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Diet and Feeding Behavior of the South Polar Skuas *Stercorarius maccormicki* in the Haswell Islands, East Antarctica

Sergey Golubev

Papanin Institute for Biology of Inland Waters, Russian Academy of Sciences, Borok 152742, Russia; gol_arctic@mail.ru

Simple Summary: This work focuses on the diet and feeding ecology of the South Polar Skua, a large gull-like seabird that breeds around Antarctica and winters in the Indian Ocean and Northern Hemisphere. This study presents information from the Haswell Islands off the Antarctic coast in the Davis Sea, where skuas breed near colonies of other seabird species. The composition of the diet of South Polar Skuas included animal (vertebrate and invertebrate organisms), plant, mineral, and anthropogenic components. The diet during the pre-breeding and breeding periods was based on eggs and chicks found in Emperor and Adélie penguin colonies. During the post-breeding period, skuas have been observed feeding at sea. In general, they obtained food by scavenging, but they could also prey on the eggs and chicks of Adélie Penguins and other seabirds. In recent decades, kitchen waste became an additional food resource that supported the skua population. It was found that South Polar Skuas did not influence the breeding success of Emperor Penguins but could potentially influence the breeding success of Adélie Penguins and other seabirds.

Abstract: The diet and feeding behavior of South Polar Skuas (*Stercorarius maccormicki*) are well studied within the species' breeding range but are poorly understood on the Haswell Islands. The aim of this study was to determine how South Polar Skuas use available resources during the pre-breeding and breeding periods at the Haswell Archipelago (66°31′ S, 93°01′ E, Davis Sea, Southern Ocean) under conditions of prolonged human activity. I studied pellets, spontaneous regurgitation, and stomach contents of feathered birds to study the diet of skuas and used direct observations of their feeding behavior. South Polar Skuas at the Haswell Islands fed primarily on the Emperor Penguin (*Aptenodytes forsteri*) colony and on terrestrial resources in the Adélie Penguin (*Pygoscelis adeliae*) and fulmarine petrel colonies. The dominant prey of skuas were breeding Antarctic penguins. Emperor Penguins and Adélie Penguins make up the bulk of the skuas' diet in the pre-breeding and breeding periods. Surface feeding at sea was observed in the post-breeding period. In recent decades, kitchen waste supported the skua population. Scavenging (placenta and feces of Weddell seals [*Leptonychotes weddellii*], frozen eggs, chicks and adults of breeding bird species, kitchen refuse) is the dominant strategy for obtaining food. Adélie Penguin eggs and chicks were the main food items of the South Polar Skuas in the Haswell Archipelago. Skua predation could potentially influence the breeding success of Adélie Penguins and fulmarine petrels, but the extent of the impact is unknown. The impact of the South Polar Skua on Emperor Penguins is negligible because skuas feed mainly on frozen chicks and eggs of the species.

Keywords: predator; pellets; regurgitates; stomach; feces; macroplastic; prey remains; scavenging; kleptoparasitism

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1. Introduction

Southern Ocean food webs are among the most vulnerable [1]. Studying food webs helps us understand how species and communities respond to climate change [1,2]. Additionally, studying diet is central to understanding the adaptations of seabirds to the marine environment [3]. The South Polar Skua (*Stercorarius maccormicki*) is distributed

in coastal Antarctica, including the Antarctic Peninsula [4], and is well-adapted to the extreme Antarctic environment [5,6]. Breeding occurs in the snow-free coastal areas of Antarctica, although small colonies exist in mountainous areas inland [4]. They winter in the Indian Ocean and in the Northern Hemisphere, including Alaska and Greenland, and their exact range in the North Atlantic is unknown [4]. South Polar Skuas feed on marine mammals, penguins, flying birds, fish, invertebrates, and kitchen refuse, and the coastal habitat provides the maximum diversity of its prey [4,7]. Their winter diet is largely unknown but probably comprises fish, complemented by some scavenging [4]. Predation, as one of the foraging strategies of South Polar Skuas, poses potential risks to the viability of other seabirds [8]. In East Antarctica, it is the only seabird predator that seriously affects breeding populations of penguins and petrels [9,10].

In the Antarctic Peninsula region (61° S–65° S), sympatric populations of South Polar and Brown (*Stercorarius antarcticus*) skuas exist in a 500 km wide zone [5,11] and exhibit a wide range of trophic interactions. For example, at Cierva Point (Antarctic Peninsula), South Polar Skuas consumed more fish, and Brown Skuas consumed more birds, although there was a relative overlap in their diets [12]. At Deception Island (Antarctica), penguins were the main resource for both species, but South Polar Skuas consumed more adult penguins and Brown Skuas fed predominantly on chicks, which may have reduced competition for the same resource [13]. On Anvers Island (Antarctica) near Palmer Station, South Polar Skuas fed primarily at sea on fish, Brown Skuas fed primarily on penguin eggs and chicks, and the diet of mixed pairs consisted of approximately equal parts fish and penguins [11]. At Half Moon Island (Antarctica), South Polar Skuas fed exclusively on marine prey (fish) and did not eat penguins, indicating the importance of fish in the diet in some places or under some conditions [14]. In allopatric areas, during the breeding season, South Polar Skuas forage in the sea, seabird colonies, and seal breeding grounds [15]. The above is consistent with the idea that South Polar Skuas may exhibit trophic plasticity, changing their feeding habits from one resource to another, depending on availability [16]. However, the feeding habits of South Polar Skuas are most likely determined by many complex interacting factors [14].

