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Population Declines, Viable Breeding Areas, and Management Options for Flamingos in Southern Africa

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Abstract: *Habitat rehabilitation or intervention to prevent species declines are rarely employed in Africa. I argue that despite protection in national parks, active intervention is necessary to halt declines in southern Africa's Greater (Phoenicopterus ruber) and Lesser (Phoeniconaias minor) Flamingo populations. Flamingos are long-lived species that breed sporadically at only two localities in southern Africa: the Makgadikgadi Pans in Botswana and Etosha National Park in Namibia. Despite well-publicized breeding on Etosha Pan, flamingos have experienced only three major breeding events in 40 years. Breeding failure occurs when high evaporation rates rapidly dry the pan, and up to 100,000 flightless chicks may starve. Consequently, pairs breeding in Etosha exhibit extraordinarily low recruitment (0.040 young pair/year) and extrapolations indicate that adults can replace themselves only if they breed for 38 to 50 years and all offspring survive. Because survival of offspring from fledging to adulthood (5 years) is about 46%, this breeding lifespan rises to an unrealistic 83 years, making Etosha a nonviable breeding site. Alternative, suitable flamingo habitats in Africa are being mined for soda-ash, are damaged by pollution, or are unprotected. Accordingly, continent-wide estimates and those from southern Africa alone suggest a population decline of about 40% in both species over the last 15 years. Because Namibia regularly supports 84% of the Greater and 93% of the Lesser Flamingos in southern Africa, conservation strategies are best focused there. Simple but effective management methods, based on those employed in western Europe, could reverse these downward trends. In Etosha a small island surrounded by a water-filled depression would allow up to 4000 pairs to breed annually. The benefits of enhancing the breeding of flamingos in Etosha include research opportunities, tourism revenue, and a safe haven for two Red Data species.*

Declinaciones poblacionales, áreas reproductivas viables y opciones de manejo para los flamíngos del sur de África

Resumen: *La rehabilitación o la intervención del hábitat para prevenir declinaciones en las especies es raramente empleada en África. En el presente estudio argumento que, a pesar de la protección en los parques nacionales, se necesita una activa intervención para detener las declinaciones de las poblaciones del Flamingo Mayor (Phoenicopterus ruber) y del Flamingo Menor (Phoeniconaias minor) del sur de África. Los flamíngos son especies longevas que se reproducen esporádicamente en solo dos localidades del sur de África: los Pans de Makgadikgadi en Botswana y el Parque Nacional Etosha en Namibia. A pesar de la bien documentada reproducción en el Pan de Etosha, los flamíngos han experimentado solo tres eventos reproductivos en 40 años. Las fallas en la reproducción ocurren cuando altas tasas de evaporación secan rápidamente el pan, pudiendo morir de inanición hasta 100,000 pichones de flamíngos que no vuelan. Consecuentemente, las parejas reproductoras en Etosha exhiben un reclutamiento extraordinariamente bajo (0,040 pichones/pareja/año) y las extrapolaciones indican que los adultos pueden reemplazarse a sí mismos sólo si se reproducen por 38-50 años y todas sus crías sobreviven. Debido a que la supervivencia de las crías entre el estado de volantón y el estado adulto (5 años) es de alrededor del 46%, este lapso vital reproductivo se eleva a unos quiméricos 83 años, lo cual hace que el sitio de reproducción de Etosha sea inviable. Hábitats alternativos apropiados para el flamenco en África están siendo explotados para la obtención de sosa, o están dañados por la contami-*

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nación o están sin protección. En efecto, las estimaciones a lo largo y ancho del continente y aquellas del sur de África solamente, indican una declinación poblacional de alrededor del 40% en ambas especies a lo largo de los últimos 15 años. Dado que Namibia mantiene regularmente el 84% de los Flamíngos Mayores y el 93% de los Menores en el sur de África, las estrategias de conservación deben enfocarse allí. Métodos de manejo simples pero efectivos, basados en aquellos empleados en Europa occidental, pueden revertir estas tendencias negativas. En Etosha, una pequeña isla rodeada por una depresión cubierta por agua podría permitir que hasta 4000 parejas se reproduzcan anualmente. Los beneficios de mejorar la reproducción de los flamíngos en Etosha incluyen las oportunidades para la investigación, los ingresos por parte del turismo y un santuario para dos especies listadas en el Libro Rojo.

Introduction

One of the world's greatest wildlife spectacles is the massing and breeding of millions of flamingos (*Phoenicopteridae*) on the vast, flooded salt pans of Africa. Yet one of the greatest tragedies is the death of thousands of chicks as they search fruitlessly for water on a searingly hot and drying salt pan. Both spectacles occur irregularly on the 4800-km² Etosha Pan in northern Namibia. As specialized habitats such as these continue to become fragmented and lost globally, active intervention has been used only infrequently to decrease the probability of extinction in environments regularly confronted by drought and human pressure. Wetland birds, the second-most threatened avian group in Africa, have rarely benefited from habitat protection to reverse population declines, and for certain highly specialized species it is not sufficient merely to protect habitats. I present data highlighting this dilemma for two long-lived and specialized African species, the Greater and Lesser Flamingos (*Phoenicopus ruber* and *Phoeniconaias minor*). I show that, despite their longevity and apparently protected breeding sites, adult birds are not replacing themselves. I consider whether management of their main breeding grounds is a feasible, long-term solution to reversing recent population declines.

