SHORT COMMUNICATIONS

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POSTBREEDING MOVEMENTS OF FRIGATEBIRDS TRACKED WITH SATELLITE TELEMETRY

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Abstract. Using satellite telemetry, we studied the postbreeding movements of Great (*Fregata minor*) and Magnificent Frigatebirds (*F. magnificens*) at two breeding colonies in the Indian and Atlantic Oceans. After breeding failure, 67% of the birds with satellite transmitters remained on the breeding colonies and continued to perform foraging trips similar to those undertaken while breeding. Two Magnificent Frigatebirds that bred at a colony off the coast of French Guiana moved west along the coast of South America, and one of the two reached Trinidad 1400 km away. One Great Frigatebird moved 4400 km from Europa Island in the Mozambique Channel to the Maldive Islands. It roosted there for at least four months, making foraging trips of up to 240 km, mainly to an area known for its high concentration of tuna. These results show that frigatebirds are able to make rapid and directed long-distance dispersal movements to other colonies or roosting sites, although the majority of birds remain based on breeding colonies.

Key words: Fregata magnificens, Fregata minor, *French Guiana, Indian Ocean, satellite tracking.*

Movimientos Post-reproductivos de *Fregata* Seguidos con Telemetría Satelital

Resumen. Estudiamos los movimientos de *Fregata minor* y *F. magnificens* en dos colonias reproductivas de los Océanos Índico y Atlántico usando telemetría satelital. Luego del fracaso reproductivo, el 67% de las fragatas con transmisores satelitales permanecieron en las colonias reproductivas y siguieron realizando viajes de forrajeo similares a los que realizaron mientras estaban criando. Dos individuos de *F. magnificens* que criaron en una colonia mar adentro de la costa de la Guayana Francesa se desplazaron hacia el oeste a lo largo de la costa de América del Sur y uno de los dos llegó hasta Trinidad, a unos 1400 km de distancia. Un individuo de *F. minor* se desplazó 4400 km desde la Isla Europa en el Canal de Mozambique a las Islas Maldivas, y permaneció allí por lo menos por cuatro meses, realizando viajes de forrajeo de hasta 240 km, principalmente a un área conocida por su alta concentración de atún. Estos resultados muestran que las fragatas son capaces de dispersarse mediante movimientos de largo alcance rápidos y dirigidos hacia otras colonias o hacia dormideros, aunque la mayoría de las aves permanecieron en las colonias reproductivas.

Juvenile and adult pelagic seabirds are able to disperse over immense oceanic areas far from the breeding grounds. Satellite telemetry studies have shown that even when engaged in breeding activities (e.g., incubation or chick-rearing), pelagic seabirds make long-distance movements to reach distant food resources, foraging thousands of kilometers from their nests (Weimerskirch et al. 1993, 1999, Hamer et al. 2000, Gonzalez-Solis et al. 2000). After the breeding season birds are no longer tied to the breeding colonies, and are able to disperse over even greater ocean areas (Nicholls et al. 1996, Weimerskirch and Wilson 2000, Hyrenbach and Dotson 2001,

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Croxall et al. 2005). Although at-sea observations allow evaluation of the distribution of some species of seabirds outside the breeding season, they do not differentiate among the origins of the individuals observed. At present, the processes and patterns of dispersal at the individual level are poorly known, and information comes mainly from band recoveries.

Like other pelagic seabirds, frigatebirds can be found thousands of kilometers away from breeding colonies (Diamond and Schreiber 2002, Metz and Schreiber 2002, Dearborn et al. 2003), and during breeding they may forage hundreds of kilometers from the colonies (Weimerskirch et al. 2003, 2004). However, their inability to land on water means they spend their foraging trips entirely in flight (Weimerskirch et al. 2004), and rely on terrestrial sites to rest. Although most seabirds exhibit biparental care, in Magnificent (*Fregata magnificens*) and some Great Frigatebird (*F. minor*) populations, some males desert the chick after a variable fraction of the chick-rearing period, leaving the female to care for the chick for the remainder of the 9 to 12 months (Diamond 1975, Osorno 1996, 1999). Such a dramatic division of labor potentially allows males to disperse widely at sea, or move to other roosting colonies (Dearborn et al. 2003). Banding records suggest that frigatebirds visit other breeding areas, but rarely breed at sites other than their birthplace (Dearborn et al. 2003). It has been hypothesized that male Magnificent Frigatebirds may visit other breeding colonies after the desertion of their offspring and breed there (Osorno 1999). However, molecular studies do not support this hypothesis, at least in Great Frigatebirds (Dearborn et al. 2003). It is only recently that movements of breeding frigatebirds have been investigated (Weimerskirch et al. 2003, 2004), and postbreeding movements of frigatebirds are still unknown.