On land, the diet of the South Polar Skua is comparatively well studied in many places in its breeding range [4,17]. However, detailed studies of the diet and feeding behavior of this bird species from the Haswell Archipelago have rarely been the focus of specific research interest among biologists [18–20], and thematic information has been scattered among various publications. They mainly contained fragmentary data on the use of certain food resources or brief reports on the feeding behavior of skuas.

Understanding what food resources and to what extent the breeding population of South Polar Skuas uses for annual reproduction is relevant in monitoring and local environmental management. In this regard, assessments of the impact of skua predation on populations of vulnerable and endangered seabirds in a changing climate are critical. This study is also valuable for providing insight into food and plastic pollution in seabird habitats. This work is a summary document that synthesizes recent and historical data (1912–2016) from dietary studies and observations of feeding ecology in the Haswell Archipelago population of South Polar Skuas. It also expands our knowledge of the ecology of this species in different parts of Antarctica.

The purpose of this study was to determine how South Polar Skuas exploited the local high diversity and abundance of living resources in the Haswell Islands, including in the face of long-term, year-round human activity in the area. The main objective of this study was to compile and analyze relevant historical and recent data on the qualitative and quantitative composition of the diet of South Polar Skuas. The secondary aim of this study was to examine what feeding strategies skuas use to obtain food.

2. Materials and Methods

2.1. Study Area

The Haswell Archipelago (66°31′ S, 93°01′ E) is located in the Davis Sea basin in Treshnikov Bay (Indian sector of the Southern Ocean) off the coast of Antarctica (Queen Mary Land, Figure 1). It includes 17 islands and 4 coastal nunataks (the tops of rocks surrounded by and rising above the ice sheet). The islands and nunataks are located in a strip about 2.5 km wide and up to 3.5 km long. This strip is oriented in a northeast direction. The size of most of the islands is small. The largest rock in the archipelago is Haswell Island. Its area is 0.82 km^2, an altitude of 93.1 m above sea level. The absolute altitudes of most islands do not exceed 35 m above sea level [21,22]. For the remainder of this study, all islands of the Haswell Archipelago, except Haswell Island, will be referred to as small islands.

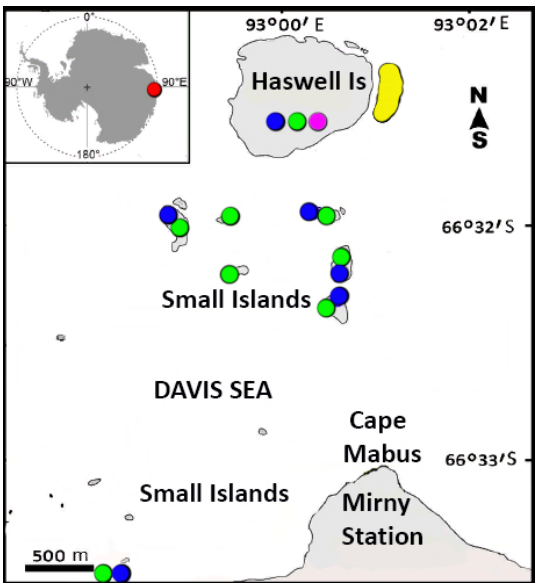

Figure 1. Study area (the red circle in the inset in the upper left corner indicates the location of the Mirny Station). Note: the yellow spot is a colony of Emperor Penguins (*Aptenodytes forsteri*); blue circles are colonies of Adélie Penguins (*Pygoscelis adelia*); green circles are the breeding grounds of South Polar Skuas (*Stercorarius maccormicki*); pink circles are the breeding grounds of Brown Skuas (*Stercorarius antarcticus*).

The weather pattern of the area is determined by frequent snowstorms, especially in winter, as well as strong katabatic winds. The average wind speed is 11.2 m/s, and the maximum is 56 m/s. During the year, on average 204 days, the wind speed in the area of the Mirny Station exceeds 15 m/s. The maximum number of days with gale force winds is 247, and there are about 20–25 days with hurricanes. The predominant wind direction is east–southeast. The average annual air temperature is −11.3 °C, with a maximum of 6.8 °C and a minimum of −40.3 °C. The area is rich in grounded icebergs. For most of the year, the sea is covered with fast ice. In the Davis Sea, the maximum width of fast ice in September–October reaches 30–40 km [23].

The Russian Antarctic research station Mirny (66°33′11″ S; 93°00′35″ E, Figure 1) served as a base for year-round zoological observations in the research area. It is located on the Mirny Peninsula (Pravda Coast) on rocks (nunataks) free of continental ice. Nunataks in some places contain sparse vegetation—mosses, lichens, and algae. The average altitude of the station location is 39.9 m above sea level. Mirny Station was opened on 13 February 1956 [22,23].

During the historical period, the territory of the Mirny Station was heavily polluted [24], including food waste. A landfill for food waste from the Mirny Station existed in the Soviet and Russian periods [19,20,25]. The date of origin of the landfill is not known

since during the Soviet period of operation of the station (1956–1991), the pollution of the occupied territory was not studied [24]. However, South Polar Skuas have been scavenging in Mirny since the first expeditions, since the second half of the 20th century [26]. During the Russian period (1991–present), food waste was buried between the Radio and Morenny nunataks in ice cracks on the moraine of the marginal zone of Antarctica. The number of food waste disposal sites and their volume have not been established. During the Russian period, the minimum annual volume of food waste was 2.5 tons. The contents that did not fall into the crack and remained on the surface of the glacier were accessible to skuas in spring, summer, and autumn. After 2016, as far as I know, no information was published on the availability of food waste for skuas.

