Polar Biology (2022) 45:153–158
https://doi.org/10.1007/s00300-021-02971-9

SHORT NOTE

Dietary niche partitioning in brown skuas (*Stercorarius lonnbergi*) during the chick-rearing period at Narębski Point on King George Island, Antarctica

Youmin Kim[1] · Jin-Woo Jung[2] · Jong-U Kim[1] · Yeon-Soo Oh[1,3] · Hosung Chung[1] · Jeong-Hoon Kim[1]

Received: 18 March 2021 / Revised: 5 November 2021 / Accepted: 8 November 2021 / Published online: 24 November 2021

Abstract

Brown Skuas (*Stercorarius lonnbergi*) are known to feed on other birds or eggs during the breeding season. In some cases, however, a few pairs monopolize a penguin colony, and the other skuas mainly forage in the sea. We installed automatic camera traps to monitor two groups of breeding Brown Skua pairs on King George Island: the nests of Group A were located near a Gentoo Penguin (*Pygoscelis papua*) colony, while those of Group B were relatively far away. From the resulting photographs, we were able to distinguish the food items that parents brought to the nest and could confirm the egg hatching date. Overall, 97.1% of the food items that group A brought to the nest were from the penguin colonies, while 94.1% of the prey items of group B were fish. Group A had a hatching date at least 8 days earlier than Group B. Our results show that a few Brown Skua pairs that bred near the penguin colony fed primarily on penguin nest contents such as eggs or chicks within their feeding territory and had earlier hatching dates. The Brown Skuas that nested close to penguin nests may have had advantages in foraging and breeding performance.

Keywords *Stercorarius lonnbergi* · Diet composition · Territoriality · Hatching date · Antarctica

Introduction

Brown Skuas (*Stercorarius lonnbergi*) and South Polar Skuas (*S. maccormicki*) breed in the Antarctic Peninsula region during austral summer (Pietz 1987; Ritz et al. 2006). Many studies on the feeding ecology of both species during the breeding season have provided information on their diets (Reinhardt et al. 2000; Malzof and Quintana 2008; Carneiro et al. 2015). Both Antarctic skuas are known to mainly prey on chicks and eggs of other birds and marine life, but South Polar Skuas primarily rely more on marine organisms such as fishes, invertebrates, and crustaceans, including krill (Mund and Miller 1995; Baker and Barbraud 2001), while Brown Skuas mainly rely on terrestrial resources, such as carcasses, garbage from Antarctic stations, and seabirds, including penguins (Pietz 1987; Reinhardt et al. 2000; Phillips et al. 2004). In some penguin breeding sites where both species nest sympatrically, interspecific partitioning of the dietary niche occurs (Pietz 1987; Malzof and Quintana 2008; Grilli and Montalti 2012). Carneiro et al. (2010) reported that the monopoly of penguin colonies by Brown Skuas led to a separation of food sources between two skua species. Interspecific dietary segregation in skua species has been reported, and several past studies have revealed that some South Polar Skua or Brown Skua pairs make feeding territories and defend penguin subcolonies from other skua individuals (Trillmich 1978; Trivelpiece et al. 1980; Pietz 1987; Young 2005). On King George Island and Avers Island, located near the northern part of the Antarctic Peninsula region, only a few pairs of breeding Brown Skuas occupy nest sites close to *Pygoscelis* penguin subcolonies and the feeding territory includes penguin subcolonies (Hahn and Peter 2003). Therefore, the skua nest distance from the penguin subcolonies may be related to their feeding ecology in these areas. Nevertheless, there have been

✉ Jeong-Hoon Kim
jhkim94@kopri.re.kr

[1] Division of Life Sciences, Korea Polar Research Institute, Incheon, Republic of Korea

[2] Research Center for Endangered Species, National Institute of Ecology, Seocheon, Republic of Korea

[3] Department of Biotechnology, Korea University, Seoul 02841, Republic of Korea

no studies focusing on dietary partitioning among breeding Brown Skua pairs in the South Shetland Islands.

