Raptor Nest Activity in the Klaserie Private Nature Reserve, South Africa, and its Relation to Rainfall and Temperature

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Abstract

Raptors are often invaluable to their environment, playing key roles in maintaining ecosystems functionality. The decline of raptors is a current conservation concern and it is important to understand how different variables may impact population numbers. Rainfall and temperature were considered in this study and were compared to nest activity within a known breeding site. Nest activity in the study site showed a significant decline over the study period (t_4=4.837, p=0.004). Rainfall was found to have no significance, but higher average minimum (r_s=-0.975, n=5, p=0.005) and average temperature (r_s=-0.900, n=5, p=0.037) during the day, and average temperature in total (r_s=-1.000, n=5, p=<0.001), all during the January to March period, were found to have significantly negative effects on nest activity. It is considered that this may be because of prolonged exposure to high temperatures during these months, rather than the high temperatures themselves influencing the decline, as maximum and average maximum temperature showed no significance. It is also considered, however, that the current dataset may be lacking, so results should be considered with caution and continued data collection is advised.

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Introduction

The term 'raptor' is an alternative for the more common 'bird of prey'. In ornithological terms, this refers to any species of carnivorous bird that is morphologically designed to catch and hold relatively large prey, typically vertebrates. Such morphologies consist of good eyesight, talons, and a curved and hooked beak (Britannica Concise Encyclopaedia 2014). Despite the connotation that raptors must hunt, vultures and condors, who characteristically focus on scavenging, are also included in this classification. It is generally agreed that most raptor species are invaluable to their environments, often playing the role of apex predators, or in the case of carrion species, providing a much needed 'clean-up' service to quickly dispose of carcasses (Rodríguez- Esterella *et al* 1998 and Şekercioğlu 2006). The former, often being one of, or the, top predator in their local ecosystem, aid in defining and maintaining populations lower down in the food chain (Houston 1974, Oaks *et al* 2004, Pain *et al* 2003, Rodríguez- Esterella *et al* 1998, Şekercioğlu *et al* 2004 and Şekercioğlu 2006), whereas the latter play a significant role in reducing the potency of potentially devastating diseases such as anthrax (Houston 1974, Oaks *et al* 2004, Pain *et al* 2003, Şekercioğlu *et al* 2004, Şekercioğlu 2006), as well as promoting the cycle of nutrients back into the environment (Houston 1974 and Şekercioğlu 2006). Many raptors have been identified as useful indicators of environmental health, as they tend to require large home-ranges that are abundant with prey and are highly susceptible to changes in said environment (Herremands & Herremans-Tonnoeyr 2000, Rodríguez- Esterella *et al* 1998 and Şekercioğlu 2006). Therefore a decrease in the numbers of raptors can act as an early warning to something being amiss in the local ecosystem, increasing the potential for the situation to be identified and remedied before too much damage is done, or to slow the progress of whatever is causing a problem until a solution can be discovered.

Over the past few decades it has been noted that many of the world's raptors have suffered excessively large number losses (Oaks *et al* 2004, Ogada & Keesing 2010, Pain *et al* 2003, Prakash *et al* 2003), often leading to pressing consequences for both the environment and human settlements. It has been suggested, for example, that the decrease in vulture numbers has caused an increase in disease and disease bearing scavengers, such as rats or feral dogs (Markandya *et al* 2008, Pain *et al* 2003). In the worst cases, some studies have shown population losses of more than 90% for a few species (Prakash *et al* 2003 and Thiollay 2007), mostly throughout Africa and Eurasia, plunging many raptor species into an extinction-prone state. Because of this, a lot of work has been put into identifying the causes of decline. In a large part, poisoning (Markandya *et al* 2008, Oaks *et al* 2004 and Thiollay 2006) and/or habitat loss (Carrete *et al* 2002) have proven to play a significant role. Other than those focused on the most detrimental causes, there have also been multiple studies that attempt to determine how various other factors may affect raptors, either on a species level or as a group of species. Knowing how natural or unchangeable factors can affect population numbers is important for understanding the differences between natural and unnatural fluctuations, and narrowing down options for future conservation efforts. This will aid with not only determining where the problem may lie, but can also diminish the overestimation of situations, potentially saving much needed time, money and manpower. This is particularly useful to know for areas designated for preserving nature and biodiversity, such as game reserves, which often have little money to spare for anything other than absolute necessity, or for reintroduction projects, or programs aimed at increasing population numbers *in-situ*. These studies include those that have looked at factors such as ectoparasites, elephant-tree impact, and effects of weather.