The study area is characterizes by high biodiversity [27]. Various species of the genus Trematomus live in the coastal waters of the Davis Sea in the vicinity of the Mirny Station. Less common are the Antarctic toothfish and the Antarctic silverfish. The abundance of crustaceans, mollusks, and fish supports a large number of breeding birds [22]. Nine seabird species breed at the Haswell Islands: the Emperor Penguin (*Aptenodytes forsteri*), Adélie Penguin (*Pygoscelis adeliae*), Southern Fulmar (*Fulmarus glacialoides*), Antarctic Petrel (*Thalassoica antarctica*), Cape Petrel (*Daption capense*), Snow Petrel (*Pagodroma nivea*), Wilson's Storm Petrel (*Oceanites oceanicus*), South Polar Skua, and subspecies of Brown Skua (*S. a. lonnbergi*) [19]. Adélie Penguins are most abundant in the Haswell Archipelago. In the 2009/2010 breeding season, 27,350 adults were counted [28]. Emperor Penguins are less abundant—at the end of May 2015, 11,777 ± 300 adults were counted in the colony [29]. Also counted were ≈5000 Southern Fulmars, ≈500 Antarctic Petrels, ≈300 Cape Petrels, >250 Snow Petrels, and >80 Wilson's Storm Petrels in November 2009 in the Haswell Islands [28]. During the historical period, the total size of the breeding population of South Polar Skuas varied from 18 to 83 pairs [30,31]. From the 2012/2013 to 2015/2016 breeding seasons, 1–2 mixed pairs of Brown Skuas (including alleged hybrids) with South Polar Skuas regularly nested on Haswell Island ([32], Figure 1).

Three species of cetaceans (sei whale (*Balaenoptera borealis*), Antarctic minke whale (*Balaenoptera bonaerensis*), killer whale (*Orcinus orca*), and five species of pinnipeds (southern elephant seal (*Mirounga leonina*), Weddell seal (*Leptonychotes weddellii*), crabeater seal (*Lobodon carcinophaga*), leopard seal (*Hydrurga leptonyx*), and Ross seal (*Ommatophoca rossii*) have been recorded here. However, only the Weddell seal is the most abundant year-round resident species of seals on the archipelago breed annually [33]. The long-term and year-round operation of the Mirny Station made it possible to study the unique coastal island ecosystem in the Davis Sea basin. In order to preserve the abundance of life, Antarctic Specially Protected Area № 127 "Haswell Island and adjacent Emperor Penguin rookery on fast ice" (hereinafter ASPA № 127 "Haswell Island") [34] was created in this area. ASPA № 127 "Haswell Island" became the main site for periodic research activity of biologists.

2.2. Study Species

The South Polar Skua is a food generalist, top predator, and seasonal resident, using up to 8 islands of the Haswell Archipelago for breeding (for example, [18,19,25,35,36]. This opportunistic predator breeds in single pairs and small groups on the small islands of the archipelago or in a loose colony on Haswell Island. The core breeding population is located on Haswell Island near the Adélie Penguin colonies and the Emperor Penguin colony (≈2.7 km north of the Mirny Station) on fast ice (e.g., [18,20,35], Figure 1). The minimum population size of South Polar Skuas (18 breeding pairs) was recorded in the 1999/2000 breeding season [30], the historical maximum (83 breeding pairs) was observed in the 2010/2011 breeding season [25,31,37]. Skuas' feeding habitats include land, sea, sea, and continental ice. In general, birds patrol the entire surface of the water area, including the Haswell Islands and fragments of the mainland coast.

Skuas arrive on the islands of the archipelago in October, when the fast ice extent is at its maximum, and in March–April [18,25,35,36,38–41], when the water area freezes. Thus, they spend approximately half of their annual cycle in their breeding areas. After the

marine stage of the annual cycle (wintering) and a sharp change from one habitat (sea) to another (land and sea ice), skuas switch to feeding primarily on Antarctic penguins and fulmarine petrels (for example, [18]). A change in habitat is accompanied by a change in their food habits. In October–December, support for the skua population on the archipelago is provided by an abundant food supply in the form of frozen eggs, chicks, and single adult Emperor Penguins. During October–November, Weddell seals in the study area produce up to 10 pups annually [33], and the placenta of these seals is used as a food resource by skuas [18,39]. Skuas also occasionally eat the feces of Weddell seals hauled out onto the fast ice (Figure 2) and fish at fishing points.

Figure 2. South Polar Skuas (*Stercorarius maccormicki*) feeding on Weddell seal (*Leptonychotes weddellii*) feces. Haswell Archipelago. 11 December 2012.

