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Nesting habitat of Chubut Steamer Ducks in Patagonia, Argentina

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Abstract. We studied nest-site selection of the flightless Chubut Steamer Duck (*Tachyeres leucocephalus*) along 292 km of continental coastline and 59 km of island coastline in Patagonia, Argentina, between 2004 and 2006. This area encompasses the main breeding range of the species. Almost all nests were on islands and islets, which ranged in area from 0.5 to 54.4 ha and were 0.01–5.6 km from the mainland. Nesting sites were within bays and inlets with shallow waters and protected from waves, winds and strong currents. Using logistic regression analyses in an information-theoretic framework to compare habitat characteristics between nesting sites and randomly chosen sites, we found that Chubut Steamer Duck nesting sites were strongly and positively associated with higher proportions of shrub vegetation cover. To a lesser degree, the percentage of silt–clay sediment was also positively associated with nesting sites. Nest-site selection is thought to be associated with concealment from aerial predators and protection from weather. This is the first study of breeding habitat and nest-site selection of Chubut Steamer Ducks, and will contribute to management and habitat conservation for this rare flightless duck through identification of both general and specific habitat features that should be preserved or enhanced.

Additional keywords: breeding habitat, endemic flightless marine duck, nest-site selection, *Tachyeres leucocephalus*.

Introduction

The nesting site of birds constitutes the finest spatial scale of habitat selection (Wiens 1986; Block and Brennan 1993) and must provide a location where adults and eggs are sheltered from environmental stresses (Ricklefs and Hainsworth 1969; Walsberg 1985) and afford some protection from predators (Martin and Roper 1988). From a conservation perspective, determining nesting habitat is a critical step towards preserving, restoring or creating areas that support reproductive activity.

The Chubut Steamer Duck (*Tachyeres leucocephalus*) is a flightless anatid duck endemic to the marine coast of Central Patagonia, Argentina (Madge and Burn 1988). Breeding range extends along approximately 500 km of coastline, from the Chubut River mouth (43°20′38″S, 65°3′19″W) south to the Santa Cruz and Chubut Province boundary (45°59′35″S, 67°35′44″W) (M. L. Agüero and J. P. García Borboroglu, unpubl. data). It is classified as Near Threatened globally (IUCN 2010). A recent systematic census indicated that, along the marine coast of Chubut Province, numbers are estimated to be 3700 breeding individuals (M. L. Agüero and J. P. García Borboroglu, unpubl. data) (Fig. 1).

The species is exposed to several potential anthropogenic threats, including oil exploration activities, and harvesting of guano and macroalgae (García Borboroglu and Yorio 2007). Egg-collecting has also been reported but appears to occur at very low intensity at a few sites (J. P. García Borboroglu, unpubl. data). Another potential threat is the presence of three introduced species: the Green Crab (*Carcinus maenus*), Asian Kelp (*Undaria pinnatifida*), and the Acorn Barnacle (*Balanus glandula*), all of which may cause dramatic changes to ecosystems (Casas *et al*. 2004; Hidalgo *et al*. 2005; Schwindt 2007) upon which Steamer Ducks rely.

The combination of its restricted breeding distribution, small population, flightlessness and the potential threats to which it is exposed mean the species would be of significant conservation concern (BirdLife International 2010). However, there is little knowledge of its basic ecology. In this study we aimed to fill some of the gaps in our knowledge, and to contribute to the conservation of the species, by: (1) describing the general breeding habitat of the Chubut Steamer Duck along the coast of Chubut Province; and (2) determining the environmental features of nesting sites within its main breeding area.

Methods

We studied breeding habitat along 292 km of continental coastline and 59 km of island coastline within the Chubut Province,

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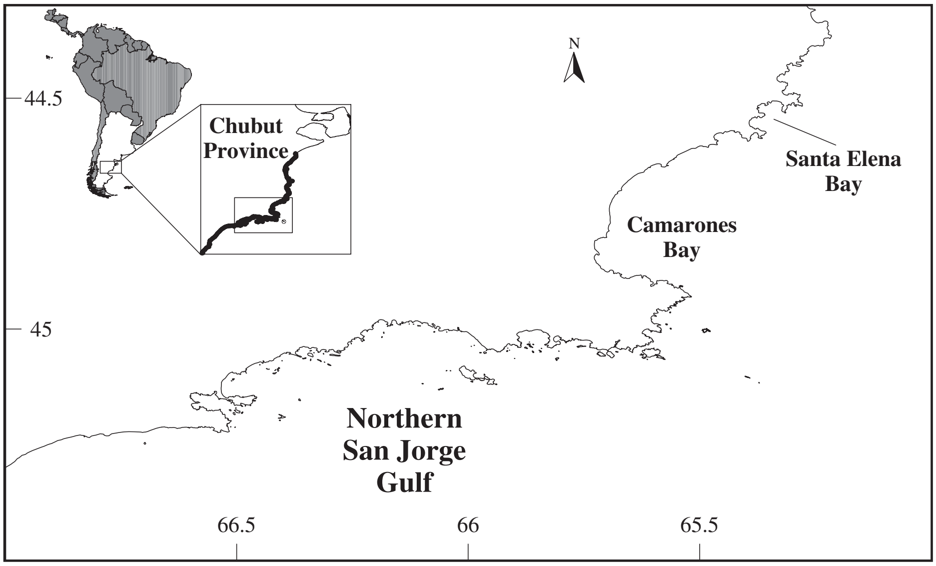

