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Nest site selection of the Kelp gull (*Larus dominicanus*) in the Beagle Channel, Tierra del Fuego, Argentina

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Abstract Nest site selection of Kelp gulls *Larus dominicanus* breeding in Conejo and Bridges islands, Tierra del Fuego, Argentina, was assessed between 14 and 30 December 2005 to describe variability in nest site features and determine variables affecting nest choice. Fourteen microhabitat variables were quantified at 40 nest sites and at 40 random points in each island during the late incubation stage. Nests at the two colonies were placed on different kinds of substrates across areas with varying degrees of cover provided either by rocks or vegetation. Despite the variability observed in nest site features, rock cover and rocky substrates were the main factors determining nest site selection. At Conejo Island, nest sites presented more rock cover, less percentage of vegetation cover and of vegetation debris substrate, and were placed further from the nearest vegetation in comparison to random points. Similarly, gulls at Bridges Island selected nest sites with more rock cover which were placed mainly on rocky and vegetation substrates. This contrasts with results previously obtained in Argentina, which indicated that vegetation is a key factor influencing Kelp gull nest site selection. Over 80% of the nests at both study colonies were placed on the northern slopes of the islands, relatively more protected from the strong prevailing southwest winds, and nests at both colonies tended to be more protected on their southern side either by rocks or vegetation. Results obtained at Tierra del Fuego confirm the plasticity of microhabitat use by Kelp gulls, and their ability to take advantage of nesting sites according to availability and local environmental factors.

Keywords Kelp gull · *Larus dominicanus* · Nest site selection · Tierra del Fuego · Argentina

Introduction

Nest site characteristics are important determinants of breeding success in most bird species (Partridge 1978; Cody 1985; Block and Brennan 1993). Birds with a wide geographic range may select different habitat types from region to region, and choice of nest sites will depend on local habitat features and availability (Cody 1985; Buckley and Buckley 1980). Several gulls and terns, e.g., show great plasticity in their habitat requirements, and individual choice of microhabitat characteristics can vary considerably between colonies (e.g. Pierotti and Good 1994; Ramos and del Nevo 1995). Therefore, the characterization of nest site requirements of such species, as well as the analysis of how habitat variability influences microhabitat choice, requires studies across a wide range of environments within their geographical distribution (Orians and Wittenberger 1991).

Kelp gulls (*Larus dominicanus*) are widely distributed in the southern hemisphere (Burger and Gochfeld 1996), and in Argentina they breed along 2,500 km in the Atlantic coast from central Buenos Aires province (38°45′S) to the Beagle Channel, Tierra del Fuego province (54°53′S) (Yorio et al. 1999). Kelp gull nesting habitat requirements have been analyzed in central and northern Patagonia,

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where they use a wide range of nesting habitats confirming its great plasticity in habitat choice (García Borboroglu and Yorio 2004a). Similar diversity in the use of habitat types has been recorded in other regions of the southern hemisphere, including southern Africa (Burger and Gochfeld 1981; Crawford et al. 1982), New Zealand (Fordham 1964), Antarctica (Quintana and Travaini 2000), and Chile (Simeone and Bernal 2000). Despite this plasticity, vegetation cover has been identified as a key component of nesting habitat and has measurable effects on breeding success (Yorio et al. 1995; García Borboroglu and Yorio 2004a, b). Although Kelp gull nest site requirements and selection have been studied in a large number of breeding sites in central and northern Patagonia (García Borboroglu and Yorio 2004b), no published information is yet available from colonies located in the southern distributional range of Argentina. The goal of this study was to assess nest site selection of Kelp Gulls breeding in the southernmost colonies of Argentina located in the Beagle Channel, Tierra del Fuego, by describing variability in nest site features and determining the most important variables affecting nest choice. Finally, results are discussed in relation to available information from northern and central Patagonia.