Two out of five species of flamingos occur in Africa: the Greater and Lesser Flamingo. Both birds attempt to breed in large numbers at only two sites on the subcontinent: at Etosha Pan once approximately every three years (Table 1) and slightly more often at Makgadikgadi Pan in Botswana (Hancock 1990; T. Liversedge, personal communication). In 1975 Kahl estimated world populations of Greater Flamingos at 790,000 and Lesser Flamingos at 6 million. Today African populations are much lower (Table 3). The birds are classed as vulnerable in Namibia's Red Data Book (Brown et al., in press) because of their specialized and highly limited breeding sites. Moreover, breeding is often unsuccessful because of the rapid drying of the salt pan and a lack of available food. The result is often 100% starvation of flightless young. Attempts at saving stranded chicks have proven both costly and unsuccessful. This raises the following questions: Is Etosha Pan, the only national park in Africa where flamingos breed, a viable breeding ground for

these Red Data species? Can their longevity compensate for the rarity of breeding events? I show that both are unlikely, and that southern African populations appear to be declining. I then show that, for this and probably several other species at the periphery of their range or preferred habitat, relatively simple management techniques could be employed to alleviate their decline.

Methods

To determine whether Etosha Pan holds viable breeding populations I traced historical records of breeding episodes by collating data from published accounts of flamingo breeding and by interviewing research and management personnel (Table 1). Where records for Etosha were unavailable (surprisingly little has been published) I assessed rainfall figures for those years and used known breeding episodes under recorded precipitation regimes to estimate numbers. Monthly precipitation records from 1955 to 1995 were provided by the Meteorological Office in Windhoek and were averaged for the three closest weather stations at Namutoni, Halali, and Okaukuejo. Most rains fall in a short period between January and March and end by May. Flamingos respond immediately to good rains in the interior by flying the 500 km from the coast to Etosha in one night. It should be noted that large amounts of rain are as detrimental to breeding success as too little rain because nests can be flooded (Sauer & Rocher 1966). Because some extrapolations of success were made using rainfall regimes, it is circular to then correlate rainfall patterns with breeding attempts. More reliability can be attached to the ultimate success of breeding in recent years in both Etosha and Botswana, however, because (gray) juveniles appear at coastal wintering areas in Namibia, where they are regularly counted by conservation officials.

For Africa-wide records I relied mainly on the recent International Waterfowl Research Bureau (IWRB) results. These are biannual counts of all wetland birds across Africa coordinated by national organizers and collated by the IWRB. Results have been published annually since 1991, and I compared these with previous published estimates. Recent records for Botswana from flights by T. Liversedge over the Makgadikgadi Pans were kindly

Table 1. Published and unpublished records of flamingo breeding attempts over 40 years on the Etosha Pan, Namibia.

Year	Location	Numbers	Species ^a	Outcome ^b	Source
June 1956	Namutoni	1 flightless young	No data	No data (LS)	Berry (1972)
Aug 1959	Andoni Flats	1 dried egg	G & L	No data (F)	Sauer & Rocher (1966)
Aug-Sept 1963	Eastern pan	"Considerable numbers"	G	Pan "littered with corpses for several miles"	Winterbottom (1964)
Aug-Sept 1963	Oshigambo River	"Incredible multitudes"	L	"Undoubtedly bred, late nesters probably unsuccessful" (S)	
Nov 1964	Wolines-Ondongab water course	> 100 dried eggs	G & L	"Failed, probably washed away by floodwater" (F)	Sauer & Rocher (1966)
1968	NW of Okerfontein	?	?	Unfledged chicks (F)	Berry (1972)
1969	Main pan	"Thousands of birds"	G & L	100,000 young; most died (receding water) (LS)	Berry (1972)
May 1971	Okerfontein	100,000	G	27,000 on nests unknown success	Berry (1972)
July 1971	Okerfontein	1,000,000	L	54,000 on nests; 22,000 reared (S)	Berry (1972)
1974	Okerfontein	100s	G	LS	Berry (personal communication)
1976	Okerfontein	10s of 1000s	G (L2)	S	Berry & C. Clinning (personal communication)
1978	Okerfontein	No data	G(L2)	Unknown (LS)	
1984	Main pan	Small numbers bred		F	
1985	Main pan	Small numbers bred	G	F	T.J. Archibald (personal communication)
Feb 1986	Okerfontein	5210 nests	G & L	1200 month-old chicks, all died (F)	Archibald & Nott (1987)
1989	W. Okerfontein	"Dense concentrations"	G	3000 nests, 800 chicks, 765 caught	Archibald (1991)
1990	Main pan	Small numbers bred	G	F	T.J. Archibald (personal communication)
1991-1993		No breeding		10% mortality; all donated zoos (F)	
Apr 1994	Okerfontein	Thousands of birds	G & L	100% mortality, 130 chicks caught, 77 released, 100% mortality; others sold (F)	C. Brain & W. Versfeld (personal communication)
1995	Springbokfontein	1000-2000 egg laying	G	Pan dried, nests deserted (F)	W. Versfeld (personal communication)

^a G = Greater Flamingo, L = Lesser Flamingo.

