# Waterbirds around the world

## A global overview of the conservation, management and research of the world's waterbird flyways

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*Cover photography:* Whooper Swans *Cygnus cygnus* arriving at Martin Mere, England. Photo: Paul Marshall. (www.paulmarshallphotography.com)

# Satellite tracking documents the East African flyway and key site network of the Lesser Flamingo *Phoenicopterus minor*

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## ABSTRACT

The itinerant Lesser Flamingo *Phoenicopterus minor* is dependent on a network of specialized sites for its survival. To study the movements of individual birds and define this network in East Africa, four adult male Lesser Flamingos were tagged with satellite transmitters (PTTs) at Lake Bogoria, Kenya, in October 2002. During the first 15 months, there was no significant difference in the length of their inter-lake flights. However, there were significant differences in the number of flights and the number of days spent at each stopover. One bird flew 2 964 km, making 20 visits to eight different lakes (mean stay 21.8 days), while another made 18 visits to six different lakes (mean stay 24.1 days), flying 3 012 km. A third bird moved among lakes 70 times, visiting 11 different lakes (mean stay 6.4 days) and flew 7 870 km. The fourth bird's PTT stopped transmitting after 38 days. There were no flights outside East Africa. The flyway for the Lesser Flamingo in East Africa consisted of a 940 km north-south range between Lake Logipi, Kenya, and Lake Bahi, Tanzania. The network of sites used by the study birds consisted of nine alkaline lakes in Kenya and Tanzania. The conservation status of these nine sites varies from well-protected to completely unprotected.

## INTRODUCTION

The Lesser Flamingo *Phoenicopterus minor* is the smallest and most numerous of the world's six flamingo species, and is estimated to number between 2 220 000 and 4 230 000 individuals (Wetlands International 2002). It occurs in four regional populations in Africa and central Asia, the largest of which (2.0-4.0 million birds) occurs on the alkaline lakes of East Africa (Wetlands International 2002). Hundreds of thousands of birds frequently gather on these lakes in Kenya and Tanzania (Brown 1975, Vareschi 1978, Howard 1994), a spectacle that is vital to eco-tourism in this region.

The species is classified by IUCN as Near Threatened, due to its dependence on a limited number of unprotected breeding sites and a narrow range of required breeding conditions that occur irregularly and infrequently (BirdLife International 2000). The East African population is known to have bred successfully at only one location during the past 40 years, Lake Natron in Tanzania, and this lake, on the border with Kenya, is unprotected. Schemes such as the recently proposed soda-ash extraction business and hydroelectric power generation at Lake Natron could result in rapid population declines (BirdLife International 2000).

The Lesser Flamingo is an itinerant species (Evans 1985), moving frequently and unpredictably from lake to lake within the Rift Valley (Brown 1975, Vareschi 1978, Tuite 1979, Brown *et al*. 1982, Tuite 2000), and between salt pans and other wetlands in southern Africa (Borello *et al*. 1998, McCulloch *et al*. 2003), but returning to the same breeding sites. The frequent inter-lake movements have traditionally been thought to be associated with fluctuation in food abundance (Vareschi 1978, Tuite 1979). However, it is not clear that this alone is responsible. At Lake Bogoria, the Lesser Flamingo population can double or halve during periods as short as two weeks, despite a constant density of *Arthrospira fusiformis*, the Lesser Flamingo's primary food in East Africa (Brown 1975, Vareschi 1978, BC unpubl. data). Other hypotheses have included changes in the availability of fresh water, changes in the conductivity of the lake water, movement to breeding sites, and disturbance by predators (Vareschi 1978). However, with the exception of movement to breeding sites, none of these hypotheses seemed viable to Vareschi (1978).

Historically, it was thought that the three African populations of the Lesser Flamingo were separate and that no regular interchange took place (Brown 1973). However, circumstantial evidence has been assembled to show that East African Lesser Flamingos may fly to Botswana and Namibia to breed during periods when the Etosha and Makgadikgadi salt pans are flooded (Tuite 1979, Borello *et al*. 1998, Simmons 2000, McCulloch & Borello 2000), and that there may be interchange between the West African and other African populations (Trolliet & Fouquet 2001). However, very little is known about the movements of individual Lesser Flamingos. The only previous study to use satellite tracking was by McCulloch *et al*. (2003), who followed three Lesser Flamingos in southern Africa.

