22, and so on until the first 23 years and the last five. The difference between these correlations was plotted against the year i.e. from 1968 to 1987 (Figures 5 - 7). A noticeable difference in correlation between one half of the data and the other might indicate the year in which a change in the environmental conditions in one of the areas affected the breeding success.

The number of occupied territories in the three areas showed significant correlation through the study. For example, using the years up to 1991 the correlation was 0.549 ($p < 0.03$) but was as high as 0.814 ($p < 0.01$) in the years up to 1985.

Most of the correlations in breeding attempts and also in success in the three areas were not significant and the figures produced were only used to look for trends in correlation changes. The breeding attempts in the communal land and the National Park showed similar correlations until 1977 after which time the correlation decreased. Breeding success showed a slight rise through time. The trend in correlations in both breeding attempts and success between the farmland and communal land show little change. Correlations in breeding attempts between the National Park and the farmland decreased from 1971 - 1978 but increased after this and by 1983 the correlation was significant (0.616, $p < 0.05$).

Effect of rainfall on Black Eagle breeding.

Normal linear regressions were performed (SYSTAT, Wilkinson 1990) between percentage occupied territories, breeding attempts and success and the rainfall of the same year, previous year and 2-years previously. Significant regressions were breeding attempts in the farmland with rainfall of 2-years previously ($P = 0.035$) and in the communal lands with the previous year ($P = 0.022$), and breeding success in the National Park with rainfall of the same year ($P = 0.004$). These results support the significant correlations produced by the Pearson correlations with the exception of breeding success in the communal lands with rainfall of the previous year and 2-years previously which may be spurious results due to small sample size.

Nesting density.

Inter-nest distance indices for occupied territories, breeding attempts and successes for each land-use area were calculated (Table 6). In cases where no nest was built or repaired, a known nest site from previous years was used for measuring inter-nest distance; the assumption being that no nest was built due to high density of neighbours. There was no significant difference in the inter-nests distances between breeding and non-breeding resident pairs or their success in any of the three land-use areas ($p > 0.05$, paired sample t-test).

The average inter-nest distance between all nest sites in each of the three areas was calculated. There was a significant difference in inter-nest distance between each area; National Park vs farmland ($p = 0.048$), National Park vs communal land ($p = 0.011$) and farmland vs communal lands ($p = 0.042$).

Discussion.

There seems little doubt that, as suggested by Newton (1991), the Black Eagle population in the Matobo Hills is regulated in some way and is not fluctuating at random. Evidence for this is the significant and synchronised correlations in the percentage of occupied territories in the National Park, farmland and communal land areas, indicating that regardless of land-use the percentage of occupied territories and resident pairs are all subject to some similar general environmental influences which are responsible for the synchronous fluctuations observed.

Reynolds (*cited by* Lawton 1988) demonstrated fluctuations in breeding density in a grey heron (*Ardea cinerea*) population which showed a 10 year period of small variation in the number of breeding pairs followed by 10 years of much greater fluctuations around the mean while overall the population remains relatively stable. It is possible that a similar natural process is occurring in the Black Eagle population and in time, and with no unnatural changes in the environment, there may be a return to the high densities of resident pairs experienced during the mid 1970's.

No occupied territories were observed in the communal lands after 1984. The number of resident pairs in the area may have been too small to survive decline caused by the general influences and the population experienced a natural extinction. However, a similar number of occupied territories were found in the farmland area and this population survived and was still present in 1991. This suggests that within each area the degree to which the general influences limit each population may be buffered or accentuated to some extent by specific local environmental conditions. The local environmental conditions in farmland possibly lessened the effect of the factors limiting the population while in the communal land these conditions only added to the negative influences.

Evidence that local conditions have a limiting eff.ct comes from the lack of any significant correlation in breeding attempts and successes between the three areas. The influence of an overall limiting factor would appear to be dampened but not altogether excluded; this influence was observed when all three areas experienced a similar period of below average breeding attempts and successes from around 1977 to 1985, but within this overall downward trend breeding efforts varied between areas from year to year.

The extent to which local environmental conditions limit breeding presumably depends on the various land-uses. It has been well documented that overstocking of the communal lands in Zimbabwe, with goats in particular, has resulted in these areas being devoid of grass and the herbaceous vegetation becoming sparse (Whitlow 1988). This loss of vegetation has probably had a deleterious effect on the number of hyrax in the area. Breeding is dependant on food supply and usually only takes place when food is readily available (Newton 1979) and a female bird will only attempt to breed when she has built up sufficient reserves and come into breeding condition (Hustler & Howells 1990). Therefore a shortage of food in the communal lands will suppress Black Eagle breeding attempts. This problem is further amplified by uncontrolled hunting of the already reduced hyrax population by the communal land people.

A breeding attempt is therefore more demanding than just surviving as a resident pair. If the particular land-use of the three areas creates slightly different habitats for hyrax then this may be reflected in the Black Eagle numbers and breeding attempts. Likewise to breed successfully a Black Eagle pair faces added complications along with those in breeding attempts. For example, apart from natural predators such as White-necked ravens (*Corvus albicollis*), Rock pythons (*Python sebae*) and baboons (*Papio ursinus*) (Gargett 1990), man is a major contributor to the loss of eggs and chicks resulting in breeding failure (Figure 1). The impact of man will be greatest in the unprotected areas outside the National Park and will further add to the negative factors which govern the breeding and existence of eagle pairs. With the greater protection of vegetation and hyrax in the National Park, it follows that this area should have greater breeding success. The farmland too will be less susceptible than the communal lands to loss of vegetation and the impact of humans on the hyrax population. This is demonstrated by the higher average breeding attempts and successes in the National Park and farmland compared to the communal lands and further illustrates the effect of local environmental conditions.

