Feeding Performance and Foraging Area of the Red-Legged Cormorant

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Abstract.—The foraging behavior and feeding locations of the Red-legged Cormorant (*Phalacrocorax gaimardi*) were studied at Ria Deseado, Argentina during the last week of the incubation period in 1999. VHF radio-transmitters were deployed on six nesting adult cormorants. Red-legged Cormorants fed during the daylight hours and made 4.0 ± 0.8 trips per day, with a mean duration of 1.2 ± 0.8 h. Birds spent 27% of daylight hours away from the colony on feeding trips, diving for 96% of the foraging trip, and made a mean of 78 dives per trip. Mean foraging range was 1.9 ± 0.9 km, being the shortest of any of the Patagonian cormorant species. Red-legged Cormorants fed mainly in shallow waters <5 m deep and within one km from the shore. Most of the feeding trips were undertaken during falling tide, when the birds performed the shortest feeding trips with maximum diving rates and, probably minimized transit times and maximized searching time on the seafloor. Our results show that foraging behavior is mainly influenced by environmental factors such as the direction of the tide. Red-legged Cormorants seems able to forage by selecting the appropriated tidal conditions to minimize foraging effort. *Received 23 March 2004, accepted 17 July 2004.*

Key words.—Argentina, feeding sites, foraging behavior, Red-legged Cormorant, *Phalacrocorax gaimardi*, radio transmitter.

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The Red-legged Cormorant (*Phalacrocorax gaimardi*) is widely distributed in the southeastern Pacific Ocean, and on the Atlantic coast of South America (Zavalaga *et al.* 2002; Frere *et al.* 2004). In Argentina, the species breeds at 13 sites, all restricted to the Santa Cruz Province, Argentina (Gandini and Frere 1995; Frere and Gandini 1998; Gandini and Frere 1998). The world population has recently showed a substantial decline (Zavalaga *et al.* 2002; Frere *et al.* unpublished data) and most of the threats are marine rather than terrestrial (Zavalaga *et al.* 2002). During the last 40 years, considerable coastal development has occurred along the Pacific and Atlantic coasts of South America, with rapidly increasing harvesting in the inter-tidal and inshore zones, which modifies the habitat over all the breeding range (Zavalaga *et al.* 2002).

Red-legged Cormorants forage in both inshore and shallow waters (Frere *et al.* 2002), and might be affected by the human activities. The Red-legged Cormorant feeds mainly upon benthic prey (Frere *et al.* unpublished data) and is an efficient diver in terms of the proportion of time spent underwater per diving cycle (Frere *et al.* 2002).

This paper presents information on the feeding patterns and foraging locations of Red-legged Cormorants. The aims were to determine the spatial distribution of feeding areas, the distances traveled to the feeding grounds, the daily activity budget, the number and duration of the feeding trips, and the number of dives per trip.

STUDY AREA AND METHODS

Fieldwork was conducted during December 1999 at Isla Elena colony, Ria Deseado (47°45'S, 65°56'W), Santa Cruz, Argentina (Fig. 1), which supports 130 breeding pairs (Gandini and Frere 1995). The area was formerly a riverbed that has been inundated by the sea. It is protected area, although many human activities such as tourism, recreation and fishing take place.

VHF radio transmitters (Standard model, Advanced Telemetry Systems, Bethel, Minnesota) were attached to six breeding adults captured during the last week of the incubation period. The instruments were fixed to the birds using Tesa tape (Beiersdorf, Hamburg, Germany)