The primary aim of the present multi-year study was to use satellite tracking to document the flyway and network of key sites used by this Near Threatened species in East Africa during different periods of the year to support the development of an effective international site conservation plan. Secondary aims were to improve understanding of the movements of individual Lesser Flamingos and document whether there was any regular interchange between the East African population and the smaller populations elsewhere in Africa and India.

## STUDY SITE

This study was based at Lake Bogoria in Kenya (0°11'-0°20'N, 36°06'E), located within the Lake Bogoria National Reserve, a

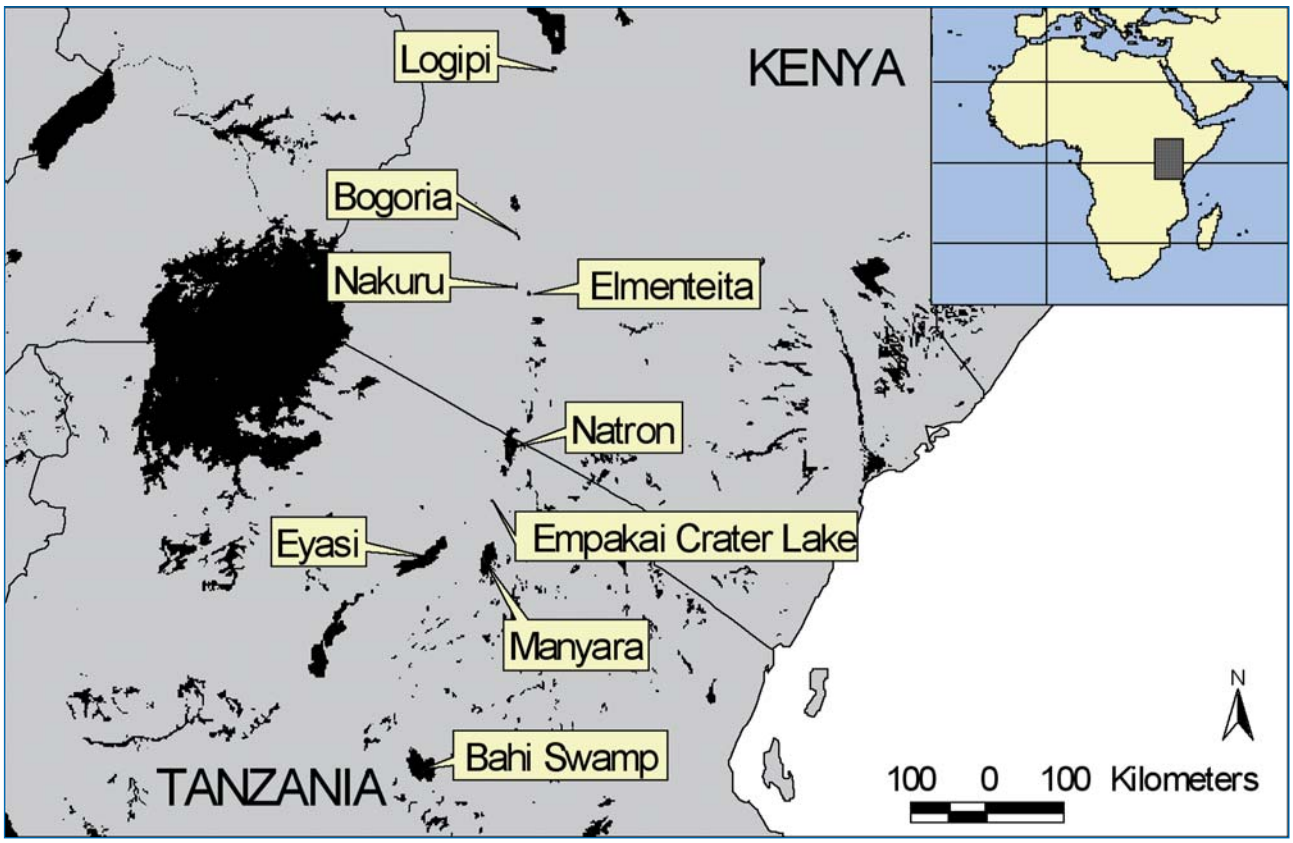


**Fig. 1.** Key sites for Lesser Flamingos *Phoenicopterus minor* in East Africa: November 2002 – January 2004.

protected area of 10 700 ha (Bennun & Njoroge 1999), 64 km north of Nakuru town in the eastern Rift Valley (Fig. 1). A recently-designated Ramsar site, Lake Bogoria is one of the two main feeding lakes for the Lesser Flamingo in Kenya, and regularly holds several hundred thousand birds. It is a long (16 km), narrow (3 km), shallow (max. depth 10.2 m), alkaline (1 160 ± 14.2 meq $l^{-1}$) lake with a pH of 10.2-10.3, situated at 975 m above sea level (Harper *et al*. 2003, Vareschi 1978).

## METHODS

In October 2002, four adult male Lesser Flamingos were captured and tagged with satellite transmitters (PTTs): two with solar-powered PTTs and two with battery-powered PTTs. The birds were captured using loops of 50 lb test polyethylene fishing line attached to a 120 x 245 cm grid of 3 mm wire mesh squares (7.5 x 7.5 cm) (Childress *et al*. 2004). Approximately 50 loops were tied to the grid. The grid was placed in the water perpendicular to the shoreline in a shallow, flat area where flamingos gathered and walked back and forth. The birds were captured when their feet became entangled in the loops.

Microwave Telemetry, Inc. supplied the two battery-powered PTTs. They were PTT-100 45 g units with estimated transmission lifetimes of 1 200 hours. The pre-set duty cycle specified for both was eight hours on and 60 hours off, which was estimated to result in operational periods of approximately 15 months. These units represented 2.2% and 2.3% of the body mass of the birds to which they were affixed. The two solar-powered PTTs had