Moreover, differences in diet could influence the breeding performance of seabirds, including Brown Skuas (Crawford and Dyer 1995; Golet et al. 2000; Kitaysky et al. 2006; Hahn and Bauer 2008; Christensen-Dalsgaard et al. 2018). In most seabirds, the laying date can be used as a breeding index to compare breeding quality, as earlier breeders have better breeding success (Moreno et al. 1997; Lepage et al. 2000; Arnold et al. 2006). In the case of Brown Skuas, the timing of breeding can partly reflect the quality of breeding performance and earlier breeders have higher hatching success and feeding ability than delayed breeder (Anderson et al. 2009; Carneiro et al. 2015). Therefore, we compared the feeding resources and hatching dates of Brown Skua pairs by the distance from the nearest penguin colony to the skua nest.

Materials and methods

We performed this study at Narębski Point (Fig. 1; 62°14.3'S, 58°46.5'W) on King George Island, Antarctica, during austral summer, from December 2016 to January 2017. In this region, approximately 3,000 pairs of Chinstrap penguins (*Pygoscelis antarcticus*) and 2,500 pairs of Gentoo penguins (*P. papua*) breed (Fig. 1) (ATCM 2019). Approximately 7 pairs of Brown Skuas nest near penguin subcolonies almost every year (ATCM 2019). To investigate intraspecific niche segregation, we studied only Brown Skuas, which mainly depend on penguins, although more than 40 pairs of South polar skuas breed sympatrically at Narębski Point (Ministry of Environment 2017). During the 2016/17 breeding season, nine pairs of Brown Skuas nested in this area (Ministry of Environment 2017). To periodically observe breeding and feeding behaviors without time constraints and human disturbances (Reif and Tornberg 2006; Hinke et al. 2018), we used autonomous camera traps. When a Brown Skua nest with at least one egg was observed, we labeled them with a wooden stick and installed trail cameras (Bushnell Trophy Cam, Model 119437C; © Bushnell Outdoor Products, Kansas, USA) more than two meters from the nests to monitor the breeding behavior of nestling Brown Skuas. Trail cameras were made to be motion active, and the red LED light was also activated for night shooting. Monitoring cameras were installed near eight nests found in December 2016; one nest built in early January 2017 was excluded from this investigation. The nests were classified into two groups on the basis of their GPS (Oregon® 550, Garmin, Olathe, KS, USA)-based distance from penguin subcolonies: those within 50 m of the penguin subcolonies (five nests; Group A) and those that more than 100 m from the penguin subcolonies (three nests; Group B).

To compare the breeding performance between the two groups, the hatching date was recorded as the time of the first photograph in which hatchlings or hatching eggs were observed. The prey items that could be distinguished clearly in the images were separated into three categories: penguin, fish, and crustacean, which adults bring to the nest or regurgitate for chick feeding (Online Resource #1). The images were counted by three different researchers and classification