Methods

Study area

Research was conducted during the 2005 breeding season at the Kelp gull colonies of Conejo Island (54°51′S, 68°16′W) and Bridges Island (54°53′S, 68°15′W) (Fig. 1). These islands are located in the Beagle Channel near the city of Ushuaia, Tierra del Fuego. Conejo Island has an area of approximately 13.4 ha, being 750 m long and less than 200 m wide. Vegetation consists mainly of *Pernettya mucronata*, *Chilliotrichum diffusum*, *Salicornia ambigua*, *Berberis buxifolia*, *Empetrum rubrum*, and tall grasses. Bridges Island has approximately 66.8 ha, being 2,000 m long in its larger axis. The main vegetation in this island consists of *P. mucronata*, *C. diffusum*, *Sphagnum magellanicum*, *Nothofagus antartica*, *Bolax gummifera* and *Azorella* spp., and tall grasses. At both islands, the main elevation runs east–west along their larger axis. Kelp gull colony size was estimated at 573 breeding pairs at Conejo Island and 133 breeding pairs at Bridges Island.

Microhabitat measurements

To assess nest site selection, a total of 14 microhabitat variables were quantified at 40 nest sites, chosen so as to cover different physiognomic and physical characteristics, heights and distances from the shoreline, and at 40 random points in each island. Information was gathered during the late incubation stage, between 14 and 30 December. Random points within each colony (i.e. the area enclosed by the peripheral nests) were selected using tables of random numbers to generate the *x* and *y* coordinates (Burger and Gochfeld 1985; Bosch and Sol 1998; García Borboroglu and Yorio 2004b). At each nest site and random point, we estimated the percentage of substrate components in the surface layer (top 5 cm). Substrate components were classified as (1) silt–clay, (2) vegetation (mostly *B. gummifera* and *Azorella* spp. or *Senecio humifusus*), (3) vegetation debris, (4) gravel and rock fragments, and (5) rock (exposed bedrock). Additional variables recorded were the percentage of rock and shrub vegetation cover (rocks and vegetation >35 cm high) within a 1 and 5 m radius around the nest or random point, the distance to the nearest vegetation and its height (in cm), the distance (in cm) to the nearest clearing from which gulls could take flight from when threatened, slope of the substrate (recorded using a Suunto type PM-5/060 PG clinometer), and orientation of the nest site. Orientation of the exposed side of nest was obtained in relation to eight compass directions (N, NE, E, SE, S, SW, W, NW), but categories were lumped in only two for the analysis, differentiating only between nests with the exposed side facing north versus south of an east–west plane.

Statistical analyses

Continuous variables were log-transformed, while percentage variables were arcsine transformed prior to analysis to approximate normality. A principal component analysis (PCA) was used to summarize the important dimensions of variation present in the selected habitat space. All components that met the broken-stick criterion recommended by Jackson (1993) were retained. Hence, we only present the components (axes) where the broken-stick eigenvalue is less than the actual eigenvalue for the axis, meaning that the axis contains more information than expected by chance and should be considered for interpretation. These components served to define new synthetic variables that described the principal independent dimensions of variation in the breeding habitat available to Kelp gulls at each colony. The new synthetic variables (principal components) were then included in an initial multivariate logistic regression model, following Hosmer and Lemeshow (1989). A forward likelihood-ratio method was applied, consisting of a forward stepwise selection with entry testing based on the significance of the score statistic, and removal testing based on the probability of a likelihood-ratio statistic (LRS), based on the maximum partial likelihood estimates. Scores, LRS and their significances are reported. The statistical procedures were performed with the PCord and the SPSS