been reconditioned by their manufacturers, North Star Science and Technology, LLC, and Microwave Telemetry, Inc., respectively. The duty cycle of the North Star PTT (weight 40 g) was pre-set to be on for eight hours and off for 18 hours. As a test, the Microwave Telemetry PTT (weight 35 g) had no pre-set duty cycle. With no pre-set duty cycle, the PTT shuts itself off when its battery power is low, and then restarts automatically every six hours. If its battery has recharged sufficiently, it continues to transmit; if not, it shuts down for another six hours. These PTTs represented 1.6% and 1.9% respectively of the body mass of the birds to which they were affixed, and were expected to have operational lifetimes of three to five years.

We used a "backpack" harness specially designed for multi-year studies of large birds such as storks and flamingos (Van den

**Table 1. Summary of number of inter-lake flights, number of different lakes visited, mean number of days spent at each stop, and approximate total distance moved by three satellite-tagged adult male Lesser Flamingos *Phoenicopterus minor* in the Rift Valley, East Africa, November 2002 – January 2004.**

| Bird | No. inter-lake flights | No. different wetlands visited | Mean days spent at each stop ± SD (range) | Approx. inter-lake distance flown |
|---|---|---|---|---|
| Safari | 18 | 6 | 24.1 ± 28.4 (1-87) | 3 012 km |
| Bahati | 20 | 8 | 21.8 ± 34.1 (2-137) | 2 964 km |
| Imara | 70 | 11 | 6.4 ±15.1 (0-110)* | 7 870 km |

* 0 = less than one day

**Fig. 2.** Lesser Flamingo *Phoenicopterus minor* ready for release at Lake Bogoria, Kenya, showing position of PTT. Photo: Richard Webster.

Bossche 2002), consisting of 3 mm braided nylon cord inside a Teflon sleeve (Childress *et al*. 2004). The PTTs were positioned as high as possible on the birds' backs (Fig. 2). We fitted the harness to allow all four fingers of a flat hand to pass easily between the transmitter and the bird.

Argos CLS (Collecte Localisation Satellites) in Ramonville Cedex, France, calculated and reported the locations of the study birds utilizing the National Oceanic and Atmospheric Administration (NOAA) satellite system to receive transmissions from the PTTs. Argos's multi-satellite service was used to enable location calculations from all six satellites that passed over the Rift Valley regularly during the study.

