

Nesting biology and food habits of the Peregrine Falcon *Falco peregrinus radama* in the south-west and central plateau of Madagascar

Gilbert Razafimanjato¹, Lily-Arison Rene de Roland¹, Jeanneney Rabearivony¹ and Russell Thorstrom^{2*}

¹ The Peregrine Fund's Project in Madagascar, BP 4113 Antananarivo (101), Madagascar

² The Peregrine Fund, 5668 West Flying Hawk Lane, Boise, ID, USA

* Corresponding author, e-mail: rthorstrom@peregrinefund.org

We studied nesting biology, behaviour, and diet of the Peregrine Falcon *Falco peregrinus radama* in Madagascar during two breeding seasons at Tsimanampetsotsa Natural Reserve in the south-west (n = 2 nests) and at Tritriva Lake (n = 1 nest) on the central plateau from July to November 1999 and June to October 2000, respectively. Pair formation took place in May at Tritriva and in June at Tsimanampetsotsa. Mating periods spanned 75 days in the south-west and 43 days on the central plateau. Eggs were laid during July on the high plateau and in August in the south-west. The incubation period at the two nests was 33 and 35 days, respectively. Five young hatched in two nests, three on the central plateau in August and a minimum of two in the south-west in September. Two young fledged successfully at 42 days of age at the south-west nest and the three young at the high plateau succumbed to unknown causes. The two fledged young dispersed at 64 days of age. The Peregrine Falcon diet in Madagascar varied between the two sites: in the south-west 100% (n = 353 birds; 19 species) of identified prey was composed of native birds and 99% (n = 94; 2 species) of identified prey at the central plateau site was almost exclusively domestic chickens *Gallus gallus*.

Introduction

The Peregrine Falcon *Falco peregrinus radama* in Madagascar is an uncommon species with a patchy distribution throughout Madagascar and into the Comoros Islands (Langrand 1990, Goodman *et al.* 1997). This species occupies rocky habitat and cliffs, usually in the vicinity of vast open areas or water (Cade 1982). Langrand (1990) and Goodman *et al.* (1997) noted that this falcon is difficult to find, even in suitable habitat in Madagascar. Most information on this cosmopolitan falcon in Madagascar is limited to avifaunal inventories and lists (Langrand and Meyburg 1984). Since little is known about the ecology and biology of the Peregrine Falcon in Madagascar, this study was initiated to gather data on breeding biology, behaviour, and food habits at two sites in different geographical areas.

Methods and study area

Two nesting pairs of Peregrine Falcons were located at Tsimanampetsotsa Reserve (south-west) and one pair at Tritriva Lake (central high plateau) (Figure 1). Observations were conducted from July (courtship period) to November (post-fledgling period) in 1999 in the southwest and from June to October 2000 on the central plateau. Daily nest observations lasted from 06:00–18:00. Observations were made 100m from the occupied nests with 10 × 50 binoculars and a 20 × 45 zoom-spotting scope. Falcon activity was recorded at 10min intervals. Data collected included notes on adult behaviour (nest attendance, fledgling behaviours). Diet was recorded by direct

observations of prey deliveries to females and young, and prey remains collected below perches in the south-west and from the nest in the central plateau nests. Recordings were taken at the south-west site and during four visits, spaced three days apart, at the central plateau site. From the observation point at the Tritriva site, the falcon nest was in the foreground and the village was in the background, and we were able to make direct observations of the falcons taking young chickens *Gallus gallus* that wandered into the fields near the village. Nest measurements were taken after the young had dispersed.

Incidental sightings of Peregrine Falcons were also recorded in several protected and unprotected areas throughout the island: namely, Camp Catta in the south central plateau, Mitsio Island lying off the coast of north-western Madagascar, Manambolo River, and Ankililaly Lake of the western area in the Morombe region, the massif of Ibity, near Ambalavary village of the north-central region, and Masoala Peninsula of north-eastern Madagascar (Figure 1).