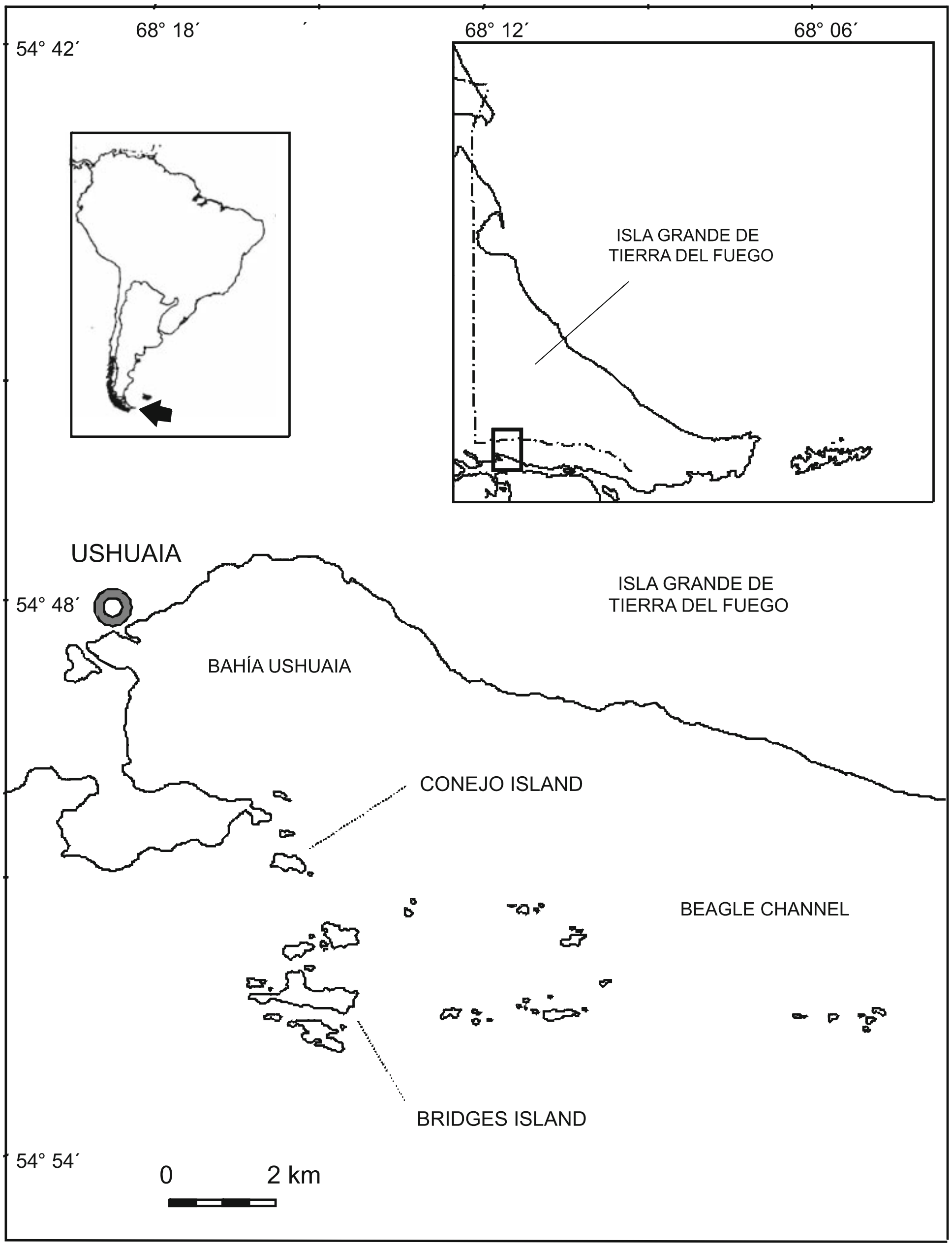

Fig. 1 Geographical location of Conejo and Bridges islands, Tierra del Fuego, Argentina

statistical package. Finally, univariate analyses at $P > 0.05$ were made between nest site and random point values of the variables selected by the logistic regression model.

