



Foraging distribution and behaviour of the Audouin's Gull (*Larus audouinii*) in the Aegean Sea



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INTRODUCTION

Audouin's Gull (*Larus audouinii*) is an endemic species of the Mediterranean Sea. In Greece, it breeds on uninhabited islands in the Aegean Sea. The species' national breeding population has decreased during the last decade and it is estimated at 350-500 pairs. Audouin's Gulls forage mainly at sea, feeding primarily on fish caught at the sea surface. The aim of the present study is to assess the foraging distribution and behaviour of the Audouin's Gull at selected colony sites to determine the foraging range and strategies, as well as variations in foraging behaviour among individuals and sites during incubation and chick rearing period, using telemetry.

METHODS

In total 25 tracking devices (12 radio-transmitters, 7 GPS-dataloggers, 5 geolocator dataloggers and 1 GPS-Bluetooth transmitter) have been mounted on incubating Audouin's Gull at colonies on Lipsi (N. Dodecanese), Amorgos (Cyclades) and Skyros (N. Aegean) during 2009-2011 as part of a LIFE-Nature project "Conservation actions for the Mediterranean Shag and Audouin's Gull in Greece, including the inventory of relevant marine IBAs", LIFE07 NAT/GR/000285. Data on foraging locations and behaviour were collected either by tracking of radiotransmitters from land or a speedboat or by retrapping of individuals carrying dataloggers. Recoveries of dataloggers were not always successful because re-trapping attempts were stopped in some cases when it was considered that additional effort could cause birds to abandon nests. The behaviour of individuals equipped with dataloggers was deduced from the recorded speed based on the fact that Audouin's gulls reduce speed during active searching and catching prey.

All tracking locations were filtered to 60s time interval between consecutive locations to compensate for differences in telemetry techniques or sampling intervals and among those foraging locations were selected. Fixed kernel density estimates with 95%, 90% and 50% volume contours were constructed for each track separately in the Hawth's Tools extensions of the ARCGIS 9.3 (Beyer 2004). Predictive habitat modelling of Audouin's Gull's foraging locations with environmental variables including bathymetry, bathymetry gradient, distance from coastline, distance from the colony, as well as, trimester average (April, May, June) of Chlorophyll-a (CHL-a), CHL-a gradient, Sea surface temperature (SST) and SST gradient on a 2.5' grid was performed using maximum entropy approach in MaxEnt (Phillips *et al.* 2004). Spatial autocorrelation of foraging locations was tested by Moran's *I* coefficient in Rook Case (Sawada 1999). Spearman rank correlation coefficient (r_s) among environmental layers was calculated by SPSS 17.0 and ENTTools software was used to estimate Akaike Information Criteria corrected for small sample sizes (AIC_c) (Burnham & Anderson 2002) for model selection. Models with combinations of environmental datasets among which there was at least one strong pairwise correlation ($|r_s| > 0.5$) were excluded from further analysis. 50 bootstrapping MaxEnt replicas for each telemetry site and each year (Skyros 2010, Amorgos 2011, Lipsi 2011) were computed by randomly assigning 80% of the original data set to the training data set and 20% to the test data set. Area under curve (AUC) of receiver operating characteristics (ROC) plots were used to evaluate MaxEnt models.

References

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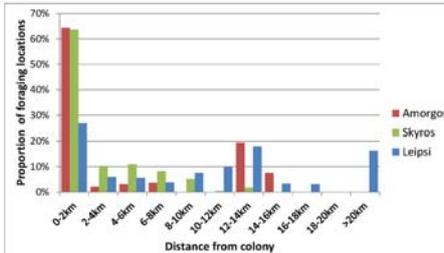


Figure 2: Proportion of foraging locations per distance from colony class

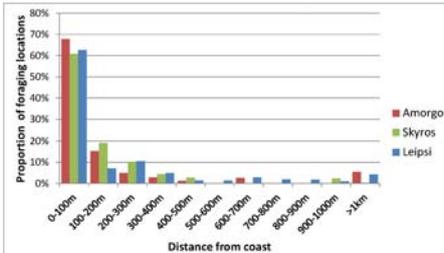


Figure 3: Proportion of foraging locations per distance from coast class

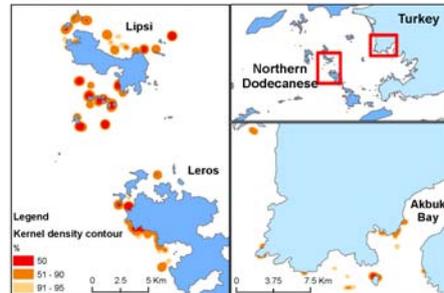


Figure 4: Kernel density contours of foraging areas for Audouin's Gull tagged on Lipsi. A single bird fed in Turkey.

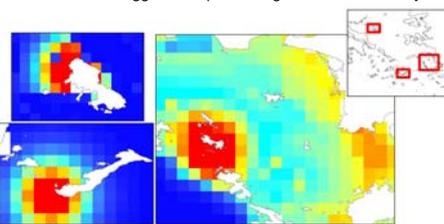


Figure 5: Results of MaxEnt predictive model of Lipsi-Leros region.

RESULTS

In total 53 foraging trips with 25992 locations with known Audouin's gulls' behaviour were recorded. Location filtering to 60s time interval resulted in 2109 foraging locations. Audouin's gulls fed primarily within a radius of 10-16km around their colonies and mainly up to 500m away from the coast (Figures 1,2 and 3).

Significant spatial autocorrelation was detected for Lipsi 2009 dataset and was thus excluded from further analysis. MaxEnt models best explaining the foraging distribution of the Audouin's gulls in the study areas, *i.e.* model with the lowest AIC_c values, contained distance from colony (DCol), distance from coastline (Dcoast), bathymetry (Bath), bathymetry gradient (BathGr) and chlorophyll-a gradient (ChlGr) (Figure 4, Table 1). The AUC values of ROC are ranging from 0.87-0.966 indicate good discriminatory ability of the models (Table 1).

	DCol	Dcoast	Bath	ChlGr	BathGr	AUC (s.d.)
Skyros 2010	68.4%	19.1%		0.3%	12.1%	0.966 (0.018)
Amorgos 2011	89.6%	5.9%		4.5%		0.927 (0.017)
Lipsi 2011	55.7%		24.8%	19.5%		0.870 (0.039)

Table 1: Proportions of contribution of environmental variables and AUC values for MaxEnt models.

DISCUSSION

The results of the present study demonstrate that Audouin's gulls during incubation and chick rearing period (May, June) primarily feed in coastal waters close to their colonies. These trips usually last from less than an hour to up to one day. Some foraging trips may last several days and birds may forage up to 60km away from their colonies as indicated by a single tracked individual from Lipsi which spent several days along the Turkish coast of Akbuk Bay (Fig. 3), as well as the fact that several birds spent several days away from their colonies. Potentially larger proportion of individuals forage far from their colonies, but their tracking was limited by bad weather and the limited range of the radio reception. Additionally, several individuals have been observed to specialize in exploiting fish farms and fishing boats as a food source.

The foraging distribution of the Audouin's gulls predicted by MaxEnt habitat modelling is similar to the distribution recorded by boat-based seabird counts, suggesting that predictive habitat modelling produces satisfactory results even in a highly complex marine environment, such as the Aegean Sea.

Furthermore, static environmental variables *i.e.* bathymetry, distances from colony and coast have the strongest effect on the Audouin's Gull foraging distribution (Table 1), therefore allowing the application of simpler methods of identification of seabird foraging areas, *e.g.* seaward extension defined by buffers around colonies and coastline.

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