^b F = failed completely; LS = limited success; S = successful, thousands of young.

supplied by Soda Ash Botswana. These counts were difficult to compare with IWRB counts because aerial counts of large flocks made from photographs give estimates 20-30% higher than ground counts among Namibian observers (Simmons 1991; Braby et al. 1992). Wide variation disallows any reliable correction factors, so direct comparisons cannot be made.

Results

Breeding Frequency and Success on Etosha Pan

Records of varying reliability extend back 40 years for Etosha Pan. In that period 17 breeding attempts have been recorded, one every 2.4 yrs. In the same 40 years only five attempts are known to have resulted in some young fledging (three others in 1956, 1963, and 1978 may have succeeded based on the above average rainfall). Thus, successful breeding occurs at most once every 5 years but more probably once every 8 years. Only three breeding attempts in 40 years fledged more than 1000 young (large circles, Fig. 1). Two other attempts may have fledged young; the evidence for each is summarized below and in Table 2.

In 1963 Lesser Flamingos were recorded breeding in large numbers, and late nesters were known to be unsuccessful. Recruitment was unknown, so I assumed that about 20,000 young fledged based on data from 1971 when breeding was monitored (Berry 1972) and of rainfall (440 mm) was similar to that measured in 1963 (503 mm).

In 1971 a known 22,000 Lesser Flamingo chicks were fledged from 54,000 pairs. Assuming that a similar (41%)

proportion of the 27,000 pairs of Greater Flamingos fledged young, about 11,000 chicks would have occurred. Maximum recruitment for 1971 was thus about 33,000 fledged young. In 1974, 715 mm of rain fell (Fig. 1), but few flamingos bred (H. Berry, personal communication). In 1976, however, 580 mm of rain fell on the pan, and tens of thousands of birds were present; success was unrecorded. I assume therefore that about the same number of young as in 1971 were produced, 33,000. In 1978 high rainfall (571 mm) occurred, but no monitoring took place. Hundreds rather than thousands of chicks probably survived based on reports of hundreds of offspring at Fisher's Pan and late breeders being unsuccessful (J. van de Reep, personal communication). More intensive annual monitoring occurred in the last 15 years, and no major breeding events nor rainfall above 495 mm have been recorded through 1995 (Fig. 1). The year 1994 was fairly typical: 435 mm of rain fell on the pan, with a peak in January that brought thousands of flamingos from their coastal wintering areas. Many birds began breeding in March, but an aerial survey in April revealed thousands of dead chicks littering the breeding areas (C. Brain, personal communication). No young survived because no gray juveniles occurred at the coast in the 12 months following the breeding season (Simmons, unpublished data). Hence, in the last four decades approximately 89,000 chicks were produced (Table 2) and average rainfall was 389 ± 118 (1 S.D.) mm per rainy season. Most egg laying (15 of 17 events) took place when precipitation was over 400 mm, and successful breeding most likely took place in a precipitation window between 440 and 600 mm. Thus, Etosha's mean rainfall is marginally below the threshold required for breeding (400 mm).