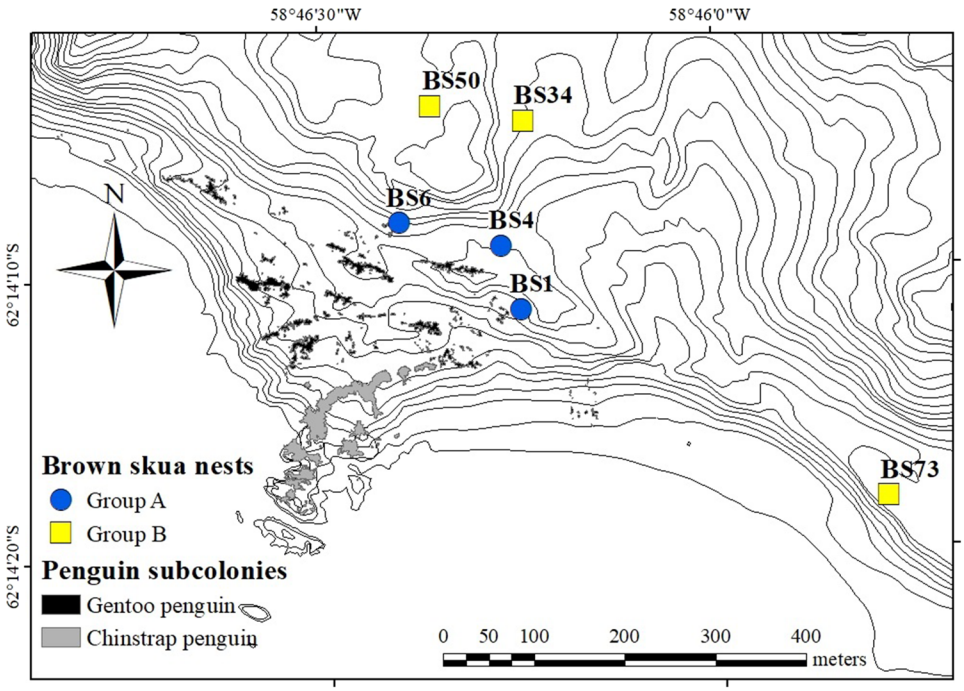

Fig. 1 The map of Narębski Point in the 2016/2017 breeding season. Gentoo Penguin (*Pygoscelis papua*) subcolonies (black polygons) and Chinstrap Penguin (*P. antarcticus*) subcolonies (gray polygons) and two groups of monitored breeding Brown Skua (*Stercorarius lonnbergi*) nests are marked with blue circle (Group A) and yellow rectangle (Group B)

was confirmed when two or more researchers identified the same category. The difference in the prey item composition ratio between the two groups was analyzed by Fisher's exact test in R (R Core Team 2020). A p value lower than 0.05 was considered significant.

Results and discussion

Since two (BS2 and BS9) of the five nests of Group A were destroyed by snow accumulation after a blizzard, the images obtained from six nests (3 nests each from Group A and B, Table 1) were analyzed for this study. The comparison of prey items between the two groups showed a distinct difference. The main prey items that parent brought to their nest in Group A were penguins (64.4%) and crustaceans (32.7%), whereas the predominant prey items in Group B were fishes (94.1%) (Fisher's exact test, $p < 0.0001$, Fig. 2). Since the crustaceans identified in Group A were thought to come from the stomach contents of penguin carcasses (Stonehouse 1956), it is estimated that 97.1% of the prey items in this group originated from penguins (Online Resource #2). This result indicates that the skuas in Group A relied on penguins as a main food source, while the skuas in Group B mostly foraged for fish at sea. The difference in the composition of the prey items between the two groups was similar to the findings reported by previous studies focused on territorial and nonterritorial skua pairs near a penguin colony (Trillmich 1978; Trivelpiece et al. 1980; Hahn and Peter 2003; Carneiro et al. 2010). According to

Table 1 Information on Brown Skua (*Stercorarius lonnbergi*) nests recorded by the monitoring cameras

Group	Nest ID	Breeding parameters				Distance from penguin sub-colony (m)
		Clutch size	Hatched chicks	Hatching date (1st egg)	Hatching date (2nd egg)	
A	BS1	2	2	22 Dec 2016, 13:44	25 Dec 2016, 05:36	15
	BS2	2	0	Failed due to snow accumulation (27 Dec 2016)		37
	BS4	2	2	20 Dec 2016, 08:54	21 Dec 2016, 16:28	38
	BS6	2	2	25 Dec 2016, 14:37	26 Dec 2016, 18:00	6
	BS9	2	0	Failed due to snow accumulation (28 Dec 2016)		13
B	BS34	2	1	04 Jan 2017, 03:02	–	169
	BS50	2	1	02 Jan 2017, 10:00	Deserted (02 Jan 2017, 23:55)	137
	BS73	2	2	07 Jan 2017, 15:26	08 Jan 2017, 15:28	332

The nests are divided into Group A and B according to distance from the nearest penguin sub-colony. Breeding parameters in the survey area were shown

