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Techniques for determining movement patterns of Blue and Wattled Cranes in South Africa – colour-ringing versus satellite telemetry

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Knowledge about the annual movement patterns of endangered species is important in understanding various aspects of their biology, such as dispersal from natal areas, seasonal movements, and areas where large numbers aggregate. We compare two techniques of determining and analysing crane movement patterns in South Africa's threatened crane species, namely colour-ringing and satellite telemetry. Wattled Crane and Blue Crane colour-ringing began in 1987 and 1993 respectively. This technique, although being labour-intensive and time-consuming, has produced valuable information about Wattled Crane movements in the eastern parts of the country, with resightings of 42% of the ringed Wattled Cranes. Since 1993, 296 Blue Crane have been ringed but in contrast to the Wattled Crane, the resightings have not added much to our knowledge of this species' movement patterns. The Blue Crane, being endemic to southern Africa and termed a local migrant, required a more sophisticated technique for elucidating Blue Crane movements. Between 1996 and 1999, ten Blue Cranes were fitted with satellite transmitters in four different provinces. The transmitters battery life lasted for an average of 333 days (range: 182–707 days) giving an average of 118 fixes per transmitter life. However, of these fixes an average of only 27 points per transmitter (22.9% of the points) were usable, i.e. had a sufficiently accurate rating and thus provided the coordinates locating the bird to the nearest kilometre. Therefore, the selection of the appropriate technique for a movement study should dependent on the specific life history and behaviour of the particular species, as both techniques have merits, depending on your needs and financial resources. Despite being time-consuming and labour-intensive, colour-ringing was by far the more accurate technique in identifying movement patterns of the Wattled Crane, while satellite telemetry, although providing surprisingly inaccurate data at a high expense (a serious consideration for African conservation work) is a consideration in species with long-distance movements. However, in a large population such as the Blue Crane in South Africa, and the short migratory distances this species undertakes it is more suitable to utilise the colour ringing technique to track movement patterns.

INTRODUCTION

Within the crane family there are two distinct strategies of annual movement patterns. There are those species that are strongly migratory, and those that show relatively short local and seasonal movements between breeding and non-breeding regions (Meine & Archibald 1996). Extreme migration has been shown for many of the temperate crane species such as the Sandhill *Grus canadensis* and Siberian Cranes *Grus leucogeranus* (Meine & Archibald 1996). Other crane species, particularly those with restricted ranges, often show localized nomadic movements, including the South African Blue Crane *Anthropoides paradiseus* population (Allan 1997). The movement of birds enables them to escape areas where survival or reproductive prospects are poor and to find other areas where conditions are better (Newton 1998). Weather or local seasonal climatic conditions may also initiate or determine movement patterns, where food supply particularly in the winter months may drive these patterns (Newton 1998). Moreover, as natural habitats become increasingly fragmented by human activities, movements of birds are likely to play an important role in maintaining local populations and in ensuring genetic continuity (Newton 1998).

The Blue Crane is endemic to southern Africa (Urban *et al.* 1986; Harrison *et al.* 1997), being almost entirely restricted as a breeding species to South Africa. The Blue Crane population is only relatively healthy and stable in two areas, namely the Overberg region of the Western Cape and the central / eastern Karoo of the Northern and Eastern Cape provinces (McCann, this proceedings). Due to its restricted range, the latest IUCN/SSC publication "The Crane - Status Survey and Conservation Action Plan" lists the Blue Crane as "critically endangered" (Meine & Archibald 1996). In the latest South African Red Data Book it is listed as "vulnerable" due to its reduced natural range and population size (Barnes 2000). Blue Cranes establish and maintain breeding territories during the summer months (Allan 1993) and during the late-summer the pairs (and their offspring) form winter flocks which are presumably nomadic. Very little information is known about the winter movements of these birds, apart from the information in The Atlas of Southern African Birds (Harrison *et al.* 1997). This poses a substantial problem to Blue Crane conservation, as it has been proven that events while on their wintering grounds have an influence on survival as well as future reproductive success (Allan 1996).