Tsimanampetsotsa Natural Reserve

Tsimanampetsotsa Natural Reserve (24°06'S, 43°45'E) is 15km east of the Mozambique Channel and includes an 18km-long alkaline lake (Figure 1). This region of south-west Madagascar is characterised by a dry climate, and the dry season is from April to October. The average annual rainfall is <500mm and more than two-thirds of the rain is recorded between December to February. Annually, the average temperature is about 24°C and minimum and

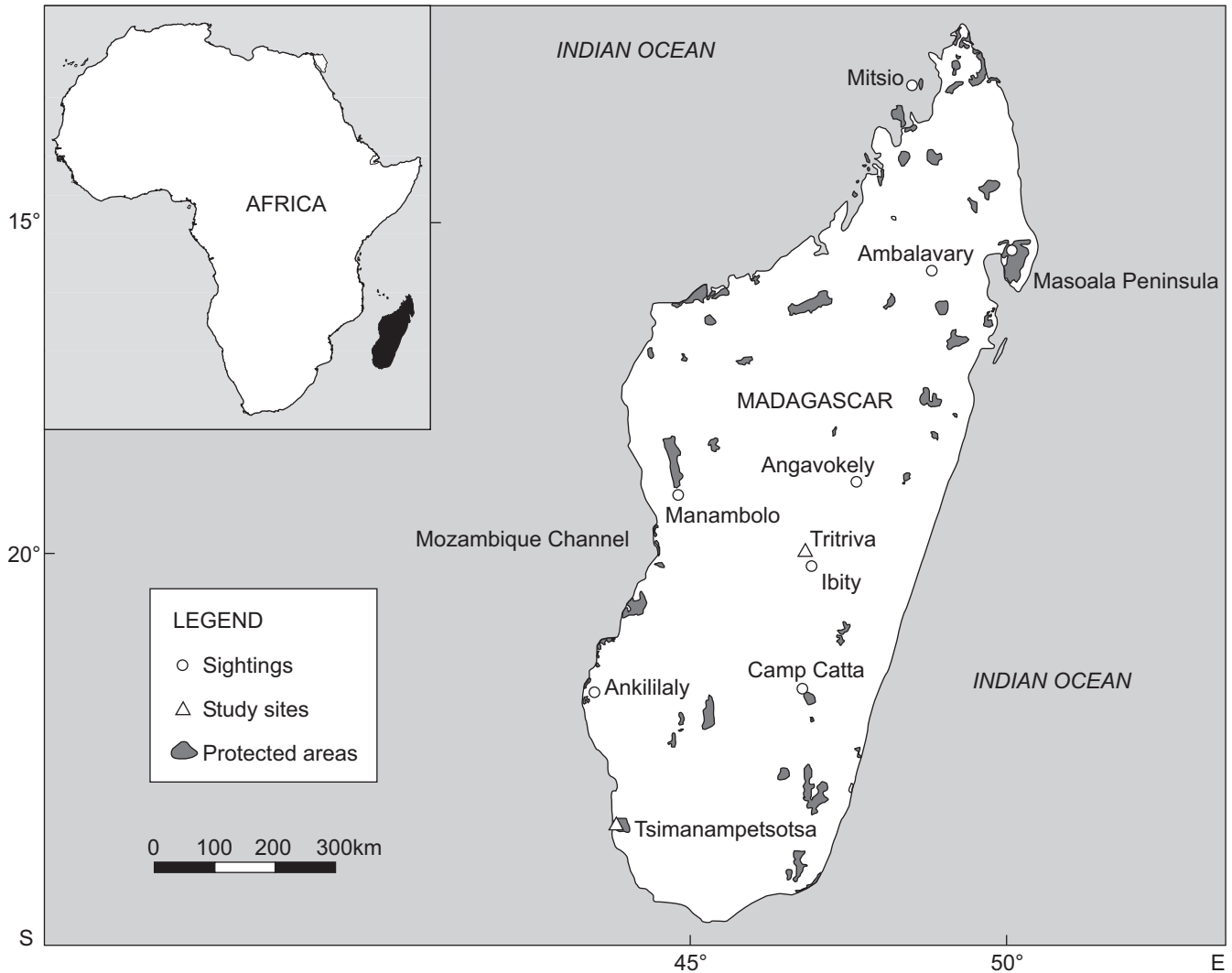


Figure 1: Peregrine Falcon *Falco peregrinus radama* sightings in Madagascar from 1999 to 2004, and study sites in 1999 and 2000