It is interesting to note from the graph of the change in correlations between the National Park and communal lands (Figure 5), that until 1977 breeding attempts were fairly well correlated, although not significantly, but from 1978 onwards this trend in correlation decreased. This poses the question that although the major drop in occupancy was not seen until 1982 was this the time that the degradation of the communal lands started to have a greater negative effect on the breeding success of this Black Eagle population? Many of the other correlations remained relatively stable, suggesting that local environmental conditions in the National Park and farmland showed no dramatic changes and indicate little or no alteration to the area or its particular land-use. One exception was the significant correlation between breeding attempts in the National Park and the farmland which decreased after 1983. It might be that changes in farming practices or maintenance of vegetation, through good management irrigation, possibly sustained Black Eagle food supplies during the drought period of the mid-80's, accounting for the difference in breeding attempts between the National Park and farmland.

As mentioned, the population may be ultimately limited by some overall influences which affect environmental conditions. In this study the only influencing factor on which there was sufficient data was rainfall, dominant in limiting many population systems. There is no doubt that rainfall affects the condition of the overall environment by dictating vegetation growth. This in turn limits the hyrax population upon which the Black Eagles are so dependant. However, the lack of significant correlation between rainfall and the number of occupied territories in each area demonstrates the complexity of the relationship between rainfall, and number of hyrax and their effect on the Black Eagle population.

On a local scale, the effect of rainfall may vary quite considerably. In the National Park, for example, good vegetation growth usually follows seasonal rainfall while in the communal lands overgrazing can leave the vegetation in such poor condition that seasonal productivity will be very low. As a result the density of hyrax and the extent of vegetation cover will be greater in the National Park. The significant negative relationship between breeding success in the National Park with the rainfall of that breeding season, along with the general trend of negative correlation with rainfall of that year, indicates that the important feature of the hyrax population is not just their numbers but their availability to the Black Eagles. This supports Gargett (1990) who suggested that if good rains fall and the vegetation cover is high, hyrax do not venture far from the safety of rock crevices to feed and are less vulnerable to Black Eagles. Skinner and Smithers (1990) describe how hyrax, in particular the Rock Hyrax (*Procavia capensis)*, seek out warm spots in which to sun themselves when not feeding. This period of exposure coincides with the time of day when Black Eagles kill the greatest proportion of their prey; 09h00 - 12h00 (Jenkins 1984, Gargett 1990), and illustrates the constraint of dense vegetation cover on Black Eagle hunting times and success.

An ideal situation, for example, might be two or three years of good rains to encourage an increase in hyrax numbers followed by one or two drought years resulting in less vegetation cover. This presumably would lead to large numbers of exposed hyrax and an ample food supply leading to good breeding success. The above average rainfall experienced from 1974 - 1981 seems to coincide with an overall drop in breeding attempts and success. When below average rains occurred, from 1982 - 1988, breeding success increased. However, the only significant correlation in rainfall of two seasons previous was found with breeding attempts in the farmland. The National Park showed the most correlation with this rainfall pattern and success but it was low and non-significant. It is possible that breeding is a more stable process and less susceptible to change than other areas, so local environmental conditions affecting breeding success in the National Park take longer to respond to the general influences.

Simmons (1992) found that in Wahlberg's Eagles almost all the variation in breeding success was explained by population density; the lower the density the greater the number of offspring produced. However, inter-nest distances calculated for the Matobo Hills found that breeding success bore no relationship to the proximity of neighbouring nests. This is probably due to the physical features such as large hills which can mean that while the straight-line distances between nest sites may be short they remain in visual isolation from other nests (Hustler & Howells 1986, Gargett 1990). The larger average inter-nest distance in the communal lands is probably a reflection of the area's poorer primary production, with less vegetation and fewer hyrax Black Eagle pairs will need larger territories. This behaviour and relationship is found in many other raptor species (Hustler and Howells 1990).

Conclusion.

The percentage of occupied territories in the National Park, farmland and communal land each year seems determined by some overall influence affecting each area to a similar extent. The breeding success of resident pairs in the three areas is dependant on this overall influence, which may be buffered or accentuated by the local environmental conditions.

This study high-lights the fact that while rainfall is essential to the survival of Black Eagles in the Matobo Hills, its effect on the population is not always apparent and only works in conjunction with a number of other factors. Rainfall has a more direct effect on the hyrax population via vegetation growth and data on their numbers and population fluctuations might lead to a better understanding of the fluctuations in the Black Eagle population.

Information on individual birds, survival rates in different age classes, longevity, and their movements in and out of the area would enable the development of population models which may prove invaluable in the management of the area. Human intervention may be having a noticeable effect on this population and only continued, or even increased protection of the environment, may be necessary ensure the survival of the Black Eagle population in the Matobo Hills.

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TABLE 1. Annual rainfall (July - June) in the Matobo Hills and percentage deviation from the mean.

Year	mm	% deviation from mean
1963/64	341	57.64
1964/65	406	68.62
1965/66	605	102.26
1966/67	658	111.22
1967/68	401	67.78
1968/69	660	111.55
1969/70	342	57.81
1970/71	521	88.06
1971/72	703	118.82
1972/73	390	65.92
1973/74	1009	170.54
1974/75	849	143.50
1975/76	743	125.58
1976/77	708	119.67
1977/78	1043	176.29
1978/79	446	75.38
1979/80	577	97.53
1980/81	835	141.13
1981/82	410	69.30
1982/83	420	70.99
1983/84	419	70.82
1984/85	638	107.84
1985/86	559	94.48
1986/87	324	54.76
1987/88	819	138.43
1988/89	575	97.19
1989/90	554	93.64
1990/91	611	103.27
Mean =	592	

Table 2. Number of territories checked, occupied territories, breeding attempts and success in the National Park areas of the Matobo Hills, Zimbabwe.