Fig. 1. Map showing where we studied breeding habitat Chubut Steamer Ducks. In the inset map, breeding distribution in the Chubut Province is shown as a thick line.

Patagonia, Argentina (Fig. 1), over three breeding seasons (September–December), from 2004 to 2006. We surveyed 41 islands, walking transects that covered the whole area of each island (total area 323 ha). Along continental coasts, we walked zigzag transects in a strip of 200 m inland and parallel to the shore. Transects started at the high-tide line and were 40 m wide. The typical landscape of the Chubut coast is an arid steppe, with low shrub vegetation (Soriano 1956).

Where nests were found, we described the general habitat characteristics of the area. The area of islands and the distance to the closest point of the mainland were estimated using nautical charts (Servicio de Hidrografía Naval Argentina, see http://www.hidro.gov.ar/Nautica/LCCosteras.asp, accessed 23 September 2009), geographic information system (GIS) tools, and published literature (García Borboroglu *et al*. 2002).

To evaluate nest-site selection, 10 habitat variables were collected at 170 nest-sites and at 167 randomly chosen points within northern San Jorge Gulf and Camarones Bay, where most of the population occurs, and at Santa Elena Bay (Fig. 1). Random points were selected using tables of random numbers to generate x and y coordinates (Bosch and Sol 1998). At each nesting site and random point the percentage of substrate components in the surface layer (top 5 cm) was estimated by means of a field texture test following Stokes and Boersma (1991). Substrate components were classified as: (1) silt–clay; (2) sand; (3) shell (shell fragments); (4) gravel and rock fragments; and (5) rock (rocky outcrops). Slope of the substrate was measured using a clinometer (PM-5/060 PG, Suunto, Finland). We also estimated percentage of shrub vegetation cover within a 1- and 5-m radius around the nest or random point. Finally, the distance to nearest high-tide line and altitude above sea level were determined.

Averages are presented as the sample mean ± s.e. We contrasted features of nesting sites with those of randomly chosen sites using logistic regression models in an information-theoretic framework (Burnham and Anderson 2002). Before creating our set of candidate models, we examined correlations between potential explanatory variables, to ensure that our candidate model set avoided models in which multicollinearity could affect results. We examined Pearson correlation coefficients, r, among all variables (see list in Table 1). We found modest degrees of correlation ($r > 0.4$) among some pairs of variables, in cases for which correlations might be expected. Specifically, sediment types were correlated, particularly silt–clay and rock ($r = -0.47$), which is to be expected as these were the dominant sediment types and one is often the inverse of the other. Also, we found that the percentage of shrubs within 1m was correlated ($r = 0.46$) with the percentage of shrub within 5 m. Finally, we found an expected correlation between distance to high tide and altitude of the nest ($r = 0.42$). Because of the observed correlation, as well as the redundancy from a biological perspective, we used only one variable from each pair, specifically: silt–clay sediment, percentage of shrubs within 1m, and distance to high tide. All pairs of variables remaining for consideration in candidate models had correlations of $|r| < 0.33$.

Table 1. List of habitat features measured

Average habitat attributes (±s.e.) of nesting sites ($n = 170$) of Chubut Steamer Ducks compared with randomly selected sites ($n = 167$)

Habitat characteristics	Nest sites	Random sites
Silt–clay substrate (%)	60.0 ± 2.9	34.3 ± 3.0
Rock substrate (%)	4.6 ± 1.1	31.3 ± 3.3
Sand substrate (%)	11.5 ± 2.1	8.7 ± 1.9
Shell substrate (%)	15.4 ± 2.0	15.9 ± 2.2
Gravel substrate (%)	7.1 ± 1.4	9.9 ± 1.8
Shrub cover within 1 m (%)	63.6 ± 2.3	5.0 ± 1.2
Shrub cover within 5 m (%)	31.1 ± 1.8	17.5 ± 1.8
Slope (degrees)	3.8 ± 0.2	4.3 ± 0.2
Distance to high tide line (m)	31.7 ± 1.6	33.5 ± 2.1
Altitude above sea level (m)	1.4 ± 0.1	1.7 ± 0.1

Our candidate model set consisted of all additive combinations of non-redundant variables (Table 2). We consider that all of these combinations represent plausible hypotheses regarding the habitat features that differentiate nesting sites from randomly selected sites.

