Polar Biology (2020) 43:2111–2116
https://doi.org/10.1007/s00300-020-02757-5

SHORT NOTE

Coprophagic behaviour of southern giant petrels (*Macronectes giganteus*) during breeding period

Denyelle Hennayra Corá[1] · Júlia Victória Grohmann Finger[2] · Lucas Krüger[3]

Received: 27 February 2020 / Revised: 21 September 2020 / Accepted: 25 September 2020 / Published online: 15 October 2020

Abstract
Southern giant petrels (*Macronectes giganteus*) are opportunistic generalists whose feeding strategies include hunting, scavenging and fishing. While seals are important for southern giant petrels as a source of carrion, we documented that live seals also provide feeding opportunities for southern giant petrels. We tracked breeding southern giant petrels from Harmony Point, Antarctica, during incubation and chick rearing with solar-powered GPS-UHF devices. Tracking results showed that animals often visited confirmed haul-out sites of seals, mainly Weddell seals (*Leptonychotes weddellii*). Feeding on seal faeces was confirmed by direct observation. Southern giant petrels were more likely to visit haul-out sites during incubation than during chick-rearing. This behaviour suggests that the birds fed on seal faeces mainly when fasting, which could last as long as 15 days. Seal faeces could be a resource consumed to quickly recover from the fast before leaving for a longer trip.

Keywords Antarctica · coprophagy · diet · foraging

Introduction

Breeding is an energetically demanding activity during which seabirds invest great effort in successfully raising a chick (Markones et al. 2009). Scavenging on fur seal (*Arctocephalus gazella*), Weddell seal (*Leptonychotes weddellii*) and southern elephant seal (*Mirounga leonina*) carcasses and placentas provides an important source of food during breeding for giant petrels (*Macronectes* spp.), especially during the post-hatching period (Hunter 1984; de Bruyn et al. 2007). Carcasses also play an important role in the growth and survival of chicks due to their high energetic and nutritional value (de Bruyn et al. 2007). However, living seals can also provide feeding resources for giant petrels. Casaux et al. (1997) briefly described southern giant petrels (*M. giganteus*) gathering around hauled-out Weddell seals at Harmony Point (Nelson Island, Maritime Antarctic Peninsula) to feed upon faeces and regurgitations. They suggested that this source of food should be further inspected, as many diet items recorded for southern giant petrels could have been consumed through scavenging on Weddell seal scat and vomit. In this study, we quantified the incursions of southern giant petrels tracked with GPS to areas where Weddell and elephant seals haul out to rest or moult at Harmony Point and showed that breeding southern giant petrels frequently feed on seal faeces. We thus provide evidence that coprophagy is a common behaviour for Southern giant petrels in the studied population. We also discuss possible causes and consequences of this behaviour.

Materials and methods

We monitored feeding behaviour and movements of breeding southern giant petrels from a population breeding at Harmony Point (Fig. 1a). The area holds a large southern giant petrel population of ca. 480 breeding pairs (Krüger 2019). While Weddell and elephant seals haul out at Harmony Point throughout the warm season (October to February), there is no recent local evidence of breeding behaviour by either seal species [although three female

✉ Lucas Krüger
lkruger@inach.cl

[1] Universidade Comunitária da Região de Chapecó, Curso de Ciências Biológicas, Servidão Anjo da Guarda, 295-D, Chapecó, SC, Brazil

[2] Laboratório de Ornitologia e Animais Marinhos, Universidade do Vale do Rio dos Sinos, Av. Unisinos, 950, São Leopoldo, RS, Brazil