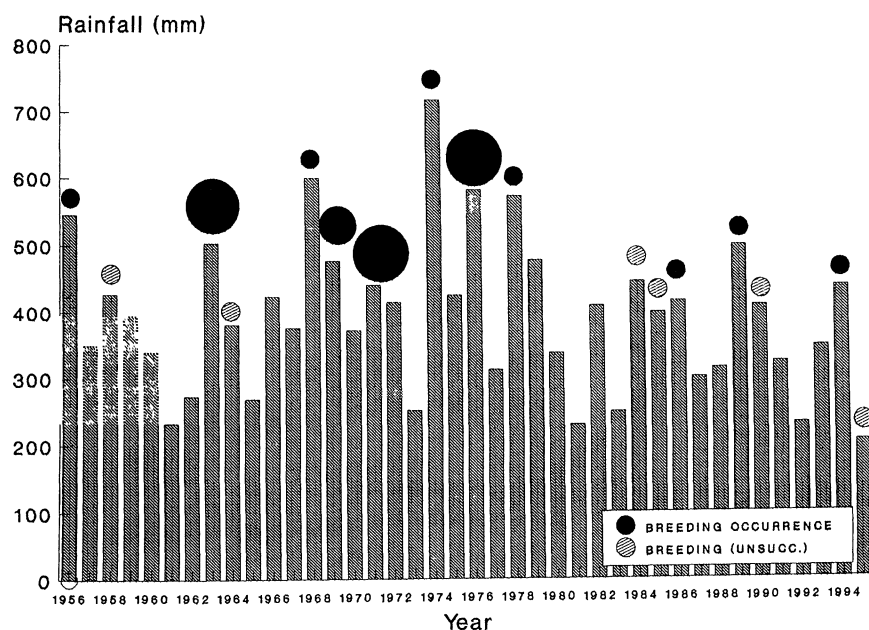


Figure 1. Rainfall patterns over the last 40 years in the Etosha National Park in relation to suspected and proven breeding events by flamingos. Breeding occurrence symbols (from small to large) indicate, respectively, eggs but not chicks (hatched circle), chicks but few fledged young (smallest filled circle), hundreds of fledged young and thousands of fledged young (largest filled circle). Mean rainfall for the whole period was 389 mm per rainy season (August to May).

Table 2. Summary of the estimated maximum numbers of young produced on Etosha Pan from 1956 to 1994 based on estimates from conservation officials, the rainfall regime, and extrapolations from accurate estimates of productivity in 1969, 1971, 1986, 1989, and 1994.

Year	Rainfall (mm)	Estimated number fledged (max)*
1956	546	< 1000
1963	503	20,000
1969	475	1000
1971	439	11,000 Greater, 22,000 Lesser
1974	715	< 200
1976	580	33,000
1978	571	< 1000
1979-1995	358 (205 to 496)	no young fledged

*Estimated young fledged in 40 years = 89,200 (species combined). Known young fledged in last 17 years = 0.

Population Size and Recruitment

The average number of adult flamingos occurring in southern Africa during the period 1980 to 1994 was estimated in two ways, giving similar results. The instantaneous count of breeding birds on the Etosha Pan by Berry (1972) was 81,000 birds, both species combined. However, 60,000 nests (i.e. 60,000 pairs) occurred putting the possible total at about 120,000 birds. Similarly, in the early 1980s Cooper and Hockey (1981) and Williams (1986) estimated 115,000 individuals of both species, most of which occurred in Walvis Bay and Sandwich Harbour (Whitelaw et al. 1978; Williams 1986; Simmons 1991). These figures were a result of summer ground counts throughout the coastal regions of South Africa and Namibia that did not encompass inland areas. They are therefore only minimum estimates. If 90% of this total was adult birds (based on proportions during 4 years of monitoring in Namibia), then about 104,000 birds or 52,000 pairs were resident. The average number of flamingos in the 1970s and early 1980s thus fluctuated between 52,000 and 60,000 pairs, an average of 56,000 pairs (112,000 birds).

With these data it is possible to estimate the maximum recruitment of pairs (species combined), assuming that the average adult population size was 56,000 pairs and that 89,000 young were produced in 40 years on Etosha Pan. The possible recruitment at 1.59 young per pair per 40 years is 0.040 young per pair per year. This is an extraordinarily low recruitment rate even if all young birds survive to breed. Assuming that all young survive and that 30,000 (not 1000) young were recruited in 1978, the maximum recruitment rate is 119,000 young from 56,000 pairs in 40 years, or 0.053 young per pair per year. This is seven-fold lower than the fecundity rate calculated by Johnson et al. (1991) for European populations to remain stable. These authors also estimated that survival from fledging to adulthood (5 years old) is 46.06% (Johnson et al. 1993). Hence the likely recruit-

ment rate of Etosha breeders is 46% of that calculated above, or 0.024 young per pair per year.

A low rate of recruitment may prove adequate for population stability if flamingos are sufficiently long-lived. The oldest captive bird known is 52 years old, and the oldest wild bird was last seen in Europe at 33 years 10 months (Johnson 1992a). Given their great longevity, perhaps low recruitment is a life-history trait typical of this family and one easily accommodated by the species' reproductive strategy. For a pair breeding for 10 years their lifetime recruitment, assuming all fledged young survive to breed, would average 0.40 young (10×0.040 young/pair/year). Maximum possible recruitment would be (10×0.053 young/pair/year) or 0.53 young per pair. Likely recruitment based on 46% survival of young to adulthood (Johnson et al. 1991) reduces the 10-year reproduction to 0.24 young. Lifetime productivity for a pair breeding for 20 years (0.49 likely, 0.80 possible, and 1.1 young, maximum; Fig. 2) is still less than that needed for replacement (2.0 young). Pairs would have to breed for an improbable 38 years (maximum recruitment) to 83 years (likely recruitment) to replace themselves (Fig. 2). Thus it seems unlikely that breeding adults at Etosha replace themselves; therefore, the Etosha Pan cannot be considered a viable breeding area for flamingos.

