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The Density, Ranging Pattern and Suitable Habitat Prediction of Seabirds in the Northern Beibu Gulf, China

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Authors' Contribution
BC and GY designed the experiments. BC, HZ, YZ and YG collected field data, XH, ZH, HG, and FT analysed the data. BC, XH and HG wrote the article.

Key words
Beibu Gulf, Density, Ranging pattern, Seabirds, Suitable habitat prediction.

ABSTRACT

The baseline information of density, distribution pattern of seabird community, and seabird-fishery interactions in the oceans are still relatively rare in China. From November 2013 to January 2014, we utilized line-transect method to investigate the bird community and fishery vessel in Beihai and Shatian, northern Beibu Gulf, China, for obtaining the baseline knowledge. The best model generated the seabirds' density of 11.47 (95% confidence interval 6.90-19.05) individuals/km^2 and 1.94 (1.27 - 2.95) individuals/km^2, respectively in Beihai and Shatian. The coefficient of variation value of 20.42% and 25.43% showed moderate accuracy. The Beihai and Shatian seabird communities had similar fixed kernel home range. Seabirds' distribution largely overlapped with various vessels' concentrated area, possibly due to abundant local fishery resources and forging behavior of seabirds. The MaxEnt model with the area under receiver operating curve (AUC) value of 0.957 for training data and 0.935 for test data showed reliable and accurate prediction. The distance to coast (64.7% contribution) and bathymetry (30.7% contribution) were the major variables. The model predicted extensive suitable coastal habitat of seabirds in northern Beibu Gulf. The present study provided valuable baseline information and a new perspective in protecting and monitoring seabirds.

INTRODUCTION

The fisheries are affecting the marine ecosystems (Votier *et al*., 2004; Bellebaum *et al*., 2013) and put negative pressure on seabirds' populations in several ways. Prey depletion by fisheries may trigger indirect trophic cascading effects and enhance competition with seabirds that rely on the same prey (Montevecchi, 2001; Verity *et al*., 2002; Cowx, 2003; Karpouzi *et al*., 2007). Fisheries may also cause unintentional bycatch of diving seabirds and young seabirds in various fishing gear (Ryan *et al*., 2002; Bellebaum *et al*., 2013; Seco-Pon *et al*., 2013).

In addition to negative impacts of fisheries, it is unneglectable that discards from commercial fisheries are a key food resource for many seabird species around the world (Votier *et al*., 2004). Globally, commercial capture fisheries generate huge quantities of discards in the form of offal, unwanted or over-quota catch, during 1992-2001 an average of 7.3 million tons of fish were discarded each year (Kelleher, 2005). This subsidy supports a large scavenger community. Some seabirds switched to feeding predominantly on the abundant fishery waste discarded by trawlers (Pichegru *et al*., 2007, 2010) and some seabirds have come to rely to some extent on fishing vessels (Kelleher, 2005). In general, these positive and negative impacts on scavengers at the population and community level are driven by individual foraging behavior (Votier *et al*., 2010; Wakefeld *et al*., 2013; Bodey *et al*., 2014). Bodey *et al*. (2014) found that several factors, such as vessel type, vessel activity of trawlers, could have impacts on the seabird foraging and commuting behavior.

The northern Beibu Gulf is one of the four famous fishing rounds in China, rich in fishery resources. Many seabirds inhabit there, but are given little attention. Up to date, the baseline data such density, distribution pattern of seabird community, and knowledge of seabird-fishery interactions are still relatively rare. The present paper aims to calculate the density of seabirds, to estimate the spatial interaction between fisheries and seabirds, and to predict

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seabirds' suitable habitat in the northern Beibu Gulf.

MATERIALS AND METHODS

Study sites

The study sites were in the nearshore area of northern Beibu Gulf, *i.e.,* Shatian, and Baihai, which affiliated to Guangxi Zhuang Autonomous Region and Guangdong Province, China (map in Fig. 1). The study area covers approximately 367.44 km^2 in Beihai and 604.14 km^2 in Shatian.