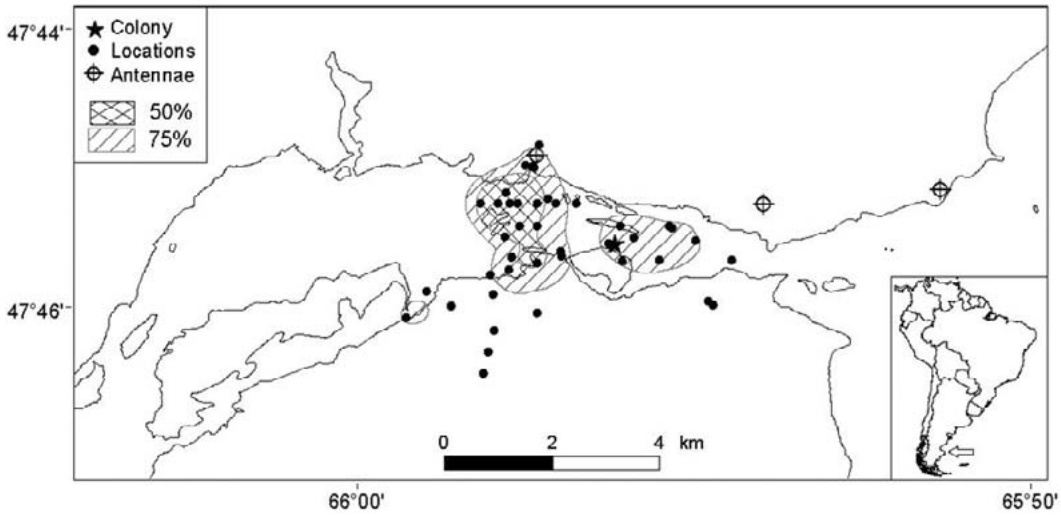

Figure 1. Foraging locations of the Red-legged Cormorant at Ria Deseado, Argentina.

to the underside of the two central tail feathers. The procedure was completed in less than 5 min. Once released, birds flew directly to sea and returned to their nests shortly afterwards. The average mass of a transmitter was 18.4 g (SD ± 0.2, n = 6), which represented approximately 1.3% of adult body mass.

Radio signals were monitored from three tracking stations, separated by 3-5 km (Fig. 1), and 20-50 m above sea level. The reception equipment consisted of a single channel or scanning receiver (R161A or R2000 model, Advanced Telemetry Systems, Bethel, Minnesota) connected to a nine-element Yagi antenna (Advanced Telemetry Systems). Birds were radio-tracked continuously from dawn to dusk from 2 to 10 December. From changes in both signal strength and characteristics, it was possible to identify when a bird was in the colony, flying, on the sea surface, or underwater (see details in Wanless and Harris 1992).

Colony attendance was recorded automatically every 10 min by a data logger (DCCII model, ATS, Inc.) connected to a scanning receiver 5-15 m from the nests of the studied birds. During some foraging trips, it was possible to determine the time between departure from the nest and the first dive. Trip duration was defined as the time between a bird leaving the nest and the time it was back to the colony.

Feeding locations were places where a bird dived repeatedly. These locations were assessed by triangulation from the direction of the signals obtained from at least two reception stations, with a mean error of ±19° (see Quintana 2001 for details). The operators at the two tracking stations were in radio contact. To control for errors, an observer with binoculars and a hand-held antenna checked a sample of positions. Absences from the colony were later confirmed with data obtained with a data logger (see above) and no bird moved out of the range of the receiving equipment (>8 km). In addition, opportunistic direct observations of tagged Cormorant, and confirmation of individual identity using telemetry, were made at the foraging grounds. Each foraging area visited during a trip was characterized by a single position. To describe the spatial distribution of feeding locations we used Kernel analysis (Naef-Daenzer 1993). Foraging range was estimated as the distance from the colony to the location fix.

Foraging parameters from all individuals were pooled when the results were not significantly different. Otherwise, a mean value was calculated for each bird and means were then pooled to calculate overall mean values (Hurbert 1984). Values are presented as means ± SD.

RESULTS

Foraging Behavior

Red-legged Cormorants typically left the colony for the first feeding trip about 10 min after sunrise (median 05.10 h) and returned from the last trip about two hours before sunset (median = 19.50 h). The mate remained with the brood when the other was away foraging. During foraging trips, cormorants typically left the breeding colony and flew directly to a precise feeding area within which they conduct an uninterrupted series of dives before flying back to the colony.