Other Breeding Areas in Africa

That movements do sometimes occur between breeding areas in East and southern Africa is apparent from the one million flamingos estimated on Etosha Pan in 1971 (Berry 1972); the resident population accounted for about 115,000 of these birds (Cooper & Hockey 1981; Williams 1986). This and large numbers occasionally present on Sua Pan (Anonymous 1990) constitute circumstantial evidence that southern African populations are not completely isolated. Given the limited possibility of immigration from elsewhere, are these source areas secure and viable? Although the main feeding grounds in Lakes Nakuru and Bogoria in East Africa are national parks, neither Lake Natron, the main breeding ground, nor Lake Magadi have any formal protection. Similarly, Sua Pan in the Makgadikgadi Pans of Botswana remains unprotected. Flamingos are exposed to increasing industrial pollution in traditional breeding sites such as Lake Nakuru, Kenya (Brown 1971; Hopcraft 1975), and recent dam developments on the inflows to Lake Natron, the most important of the rift valley breeding grounds, threatens to disrupt regular breeding there (Anonymous 1993; Johnson & Bennun 1994). Recent proposals to mine soda from the center of the breeding area in Tanzania adds a further disturbance factor (Anonymous 1993). Similarly, mining soda ash from Sua Pan (Anonymous 1990; T. Liversedge, unpublished data) may disturb flamingos there (Anonymous 1990; Aves 1992), even



Figure 2. The number of years that flamingo pairs need to breed at Etosha in order to replace themselves (to produce 2.0 young). Three recruitment levels are shown: maximum recruitment (100% fledgling survival and all suspected breeding successful), possible recruitment (100% survival and suspected breeding unsuccessful), and likely recruitment (46% survival to adulthood and suspected breeding unsuccessful).

though breeding attempts by Lesser Flamingos have been relatively high in the last 5 of 7 years (T. Liversedge, personal communication). As it becomes better known this unprotected colony may face threats from sightseers on four-wheel motorbikes. Similar disturbances leading to breeding failure occur elsewhere (Allen 1956; Johnson 1989) and have prompted swift and long-term intervention in Europe (Johnson 1975). The Botswana pans have experienced slightly higher rainfall and more flamingo breeding attempts than Etosha recently, but they suffer the same rapid drying and reproductive failure apparent in Etosha. For example, no recruits occurred at the Namibian wintering grounds following reports of 30,000–40,000, Lesser Flamingo chicks about 1 month old in 1994 (last Botswana aerial census [T. Liversedge, personal communication]). Because water on the pan was then scarce it is likely that all young died of starvation after the survey. Thus, Etosha Pan is possibly the only undisturbed, pollutant-free, formally protected flamingo breeding site in Africa, yet it is a nonviable breeding ground.

Given that breeding is poor on Etosha Pan and that other sites are experiencing increased threats, is there evidence for an overall population decline? Southern African flamingo populations in the mid 1970s and early 1980s numbered 60,000 Greater and 55,000 Lesser Flamingos (Cooper & Hockey 1981; Williams 1986). Recent national censuses in Namibia, South Africa, and Botswana (Perennou 1992; Taylor 1993) reveal that in July 1991, 56,000 individuals of both species were present in southern Africa. Because birds may have been inland on flooded pans, a more accurate assessment is provided by the January 1992 count, when 78,000 birds were re-

corded in southern Africa (Perennou 1992). In January 1993 Walvis Bay (A. Williams, unpublished data), all other Namibian wetlands (R. Simmons, unpublished data), and South African wetlands (J. Harrison, personal communication) held 72,951 birds of both species (Table 3). Although movements do occur, these three recent figures suggest a 35% decline from 115,000 birds to about 75,000 birds. This is in accord with the very low recruitment from Etosha Pan for the last four decades. The aerial counts from Botswana (T. Liversedge, personal communication) during breeding in February 1993 indicate a higher total of 36,000 Greater and 98,900 Lesser Flamingos. These figures may represent migrants from elsewhere, however, and aerial counts are known to produce higher totals than ground counts. Thus, these numbers cannot be compared directly with national counts elsewhere.

The recent Africa-wide counts (Taylor 1993) also allow a reassessment of the 1975 figures for flamingo populations throughout Africa computed by Kahl (1975). He estimated 165,000 Greater Flamingos in Africa (75,000 southern Africa; 50,000 East Africa; 40,000 northwest Africa). Present estimates (Table 3) indicate only 85,000 birds, an apparent decrease of 48%. Namibia, with 40,012 Greater Flamingos, holds 47% of the African population and 84% of the southern African population (40,012 of 47,427 birds). Among Lesser Flamingos, Kahl (1975) estimated 6 million birds, which was altered to just over 5 million birds because he incorrectly assumed that 1 million birds were resident in Namibia. I replaced Kahl's estimates with the 55,000 estimate of Cooper and Hockey (1981). Hence 5,056,800 Lesser Flamingos were recorded in Africa in 1975 (Table 3). According to 1993

ground counts and one 1994 aerial survey (Howard 1994) about 4 million Lesser Flamingos occur in Africa today, an apparent decline of 21%. Namibia (with 23,671 birds) holds less than 1% of the African population yet 93% of the southern African population (25,524 birds). Because all major breeding and feeding areas were covered by the 1993 count, the apparent declines either arise from overestimates by Kahl (1975) or they are real declines. Because southern African populations also appear to have simultaneously decreased by 35% and world-wide declines have been noted by del Hoyo et al. (1992), it is probable that the decreases are real and not artifacts.