Year	Territories Checked	Occupied Territories	Breeding Attempts	Breeding Success
1964	28	28	24	19
1965	28	27	23	16
1966	30	30	21	9
1967	32	32	29	17
1968	34	33	31	26
1969	35	34	33	20
1970	35	34	32	23
1971	34	33	33	20
1972	36	35	29	17
1973	37	36	34	25
1974	39	38	33	19
1975	41	40	31	16
1976	44	44	40	24
1977	37	36	33	18
1978	42	40	29	18
1979	44	41	38	23
1980	42	40	27	15
1981	44	42	28	13
1982	44	40	26	15
1983	44	41	27	16
1984	29	28	15	9
1985	34	30	11	5
1986	35	31	18	13
1987	36	29	18	12
1988	36	26	15	7
1989	42	29	15	12
1990	43	30	19	13
1991	40	31	16	10

Table 3. Number of territories checked, occupied territories, breeding attempts and success in the farmland area of the Matobo Hills, Zimbabwe.

Year	Territories Checked	Occupied Territories	Breeding Attempts	Breeding Success
1964	7	7	5	4
1965	8	8	5	4
1966	8	8	5	3
1967	8	8	6	4
1968	8	8	7	4
1969	8	8	7	5
1970	8	8	7	4
1971	8	8	6	4
1972	8	8	8	6
1973	8	8	7	4
1974	8	8	6	3
1975	8	8	7	6
1976	9	8	7	2
1977	6	6	4	3
1978	8	7	3	3
1979	9	8	7	6
1980	8	7	4	0
1981	9	8	5	4
1982	7	5	2	0
1983	9	8	6	2
1984	5	4	3	2
1985	5	2	2	0
1986	7	6	6	4
1987	7	5	3	3
1988	7	6	5	4
1989	6	4	3	2
1990	8	7	4	3
1991	5	4	3	3

Table 4. Number of territories checked, occupied territories, breeding attempts and success in the communal lands area of the Matobo Hills, Zimbabwe.

Year	Territories Checked	Occupied Territories	Breeding Attempts	Breeding Success
1964	6	6	4	4
1965	7	7	5	3
1966	9	7	4	2
1967	11	9	6	3
1968	11	9	5	3
1969	12	10	9	6
1970	12	10	10	8
1971	12	10	7	4
1972	11	9	6	4
1973	11	9	7	5
1974	11	9	5	1
1975	11	8	4	2
1976	10	7	5	1
1977	2	2	0	0
1978	7	5	4	3
1979	8	6	5	1
1980	4	3	0	0
1981	7	5	2	1
1982	7	2	1	1
1983	5	1	1	0
1984	1	0	0	0
1985	0	0	0	0
1986	0	0	0	0
1987	0	0	0	0
1988	0	0	0	0
1989	0	0	0	0
1990	0	0	0	0
1991	0	0	0	0

Table 5. Correlations between occupied territories, breeding attempts and success, and rainfall.

	Rain1	Rain2	Rain3
% Occupied territories			
National Park	0.018	0.069	0.114
Farmland	0.07	0.122	0.278
Communal lands	0.063	0.315	0.05
% Breeding attempts			
National Park	-0.12	0.295	0.297
Farmland	-0.007	-0.089	0.415*
Communal lands	-0.253	-0.509*	0.426*
% Breeding success			
National Park	-0.530*	-0.048	0.231
Farmland	-0.054	0.212	0.191
Communal lands	-0.258	-0.465*	-0.068

* significant correlation
Rain1 = rainfall of same year
Rain2 = rainfall of previous year
Rain3 = rainfall of two years previously

TABLE 6. Inter-nest distances between breeding Black Eagle pair and prevously known nests of non-breeding pairs in each of the three land-use areas.

	Resident pair	Breeding attempt	Breeding success
National Park			
Ave. inter-nest distance	2683	2657	2610
Maximum	6494	4827	4885
Minimum	1264	1207	1246
S.D.	780	670	622
Overall average inter-nest distance =		2650	
Farmland			
Ave. inter-nest distance	2961	2889	3085
Maximum	5057	5804	6034
Minimum	1609	1552	1552
S.D.	686	995	932
Overall average inter-nest distance =		2978	
Communal Land			
Ave. inter-nest distance	3748	4101	3678
Maximum	6953	6953	6896
Minimum	2299	2356	2241
S.D.	1185	1255	1338
Overall average inter-nest distance =		3842	

Inter-nest distance = meters

Captions to Figures.

Figure 1. Conceptual Model showing the inter-action of factors affecting Black Eagle numbers and breeding success. Arrows show direction of influence and + or - indicate a positive or negative influence with an increase in the factor. e.g. increased rainfall has positive effect on vegetation cover.

Figure 2. Change in percentage of occupied territories in each area with time.

Figure 3. Change in percentage breeding attempts in each area with time.

Figure 4a). Change in breeding success as a percentage of attempts in each area with time.

Figure 4b). Change in breeding success as a percentage of occupied territories in each area.

Figure 5. Change in correlations in breeding attempts and success between National Park & farmland through the study. Plot of difference in correlation from two halves of study period.

Figure 6. Change in correlations in breeding attempts and success between National Park & communal lands through the study. Plot of difference in correlation from two halves of study period.

Figure 7. Change in correlations in breeding attempts and success between farmland & communal lands through the study. Plot of difference in correlation from two halves of study period.

