

# Diet of a breeding population of South Polar Skuas (*Stercorarius maccormicki*) of the Schirmacher Oasis, Central Dronning Maud Land, East Antarctica

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**Abstract** The first detailed study on the diet of a breeding population of South Polar Skuas (*Stercorarius maccormicki*) at Schirmacher Oasis is based on the collection and analysis of prey remains and pellets from the 2024/2025 breeding season and food samples from previous seasons near active skua nests (n=8) and old breeding territories (n=2). The diet composition of the skua population and its changes in the context of human activity were determined. The diet included five bird species, fish, squid, and food scraps and garbage from Antarctic stations and bases. The diet was dominated by Snow Petrels (*Pagodroma nivea*), with subdominants being Antarctic Petrels (*Thalassoica antarctica*) and Adélie Penguins (*Pygoscelis adeliae*). Native marine fish and squid were likely incidental dietary components, introduced into pellets along with the skuas' prey. Human activities have influenced the diet of skuas on a population-wide scale by introducing imported food and garbage into their diet. Food waste was found in seven of eight surveyed breeding territories and in one of two old breeding territories. Diet composition and behaviour of skuas in areas of human activity in Antarctica can be used as an indicator of the quality of local human waste management, as well as an indicator of the health of the ecosystem.

Keywords: predation, scavenging, kleptoparasitism, cannibalism, feeding

**Összefoglalás** Jelen tanulmány az első, ami a Schirmacher-óázisban költő délsarki halfarkasok (*Stercorarius maccormicki*) táplálkozását vizsgálta a 2024/2025-ös költési szezonból származó zsákmánymaradványok és köpetek, valamint a korábbi szezonokból származó táplálékminták alapján, aktív halfarkas-fészkek (n=8) és régi költőhelyek (n=2) közelében. Meghatároztuk a halfarkas-populáció táplálékösszetételét és annak változását az emberi tevékenységgel összefüggésben. Az étrend öt madárfajt, halat, tintahalat, valamint az antarktisi állomásokról és bázisokról származó ételmaradékot és szemetet tartalmazott. A táplálékban a hóhojszák (*Pagodroma nivea*) domináltak, a szubdomináns fajok az antarktisi hojszák (*Thalassoica antarctica*) és az Adélie-pingvinek (*Pygoscelis adeliae*) voltak. Az őshonos tengeri halak és a tintahalak valószínűleg véletlenül kerültek a köpetekbe a halfarkasok zsákmányával együtt. Az emberi tevékenységek a populáció egészére kiterjedően befolyásolták a halfarkasok étrendjét azáltal, hogy behozott táplálékot és szemetet vittek be a táplálékukba. A nyolc vizsgált költőterületből hében, és a két régi költőterületből egyben találtak élelmiszerhulladékot. Az antarktisi emberi tevékenységgel érintett területeken élő halfarkasok táplálékösszetétele és viselkedése a helyi emberi hulladékgyűjtés minőségének, valamint az ökoszisztéma egészségének mutatójaként is használható.

Kulcsszavak: predáció, szemet eltakarítás, kleptoparazitizmus, kannibalizmus, táplálkozás

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## Introduction

At the scale of Antarctica, the human footprint is much smaller than in most other regions of the Earth (Perterra *et al.* 2017), but human activities can influence Antarctic flora and fauna at different levels of biological organization (Tin *et al.* 2009). The presence of more permanent settlements in Antarctica will increase, and this will likely bring conservation challenges (Chown *et al.* 2012). Research into Antarctic oases is of particular interest. They occupy an insignificantly small area of the ice continent, where most Antarctic stations are located and tourism is developing (Sokratova 2009). At the same time, the seasonal and year-round human settlements in Antarctica suggest the longest and closest contacts with biota and birds, in particular.

After the discovery of the Schirmacher Oasis (hereinafter the Oasis) on 3 February 1939, its territory was first visited in 1959 by members of the Fourth Soviet Antarctic Expedition (Konovalov 1962a, Fritzsche & Bormann 1995). Subsequently, the Oasis experienced increasing anthropogenic influence, which was expressed in the construction and then continuous year-round operation of Antarctic stations (Fritzsche & Bormann 1995, AARI Press Service 2011, Aleksandrov 2014, Tiwari 2017) and annually functioning seasonal tourist bases (White Desert 2020). In 1961, the Novolazarevskaya Station was opened, the infrastructure of which included the George Forster base from 1976 to 1996 (AARI Press Service 2011). In 1988/1989, the Maitri Station opened (Tiwari 2017). From 2006 to the present time, commercial tourism has been organized on the basis of the White Desert Antarctic Camp (White Desert 2020). Thus, the permanent human population in the Oasis is now a reality, and in fact, human activity does not allow it to be considered a virgin habitat for the biota inhabiting it.

Despite a long history of bird records at Oasis (Ryan 2024), many aspects of bird life remain unclear due to insufficient research. One of the relevant aspects is the study of the diet and feeding behaviour of the South Polar Skua (*Stercorarius maccormicki*) (hereinafter SPS), an avian predator and food generalist. They breed on the periphery of Antarctica (Higgins & Davies 1996, Ritz *et al.* 2008). In the interior mountainous regions of the continent, there are small colonies of this species (Furness *et al.* 2020).

SPS is a migratory species, a seasonal resident, whose reproduction occurs throughout the land of the Oasis. Nests are located in lake basins or at some distance from them. There are 1–2 eggs in a clutch. The distance between the nearest nests varies from several hundred meters to several kilometres (data of the authors). The total size of the breeding population varies from a few pairs to more than 10 pairs (Pande *et al.* 2020).