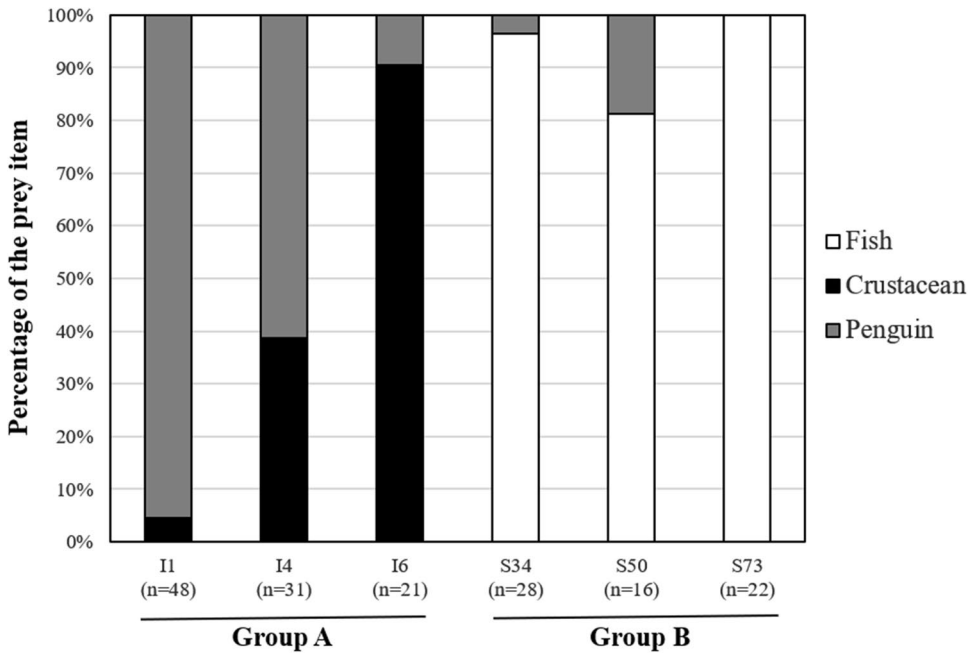

Fig. 2 Percentage of prey items for Brown Skuas (*Stercorarius lonnbergi*) during the chick-guarding period

the results obtained in this study, Brown Skuas breeding at Narębski Point seem to be separated into territorial pairs and nonterritorial pairs, depending on the distance from the nearest penguin colony to their nest. The pairs that bred close to penguin nests exploited the penguin subcolonies as their feeding territory (territorial pairs; Group A), whereas the other pairs, which bred away of the penguin colonies mainly foraged at sea (nonterritorial pairs; Group B). Furthermore, breeding Brown Skuas in Group A (with their feeding territory) had relatively earlier hatching dates than the skuas in Group B (without feeding territory) in this study (Table 1). Skuas that breed early may have access to more nutritious foods and high food availability (Hahn and Peter 2003; Anderson et al. 2009) and have various advantages in breeding success (Wood 1971). In addition to the advantages of early breeding, compared to skuas without feeding territory, territorial skua pairs have some benefits in breeding performance. First, territorial pairs receive a steady food supply from their feeding territory (Hahn & Bauer 2008). In particular, in years in which marine production is poor, the breeding success of nonterritorial breeders may be critically impacted, while that of territorial breeders may not be directly affected (Hahn et al. 2007). Second, skua pairs with their own feeding territory can defend their nests efficiently (Trillmich 1978; Trivelpiece et al. 1980). Skuas without feeding territory need to spend more time foraging, which may reduce the effectiveness of nest guarding (Caldow and Furness 2000). Finally, Brown Skuas that breed at Narębski Point have more chances to gather food without the risk of losing eggs to penguins when they build nests near penguin subcolonies (Hagelin and Miller 1997; Young 2005). Generally, there is a trade-off in nesting around colonies of the Adelie penguin (*P. adeliae*) which enhances accessibility to penguin nests but increases the possibility of egg trampling by penguins (Hagelin and Miller 1997). However, there have been no reports of skua egg loss due to Gentoo Penguins and even penguin interference with breeding skua nests was not observed in this study. Therefore, at the study sites, establishing skua nests near penguin nests confers the advantage of efficient foraging without the additional threat of losing eggs.