Discussion

Breeding Strategies

Of the two species, breeding in Lesser Flamingos is more likely to fail than in Greater Flamingo because they require more saline conditions (Brooke 1984) and breed later, by which time the rains have ended and water is already receding. They thus rely on residual water. Despite fledgling Lesser Flamingos appearing at their non-breeding grounds in coastal Namibia, no Lesser Flamingos have bred on Etosha since 1985 (T. Archibald, personal communication), and they have never bred successfully in South Africa (Broekhuysen 1975). These birds are therefore probably offspring from birds breeding on Makgadikgadi Pan (Hancock 1990; T. Liversedge, personal communication). In Botswana Lesser Flamingos adopt a different strategy and breed on barely flooded pans in anticipation of rains. Fewer Great Flamingos breed because they delay until the raised calcrete "islands" become completely surrounded by water (T. Liversedge, personal communication). Sporadic nest building on the cool Namibian coast at the Cape Cross

salt pan has always proven unsuccessful (C. Clinning, personal communication), even though coastal breeding birds are known from Mauritania (Johnson 1992b).

Rescue Operations

Previous conservation measures have been aimed at short-term solutions to "rescue" stranded chicks. The first publicized attempts were made in 1963, when thousands of chicks became stranded as waters on the Etosha Pan receded (Winterbottom 1964). The pan receives over 400 mm of rain (the apparent threshold for any breeding; Fig. 1) only once every 2 years, and successful breeding generally requires over 440 mm (Berry 1972; Fig. 1). There has been 440 mm of rain only nine times in the last four decades (Fig. 1). High evaporation rates of approximately 2.6 m per year (van der Merwe 1983) contribute to the rapid disappearance of water. Another operation to save stranded chicks was undertaken in 1969, in which about one fifth of 100,000 flightless young were rounded up (Berry 1972). The final mortality was unknown, but all 80,000 of the unaided young probably perished, as did some of the "rescued" young. Again in 1986 (Archibald & Nott 1987) young flamingos were found dying on the pan because of lack of water; 1200 were "rescued" from an estimated 5220 nesting attempts. None survived.

In 1989 about 3000 pairs of flamingos built and abandoned their nests. Later 800 young became stranded as the water evaporated. Of these, 765 chicks were captured, and most were donated to zoos and bird parks (Archibald 1991). These birds experienced a relatively low mortality rate (A. Arbrey, personal communication).

In 1994, 130 flightless young were caught and artificially fed for a month and sold or released. The 77 color-marked birds were released at their coastal wintering grounds and suffered 100% mammal-related mortality. The thousands of remaining chicks all perished. Similar

Table 3. Africa-wide population estimates of Greater and Lesser Flamingos from January 1993 and 1994.^a

Region	Greater	Lesser	Source	1975 numbers ^b	
				Greater	Lesser
West Africa ^c	5848	3093	Taylor (1993)	40,000	1800
East Africa ^d	31,814		Taylor (1993)	50,000	5,000,000
		4,000,000	Howard (1994)		
Southcentral Africa ^e	18,397	8240	Taylor (1993)	75,000	[1,000,000] ^f
South Africa ^g	29,030	17,284	J. Harrison (personal communication)		55,000
Totals (1993-1994)	85,089	4,028,617	Totals (1975)	165,000	5,056,800

^aAll major breeding/wintering areas are included. Comparisons are made with estimates from 1975.

^bFrom Kahl (1975).

^cThe Gambia, Mauritania, and Senegal.

^dEthiopia, Kenya, Sudan, and Uganda.

^eBotswana, Madagascar, Namibia (excluding Walvis Bay).

^fInappropriate estimate based on 1,000,000 recorded once in Namibia in 1971, replaced with 55,000 birds recorded by Cooper & Hockey (1981).

^gIncludes Walvis Bay (now Namibian); Lesser Flamingo numbers in southern Africa fluctuate more than those of Greater Flamingos.

operations elsewhere, dealing with smaller numbers, have had some success (Boshoff 1979), but hand-rearing chicks is time consuming, is rarely successful (Berry & Berry 1976), and thus probably contributes nothing to future generations.