SPS arrive at their breeding grounds in October (Richter & Bormann 1995, Venkataraman 1998, Chupin 2001, Voevodin 2002, Venkataraman & Hazra 2005, Pande *et al.* 2020) and leave the Oasis in March–April (Chupin 2001, Voevodin 2002, Chupin 2019, Pande *et al.* 2020). Thus, they spend about half of their annual cycle at sea and the other half at their breeding grounds on land. The foraging habitats and foraging behaviour of SPS have not been sufficiently studied. In search of food, they explore the entire territory of the Oasis and its environments and visit Antarctic stations and bases (observations by the authors). The main foraging strategy of SPS is predation, and the dominant prey items are petrels. During

the historical period, SPS also received food waste mainly from the Antarctic stations Novolazarevskaya, George Forster and Maitri (Venkataraman 1998, Venkataraman & Hazra 2005, Surwade 2006–2007, Pande *et al.* 2020), where scavenging was the food procurement strategy.

In the Oasis, SPS predation affects breeding and visiting seabirds (Chandra 2007, Chupin 2019, Pande *et al.* 2020). However, the decline in SPS prey such as Snow Petrels (*Pagodroma nivea*) and Wilson's Storm Petrels (*Oceanites oceanicus*) may affect SPS breeding success (Venkataraman 1998, Venkataraman & Hazra 2005). On the shores of the Oasis lakes, where SPS nests are located and which are exposed to the influence of Antarctic stations and tourist camps, a slight increase in the trophicity of water bodies was recorded (Smirnova *et al.* 2020), which is also important to study from a hydrobiological point of view.

Opportunistic observations of SPS diet at Oasis have been published sporadically (Mathew 1986, Chaturvedi & Tripathi 1999, Chandra 2007). Detailed studies and analyses of diet and feeding behaviour data of breeding SPS on a population-wide scale have not been undertaken. Furthermore, previous efforts to study SPS diet have been inconclusive in assessing the extent of dietary diversity, the importance of certain prey categories in SPS diets, and the influence of available food scraps on dietary variation in the local breeding population. Our study is a continuation of SPS population monitoring at this Antarctic land mass, with some emphasis on examining SPS diets in relation to distances from different Antarctic stations and bases (Bhatnagar 1999, Ryan 2024).

The aim of this study was to answer the question related to the diet composition of the SPS breeding population at the Oasis and how it has changed in the face of increasing human activity. Objectives: (1) to determine the size of the SPS breeding population in the 2024/2025 breeding season; (2) to establish the survival rate of SPS chicks during the study period; (3) to identify the diet of SPS breeding pairs in the current and past breeding seasons; (4) to compile data from the 2024/2025 season and historical information (1960–2023); (5) to identify feeding strategies that ensure SPS survival.

## Material and Methods

### Study area

The Oasis is located on the edge of the Antarctic continent, on land free of continuous snow and ice cover (Princess Astrid coast of central Dronning Maud Land, 70°44' – 70°46' S, 11°26' – 11°49' E). It is separated from the Lazarev Sea by an ice shelf. The Oasis is below the continental ice but above the shelf ice. It is a low hillock about 17 km long and 3 km wide, with a maximum height of 228 m above sea level and an area of about 34 km<sup>2</sup>. There are up to 180 lakes in the Oasis, ranging in depth from 3 to 120 m; according to other estimates, there are more than 200 stagnant and running bodies of water there. The climate of the area is predominantly continental. The average annual air temperature is about -10 °C, the average annual precipitation is 250–300 mm. In summer, the surface of the rocks can heat up to 26 °C, the temperature of the ground layer of air rises to 5 °C. The relative

humidity of the air, on average throughout the year, does not exceed 52% (Fritzsche & Bormann 1995, Aleksandrov 2014, Smirnova *et al.* 2020).

The flora of the Oasis around the Novolazarevskaya Station is the richest in continental Antarctica. It includes 75 species of lichens and 13 species of mosses (Andreev & Kurbatova 2019). In the water bodies of the Oasis, 309 species and intraspecific taxa of algae were recorded: 179 species and intraspecific taxa of cyanoprokaryotes (Cyanophyta/Cyanobacteria/Cyanoprokaryota), 64 species of diatoms (Bacillariophyta), 46 species of green algae (Chlorophyta), 11 species and 3 intraspecific taxa of desmid algae (Charophyta, Zygnematophyceae, Desmidiales), 4 species of yellow-green algae (Ochrophyta, Xanthophyceae) and 1 species each of dinophytes (Dinoflagellata) and golden algae (Ochrophyta, Chrysophyceae) (Smirnova *et al.* 2020).

There are no marine mammals in the Oasis (Richter 1995) and no fish. Birds are represented by 7 species: the Adélie Penguin (*Pygoscelis adeliae*), the Southern Fulmar (*Fulmarus glacialoides*), the Snow Petrel and Antarctic Petrel (*Thalassoica antarctica*), the Wilson's Storm Petrel, the South Polar Skua and the Kelp Gull (*Larus dominicanus*). Five bird species occur annually in the Oasis and four species have been recorded breeding. The Southern Fulmar and Kelp Gull are classified as vagrants (Gerbovich 1963, Artem'ev 1964, Richter 1995, Pande *et al.* 2020, Ryan 2024). To study the impact of climate change on glaciers, as well as to study algae, mosses, cyanobacteria and lichens, Antarctic Specially Protected Area №163 Dakshin Gangotri Glacier was established on an area of 4.53 km<sup>2</sup>.

