CSIRO PUBLISHING
www.publish.csiro.au/journals/emu
Short Communication
Emu, 2010, **110**, 155–159

Availability and use of breeding habitat by the Red-legged Cormorant (*Phalacrocorax gaimardi*): evidence for habitat selection

Ana Millones[A,D], *Esteban Frere*[A,B,C] *and Patricia Gandini*[A,B,C]

[A]Centro de Investigaciones de Puerto Deseado, Universidad Nacional de la Patagonia Austral, cc 238 (9050), Puerto Deseado, Santa Cruz, Argentina.
[B]Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET), cc 238 (9050), Puerto Deseado, Santa Cruz, Argentina.
[C]Wildlife Conservation Society, Representación Argentina, Buenos Aires, Argentina.
[D]Corresponding author. Email: ana_millones@yahoo.com.ar

Abstract. We studied the availability and use of breeding habitat by Red-legged Cormorants (*Phalacrocorax gaimardi*) to identify the factors involved in habitat selection. The species nests on cliff-faces. We identified cliffs suitable for nesting along 21 km of coastline of the Ría Deseado, and recorded the characteristics of each, including the distance to the nearest potential foraging area. Previous research had indicated that zones of the river with a gravel substrate and <10 m deep were preferred foraging areas for this species. Of the 16 cliffs identified as potential breeding sites, eight were used by Red-legged Cormorants for nesting. The probability of occurrence of active nests increased with the height and slope of cliffs and decreased with the distance to the nearest foraging area. Significant differences were observed between characteristics of cliffs that were used for breeding and those of available habitat in the environment. Cliffs higher than 12 m, steeper than 85° and within 3 km of a foraging area were the most frequently used but were not the most common in the environment. Factors that influence habitat selection by Red-legged Cormorants appear to be protection from predators and proximity to an abundant source of food. In this study, we also showed a non-random use of foraging sites. This species prefers zones with shallow water and gravel substrates.

Introduction

Habitat use refers to the distribution of individuals and the correlation of that distribution with specific characteristics of their habitat (Johnson 1980; Jones 2001). To make inferences about choice of habitat, it is necessary to compare habitat used by a species with the habitat available in their environment. Such comparisons allow researchers to describe the process of habitat selection (Jones 2001; Hamer *et al*. 2002).

The availability and quality of suitable nesting habitat are important factors determining the distribution, abundance and breeding success of seabirds (Buckley and Buckley 1980; Hamer *et al*. 2002). For seabirds, the ultimate factors that determine choice of breeding site are proximity to food and shelter from predators (Bried and Jouventin 2002). Because nesting site is a critical resource, selection of nesting sites often dominates other components of habitat selection (Orians and Wittenberger 1991). However, seabirds tend to settle in breeding localities that are as close to their feeding areas as possible, minimising the mean distance travelled between the nest and foraging sites (Buckley and Buckley 1980; Bried and Jouventin 2002).

The Red-legged Cormorant (*Phalacrocorax gaimardi*) breeds along the coast of the Pacific Ocean, from northern Peru to southern Chile, and a small section of the Argentinean coast of the Atlantic Ocean, between 47°05′S and 50°23′S (Frere *et al*. 2004). This species nests on cliff-faces, with most nests built on small ledges. Red-legged Cormorants uses sites that are difficult for predators to reach (their nests are located on steep cliffs with small outcrops), have a high availability of usable surface (cliffs with ledges, outcrops or caves) and are protected from prevailing winds and the effect of sea-waves (Millones *et al*. 2008). Its foraging areas are located in inshore waters, usually <10 m deep, and within 3 km of the breeding colony (Gandini *et al*. 2005; Frere *et al*. 2008). Red-legged Cormorants feed mainly upon benthic organisms (Frere *et al*. 2002; Millones *et al*. 2005).

In this study, we examined the availability and use of breeding habitat by Red-legged Cormorants, at a local spatial scale (Ría Deseado, Argentina), to identify the factors involved in habitat selection. Because some of the factors we studied were related to the food resources of this species, we also examined the pattern of use of feeding habitat of Red-legged Cormorants.