In November and December, skuas continue to use food resources in the Emperor Penguin colony ([18], author's observations). However, by the end of November–beginning of December, the consumption of Adélie Penguin eggs by skuas increases (author's observations). Subsequently, Adélie Penguin chicks became victims of skuas [35,42], and chicks could occupy the main place in their diet [43]. Fulmarine petrels are less frequently used by skuas as food during this period (for example, [18,39,44–47]). Starting from February [38] and March, solitary skuas and loose groups of up to 16 individuals (8 individuals per km^2) are observed feeding on prey from the surface of the water (author's observations). At the end of March–beginning of April, against the background of lowering air temperatures and increasing katabatic winds, feeding conditions for South Polar Skuas become very limited. In April, when almost the entire water area is covered with young ice, South Polar Skuas feeding in the sea were not recorded (author's observations). They stop feeding on the ground and on the ice, which coincides with the end of their autumn migrations in the study area and their stay here (author's observations). It should also be noted that from October to March, South Polar Skuas visited the Mirny Station food waste dump [19,20,25,38,41].

2.3. Material and Research Methods

I made opportunistic observations of the feeding behavior of South Polar Skuas and collected food samples between 8 January 2012 and 7 January 2013, as well as between 9 January 2015 and 14 January 2016. This corresponded to the pre-breeding, breeding, and post-breeding periods of the annual cycle of the South Polar Skuas. Observations were carried out in a sea area free of fast ice, on continental and sea ice, and on islands and nunataks of the Antarctic coast. In 2012, 46, and in 2015, 15 hiking trips were made from the Mirny Station to the islands and the Emperor Penguin colony. Each trip usually involved

at least 2 people. In the Mirny Station, daily observations were carried out on the nunataks Radio, Komsomolsky, and between them on the continental ice. The duration of work on the islands and fast ice ranged from 3 to 5 h, and at the Mirny Station, the duration was from 1 to 8 h a day. The area covered by the survey from the Mirny nunataks was about 8 km^2, but it sometimes increased up to 12 km^2. The total area studied was about 17.5 km^2. Islands and sea ice were visited on foot during the fast ice period (April–December).

I used the classic approach of studying the diet of high-trophic level predators [2], including direct observation of the feeding behavior of South Polar Skuas and their prey, the collection of prey remains, pellets and spontaneous regurgitations, and the stomach contents of dead birds. In the study area, 55 pellets, 3 spontaneous regurgitations, and the stomachs of 2 dead birds were collected and examined. In 2012, 21 pellets were collected (2 pellets were found at the Mirny Station and 19 pellets on the Haswell Islands). In 2015, 34 pellets (7 pellets were found at the Mirny Station and 27 pellets on the Haswell Islands) were collected. At the Mirny Station, pellets were collected on the Radio and Komsomolsky nunataks and on the surface of continental ice between these hills. On the Haswell Islands, pellets were collected near or some distance from South Polar Skua nests. Three spontaneous regurgitation samples, as well as 2 dead feathered South Polar Skuas, whose stomachs were examined, were found in 2012 at the Mirny Station and in its environs. Prey remains of South Polar Skuas (mainly the carcasses of penguins and petrels or their fragments) were also recorded, but the total number of samples detected was not recorded.

The focus of this study was juvenile and adult non-breeding and breeding birds. The diet of downy skua chicks has not been studied. Unpublished and published historical data, based primarily on observations, served as an important additional information resource.

The determination of the qualitative composition of prey remains (bird corpses and their fragments) was carried out by direct year-round observations in the field in the places where they were found. Pellet, spontaneous regurgitation, and stomach contents of dead birds were identified in the laboratory. The pellets were collected in plastic bags. Under station conditions, the pellets were measured and air dried. Samples were stored in a dry and dark place. Before a detailed study of the samples in the laboratory, the contents of the pellets were soaked in water, fragmented into small components, and identified. The prey of avian species was identified to the species level, although some components (petrel bones and chicken down of petrels) in pellets were sometimes not identified to species (n = 6). In such cases, samples were designated as fulmarine petrels or tube-nosed bird species. Fish bones and scales and cephalopod beaks were not identified to species rank (n = 6).

Qualitative and some quantitative parameters of the diet were analyzed. The research approach and terminology in studying the diet of skuas was based on the review by Reinhardt and colleagues [7]. The determination of the foraging strategy status of South Polar Skuas, based on the author's data, was carried out through numerous recordings of their feeding behavior, including the use of digital cameras. The identification of the feeding status of each prey category (e.g., adults, chicks, eggs) of a particular species, higher-ranking taxon, or other inclusions (kitchen refuse) contained in the historical data was made by the author based on details of observations and researcher interpretations of relevant publications. The analysis of the diet of South Polar Skuas did not use historical data containing general phrases that do not convey specific, valuable scientific information about the subject of this study. For example, it is not clear from which colonies of Emperor and Adélie penguins in East Antarctica Korotkevich [35] presented observations of the feeding behavior of South Polar Skuas. In such cases, the lack of specificity did not guarantee the correct use of information about a particular penguin colony. The frequency of occurrence (FO) was calculated by the formula $FO = (f_i/N) \times 100$, where f_i is the number of pellets with item i and N is the total number of pellets [48].

In 2012, the number of frozen eggs, chicks, and adults of Emperor Penguins, an important food source for South Polar Skuas during the pre-breeding and breeding periods,

was determined using the cumulative method [49], i.e., periodic counts of frozen eggs, chicks, and adults (Table 1).

Table 1. Cumulative counts (exemplars) of frozen eggs, chicks, and adults of Emperor Penguins (*Aptenodytes forsteri*) at the colony off Haswell Island in 2012.