## Field work

The field survey was conducted from 5 December 2024 to 10 January 2025. The Oasis was divided into three equal areas: eastern, central and western. The main bases of our research were located at the Russian Antarctic Novolazarevskaya Station (eastern area), the Indian Antarctic Maitri Station (central area) and a temporary field camp (western area).



Figure 1. Images of some active nests of South Polar Skuas found during the 2024/2025 season at Oasis: A – adult bird on the nest, Lake Glubokoe; B – clutch of eggs in the nest on the shore of the lake in the north-central part of the Oasis; C – downy chick in the vicinity of the nest near the lake to the south-east of Lake Zub

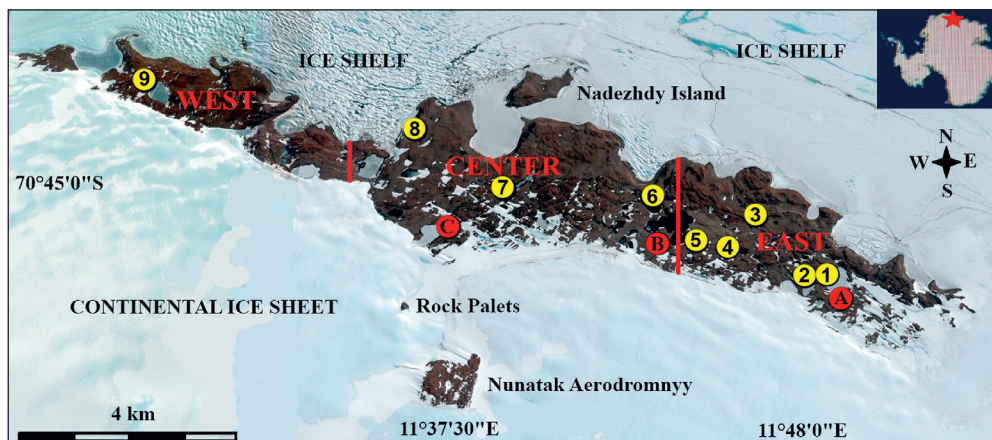
1. ábra Képek néhány aktív fészekről, amelyeket a 2024/2025-ös szezonban találtak az Oasis területén: A – öreg madár a fészken, Glubokoe-tó; B – tojásos fészek a tó partján, az Oasis északi-középső részén; C – pelyhes fióka a fészek mellett a Zub-tótól délkeletre fekvő tó közelében

The size of the breeding SPS population in the Oasis during the 2024/2025 breeding season was estimated by searching for active nests or territorial pairs. A nest was classified as active if (1) there were one or two adults on the nest, (2) there was a clutch of eggs or chick(s) in the nest (*Figure 1*). A nest was considered abandoned during the incubation stage if the eggs in the nest disappeared along with the breeding adults.

We explored the entire land area of the Oasis on foot in varying detail, with the greatest survey in the eastern part. In addition to the 2024/2025 season, one of the authors (I. I. Chupin) briefly visited Novolazarevskaya Station during the 2001 and 2019 seasonal work to collect some ornithological material on the state of the local avifauna and the impact of Antarctic stations on birds. We partially used the data from surveys of polar explorers from these studies.

Outside the Antarctic stations, our focus was on surveying the shores of all the large lakes of the Oasis and smaller lakes where SPS had historically nested. Eleven main routes were completed, ranging in length from 5 to 27 km. The total length of the routes was 123.5 km. Among them were the nunatak Aerodromny/Vetehia Hills, the Rock (nunatak) Palets, and three small unnamed islets north of Nadezhdy Island/Lanka (*Figure 2*).

The survival of chicks in the SPS population was established by continuous monitoring of six active SPS nests (nests №1–№6), located mainly to the east of the Oasis. Nests №7–№9, located in the centre and west of the Oasis, were not monitored further. The timing



*Figure 2.* Spatial distribution of active nests of South Polar Skuas (yellow circles with numbers) at Oasis during the 2024/2025 breeding season: nest №1 – Lake Glubokoe; nest №2 – Lake Pomornik; nest №3 – Lake Chernoe; nest №4 – Lake Melkoe; nest №5 – lake to the southeast of Lake Zub; nest №6 – lake to the northwest of Lake Zub; nest №7 – Lake Dlinnoe; nest №8 – lake in the north-central part of the Oasis; nest №9 – Lake Zapadnoe. A – the Novolazarevskaya Station, B – the Maitri Station, C – the White Desert Antarctic Camps. The vertical red lines show the conditional boundaries of the three main sites of the Oasis

2. ábra A délsarki halfarkasok aktív fészkeinek (sárga körök számokkal) területi eloszlása az Oasis területén a 2024/2025-ös költési szezonban. Fészkek: 1. számú: – Glubokoe-tó; 2. számú: – Pomornik-tó; 3. számú: – Chernoe-tó; 4. számú: – Melkoe-tó; 5. számú: – a Zub-tótól délkeletre fekvő tó; 6. számú: – a Zub-tótól északnyugatra fekvő tó; 7. számú: – Dlinnoe-tó; 8. számú: – az Oasis északi-középső részén lévő tó; 9. számú: – Zapadnoe-tó. A – a Novolazarevskaja állomás, B – a Maitri állomás, C – a White Desert antarktisi táborai. A függőleges piros vonalak az Oasis három fő helyszínének feltételes határait mutatják

of establishing the survival rate of chicks in the SPS population corresponded to the stage of incubation of eggs, hatching of chicks and their subsequent growth. The final breeding success in the SPS population is not indicated in this work. It was limited by the timing of our fieldwork.