Methods

We conducted fieldwork along the Ría Deseado, in the province of Santa Cruz, Argentina (Fig. 1). The Ría Deseado is an old river valley now flooded by the sea. There are six colonies of Red-legged Cormorant, with a total population of ~230 breeding pairs (Millones *et al*. 2008). During October 2005, we surveyed 21 km of coastline of the Ría Deseado to identify potential nesting

10.1071/MU09099 0158-4197/10/020155

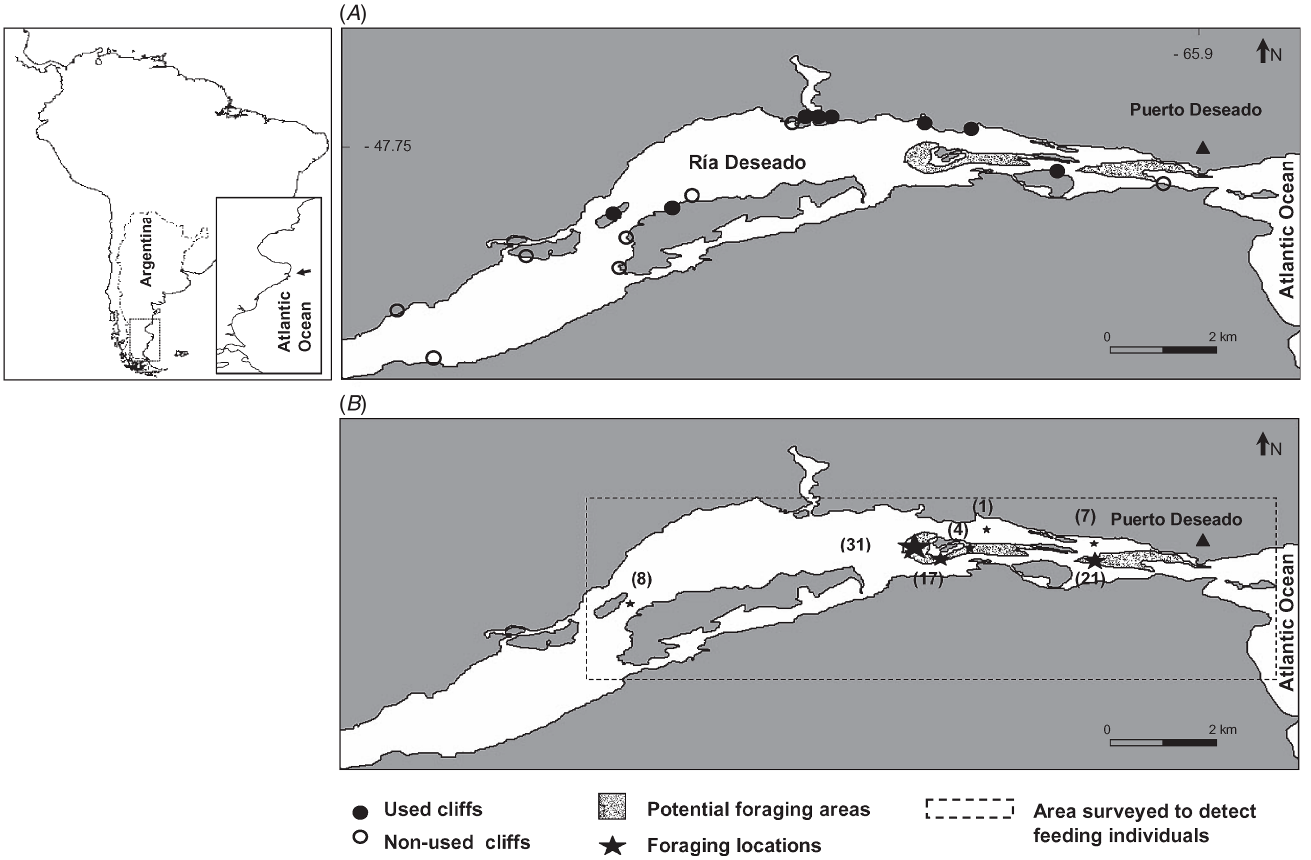

Fig. 1. The Ría Deseado, Argentina. (*a*) Cliffs we identified along the Ría Deseado, and potential foraging areas for Red-legged Cormorants. (*b*) Sites where Red-legged Cormorants were observed foraging in the Ría Deseado (numbers are the number of individuals foraging at each site).