Count Date/Number	Eggs	Chicks	Adults
6 June			2
7 June	634		
25 June	+70		
26 June	+23		
19 July	+8		
19 July		3	
5 August		+119	
5 August	+157		
10 September	+98		
10 September		+14	
17 September			+1
30 September	+8		
30 September		+27	
8 October		+6	
2 November	+12		
Total	1010	169	3

Note: "+" before the number means the number of frozen eggs, chicks, or adults that died in a specific period of time and were added to the previous total number of dead samples during the cumulative count.

The size of the skua breeding population in 2012 was determined by direct counts of active nests. A pair with a clutch of eggs or chick(s) was identified as a breeding pair.

In the field, the feeding behavior of South Polar Skuas was observed using 8 × binoculars. Digital images and videos were obtained using a hand-held Canon 60D digital camera fitted with a Sigma 50–500 mm zoom lens and with a portable digital camera, Sony Cyber-shot DSC-WX220 Black. A Garmin eTrex 30™ GPS recorder was also used to record geographic coordinates. Digital image processing was carried out at the station on a laptop computer. Linear dimensions of pellets and spontaneous regurgitation (their length and width) were measured to ± 1.0 mm using Vernier calipers. A map of the study area (Figure 1) and an image of feeding South Polar Skuas (Figure 2) were prepared or edited using Adobe Photoshop CC 2015.0.0 Portable Version (USA). The linear distance between the Mirny Station and the Adélie Penguin colonies on Haswell Island and Emperor Penguins near this island was measured using Google Earth Pro 2022 (USA). The primary compilation of data was carried out in the spreadsheet processor Microsoft Excel 2013 (USA).

3. Results

Consistent with the historical data in Table 2, it is clear that South Polar Skuas used a wide range of prey items, with birds predominating in a number of species over other prey categories in the overall diet. Scavenging (n = 14) was twice as common as predation (n = 7), according to the analysis of the prey status of skuas. The researchers used at least two sampling techniques, including direct observations and examinations of stomach contents. The historical data in Table 2 show that direct observations were the dominant sampling technique.

Qualitative diet composition data (2012–2016) indicate scavenging as the primary foraging strategy of South Polar Skuas, although some samples showed apparent or suggestive predation or kleptoparasitism (Table 3). The scant data on spontaneous regurgitation and stomach contents of skuas complement, but do not fundamentally affect, the representativeness of the prey categories identified through pellet examination. Birds are the most diverse prey category (Table 3).

Table 2. Historical data on the qualitative composition of the diet of South Polar Skuas (*Stercorarius maccormicki*) of the Haswell Archipelago, 1912–2011.

Name of Species/Status of Prey	Foraging Strategy	Sampling Technique	References
	Mammals		
Leptonychotes weddellii			
Adults	S	O	[38,50]
Placenta	S	O	[18,39]
	Birds		
Aptenodytes forsteri			
Adults	S	O	[18,49]
Chicks	S, P	O	[18,39,49–51]
Eggs	S	O	[18,49]
Pygoscelis adeliae			
Adults	S, P	O	[20,38]
Chicks	S, P	O	[18,20,38,42]
Eggs	S, P	O	[18,27,38,42]
Fulmarus glacialoides			
Adults	?	O	[38]
Chicks	S	O	[18,46]
Eggs	S	O	[18,39,46]
Thalassoica antarctica			
Adults	?	O	[38]
Eggs	P	O	[44]
Daption capense			
Adults	?	O	[38]
Chicks	S, P	O	[47]
Pagodroma nivea			
Chicks	?	O	[47]
Oceanites oceanicus			
Chicks	?	O	[45]
Stercorarius maccormicki			
Chicks	S, P	O	[18]
Eggs	S	O	[18]
	Fish		
Unidentified fish items	?	?, C	[20,38]
	Invertebrates		
Crustaceans	?	?	[38]
Cephalopods	?	?	[38]
	Anthropogenic items		
Kitchen refuse	S	O, C	[20,38]

Note: the foraging strategy of skuas includes scavenging (S); predation (P); ?—feeding strategy is not clear. The sampling technique of the observer includes direct observation (O); stomach contents (C); ?—sampling technique is not clear. In flying birds (tube-nosed birds and skuas), the category "chick" includes individuals that have not reached the flight stage. Fully feathered and flying birds are treated as adults (mature and immature). In penguins, chicks are called individuals in downy plumage.

According to the recent quantitative data (2012–2016), Antarctic penguins, stone and gravel fragments, and fulmarine petrels form the main food sources for the South Polar Skuas (Table 4). Antarctic penguins dominated in the frequency of occurrence of samples in the fifty-five studied pellets, Adélie Penguin samples were found in thirty-five (63.6%) pellets, and Emperor Penguin samples were found in seven (12.7%). Procellariiforms were recorded approximately three times less often in the samples. Occurrence rates of other prey categories of South Polar Skuas were low but were dominated by fish and kitchen refuse. Cephalopods were minimally represented in the samples. Stone and gravel fragments turned out to be an important component of pellets, and in terms of frequency of occurrence in the samples, they were second only to samples from Antarctic penguins.

The size of 31 pellets (mm) of South Polar Skuas was average 51 mm (±14.3 [SD]; 30–84 [min–max] × 30 mm (±7.0 [SD]; 17–42 [min–max]. The median size was an average 49 mm × 29 mm. The largest stone in the examined pellets had a size 17 mm × 28 mm. Three spontaneous regurgitation samples found in February and March 2012 contained feathers, skin, bones, and muscle tissue from adult Adélie Penguins, as well as bones from tube-nosed birds. A piece of glass was found in one of the three samples. The size of this one sample was 111 mm × 38 mm. In November 2012, the shell and feathers of an Adélie

Penguin were found in the stomach of one dead individual of the South Polar Skua; the stomach of the second dead individual was empty. Both stomachs contained gravel.