Weather is an unchangeable factor, making it arguably one of the more important aspects to consider for conservation purposes (Ackerly *et al* 2010 and Root & Schneider 2006). It is becoming increasingly argued that climate change, though currently still often disregarded or downplayed, is not only a relevant factor but will be one of the most influential causes of species loss in the near future (Ackerly *et al* 2010, Araújo *et al* 2011 and Root & Schneider 2006). Knowing if and how past/current weather conditions have/are impacting a species can potentially provide a significant aid to ensuring its long term survival as weather conditions become more extreme. Existing studies that focus on the effects of weather towards raptor species often focus on rainfall and relate specifically to breeding or hunting success (Gende *et al* 1997, Pennycuick 1972, Hiraldo & Donázar 1990 , Hiraldo *et al* 1990, Kostrzewa & Kostrzewa 1990, Olsen & Olsen 1989, Steenhof *et al* 1999, and Watts 1991). There is a fair amount of variation in results, but most articles agree that high rainfall can have a negative impact on the fitness of raptor populations across multiple species. Low temperatures have also shown to play a significant role in fledgling mortality (Kostrezwa & Kostrezwa 1990 and Kostrezwa & Kostrezwa 1991), but most of such studies have been conducted on species in temperate climates.

Numerous raptor species have been reported to return to the same nesting site each year to breed (Alerstam *et al* 2006 and Ontiveros *et al* 2008), making it theoretically possible to use active nests as an estimation of changes in the population on a yearly basis. Each time a nest is reused, it is reworked, fixed and improved by the user with new materials, and thus the active nests are relatively easy to distinguish from the inactive by someone with experience. Multiple studies have reported that individual nests tend to be used bi-annually as opposed to annually (Margalida & García 1999 and Ontiveros *et al* 2008), so it can be assumed that roughly 50% of the nests may be active within any one breeding site.

This study will aim to use the yearly presence of nests and nest activity of a known breeding site in the KPNR (Klaserie Private Nature Reserve), South Africa, to assess if and how rainfall or temperature may be affecting the raptor population.

Methods

Study Site

The study was conducted in the Klaserie Private Nature Reserve (KNPR), an area of managed scrub-savannah habitat that covers approximately 60,000ha, one third of the Associated Private Nature Reserves (APNR), which it is part of. It is divided by the Klaserie River, one of the tributaries for the Olifants River, and is home to a wide array of savannah species, including the 'Big 5'. The boundaries of the KPNR meet two other reserves of the APNR (Timbavati PNR and Balule PNR), as well as bordering directly with the Kruger National Park. The KPNR is home to numerous private land owners, but other than those who live there and guests of one of the three lodges or camps, the public is not allowed on the reserve.

Survey Methods

Information on nest location was gathered via game count surveys, local knowledge and tree surveys and then confirmed to be raptor nests by an expert. The reported nest sites (n=102) were then relocated yearly during one of three months within the raptor breeding period (July, August or

September). Nest presence and activity were recorded. The rainfall and temperature data were collected by electronic weather stations within the KPNR.

As nest data was collected in three consecutive months (July, August & September) weather data was grouped into four corresponding three-month groups. These groups were January to March (Jan-Mar), April to June (Apr-Jun), July to September (Jul-Sep) and October to December (Oct-Dec). Rainfall was then further separated into Maximum, Minimum, Average and Total Rainfall for analysis. Temperature data was also divided into Maximum, Minimum and Average, as well as Average Maximum and Average Minimum, for Day, Night and the total 24-hour period for the four groups.

Statistical Analysis

All statistical analyses were completed with IBM SPSS Statistics 21. The present nests and active nests data tested for normality using Kolmogorov-Smirnov and Shapiro-Wilk. The percentages of active nests in relation to present nests were transformed into radian values for analysis. Rainfall and temperature data were assumed not normal due to low sample sizes. As the data were normal, one-sample t-tests were used to test for significance in the numbers of Present Nests, Active Nests and Percentage of Active Nests, and a Pearson's Correlation test was used to test for correlation between Present and Active Nests. Spearman rho tests were conducted on Active Nests versus all forms of weather data to test for individual correlation. Active Nests were compared to weather data for the four month groupings prior to the relevant survey.