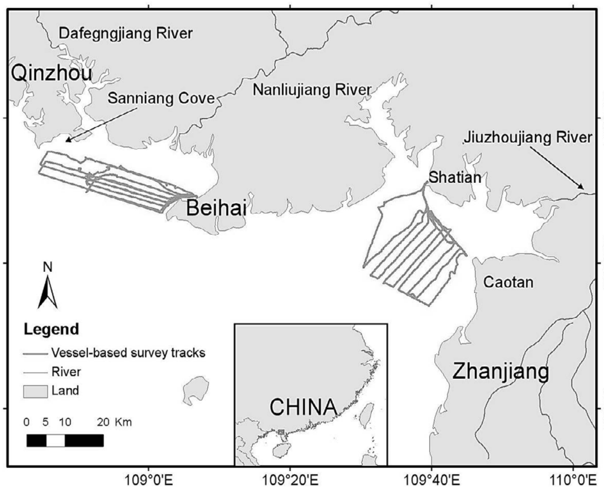

Fig. 1. Map of study area in the Northern Beibu Gulf, showing the tracks of vessel-based line transect surveys.

Field work

Vessel-based field survey was conducted during 9th-20th November 2013 in Beihai and 18th-25th January 2014 in Shatian. Line-transect methodology was employed, fourteen and nine transect lines with approximately 1 km interval were designed respectively in Beihai and Shatian (survey tracks in Fig. 1). In Beihai, these transect lines ranging from 3.3 to 21.8 km, with total length of 182.6 km, were surveyed. In Shatian, these transect lines ranged from 17.1 to 23.1 km, with total length of 175.3 km.

The survey was conducted at a steady speed of 10-14 km/h by a 15 m-length fishing vessel when the weather permitted. All data were collected by two investigators. Observation platforms were 2-4 m above sea level. The investigators searched for seabirds and all fishing vessels using the naked eyes. Only birds staying on the surface or forging were recorded, while the traveling birds were excluded. When seabirds were sighted, the time, sighting angle between transect line and the initial location of the bird (goniometer), distance (measured directly with a laser range finder or by GPS), were recorded. Moreover, the position, number, type of various vessels was also recorded.

Data analysis

Our research aimed at detecting the habitat selection of birds in marine environment. Due to these bird species have same characteristic living at sea, the object is the bird community instead of one species. The density of seabird community in Beihai and Shatian were estimated respectively, using DISTANCE 6.0. We used the Conventional Distance Sampling (CDS) engine which employs the flexible semi-parametric detection function modeling framework (Buckland, 1992; Thomas *et al*., 2010). In CDS engine, four key functions are available, *i.e.* uniform, half-normal, hazard-rate, and negative exponential, and can be adjusted by cosine terms, hermite, or simple polynomials. Therefore, twelve kinds of combined models were calculated. The model that best fits the data was selected for each sampling unit line (Burnham *et al*., 1980) with the lowest value of the Akaike's Information Criterion (AIC), and fewer parameters (Buckland *et al*., 2001, 2012). In general, our data satisfied the following premises: over 40 objects were observed via line-transect sampling schemes (Anderson *et al*., 1979) and birds recorded in the final distance band (200 m or more) were excluded from the analyses (Buckland *et al*., 2001).

The home ranges of seabirds were estimated by fixed kernel method (Worton, 1989) in ArcView3.3 (ESRI, 1996). The spatial overlap between seabirds and fisheries were analyzed by ArcGIS 9.3. In the figures, all raster was generated by using equal-area grids of 2.2×2.2 km (0.02° of latitude).