Results

Conejo Island

The colony was located in the northern sector of the island, and 89% of nests were placed on its north facing slope. Nests were built in vegetated areas dominated by grasses which included bushes of *C. diffusum*, *Pernettya maconata*, and *S. humifusus*. Vegetation height was variable, with a mean of 61.3 ± 30.2 cm ($n = 40$). Vegetation cover around nest sites, within a 1 m radius, averaged 55.25 ± 32.89 ($n = 40$), while rock cover within a 1 m radius averaged 11.25 ± 18.42% ($n = 40$). Most nests were located near clearings from which gulls could take flight (2.5 ± 11.0 cm, $n = 40$). Substrate used to place nests was variable and diverse, with areas of rock, silt–clay or gravel, and areas where the ground was covered by vegetation debris and mats of *S. humifusus* of a few cm high. Rock (30.0 ± 43.2%, $n = 40$) and vegetation debris (55.0 ± 47.5%, $n = 40$) were the dominant substrates. Nest sites were more likely to be exposed towards the north than random points (83 vs. 54%, respectively; Chi-square = 12.2; $df = 1$; $P < 0.05$). Nests were located on

Table 1 Factor loadings and total and cumulative percent variance explained for principal components analysis of microhabitat variables measured in 40 random points at Conejo and Bridges islands, Beagle Channel, Argentina

Nest site variables	Principal components			
	Conejo Island		Bridges Island	
	I	II	I	II
Rocky substrate (%)	0.2432	**0.4075**	−0.0094	**0.3925**
Vegetation debris substrate (%)	**−0.3386**	**−0.4114**	**−0.4818**	−0.1002
Silt–clay substrate (%)	0.1967	−0.2691	−0.1411	−0.0308
Gravel substrate (%)	0.121	−0.2487	0.0243	−0.1286
Vegetation substrate (%)	0.0745	−0.3117	0.1648	**−0.3613**
Slope	−0.0428	0.0608	−0.1414	0.1736
Distance to nearest vegetation	**0.3523**	0.1547	**0.3546**	−0.2137
Vegetation height	−0.2385	0.2017	−0.0557	0.1665
Distance to nearest clearing	−0.0974	**−0.4146**	−0.2248	−0.1402
Vegetation cover 1 m radius (%)	**−0.3978**	0.1737	**−0.4941**	−0.1597
Vegetation cover 5 m radius (%)	**−0.3998**	0.2307	**−0.4644**	−0.2389
Rock cover 1 m radius (%)	**0.3225**	0.0606	0.1986	**0.3196**
Rock cover 5 m radius (%)	**0.3358**	−0.2075	0.0715	**0.465**
Orientation exposed side	**−0.4121**	0.1111	**0.3391**	0.1823
Eigenvalue	3.84	2.42	3.84	2.42
Percentage total variance	32.81	16.09	28.3	15.9
Cumulative variance	32.81	48.9	28.3	44.2

Factor loadings with absolute values >0.3 are shown in bold

level terrain, with slopes ranging between 0° and 41°, and an average of 12° ± 9°.

The PCA generated two components that met the broken-stick criterion and explained 48.9% of the total variance (Table 1). The first principal component was positively associated to rock cover within 1 and 5 m radius and the distance to the nearest vegetation and negatively associated to shrub cover within 1 and 5 m radius, vegetation debris substrate, and the orientation of the exposed side. This component opposes rock cover and shrub cover, and thus may be interpreted as a "microhabitat cover" component, explaining 32.8% of the total variance. The second component represents an additional 16.1% of variance, and was positively associated to rocky substrate and negatively to vegetation debris substrate and the distance to the nearest clearing. This factor opposes these two types of substrate present in the colony, and thus may be interpreted as a "substrate" component.

The final multivariate logistic regression model of nest site selection only included the PC1 ("microhabitat cover" component), classifying 78% of the sites correctly (coefficient ± SE = 0.012 ± 0.004; Wald statistic = 8.12; $P < 0.01$). When examining the relationships between random points and nest sites, considering the variables determining nest site selection, we found a consistent pattern. The nest sites presented more rock cover, were placed further from the nearest vegetation, had significantly less vegetation cover and less vegetation debris substrate than random points (Table 2).