Many studies have estimated the feeding habits of breeding skuas using pellets or food remains (Osborne 1985; Moncorps et al. 1997; Malzof and Quintana 2008), but there are limits to the quantitative estimation that can be performed with these methods (Moncorps et al. 1997; Barrett et al. 2007a, b). In this study, we used camera traps to observe nests without producing a variety of error-inducing effects (such as observation error, nest abandonment, and the digestibility of food) that can occur when using the aforementioned method (Carney and Sydeman 1999). Although the accurate identification of food sources is limited due to the low quality of some photographs taken at a distance, using the motion detection mode makes it possible to monitor nests for long periods of time and observe special events without time constraints.

In this study, we obtained reliable breeding and foraging data using autonomous camera trap monitoring. We found that the different prey sources of Brown Skua pairs depend on the location of nests relation to penguin rookeries. The pairs breeding near the penguin colony, which predominantly fed on penguins rather than fishes seemed territorial, while the other pairs, which primarily fed on fishes, seemed nonterritorial. Additionally, the eggs of the former group hatched earlier than those of the latter, which suggest that territorial pairs have better breeding conditions than nonterritorial pairs. At the study sites, skua pairs breeding near the penguin colonies and occupying the feeding territory would have breeding advantages, with better food access and the ability to efficiently defend their nests. Later, monitoring tagged breeding skuas through consecutive years and tracking with GPS loggers could reveal the details of their breeding ecology.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s00300-021-02971-9.

Acknowledgements We thank Heemin Yang, Minsu Jung, Junsu Kim, and Timothy Patrick Lynch for assistance in field work. We are grateful to overwintering members for logistical support at King Sejong Station. We thank Dr. Sjudur Hammer and an anonymous reviewer for providing constructive comments and suggestions that substantially improved the manuscript.

Author contributions JHK designed and funded the study and performed fieldwork at the study sites. YK analyzed data and wrote the manuscript draft. JWJ wrote the primary text. HC co-funded the study. JUK and YSO checked the photographs and filtered data. All authors contributed to the review of earlier manuscript drafts.

Funding This research was supported by the Ecophysiology of Antarctic Terrestrial Organisms to Reveal Mechanisms of Adaptation to a Changing Environment program, funded by the Korea Polar Research Institute (PE21130) and long-term ecosystem monitoring in Antarctic Specially Protected Area no. 171 on King George Island was funded by The Korean Ministry of Environment (PG20040).

Declarations

Conflict of interest The authors report no conflict of interest.

Ethical approval This study was performed with permission from the Korean Ministry of Foreign Affairs in accordance with the Act on Antarctic Activities and Protection of the Antarctic Environment. This study was carried out in accordance with the 'SCAR Code of Conduct for the use of Animals for Scientific Purposes in Antarctica.'

References

Anderson O, Phillips R, Shore R, McGill R, McDonald R, Bearhop S (2009) Diet, individual specialisation and breeding of Brown skuas (*Catharacta antarctica lonnbergi*): an investigation using

stable isotopes. Polar Biol 32:27–33. https://doi.org/10.1007/s00300-008-0498-9

Arnold JM, Hatch JJ, Nisbet IC (2006) Effects of egg size, parental quality and hatch-date on growth and survival of Common Tern Sterna hirundo chicks. Ibis 148:98–105. https://doi.org/10.1111/j.1474-919X.2006.00487.x

ATCM (Antarctic Treaty Consultative Meeting) 2019 *Revised Management Plan for Antarctic Specially Protected Area no. 171, Narębski Point, Barton Peninsula, King George Island. Working Paper 16*. Antarctic Treaty Consultative Meeting XLII and Committee for Environmental Protection Meeting XXII, 1 – 11 Jul 2019. Prague.