Food samples of SPS prey were collected only at sites of their concentrations in the Oasis – on SPS-defended breeding territories (n=8) and on SPS-undefended old breeding territories (n=2), i. e. breeding sites used for breeding until the 2024/2025 season. The old nesting territories were distant from each other. One was located in the eastern sector of the Oasis, the other in the western. The eastern old nesting territory was located 50 meters from nest №4 on Lake Melkoe. The western old nesting territory was located at some distance from nest №9 on Lake Zapadnoe.

Food samples included regurgitated pellets and prey remains of SPS prey. Prey remains (wings, feet, skulls and other bones and body fragments of animals), which did not pass through the digestive tract of SPS, but were important for studying their diet, were analysed separately from regurgitated pellets. Each prey remains belonged to only one species of wild birds, introduced animals and marine fish, in contrast to pellets, which could contain inclusions of one or more animal species (*Figure 3*).

All nest sites included old (Ryan 2024) and/or very old bone remains of petrels (Venkataraman 1998, Venkataraman & Hazra 2005), and occasionally penguins and SPS. In addition, remains of recent SPS victims were found in, near and in the immediate vicinity of nests. Thus, food samples from SPS collected in their breeding territories consisted predominantly of samples from previous SPS breeding seasons and rare fresh samples from the current breeding season. The number of fresh samples was low and did not form a representative sample. Therefore, we combined them with food samples from previous seasons into a single sample.

The technique for collecting samples and processing them was carried out using the methodological guidelines of Voronetsky and Kuzmenko (2013). It included direct observations and collection of prey remains and pellets near nests. Outside the protected areas, food samples were usually visually recorded at a lower density but were not analysed. Pellets and prey remains were collected within a 10-metre radius from the centre of the active nest. The wings of petrels and SPS were collected within a 25-metre radius from the centre of the nest. In some cases, the radius of wing collection could be larger. In laboratory conditions, samples were measured with a calliper with an accuracy of 0.1 mm. Large fragments of samples were measured with a tape measure with an accuracy of 1 mm. The frequency of occurrence (FO) was calculated using the formula

$$FO = \left( \frac{f_i}{N} \right) \times 100$$

where  $f_i$  is the number of pellets with item  $i$  and  $N$  is the total number of pellets (De Villa-Meza *et al.* 2002). Each pellet was crushed into small fractions after measurements to allow detailed identification of its contents. Bones, feathers, wings, feet, mummified carcasses, and eggshells of birds were identified to species level. Bones of local marine fish and squid beaks were not identified to species level. From 10 categories of SPS prey remains,



**Figure 3.** Feeding, prey remains and pellets of South Polar Skuas collected at Oasis during the 2024/2025 field season: A – eating by SPS Snow Petrel (*Pagodroma nivea*), vicinity of nest N°8; B – prey remains from a Snow Petrel, nest N°9; C – prey remains from an Antarctic Petrel, nest N°9; D – wings and skeleton of a juvenile SPS as evidence of cannibalism, nest N°3; E – SPS pellet from Adélie Penguin (*Pygoscelis adeliae*) feathers, nest N°4; F – fragment of the skeleton of the head of a non-native (introduced) fish near nest N°6; G – bone fragments of imported animals near nest N°2; H – ceramic fragment in an SPS pellet of Adélie Penguin feathers and food waste near nest N°8; I – green plastic in an SPS pellet near nest N°6

**3. ábra** A 2024/2025-ös terepi szezonban az Oasis területén gyűjtött, délsarki halfarkasoktól származó táplálék, zsákmánymaradványok és köpetek: A – délsarki halfarkas hóhojsza- (*Pagodroma nivea*) zsákmánya a 8. számú fészkek közelében; B – egy hóhojsza maradványai a 9. számú fészkek-ből; C – egy antarktisi hojsza zsákmánymaradványai a 9. számú fészkek-ből; D – egy fiatal délsarki halfarkas szárnya és csontváza a kannibalizmus bizonyítékaként a 3. számú fészkek-ből; E – Adélie-pingvin (*Pygoscelis adeliae*) tollából álló köpet a 4. számú fészkek-ből; F – egy nem őshonos (behurcolt) hal koponyájának töredéke a 6. számú fészkek közelében; G – behurcolt állatok csonttöredékei a 2. számú fészkek közelében; H – kerámiatöredék egy Adélie-pingvin tollából és táplálékmaradványokból álló köpetben a 8. számú fészkek közelében; I – zöld műanyag egy délsarkihalfarkas-köpetben a 6. számú fészkek közelében

we measured Snow Petrel wings and skulls or skull fragments with or without cervical vertebrae, i. e. skulls as body fragments of Snow and Antarctic Petrels. To identify Snow Petrel morphs hunted by SPS within the Oasis, we collected only fresh petrel wings and measured their length as an important diagnostic parameter. All SPS food samples after laboratory testing were subjected to thermal disposal in a high-temperature incinerator ИУ-300 at the Novolazarevskaya Station.

The compilation of historical data is based on the study of available information resources collected until the 2024/2025 breeding season. Based on this, we compiled a general list of prey categories and attempted to identify the foraging strategy for each prey category. Historical data on SPS diet in 1960–2023 were obtained from scientific literature and unpublished reports. Primary historical data without exact dating, i. e. before the 2024/2025 season and data from the 2024/2025 season were collected by us in SPS nesting areas. They contained 704 food samples – 298 pellets, 406 prey remains including bone fragments from Antarctic stations and tourist bases from imported animals and marine fish.