Results

Nest Presence & Activity

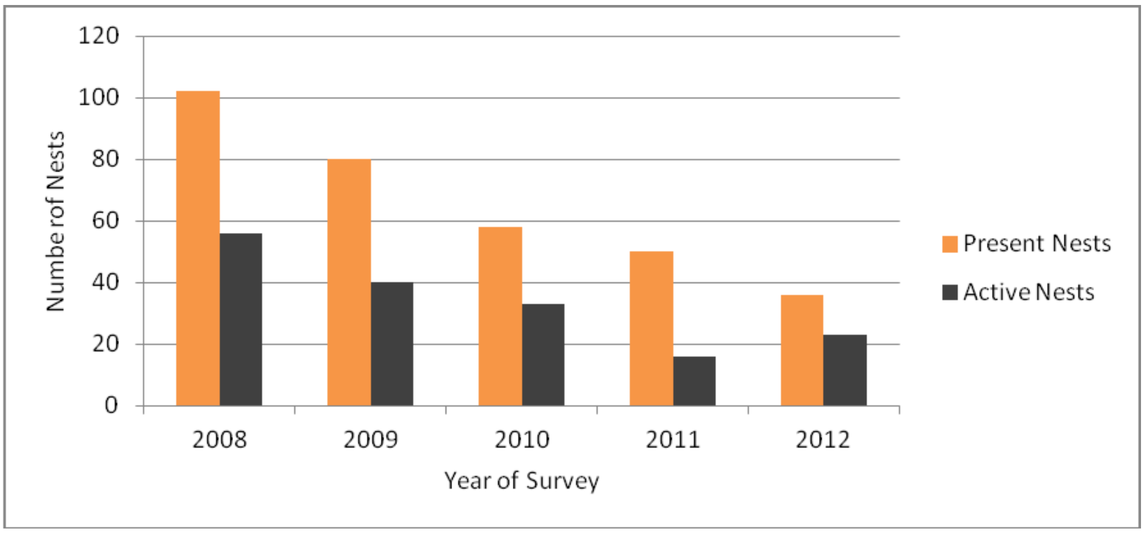

Figure 1. Chart to show the number of Present Nests and Active Nests each year.

Figure 1 shows a visual trend of decline for both Present Nests and Active Nests. In both cases, this decline was significant (Present Nests: t_4=5.602, p=0.005; Active Nests: t_4=4.837, p=0.004). However, there is also a slight increase of Active Nests in the 2012 despite a continued decline of present nests. There is a significant correlation between the decline of Present Nests and Active Nests (r=0.928, n=5, p=0.023).