The Wattled Crane is the largest and rarest of the six crane species that occur in Africa (Meine & Archibald 1996). The Wattled Crane is a winter breeding wetland-dependent species,

with a restricted population in South Africa (Tarboton *et al.* 1987). Adult breeding pairs maintain territories throughout the year, while non-breeding individuals gather in flocks and move nomadically between traditional feeding sites. During recent years its range has contracted in southern Africa and its conservation status is listed as "critically endangered" (Meine & Archibald 1996; Barnes 2000). There exists no evidence to suggest movement between the South African Wattled Crane population and populations further north (Allan 1997).

As the migration period (whether regular or nomadic) is such a critical phase in the annual cycle of cranes, crane biologists in North America and Asia have in recent years devoted much time and effort to the study of migration through colour ringing, radio telemetry, and satellite tracking programmes (e.g. Nesbitt 1976; Melvin *et al.* 1987; Ellis *et al.* 1992; Higuchi *et al.* 1996). This study analyses the movement patterns of the Blue and Wattled Crane, using colour ringing and satellite telemetry, and compares the differences between these two techniques.

METHODS

Colour-ringing

Individual Blue and Wattled Crane unfledged chicks were captured in the wild before flying age was reached. These birds were then ringed with wrap-around coloured plastic (Darvic PVC) leg-bands above the intertarsal (ankle) joint. Rings in six different colours were used, namely blue, green, yellow, orange, red and white. Three-inch colour-rings, with a colour specific to each province, were placed on one leg and a unique combination of smaller 1.5 inch rings (maximum of three rings) were placed on the other leg. Each bird was also fitted with a numbered metal ring from SAFRING (South African Bird Ringing Unit). Ringed cranes were resighted by field staff monitoring flocks of cranes, by volunteer birdwatchers, or alternatively through the recovery of dead ringed birds. As it is not possible to approach wild cranes closely (and thus read the ring combinations), observations were made with different birding optics (including 10 X 60 spotting scopes). Several injured birds were also ringed and released after rehabilitation.

Satellite telemetry

In South Africa only Blue Cranes were fitted with satellite transmitters, with the purpose being to determine the wintering areas of the various subpopulations in the country. The satellite transmitters were manufactured by Microwave Telemetry Inc. and weighed 95 g, approximately 2% of an adult bird. The transmitters were pre-programmed to transmit a signal once a week for a 12-hour period, and were predicted to last for a two-year period. Between 1996 and 1998, ten unfledged Blue Crane chicks were caught and fitted with satellite transmitters. The transmitters were fastened to their backs with a Teflon ribbon harness. On 21 and 23 January 1996, two Blue Cranes (PTT 23388 and 23389) were fitted with satellite transmitters in the KwaZulu-Natal midlands. Two further Blue Cranes (PTT 12078 and 12079) were fitted with satellite transmitters on 25 and 26 February 1998 in the Northern Cape province and two Blue Cranes in the Dullstroom region of Mpumalanga (PTT 12080 and 12081) on 27 February 1998. Four Blue Cranes were fitted with satellite transmitters in the Overberg of the Western Cape, two on the 30 April and 1 May 1996 as well as two on the 16 April 1998. Two of the Blue Cranes were fitted with transmitters outside Caledon (PTT 16920 and PTT 16921), one outside Bredarsdorp (PTT 12082) and the last outside Botrivier (PTT 12083).

Once individuals were released, the position fixes for the birds were received from Argos via e-mail on a weekly basis. The information accompanying each fix included the date, time of day, latitude and longitude, as well as an estimate of the accuracy of the fix. The accuracy was represented by a code, "3" indicating an accuracy of ≤ 150 m, a "2" indicating an accuracy of ≤ 350 m, a "1" indicating an accuracy of ≤1000 m, and a "0" or an alphabetical letter indicating no estimated accuracy.

RESULTS

Colour-ringing

A total of 296 Blue Cranes have been colour-ringed since 1993, only 1.47% of the overall estimated South African Blue Crane population of 20 100 individuals (McCann, this proceedings). The most extensive colour-ringing has taken place in the Northern Cape and the Western Cape where large populations of Blue Cranes occur (Table 1). A total of 65 Wattled Cranes have been colour-ringed since 1986, which represents 27.1% of the total population in South Africa of 240 individuals (McCann, this proceedings). Most of these individuals were colour-ringed in the KwaZulu-Natal province, where the core population is situated (Table 1).