Nests, nesting territories, and encounters of adult SPS at a distance from breeding sites or individuals with unclear status were mapped using a GPS navigator. All digital images of adults on the nest, clutches, chicks, feeding, prey remains, and SPS pellets collected in the Oasis during the 2024/2025 field season were obtained by S. V. Golubev. We consider four feeding strategies characteristic of southern hemisphere skuas: predation, scavenging, cannibalism and kleptoparasitism (Reinhardt *et al.* 2000).

## Equipment

Binoculars, laptops, GPS navigators, mobile phones, radio communication devices were used in the field work. Computer programs MS Excel, SASPlanet, Adobe Photoshop CC were used for data storage, processing and visualization.

## Results and Discussion

### SPS population size

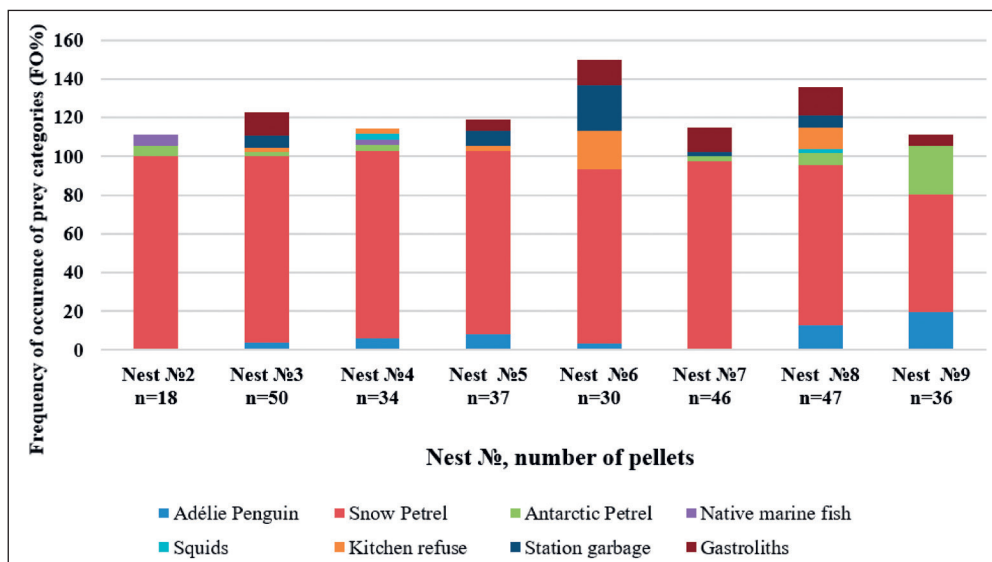
We found nine SPS active nests in the 2024/2025 breeding season. Nests were located on the shores of lakes and in their immediate vicinity inside the Oasis. The number of nests increased from west to east. In the western sector of the Oasis, one nest was found, in the central sector three nests, and in the eastern sector five nests (*Table 1, Figure 2*). The distance from the nest to the nearest Antarctic station or tourist base varied from 470 m to 7,000 m, on average 1,871 m (n=9). The affinity of SPS towards human settlements in the Oasis is confirmed by the spatial distribution of their nests, i. e. an increase in the number of active nests from west to east against the background of an increase in human activity in this direction.

From 3–5 to 11 pairs of SPS have bred at the Oasis each year (e. g. Pande *et al.* 2020, Ryan 2024). Our actual estimates of nine breeding pairs for the 2024/2025 season are close to the upper limit of the historical total SPS breeding population size. Early estimates of

*Table 1.* Spatial distribution parameters of active nests of South Polar Skuas in the Oasis in the 2024/2025 breeding season, considering the distances to the nearest Antarctic stations and bases. The nest numbering in *Table 1* corresponds to the nest numbering in *Figure 2* and the captions to it.

*1. táblázat* A délsarki halfarkas aktív fészkeinek térbeli eloszlási paramétereit az Oasis területén a 2024/2025-ös költési időszakban, figyelembe véve a legközelebbi antarktisi állomásoktól és bázisoktól mért távolságokat. A fészkek számozása megfelel a 2. ábrán szereplő számolásnak és a hozzá tartozó feliratoknak

Nest №	Coordinates	Date of discovery	Distance between the nest and the nearest station or base
1	70°46'216"S, 11°49'041"E	06.12.2024	470 m from the Novolazarevskaya Station
2	70°46'233"S, 11°48'376"E	06.12.2024	570 m from the Novolazarevskaya Station
3	70°45'452"S, 11°46'502"E	22.12.2024	2.2 km from the Novolazarevskaya Station and 1.9 km from the Maitri Station
4	70°46'028"S, 11°46'128"E	10.12.2024	2.2 km from the Novolazarevskaya Station and 1.4 km from the Maitri Station
5	70°46'011"S, 11°45'051"E	19.12.2024	700 m from the Maitri Station
6	70°45'345"S, 11°43'381"E	22.12.2024	800 m from the Maitri Station
7	70°45'293"S, 11°38'499"E	18.12.2024	1.2 km from the White Desert Antarctic Camp
8	70°44'542"S, 11°36'066"E	14.12.2024	2.8 km from the White Desert Antarctic Camp
9	70°44'190"S, 11°27'086"E	13.12.2024	7 km from the White Desert Antarctic Camp



*Figure 4.* Frequency of occurrence of prey categories (FO%) in pellet samples from eight breeding territories of South Polar Skuas, based on data from past seasons and the 2024/2025 season combined