sites (cliffs). For each cliff we identified, we recorded the type of location (continental or island), height of the cliff (distance between the mean high-water tide line to the top of the cliff), length, general slope (from 0° = flat, i.e. no cliff; to 90° = vertical) and principal orientation (recorded as degrees in the field and then analysed according to principal compass directions). For each cliff, we estimated the available area of potential breeding sites, defined by the presence of ledges, outcrops or caves. We also estimated the fetch (the distance of sea over which the wind blows) in front of the cliff, thereby indirectly measuring the potential effect that waves may have on nests. A fetch of 0 corresponded to no seawater at the base of the cliff, a fetch of 100 m indicated a cliff with 100 m of water in front of it. We recorded the presence or absence of Red-legged Cormorants nesting on each cliff. In those cliffs where Red-legged Cormorants were present, we recorded the number of active nests by direct counts. We also studied the bathymetry within 3 km of each cliff (using the Nautical Chart Number H361, Servicio de Hidrografía Naval de la República Argentina, Buenos Aires) and recorded the distance to the nearest potential foraging area. We considered potential foraging areas to be zones <10 m deep with high abundance of prey. For this purpose, areas shallower than 10 m were grouped into four categories based on sediment type (Iantanos 2002): (1) gravel; (2) coarse and medium sand; (3) fine and very fine sand; and (4) silt. For each category, a professional diver obtained benthic samples using a collecting net following the methodology detailed in Millones (2009). Samples were sorted in the laboratory. For every identified taxon, we estimated its relative abundance for each substrate type as abundant, poor or absent. To obtain more complete information we considered previous studies of fish species at Ría Deseado (Kühnemann 1969; Iantanos 2002; Martin and Bastida 2008). Based on previous studies of the diet of Red-legged Cormorants (Millones *et al.* 2005) we could then make predictions about which areas had high abundance of prey and were therefore most suitable for feeding. We sought to confirm these predictions via a boat-based survey, identifying foraging sites and determining their characteristics (depth and substrate type). From October to December 2006, 53 transect lines, covering a total of 16 km of the Ría Deseado, were surveyed for foraging Red-legged Cormorants. Transect lines were roughly 300 m apart and perpendicular to the shoreline (Fig. 1*b*). Feeding behaviour was identified based on descriptions in Frere *et al.* (2002). This foraging survey also allowed us to study the feeding habitat of Red-legged Cormorants.

Statistical analyses

To test for differences in the characteristics of occupied and unoccupied cliffs we used Mann–Whitney *U*-tests and Chi-square tests. Chi-square tests were used only for the two variables 'type of location' and 'orientation', which were categorised in groups. To determine which variables explained the presence or absence of Red-legged Cormorants nesting on cliffs we performed a logistic regression. We used presence and absence of active nests on the cliffs as response variables, and height, length, slope, orientation, available area, fetch, median depth within 3 km of the cliff and the distance to the nearest potential foraging area as explanatory variables. We used the maximum likelihood criterion to estimate the parameters of the logistic regression model. To compare habitat use to corresponding habitat availability we followed the Neu method (Alldredge and Ratti 1992). This method compares the observed occurrence to the expected occurrence for each habitat category. We categorised every identified variable into four categories. Then the number of cliffs in each category was compared to the counts expected if each category were used in proportion to its availability. To test for significant differences we used the Chi-square test.

Results

We identified 16 cliffs along 21 km of coast of the Ría Deseado. Nine cliffs (56%) were on islands, the rest (seven cliffs, 44%) were on continental shores (Fig. 1*a*). Overall, eight cliffs (50%) were used by Red-legged Cormorants for nesting, four were on islands and four were on continental shores (Fig. 1*a*). The number of active nests on each cliff ranged from 3 to 101.

