2

INFLUENCE OF SEA SURFACE TEMPERATURE ON PELAGIC SEABIRD DISTRIBUTION IN THE SOUTH ATLANTIC OCEAN

Victória Renata Fontoura Benemann[1]*, Elisa de Souza Petersen[1], Lucas Krüger[2] & Maria Virginia Petry[1]

[1]Universidade do Vale do Rio dos Sinos – UNISINOS. Laboratório de Ornitologia e Animais Marinhos.
Av. Unisinos, nº 950, Cristo Rei, 93022-000, São Leopoldo, Rio Grande do Sul, Brazil.
[2]MARE - Centro do Mar e Ambiente, Faculdade de Ciências e Tecnologia,
Universidade de Coimbra, 3004-517 Coimbra, Portugal.

*e-mail: victoriabenemann@gmail.com

https://doi.org/10.4322/apa.2016.002

Abstract: *Seabird distribution is mostly related to high primary productivity zones, as well as to abiotic factors, such as hydrographic conditions. This study aimed at evaluating the influence of sea surface temperature on Antarctic and sub-Antarctic seabirds in the South Atlantic Ocean. Sampling was conducted on board between Rio Grande, Brazil, and Antarctica from 2009 to 2012. A PCA was performed to identify the species associations and Linear Regressions were used to identify the relation with sea surface temperature. We registered 22 Procellariiformes species, belonging to three families: Procellariidae (n=13), Diomedeidae (n=7), and Hydrobatidae (n=2). Three distinct species groups were identified, and two presented a significant relationship with sea surface temperature.*

Keywords: Procellariiformes, SST, Southern Ocean, Sub-Antarctic

Introduction

The at-sea distribution of seabirds is constantly regulated by biotic and abiotic factors. During the non-breeding season, seabirds disperse over wide distances and their distribution is mainly influenced by the availability of prey (Péron *et al.*, 2010; Krüger & Petry, 2011; Ribic *et al.*, 2011). Hydrographic conditions, such as sea surface temperature (SST), are determining factors that regulate the entire marine environment, influencing the distribution and population dynamics of top predator species; however, the species may respond in different ways to these variables (Garthe, 1997; Péron *et al.*, 2010; Krüger & Petry, 2011).

Under a warming ocean scenario, the understanding of how seabird distribution is related to climate is of fundamental importance (Grémillet & Boulinier, 2009), considering that species seem to be changing their distribution accordding to changes in the availability of prey as a result of oceanographic regime shifts (Péron *et al.*, 2010; Weimerskirch *et al.*, 2012).

The aim of this study is to evaluate the distribution of Procellariiformes on a latitudinal gradient of sea surface temperature (SST) between southern South America and Antarctica and investigate the relationship between SST and each seabird species.

Materials and Methods

Data was collected aboard the ships NapOc Ary Rongel and NPo Almirante Maximiano during displacement between Rio Grande, south of Brazil, and South Shetland Islands, Antarctica, from 2009 to 2012 Antarctic Expeditions, in the austral summer of each year. Ten-minute censuses were conducted every hour and a half only on clear days, when visibility conditions ensured the correct identification of birds. All birds within 300m from the ship deck were counted (Tasker *et al.*, 1984). Birds identified as ship-followers were excluded from the analysis to avoid recounting. The temperature data (SST) were collected from the ships.

A categorical Principal Component Analysis (PCA) was applied to identify seabird assemblages. PCA is a multivariate technique that allows reduction of information on dimensions (axes) representing linear combinations of the original variables (in this case, species abundance). The categorical PCA ranks numeric variables, thus allowing better control of dimensional distortions as a consequence of lack of multivariate normality, which is usually common on count data. The scores obtained from the PCA were used in Linear Regressions to test the association of these assemblages with the SST, assuming statistical significance at $p<0.05$. The analysis was performed using the SPSS 18.0 statistical software.

Results

A total of 22 Procellariiformes species from three families were recorded: Procellariidae (n=13), Diomedeidae (n=7), and Hydrobatidae (n=2), totaling 6446 individuals exemplified on Figure 1, where 4 species are shown. The most abundant species were *Daption capense* (n=1492), *Pachyptila sp.* (n= 1488), and *Thalassarche melanophrys* (n=1311), taking into account the cumulative abundance along the year (Table 1).