Red-legged Cormorants performed two to five feeding trips each day during the daylight hours (mean 4.0 ± 0.8 trips per day; N = 5 birds). Mean duration of feeding trips was 1.2 ± 0.8 hours (N = 6 birds) (Table 1). The maximum trip duration was 4.8 hours (Table 1).

Red-legged Cormorants spent 73% of the day (time between twilight: 17 hours) at the colony and 27% foraging (N = 23 days). Dur-

Table 1. Number and duration of feeding trips (mean ± SD) of adult Red-legged Cormorants during the last week of incubation at Ria Deseado, Argentina.

Bird	Trips per day	Trip duration (h)	Range trip duration (h)
12	3.86 ± 0.9 (N = 7)	1.07 ± 0.6 (N = 30)	0.4-2.4
54	3.86 ± 1.1 (N = 7)	0.88 ± 0.4 (n = 29)	0.4-1.8
85	4.33 ± 0.5 (N = 6)	1.44 ± 1.3 (N = 21)	0.4-4.8
114*b*	4.5 ± 0.7 (N = 2)	1.02 ± 0.5 (N = 8)	0.4-1.7
123	3.86 ± 0.7 (N = 7)	1.38 ± 0.7 (N = 29)	0.4-3.1
153	—	1.21 ± 0.1 (N = 2)	1.2-1.2
Average	4.0 ± 0.8	1.19 ± 0.8	

ing each feeding trip, birds spent an average of 96% (N = 19 trips) of the time diving and recovering, and 4% was used to fly to and from feeding areas. The time flying from the colony to the feeding area was 1.5 ± 0.7 minutes and the mean time at the patch was 1.14 ± 0.19 hours (N = 19 trips). There was no relationship between the daily mean of trip duration and the number of trips made per day (Spearman rank correlation, r_{29} = -0.12; n.s.).

Red-legged Cormorants performed 78 ± 52 dives per trip (n = 26 trips). The maximum number of dives per trip was 283. The dive rate in a foraging trip decreased with the duration of that foraging trip (all data pooled; r_{24} = - 0.67, P < 0.002) (Fig. 2). Dive rate also declined with time in the same individual (Pearson correlation *r*, range: -0.95 and -0.65, P < 0.05; N = 4 birds). The duration of a foraging trip increased with tidal height according to a linear function (duration = 0.5 + 0.2 tidal height; r_{119} = 0.32, P < 0.001). Overall, 65% of the foraging trips (n = 119) started when the tide was falling (χ^2_1 = 10.3, P < 0.001).

Feeding Locations

Feeding areas were located for 58 foraging trips. Birds generally remained in one location during each feeding trip, although on four occasions birds changed the feeding site during a foraging trip.

Mean foraging range was 1.9 ± 0.9 km (n = 58). The distance estimated from the colony ranged from 0.1 to 4.1 km, but 85% of the foraging sites were within 3 km of the colony. Red-legged Cormorants at Ría Deseado fed in inshore waters, inside the estuarine and less than 1 km to the shore (Fig. 1).

Red-legged Cormorants foraged mostly in waters located west of the colony (83% of locations, n = 58), and no individual fed at the mouth of the estuary (Fig. 1). A high-density area (50% Kernel density contour) occurred around an island (Isla de los Pajaros) located 11 km from the mouth of the estuary (Fig. 1). Individual birds were not consistent in the use of one particular feeding area. According to the bathimetry and the tidal range of the area (Nautical Chart Nr. H361, Servicio de Hidrografía Naval de la República Argentina), all of the foraging sites, even those beyond the kernel contours, were at depths of less than 19-24 m. The main area used around the island (see above) (Fig. 1) was a zone where the depths range from 0 to 24 m, but 90% of the area corresponded to depths shallower 10 m at the time of feeding.