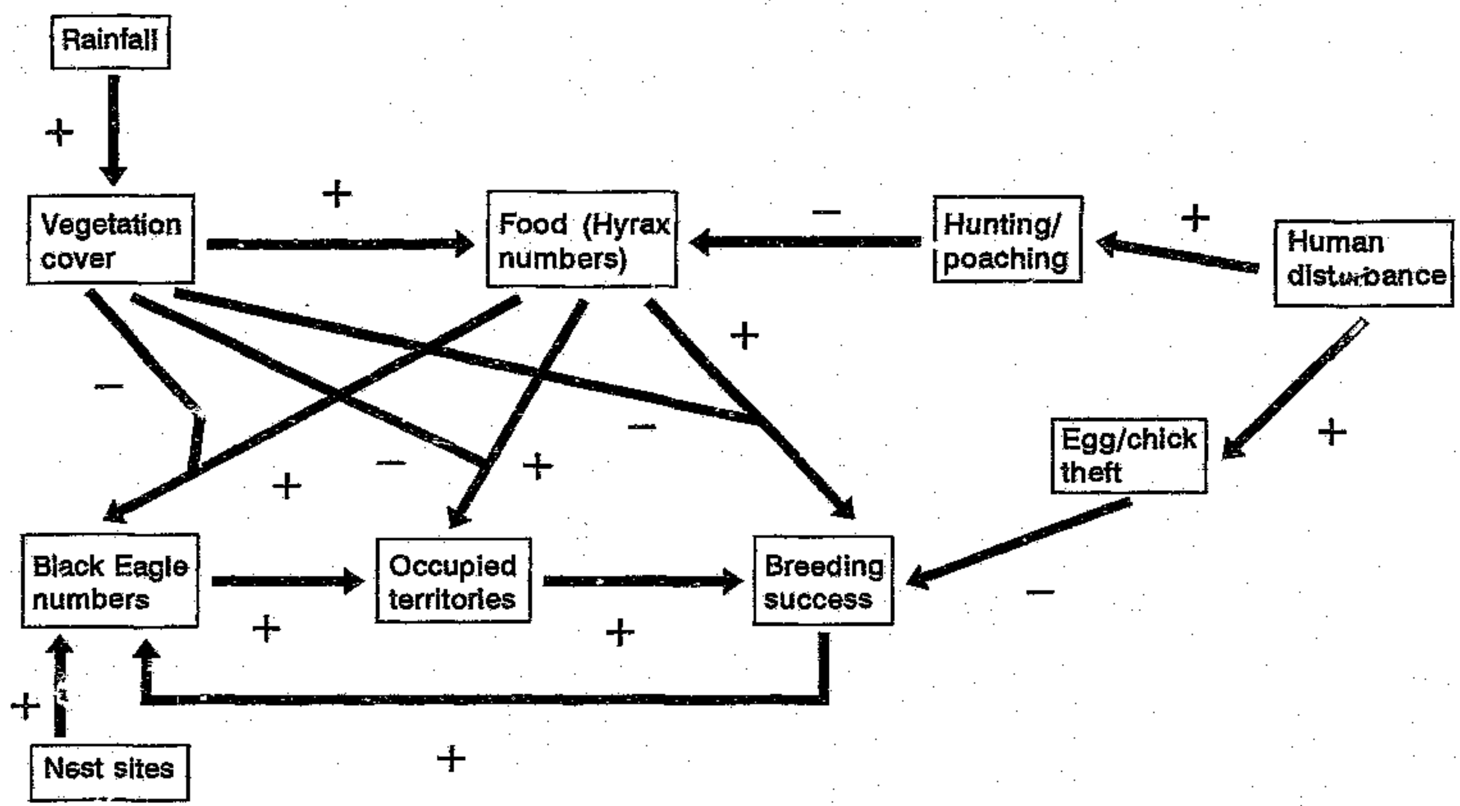

Rainfall
+
Vegetation cover
+
Food (Hyrax numbers)
−
Hunting/ poaching
+
Human disturbance
+
Egg/chick theft
−
Black Eagle numbers
Occupied territories
Breeding success
Nest sites
+
−
+
−
+
−
+
+
+
+
+