SST varied from -0.5°C (59°S) to 21.4°C (34°S) along all measurements. The PCA axes explained 15.79% of data variance (Axis 1 = 8.19% and Axis 2 = 7.59%). Three species groups were revealed. Group I presented a negative correlation with Axis 1, group II presented a positive correlation with Axis 1, and group III presented a positive correlation with Axis 2 (Figure 2). Axis 1 presented significant negative regression with temperature (R^2= 0.186, F= 34.912, Slope=-0.82, p< 0.001), whereas Axis 2 did not present a correlation with temperature (R^2= 0.004, F= 0.566, Slope= 0.15, p= 0.453). Consequently, group I is composed of species associated with warmer SST, whereas group II is composed of species associated with colder SST. Group III is not temperature related.

Discussion and Conclusion

Most species recorded in this study present circumpolar, subtropical distribution around the Atlantic, Indian, and Pacific Oceans and breed on Sub-Antarctic and/or Antarctic islands, except for *Puffinus puffinus,* which breeds in the Northern Hemisphere and spends the winters in South Atlantic waters during migration. Generally, the species relation with temperature seems to be consistent with knowledge on the latitudinal distribution of species (IUCN 2013).

South Atlantic temperatures are in a rising trend along the coast of South America (Grémillet & Boulinier, 2009; Arruda & Lentini, 2013) and there are clear abundance and distribution shifts in seabird communities because of changes in water temperature. In the past two decades, there was a decrease in the abundance of several species (*Diomeda exulans, Procellaria aequinoctialis, Macronectes* sp.*, Thalassarche chlororhynchos.* and *Pterodroma mollis*) in the South Oceans due to SST warming (Péron *et al*., 2010). Changes in hydrographic conditions also affect species behavior. For example, foraging distribution of *Diomedea exulans* is enhancing to the South (Weimerskirch *et al*., 2012),

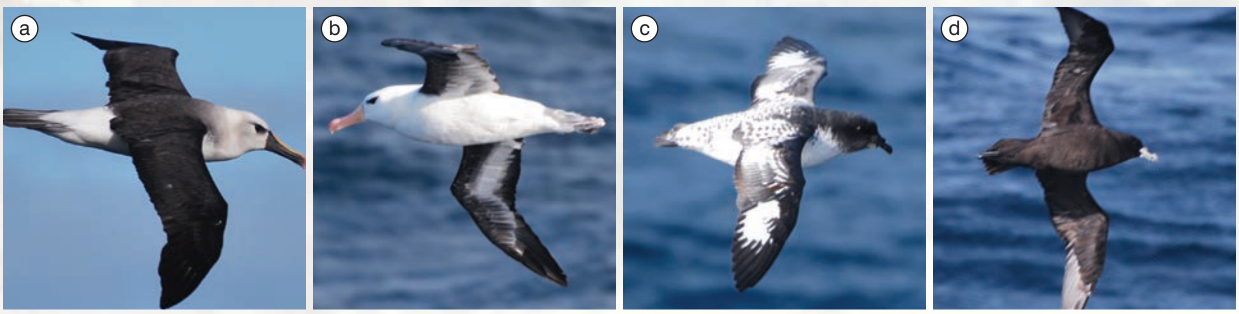

Figure 1. Examples of seabird species recorded: (a) *Thalassarche chlororhynchos,* (b) *Thalassarche melanophrys,* (c) *Daption capense,* (d) *Procellaria aequinoctialis.*