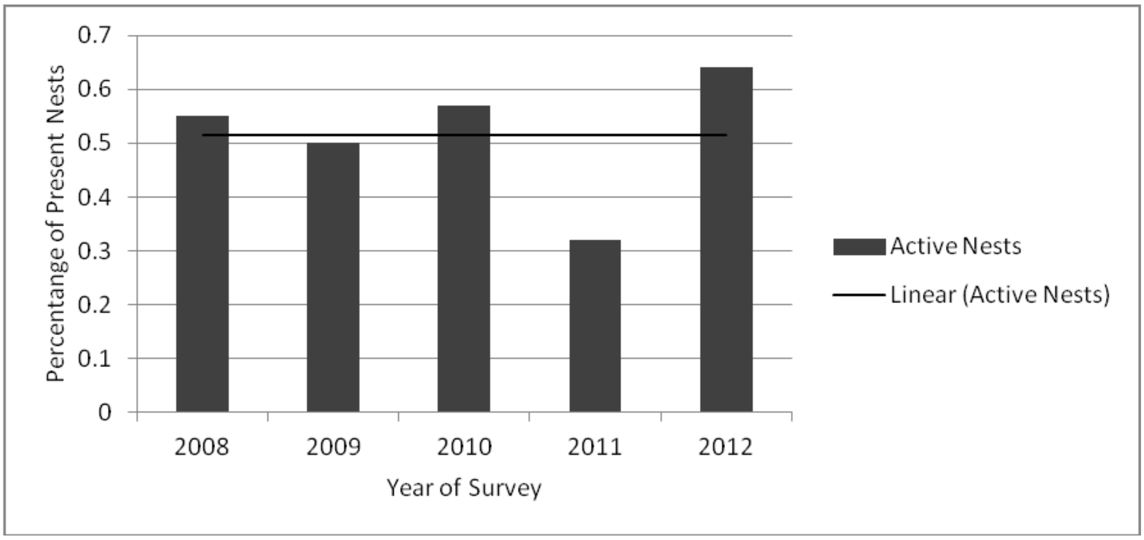

Figure 2. Chart to show the percentage of Present Nests that are Active each year, and the linear trendline.

The percentage of Active Nests to Present Nests (Figure 2) shows a significant trend (t_4=14.593, p=<0.001) and suggest a fluctuation each year around a mean of 52%, with more extreme fluctuations in the latter two years (2011=32%; 2012=64%).

Rainfall

There were no significant correlations found between the number of active nests and the maximum, minimum, average or total rainfall for any of the four groups.

Temperature

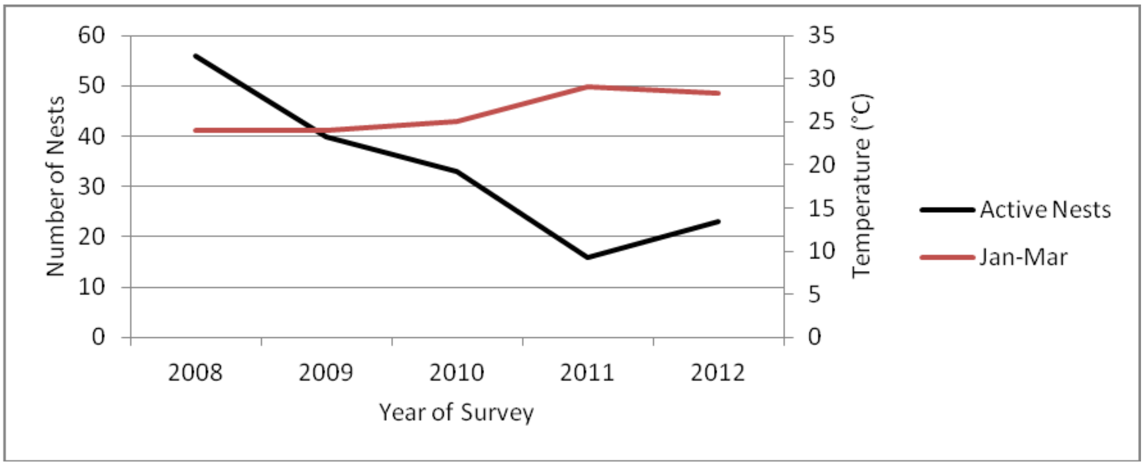

Figure 3. Graph showing Average Minimum Temperature (°C) (Day) in the Jan-Mar periods prior to the indicated year's survey, and the number of Active Nests recorded in the indicated year. Active Nests have been shown in a continuous format for presentation.

The average minimum temperature (Day) for the months between January and March shows a fairly strong visual trend with the number of active nests (Figure 3), with temperature increasing as the number of nests decreases, and dropping slightly along with the increase of active nests in 2012. This relationship shows significance of r_s=-0.975, n=5, p=0.005. None of the other three groups show a significant correlation between active nests and average minimum temperature (Day).