To test for overdispersion, we calculated $\hat{c}$ for the global model, including all four explanatory variables. $\hat{c}$ is a variance inflation factor calculated as the deviance Chi-square statistic for goodness-of-fit divided by the degrees of freedom. In this case, $\hat{c}$ was <1 (0.57), indicating that no overdispersion was present, so a variance inflation factor was not required.

For each model in the candidate set, we calculated the second-order Akaike information criterion (AIC_c), which accounts for any small sample bias (Burnham and Anderson 2002). Models with lower AIC_c values have more support from the data. We also calculated ΔAIC_c values for each model, which are simply the difference in AIC_c values between a model and the best supported model in the set. Finally, we calculated Akaike weights (w_i) for each model, which provide easily comparable numbers to gauge the degree of evidence that a given model is the best in the set.

We also calculated several information-theoretic statistics that provide information about the explanatory value of each of the variables, including parameter likelihoods, weighted parameter estimates, and unconditional standard errors, all of which are based on the entire model set and thus incorporate model uncertainty into final values and ultimately the inferences drawn (Burnham and Anderson 2002).

Results

We found a total of 170 nests. All nests but one were on islands and islets (99.412%), which ranged in area from 0.5 to 54.4 ha (10.4 ± 2.1 ha; $n = 39$) and were 0.01 to 5.6 km (1.2 ± 0.2 km; $n = 32$) from the mainland. For some islands no GIS data exist so these have not been included. All nests were within bays and inlets with shallow waters and protected from waves and predominant winds. The distance from the nest to the high-tide line ranged from 1 m to 159 m (33.9 ± 1.9 m; $n = 170$).

We found that there was a high degree of model uncertainty, with no model in the candidate set with a $w_i > 0.23$ (Table 2). This indicates that several combinations of variables had similar value for explaining nest-site selection by Steamer Ducks. However, all of the models with some degree of support consistently included the *shrub* parameter (% coverage of shrub within 1 m). In turn, this led to a parameter likelihood of 1.0 (after rounding) for the *shrub* parameter (Table 3), further confirming the importance of this variable. In addition, the weighted parameter estimate for *shrub* indicated a strong positive relationship of a site being a nest with increasing percentage of shrub (Table 3); the associated unconditional standard error was small relative to the parameter estimate, confirming the explanatory value of the *shrub* parameter. Finally, a comparison of means (Table 1) highlights that the % shrub cover within 1 m was markedly higher at nesting sites than at random sites. As expected, the average % shrub cover within 5 m was higher at nesting sites than random sites (Table 1), though not to the same degree as % shrub cover within 1 m.

Of the remaining explanatory variables, only *substrate* (% silt–clay) received modest support, with a parameter likelihood of 0.60. However, models including *substrate* in the absence of *shrub* were poorly supported ($w_i < 0.01$; Table 2), suggesting a relatively small influence of *substrate*. This is similarly reflected in the parameter estimate, which is small and has an associated unconditional standard error that is larger than the parameter estimate (Table 3). The parameter estimate is suggestive of a positive trend, that is that nests tend to be more likely to be associated with higher proportions of silt–clay. This is reflected in the higher average proportion of silt–clay sediments at nesting sites relative to random sites (Table 1). Taking into account that the proportion of silt–clay is essentially the inverse of the proportion of *rock*, this result can be interpreted as a preference for the former or an avoidance of the latter.

Neither *slope* nor the *distance to high-tide line* (and by extension *altitude*) received any support as having value explaining nest-site selection. This is indicated by the low parameter likelihoods (Table 3), the small parameter estimates with relatively large unconditional standard errors (Table 3), and very similar averages between nest-sites and random sites (Table 1).

Table 2. Candidate model set

Candidate models and associated statistics from an analysis using logistic regression models in an information-theoretic framework to contrast habitat attributes of Chubut Steamer Duck nesting sites ($n = 170$) with those of randomly selected sites ($n = 167$). K, number of estimated parameters; AIC_c, second-order Akaike's Information Criterion; ΔAIC_c, differences in AIC_c relative to the best-supported model in the set; w_i, Akaike weight, indicating the probability that the model is the best in the set. 'Substrate', percentage of silt–clay; 'Shrub', proportion shrub cover within 1 m; 'Distance', distance to high-tide line (m); 'Slope', ground slope (degrees)