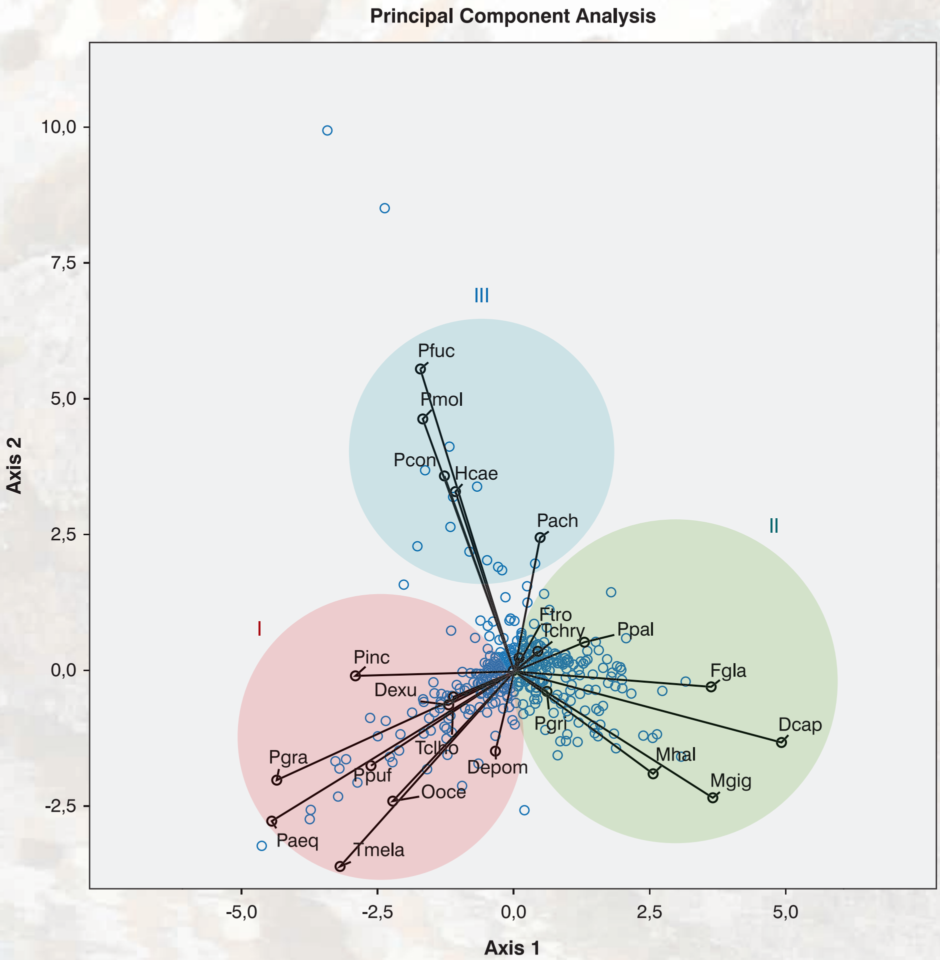

Figure 2. Species Principal Component Analysis. Associations I and II represent the "warm" and "cold" groups, respectively. Pfuc = *Phoebetria fusca;* Ppal = *P. palpebrata*; Tchlo = *Thalassarche chlororhynchos*; Tmela = *T. melanophrys*; Tchry = *T. chlororhynchos*; Depom = *Diomedea epomophora*; Dexu = *D. exulans*;Mgig = *Macronectes giganteus*; Mhal = *M. halli*; Fgla = *Fulmarus glacialoides*; Dcap = *Daption capense*; Pmol = *Pterodroma mollis*; Pinc = *P. incerta*; Hcae = *Halobaena caerulea*;Pach = *Pachyptila* sp.;Paeq = *Procellaria aequinoctialis*;Pcon = *P. conspicillata*; Pgri = *Puffinus griseus*;Pgra = *P. gravis*; Ppuf = *P. puffinus*; Ftro = *Fregetta tropica*; Ooce = *Oceanites oceanicus*.

Table 1. Species associations and total abundance. I = warm group, II = cold group.

Group I		Group II		Group III	
Species	**n**	**Species**	**n**	**Species**	**n**
Thalassarche chlororhynchos	25	*Phoebetria palpebrata*	12	*Phoebetria fusca*	3
T. melanophrys	1311	*Thalassarche chrysostoma*	35	*Pterodroma mollis*	4
Diomedea epomophora	68	*Macronectes giganteus*	595	*Halobaena caerulea*	36
D. exulans	66	*M. halli*	44	*Pachyptila sp.*	1488
Pterodroma incerta	178	*Fulmarus glacialoides*	154	*Procellaria conspicillata*	4
Procellaria aequinoctialis	394	*Daption capense*	1492		
Puffinus gravis	300	*Puffinus griseus*	37		
P. puffinus	5	*Fregetta tropica*	63		
Oceanites oceanicus	132				

as well as of King Penguins *Aptenodytes patagonicus* (Péron *et al.*, 2012), which seems to be a probable explanation for a potential breeding range extension (Petry *et al.*, 2013).