MaxEnt model version 3.4.0 (Phillips *et al*., 2004, 2006; Phillips and Dudik, 2008) were employed to predict the probabilistic distribution of seabird based on analyses of habitat factors of sea surface temperature, distance to coast, chlorophyll-a, bathymetry and distance to the major river mouths to predict the suitable habitat of seabird community. Bathymetry data were downloaded from the etopo1 website (https://www.ngdc.noaa.gov/mgg/global/). Sea surface temperature and chlorophyll-a data in 2011 were extracted from OceanWatch of NOAA web site (https://oceancolor.gsfc.nasa.gov). The data of the other habitat factors were obtained on ArcGIS platform. In MaxEnt, the 75% and 25% of the data were respectively used as training data and modeling testing. The area under the curve (AUC) metric of the receiving operator characteristic (ROC) curve were used to examine the performance of the threshold-independent test (Fielding *et al*., 2002; Phillips *et al*., 2006; Elith *et al*., 2011). Jacknife tests were conducted in MaxEnt software for relative importance of environmental characteristics. The output logistic format has values ranging from 0 to 1 which indicates probability of species presence ranging from low to high.

RESULTS

The density of seabirds

In Beihai, a total of 589 cumulative seabirds were observed, of which, 332 seabirds in Shatian and 257 seabirds in Beihai. These seabirds included common seagulls (*Larus canus*), little egret (*Egretta garzetta*), common tern (*Sterna hirundo*) and little barn swallow (*Hirundo rustica*), and some seabirds unidentified due to distance. In Beihai, the Negative Exponential/Cosine, Negative Exponential/Polynomial and Negative Exponential/Hermite fit data well with the lowest Akaike's Information Criterion (AICs) value and one parameter (Table I). These models generated the same density of 11.47 individuals/km^2. In Shatian, Half-normal/Hermite fits best to the data, and estimates 1.94 bird individuals/km^2. The coefficient of variation (CV) of 20.42% and 25.54% represented moderate accuracy, the density estimate is reliable and provides valuable baseline information.

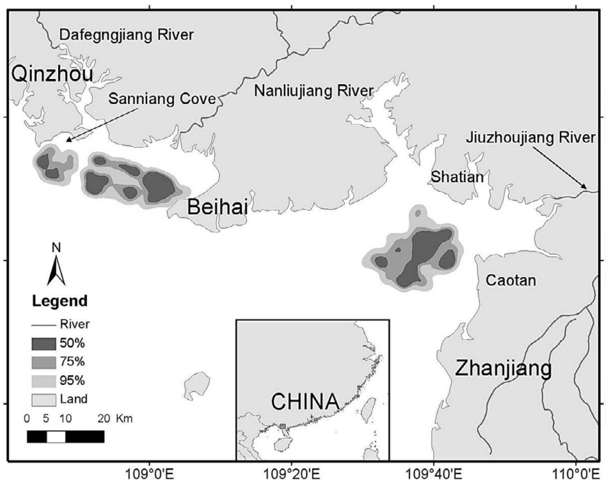

Fig. 2. The fixed kernel range of seabirds in Beihai and Shatian, the Northern Beibu Gulf, China.

Table I.- The density and relative parameter information of seabirds in Beiha and Shatian, northern Beibu Gulf, China.