Table 3. Data on the qualitative composition of the diet of South Polar Skuas (*Stercorarius maccormicki*) of the Haswell Archipelago, 2012–2016. *Captions for* Table 3. The foraging strategy of skuas includes scavenging (S); predation (P); feeding strategy not established, but predation is assumed (P?); feeding strategy not established (?); kleptoparasitism (K). "+"—the prey category is present in the sample, "—"—the prey category is absent in the sample.

Name of Species/Status of Prey	Foraging Strategy	Pellets, *n* = 55	Regurgitations, *n* = 3	Stomach Contents, *n* = 2
MAMMALS				
Leptonychotes weddellii				
Feces	S	—	—	—
BIRDS				
Aptenodytes forsteri				
Chicks	S	+	—	—
Eggs	S	+	—	—
Spontaneous regurgitation in adults	S	—	—	—
Pygoscelis adeliae				
Adults	S, K	+	+	+
Chicks	?	+	—	—
Eggs	P	+	—	+
Fulmarus glacialoides				
Adults	P?	+	—	—
Daption capense				
Adults	P?	—	—	—
Pagodroma nivea				
Adults	?	+	—	—
Unidentified fulmarine items	?	—	+	—
Stercorarius maccormicki				
Adults	?	+	—	—
FISH				
Unidentified fish items	S	+	—	—
INVERTEBRATES				
Cephalopods	?	+	—	—
MINERAL ITEMS				
Stone and gravel fragments	?	+	—	+
ANTHROPOGENIC ITEMS				
Kitchen refuse	S, K	+	—	—
Station garbage	?	+	+	—

Table 4. Quantitative representation of prey categories (*n*) and frequency of occurrence of food samples FO (%) in 55 pellets of South Polar Skuas (*Stercorarius maccormicki*) on the Haswell Archipelago (2012, 2015).

Prey Category	*n*	FO (%)
Antarctic penguins	42	76.3
Stone and gravel fragments	21	38.1
Fulmarine petrels	13	23.6
Fish	5	9.0
Kitchen refuse	5	9.0
Skuas	2	3.6
Station garbage	2	3.6
Cephalopods	1	1.8

In general, among vertebrate animals, South Polar Skuas used as food one species of seal (Weddell seal), eight species of birds (Emperor Penguin, Adélie Penguin, Southern Fulmar, Antarctic Petrel, Cape Petrel, Snow Petrel, Wilson's Storm Petrel, South Polar Skua), and fish. Five non-breeding bird species on the archipelago (Chinstrap Penguin (*Pygoscelis antarctica*), Macaroni Penguin (*Eudyptes chrysolophus*), Southern Giant Petrel (*Macronectes*

giganteus), Pomarine Jaeger (*Stercorarius pomarinus*), Kelp Gull (*Larus dominicanus*), and one subspecies of Brown Skua, which breeds in mixed pairs with the South Polar Skua on Haswell Island) were not recorded in the diet. Invertebrates in the skua's diet consisted of cephalopods and crustaceans. Native vegetation (mosses and lichens) was not present in food samples and was not confirmed by direct observations. In addition, plant components of anthropogenic origin (vegetable and fruit remains) were consumed if skuas visited the food waste dump at the Mirny Station ([38], author's observations). Stone and gravel fragments were mineral components of some food samples. Anthropogenic components such as kitchen refuse and station garbage containing macroplastic fragments in two pellets out of fifty-five pellets examined and a glass fragment in one sample out of three spontaneous regurgitation samples examined were also identified. Thus, the composition of the diet of South Polar Skuas included animal (vertebrate and invertebrate organisms), plant, mineral, and anthropogenic components.

4. Discussion

The results of the research indicated that the diet of South Polar Skuas consists of a wide range of foods. The results of this study indicated that eggs and chicks of Emperor and Adélie penguins are the main food sources of the South Polar Skuas [43] during pre-breeding and breeding periods. However, the volume of Emperor Penguin eggs and chicks available for consumption by skuas can vary greatly from season to season. For example, in 2012, 1010 eggs and 169 chicks froze in the Emperor Penguin colony alone, as mentioned above. By 14 December 2012, almost all the frozen eggs and chicks were eaten by skuas, the total number of which on the Haswell Archipelago amounted to 72 breeding pairs in the 2012/2013 breeding season. Along with this, the winter of 2015 was snowy, and many frozen eggs and chicks were hidden under a thick layer of compressed snow (author's observations). Under these circumstances, the available food resources in the Emperor Penguin colony were very limited, which may have affected the size of the breeding population of South Polar Skuas early in the breeding season. However, during the 2015/2016 breeding season, the number of breeding pairs of skuas on the Haswell Archipelago was not determined.

The results supported the earlier findings of Pryor [18] that the South Polar Skua uses abundant bird species (Emperor Penguin, Adélie Penguin, and Southern Fulmar) for food. Although, for example, the contribution of other breeding bird species on Haswell Island to the food supply of skuas is small [18]. The conclusion about the minor importance of fulmarine petrels in the diet of skuas [18,44] was supported by subsequent observations [45,47] and in studies of pellets collected in 2012 and 2015. Elsewhere in East Antarctica, on the coast or some distance from it, the diet of South Polar Skuas is also based on the most abundant bird species—Antarctic penguins and fulmarine petrels; however, the proximity of Antarctic stations contributes to the significant dependence of skuas on kitchen waste [52–62].