The purpose of this work is to document the extent of postbreeding dispersal in frigatebirds. Using satellite telemetry, we studied the postbreeding movements of Great and Magnificent Frigatebirds after offspring desertion or breeding failure in the Atlantic and Indian Oceans.

METHODS

Our study was carried out on Grand Connétable Island Nature Reserve (4°50′N, 51°56′W), off the coast of French Guiana, from 19 April to 5 May 2002 and 3–14 March 2003, and on Europa Island (22°18′S, 40°22′E) in the Mozambique Channel (Indian Ocean) between 18 August and 30 September 2003. Approximately 650 breeding pairs of Magnificent Frigatebirds nest on the ground on Grand Connétable Island, and 700–1100 breeding pairs of Great Frigatebirds nest in trees on Europa Island. Details of field studies are given by Weimerskirch et al. (2003, 2004). We observed all stages of breeding during our study periods, from egg-laying to rearing of large chicks. On Europa, study colonies were monitored daily in the afternoon, and on Grand Connétable colonies were monitored hourly from dawn to dusk at a distance of 30–50 m. Males and females were distinguished using plumage characteristics. Since frigatebird colonies are very sensitive to disturbance, birds were handled at night to avoid desertion or pirating of nest material. Birds were captured by hand and fitted with a satellite transmitter (PTT) before being returned to their nest after 3–5 min of handling. Using this technique we observed no desertion immediately following capture and transmitter attachment, with released birds always resuming their breeding activities. Breeding success in frigatebirds is typically very low (Diamond 1975, Diamond and Schreiber 2002, Metz and Schreiber 2002), and the rate of nest desertion is high (Dearborn 2001). Thus, we were able to study successive foraging trips of the same bird both during breeding and after breeding failure.

We fitted nine birds (two males and seven females) on Europa, and 11 birds (five females and six males) on Grand Connétable with PTT 100 satellite transmitters (Microwave Telemetry, Columbia, MD) during 2–17 successive foraging trips. Solar-powered transmitters weighed 18 g, and battery-powered transmitters weighed 30 g. PTTs with batteries transmitted continuously, and PTTs powered with a solar panel had a duty cycle of 10 hr on and 20 hr off. The heavier PTTs represented 1.2%–3% of adult body mass. Most transmitters were taped to the back or tail feathers using Tesa© tape, except for two solar-panel PTTs that were fitted to birds using Teflon harnesses.

Signals from the satellite transmitters were received by internet through the Argos system (Argos CLS, Toulouse, France). Locations were filtered following Weimerskirch et al. (1993), allowing a maximum flight speed of 65 km h^{-1} for frigatebirds (Weimerskirch et al. 2003, 2004). For the battery-powered PTTs we calculated real speeds between each location, and for those powered by a solar panel we calculated both an overall speed between two locations including periods when the PTT was off (i.e., when the bird could have been stationary), and real speeds between successive locations excluding periods when the PTT was off. Wind directions were obtained from Ocean Surface Winds Derived from the SeaWinds Scatterometer available at http://manati.orbit.nesdis.noaa.gov/quikscat/ (28 October 2004). Mean values are given ± SD.

RESULTS

POSTBREEDING MOVEMENTS OF MAGNIFICENT FRIGATEBIRDS

Of 11 Magnificent Frigatebirds fitted with satellite transmitters on Grand Connétable while incubating or rearing a chick (six females and five males), four were tracked after breeding failure. Three females were tracked after nest failure during incubation and one male naturally deserted its chick. Two females remained in the vicinity of the island, continuing to undertake short trips similar to those before failure (average duration 2.1 ± 1.8 days, $n = 5$ trips; maximum range 240 km, average 69.7 ± 54.6 km), and two, one male and one female, moved away from the range of breeding birds.