Explanatory variables	K	AIC_c	ΔAIC_c	w_i
Substrate + shrub	3	197.3	0	0.23
Shrub	2	197.7	0.4	0.19
Substrate + shrub + distance	4	198.1	0.8	0.15
Substrate + shrub + slope	4	198.6	1.3	0.12
Substrate + shrub + slope + distance	5	199.1	1.8	0.09
Shrub + distance	3	199.1	1.8	0.09
Shrub + slope	3	199.5	2.2	0.08
Shrub + slope + distance	4	200.9	3.6	0.04
Substrate + distance	3	433.3	236	0
Substrate + slope + distance	4	435.3	238	0
Substrate	2	435.7	238.4	0
Substrate + slope	3	437.7	240.4	0
Slope	2	466.9	269.6	0
Slope + distance	3	468.6	271.3	0
Distance	2	470.8	273.5	0

Table 3. Metrics for logistic regression explanatory variables

Metrics for logistic regression explanatory variables, calculated across the candidate model set. Definitions for variables are given in Table 2

Explanatory variable	Parameter likelihood	Parameter estimate	Weighted unconditional s.e.
Intercept	1	–2.38	0.44
Substrate	0.6	0.01	0.01
Shrub	1	0.09	0.01
Slope	0.33	0.02	0.04
Distance	0.38	0	0.01

Discussion

Nests of Chubut Steamer Ducks were found almost solely on islands and islets. Such sites are thought to offer better protection from terrestrial predators, human disturbance and pollution (Lack 1968). Several potential mammalian predators have been recorded on the mainland coast area in our study area but do not occur on islands, such as the Hairy Armadillo (*Chaetophractus villosus*), Argentine Grey Fox (*Pseudalopex griseus*), Patagonian Ferret (*Galictis cuja*), Geoffroy's Cat (*Felis geoffroyi*), Culpeo (*Lycalopex culpaeus*) and Pumas (*Puma concolor*). There is also less human disturbance on the islands, which may enhance the suitability of the islands for breeding by this flightless marine duck. There are a range of human activities that take place along the continental coast, including tourism, recreation and nautical sports (Tagliorette and Losano 1996), small-scale coastal fishing (Caille 1996) and harvesting of macroalgae (Piriz and Casas 1996) that do not occur on the islands. The inaccessibility of the islands is increased by the difficult navigation conditions in the area. Steamer Ducks may have nested more commonly on mainland shorelines historically, when levels of human disturbance were lower, but no data are available to evaluate that hypothesis.

Nesting sites were mostly along shorelines sheltered from wind, waves and strong currents (Agüero 2006). All members of the genus *Tachyeres* breed in sheltered bays, inlets or creeks with shallow and calm waters (Weller 1975, 1976; Johnsgard 1978). In general, sites protected from wave action would presumably be easier for Chubut Steamer Ducks to forage, and they would be more adequate for the chicks to swim and forage, in comparison to sites exposed to wave action.

Consistent with a preliminary study of Humphrey and Livezey (1985), of five nests on one island, our analysis showed that vegetation cover was a key variable in nest-site selection by Chubut Steamer Ducks. Vegetation cover in part determines the thermal properties of a nest and the incubating female (Carboneras 1992), providing increased protection from wind, and reduced nocturnal radiative heat-loss and diurnal heat-gain (Walsberg 1981, 1985; Gloutney and Clark 1997). Another advantage of greater nesting cover is increased concealment from predators (Laurila 1989; Clark and Nudds 1991; Lester 2004; Baldassarre and Bolen 2006). In most ground-nesting birds, vegetation may provide protection from avian predators (Clark and Nudds 1991). In our study area, two species were observed to take eggs of Chubut Steamer Ducks: Kelp Gulls (*Larus dominicanus*) and Southern Caracara (*Caracara plancus*). Notably, 38% of the Kelp Gull population of Patagonia (43 875 breeding pairs) breeds in the northern San Jorge Gulf (N. Lisnizer, J. P. García Borboroglu and P.M. Yorio, unpubl. data), occurring with Chubut Steamer Ducks on 72% of the islands (N. Lisnizer, J. P. García Borboroglu and P.M. Yorio, unpubl. data).

The selection and use of habitat are measures of the relative importance of habitats for a species and, as such, provide information necessary for effective conservation (Fleskes *et al.* 2003). Our study provides new information about the breeding habitat and nesting sites used by Chubut Steamer Ducks. This can be used to identify habitats and habitat features to protect or enhance. In particular, the results of this study are being used to define the zoning schemes for the Parque Interjurisdiccional Costero Marino de la Patagonia Austral (First Marine National Park of Argentina), and to update the information of existing management plans in other coastal sectors of Patagonia where this species breeds. We recommend that further research examining the links between characteristics of breeding habitat and reproductive success would provide important insights into the biology of this poorly understood species and help further direct conservation efforts.

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