Figure 1

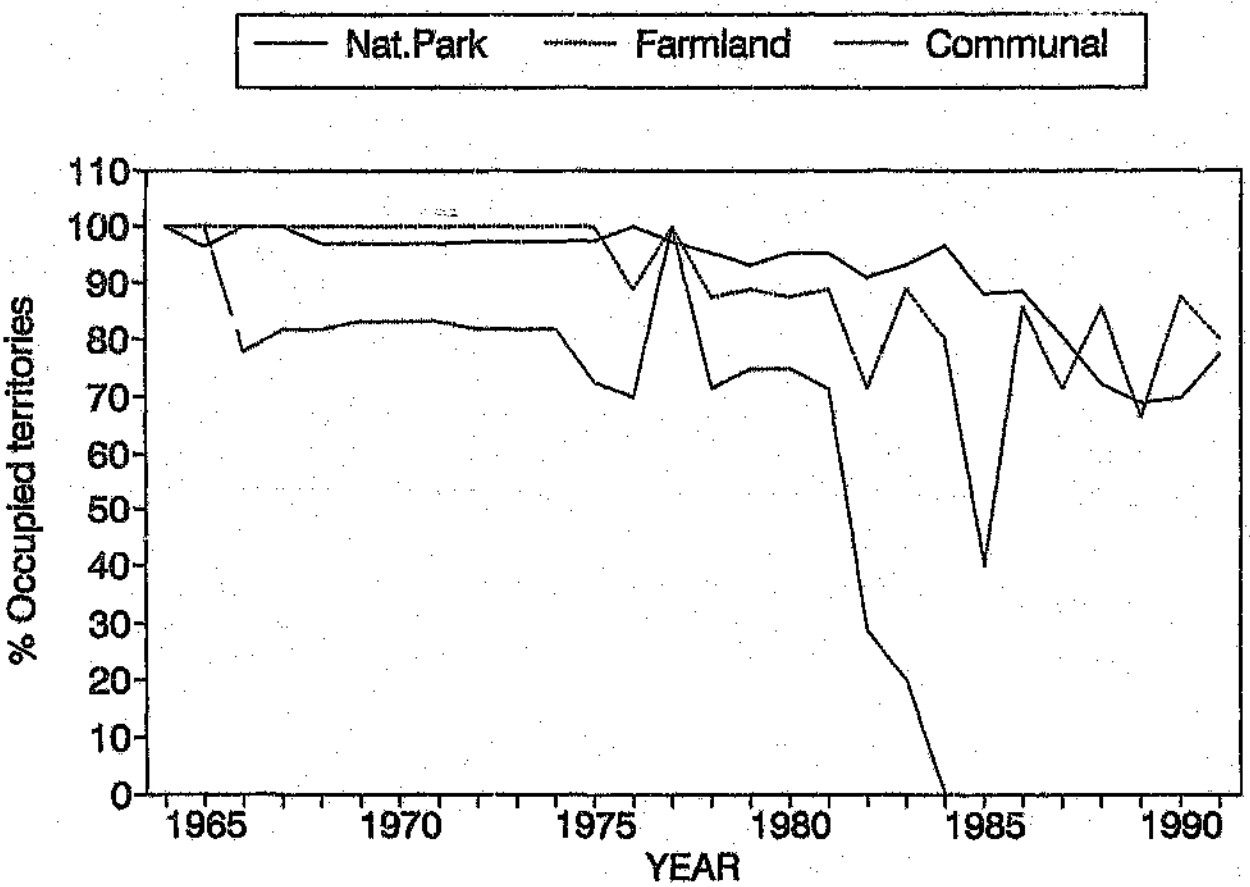

Nat.Park
Farmland
Communal
110
100
90
80
70
60
50
40
30
20
10
0
% Occupied territories
1965
1970
1975
1980
1985
1990
YEAR

Figure 2.

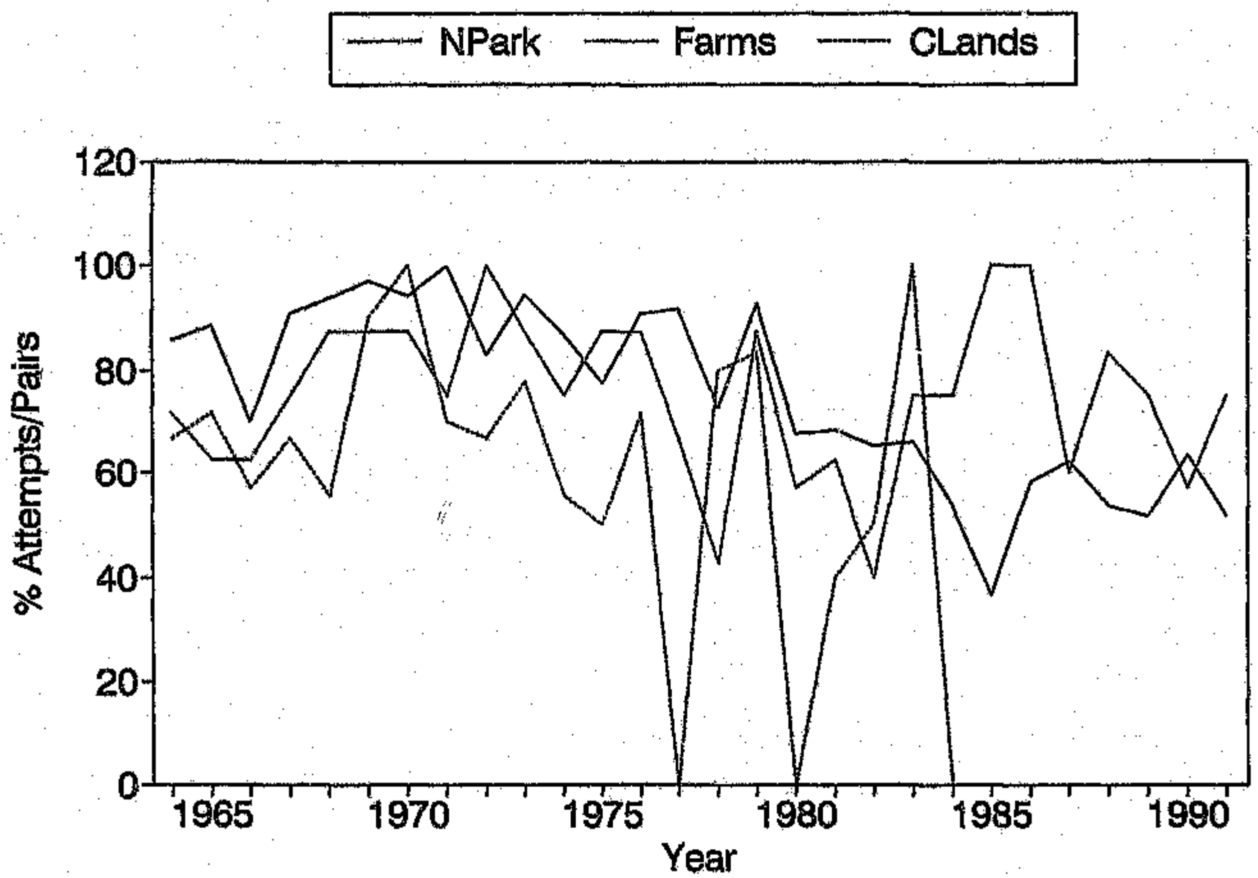

NPark
Farms
CLands
120
100
80
60
40
20
0
% Attempts/Pairs
1965
1970
1975
1980
1985
1990
Year

Figure 3.