Both latter birds moved slowly to the west along the coast of South America (Fig. 1). The last location

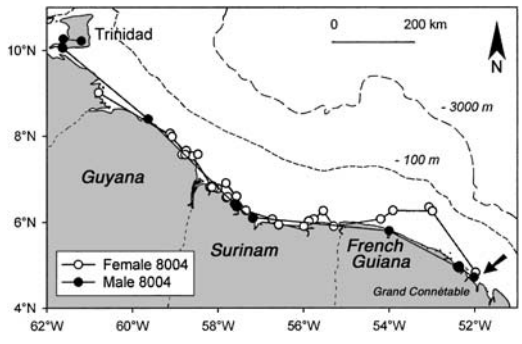

FIGURE 1. Map of the northeast coast of South America showing the dispersal movements of two Magnificent Frigatebirds from Grand Connétable Island off French Guiana. The female had a battery-powered transmitter that emitted a continuous signal (18–27 May 2002), and the male had a solar-powered transmitter with a duty cycle (10–23 May 2002). Throughout the period of dispersal of the two birds, wind was blowing from the east-northeast. Bathymetry (in meters) indicated by −100 m and −3000 m isoclines. Arrow indicates location of Grand Connétable Island.

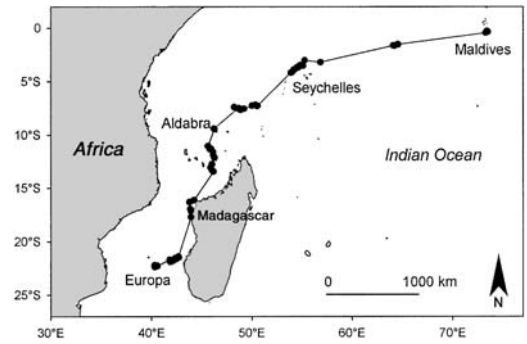

FIGURE 2. Map of the western Indian Ocean showing the dispersal movement of a female Great Frigatebird from Europa in the Mozambique Channel to the Maldives (25 October–7 November 2003). The bird was fitted with a solar-powered transmitter with a duty cycle.

noted for the female was along the coast of the Orinoco Delta, after a movement of 1341 km in 9.8 days at an overall speed of 4.8 km h^{-1}. The last location of the male was on Trinidad where the bird was found dead after a movement of 1462 km in 12.8 days at an overall speed of 5.7 km h^{-1}. The slow overall speeds were due to frequent stops of several hours each on the coast, generally at the mouth of large streams coming from the Guyana plateau or the Orinoco River.

POSTBREEDING MOVEMENTS OF GREAT FRIGATBIRDS

On Europa, five of nine Great Frigatebirds tracked while incubating or rearing young chicks stopped breeding between 5 and 25 days after being fitted with transmitters, because either they or their partner deserted the nest. Four (one male, three females) continued to perform trips similar to those before failure, i.e., long trips (average duration 4.5 ± 2.6 days, $n = 7$ trips; maximum range 617 km, average 329 ± 73 km) for incubating birds, and short trips (0.6 ± 0.2 day, $n = 5$ trips; maximum range 168 km, average 94 ± 45 km) for chick-rearing adults. A female that for 32 days had been alternating incubation with long foraging trips to the east and southeast typical of a breeding bird, suddenly left the Mozambique Channel on 25 October 2003. By this date we had left the island, so we were not able to check the status of the nest.

On the first day, this female flew north past Madagascar and reached Aldabra Atoll, 1572 km from Europa. The following day she began to move northeast, passing to the north of the Seychelles Islands and then turning east to reach the Maldives on 7 November (Fig. 2). She turned northward to settle on Hithaadhoo Island in Suvadiva Atoll on the same day, 4405 km from Europa (Fig. 2, 3). Between Europa and Suvadiva Atoll, this bird covered a minimum distance of 5354 km in less than 13 days, giving an overall flight speed of 17.2 km h^{-1}. Dispersal was very rapid; speeds were much higher than during foraging trips while breeding, or when foraging around the Maldives (considering all sections between locations: $F_{2,447} = 10.8$, $P < 0.001$). Real flight speeds at night were similar to those during the day (28.9 ± 18.4 and 29.2 ± 19.2 km h^{-1}, respectively). During dispersal the bird had crosswinds before reaching the Seychelles, and tail winds thereafter.