These rescue operations also result in considerable scarring of the water-logged pan. Large flat-bed trucks used for transport of captured flamingos in early operations left tire tracks over 30 cm deep that remained visible for years (J. Lensen, personal communication). Such scarring would occur repeatedly if future operations to save stranded chicks are mounted. Similarly high evaporation rates, mass die-offs, and failed rescue operations are characteristic of the Makgadikgadi Pans in Botswana (T. Liversedge, personal communication).

In summary, rescue operations (1) are generally unsuccessful, (2) are expensive and time-consuming, (3) scar the main pan with tire tracks, and most important, (4) do nothing to alleviate the cause of a long-term problem. The cause,—the natural drying of the pan—results in the low recruitment of two red data species.

Future Conservation Options

Given that Namibia holds the majority of southern Africa's flamingos and that Etosha is a protected yet nonviable breeding ground, several options are open for future conservation to assist declining populations. It is clearly essential to (1) understand the causes of decline, (2) identify successful conservation options that have been attempted elsewhere, and (3) determine whether such measures are feasible in Namibia.

It is apparent that the most probable cause of flamingo decline in southern Africa is low recruitment. There is no evidence to suggest that birds on nonbreeding grounds in coastal Namibia are suffering high mortality: both major areas (Sandwich Harbour and Walvis Bay) are protected, regularly counted, and large enough to accommodate more birds. Minor mortality occurs only from jackal (*Canis mesomelis*) predation at Sandwich Harbour, and no disease has ever been reported from either area. There is also no impending development that might degrade these areas. Hence, conservation is best focused on enhancing the breeding areas.

In southern France *P. ruber* exhibits similar population patterns and has limited breeding sites. Management of the Tour du Valat Biological Station in the Camargue, in collaboration with a local salt extraction company, created several islands permanently surrounded by water where flamingos frequently attempted to breed but were often unsuccessful. By constructing artificial nests from upturned buckets of mud and clay, Johnson (1975) and co-workers were able to induce almost 3000 pairs of flamingos to breed. France supports the only regularly breeding population of

Greater Flamingos in Europe, despite their widespread occurrence throughout western Europe and West Africa (Johnson 1989). Over the last 15 years this project has produced 2000–8590 young flamingos annually (Johnson et al. 1991).

Given the immense success of the French initiative, would a similar project be feasible in the main African breeding grounds? In Kenya and Tanzania many of the main soda lakes are inhospitable, and some are so inaccessible that the breeding area, Lake Natron, was not discovered until 1954 (Brown 1957). Thus, protection is probably the best alternative. Southern African sites, by contrast, are generally dry for much of the year, and size rather than the inhospitable environment is the limitation to conservation initiatives.

In June 1992 an artificial island was proposed for Etosha. The island was to be situated on a small pan to the west of the main pan for experimental purposes and surrounded by saline water for the duration of flamingo breeding. An experimental and implementation phase was proposed. Geomorphological investigations revealed permanent ground water at about 80 cm below the surface and a clay layer over 1 m deep. The pan's clay is 1.2 to 1.5 m deep and underlain by an impermeable limestone layer at least 38 m deep (M. Buch, personal communication). Hence, ground water would be available if rains did not naturally fill the proposed depression, and earth moving on the pan would not "puncture" the impervious layer and drain surface water. If successful, the idea could be implemented on the main pan at the Ekuma River inlet—(a known feeding area)—tapping water from the inflow and thereby allowing birds to breed in phase with naturally occurring rains and floods. There would also be little interference with the natural flooding of the pan. Private sponsorship was arranged, but various objections prevented implementation.

Such management may not be feasible in Etosha for several reasons.

- (1) Building an island may not attract flamingos. This is unlikely because of the continued success of the Camargue site and the ability of "artificial" mud nests to attract birds.
- (2) The proposed colony of 4000 pairs may not add significantly to breeding productivity. Assuming flamingo pairs require an area of 0.5 to 0.8 m² for nesting (Johnson 1975; Berry 1975), an island of 2000 m² (100 m long by 20 m wide) would provide breeding space for up to 4000 pairs. If about 50% of all nests are successful (Berry 1972) over 10 years, 20,000 young would be produced. This compares well with a natural productivity from a maximum of 27,000 pairs breeding at any one time (Berry 1972), at a maximum recruitment rate of 0.054 young per pair per year, of 14,580 young in the same period. Thus, the colony would produce

more chicks than would be produced naturally in the same period;