Satellite telemetry

Each of the ten transmitters were active for a 12-hour period during each week, i.e. 0.5 days actively transmitting within a seven day period. There were an average of 47.6 active periods per transmitter life, with an average 2.5 fixes per active period (Table 2). Transmitters were active for an average of 333 days (range 182–707 days) giving an average of 118 fixes over that period. Only 23% of all fixes received from transmissions were of sufficient accuracy that they could be used in the movement analysis.

Crane movements

A total of 52 Blue Cranes ringed have been resighted (17.6%), mainly from the two regions where most of the ringing has taken place, the Overberg in the Western Cape and the Karoo in the Northern Cape. Twenty-nine of these individuals were found dead and were identified by their rings. All 29 cranes were found in close proximity to the area in which they were ringed, i.e. less than 5km from the ringing site. There were however only two exceptions: (i) a bird ringed in the Northern Cape outside Hanover was resighted four months later on a farm near Graaff Reinet in the Eastern Cape, 95 km away in a south-easterly direction; (ii) a bird ringed in the Overberg was recovered 40 months later in the Swartland area north of Cape Town, a distance of 66 km from the ringing site.

TABLE 1. The numbers of Blue Cranes and Wattled Cranes ringed per province in South Africa, together with the percentage it represents of the estimated South African population size.

Region/Province	Year	No. ringed	% of estimated population
Blue Cranes			
Mpumalanga	1995–1999	15	0.08%
Free State	1998–1999	6	0.03%
KwaZulu-Natal	1995–2000	11	0.06%
Eastern Cape	1998–1999	14	0.07%
Northern Cape	1993–2000	77	0.39%
Western Cape	1993–2000	172	0.86%
South Africa	1993–2000	296	1.47%
Wattled Crane			
Mpumalanga	1987–1998	20	8.3%
KwaZulu-Natal	1986–2000	45	18.7%
South Africa	1986–2000	65	27.1%

Twenty-seven of the 65 Wattled Cranes (41.5%) which were colour ringed were resighted between the period 1994 and 2000 (Fig. 1). Individuals from Mpumalanga moved an average of 127.2 km from their breeding sites while those ringed in KwaZulu-Natal moved an average of 74.1 km. The longest distance moved was by a bird ringed in Mpumalanga which was resighted as part of a breeding pair 92 months later in the KwaZulu-Natal midlands, 426 km from its natal area (Underhill *et al.* 1999). The recovery of dead Wattled cranes and the observation of ringed birds show that there is interchange of individuals between the two core regions.

Satellite telemetry

In the Northern and Western Cape provinces the Blue Cranes were more sedentary, while in the eastern parts of the country more seasonal movements were shown (Fig. 2). Individuals in both the Mpumalanga and KwaZulu-Natal regions moved out of their breeding areas during the winter months and returned in early Spring (September). The Mpumalanga individuals moved southwards towards Carolina/Ermelo, while the KwaZulu-Natal individuals moved northwards to the Elands Laagte / Glencoe region.

Cost Comparison of techniques

An additional factor considered was the cost of the technique used in carrying out the movement study (Table 3), represented by the cost of resighting an individual. This analysis gives an average cost of resighting a bird using colour ringing at R212.95, while for satellite telemetry the average cost of resighting a bird (using only the usable fixes with accuracy values) was R714.53, a significant difference ($P < 0{,}001$).

DISCUSSION

Descriptions of movements of Wattled Cranes are restricted to statements in the literature, where they appear to be highly nomadic, their movements varying between years in the south-central African wetland systems (Konrad 1981), while the South African population is said to be highly sedentary (Tarboton 1984). The movements of

TABLE 2. Summary information for each satellite transmitter fitted to the ten Blue Cranes in South Africa, including the number of days transmitting, the number of fixes over that period and the accuracies of these fixes.