maximum temperatures vary between 14–27°C, respectively. Tsimanampetsotsa Reserve is a low-altitude dry forest with elevations ranging from sea level to 110m. The reserve is vast and covers a surface of 43 200ha on red lateritic soil type. A narrow band of gallery forest, composed of herbaceous and ligneous plants, lies at the base of an escarpment rising up to an elevation of 110m. East of this escarpment a scrubby, dry and open canopy forest diminishes to a vast limestone plateau covered with dense, spiny, succulent and xerophilous plants. Over 185 species of plants have been recorded in the reserve, with 90% being endemic (Rabarison and Rakouth 1999).

Triteriva Lake

Triteriva Lake (19°55'S, 46°55'E) is 17km south-west of Antsirabe on the central plateau (Figure 1). This volcanic mountain contains a granitic caldera with a 40m cliff and a freshwater lake inside the crater. This site is at 907m asl and surrounded by exotic *Pinus* trees and agricultural and fallow fields. The rainy season is from November to May

and the average annual precipitation is 1 291mm. The average monthly temperature is 17°C and varies from 3–21°C.

Results

Nest characteristics

Three nests were observed, for which observation time totalled 2 079.3h: two at Tsimanampetsotsa Nature Reserve (N1 observed for 1 126h and N2 for 102h) and one at Triteriva Lake (observed for 815.3h). All nests were in potholes or ledges on cliffs. Nest measurements and characteristics are summarised in Table 1. At Tsimanampetsotsa, nests were placed inside natural potholes on a cliff face of an escarpment running north to south, lying east of the alkaline lake and separated by 8km. The entrances to both nests were narrow and the nests were inaccessible for measurements. The nest at Triteriva Lake was situated on a natural ledge on the cliff face of a caldera. The centre of the nest scrape consisted of short grass with small stones pushed towards the outside edge.

Table 1: Nest and nest characteristics of three Peregrine Falcon *Falco peregrinus radama* nest sites, at two study sites, from 1999–2000 (Tsimanampetsotsa site: N1 = Nest 1, N2 = Nest 2, Tririva site: N3 = Nest 3)

Nest characteristics	Tsimanampetsotsa		Tritriva
	N1	N2	N3
Cliff slope (°)	90	90	90
Cliff height (m)	100	100	39.6
Cliff distance from the water (m)	80	100	<1
Nest distance from the cliff peak (m)	40	40	31.7
Nest height (m)	60	60	7.9
Nest distance to nearest raptor's nest (m)	350	400	150

Courtship and egg laying

The courtship period began in June at Tritriva and in July at Tsimanampetsotsa. The courtship period was defined as follows: the male provisioning food to the female, mating, and the female remaining near the nest vocalising and guarding it. In Tritriva, eggs were laid in July, 38 days after the first observed copulation, while at Tsimanampetsotsa, the eggs were laid in August, 40 days after the first observed copulation. We believe that no eggs were laid in Nest N1 at Tsimanampetsotsa, due to the lack of incubation behaviour. Copulations lasted 7 ± 1.2 (SD) sec ($n = 157$, range 4–9sec). Laying dates at Tritriva for the three-egg clutch were 19, 22 and 24 July 2000. Nest N2 at Tsimanampetsotsa was not accessible or observable for determining the number of eggs laid but we believe the clutch was completed on 18 August 1999, when the female began daily incubation behaviour.