[3] Instituto Antártico Chileno, Plaza Muñoz Gamero, 1055 Punta Arenas, Chile

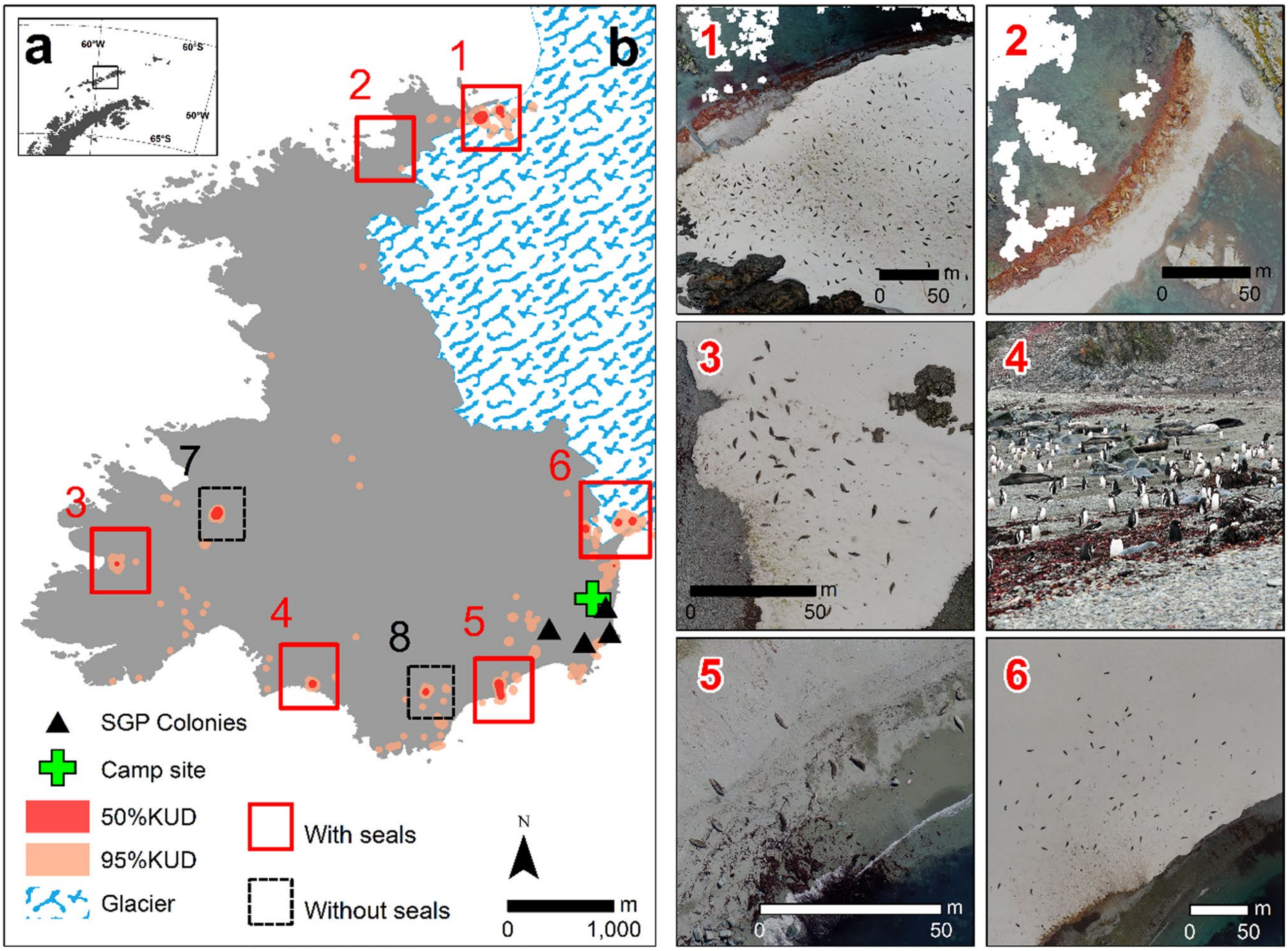

Fig. 1 **a** Location of Nelson Island on the Maritime Antarctic Peninsula and **b** location of Harmony Point on Nelson Island; **b** at-land kernel usage density of southern giant petrels (*Macronectes giganteus*) at Harmony Point; red squares with solid contour are areas where we registered groups of seals resting; black squares with dashed contour are areas frequented by southern giant petrels where no seals were observed. Frames 1 to 6 present pictures of the areas identified by numbers in **a**. Frames 1, 3 and 6 are resting areas exclusively used by Weddell seals (*Leptonychotes weddellii*), whereas frames 2, 4 and 5 are also used by elephant (*Mirounga leonina*) and fur seals (*Arctocephalus gazella*)