Transmitter no.	No. days transmitting	No. fixes	No. fixes with no Accuracy	No. fixes with accuracy	% accurate fixes
KwaZulu-Natal					
PTT 23388	280	28	15	13	46.4%
PTT 23389	280	9	7	2	22.2%
Northern Cape					
PTT 12078	257	73	40	33	45.2%
PTT 12079	230	127	106	21	16.5%
Mpumalanga					
PTT 12080	231	121	97	24	19.8%
PTT 12081	182	50	37	13	26.0%
Western Cape					
PTT 12082	203	133	108	25	18.8%
PTT 12083	255	111	84	27	24.3%
PTT 16920	707	246	200	46	18.7%
PTT 16921	705	279	213	66	23.6%
Summary					
Average	333	118	90.7	27	22.9%
Range	182–707	9–279			

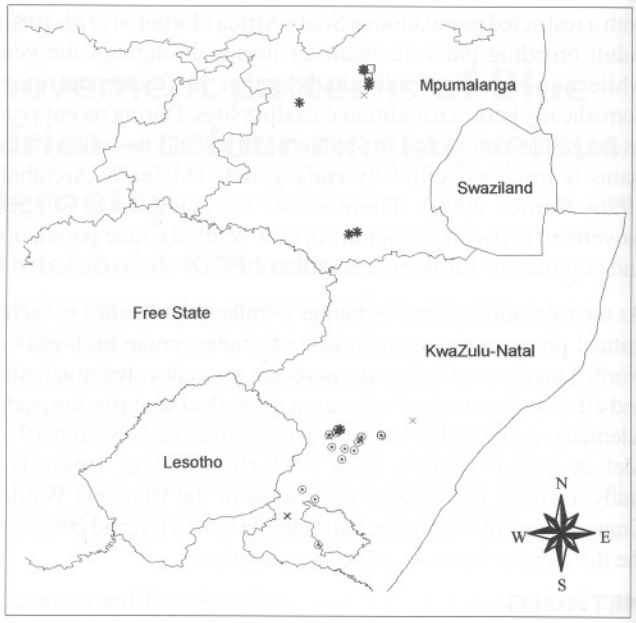

FIG. 1. Map of the eastern regions of South Africa, showing the Wattled Cranes ringed in Mpumalanga (□), and KwaZulu-Natal (⊙), individuals resighted who were ringed in Mpumalanga (*), and those individuals who were ringed in KwaZulu-Natal and resighted (X).

Blue Cranes in South Africa were extensively reviewed by Allan (1997), where the author's analysis and historical literature were in direct contradiction with each other. Together with this, no statements or findings were suggested for the populations on the eastern sides of the country. Therefore, a high priority has been placed on understanding the movement patterns of Blue Cranes in South Africa.

The colour-ringing of Wattled Cranes has shown movements of individuals between the two core breeding populations in the country, namely Mpumalanga and the KwaZulu-Natal midlands. These movements appear to have been a once off movement (i.e. dispersal from the Natal area) as these individuals have now become part of breeding pairs and are now resident in their respective regions. Other movements of non-breeding immature birds have shown extensive short distance movements within the KwaZulu-Natal midlands region into the southern regions, while several Mpumalanga birds have moved southwards to Wakkerstroom and back to the Mpumalanga highlands around Dullstroom.

The Blue Crane satellite telemetry programme was an attempt to understand the movements of the South African subpopulations and the interactions, if any, between these regions. Most movements shown were of short distances, all within their regional areas, corresponding to the supported nomadic nature of the species. New information was obtained for the two populations in Mpumalanga and KwaZulu-Natal on the eastern parts of the country. These movement patterns shown by the eastern populations of Blue Cranes corresponds to the altitudinal movements previously described for this species (Allan 1993), moving to lower altitudes during the winter months, where presumably conditions are more favourable.

Evaluation of techniques

The distinctive marking of individuals and subsequent observation of these animals has been a standard tool for wildlife studies for

TABLE 3. Cost comparison between colour ringing and satellite telemetry bird resightings.

	Costs of technique between 1996–99	No. Resightings between 1996–99	Overall cost per resighting
Colour ringing	R 24 915.48	117	R 212.95
Satellite telemetry	R 192 924.32	270	R 714.53