Seabirds location	Model (key function)	AIC	No. of parameters	Density (individuals km^{-2})	95% CI for density	SE	CV (%)	ESW (m)
Beihai	Negative Exponential/ Cosine	1098.92	1	11.47	6.90 - 19.05	2.93	25.54	89.78
	Negative Exponential/ Polynomial	1098.92	1	11.47	6.90 - 19.05	2.93	25.54	89.78
	Negative Exponential/ Hermite	1098.92	1	11.47	6.90 - 19.05	2.93	25.54	89.78
	Hazard/Cosine	1098.95	2	8.44	5.09 - 13.99	2.15	25.43	126.44
	Hazard/ Polynomial	1098.95	2	8.44	5.09 - 13.99	2.15	25.43	126.44
	Hazard/ Hermite	1098.95	2	8.44	5.09 - 13.99	2.15	25.43	126.44
	Uniform/Cosine	1107.56	3	7.12	4.42 - 11.47	1.69	23.71	158.13
	Uniform/ Polynomial	1118.35	2	5.72	3.58 – 9.14	1.33	23.16	207.22
	Half-normal/Cosine	1104.47	2	7.89	4.89 - 12.74	1.89	23.84	137.06
	Half-normal/ Polynomial	1108.81	3	7.99	4.94 - 12.91	1.91	23.90	134.32
	Half-normal/ Hermite	1110.57	1	7.18	4.48 - 11.52	1.69	23.47	154.92
	Uniform/Hermite	1202.62	1	3.48	2.18 - 5.56	0.81	23.21	373.53
Shatian	Half-normal/Hermite	1076.1	1	1.94	1.27 - 2.95	0.40	20.42	272.45
	Uniform/Cosine	1076.21	1	1.99	1.31 – 3.03	0.40	20.24	261.24
	Uniform/ Polynomial	1076.53	1	1.85	1.24 – 2.77	0.35	19.03	290.72
	Uniform/Hermite	1076.53	1	1.85	1.24 – 2.77	0.35	19.03	290.72
	Half-normal/Cosine	1076.09	1	1.94	1.27 – 2.95	0.40	20.42	272.45
	Half-normal/ Polynomial	1076.09	1	1.94	1.27 – 2.95	0.40	20.42	272.45
	Hazard/ Cosine	1077.90	2	1.85	1.19 – 2.89	0.41	21.91	284.60
	Hazard/ Polynomial	1077.90	2	1.85	1.19 – 2.89	0.41	21.91	284.60
	Hazard/ Hermite	1077.90	2	1.85	1.19 – 2.89	0.41	21.91	284.60
	Negative exponential/ Cosine	1075.73	2	2.32	1.34 – 4.03	0.65	28.13	234.92
	Negative exponential/ Polynomial	1076.49	1	2.32	1.44 – 3.74	0.55	23.88	229.21
	Negative exponential/ Hermite	1076.49	1	2.32	1.44 – 3.74	0.55	23.88	229.21

*SE, standard error; ESW, effective stripe width.