Incubation

Females and males participated in incubation. Incubation periods for the males and females varied between the two study sites. At Tritriva, the female incubated for 69.7% ($n = 176$ h), and the male for 30.2% ($n = 76$ h) of the observation time. At Tsimanampetsotsa, 81.1% ($n = 214$ h) and 12.9% ($n = 34$ h) of the incubation time was by the female and male, respectively. Adults were absent from the nest for 0.1% ($n = 0.3$ h) and 6% ($n = 16$ h) of observation time at Tritriva and Tsimampetsotsa, respectively. During the incubation period at Tsimanampetsotsa, the female was fed by the male and was never observed hunting. At Tritriva, 8.7% ($n = 2$) of the prey deliveries were by the female during the incubation period. The incubation period was 33 and 35 days at Tritriva and Tsimanampetsotsa, respectively.

Nestling period

Females brooded the young while the male supplied food for her and the nestlings. The young at Tritriva died in the nest from unknown causes at 7–12 days of age, possibly from exposure or food shortage. At Tsimanampetsotsa N2, the male provisioned food to the female until she began searching for food when the young were 14 days of age. The female searched for food only during the morning hours, from 06:00–09:00 ($n = 14$). At 23 days of age, the young were able to feed themselves and were observable at the nest entrance. At 37 days of age, the young began wing exercising at the nest entrance.

Fledging

Before fledging, the young stayed in the nest during the night while the adults roosted outside the nest. At Tsimanampetsotsa, the young fledged during the first week of November at 42 days of age. At 47 days of age, the young chased, played, and tried to catch other flying animals from small insects (dragonflies) to large birds (flamingos) ($n = 6$ observations). At 50 days of age, the fledglings began taking prey from adults in flight. On 13 occasions, we observed adults dropping prey in the air when the young approached them, requiring the young to descend quickly to grab the prey item in flight. Young were not observed in their natal area after 64 days of age, thus suggesting that they may have followed adults to another area outside of our observational area, or may have dispersed.

Reproductive success

At Tsimanampetsotsa, no eggs were laid in N1, and the number of eggs in N2 was unknown. Reproduction success was calculated on the number of nesting attempts that fledged young. In two confirmed nesting attempts, five eggs were laid, made up of two- and three-egg clutches, five young hatched and two young fledged. One of two nesting attempts was successful in producing two fledglings to dispersal.

Food habits

Madagascar Peregrine Falcons captured birds exclusively. Of 388 prey items (317 from direct observations and 17 from prey remains below perches) recorded at the Tsimanampetsotsa nests, 353 were identified to 19 species of birds, and 35 prey items were unidentified. The most numerous prey were the Madagascar Bulbul *Hypsipetes madagascariensis* ($n = 78$), Madagascar Red Fody *Foudia madagascariensis* ($n = 65$), Madagascar Swamp Warbler *Acrocephalus newtoni* ($n = 38$), Common Newtonia *Newtonia brunneicauda* ($n = 37$), and Madagascar Green Pigeon *Treron australis* ($n = 33$). These species are made up 71% ($n = 251$) of the identified prey. Prey ranged in size from a Souimanga Sunbird *Nectarinia souimanga* at 12g, to a Madagascar Green Pigeon (c. 220g). At Tritriva nest, of 98 prey items (93 from direct observations and five from prey remains in the nest) delivered to the female and nestlings, 95 were identified and of these 99% ($n = 94$) were young chickens *Gallus gallus*, and one Rock Dove *Columbia livia* was present. Three prey items were unidentified.

Recent sightings

Peregrine Falcons were documented at eight additional areas throughout Madagascar, adding substantially to our knowledge of their current distribution in Madagascar (Langrand 1990, Morris and Hawkins 1998) (Table 2). During a recent survey on Masoala Peninsula of north-eastern Madagascar, (RdR pers. obs.) found a pair occupying a large exposed cliff above the primary forest. One of these sites, a cliff near the village of Ambalavary in the north-central region, is known only from an interview with local community members (RdR pers. comm.). A recent survey in the Morombe region of central-western Madagascar located a pair perched in the spiny forest near Ankililaly Lake (GR pers. obs.). Another pair was located on Massif of Ibity (south of Antsirabe on the central plateau) (TS Sam, The Peregrine Fund, pers. comm). At Angavokely, in the eastern high central plateau, about 25km from Antananarivo, at least two pairs were reported (Randriamanindry, BirdLife International, Madagaascar Program, pers. comm.). One nest was observed on a cliff near Ambatoroa village, near the entrance of the forest guard station. Another nest was situated in a pothole on a cliff inside the Angavobe forest.