elephant seals were recorded with pups in 2001 (Carlini et al. 2003; Harris et al. 2015)]. Non-breeding adult fur seals start arriving at the area at the end of January, after the breeding season. Therefore, seal placentas and carrion are scarce or even absent in the area, and faeces is the main resource provided by seals [regurgitations are produced less frequently than faeces at seal haul-out sites (Casaux et al. 1997)]. We equipped 10 breeding pairs of southern giant petrels with solar-powered GPS-UHF (Ecotone Kite-M, 20 g) attached with Teflon harnesses. We continuously tracked the 20 southern giant petrels between 3 December 2019 and 31 January 2020. GPSs were programmed to collect a geographical fix every 5 min. A foraging trip was considered to comprise all fixes recorded after the bird's departure from the breeding colony—following the arrival of its breeding pair—until its return.

As we focussed our efforts on inspecting areas that were accessible by foot (so we could confirm birds' behaviours in situ), we selected GPS fixes positioned inside the Harmony Point area. We excluded all fixes within 100 m from the colonies, so that positions taken when individuals were incubating, resting by the nest or arriving/leaving the colony were not mistaken with feeding areas (Fig. 1b). By applying a kernel utilization distribution (KUD) function using the 'kernelUD' command of the 'adehabitatHR' R package (Calenge 2011), KUDs were calculated for each individual separately, and were averaged a posteriori to generate a non-biased population-level KUD. We specified an Epanechnikov kernel (Samiuddin and El-Sayyad 1990), a smoothing bandwidth (h) of 250 m and a grid size of 1000 m. Areas with a greater density of fixes are represented by 50% KUD contours (Fig. 1b). Aiming to obtain visual confirmation of faeces ingestion by southern giant petrels, we visited accessible places used by tracked individuals at least once (frames 2–6, Fig. 1b). We took aerial photographs using a MAVIC 2 Pro DJI drone to characterize main seal haul-out sites at Harmony Point (Fig. 1). Sites 1 and 6 are on the border of glaciers and covered by snow year-round (Fig. 1). Only Weddell seals were seen resting on the ice. Site 2 is a pebble beach covered by beached sea algae; the site is used as a haul-out site by elephant seals. Site 3 is located close to the beach at the distal end of a talus slope (Rodrigues et al. 2019) and is covered by ice most of the summer. Again, only Weddell seals were seen resting over the ice. Sites 4 and 5 are beaches formed by thin sand, where both elephant and Weddell seals haul out. The substrate of sites 1 and 3–6 were classified as homogeneous and that of site 2 as heterogeneous.

The frequency of visits to haul-out sites was compared between sexes using a binomial linear mixed model in the 'lmerTest' R package (Kuznetsova et al. 2018), using both individual ID and foraging trip number as random factors. Incubation occurred until early January, when eggs started to hatch. The number of complete trips (including points from the start to the end of the foraging trips) and the number of visits to seal haul-out sites were calculated for each individual, and a Poisson generalized linear model was used to test whether the number of visits was proportional to the number of foraging trips.

Results

We recorded 55 foraging trips by 20 southern giant petrels. A total of 38 trips from 16 southern giant petrels were completed. Out of the 38 foraging trips, 28 (73.7%) evidenced that 14 southern giant petrels (7 males and 7 females) visited 6 seal haul-out sites at Harmony Point (50% and 95% KUDs, Fig. 1b) at least once (min. = 1, max. = 4). Females and males used the haul-out sites with the same frequency ($z = -1.14$, $\beta = -1.5$, $p = 0.255$), but the effect of random terms (individual ID and foraging trip number) was significant (Fig. 2). Southern giant petrels were more likely to repeatedly visit seal haul-out sites during incubation than during chick-rearing (Fig. 2). The individual number of visits to seal areas was associated with the total number of trips, with a general trend of animals visiting seal areas on half the trips ($z = 2.75$, $\beta = 0.48$, $p = 0.006$). All except one haul-out site (site 2, with heterogeneous substrate) were not visited by southern giant petrels. Out of the seven areas frequently used by southern giant petrels at Harmony Point, two were not haul-out sites, but chinstrap penguin (*Pygoscelis antarcticus*) colonies (Fig. 1). Ground observations confirmed southern giant petrels were feeding on Weddell seal faeces (Fig. 3), displaying resource defence behaviour patterns (Fig. 3b, c).