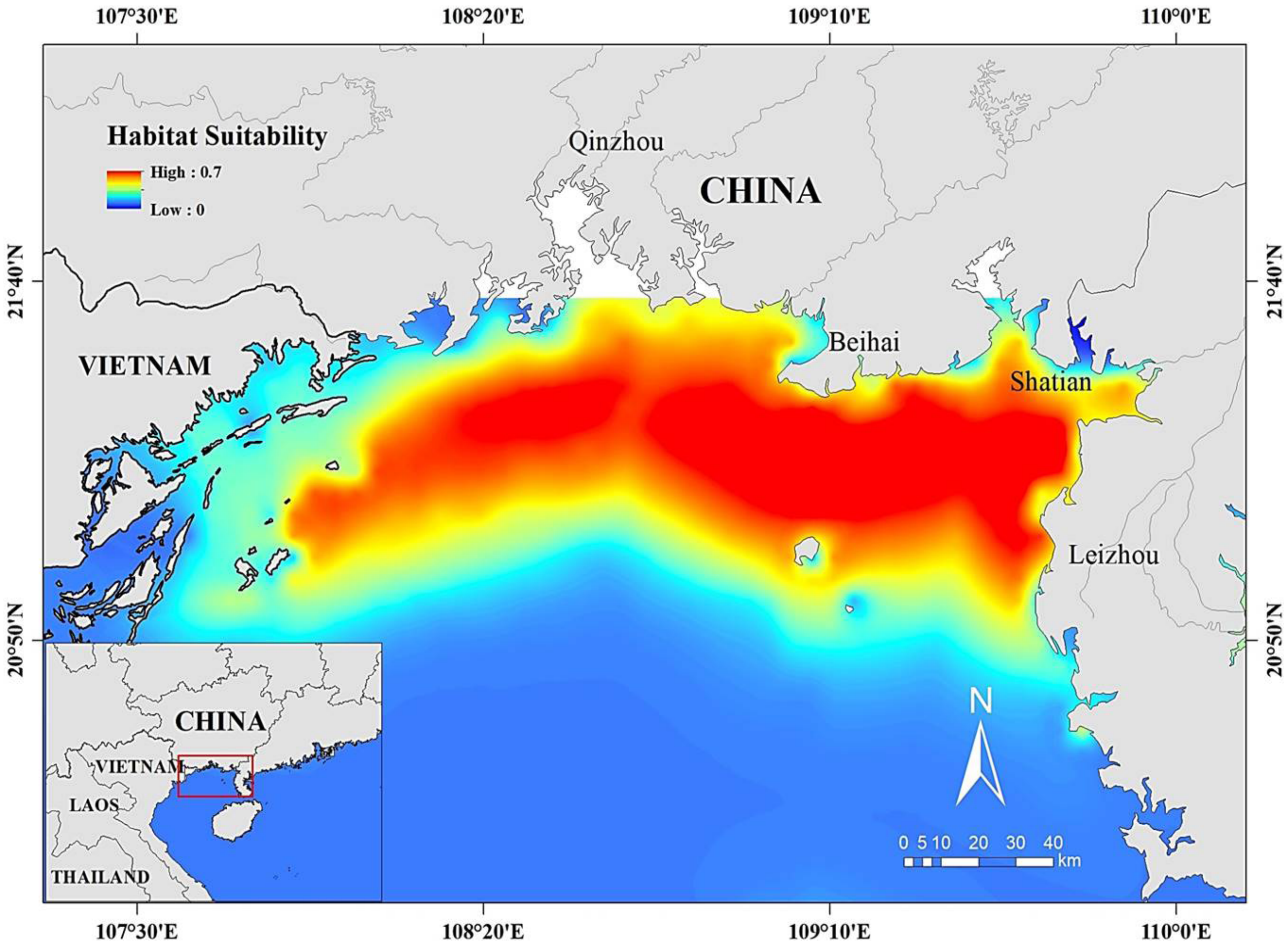

Fig. 3. The prediction of suitable habitat of birds at northern Beibu Gulf, China.

Home range of bird community

The 50%, 75% and 95% fixed kernel home range of Beihai bird community were respectively 116.96 km^2, 235.41 km^2 and 389.33 km^2. Comparatively, Shatian bird community had relatively similar home range of 115.65 km^2, 226.31 km^2 and 364.29 km^2 (Fig. 3).

Suitable habitat prediction

For the threshold independent tests, the average training AUC for the replicate runs is 0.957, which is higher than 0.5 for the random prediction, indicating that the MaxEnt model can well predict the habitat distribution of seabirds. The Jackknife test showed that distance to coast was the top environment variable (64.7% contribution) influencing the distribution of the seabirds in Beibu Gulf, followed by the bathymetry (30.7% contribution). By contrary, other three variables' contribution were rather low with total 4.7%. The final MaxEnt model predicted extensive suitable habitat (Fig. 3).

Table II.- The number of various vessels in Beihai and Shatian study area.

	Beihai	Shatian
Small fishing boat	160	88
Trawlers	54	32
Vessel catching spiral shell	2	21
Yachts	5	3
Other vessels	3	3
Total number	224	147

Fishing vessels and spatial overlap with seabirds

In all these survey cruises in Northern Beibu Gulf, several main types of vessels had been found, *i.e.* small fishing boat, single trawler, pair trawler, vessel catching spiral shell and other vessels. A total of 371 vessels were recorded, 224 in Beihai and 147 in Shatian (Table II) The most common vessel was small fishing boat, which represented about 59.5% and 71.4% of the total number of vessels in Shatian and Beihai, respectively.

In both Beihai and Shatian, seabirds showed a clear spatial overlap with operating vessels (Fig. 4A, B). Most of the overlap areas between seabirds and fisheries distribution were in the unit which vessels' number for one to four. However, some seabirds were observed in the areas where the fishing vessels are densely distributed. Such as in the Northern Beibu Gulf, the number of fishing boats reached 12, there were a few observed birds. Similarly, seabirds were observed with the distribution when the number of vessels reached 7 in Shatian area.