Bridges Island

The Kelp gull colony was located in the northwest sector of Bridges Island, with most of the nests (78%) placed on its north facing slope. Nests were built in vegetated areas of *C. diffusum* and *P. maconata*, and mats of *B. gummifera* and *Azorella* spp. Average vegetation height was 42.8 ± 18.5 cm ($n = 40$), and the percent of vegetation cover within a 1 m radius of the nest site averaged 30.5 ± 21.5% ($n = 40$). Rock cover within a 1 m radius averaged 16.0 ± 15.7% ($n = 40$). Most nests were located near clearings from which gulls could take flight (6.3 ± 13.3 cm, $n = 40$). Substrate components at the nest site were mostly rock (42.5 ± 50.1%, $n = 40$) or low vegetation of *B. gummifera* and *Azorella* spp. of a few cm high (41.0 ± 42.7%, $n = 40$), and to a lesser extent on vegetation debris. Nest sites were more likely to be exposed towards the north than random points (92 vs. 59%, respectively; Chi-square = 17.6; $df = 1$; $P < 0.05$). Nests were located on level terrain, with slopes ranging between 0° and 45° and an average of 10° ± 7°.

The PCA of 13 nest site habitat variables measured on 40 randomly selected points yielded two components that met the broken-stick criterion, collectively accounting for 44.2% of the total variation in the original data (Table 1). The first principal component, representing 28.3% of the variation, was related with the effects of the vegetation on the nest ("vegetation" component hereafter), contrasting high negative factor loadings for shrub cover within 1 and 5 m radius and vegetation debris substrate with positive

Table 2 Mean (±standard deviation) of microhabitat variables measured at Kelp gull nest sites and random points in Conejo and Bridges islands, Beagle Channel, Tierra del Fuego

Nest site variables	Nest sites ($n = 40$)	Random sites ($n = 40$)	Mann–Whitney P
Conejo Island			
Vegetation debris substrate (%)	55.0 ± 47.5	92.5 ± 26.7	0.012
Distance to nearest vegetation (cm)	32.5 ± 52.8	15.5 ± 42.4	0.043
Vegetation cover 1 m radius (%)	55.3 ± 32.9	76.5 ± 30.4	0.002
Vegetation cover 5 m radius (%)	59.3 ± 28.6	79.3 ± 23.0	0.007
Rock cover 1 m radius (%)	11.3 ± 18.4	1.0 ± 6.3	0.034
Rock cover 5 m radius (%)	10.3 ± 16.4	1.3 ± 4.6	0.041
Bridges Island			
Rocky substrate (%)	42.5 ± 50.1	20.0 ± 40.5	0.031
Vegetation substrate (%)	41.0 ± 42.7	35.0 ± 43.9	0.100
Rock cover 1 m radius (%)	16.0 ± 15.7	6.3 ± 8.4	0.004
Rock cover 5 m radius (%)	20.8 ± 14.9	7.5 ± 8.7	0.001

Only variables determining nest site selection identified by the PCA analysis and logistic regression model are included in the table

factor loading for the distance to the nearest vegetation and the orientation of the exposed side of nest. The second component mainly represents the effects of rocky characteristics ("rock" component hereafter), with positive values for rock cover within 1 and 5 m radius and for rocky substrate and a negative value for vegetation substrate. This component represents 15.9% of the variance.

The final multivariate logistic regression model of nest site selection only included the PC2 ("rock" component), classifying 71% of the sites correctly (coefficient ± SE = 0.44 ± 0.17; Wald statistic = 6.75; $P < 0.01$). Nest sites presented more rock cover and rocky substrate than random points (Table 2).

Discussion

Nests at the two Kelp gull colonies in the Beagle Channel were placed on different kinds of substrates across areas with varying degrees of cover provided either by rocks or vegetation of different physiognomic characteristics. These results agree with studies in northern and central Patagonia, Argentina, which have shown great variability and diversity in nest site features and have indicated the importance of cover for Kelp gull nest site selection (García Borboroglu and Yorio 2004b). Similar variability in nest site habitat characteristics with a preference for areas with nest cover has been recorded at other regions in the southern hemisphere. Nesting Kelp gulls select sites next to rock and vegetation cover in southern Africa (Burger and Gochfeld 1981), in structured habitats with higher percentages of large stones and plant cover in the Antarctic Peninsula (Quintana and Travaini 2000), and near rocks or vegetation in central Chile (Simeone and Bernal 2000). These features of the microhabitat should be important in providing protection against factors such as inclement weather conditions, predation, and intra- or inter-specific social interference (Burger 1977; Jehl and Mahoney 1987; Saliva and Burger 1989; Bukacinska and Bukacinski 1993; Good 2002).