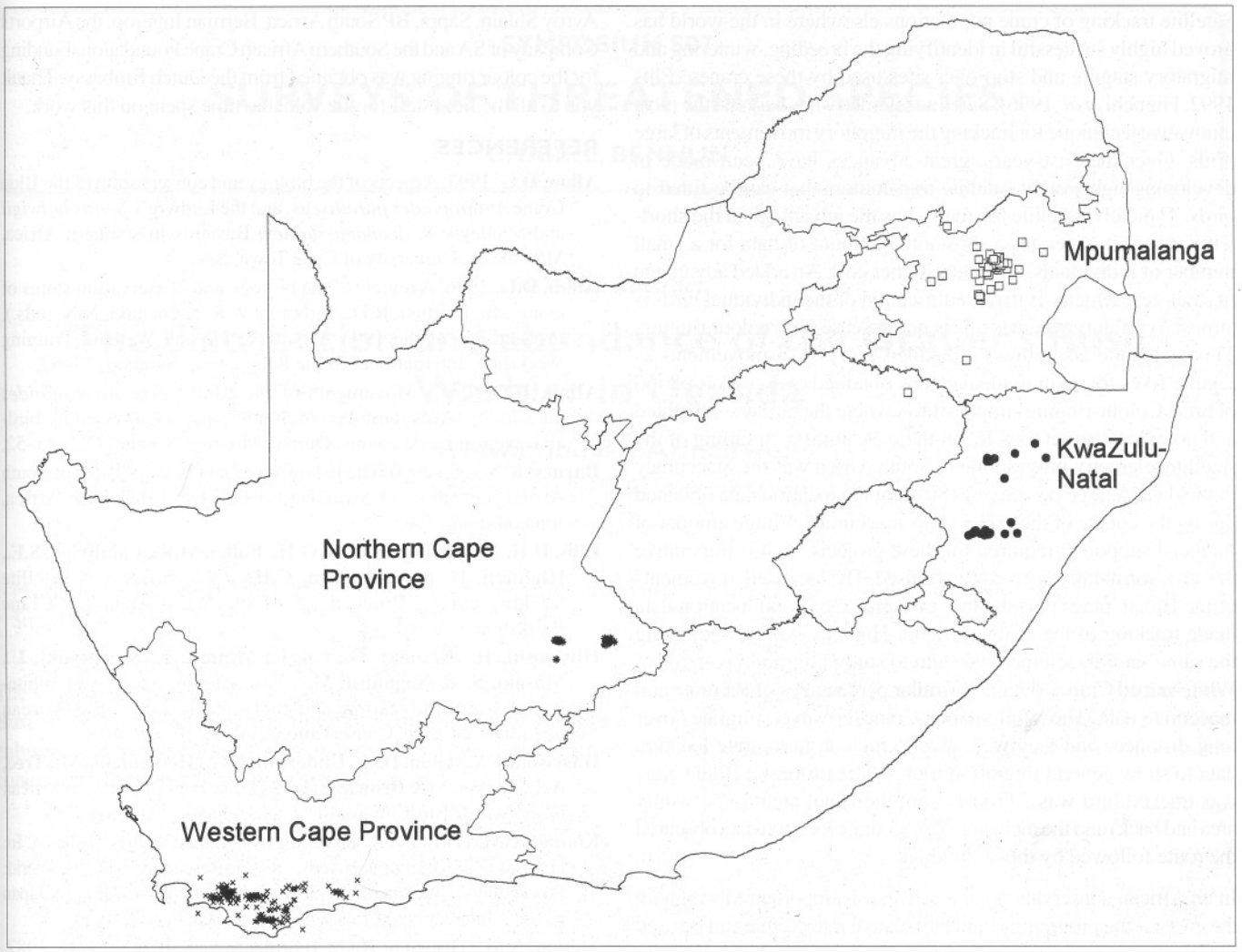

FIG. 2. Map of South Africa showing the location of the satellite telemetry fixes of Blue Cranes in Mpumalanga (□), KwaZulu-Natal (●), the Northern Cape Province (*) and the Overberg of the Western Cape (X).

many decades (Nesbitt *et al.* 1988). This technique has since progressed to utilizing telemetry equipment with much reduced follow-up effort, namely satellite telemetry. In comparing the two techniques of colour ringing and satellite telemetry, several differences become evident and influence their use according to different research programmes and questions needed answering.