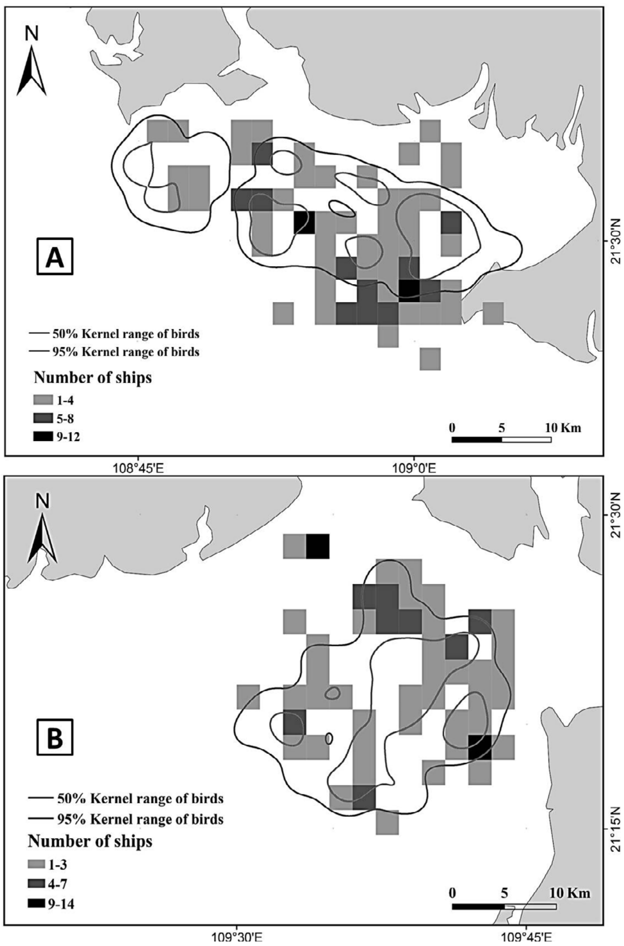

Fig. 4. The overlap area between rang of birds and operating vessels in Baihai (A) and Shatian (B), northern Beibu Gulf.

DISCUSSION

This study provided some valuable baseline information of density and distribution pattern of seabirds in northern Beibu Gulf. In our knowledge, it represented the first study in northern Beibu Gulf.

The abundant fish resources in northern Beibu Gulf support a large amount of fishing vessels. The seabirds' distribution largely overlapped with fishing vessels, as our results showed. This might produce potential competition between seabirds and fisheries for the same prey. In general, the abundant resources there might satisfied the prey demands of seabirds and local fishermen. On the other hand, the considerable discards from these commercial fisheries attracted many seabirds to follow the fisheries vessels foraging.

The density of Beihai seabirds was higher than that of Shatian seabirds. In Beihai, Dafengjiang River and Nanliujiang River are injected into Beihai, which bring a plenty of nutrients, possibly resulting in more abundant fish resources than Shatian.

In Baihai and Shatian, the seabirds' protection was rarely concerned by local fisheries bureau or government. No seabird nature reserve was established. Fortunately, another marine flagship species, Indo-Pacific humpback dolphin (*Sousa chinensis*), were also distributed in the study area. The Indo-Pacific humpback dolphins and habitat have been given priority protection, all species including fish, dolphin, seabirds would benefit from this protection. Up to date, we had not found that fishing vessels in northern Beibu Gulf used to hurt seabirds, and sometimes vessels would attract the seabirds to forage. Even though, some monitor on interaction between seabirds and fisheries vessels, and protection should be given as soon as possible. Our study provided valuable reference information for future monitor and protection.

CONCLUSIONS

This study revealed that the density of Beihai seabirds was higher than that of Shatian seabirds but both communities had similar fixed kernel home range. The MaxEnt model indicated that the distance to coast is the most important predictor of seabirds' habitat. Possibly due to rich fishery resources, the distribution of seabirds largely overlapped with various vessels' concentrated area. This article is to make up for the lack of baseline information of the seabirds in Beihai and Shatian.