Discussion

Our results show that seals provide feeding resources to southern giant petrels not only as carrion (i.e. Hunter 1984; de Bruyn et al. 2007). When at Harmony Point, tracked southern giant petrels visited Weddell seal haul-out sites more often than other areas, including those with penguin rookeries. Although we did not quantify the number of times that petrels consumed faeces, at each of our visits to haul-out sites 1, 3 and 6 (Fig. 1), at least one petrel was consuming Weddell seal faeces. Tracking data showed that areas with homogeneous substrate (i.e. accumulated snow, glaciers, or thin sand beaches) were more often visited by southern giant petrels. The substrate probably influenced detection of faeces and increased faeces accumulation, thereby facilitating feeding. This could be the reason why no tracked birds visited site 2 (Fig. 1). Its heterogeneous substrate probably favours outflow of faeces, making detection by southern giant petrels more difficult.

Breeding southern giant petrels undergo long periods of fasting during incubation, when female and male alternate long bouts of incubation (González-Solís et al. 2000; Schulz et al. 2014). The southern giant petrels we tracked carried out foraging trips that lasted between 5 and 15 days. Fasting can decrease body reserves before the return of the pair to the nest, thereby reducing the probability of survival (González-Solís et al. 2000). Our data show that southern giant petrels visited seal haul-out sites mostly at the start of foraging trips, before going to forage for a longer distance out at sea, and visits to haul-out sites were more likely to occur during incubation when fasting was longer. Weddell seals' diet includes cephalopods, crustaceans and fishes, and a part of the nutrients and fat present in prey can be retained in faeces (Casaux et al. 1997, 2006). We hypothesise that, after a long period of fasting, southern giant petrels ingest seal faeces as a way to gain a quick intake of energy before starting a long foraging trip in search of more energetic food. However, faeces are probably a less important item after the chick hatches. To promptly attend the chick's energetic demands, southern giant petrels shift to shorter foraging trips, and consequently undergo shorter fasting periods at the nest. They also focus on feeding the chick with high-energy-content prey, such as penguin and