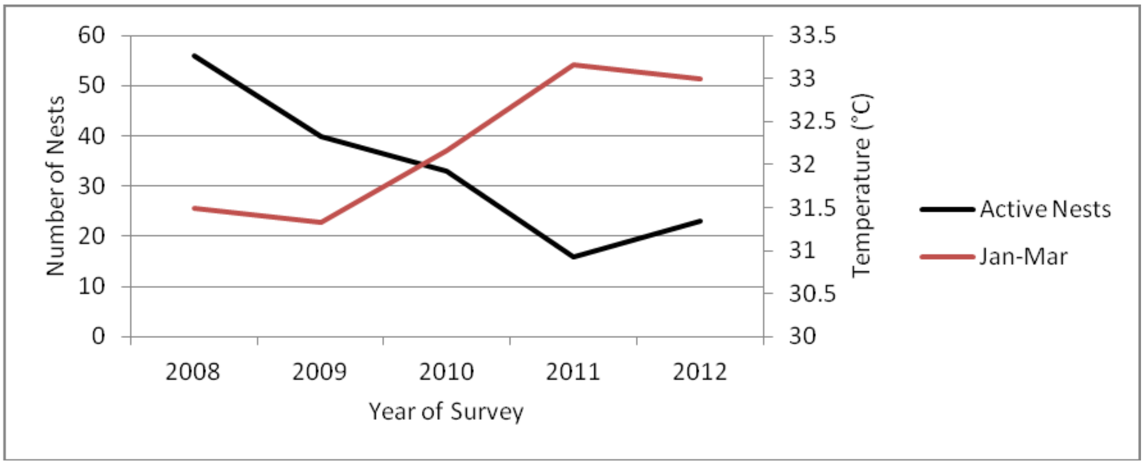

Figure 4. Graph showing Average Temperature (°C) (Day) in the Jan-Mar period <u>prior</u> to the indicated year's survey, and the number of Active Nests recorded in the indicated year. Active Nests have been shown in a continuous format for presentation.

Figure 4 shows a significant correlation between the number of active nests and the overall average temperature (Day), again in the January to March period (r_s=-0.900, n=5, p=0.037). As with the average minimum temperature (Day) (Figure 3), the visual trend suggests a decrease in active nests when there is an increase in temperature, and vice versa. This is true for all but 2009, where the average temperature (Day) drops slightly, yet the number of active nests continues to decline. None of the other three groups show a significant correlation between active nests and average temperature (Day).

No other variables for temperature during the day, and none for temperature during the night, show any significant correlation with the number of active nests for any of the four groups.

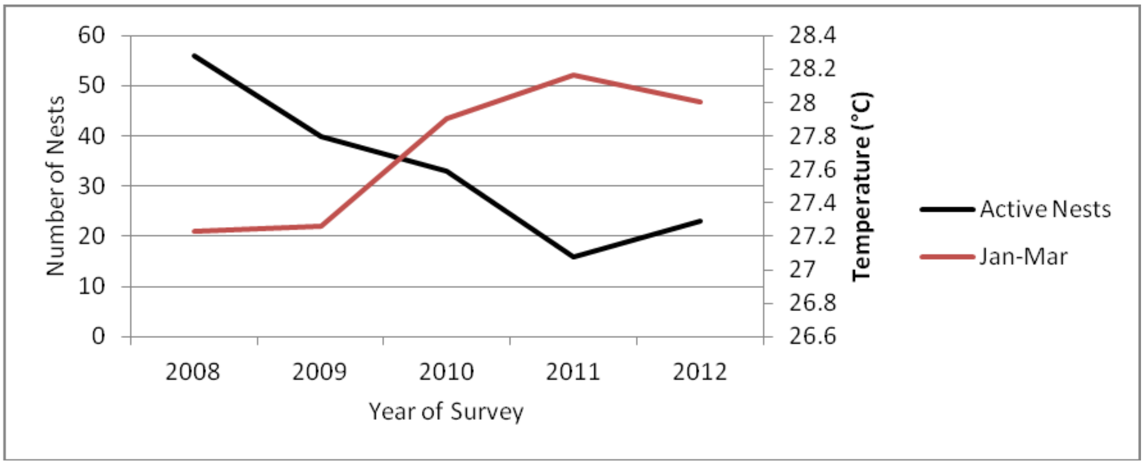

Figure 5. Graph showing Average Temperature (°C) in the Jan-Mar period <u>prior</u> to the indicated year's survey, and the number of Active Nests recorded in the indicated year. Active Nests have been shown in a continuous format for presentation.

Figure 5 shows a strong correlation between average temperature (24-hours) in Jan-Mar and the number of active nests (r_s=-1.000, n=5, p=<0.001). This trend can also clearly be seen visually, where, like average minimum temperature (Day) and average temperature (Day) (Figures 3 & 4), an increase in temperature is associated with a decrease in active nests. No other significant correlations were found for average temperature (24-hours) for the other three groups.