Before we compared differences in the characteristics of cliffs occupied by Red-legged Cormorants and those not occupied, we identified which areas of the Ría Deseado were most suitable for feeding. Using sampling of benthic organisms, diver observations and previous studies of the Ría Deseado, we found that fish and algae, the most frequently observed items in the diet of the Red-legged Cormorant (Millones *et al*. 2005), were abundant in gravel substrates. In the other type of bottom substrates, the relative abundance of fish and algae was poor. Further, of the 89 Red-legged Cormorants that were observed foraging in the Ría Deseado, 82% ($n = 73$) were in zones with gravel substrates and depths <10 m (Fig. 1*b*). The rest were in zones with silt or medium sand substrates, and 0–20 m deep. Gandini *et al*. (2005), who studied foraging sites of Red-legged Cormorants in the Ría Deseado using radio-transmitters, also observed a high proportion of Red-legged Cormorants foraging in zones with gravel substrates and shallow waters. Therefore, we determined that regions of the Ría Deseado with a gravel substrate and water depths <10 m were the main potential foraging areas for this species (Fig. 1*a*). Based on this assumption, we were able to record the distance from each cliff to the nearest potential foraging area, and included this variable in the analyses.

When we compared differences in characteristics of cliffs that were used for nesting by Red-legged Cormorants and those that were not, we observed significant differences in the variables height, slope and distance to the nearest potential foraging area (Table 1). The height and slope of cliffs used for nesting were significantly greater than those of cliffs not used for nesting (Table 1). The distance to the nearest potential foraging area of cliffs used for nesting was significantly less than that of unused cliffs (Table 1). There were no significant differences between used and unused cliffs for the other variables measured (Table 1). A significant logistic regression ($\chi^2_3 = 21.7$, $P < 0.001$) also indicated that height, slope and the distance to a nearest potential feeding area explained the presence or absence of nesting Red-legged Cormorants on a cliff. The probability of occurrence (PO) of active Red-legged Cormorant nests on a cliff increased with height and slope, and decreased with the distance to the nearest potential foraging area (distance), according to the following equation:

$$\mathrm{PO} = e^{(-61.93 + 3.77 \times \mathrm{HEIGHT} + 0.43 \times \mathrm{SLOPE} - 3.7 \times \mathrm{DISTANCE})} / \left(1 + e^{(-61.93 + 3.77 \times \mathrm{HEIGHT} + 0.43 \times \mathrm{SLOPE} - 3.7 \times \mathrm{DISTANCE})}\right).$$

This model correctly classified 100% of the cliffs used by Red-legged Cormorants.

We found no significant differences between use and availability of habitat when we compared the number of cliffs in each category to the counts expected if each category were used in proportion to its availability (all χ^2-tests non-significant). However, when we considered all possible combinations of height, slope and distance to the nearest feeding area (all variables included in the logistic model) we found significant differences between use and environmental availability. Cliffs >12 m in height, within 3 km of a foraging area, and steeper than 85°, were the most frequently used but not the most commonly available along the Ría Deseado ($\chi^2_3 = 9.3$, $P = 0.02$).

We also observed some differences in the characteristics of foraging areas that were used and available. Among possible combinations of substrate type and depth (0–10 m, 10–20 m,

Table 1. Median values for habitat characteristics of cliffs used for breeding by Red-legged Cormorants and unoccupied cliffs on the Ría Deseado

Variable	Used cliffs ($n = 8$)	Unused cliffs ($n = 8$)	Test score	P
Length (m)	130.0	175.5	$Z = 0.8$	0.4
Height (m)	14	8	$Z = -2.25$	0.02
Slope (°)	90.0	82.5	$Z = -2.1$	0.03
Available area (m^2)	1132	1204	$Z = -0.26$	0.3
Fetch (m)	1250	1423	$Z = 1.05$	0.3
Median depth of water within 3 km of the cliff (m)	12	8	$Z = -1.68$	0.07
Distance to the nearest potential foraging area (km)	1.0	6.5	$Z = 1.9$	0.04
Location (continental or island)	–	–	$\chi^2 = 1.75$	>0.05
Orientation	–	–	$\chi^2 = 2$	>0.05

>20 m deep), zones with both gravel substrate and depths ≤10 m were the most frequently used by Red-legged Cormorants ($\chi^2_4 = 387.2$, $P < 0.001$). Nevertheless, as shown in Fig. 1*b*, areas of the Ría Deseado with these characteristics were neither the most abundant nor the most commonly available.