Despite the variability observed in nest site features, rock cover and rocky substrates were the main factors determining nest site selection in the Beagle Channel. At Conejo Island, nest sites presented more rock cover, less percentage of vegetation cover and of vegetation debris substrate, and were placed further from the nearest vegetation in comparison to random points. Similarly, Kelp gulls breeding at Bridges Island selected nest sites with more rock cover which were placed mainly on rocky and vegetation substrates. This contrasts with results obtained in previous studies in Argentina, which indicate that vegetation is a key factor influencing Kelp gull habitat selection and breeding success at both the macro- and microhabitat scale (Yorio et al. 1995; García Borboroglu and Yorio 2004a, b, c). These studies, encompassing 16 colonies along 2,500 km of coastline, also showed that within vegetated areas Kelp gulls avoid the densest vegetation, preferring areas with lower cover (mean 17%) compared to areas not used for nesting (García Borboroglu and Yorio 2004a). Similar avoidance of areas with high vegetation cover was recorded in southern Africa (Burger and Gochfeld 1981). This may explain the choice of rocky habitats at least at Conejo Island, where unlike Kelp gull breeding locations in northern Patagonia, grasses are the dominant vegetation type and are relatively tall and distributed in dense patches (average cover in available habitat over 75%). Structured rocky habitats may thus provide nesting gulls with the benefits of cover while minimizing the costs associated with reduced visibility around the nests and limited access to clearings to take off. The choice of rocky over vegetation features at Bridges Island is less clear in this context, as vegetation cover of available habitat was relatively low (approximately 30%).

At high latitude, nesting birds are confronted with stressful environments, particularly during incubation (Carey 2002). Extreme weather conditions can be an important factor determining nest site selection and breeding success (Buckley and Buckley 1980; Walsberg 1985; Stokes and Boersma 1998; Olivier and Wotherspoon 2006), and the direction of prevailing winds, in particular, has been shown to affect nest placement and orientation (Becker and Erdelen 1982; Kim and Monaghan 2005; Olivier and Wotherspoon 2006). Over 80% of the nests at both colonies in the Beagle Channel were placed on the northern slopes of the islands, relatively more protected from the prevailing southwest winds which average between 31 and 33 km/h throughout the nesting season (Servicio Meteorológico Nacional of Argentina, unpubl. data). Moreover, nests at both colonies tended to be more protected on their southern side either by rocks or vegetation. This preference for breeding on the northern slope and building nests with exposed sides facing north may also be directly related to increased sun exposure and improved nesting temperatures, reducing energy demands of breeding gulls and their offspring. In addition, besides offering benefits with respect to cover against predators and social interference, rocky habitats may retain heat longer after sunset, as suggested by Burger and Gochfeld (1981). Thus, the observed choice of nest site features by Kelp gulls in the Beagle Channel may be an adaptation to nesting in high latitudes with chances of relatively cold weather and even late-season snow storms, as average ambient temperatures during the Kelp gull nesting season vary between 8.5 and 10.5°C (Servicio Meteorológico Nacional of Argentina, unpubl. data).

Results obtained at the Beagle Channel colonies confirm the plasticity of microhabitat use by the Kelp gull, and their ability to take advantage of nesting sites according to availability and local environmental factors. In the study area, Kelp gull selected different nest site features than those commonly used at lower latitudes, choosing rocky over vegetated microhabitats. Unfortunately, information on breeding success is lacking and thus it is not possible to assess if Kelp gull microhabitat preferences at these locations are adaptive. Future studies should evaluate the effects of selected nest site variables on Kelp gull breeding output.

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