*4. ábra* A szakmánykategóriák előfordulási gyakorisága (FO%) a délsarki halfarkasok nyolc fészkelőhelyéről származó köpetmintákban, az előző szezonok adatai és a 2024/2025-ös terepi szezon adatai alapján

**Table 2.** Survival of chicks in the population of South Polar Skuas in Oasis on 10 January 2025. The nest numbers in *Table 2* correspond to the nest numbers in *Figure 2* and the legends to it.  
**2. táblázat** Az Oasis területén fészkelő délsarki halfarkas fiókák túlélése 2025. január 10-én. A 2. táblázatban szereplő fészkek számozása megfelel a 2. ábrán szereplő fészekszámozással és a hozzá tartozó ábraaláírással

Nest №	Date of nest discovery	Number of eggs/chicks in the nest	Date of last nest visit	Number of eggs/chicks in the nest	Survival rate of chicks, %
1	06.12.2024	2 eggs	16.12.2024	the eggs are gone	0
2	06.12.2024	2 eggs	10.01.2025	1 chick	50
3	22.12.2024	1 egg, 1 chick	10.01.2025	1 chick	50
4	10.12.2024	2 eggs	10.01.2025	1 chick	50
5	19.12.2024	1 chick	10.01.2025	1 chick	100
6	22.12.2024	1 egg, 1 chick	10.01.2025	1 chick	100
7	18.12.2024	1 egg	–	?	?
8	14.12.2024	2 eggs	–	?	?
9	13.12.2024	2 eggs	–	?	?

the SPS breeding population size ( $\leq 11$  breeding pairs) in the Oasis, dating back to the 1970s and 1980s (Pande *et al.* 2020), could already bear the imprint of the influence of imported food on the diet and habits of SPS. Most likely, the natural size of the SPS population was lower than historical values.

### Survival rate of SPS chicks

The results of the study showed that the breeding success of SPS in the early postembryonic period is low in the 2024/2025 breeding season. The survival rate of chicks by the end of the first 10 days of January (*Table 2*) was 0.83 chicks per breeding pair. This could be due to weather conditions during the current breeding season, but is more likely due to a decrease in the abundance of available food. In the 2000/2001 breeding season, three monitored nests at Oasis contained two eggs per clutch, but subsequently (date not given) one fledged flightless chick was found near each nest, where

**Table 3.** Quantitative distribution of pellets and prey remains across surveyed nests/ nesting territories of South Polar Skuas in the Oasis. Food samples from the SPS 2024/2025 breeding season are shown in parentheses, and those from previous breeding seasons are shown without parentheses

**3. táblázat** A köpetek és zsákmánymaradványok mennyiségi eloszlása az Oasis területén lévő délsarki halfarkasok vizsgált fészkeiben/fészkelőhelyein. A 2024/2025-ös költési szezonból származó táplálékminták zárójelben, a korábbi szaporodási szezonokból származó minták zárójel nélkül szerepelnek

Nest №	Pellets	Prey remains	$\Sigma$
1	0	0	0
2	14(4)	39(21)	53(25)
3	38(12)	48(7)	86(19)
4	34	43(3)	77(3)
5	35(2)	60(1)	95(3)
6	30	27(7)	57(7)
7	46	54(8)	100(8)
8	46(1)	13(21)	59(22)
9	32(4)	48(6)	80(10)
$\Sigma$	275(23)	332(74)	607(97)

the survival rate was one chick per breeding pair (Chupin 2001). In the 2001/2002 breeding season, the four nests containing relevant information contained a total of seven eggs, and by 10 January six chicks had survived, i. e. 1.5 chicks per breeding pair (Voevodin 2002, authors' calculations).

### Compilation of data from the 2024/2025 field season

Sample sizes from the studied active SPS nests are presented in *Table 3*. A total of 42 food samples (32 pellets and 10 prey remains) were collected from the old nesting territories (*Table 4*). In general, old nesting territories, as places of concentration of SPS prey remains, were not a common phenomenon in the feeding territories of SPS. Fresh pellets and prey remains of SPS in old nesting territories indicate that SPS occasionally use them to cut up and consume prey.

A data compilation based on the analysis of SPS pellet contents is presented in *Figure 4*. It includes data from the 2024/2025 season combined with data from previous breeding seasons. The histogram shows the contribution of a specific prey category to the overall spectrum of identified prey categories for each active nest studied as frequency of occurrence (%).

A similar data visualization is presented in the histogram in *Figure 5* from two old SPS breeding territories. The pellet sizes (mm) from active SPS nests (mean±SD (min–max), n=295) were 67.2±21.5 (23–203) × 28.8±8.6 (15–84). The pellet sizes (mm) from old SPS breeding territories (n=32) were 74.5±27.7 (40–156) × 27.7±7 (17–43). Ten categories of prey remains were found in the breeding territories and the eastern old breeding territory of SPS. The results of prey collection and analysis are presented in *Table 5*.

### Compilation of historical data (1960-2023) on the diet of the SPS breeding population

Two foraging strategies were identified: predation and scavenging. In some cases, the foraging strategy of some prey categories was not identified. The results of the data compilation and foraging strategy identification are presented in *Table 6*. The compilation of SPS prey categories derived from historical and our recent data is currently the most comprehensive study of the qualitative composition of their diet at Oasis. The results of this research effort are presented in *Table 7*.