Discussion

Habitat use refers to the distribution of animals and the correlation of that distribution with specific habitat components (Johnson 1980). In this study, we identified several factors that appear to influence the pattern of use of breeding habitat by Red-legged Cormorants. Characteristics of cliffs that provide protection against predators (steep and high cliffs) seem to determine the use of a given nesting habitat by Red-legged Cormorants. Our results are consistent with those obtained by Millones *et al.* (2008), who studied the habitat use of Red-legged Cormorants at a site scale, along the Argentinean coast. The slope of cliffs has been suggested as an important factor affecting the rate of predation on nests of seabirds (Siegel-Causey and Hunt 1981; Coulson 2002). Along the Ría Deseado, slopes of cliffs ranged from 65° to 90° but Red-legged Cormorants were found breeding only on the steeper cliffs (80° to 90°). Furthermore, the height of cliffs can also help to avoid the splash effect of waves breaking against the base of the cliff.

We also found that the proximity to and accessibility of an abundant source of food seem to determine the use of a potential breeding sites by Red-legged Cormorants. Cormorants feed mainly upon benthic prey, in shallow waters close to the shore. Their feeding performance is affected by environmental characteristics like the depth of water, bottom substrate and density of prey (Monaghan *et al.* 1994; Frere *et al.* 2005). As found by Gandini *et al.* (2005), Red-legged Cormorants tended to forage in shallow waters over gravel substrates, where algae and fish (both of them very frequent items in the diet of Red-legged Cormorants) are common (Kühnemann 1969; Iantanos 2002; E. Frere and A. Millones, pers. obs.). The proximity to such good foraging areas seems to determine the use of a given cliff for breeding by this species.

Comparisons of habitat used by a species with available habitat are commonly used to describe habitat selection (Jones 2001). In this study, we tested for non-random use of breeding habitat by Red-legged Cormorants. Cliffs that provide protection (steep and high) and which are close to a suitable foraging site were used more than expected by environmental availability. Thus, in this species, habitat selection is influenced by habitat characteristics related to protection from predation and proximity to a source of abundant food. Seabirds generally settle in breeding localities that are as close as possible to their foraging areas (Buckley and Buckley 1980; Bried and Jouventin 2002). In Red-legged Cormorants, both the distance and duration of daily foraging trips are shorter than those of other cormorant species breeding in the Argentinean coast (Gandini *et al.* 2005; Frere *et al.* 2008). Thus, nesting close to a source of food seems to be an optimal choice for Red-legged Cormorants. Red-legged Cormorants have also been seen foraging mainly when the tide is falling. During low tides, Red-legged Cormorants performed shorter feeding trips, by diving faster, presumably by minimising the transit time to and from the bottom and maximising prey searching time at the sea-floor. It seems to be the optimal condition to begin feeding, acquire food faster and reduce diving cost (Gandini *et al.* 2005). Breeding on cliffs near a foraging area can help Red-legged Cormorants choose the optimal tide height to initiate a foraging trip. Finally, in this study, we also observed that individual Red-legged Cormorants did not exhibit random use of foraging sites. At Ría Deseado, this species exhibited non-random preferences for certain characteristics of foraging sites, which are not the most commonly available sites.

Acknowledgements

The Universidad Nacional de la Patagonia Austral, Wildlife Conservation Society and the PME 2003 N° 271 (FONCyT) funded this work. We thank Juan Pablo Martin, Néstor Juanola, Adrian Pérez and Omar Juanola for field assistance. We also thank Annick Morgenthaler, Oliver Yates and two anonymous reviewers for advice on earlier versions of the manuscript.

References

Alldredge, J. R., and Ratti, J. (1992). Further comparison of some statistical techniques for analysis of resource selection. *Journal of Wildlife Management* **56**, 1–9. doi:10.2307/3808785

Bried, J., and Jouventin, P. (2002). Site and mate choice in seabirds: an evolutionary approach. In 'Biology of Marine Birds'. (Eds E. A. Schreiber and J. Burger.) pp. 263–305. (CRC Press LLC: Boca Raton, FL.)

Buckley, F. G., and Buckley, P. A. (1980). Habitat selection and marine birds. In 'Behavior of Marine Animals'. (Eds J. Burger, B. L. Olla and H. E. Winn.) pp. 68–112. (Plenum Press: New York.)