Discussion

Results

Based on the results of the analyses it can be assumed that the raptor populations of the KPNR (Klaserie Private Nature Reserve), in parallel with the number of active nests, are suffering a significant decline. The degree of significance is very high ($p=0.004$), so it seems plausible that there is another issue or issues affecting raptors in the KPNR, since natural factors alone seem unlikely to present such a reduction. The numbers of present nests are also exhibiting a significant decrease, and the correlation between present and active nest numbers, too, appears to be significant. This suggests that both may be affected by the same variable, which, for present nests, is unlikely to be due to temperature. Regardless, temperature in particular does appear to have an impact, and so it is still important to understand why and to what extent this impact occurs for future conservation efforts and management schemes. Such results would also make sense if the number of present nests affected the number of active nests, or vice versa, and analysis suggests that the percentage of active to present nests have a steady mean of 52%. However, though this looks to conform with other studies (Margalida & García 1999 and Ontiveros *et al* 2008), the results in this case are questionable. If it is accepted that the 52% trend is accurate, and is associated with an annual alternation of nests, then it must also be assumed that all lost nests (non-present nests) belonged to the raptors who have disappeared from the study site, which is an extremely unlikely scenario. Nor does it seem feasible that the number of present nests influences the number of active nests, despite the significant correlation, since, again, it would suggest that the birds who don't return to the area have lost both nests, or are unwilling to occupy another. Improbable is not impossible, however, so the possibility should not be completely disregarded. It should also be noted that newly found nests were not included in the analysis of this study since, though a few were recorded, this was only the case for the last few years of the dataset provided. Reanalysis for significance and trends would be recommended once new nest data has been collected for a number of years, but based on pure observation of current data, it does not seem likely that there will be any significant change. It seems more likely, however, that the percentage of active nests to present nests may no longer present a stable linear pattern as more information is collected, as even the data used in this analysis shows high variability in 2011 (32%) and 2012 (64%) from the initial three years of the survey (55%, 50% and 57%, respectively). This suggests that the yearly nest percentage may not be as stable as initially assumed, based on only the few years worth of data available.

It is interesting to see that rainfall, at least on its own, does not appear to have any significant impact on the decline of active nests, and thus the raptor population. Numerous past studies have attested to high rainfall or long periods of rain leading to a significant decrease in survival fitness, mostly through a reduction of hunting and breeding success (Gende *et al* 1997, Pennycuick 1972, Hiraldo & Donázar 1990 , Hiraldo *et al* 1990, Kostrzewa & Kostrzewa 1990, Olsen & Olsen 1989, Steenhof *et al* 1999, and Watts 1991). For example, a study on Cinereous Vultures (*Aegypius monachus*) by Hiraldo & Donázar (1990) found that rain significantly decreased the amount of time that the birds spent in flight, reducing or even eliminating daily time spent on foraging for food. Other studies have linked rainfall to high ectoparasites loads (Arendt 2000 and Merino & Potti 1996), causing increased fledgling mortality. Although not necessarily expected, based on such research it wouldn't be surprising to find that the local population should decrease due to heavy rainfall based on lower survival and reproduction, or from the abandoning of a poor quality breeding site in favour for a better one. The lack of significance in this analysis compared to others may potentially be seen as a testament that, though heavy rain may have a negative impact on raptors, it simply reduces the population increase potential to a lower positive, as opposed to causing it to become negative. However, there are also multiple reasons as to why no significant correlations were found, where they perhaps should have been. The first and foremost reason is, of course, due to a lack of data. Depending on the group, there were only four to five years worth of data for comparison, some of which will have had a much higher variability than normal due to, for example, the unusually devastating floods in the study area at the end of 2011/beginning of 2012. Interestingly, and contrary to the aforementioned studies, there appears to have been an increase of active nests in 2012, the survey that proceeded the floods. This is perhaps due to a possible increase in deaths or displacement of prey species, thus food availability, or the destruction of other breeding sites, etc.