*Table 4.* Quantitative distribution of pellets and prey remains across surveyed old breeding territories of South Polar Skuas in the 2024/2025 field season in Oasis. Note: EONT – eastern old breeding territory; WONT – western old breeding territory. Numbers in parentheses indicate SPS food samples belonging to the 2024/2025 breeding season, numbers without parentheses – previous breeding seasons

*4. táblázat* A köpetek és zsákmánymaradványok mennyiségi eloszlása a délsarki halfarkasok régi költőterületein a 2024/2025-ös terepi szezonban az Oasis területén. Megjegyzés: EONT – régi keleti költőterület; WONT – régi nyugati költőterület. A zárójelben lévő számok a 2024/2025-ös szaporodási időszakhoz tartozó táplálékmintákat jelzik, a zárójel nélküli számok a korábbi szaporodási időszakokét

Old nesting territories	Pellets	Prey remains	Total
EONT	18(1)	9(1)	27(2)
WONT	9(4)	0	9(4)
Total	27(5)	9(1)	36(6)

Table 5. Distribution and sample size of prey remains in 8 breeding territories and the eastern old breeding territory of South Polar Skuas in the 2024/2025 breeding season

5. táblázat A zsákmánymaradványok eloszlása és mintanagysága a délsarki halfarkasok nyolc költőterületén és a régi keleti költőterületen a 2024/2025-ös költési időszakban

Nest № and name of old nesting territory	Nest №2	Nest №3	Nest №4	Nest №5	Nest №6	Nest №7	Nest №8	Nest №9	Eastern old breeding territory
Name of prey remains/ number of samples in the sample	n=60	n=55	n=46	n=61	n=34	n=62	n=34	n=53	n=7
Snow Petrel skull		+	+	+	+	+	+	+	+
Antarctic Petrel skull	+	+	+	+	+	+		+	
Snow Petrel wing/wings	+	+				+	+	+	
Antarctic Petrel wing/wings	+					+	+	+	
South Polar Skua wing/wings							+		
Adélie Penguin leg								+	
Snow Petrel's leg		+	+	+	+	+	+	+	
Antarctic Petrel leg		+		+		+		+	+
South Polar Skua leg		+		+	+	+			
Bone remains of imported animals	+	+	+			+	+		+

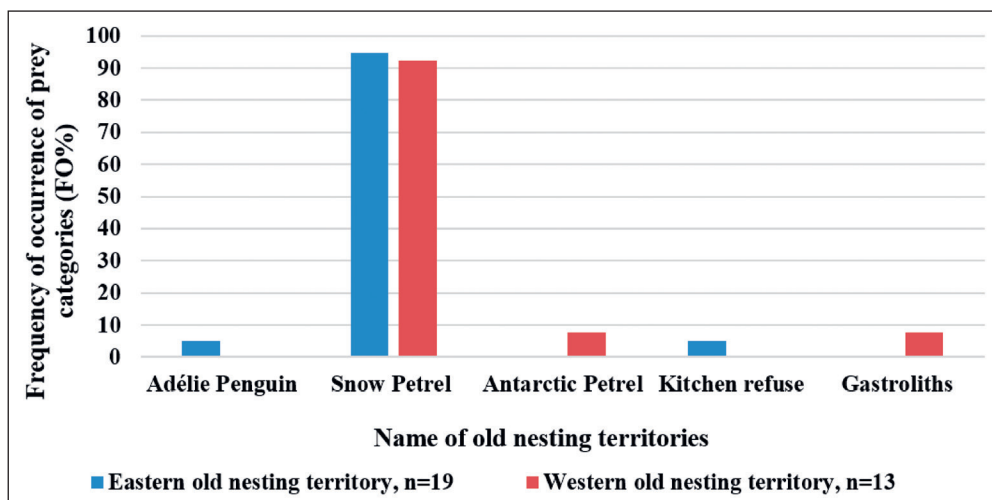


Figure 5. Frequency of occurrence of prey categories (FO%) in pellet samples from two old breeding territories of South Polar Skuas, based on data from previous seasons and the 2024/2025 field season combined

5. ábra A zsákmánykategóriák előfordulási gyakorisága (FO%) a délsarki halfarkasok két régi fészkelőhelyéről származó köpetmintákban, az előző szezonok adatai és a 2024/2025-ös terepi szezon adatai alapján

Table 6. Identification of feeding strategies and compilation of historical (published and unpublished reports) dietary qualitative data for South Polar Skuas from Oasis, 1960–2023

6. táblázat A táplálkozási stratégiák azonosítása és a történeti táplálékminék minőségi összetétele az Oasis területéről származó délsarki halfarkasok adatai alapján 1960 és 2023 között

Name of species/ category of prey	Feeding strategy	References
<b>BIRDS</b>		
<i>Pygoscelis adeliae</i>		
Adults	?,P,S	Chaturvedi & Tripathi 1999, Voevodin 2002, Chupin 2019
<i>Thalassoica antarctica</i>		
Adults	?,P	Richter 1995, Voevodin 2002, Chupin 2019
<i>Pagodroma nivea</i>		
Adults	?,P	Mathew 1986, Richter 1995, Voevodin 2002, Chandra 2007, Chupin 2019, Pande <i>et al.</i> 2020, Ryan 2024
<i>Oceanites oceanicus</i>		
Adults	?,P	Mathew 1986, Richter 1995, Chupin 2001, 2019
<i>Stercorarius maccormicki</i>		
Adults	?	Richter 1995
Chicks	?	Mathew 1986
Eggs	?	Richter 1995
Faeces	S	Surwade 2006–2007
<b>Anthropogenic items</b>		
Station garbage	S	Venkataraman 1998, Venkataraman & Hazra 2005
Kitchen refuse	S	Venkataraman 1998, Voevodin 2002, Venkataraman & Hazra 2005, Surwade 2006–2007, Chandra 2007, Chupin 2019

**Legend:** P – predation; S – scavenging; ? – feeding strategy is not clear

### Compilation of historical information (1960–2023) and identification of the diet of each specific breeding pair of SPS in the 2024/2025 season

The results of the studies have established the important role of Snow and Antarctic Petrels in the diet of SPS during the historical period (Mathew 1986, Richter 1995, Voevodin 2002, Chandra 2007, Chupin 2019, Pande *et al.* 2020, Ryan 2024). Snow Petrels are the main, most abundant prey species of SPS. Antarctic Petrels, together with Adélie Penguins, occupy a subdominant position in the diet with a significantly lower abundance in food samples.