Coulson, J. C. (2002). Colonial breeding in seabirds. In 'Biology of Marine Birds'. (Eds E. A. Schreiber and J. Burger.) pp. 87–113. (CRC Press LLC: Boca Raton, FL.)

Frere, E., Gandini, P., and Quintana, F. (2002). Diving behaviour of the Red-legged Cormorant in southeastern Patagonia, Argentina. *Condor* **104**, 440–444. doi:10.1650/0010-5422(2002)104[0440:DBOTRL]2.0.CO;2

Frere, E., Gandini, P., Ruiz, J., and Vilina, Y. A. (2004). Current status and breeding distribution of Red-legged Cormorant *Phalacrocorax gaimardi* along the Chilean coast. *Bird Conservation International* **14**, 115–123. doi:10.1017/S0959270904000139

Frere, E., Quintana, F., and Gandini, P. (2005). Cormoranes de la costa Patagónica: estado poblacional, ecología y conservación. [Cormorants of the Patagonian coast: population status, ecology and conservation.] *El Hornero* **20**, 35–52. [In Spanish]

Frere, E., Quintana, F., Gandini, P., and Wilson, R. P. (2008). Foraging behaviour and habitat partitioning of two sympatric cormorants in Patagonia, Argentina. *Ibis* **150**, 558–564. doi:10.1111/j.1474-919X.2008.00824.x

Gandini, P., Frere, E., and Quintana, F. (2005). Feeding performance and foraging area of Red-legged Cormorant. *Waterbirds* **28**, 41–45. doi:10.1675/1524-4695(2005)028[0041:FPAFAO]2.0.CO;2

Hamer, K., Schreiber, E. A., and Burger, J. (2002). Breeding biology, life histories, and life history–environment interactions in seabirds. In 'Biology of Marine Birds'. (Eds E. A. Schreiber and J. Burger.) pp. 217–261. (CRC Press LLC: Boca Raton, FL.)

Iantanos, N. (2002). Dinámica sedimentaria de la Ría del Deseado, Provincia de Santa Cruz. Ph.D. Thesis, Universidad Nacional de la Patagonia San Juan Bosco, Chubut, Argentina.

Johnson, D. H. (1980). The comparison of usage and availability measurements for evaluating resource preference. *Ecology* **61**, 65–71. doi:10.2307/1937156

Jones, J. (2001). Habitat selection in avian ecology: a critical review. *Auk* **118**, 557–562. doi:10.1642/0004-8038(2001)118[0557:HSSIAE]2.0.CO;2

Kühnemann, O. (1969). Vegetación marina de la ría de Puerto Deseado. *Opera Lillioana* **17**, 1–123.

Martin, J. P., and Bastida, R. (2008). Comunidades bentónicas y dieta de *Eleginops maclovinus. Latin American Journal of Aquatic Research* **36**, 1–13. doi:10.3856/vol36-issue1-fulltext-1

Millones, A. (2009). Uso y selección de hábitat reproductivo del cormorán gris (*Phalacrocorax gaimardi*). Ph.D. Thesis, Universidad de Buenos Aires, Buenos Aires.

Millones, A., Frere, E., and Gandini, P. (2005). Dieta del cormorán gris (*Phalacrocorax gaimardi*) en la Ría Deseado, Santa Cruz, Argentina. *Ornitologia Neotropical* **16**, 519–527.

Millones, A., Frere, E., and Gandini, P. (2008). Breeding habitat use by Red-legged Cormorant (*Phalacrocorax gaimardi*) in Patagonia, Argentina. *Waterbirds* **31**, 656–660.

Monaghan, P., Walton, P., Wanless, S., Uttley, J. D., and Burns, M. D. (1994). Effects of prey abundance on the foraging behaviour, diving efficiency and time allocation of breeding Guillemots *Uria aalgae. Ibis* **136**, 214–222. doi:10.1111/j.1474-919X.1994.tb01087.x

Orians, G. H., and Wittenberger, J. F. (1991). Spatial and temporal scales in habitat selection. *American Naturalist* **137**, S29–S49. doi:10.1086/285138

Siegel-Causey, D., and Hunt, G. L. (1981). Colonial defence behaviour in Double-crested and Pelagic cormorants. *Auk* **98**, 522–531.

Manuscript received 17 October 2009, accepted 3 February 2010