Based on singular correlations, January to March appears to be the most significant period and temperature the most significant factor for impacting nest activity in the raptors of the KPNR. The results suggest that higher average temperatures during this period, particularly throughout the day, have a negative impact on the active nest number in the following breeding season. For the most part, this trend can be seen visually. The significant variables found were, during the day, average minimum temperature and average total temperature, and for the full 24-hour periods, again, average total temperature. Note that neither maximum nor average maximum temperature showed any significant correlation, suggesting that it is not necessarily high temperatures that have a negative impact on raptors, but rather the lack of respite from it. There is little to be found on the effects of temperature on raptors within countries with a climate similar to South Africa, though such results do contradict other reports from more temperate areas that suggest low temperatures have a negative impact on breeding success (Kostrezwa & Kostrezwa 1990 and Kostrezwa & Kostrezwa 1991). However, it does make sense from a logical point of view that consistently hot days should negatively affect how long the raptors can spend exposed to the sun whilst they fly in search for food or water. Even shaded areas are likely to be particularly warm, which may lead to increased instances of heat exhaustion. For these scenarios to be accepted, however, further research would have to be performed with such hypotheses in mind.

Further Research

Recommendations for continuing or improving upon this study include, of course, the continuation of data collection to reduce potentially biased results caused by lack of data. Many of the results described above do not conform with other studies. It is likely that the lack of information has increased the influence that any abnormal weather data has had on their respective analyses. Though it seems unlikely that the decline in present and active nests will become less significant with increased data, it may be that the association between the two is less pronounced. As argued above, the percentage of active nests to present nests seems unlikely to be as stable as otherwise appears with the current five years worth of data. Of course, this does not mean that future surveys may not show more stability, which would affirm the initial appearance of a common factor leading to the decrease of both present and active nests.

Another improvement would be testing combined correlations between rainfall and temperature. This was not done for the current study, as initial tests raised numerous overly extreme and highly unlikely results (e.g. <99% correlations). The reason behind this is liable to be due to lack of data and reanalysis shouldn't be considered until a substantial dataset is acquired.

There are multiple additional analyses that would improve on this report, such as the inclusion of new nests, analysis of individual nests, and the addition of aspects already considered in other studies, such as breeding success and parasite load. Including new nests would reduce inaccuracies caused by the underestimation of present and/or active nests in the study area, and may prove to lessen the apparent severity of the population decrease suggested by the current results. It may be, for example, that some old nesting sites have been abandoned in preference for new ones. But, as mentioned before, judging from the low number of new nests noted in comparison to the numbers lost, it does not seem likely that results will change to a significant extent.

The analysis of weather effects on individual nests could provide more in-depth knowledge as to exactly how these variables affect nest activity. Though rainfall on its own does not show any significant correlation with the total number of active nests, it may be that it does influence how often an individual nest is used. If this is the case, then the dataset would possibly then conform with the studies that suggest high or long rainfall have a negative impact on raptor populations. Specifically of note, in this instance, one study suggested that nest rotation may be influenced by rainfall due to a consequential increase in ectoparasites abundance (Margalida & García 1999), for example. Temperature has also shown to play a role in ectoparasites levels (Dawson *et al* 2005 and Merino & Potti 1996).

Leading on from this is the inclusion of factors such as breeding success and ectoparasites load, though in both cases the nest surveys would become more intrusive. It may be that weather variables are affecting breeding success or ectoparasites load, which could then be causing the raptors to abandon the breeding site if such effects are detrimental. Considering such factors could help explain exactly how the raptor populations are being impacted.

It may also be possible to analyse and compare nest activity across different sites within the study area, as coordinates have been provided with each nest information and rainfall data was provided for different locations within the KPNR. The main issue with considering this as an option, however, is the potential small size of each subarea with regards to a raptor's sense of distance. Subareas that are too small may well show extreme fluctuations in nest activity each year as a result. On the other hand, this issue could potentially be easily countered by grouping multiple small subareas into single larger ones. Expanding the study to include other nearby reserves is also an option to consider for the future, and could help answer the question of if the raptors are simply no longer using the study site, rather than disappearing altogether. If this is the case, then the effects of climate change could potentially be considered to a higher degree.

Conclusion

The overall conclusion of this study is that the most important variable out of rainfall and temperature on the nest activity of raptors in the KPNR is the consistency of elevated temperatures during the day between the January to March period. The continuation of data collection and reanalysis in subsequent years is recommended, along with the inclusion of new nest data and testing for combined correlations between rainfall and temperature towards nest activity. More specific or expanded research could prove informative, but may not provide much more insight into the effects of weather of the population as a whole.

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