Given the trends of association of seabird species groups in our results, long-term shifts on the seabird population dynamics are expected in Southern Ocean, where species associated with both warm (Group I) and cold (Group II) waters may enhance their distribution southward, considering that species distribution patterns are clearly associated with SST changes. This study provides preliminary information on the influence of SST on seabird communities. Further studies including other abiotic and biotic variables, such as wind speed, ocean fronts, atmospheric pressure systems, and oceanic primary productivity are fundamental to understand how seabirds respond to marine environmental changes.

Acknowledgements

This work integrates the National Institute of Science and Technology - Antarctic Environmental Research (INCT-APA), which receives scientific and financial support from the National Council for Research and Development (CNPq process no. 574018/2008-5) and Carlos Chagas Research Support Foundation of the State of Rio de Janeiro (FAPERJ no. E-16/170.023/2008). The authors also acknowledge the support of the Brazilian Ministries of Science, Technology and Innovation (MCTI), Environment (MMA), and Inter-Ministry Commission for Sea Resources (CIRM).

References

Arruda, W. Z., & Lentini, C. A. D. (2013) Temperature and Salinity trends in the South Atlantic. In *Anais do XVI Simpósio Brasileiro de Sensoriamento Remoto - SBSR*. Foz do Iguaçu: INPE.

Garthe, S. (1997). Influence of hydrography, fishing activity, and colony location on summer seabird distribution in the south eastern North Sea. *ICES Journal of Marine Science*, *54*(4), 566-577.

Grémillet, D., & Boulinier, T. (2009). Spatial ecology and conservation of seabirds facing global climate change: a review. *Marine Ecology Progress Series*, *391*, 121-137.

IUCN. (2013). *The IUCN Red List of Threatened Species*. Retrieved in 15 August 2013, from http://www.iucnredlist.org

Krüger, L., & Petry, M. V. (2011). On the relation of antarctic and subantarctic seabirds with abiotic variables off South and Southeast Brazil. *Oecologia Australis*, *15*(1), 51-58.

Péron, C., Authier, M., Barbraud, C., Delord, K., Besson, D., & Weimerskirch, H. (2010). Interdecadal changes in at-sea distribution and abundance of subantarctic seabirds along a latitudinal gradient in the Southern Indian Ocean. *Global Change Biology*, *16*(7), 1895-1909.

Péron, C., Weimerskirch, H., & Bost, C. A. (2012) Projected poleward shift of King Penguins' (Aptenodytes patagonicus) foraging range atthe Crozet Islands, southern Indian Ocean. *Proceedings of the Royal Society B*. http://dx.doi.org/10.1098/rspb.2011.2705

Petry, M. V., Basler, A. B., Valls, F. C. L., & Krüger, L. (2013). New southerly breeding location of king penguins (Aptenodytespatagonicus) on Elephant Island (Maritime Antarctic). *Polar Biology*, *36*(4), 603-606.

Ribic, A. C., Ainley, D. G., Ford, R. G., Fraser, W. R., Tynan, C. T., & Woehler, E. J. (2011). Water masses, ocean fronts, and the structure of Antarctic seabird communities: Putting the eastern Bellingshausen Sea in perspective. *Deep-sea Research. Part II, Topical Studies in Oceanography*, *58*(13-16), 1695-1709.

Tasker, M. L., Jones, P. H., Dixon, T. J., & Blake, B. F. (1984). Counting seabirds at sea from ships: a review of methods employed and a suggestion for a standardized approach. *The Auk*, *101*, 567-577.

Weimerskirch, H., Louzao, M., Grissac, S., & Delord, K. (2012). Changes in Wind Pattern Alter Albatross Distribution and Life-History Traits. *Science*, *335*(6065), 211-214. http://dx.doi.org/10.1126/science.1210270.