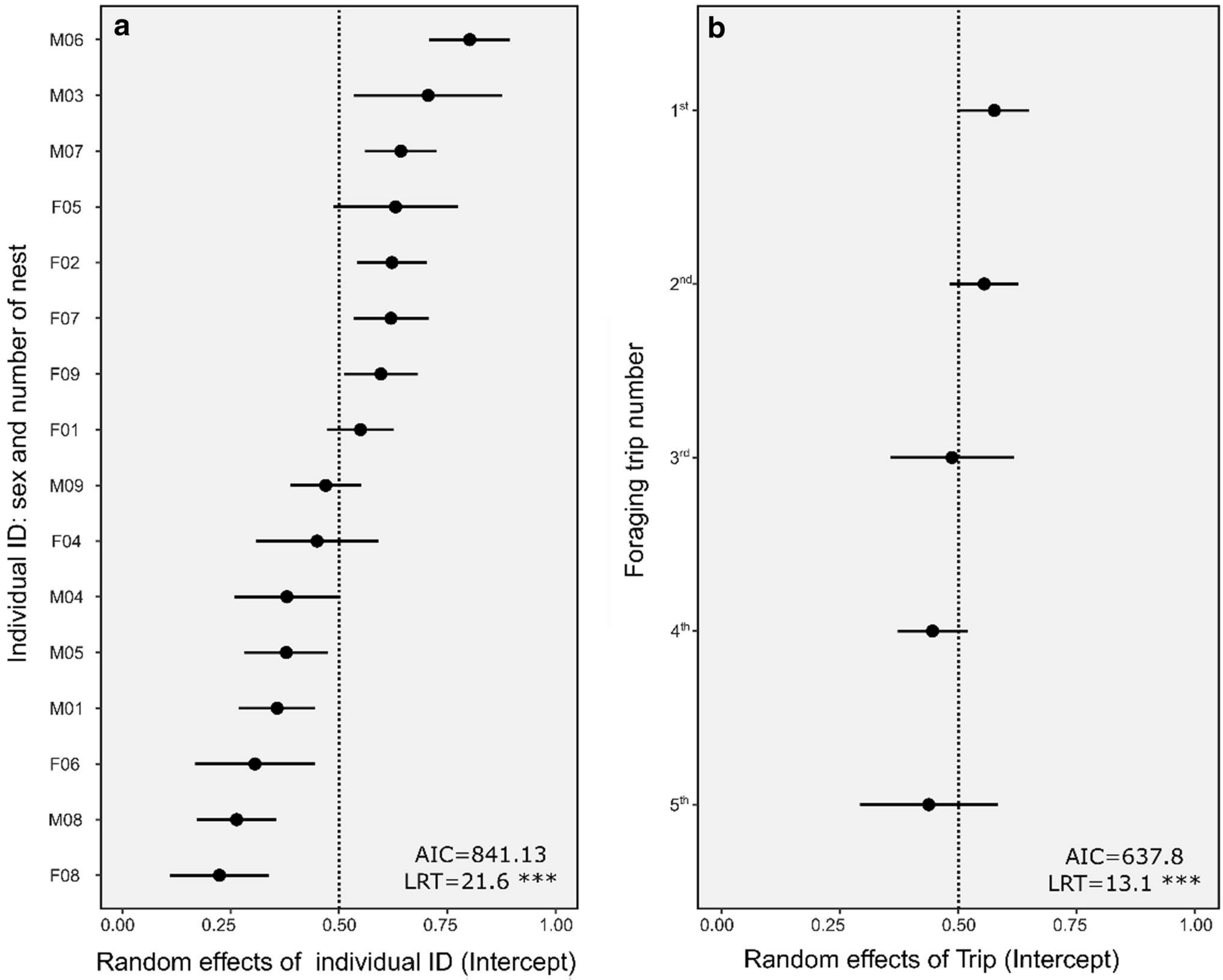

Fig. 2 Random effects (intercept) of binomial linear mixed models comparing the probability of breeding southern giant petrels (*Macronectes giganteus*) visiting seal haul-out sites at Harmony Point, Nelson Island, during foraging trips. **a** Individual identification is based on sex (*F* females, *M* males) and nest number; individuals with the same nest number are breeding pairs; **b** foraging trip number estimated based on date of GPS deployment on each bird. Akaike information criteria (AIC) is a measure of prediction error; the smaller the AIC, the better the model. The likelihood ratio test (LRT) compares differences among models with and without a random term. ***$p<0.001$

seal carrion (Forero et al. 2005; Raya Rey et al. 2012), while seal faeces possibly do not contain sufficient energy to boost chick growth. This study reinforces the importance of mammals as sources of food for southern giant petrels during the breeding season. Finally, it adds coprophagy as a further behaviour to the broad feeding repertoire of southern giant petrels.

Acknowledgements This study benefited from the Marine Protected Areas program of the Instituto Antártico Chileno. Data used for this study was collected using funding from FONDECYT (Fondecyt Iniciación 11180175). We thank the Instituto Antártico Chileno, Base Escudero, RS Karpuj and the Chilean Navy Vessel OPV *Marinero Fuentealba* for logistical support, and Coordenação de Aperfeiçoamento de Pessoal de Nivel Superior (CAPES) for providing a PhD scholarship for Julia V. G. Finger (Finance Code 001). Entrance to Harmony Point Antarctic Specially Protected Area was authorized by Instituto Antártico Chileno. Animal ethics were evaluated and approved

Fig. 3 **a** Weddell seals (*Leptonychotes weddellii*) at haul-out site surrounded by southern giant petrels (*Macronectes giganteus*) (dashed black circles). Solid red circles depict seal faeces—this area corresponds to frame 1 in Fig. 1. **b**, **c** Group of southern giant petrels disputing access to faeces. **d–e** Evidence of seal faeces consumption by southern giant petrels. Arrow in **e** indicates a tagged individual feeding on faeces

by Instituto Antártico Chileno and the Comité Ético Cientifico de la Universidad de Magallanes. The authors thank Jared R. Towers and Mariano Sironi for their comments during the review process.

Author contributions L.K. idealized the study. D.H.C., J.V.G.F. and L.K. equally contributed to data sampling, analysing and manuscript writing.

Funding This study was funded by FONDECYT (Fondecyt Iniciación 11180175) and Instituto Antártico Chileno (Programa de Áreas Marinas Protegidas).