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Statement of conflict of interest

We declare that we have no conflict of interest.

REFERENCES

Anderson, D.R., Laake, J.L., Crain, B.R. and Burnham, K.P., 1979. Guidelines for line transect sampling of biological populations. *J. Wildl. Manage*., **43**: 70-78. https://doi.org/10.2307/3800636

Bellebaum, J., Schirmeister, B., Sonntag, N. and Garthe, S., 2013. Decreasing but still high: bycatch of seabirds in gillnet fisheries along the German Baltic coast. *Aquat. Conserv*., **23**: 210-221. https://doi.org/10.1002/aqc.2285

Bodey, T.W., Jessopp, M.J., Votier, S.C., Gerritsen, H.D., Cleasby, I.R., Hamer, K.C., Patrick, S.C., Wakefield, E.D. and Bearhop, S., 2014. Seabird movement reveals the ecological footprint of fishing vessels. *Curr. Biol*., **24**: R514-R515. https://doi.org/10.1016/j.cub.2014.04.041

Buckland, S.T., 1992. Fitting density functions with polynomials. *Appl. Stat*., **41**: 63-76. https://doi.org/10.2307/2347618

Buckland, S.T., Anderson, D.R., Burnham, K.P. and Laake, J.L., 1993. *Distance sampling: Estimating abundance of biological populations*. Chapman and Hall, New York. https://doi.org/10.1007/978-94-011-1572-8

Buckland, S.T., Anderson, D.R., Burnham, K.P., Laake, J.L., Borchers, D.L. and Thomas, L., 2001. *Introduction to distance sampling-estimating abundance of biological populations*. Oxford University Press, Oxford.

Buckland, S.T., Anderson, D.R., Burnham, K.P. and Laake, J.L., 2012. *Distance sampling: Estimating abundance of biological populations.* Springer Science and Business Media, Berlin/Heidelberg.

Burnham, K.P., Anderson, D.R. and Laake, J.L., 1980. Estimation of density from line transect sampling of biological populations. *Wildl. Monogr*., **72**: 3-202.

Cowx, I.G., 2003. *Interactions between fish and birds: Implications for management*. Blackwell Science, Oxford. https://doi.org/10.1002/9780470995372

Elith, J., Phillips, S.J., Hastie, T., Dudík, M., Chee, Y.E. and Yates, C.J., 2011. A statistical explanation of MaxEnt for ecologists. *Divers. Distrib*., **17**: 43-57. https://doi.org/10.1111/j.1472-4642.2010.00725.x

ESRI, 1996. *ArcView GIS 3.3 environmental systems*. Research Institute, Redlands, California.

Fielding, A.H. and Bell, J.F., 2002. A review of methods for the assessment of prediction errors in conservation presence/absence models. *Environ. Conserv*., **24**: 38-49. https://doi.org/10.1017/S0376892997000088

Karpouzi, V.S., Watson, R. and Pauly, D., 2007. Modelling and mapping resource overlap between seabirds and fisheries on a global scale: A preliminary assessment. *Mar. Ecol. Prog. Ser*., **343**: 87-99. https://doi.org/10.3354/meps06860

Kelleher, K., 2005. *Discards in the world's marine fisheries: An update*. FAO Fisheries Technical Paper 470. Food and Agriculture Organization of the United Nations, Rome.

Montevecchi, W.A., 2001. Interactions between fisheries and seabirds. In: *Biology of marine birds* (eds. E.A. Schrieber and J. Burger). CRC Press, Boca Raton, pp. 527-557. https://doi.org/10.1201/9781420036305.ch16

Phillips, S.J. and Dudík, M., 2008. Modeling of species distributions with maxent: New extensions and a comprehensive evaluation. *Ecography*, **31**: 161-175. https://doi.org/10.1111/j.0906-7590.2008.5203.x

Phillips, S.J., Dudík, M. and Schapire, R.E., 2004. A maximum entropy approach to species distribution modeling. In: *Proceedings of the 21st International Conference on Machine Learning*. ACM Press, New York, pp. 655-662. https://doi.org/10.1145/1015330.1015412