After one night on Hithaadhoo Island, the female started to make foraging trips from the roost. A total of 39 foraging trips were recorded, all starting from this island. Foraging was concentrated to the north of Suvadiva Atoll, in the One-and-a-half-degree Channel (Fig. 3). However, several trips were directed much farther, to oceanic waters or the vicinity of other atolls, although the bird never stopped on other islands. The distance of these foraging trips from Hithaadhoo Island averaged 86 ± 27 km (range 56–270 km), and the distance covered per trip averaged 261 ± 68 km (range 155–783 km).

DISCUSSION

The overall breeding success of frigatebirds is very low, averaging 10%–50% in Magnificent Frigatebirds (Osorno 1996, Diamond and Schreiber 2002) and 20%–40% in Great Frigatebirds (Diamond 1975; HW et al., unpubl. data). The observed rate of failure of birds fitted with transmitters in our study is well within this range. After breeding failure, 67% of birds continued to forage around the breeding grounds for at least a month. Although re-laying has rarely been recorded in frigatebirds, these birds may have stayed near breeding colonies to engage in another reproductive attempt, however the duration of our stays on the islands did not allow us to verify this

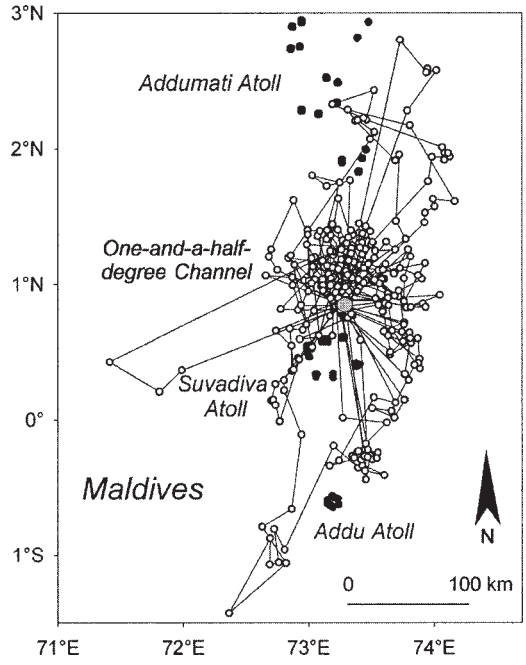

FIGURE 3. Thirty-nine foraging trips of a Great Frigatebird in the southern Maldives area over two months during the nonbreeding season. Islands are indicated in black, and the gray circle shows the location of the roosting site on Hithaadhoo Island in Suvadiva Atoll. Unfilled circles indicate locations signaled by the transmitter during times it was on.

hypothesis. In Magnificent Frigatebirds, foraging trips after failure either during brooding or incubation were always short and over coastal waters, similar to when they were breeding (Weimerskirch et al. 2003). After failure, Great Frigatebirds also made foraging trips similar to those during breeding, with oceanic trips of short duration after failure during brooding, and longer trips after failure during incubation (Weimerskirch et al. 2004). Thus, most birds after failure continued to perform trips of similar duration and range to those performed during breeding. However, three frigatebirds changed behavior radically and made extensive postbreeding movements to other sites where frigatebirds are known to occur. The differences were not sex-related and we have no explanation as to why individuals differed so markedly in their postbreeding movements.