Compliance with ethical standards

Conflict of interest The authors declare no conflicts of interest.

Ethical approval Animal ethics were evaluated and approved by Instituto Antártico Chileno and the Comité Ético Cientifico de la Universidad de Magallanes.

Research involving human and animal rights Applicable guidelines for the care and use of wild animals for scientific investigation at the international, national and/or institutional levels were followed, as evaluated and approved by the Instituto Antártico Chileno and the Comité Ético Cientifico de la Universidad de Magallanes.

References

Calenge C (2011) Home range estimation in R: the adehabitatHR Package. R vignette. Office national de la classe et de la faunesauvage, Auffargis

Carlini AR, Poljak S, Casaux R et al (2003) Southern elephant seals breeding at Nelson Island, South Shetland Islands. Pol Polar Res 24:143–147

Casaux R, Baroni A, Carlini A (1997) The diet of the Weddell seal *Leptonychotes weddelli* at Harmony Point, South Shetland Islands. Polar Biol 18:371–375. https://doi.org/10.1007/s003000050202

Casaux R, Baroni A, Ramón A (2006) The diet of the Weddell Seal *Leptonychotes weddellii* at the Danco Coast, Antarctic Peninsula. Polar Biol 29:257–262. https://doi.org/10.1007/s00300-005-0048-7

de Bruyn PJN, Cooper J, Bester MN, Tosh CA (2007) The importance of land-based prey for sympatrically breeding giant petrels at sub-Antarctic Marion Island. Antarct Sci 19:25–30. https://doi.org/10.1017/S0954102007000053

Forero MG, González-Solís J, Hobson KA, Donázar JA, Bertellotti M, Blanco G, Bortolotti GR (2005) Stable isotopes reveal trophic segregation by sex and age in the southern giant petrel in two different food webs. Mar Ecol Prog Ser 296:107–113. https://doi.org/10.3354/meps296107

González-Solís J, Croxall JP, Wood AG (2000) Sexual dimorphism and sexual segregation in foraging strategies of northern giant petrels, *Macronectes halli*, during incubation. Oikos 90:390–398. https://doi.org/10.1034/j.1600-0706.2000.900220.x

Harris CM, Carr R, Lorenz K, Jones S (2015) Important bird areas in Antarctica. BirdLife International and Environmental Research & Assessment Ltd., Cambridge

Hunter S (1984) Breeding biology and population dynamics of giant petrels *Macronectes* at South Georgia (Aves: Procellariiformes). J Zool 203:441–460

Krüger L (2019) An update on the Southern giant petrels *Macronectes giganteus* breeding at Harmony Point, Nelson Island, Maritime Antarctic Peninsula. Polar Biol 42:1205–1208. https://doi.org/10.1007/s00300-019-02504-5

Kuznetsova A, Brockhoff PB, Christensen RHB (2018) lmerTest package: tests in linear mixed effects models. J Stat Softw. https://doi.org/10.18637/jss.v082.i13

Markones N, Dierschke V, Garthe S (2009) Seasonal differences in at-sea activity of seabirds underline high energetic demands during the breeding period. J Ornithol 151:329–336. https://doi.org/10.1007/s10336-009-0459-2

Raya Rey A, Polito M, Archuby D, Coria N (2012) Stable isotopes identify age-and sex-specific dietary partitioning and foraging habitat segregation in Southern giant petrels breeding in Antarctica and southern Patagonia. Mar Biol 159:1317–1326. https://doi.org/10.1007/s00227-012-1912-y

Rodrigues WF, Oliveira FS, Schaefer CE, Leite MG, Gauzzi T, Bockheim JG, Putzke J (2019) Soil-landscape interplays at Harmony Point, Nelson Island, Maritime Antarctica: Chemistry, mineralogy and classification. Geomorphology 336:77–94. https://doi.org/10.1016/j.geomorph.2019.03.030

Samiuddin M, El-Sayyad GM (1990) On nonparametric Kernel density estimates. Biometrika 77:865–874. https://doi.org/10.1093/biomet/77.4.865

Schulz UH, Kruger L, Petry MV (2014) Southern giant petrel *Macronectes giganteus* nest attendance patterns under extreme weather conditions. Zool Sci 31:501–506. https://doi.org/10.2108/zs130135