In comparing the techniques, the basic differences are seen in their long-term and short-term nature. Marking individuals with colour rings provides reliable data from individuals in the long-term, as individuals remained marked for extended periods of time, often their life-times. A larger number of marked birds increases the chance of establishing movement patterns, especially when the movements are localised. In contrast to the Blue Crane, a significant proportion of the Wattled Crane population has been colour-ringed. This technique has very successfully shown the interchange of individuals between the core Wattled Crane populations in KwaZulu-Natal and Mpumalanga. The success of a colour ringing project depends not only on the number of birds ringed but also the number of birds resighted. The resighting process takes a lot more effort than the actual colour ringing and often extends beyond the period of colour ringing. A resighting programme can however be enhanced by encouraging people (such as amateur bird-watchers), through awareness campaigns, to look out for and report marked birds. Colour ringing therefore works well with large, charismatic species such as the Blue and Wattled Crane. To date, however, resightings of colour ringed Blue Cranes have not been sufficient to make predictions about movement patterns. This is understandable as only a small percentage (< 2%) of the Blue Crane population has been fitted with colour rings, and the resighting effort has been substantially lower than that for Wattled Cranes.

However, colour rings are often difficult to identify in the field. Ring combinations are often read incorrectly, especially by the general public. This leads to the identification of the wrong individual and can lead to incorrect data. An advantage of the technique is that a dead bird fitted with coloured rings is more likely to be reported than a dead bird without colour rings. This, plus the fact that the rings will last for the entire life of the bird, allows information to be gathered on mortality rates of different age cohorts as well as longevity of individual birds.

Colour-ringing proved to be highly effective in determining movement patterns of small populations of birds, such as the South African Wattled Crane population. Coupled with the extensive national programme directed at Wattled Cranes, including an awareness programme and supplementation programme, this increased attention has allowed a higher proportion of the individuals to be ringed with a corresponding high resighting rate. However, where ringing is at a disadvantage is in large populations where it may take many years before a large enough proportion of the population is ringed to gain information on actual movement patterns.

Satellite tracking of crane populations elsewhere in the world has proved highly successful in identifying the breeding, wintering and migratory staging and stop-over sites used by these cranes (Ellis 1992; Higuchi *et al.* 1996). Satellite telemetry has become the most innovative technique for tracking the migratory movements of large birds. Over the past years, great advances have been made in developing lightweight satellite transmitters that can be fitted to birds. Typically, satellite telemetry has the advantage in the short-term, where it generates a substantial amount of data for a small number of individuals, albeit at a higher cost. An added advantage of satellite telemetry is that identification of the individual birds is almost a certainty whereas this is not the case with colour ringing. This technique also allows a detailed analysis of movements as regular fixes for an individual can be obtained over a short period of time. Colour-ringing simply shows where the bird was resighted and not what route it took to get there. A significant failing of the satellite telemetry programme in South Africa was the inaccuracy of the data. A large percentage (80%) of the location data obtained during the course of the project was inaccurate. A huge amount of financial support is required for these projects, so it is imperative that all information received can be used. The localised movements of the Blue Cranes plus the low percentage of good location data made tracking of the birds difficult. Higuchi *et al.* (1996) using the same satellite telemetry system to study migration patterns of White-naped Cranes obtained similar percentages of accurate and inaccurate data. The White-naped Crane, however, migrates over long distances and they were able to include inaccurate location data to show general migration routes. The furthest a Blue Crane was tracked bird was 237 km (from the Natal area to the winter area and back) and the inclusion of inaccurate location data obscured the route followed by this individual.

In an African conservation perspective, it is important to weigh up the costs of the programme and the relative returns that can be used for effective conservation action. Colour ringing has been shown to cost a third of satellite telemetry over the same time period, in terms of the cost of resighting a bird (see Table 3). However, the colour ringing resighting costs do not take into consideration the costs incurred by the resighting effort, i.e. the people's time and expenses in resighting the birds. Therefore, if these could be included, over a similar short time period (2 to 3 years), then the two techniques may differ far less in their resighting costs. In situations where funding is available, then it would be beneficial to perform satellite telemetry where a few birds could be tracked, hoping these few birds show the movement patterns of the entire population. This is obviously a disadvantage of satellite telemetry, where the small sample sizes that can be achieved may not "represent" the movements of the entire population. Hence, satellite telemetry appears to be more effective in species showing definite migration routes, such as those species in the more temperate regions.

Thus, the selection of the appropriate technique for a movement study should dependent on the specific life history and behaviour of the particular species, as both techniques have merits, depending on your needs and financial resources. In a large population such as the Blue Crane in South Africa, and the short migratory distances this species undertakes it is more suitable to utilise the colour ringing technique to track movement patterns. However, if your research question requires you to determine the actual pathway utilized by migrating species, then satellite telemetry would be the appropriate technique.

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