Historical evidence suggests that South Polar Skuas consume placentas and adult Weddell seals harvested for scientific research [18,38,39,50]. Recent observations have shown skuas feeding on Weddell seal feces (Figure 2). Skuas also undoubtedly continued to utilize the placenta of Weddell seals, although this fact was not recorded by direct observations of the author. Large blood stains on the sea ice in the areas where Weddell seal pups were born indirectly confirmed this. No adult Weddell seals have been captured for research recently, and no dead adults have been recorded within the Haswell Archipelago [33]. Consequently, South Polar Skuas did not use adult animals for food.

According to recent data, local fish, possibly Antarctic silverfish, were rarely present in the diet of skuas. In pellets (n = 5), they could come from the sea (n = 1) or from the stomach contents of skuas victims or dead birds (Adélie Penguins and fulmarine petrels, n = 4). One fresh pellet discovered on 22 February 2015 contained only fish bones. This suggested active predation of skua in the sea during the ice-free period and corresponded to the phenological data of feeding of South Polar Skuas in the sea in 1957, as indicated

by Syroechkovsky [38]. Also, some small quantities of local fish may have come from an organized recreational ice fishing site on fast ice near Cape Mabus at the Mirny Station, where up to 40 South Polar Skuas congregated at a time. In such cases, skuas picked up fish on the surface of sea ice if the fish caught by some fishermen was stored openly on the ice and not in fishing boxes. Fragments of non-local fish skeletons from the Mirny Station were not recorded in the pellets; they were not registered in spontaneous regurgitation samples and the stomach contents of dead birds, as well as near or at a distance from skuas nests. Cephalopod beaks found in one skua pellet, containing mostly feathers and bones of an adult Snow Petrel, may have originated from the stomach of its petrel. Crustaceans were not represented in the sample. The above can be explained by the fact that all or almost all of the studied samples belonged to the period preceding the feeding of skuas in the sea. The relatively small number of samples examined could also influence the result and its interpretation. Historical records suggest that fish, crustaceans, and cephalopods tend to be present in the diet in February [38], when the sea is free of fast ice.

Kitchen waste was found in pellets. The low occurrence of kitchen refuse in South Polar Skua pellets may indicate that some individuals or pairs with active nests found sufficient food in the breeding colonies of Antarctic penguins and fulmarine petrels. They did not need kitchen refuse from the Mirny Station. According to the author's preliminary data, parallel recordings of individually identifiable skuas at active nests on the Haswell Islands and the Mirny Station partially confirm this assumption. On the other hand, non-breeding adult South Polar Skuas visited a kitchen waste dump with different frequencies (author's unpublished data). However, they dropped pellets outside of areas protected by breeding territorial skuas. Since a significant portion of the pellets were collected near active nests on Haswell Island, as mentioned above, the sample most likely included pellets from territorial skuas that did not or rarely visit the Mirny Station waste dump. Thus, sample collection locations may influence the interpretation of the results.

There was no information in historical publications about the content of stone, gravel fragments, and station garbage in the food of South Polar Skuas (for example, [18,20,38,39]). However, the presence of stone and gravel fragments in the digestive tract in almost half of the studied pellets and the stomachs of two dead skuas indicates the importance of the use of mineral components during the assimilation of prey by South Polar Skuas. A study of the samples revealed the presence of station garbage (fragments of macroplastic) in two pellets [63] and a glass fragment in one sample of spontaneous regurgitation, as mentioned above. One pellet containing macroplastics and one sample of spontaneous regurgitation were found at the Mirny Station, although another pellet containing macroplastics was found on Haswell Island [63]. Unfortunately, there are no collections of pellets from the small islands of the Haswell Archipelago to judge the prevalence of macroplastics between the presumed source of its origin (Mirny Station) and the most remote island (Haswell Island) where South Polar Skuas breed. Along with this, it is known that at Esperanza/Hope Bay, Antarctic Peninsula, plastic was only found in 9% of pellets in breeding Brown Skuas from an area with high anthropogenic activity [64].

South Polar Skuas obtain food using three main feeding strategies: scavenging, predation, and kleptoparasitism [7]. Carrion was used by skuas throughout their seasonal stay on the archipelago. This is the main way of obtaining food for South Polar Skuas [18,20,35,42,46,51,65].

Egg predation has not been observed in the Emperor Penguin colony because the Emperor Penguins complete egg incubation before the South Polar Skuas arrive at the breeding grounds. However, from the historical data, we see that very rarely did South Polar Skuas resort to active predation on weakened Emperor Penguin chicks [18,49,51]. There is only one poorly documented historical indication of successful predation by South Polar Skuas on healthy Emperor Penguin chicks [50].

In 2012, no cases of South Polar Skuas attacking Emperor Penguin chicks were recorded, although observations in the colony were made by the author relatively often. Apparently, this was due to a significant abundance of frozen eggs and chicks and the

availability of food resources for skuas after wintering. This circumstance could neutralize predation, although weakened Emperor Penguin chicks were occasionally observed in the colony.