Discussion

At Tsimanampetsotsa, the inter-nest distance of 8km between N1 and N2 was similar to that of other tropical subspecies of Peregrine Falcons, ranging from 1–6.4km for African Peregrines *F. p. minor* (Thomsett 1988, Hartley 2000) and 9.5km for *F. p. pelegrinoides* (Thiollay 1988). Obviously, the variation in inter-nest distance among different races of Peregrine Falcons depends on the suitable nesting habitat and topography, prey densities and availability, safety from predators, and perhaps habitat types in the area (Pepler *et al.* 1991, Jenkins 2000). The variation in inter-nest distance among Peregrine Falcons may reflect the unique nesting habitat Peregrine Falcons need: generally cliffs above vast open areas and water. The proximity of a nest to open areas suggests that it may facilitate prey capture because prey lack an area to retreat to quickly while the Peregrine Falcon is hunting (Cade 1982, Pepler *et al.* 1991). Also at Tsimanampetsotsa, some bird species appeared to be more abundant near the vicinity of the lake. Cliff nests situated above water may also provide shelter for Peregrine Falcons in Madagascar, allowing them to live in

an area without human disturbances or predator activity (Newton 1988).

The distance of the nearest raptor's nest of a different species to the Peregrine Falcon nests was between 150m and 400m in Madagascar and in Greenland it was 300m (Burnham and Mattox 1984). There is a minimum distance that is respected by other raptors, in order to minimise nest defence and territoriality.

Nest height above ground varied from 7.9–60m for Peregrine Falcons in Madagascar, and within the range reported for African Peregrine Falcons (Pepler *et al.* 1991) and other races of Peregrine Falcons (Ratcliffe 1993), and Peregrine Falcons in South Africa tended to select higher nest sites to benefit hunting opportunities (Jenkins 2000).

The clutch size for Peregrine Falcons generally varied from 2–4 eggs, and rarely five (Cade *et al.* 1988, Ratcliffe 1993) and 2–4 eggs for African Peregrine Falcons in the wild and in captivity from 1–4 eggs (Hartley 2000). In Madagascar, one three-egg clutch was observed at Tritriva, and it was suspected that a two-egg clutch occurred during the successful nesting attempt at Tsimanampetsotsa.

In Madagascar, both sexes incubated and male Peregrine Falcons incubated for 12.9% at Tsimanampetsotsa, and 30.2% at Tritriva, of the observation time. This is within the range of reported incubation times of male Peregrine Falcons that incubated for up to 50% during the daylight hours (Newton 1979, Hustler 1983, Tarboton 1984, Ratcliffe 1993).

Tritriva is a tourist site and the Peregrine Falcon's nest is visible and on an exposed ledge. We believe that the adults at Tritriva were conditioned to human activity and remained on the nest diligently to protect the eggs from exposure and predators, as reflected by the female and male's constant nest attendance (99.9%) during the incubation period. This explains the difference in the incubation rate of the male at Tritriva (higher-altitude nest) and the male at Tsimanampetsotsa. The nest at Tsimanampetsotsa was inside a pothole and inaccessible to most predators, offering greater protection to the eggs and young, which allowed the adults to leave the nest unattended for longer periods of time than was the case for the pair at Tritriva.