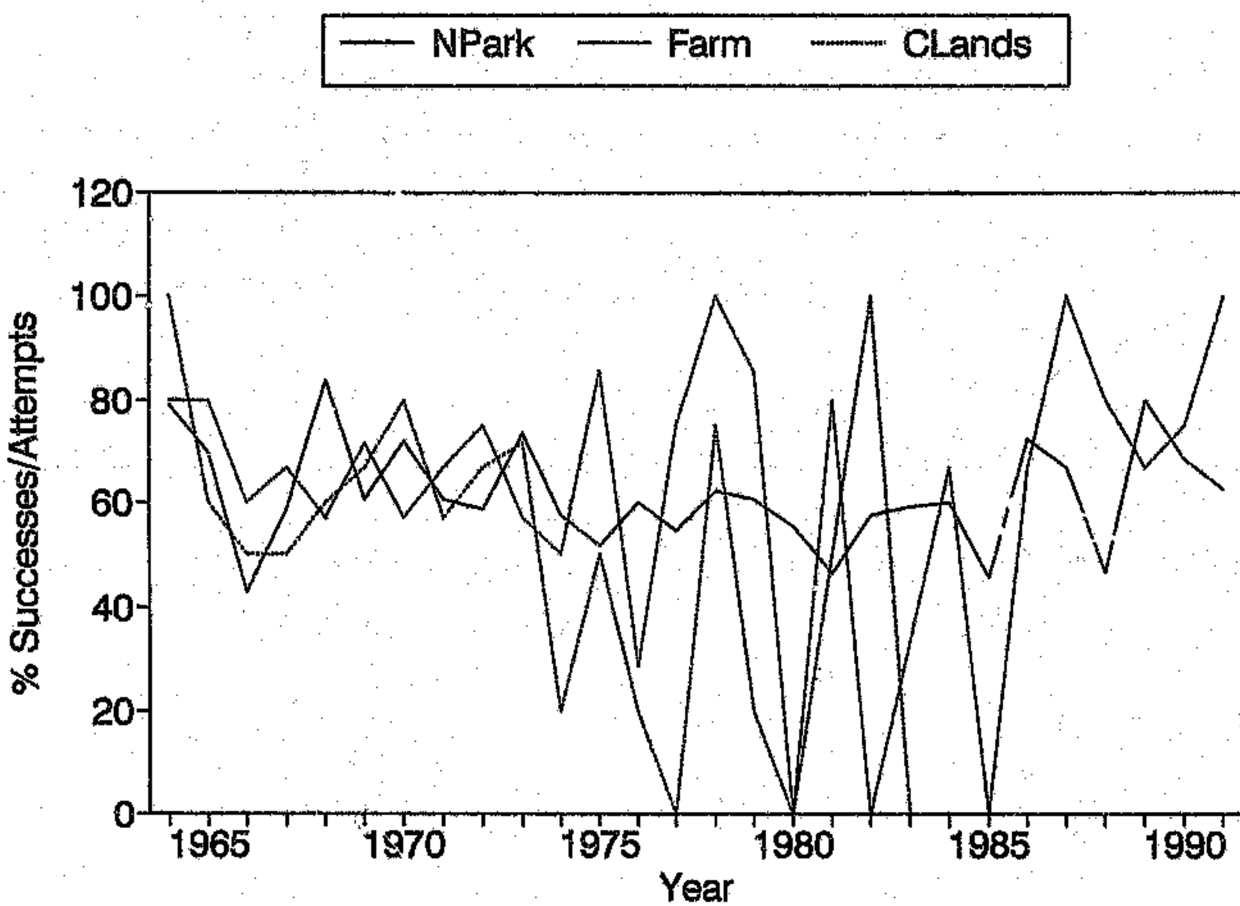

NPark
Farm
CLands
% Successes/Attempts
120
100
80
60
40
20
0
1965
1970
1975
1980
1985
1990
Year