Baker SC, Barbraud C (2001) Foods of the south polar skua *Catharacta maccormicki* at Ardery Island, Windmill Islands, Antarctica. Polar Biol 24:59–61

Barrett RT, Camphuysen K, Anker-Nilssen T, Chardine JW, Furness RW, Garthe S, Hüppop O, Leopold MF, Montevecchi WA, Veit RR (2007a) Diet studies of seabirds: a review and recommendations. J of Mar Sci 64:1675–1691. https://doi.org/10.1007/s003000000163

Barrett RT, Camphuysen K, Anker-Nilssen T, Chardine JW, Furness RW, Garthe S, Huppop O, Leopold MF, Montevecchi WA, Veit RR (2007b) Diet studies of seabirds: a review and recommendations. J of Mar Sci 64:1675–1691. https://doi.org/10.1093/icesjms/fsm152

Caldow R, Furness R (2000) The effect of food availability on the foraging behaviour of breeding Great Skuas *Catharacta skua* and Arctic Skuas *Stercorarius parasiticus*. J Avi Biol 31:367–375. https://doi.org/10.1034/j.1600-048X.2000.310313.x

Carneiro AP, Manica A, Trivelpiece WZ, Phillips RA (2015) Flexibility in foraging strategies of Brown Skuas in response to local and seasonal dietary constraints. J of Ornith 156:625–633. https://doi.org/10.1007/s10336-015-1156-y

Carneiro APB, Polito MJ, Sander M, Trivelpiece WZ (2010) Abundance and spatial distribution of sympatrically breeding *Catharacta spp*. (skuas) in Admiralty Bay, King George Island. Antarctica Polar Biol 33:673–682. https://doi.org/10.1007/s00300-009-0743-x

Carney KM, Sydeman WJ (1999) A review of human disturbance effects on nesting colonial waterbirds. Waterbirds 22:68–79. https://doi.org/10.2307/1521995

Christensen-Dalsgaard S, May RF, Barrett RT, Langset M, Sandercock BK, Lorentsen SH (2018) Prevailing weather conditions and diet composition affect chick growth and survival in the black-legged kittiwake. Mar Ecol Prog Ser 604:237–249. https://doi.org/10.3354/meps12744

Crawford RJ, Dyer BM (1995) Responses by four seabird species to a fluctuating availability of Cape anchovy Engraulis capensis off South Africa. Ibis 137:329–339. https://doi.org/10.1111/j.1474-919X.1995.tb08029.x

Golet GH, Kuletz KJ, Roby DD, Irons DB (2000) Adult prey choice affects chick growth and reproductive success in pigeon guillemots. Auk 117:82–91. https://doi.org/10.1093/auk/117.1.82

Grilli MG, Montalti D (2012) Trophic interactions between brown and south polar skuas at Deception Island, Antarctica. Polar Biol 35:299–304. https://doi.org/10.1007/s00300-011-1054-6

Hagelin JC, Miller GD (1997) Nest-site selection in south polar skuas: balancing nest safety and access to resources. Auk 114:638–645. https://doi.org/10.2307/4089283

Hahn S, Bauer S (2008) Dominance in feeding territories relates to foraging success and offspring growth in Brown skuas *Catharacta antarctica lonnbergi*. Behav Ecol and Sociobiol 62:1149–1157. https://doi.org/10.1007/s00265-007-0543-7

Hahn S, Peter H-U (2003) Feeding territoriality and the reproductive consequences in Brown skuas *Catharacta antarctica lonnbergi*. Polar Biol 26:552–559. https://doi.org/10.1007/s00300-003-0522-z

Hahn S, Reinhardt K, Ritz MS, Janicke T, Montalti D, Peter H-U (2007) Oceanographic and climatic factors differentially affect reproduction performance of Antarctic skuas. Mar Ecol Prog Ser 334:287–297