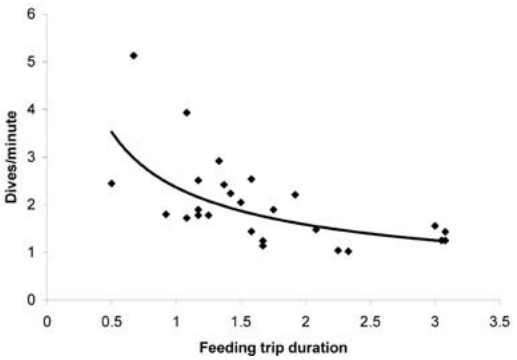

Figure 2. The diving rate (dives per minute) as a function of feeding trip duration of Red-legged Cormorants.

DISCUSSION

This study provides the first description of the feeding performance and foraging locations of the Red-legged Cormorant. This bird is clearly an inshore and shallow water feeder. Its feeding range is less than those recorded for the other cormorant species in Patagonia (Quintana 2001; Sapoznikow and Quintana 2003) and could explain the characteristic feeding pattern of several extremely short foraging trips per day.

Trip duration observed for the Red-legged Cormorant was shorter than those noted for the two other sympatric species of cormorant: the Rock Shag (Quintana 2001) and the Imperial Cormorant (Sapoznikow and Quintana 2003). Red-legged Cormorant feeding trips were almost 47% and 75% shorter than those performed by Rock Shag and Imperial Cormorant, respectively. In addition, the percentage of daylight hours spend foraging by the Red-legged Cormorant is less than that recorded for the Rock Shag (27% vs 36%) (Quintana 2001; Quintana *et al.* 2002). There are no comparable data for the Neotropic Cormorant (*Phalacrocorax olivaceus*) or the Imperial Cormorant. The feeding pattern described for the Red-legged Cormorant at the Ría Deseado (short foraging trips associated with the use of feeding areas in the proximity of the colony) supports the energy-limitation hypothesis as derived from clutch size and foraging area comparisons (Lack 1968; Nelson 1983) and emphasizes the idea suggested by Frere and Gandini (2001) that the higher clutch size of Red-legged Cormorant, compared to the other two Patagonian cormorants, accords with its small foraging range.

The high proportion of time that Red-legged Cormorant spends at the nest (73%) could help reduce predation on eggs and young. Predation by Kelp Gulls (*Larus dominicanus*) is a major cause of egg loss at the colony of Isla Elena (Frere and Gandini 2001).

Red-legged Cormorants fed mainly when the tide was falling. Trip duration increased with the tidal height and the diving rate (dives/min) was higher during short foraging trips. As tide level decreased, cormorants performed shorter feeding trips by diving faster, presumably by minimizing the transit time to and from the bottom and maximizing searching prey times at the seafloor. The falling tide seems to be the optimal condition to begin feeding, acquire food faster and reduce diving costs. This behavior might be possible because of the small feeding range (<2 km) and probably food availability is not a constraint for this species at Ria Deseado. As in other coastal diving seabirds, Red-legged Cormorant diving behavior is strongly influenced by many environmental characteristics of the coast of Patagonia (Frere *et al.* 2002). Our results suggest that its foraging behavior is also influenced by environmental factors such as the height of the tide. However, the suggestion that the cormorants are selecting an optimal time to feed requires more detailed data.

Foraging activity was concentrated inside the estuary, mostly around the Isla de los Pajaros (Fig. 1) where the mean sea depth is around 5 m. The area is far from the fishing port where daily ship movements are high, but near to the colony, many recreational activities such as fishing and water sports take place. Those activities are likely to affect normal foraging behavior and the spatial distribution of the Red-legged Cormorant, so information on foraging patterns are valuable to assist in defining the spatial and temporal zones needed to protected the Ria Deseado, and prevent disturbance at key feeding habitats.