The incubation period for Peregrine Falcons is fairly well established to be around 32–34 days (Ratcliff 1993). Egg laying and incubation in Australian Peregrine Falcons are delayed or influenced by weather conditions, mainly high rainfall and lower temperatures and nest location (Olsen and Olsen 1989). Little difference was recorded in the incu-

Table 2: Recent sightings of Peregrine Falcons *Falco peregrinus radama* in Madagascar during and after this study (1999–2004)

Recent sightings	Location in Madagascar	Results	Year observed
Camp Catta	South-central plateau	One pair with nest	July 1999
Mitsio Island	North-west oceanic island	One pair	June 2000
Manambolo River	Western-central (19°08'S; 44°50'E)	One individual	July 2000
Ambalavary village	North-central plateau	One pair	November 2000
Masoala Peninsula	North-eastern (15°16'S, 50°06'E)	One pair	November 2001
Massif of Ibity	Central plateau (20°10'S, 46°58'E)	One pair	May 2003
Angavokely Forest Station	Central plateau	Two pairs	July 2003
Ankililaly Lake	Western (22°07'S, 43°23'E)	One pair	February 2004

bation period in the cooler climate of Tritriva and the hotter temperatures of Tsimanampetsotsa — 33 and 35 days, respectively. The incubation period we recorded for Peregrine Falcons in Madagascar was the same as all other subspecies of Peregrine Falcons (Linthicum 1996). The 41-day nestling period of the Peregrine Falcon in Madagascar was similar to those of two North American subspecies: *F. p. tundrius* at 40 days (Linthicum 1996), and *F. p. pealei* at 41–44 days. (Nelson 1977).

In Tsimanampetsotsa, the young fledged in the first week of November at 42 days of age and this was the same for the fledging age for other subspecies of Peregrine Falcons, and in the same month as the African subspecies *Falco peregrinus minor* (Hartley 2000). After 64 days of age, the young were not observed for several weeks and we assumed that they had dispersed. The adult female was observed constantly chasing the young during this period, perhaps driving the young from the territory, prior to their dispersal.

In Madagascar, the Peregrine Falcon's diet was determined predominantly from direct nest observations, which is time-consuming but also the most reliable and accurate estimate for determining food habits of most raptors (Marti 1987, Margalida *et al.* 2005). Although our observations were limited to three nests, we concluded that the Peregrine Falcon's diet varied according to prey species availability, and possibly to the biogeographic region. Hustler (1983), Tarboton (1984) and Jenkins and Avery (1999) reported that African Peregrine Falcons (*F. p. minor*) preyed mostly on birds from woodlands, with pigeons and *Streptopelia* doves making up the bulk of their diet (38–66%). Peregrine Falcons captured only wild birds in south-western Madagascar at Tsimanampetsotsa and *Treron* pigeons made up a good portion of the falcon's diet at this nest site. Of interest, and most likely a unique situation, was the diet of the pair at Tritriva Lake, where young domestic chickens were taken almost exclusively and captured from the ground. The diet of Lanner Falcons (*F. biarmicus*) in South Africa showed some similarity to the Peregrine Falcons at Tritriva Lake, where 40% of their diet consisted of young chickens (Jenkins and Avery 1999). The nest at Tritriva Lake is situated near a small village where there is a high density and availability of free-ranging chickens, and a poultry farm. The surrounding habitat in this area is human-modified, planted with exotic *Pinus* trees, and is frequently disturbed by fires. Consequently, this has led to a low density of grassland and open-habitat bird species (e.g. Madagascar Red Fody *Foudia madagascariensis* and Madagascar Mannikin *Lonchura nana*), making chickens the most suitable prey species for the nesting Peregrine Falcons.

Due to their patchy distribution, low density, habitat requirements, and lack of access to remote areas, nesting Peregrine Falcons are difficult to detect in Madagascar. For conservation reasons, there is a need to learn more about nesting Peregrine Falcons in different habitat types within Madagascar and into the Comoros Islands, for comparison across regions and for determining their breeding status throughout these regions. The present study on the breeding biology, with two nests in Tsimanampetsotsa and one in Tritriva, is the most recent observation on nesting Peregrine

Falcons in Madagascar. The eight sites of observations of Peregrine Falcon described in this study add to previous records and known sites for this species throughout Madagascar.

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