We used locations in Argos's classes 0-3 (0: >1 000 m with no upper limit; 1: 1 000 m; 2: <350 m; 3: <150 m; Taillade 1992), as our purpose was only to identify the lake or wetland being used by the study birds during each transmission period. The length of each stopover visit was determined by subtracting the first date a location calculation was received from that lake (assumed date of arrival) from the first date a location calculation was received from a succeeding lake. We assumed that the date of departure from one lake and date of arrival at a new lake were the same, although this may not have been the case in all instances, as we were unable to tell when a movement was made if it was made when the PTT was in its "off" phase (60 hours out of every 68 hours). In most cases, the distance between the lakes and the quality of the location calculations were sufficient to determine that the bird had indeed moved from one lake to another. However, in some cases, the quality of the location calculations received was too poor to enable us to distinguish between two locations that were fairly close to each other. In these cases, we assumed that the bird had not moved.

Statistical analyses of inter-lake flight distances and lengths of stopovers were conducted with Kruskal-Wallis and Mann-Whitney tests in Minitab Statistical Software, Release 13 (Minitab Inc. 2000), as these data were either counts (length of stopovers) and/or not randomly distributed (both). We named the four birds "Bahati", "Safari", "Imara" and "Bendera" for discussion purposes.

## RESULTS

### Inter-lake movements

Between November 2002 and January 2004, Safari made 18 inter-lake flights, visited six different lakes, spent 24.1 days (SD ±28.4) at each stop (range 1-87 days) and travelled approximately 3 012 km; Bahati made 20 inter-lake flights, visited eight different lakes, spent 21.8 days (SD ± 34.1) at each stop (range 2-137 days), and travelled approximately 2 964 km; Imara made 70 inter-lake flights and visited 11 different lakes and wetlands, spent 6.4 days (SD ±15.1) at each stop (range <1-110 days), and travelled

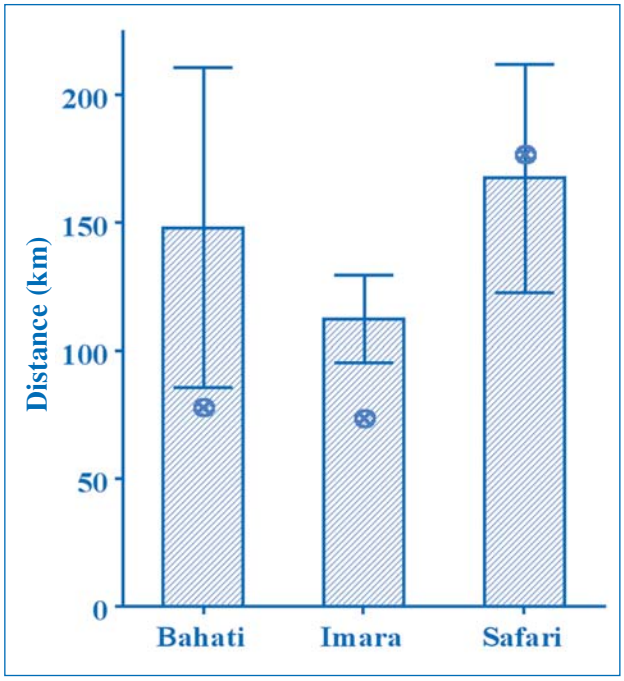


**Fig. 3.** Mean and median lengths of inter-lake flights by three Lesser Flamingos *Phoenicopterus minor*, with 95% confidence intervals for the means; cross-hair symbols are medians: November 2002 – January 2004.