Hinke JT, Barbosa A, Emmerson LM, Hart T, Korczak-Abshire JMA (2018) Estimating nest-level phenology and reproductive success of colonial seabirds using time-lapse cameras. Meth in Ecol and Evol 9:1853–1863. https://doi.org/10.1111/2041-210X.13015

Kitaysky AS, Kitaiskaia EV, Piatt JF, Wingfield CJ (2006) A mechanistic link between chick diet and decline in seabirds? Proc of the Royal Soci b: Bioll Sci 273:445–450. https://doi.org/10.1098/rspb.2005.3351

Lepage D, Gauthier G, Menu S (2000) Reproductive consequences of egg-laying decisions in snow geese. J of Ani Ecol 69:414–427. https://doi.org/10.1046/j.1365-2656.2000.00404.x

Malzof SL, Quintana RD (2008) Diet of the south polar skua Catharacta maccormicki and the Brown skua *C. antarctica lonnbergi* at Cierva Point Antarctic Peninsula. Polar Biol 31:827. https://doi.org/10.1007/s00300-008-0421-4

Ministry of Environment (2017) Environmental monitoring and management of the Antarctic Specially Protected Areas and the Antarctic Stations(3). BSPG16040–081–3. Korean Ministry of Environment

Moncorps S, Chapuis J-L, Haubreux D, Bretagnolle V (1997) Diet of the Brown skua *Catharacta skua lönnbergi* on the Kerguelen archipelago: comparisons between techniques and between islands. Polar Biol 19:9–16. https://doi.org/10.1007/s003000050210

Moreno J, Barbosa A, Potti J, Merino S (1997) The effects of hatching date and parental quality on chick growth and creching age in the chinstrap penguin (*Pygoscelis antarctica*): a field experiment. Auk. https://doi.org/10.2307/4089064

Mund MJ, Miller GD (1995) Diet of the south polar skua Catharacta maccormicki at Cape Bird, Ross Island, Antarctica. Polar Biol 15:453–455. https://doi.org/10.1007/BF00239723

Osborne R (1985) Aspects of the breeding biology and feeding behaviour of the Brown Skua *Catharacta lonnbergi* on Bird Island, South Georgia British. Antar Sur Bull 66:57–71

Phillips RA, Phalan B, Forster IP (2004) Diet and long-term changes in population size and productivity of brown skuas Catharacta antarctica lonnbergi at Bird Island, South Georgia. Polar Biol 27:555–561. https://doi.org/10.1007/s00300-004-0633-1

Pietz PJ (1987) Feeding and nesting ecology of sympatric south polar and Brown skuas. Auk 104:617–627. https://doi.org/10.1093/auk/104.4.617

R Core Team (2020) R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/

Reif V, Tornberg R (2006) Using time-lapse digital video recording for a nesting study of birds of prey. Euro J of Wild Res 52:251–258. https://doi.org/10.1007/s10344-006-0039-1

Reinhardt K, Hahn S, Peter H-U, Wemhoff H (2000) A review of the diets of Southern Hemisphere skuas. Mar Ornith 28:7–19

Ritz MS, Hahn S, Janicke T, Peter HU (2006) Hybridisation between South polar skua (*Catharacta maccormicki*) and Brown skua (*C. antarctica lonnbergi*) in the Antarctic Peninsula region. Polar Biol 29:153–159. https://doi.org/10.1007/s00300-005-0034-0

Stonehouse B (1956) The Brown Skua (*Catharacta skua lonnbergi*, Mathews) of South Georgia. 14. HMSO

Trillmich F (1978) Feeding territories and breeding success of South Polar Skuas. Auk 95:23–33. https://doi.org/10.2307/4085492

Trivelpiece W, Butler RG, Volkman N (1980) Feeding territories of Brown skuas (*Catharacta lonnbergi*). Auk 97:669–676. https://doi.org/10.1093/auk/97.4.669

Wood RC (1971) Population dynamics of breeding South Polar Skuas of unknown age. Auk 88:805–814. https://doi.org/10.2307/4083839

Young E (2005) Skua and penguin: predator and prey. Cambridge University Press