Phillips, S.J., Anderson, R.P. and Schapire, R.E., 2006. Maximum entropy modelling of species geographic distributions. *Ecol. Model*., **190**: 231-259. https://doi.org/10.1016/j.ecolmodel.2005.03.026

Pichegru, L., Ryan, P.G., Crawford, R.J.M., van der Lingen, C.D. and Grémillet, D., 2010. Behavioural inertia places a top marine predator at risk from environmental change in the benguela upwelling system. *Mar. Biol*., **157**: 537-544. https://doi.org/10.1007/s00227-009-1339-2

Pichegru, L., Ryan, P.G., van der Lingen, C.D., Coetzee, J., Ropert-Coudert, Y. and Grémillet, D., 2007. Foraging behaviour and energetics of cape gannets *Morus capensis* feeding on live prey and fishery discards in the benguela upwelling system. *Mar. Ecol. Prog. Ser*., **350**: 127-136. https://doi.org/10.3354/meps07128

Ryan, P.G., Keith, D.G. and Kroese, M., 2002. Seabird bycatch by tuna longline fisheries off southern Africa, 1998–2000. *S. Afr. J. mar. Sci*., **24**: 103-110. https://doi.org/10.2989/025776102784528565

Seco-Pon, J.P., Copello, S., Moretinni, A., Lértora, H.P., Bruno, I., Bastida, J., Mauco, L. and Favero, M.,

2013. Seabird and marine-mammal attendance and by-catch in semi-industrial trawl fisheries in near-shore waters of northern Argentina. *Mar. Freshw. Res.*, **64**: 237-248. https://doi.org/10.1071/MF12312

Thomas, L., Buckland, S.T., Rexstad, E.A., Laake, J.L., Strindberg, S., Hedley, S.L., Bishop, J.R.B., Marques, T.A. and Burnham, K.P., 2010. Distance software: Design and analysis of distance sampling surveys for estimating population size. *J. appl. Ecol.*, **47**: 5-14. https://doi.org/10.1111/j.1365-2664.2009.01737.x

Verity, P.G., Smetacek, V. and Smayda, T.J., 2002. Status, trends and the future of the marine pelagic ecosystem. *Environ. Conserv.*, **29**: 207-237. https://doi.org/10.1017/S0376892902000139

Votier, S.C., Bearhop, S., Witt, M.J., Inger, R., Thompson, D. and Newton, J., 2010. Individual responses of seabirds to commercial fisheries revealed using GPS tracking, stable isotopes and vessel monitoring systems. *J. appl. Ecol.*, **47**: 487-497. https://doi.org/10.1111/j.1365-2664.2010.01790.x

Votier, S.C., Furness, R.W., Bearhop, S., Crane, J.E., Caldow, R.W.G., Catry, P., Ensor, K., Hamer, K.C., Hudson, A.V., Kalmbach, E., Klomp, N.I., Pfeiffer, S., Phillips, R.A., Prieto, I. and Thompson, D.R., 2004. Changes in fisheries discard rates and seabird communities. *Nature*, **427**: 727-730. https://doi.org/10.1038/nature02315

Wakefield, E.D., Bodey, T.W., Bearhop, S., Blackburn, J., Colhoun, K., Davies, R., Dwyer, R.G., Green, J.A., Grémillet, D., Jackson, A.L., Jessopp, M.J., Kane, A., Langston, R.H.W., Lescroël, A., Murray, S., Le Nuz, M., Patrick, S.C., Péron, C., Soanes, L.M., Wanless, S., Votier, S.C. and Hamer, K.C., 2013. Space partitioning without territoriality in gannets. *Science*, **341**: 68-70. https://doi.org/10.1126/science.1236077

Worton, B.J., 1989. Kernel methods for estimating the utilization distribution in home-range studies. *Ecology*, **70**: 164-168. https://doi.org/10.2307/1938423