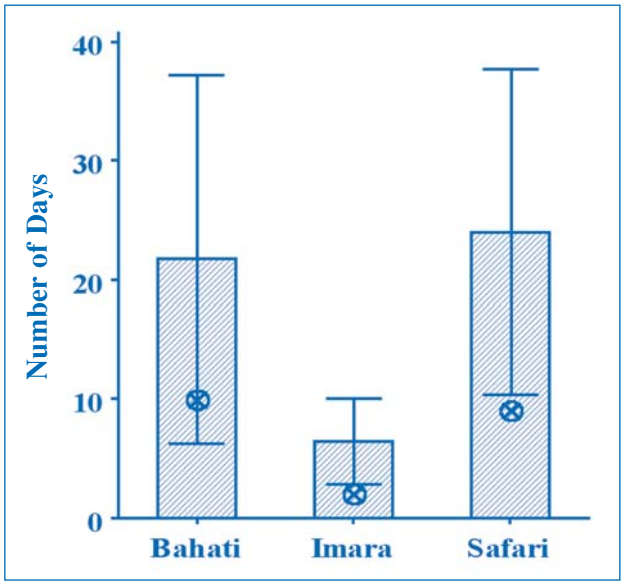


**Fig. 4.** Mean and median lengths of stopovers by three Lesser Flamingos *Phoenicopterus minor*, with 95% confidence intervals for the means; cross-hair symbols are medians: November 2002 – January 2004.

7 870 km (Table 1). Bendera's PTT stopped transmitting after 38 days at Lake Bogoria. The movement sensor on the PTT indicated no movement throughout the final day of transmission.

There were no significant differences among the three birds in terms of the length of their inter-lake flights ($H = 4.76$, $DF = 2$, $P > 0.05$ adj. for ties, $N_1 = 18$, $N_2 = 20$, $N_3 = 70$; Kruskal-Wallis Test), although there was a significant difference between Imara and Safari on this dimension ($W = 1\,018.5$, $P < 0.05$ adj. for ties, $N_1 = 18$, $N_2 = 70$; Mann-Whitney Test) (Fig. 3). There were significant differences among the three birds in terms of the number of days spent at each stopover ($H = 23.5$, $DF = 2$, $P < 0.001$ adj. for ties, $N_1 = 19$, $N_2 = 21$, $N_3 = 71$; Kruskal-Wallis Test), and these differences were between Imara and the other two birds (Fig. 4), as there was no significant difference between Bahati and Safari on this dimension ($W = 370.5$, $P > 0.05$ adj. for ties, $N_1 = 19$, $N_2 = 21$; Mann-Whitney Test).

### The East Africa flyway and key site network

Ninety-nine percent of all flights by the three study birds were within the Rift Valley along a 940 km range between Lake Logipi in northern Kenya and Lake Bahi in central Tanzania (Fig. 1). There were no flights outside these two countries.

The three birds spent 99.9% of their combined stop over days at nine alkaline lakes in Kenya and Tanzania (Logipi, Bogoria, Nakuru, Elmenteita, Natron, Empakai Crater, Eyasi Manyara and Bahi), and 73.1% on just four lakes (Bogoria, Logipi, Manyara and Nakuru).

## DISCUSSION

### Movements

During the first fifteen months of this multi-year study, the three tagged birds remained within the Rift Valley, travelling north and south along a 940 km range between Lake Logipi in northern Kenya and Lake Bahi in central Tanzania. They spent 99.9% of their combined time on alkaline lakes, Bahati moved between lakes 20 times, Safari moved 18 times, and Imara moved 70 times.

The reasons for these movements are still unclear. The birds moved independently of one another, and it was often the case that one of the tagged birds would depart from a lake within days of another arriving at the same lake, or that another remained on the lake for several days/weeks after the first bird had departed. This phenomenon has become more apparent with the addition of a further four tagged birds to the study in June-July 2003, and indicates that the movements are probably not related to major fluctuations in food availability. There are occasions, such as those reported by Tuite (2000) and Vareschi (1978), where substantial changes in food availability result in large-scale population shifts away from or towards one particular lake. However, these large-scale changes in food availability do not occur overnight (Vareschi 1978), and do not seem to be directly related to the daily arrivals and departures of Lesser Flamingos at a given lake. There may be seasonal patterns in the movements, related either to the rains or the annual breeding season (October-December) at Lake Natron, or both. However, too few data are available to form any conclusions at this stage. Although Lesser Flamingos bred in large numbers at Lake Natron during both the 2002 and 2003 breeding seasons, none of the tagged birds appeared to have made an effort to breed. During October-December 2002, two of the three tagged birds did not visit Lake Natron at all, while the third made seven visits to that lake, all of between one and three days in length. During October-December 2003, two of the three tagged birds did not visit Lake Natron, while the other visited the lake for 12 days in October and three days in November, but not at all in December. All four tagged birds added to the study in 2003 made one three-day visit to Lake Natron in November, but no visits in October or December. It appears that all of the study birds were non-breeders during these two years.