Historical data indicate that Adélie Penguins suffered most from predation by skuas [18,39], but predation was rare in Adélie Penguin colonies [18]. Predation of South Polar Skuas on Adélie Penguin eggs has been observed since 1912 [27]. Chicks in the early stages of development were frequent victims of skuas [35,42]. Successful predation on large chicks was also recorded [38]. Sick or injured (dog bites) adult Adélie Penguins became victims of skuas [38]. During the 2012/2013 breeding season, predation by skuas on Adélie Penguin eggs was observed by the author on the small islands of the Haswell Archipelago.

I did not obtain direct evidence of skua predation on fulmarine petrels, although the concentration of skua-eaten adult Cape Petrels (five individuals) on an approximately 1 m^2 feeding table of one skua on Haswell Island indirectly indicated clear predation. This is also true for adult Southern Fulmars. One of the pellets found on Haswell Island contained the feathers and bones of a Snow Petrel, which may have been the result of predation by a skua. Historical data also indicate repeated recordings of remains of adult Southern Fulmars, Antarctic, and Cape Petrels on Haswell Island [38]. Pryor [18] noted that the Antarctic Petrel does not suffer much from predation by skuas, and egg losses from skua raids are negligible [44]. The fact of direct predation on a weakened Cape Petrel chick was established [47]. Thus, predation by skuas on fulmarine petrels occurs, but it is not the determining strategy for obtaining food. Predation of skuas on chicks of their own species (cannibalism) expelled from nests in neighboring territories has been observed frequently [18]. Hunting of South Polar Skuas in marine waters, possibly for fish and invertebrates, was very rarely observed before freeze up.

In the Haswell Archipelago, kleptoparasitism was used extremely rarely by skuas. In 2012 and 2015, it was observed six or seven times in total from October to March. Intraspecific and interspecific (between South Polar and Brown Skuas) kleptoparasitism was established on food waste from the Mirny Station. Intraspecific kleptoparasitism was also identified when the remains of Adélie Penguins, victims of the leopard seal, were disposed of at sea by a group of South Polar Skuas. All air attacks of skuas were recorded by chance, in the sea (with or without the presence of fast ice) north of the Mirny Station at a distance of approximately 500–2000 m from the observer. The success of piracy has not been established. In West Antarctica, for example, on Anvers Island in the vicinity of the Palmer Station near the Antarctic Peninsula, kleptoparasitism was observed from October to March [66], although cases of kleptoparasitism were recorded much more often than on the Haswell Islands. The kleptoparasitism observed on Anvers Island was not an important means of foraging for South Polar Skuas, as out of 280 skuas chasing Blue-eyed Shags (*Phalacrocorax atriceps*) to obtain fish, only 13 (4.6%) were successful [55,66].

An important limitation of this study conducted by the author is the lack of data on the diet and feeding behavior of breeding South Polar Skuas on islands with mid and late chick-rearing stages to the fledging period. The short duration of recent observations on the Haswell Islands during the pre-breeding and breeding periods affected the quality and volume of material collected. The collection and subsequent analysis of fresh and earlier pellets were carried out without differentiating them by age. This did not allow for a comparison of the contents of pellets collected in 2012 and 2015, as some pellets collected in 2015 may have come from skuas regurgitated in 2012 or earlier. The lack of quantitative data on the diet of South Polar Skuas in historical collections prevented appropriate comparisons with the 2012 and 2015 sample collections. Finally, dietary studies based on the analysis of regurgitated pellets near skua nests may underestimate the presence of fish because otoliths are lost during digestion [14,62].

To summarize, it should be noted that in the future, it is very important to organize targeted research on the impact of South Polar Skuas on the breeding success of Adélie Penguins and fulmarine petrel populations. From a comparative point of view, this study of predation on skua breeding on Haswell Island and the small islands of the Haswell

Archipelago is of particular interest. Studying a larger number of pellets and a combination of different nutrition research methods could expand the already known dietary spectrum of the species off the Davis Sea coast. The diet and feeding ecology of adult South Polar Skuas on the Haswell Islands during periods of strong fast ice breakdown and removal from the study area (usually January and early February), as well as the absence of fast ice (usually February–March) and the diet of downy chicks, remain as gaps in our knowledge. At the species level, the taxonomic composition of squid and fish consumed by skuas, partly fulmarine petrels, remains unknown. Finally, it is necessary to continue the quantitative recording of kitchen waste in pellets against the background of reduced access to it and non-food waste from the Mirny Station. Of particular interest are the study of the diet and trophic interactions of Brown Skuas, which are expanding their range along the coast of East Antarctica and breeding in mixed pairs with South Polar Skuas. All of the above aspects require detailed verification in the future.

5. Conclusions

In the ecological conditions of the Haswell Archipelago, the maintenance of the population of South Polar Skuas was ensured by feeding on terrestrial resources, mainly breeding bird species. Surface feeding at sea was observed in the post-breeding period. The dominant prey in the diet of South Polar Skuas were vertebrates. Antarctic penguins make up the bulk of the skuas' diet during the pre-breeding and breeding periods. During the last few decades, kitchen waste became an additional component of the diet that supported the skua population. Scavenging is the leading strategy for obtaining food by South Polar Skuas. South Polar Skuas do not affect the breeding success of Emperor Penguins if they feed on frozen chicks and eggs in their colony, including live weakened chicks doomed to death. However, given that South Polar Skuas prey on the eggs and young of Adélie Penguins and other breeding bird species, they could potentially have an impact on their breeding success, but to what extent is unknown.

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