- (3) The colony would be out of synchrony with other breeding birds (mass courtship displays are a feature of wild birds [Brown 1971; del Hoyo et al. 1992], and a satellite colony may not attract sufficient numbers of birds). Because the rains and subsequent river flow would fill the surrounding depression, the island would attract birds only at the time they typically arrive at Etosha and begin breeding. Hence, synchrony would be achieved. Also, breeding is often successful in captivity without mass courtship displays (Kear & Duplaix-Hall 1975; del Hoyo et al. 1992).
- (4) Food availability would be insufficient. The "moat" of 100–200 m radius would not be the only food source. Nearby feeding would be available on the surrounding pan and in the lower-lying Ekuma River adjacent to the colony, where water remains for many months.
- (5) Predators would prevent or disturb breeding. The flooded moat (60 cm deep) surrounding the island would hold water for the duration of breeding (about 3.5 months for both *P. ruber* and *P. minor*, Berry 1972) and would act as a predator deterrent. Persistent individual predators could be captured and moved elsewhere. Flamingos do breed naturally on the pan without undue harassment from mammalian predators (Berry 1972), so the flooded area alone should prove a sufficient deterrent. Jackals, the most likely terrestrial predator of flamingos in Etosha, are known to avoid deep water in other areas where they interact with flamingos (P. Tarr, personal communication). Other mammals have access to water at natural springs in Etosha and are unlikely to be attracted to saline water. Marabou Storks (*Leptoptilos crumeniferus*), a major predator at Rift valley colonies in Kenya (Brown 1957), are present only in small numbers in Etosha Park.
- (6) Earth moving may promote anthrax outbreaks. The possible threat of the anthrax bacillus in excavated gravel pits in Etosha was given wide publicity 10 years ago. Two recent reports, however, conclude that standing water and gravel pits are not a source of anthrax as previously assumed (Turnbull 1989; Turnbull et al. 1989; P. Lindeque, personal communication). Further, no evidence that dense breeding colonies promote disease has emerged from either the Camargue colony or from any breeding studies in southern Africa. Thus neither anthrax nor other diseases seem likely.
- (7) Active intervention will destroy Etosha's pristine state. The criticism that intervention is "tampering with a pristine system" has been mentioned more often than any other. This is ironic because Etosha

Park, like other national parks in Africa, has hundred of kilometers of fencing and numerous artificial water holes, and its large mammals are routinely tagged, darted, sterilized, translocated, culled, or sold (Orford et al. 1988; Panagis & Stander 1989; Stander et al. 1990; Lindeque 1991; Morkel & Geldenhuys 1989; Scheepers & Venzke 1993). More important, the main pan itself has already been altered—for the benefit of tourists—by the addition of a drive-on road on the southern pan with an overall area of 12,800 m². A breeding island covering no more than 125,000 m² on a pan of 4800 km² is insignificant.

Conclusions

This paper has provided evidence that flamingo populations across Africa and particularly in southern Africa have declined since the mid 1970s. The probable cause is the highly infrequent breeding of birds on one of only two major sites in southern Africa, the Etosha Pan. I have also shown that Namibia holds over 80% of the southern African population of Greater Flamingos and 90% of its Lesser Flamingos, yet the main breeding area is at the very edge of the rainfall threshold required for regular and sustained breeding. Although breeding attempts occur more often in Botswana, high evaporation and mass mortality are as frequent as in Etosha, and recruitment is low.

Conservation efforts to date have focused on saving chicks when they start to die, rather than on long-term measures, and most young birds rescued in such interventions perish. Based on the success of enhanced breeding in southern France, through the provision of safe nesting sites, I suggest that the downward trend in flamingo numbers can be immediately reversed with a similar scheme in the Etosha National Park. Many of the initial problems can be overcome with careful siting of the island to tap natural flood waters, and with careful monitoring of experimental and construction phases. Overcoming the concerns of natural-area preservationists is by far the biggest hurdle to clear in constructing a nesting site. Setting aside natural areas where rare and endangered species occur may not be sufficient to secure their future, and there may be a role for active intervention in cases where it is apparent that habitat preservation is insufficient. Clearly, the answer cannot be generalized: for some species habitat preservation is sufficient, for others habitat enhancement is required. When the habitat is so specialized that it only occurs within national parks, conflict can arise. We should make full use of the remaining habitat fragments to maximize the chances of survival of those species entirely reliant on them. This is particularly important in cases in which no other breeding grounds are nationally pro-

tected and the habitat so specialized that successful breeding occurs in very few sites. The success of the Camargue colony shows that an "artificial" colony could alleviate the problem of mass mortality. An artificial colony would not prevent birds from breeding elsewhere when major rainfall (> 400 mm) does occur.

The potential benefits of creating the artificial island are multi-faceted. It would provide potential nesting areas for two imperiled species that breed at only one other area on the subcontinent. Flamingo chicks would not perish for lack of food and water because they would be available until the birds fledged. Money spent on rescue operations could be redirected to constructing a long-term breeding site. Finally, tourism, one of Namibia's top money earners, would be enhanced by the only consistently breeding flamingo colony in southern Africa.

As natural ecosystems are fragmented and degraded, it is important to utilize our national parks to their maximum potential without destroying the essential characters they embody. The manipulation of Etosha's 4800-km² main pan by adding a breeding island no larger than 0.125 km² would have minimal aesthetic impact and considerable conservation benefits. As the first management plan proposed for Etosha National Park's avifauna it has the potential to add significantly to the long-term viability of two species whose alternative breeding areas in Africa are neither protected nor free of disturbance.

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