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LITERATURE CITED

Frere, E. and P. Gandini. 1998. Distribución reproductiva y abundancia de aves marinas de Santa Cruz. Parte I: De la Lobería a Islote del Cabo. Pages 119-151 *in* Atlas de la distribución reproductiva de aves marinas en el litoral patagónico Argentino (P. Yorio,

E. Frere, P. Gandini and G. Harris, Eds.). Instituto Saleciano de Artes Graficas, Buenos Aires.

Frere, E. and P. Gandini. 2001. Aspects of the breeding biology of the Red-legged Cormorant *Phalacrocorax gaimardi* on the Atlantic coast of South America. Marine Ornithology 29: 67-70.

Frere, E., F. Quintana and P. Gandini. 2002. Diving behavior of the Red-legged Cormorant in southeastern Patagonia, Argentina. Condor 104: 440-444.

Frere, E., P. Gandini, J. Ruiz and Y. Vilina. 2004. Current status and breeding distribution of Red-legged Cormorant *Phalacrocorax gaimardi* along the Chilean coast. Bird Conservation International 14: 115-123.

Gandini, P. and E. Frere. 1998. Distribución reproductiva y abundancia de aves marinas de Santa Cruz. Parte II: De Bahía Laura a Punta Dungeness. Pages 153-177 *in* Atlas de la distribución reproductiva de aves marinas en el litoral patagónico Argentino (P. Yorio, E. Frere, P. Gandini and G. Harris, Eds.). Instituto Saleciano de Artes Graficas, Buenos Aires.

Gandini, P. and E. Frere. 1995. Distribución, Abundancia y Ciclo Reproductivo del Comorán gris (*Phalacrocorax gaimardi*) en la costa patagónica, Argentina. Hornero 14: 57-60.

Hurlbert, S. H. 1984. Pseudoreplication and the design of ecological field experiments. Ecological Monographs 54: 187-211.

Lack, D. 1968. Ecological adaptations for breeding in birds. Methuen, London.

Naef-Daenzer, B. 1993. GRID. Calculations for home range and spatial analysis. Swiss Ornithological Institute.

Nelson, J. B. 1983. Contrasts in breeding strategies between some tropical and temperate marine pelecaniformes. Studies in Avian Biology 8: 95-114.

Quintana, F. 2001. Foraging behavior and feeding locations of Rock Shags, *Phalacrocorax magellanicus*, from a colony in Patagonia, Argentina. Ibis 143: 547-553.

Quintana, F., F. Morelli and Y. Benedetti. 2002. Buceo eficiente en aguas poco profundas: comportamiento de buceo y patrón de alimentación del Cormorán Cuello Negro, *Phalacrocorax magellanicus*, en dos colonias de la costa patagónica. Ecología Austral 12: 19-28.

Sapoznikow, A. and F. Quintana 2003. Foraging Behavior and Feeding Locations of Imperial Cormorants and Rock Shags Breeding in Sympatry in Patagonia, Argentina. Waterbirds 26: 184-191.

Wanless, S. and M. P. Harris. 1992. At-sea activity budgets of a pursuit-diving seabird monitored by radiotelemetry. Pages 591-598 *in* Wildlife Telemetry: Remote monitoring and tracking of animals (J. G. Priede and S. M. Swift, Eds.). Ellis Horwood, New York and London.

Yorio, P., E. Frere, P. Gandini and G. Harris. 1998. Atlas de la distribución reproductiva y abundancia de aves marinas del litoral patagónico Argentino. Plan de Manejo Integrado de la Zona Costera Patagónica. Fundación Patagonia Natural and Wildlife Conservation Society, Patagonia Argentina.

Zavalaga, C. B., E. Frere and P. Gandini. 2002. Status of the Red-legged Cormorant in Peru: What factors affect distribution and numbers? Waterbirds 25: 8-15.