Figure 4a

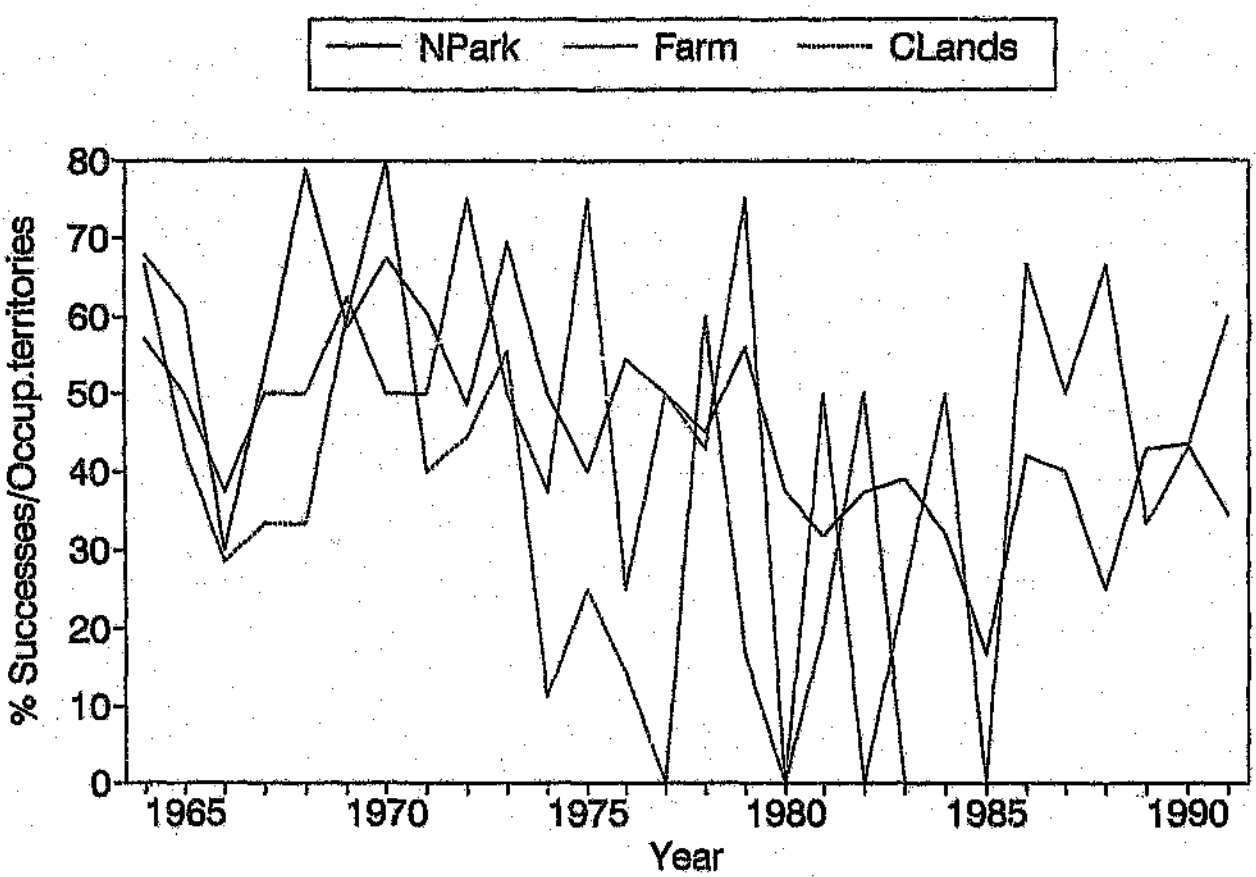
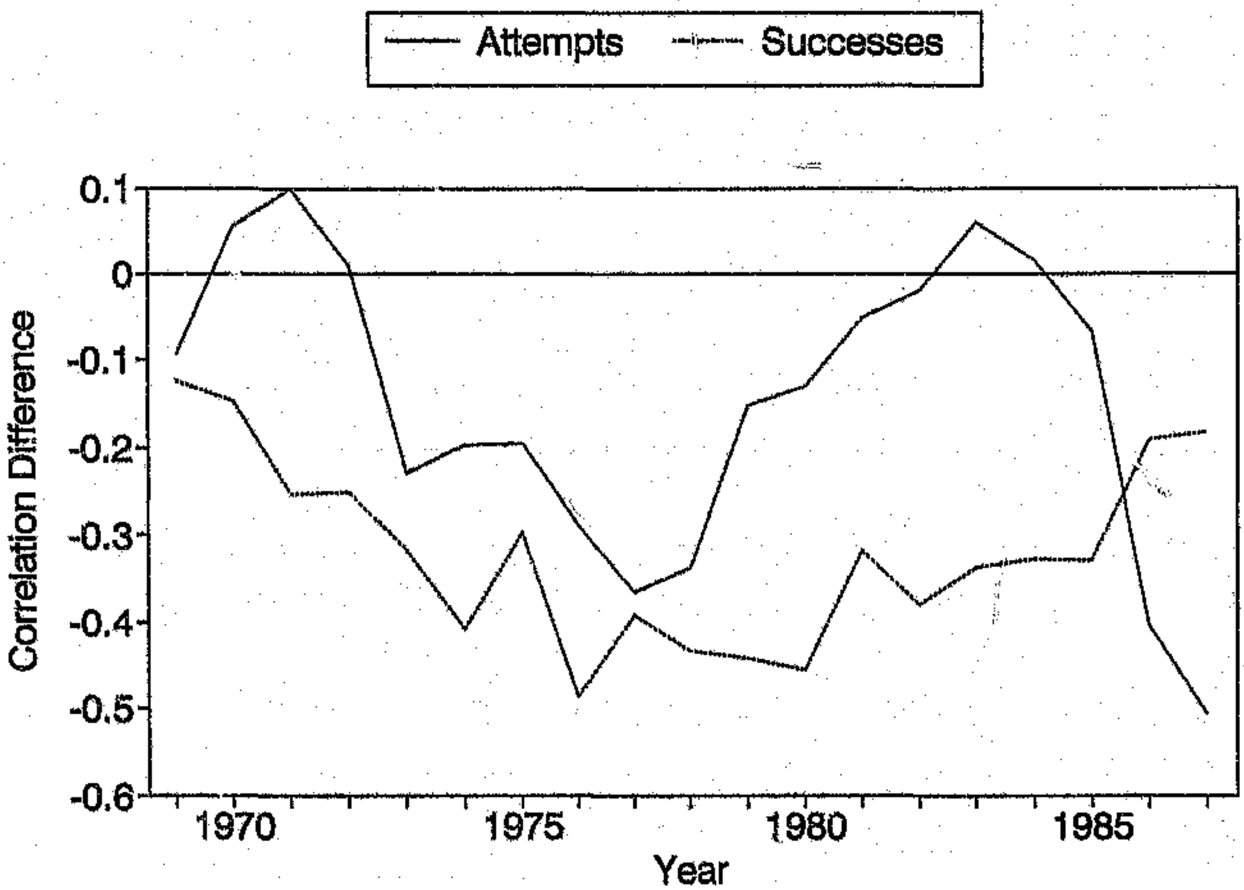

NPark
Farm
CLands
80
70
60
50
40
30
20
10
0
% Successes/Occup.territories
1965
1970
1975
1980
1985
1990
Year

Figure 4b



Attempts
Successes
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
Correlation Difference
1970
1975
1980
1985
Year

Figure 5.