The movements of the two Magnificent Frigatebirds that dispersed from Grand Connétable were very similar, with both moving to the west along the coast of South America at slow speeds. This suggests a migration route along the coast from French Guiana to Venezuela. These birds encountered tail to cross winds, since the wind was blowing continuously from the east-northeast. Their recorded speeds were slower than those of breeding birds during foraging trips (5.3 vs. 10 km h^{-1}; Weimerskirch et al. 2003), due to regular stops along the coast, especially at the mouth of rivers where they probably found undisturbed roosting conditions in mangroves or forests. Magnificent Frigatebirds breed on Trinidad and Tobago, and are abundant around these islands (Diamond and Schreiber 2002), which are the first colonies to the west of Grand Connétable. It is likely that the dispersing birds were heading to the colonies or roosts occurring on these islands. However, the cessation of transmission from one bird because of low batteries, and the death of the second bird, prevented us from learning more about the final destination and behavior of these birds. In French Guiana, frigatebirds rely mainly on fish obtained from shrimp trawlers, a food resource available year-round (Dujardin and Tostain 1990). Furthermore, large numbers of nonbreeding adults (up to 3000 birds with only 400–600 breeding pairs; Dujardin and Tostain 1990) roost on Grand Connétable. Therefore it is surprising that some failed breeding birds left the area and headed to the West Indies. As the body condition of male and female Magnificent Frigatebirds deteriorates sharply during breeding (Chastel et al. 2005), failed breeding birds or males that have deserted their chick may migrate to areas with important food resources to restore their body condition. Although Magnificent Frigatebirds are able to make long-distance movements (Diamond and Schreiber 2002), the coastal movement of the two dispersing birds is in agreement with the overall distribution of the species, which is restricted to the vicinity of land (Diamond and Schreiber 2002).

In contrast to the two Magnificent Frigatebirds, the postbreeding movement of the dispersing Great Frigatebird from Europa was purely oceanic, in keeping with the much more oceanic distribution of Great Frigatebirds compared to Magnificent Frigatebirds (Metz and Schreiber 2002). Aldabra was the only detectable stopover on the entire journey. The route taken by this bird suggests it had a knowledge of its destination, since it followed the same compass direction from the Seychelles until reaching its destination. The goal-oriented movement suggests this bird may regularly spend the nonbreeding season at Hithaadhoo Island. Similar behavior occurs in other pelagic seabirds, for example Wandering Albatrosses (*Diomedea exulans*) spend their sabbatical year (the period between two breeding seasons) in the same oceanic sector throughout their life (Weimerskirch and Wilson 2000). In the Pacific, band returns and resightings of marked birds show that Great Frigatebirds disperse from breeding islands into the entire Pacific Ocean area (Metz and Schreiber 2002, Dearborn et al. 2003).

In the Maldives, the Great Frigatebird settled on a small vegetated sand cay where there is a well-known roost of at least 300 individuals, mainly Lesser Frigatebirds (*Fregata ariel*), but also some Great Frigatebirds (R. C. Anderson, Maldivian Sea Fisheries, pers. comm.). Frigatebirds do not breed in the Maldives (Anderson 1996), so the presence of frigatebirds is probably related to the availability of prey. From this island, the female Great Frigatebird

behaved as a typical "central place forager," departing from the same island roost throughout the four months she was tracked in the Maldives. Her primary foraging area in the One-and-a-half-degree Channel is known for high concentrations of skipjack tuna (*Katsuwonus pelamis*), with which frigatebirds are often associated (Anderson 1996, Au and Pitman 1986). Tuna are particularly abundant in November and December, when the fishing season takes place, and the tuna fishery in this area is known to rely heavily on seabirds, especially frigatebirds, to find tuna schools; 90% of schools are located this way (Anderson 1996). Thus, this frigatebird appears to have dispersed to a well-known zone of high tuna concentration where it was probably feeding in association with tuna, in a similar way as during breeding (Weimerskirch et al. 2004).

Band recoveries have provided evidence of extensive movements of juvenile and adult frigatebirds (Diamond 1975, Sick 1993). Although frigatebirds disperse over extensive distances, band recoveries and genetic studies suggest that adults as well as juveniles return to their breeding or birth place, and there is very little gene flow among breeding sites (Dearborn et al. 2003). This contrasts with the numerous interisland movements outside the breeding season that characterize frigatebirds. Such movements may be due to frigatebirds' inability to land on water, since all other pelagic seabird species remain at sea throughout the nonbreeding season and most disperse over huge areas, often very far from breeding sites. This dispersal may have the advantage of limiting interspecific competition, and allow nonbreeding birds to feed at productive marine areas far from breeding colonies, as suggested by the Great Frigatebird visiting the Maldives. Thus, frigatebirds may behave similarly to other pelagic seabirds; but because they cannot rest on water, their dispersal is constrained by the presence of islands from which they base their foraging.

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