Although the number and frequency of movements by the three birds differed substantially between Bahati and Safari, and Imara, there was no significant difference in the length of their inter-lake flights. On the other hand, there was a significant difference between Bahati and Safari, and Imara, in the length of their stopovers, even though all three birds spent long periods of time (e.g. 45-137 days) at several different lakes.

The reasons for these differences in movement patterns are as unclear as the reasons for the inter-lake movements themselves. Since Lesser Flamingos rarely fly alone, all of the recorded movements are believed to have been made within flocks of other Lesser Flamingos. This confirms the general view that the Lesser Flamingo is a truly itinerant species. During the 15-month period reported here (and the subsequent period to March 2004), there were no flights outside Kenya and Tanzania, either by the initial three birds tagged or the four tagged birds added to the study in July 2003. Thus the study has provided no direct evidence as yet of any interchange between the East African population and any of the other smaller populations.

Conditions at the Makgadikgadi salt pans in Botswana and at Etosha Pan in Namibia during the 2002-03 breeding season were not conducive to Lesser Flamingo breeding, as it was a drought year and both locations were too dry for nest-building (G. McCulloch & R. Simmons *in litt.*). The 2003-04 breeding season was wetter, and Lesser Flamingo breeding occurred at both locations (G. McCulloch & R. Simmons *in litt.*). However, because there was breeding at Lake Natron during both 2002 and 2003, the finding that the tagged birds showed no interest in breeding at Lake Natron probably indicates that conditions in southern Africa had no effect on the movements of the tagged birds during these periods.

### Key site network: implications for protection and conservation

On a combined basis, the initial three tagged birds spent 99.9% of their time at nine alkaline lakes in Kenya and Tanzania (Logipi, Bogoria, Nakuru, Elmenteita, Natron, Empakai Crater, Eyasi, Manyara and Bahi), and these nine lakes, appear to comprise the key site network for Lesser Flamingos in East Africa. It has been known for many years that these nine alkaline wetlands are important for this species in East Africa (e.g. Bartholomew & Pennycuick 1973). This study documents their relative importance.

The conservation status of the nine lakes varies considerably. In Kenya, Lakes Bogoria and Nakuru are well protected, both being Ramsar sites and Lake Bogoria being entirely within a national reserve, while Lake Nakuru is within a national park. Lake Elmenteita is partly within a private wildlife sanctuary and partly unprotected (Bennun & Njoroge 1999). It is a small lake (1 800 ha) with several tourist facilities around its perimeter. Lake Logipi is completely unprotected and suffers from high levels of insecurity and overgrazing (W. Kimosop pers. comm.).

In Tanzania, the Empakai Crater Lake is well protected, being within the Ngorongoro Conservation Area. However, only

the north-western quadrant of Lake Manyara is within the Lake Manyara National Park. The remainder of the lake, where the Lesser Flamingos congregate most frequently, is outside the park and thus unprotected. Incredibly, Lake Natron, the only successful breeding location for the East African population of Lesser Flamingos during the past 40 years, is also unprotected. This lake has been threatened in recent years by proposals for a major dam and hydroelectric power generation project on one of the major inflows from Kenya and a new soda ash extraction scheme (BirdLife International 2000), and there is currently a proposal for a new tourist lodge and facilities along its shore (N. Baker *in litt*.). Lake Eyasi and Lake Bahi are not protected in any way, and their surrounding areas are under heavy pressure from deforestation, overgrazing and agriculture (Baker & Baker 2002, N. Baker *in litt*.).

In view of the critical importance of these nine sites to the survival of the Lesser Flamingo in East Africa, it seems clear that there is an urgent need to protect those sites that remain unprotected. Proposals for such protection will be included in the forthcoming AENA/CMS Flamingo Conservation Action Plan currently being prepared by the Wetlands International/IUCN-SSC Flamingo Specialist Group, and supported by the findings from this study.

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