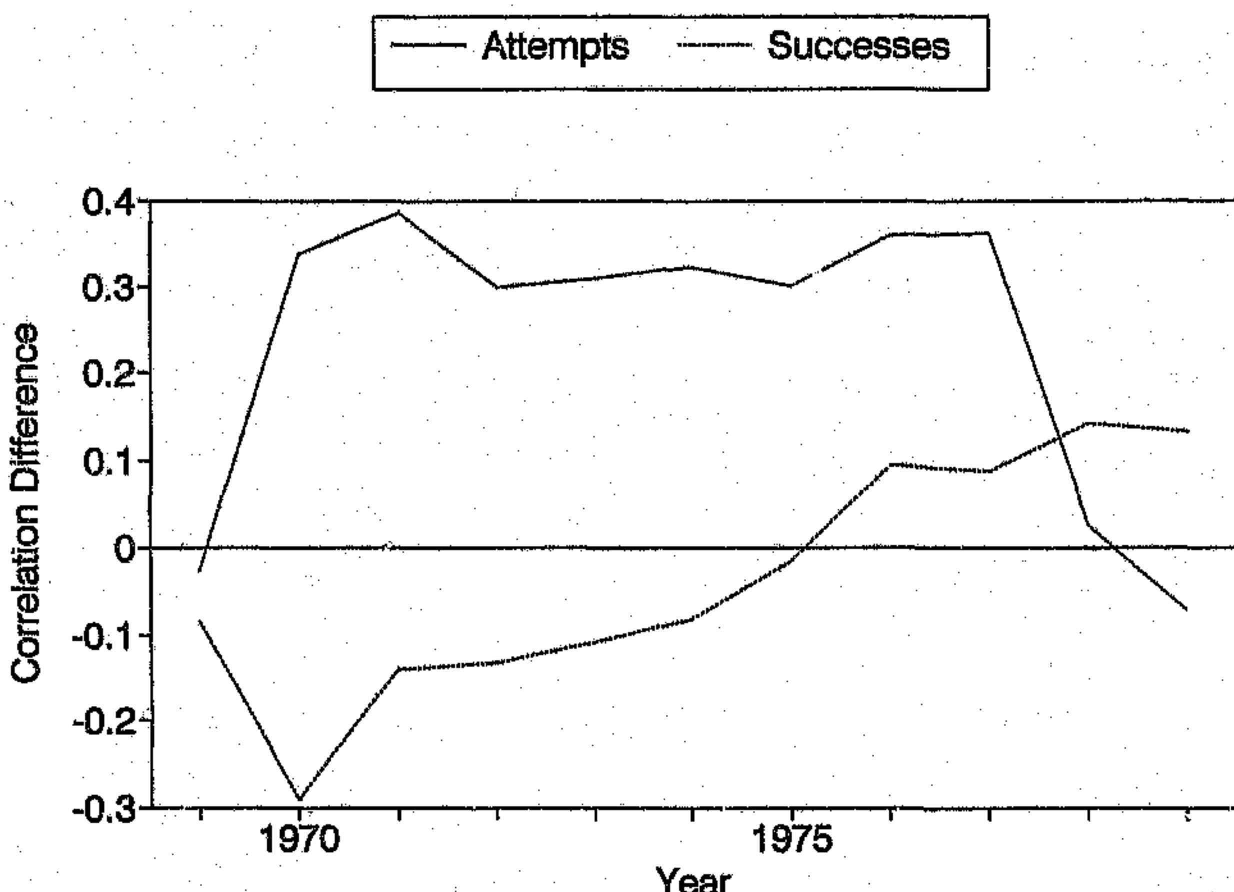

Attempts
Successes
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
Correlation Difference
1970
1975
Year

Figure 6.

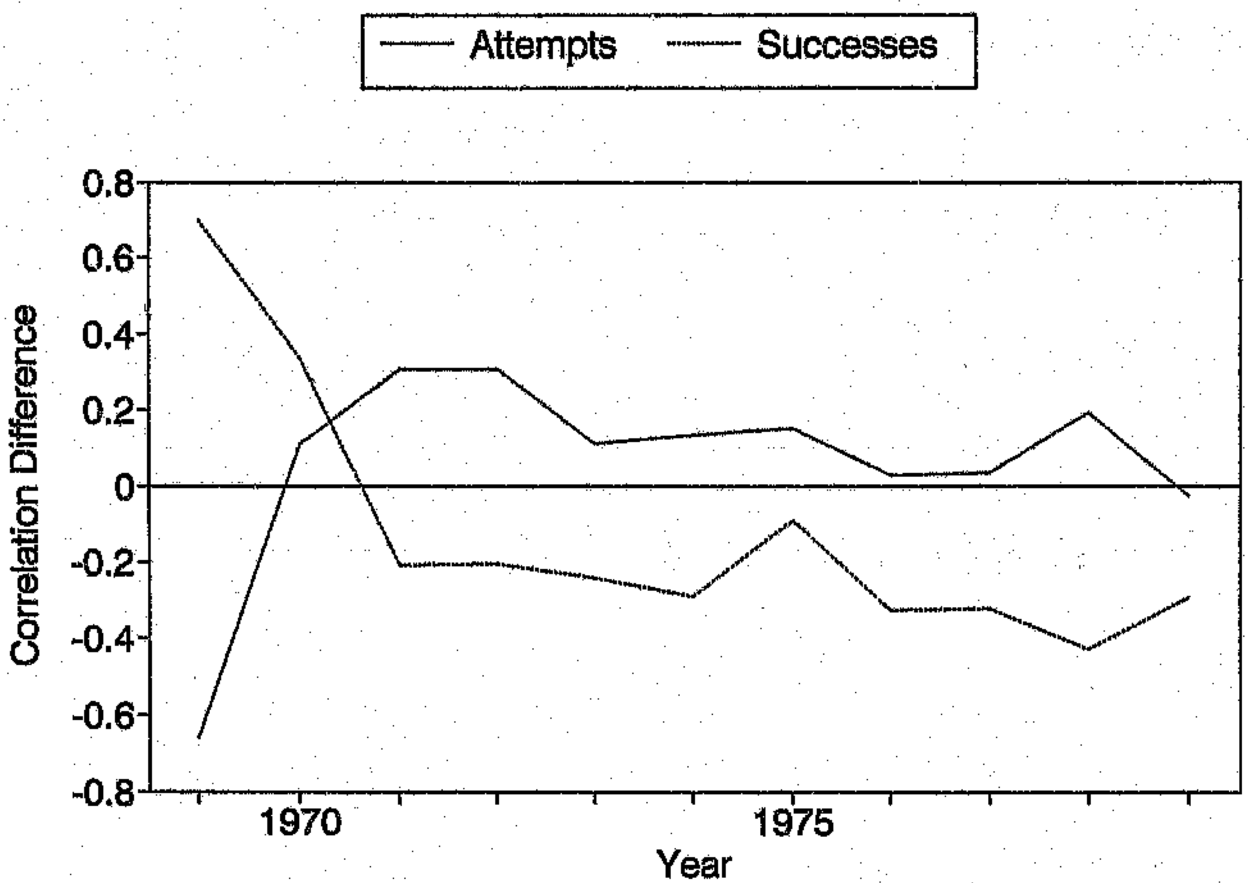

Attempts
Successes
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
Correlation Difference
1970
1975
Year

Figure 7.