Adélie Penguins have visited the Oasis throughout history and have occasionally made unsuccessful breeding attempts (e. g. Gerbovich 1963, Artem'ev 1964, Chaturvedi & Tripathi 1999, Pande *et al.* 2020, Ryan 2024, authors' observations). In contrast, some penguins have not attempted to breed there.

In April 2019, the Adélie Penguin accounted for 4.5% of the prey remains at one of the SPS nests (Chupin 2019). In the 2024/2025 field season, the average frequency of Adélie Penguin inclusions in SPS pellets was 8.8%. In nests remote from human settlements, it increased significantly.

Table 7. General list of qualitative diet composition of the South Polar Skuas population at Oasis (1960–2024), based on historical data (published and unpublished reports) and food sampling data from the 2024/2025 season by the authors of this article

7. táblázat Az Oasis területén élő délsarki halfarkas populáció táplálékösszetételének általános listája (1960–2024) történelmi adatok (publikált és nem publikált jelentések) és a 2024/2025-ös szezonban a jelen cikk szerzői által végzett táplálékminavétel adatai alapján

Prey categories /Data	Historical data, 1960–2023	Authors' collection, season 2024/2025	
	Published data and unpublished reports	Food samples until the 2024/2025 season	Food samples, season 2024/2025
<b>Birds</b>			
<i>Pygoscelis adeliae</i>			
Adults	+	+	+
<i>Thalassoica antarctica</i>			
Adults	+	+	+
<i>Pagodroma nivea</i>			
Adults	+	+	+
<i>Oceanites oceanicus</i>			
Adults	+	–	–
<i>Stercorarius maccormicki</i>			
Adults	+	+	+
Chicks	+	–	–
Eggs	+	–	–
Faeces	+	–	–
<b>Fish</b>			
Local marine fish	–	+	–
<b>Invertebrates</b>			
Squid	–	+	–
<b>Minerals</b>			
Stones and pebbles	–	+	+
<b>Anthropogenic items</b>			
Station garbage	+	+	+
Kitchen refuse	+	+	+

**Legend:** “+” – presence of prey categories in the sample; “–” – absence of prey categories in the sample. Historical data 1960–2023 are based on the sources of information in Table 6.

Adélie Penguins served as food for SPS throughout the entire historical period. The importance of this category of prey varies greatly between the nests studied. It increased with distance from the centre of the Oasis to the periphery of the western sector and generally decreased from the centre of the Oasis to the east, where anthropogenic influence on the island land increased.

Snow Petrels bred in the Oasis in the 1959/1960 season (Konovalov 1962b). Their breeding subsequently ceased and was not confirmed (Bhatnagar 1999, Chupin 2001, Voevodin 2002, Pande *et al.* 2020). Although there is an opinion about possible modern breeding of Snow Petrels in the Oasis in small numbers (Chupin 2019). In fact, after 1960, SPS predated on transient Snow Petrels, which bred outside the Oasis if they did. This is supported by historical evidence and our data from the 2024/2025 field season.

Throughout the historical period, Snow Petrel remains have been consistently recorded near SPS nests and their vicinity (Mathew 1986, Bhatnagar 1999, Survade 2006–2007). They were the main component of SPS chicks' food (Chandra 2007). In the second half of the 20<sup>th</sup> century, Snow Petrels accounted for more than 95% of SPS prey in summer (Richter 1995). At the beginning of the 21<sup>st</sup> century, Snow Petrels were also the main prey of SPS (Ryan 2024). For example, in April 2019, skulls and wings of Snow Petrels were found at two SPS nesting sites; at one nest, they accounted for 74% of the prey remains (Chupin 2019).

The results of the 2024/2025 field season demonstrate the absolute dominance of Snow Petrels in SPS prey. Snow Petrel inclusions in SPS pellets were found in all nests surveyed and in pellets from both old breeding territories. The frequency of Snow Petrel inclusions in pellet samples from all SPS breeding territories, based on data from past seasons and the 2024/2025 season combined, averaged 89.9%, and 93.5% from the two old breeding territories. Prey remains (skulls, wings and feet of Snow Petrels) were found in all breeding territories surveyed and in the eastern old breeding territory.

It has recently been established that the wings of living Snow Petrels are much longer than those of mummies or isolated wings (Rümmeler *et al.* 2024). All the wings of the SPS prey that we measured did not belong to living Snow Petrels. The duration of existence of isolated wings hardly exceeded 1.5–2 months. In recent SPS prey, the wing length (mm) of Snow Petrels was (n=46):  $244.5 \pm 19.7$  (194–273). The results of measurements did not exceed the lower threshold of wing length of 280 mm, which corresponds to the large morph (*P. n. major*) of Snow Petrels. The results of the morphometric analysis of the Snow Petrel wings did not indicate belonging to the large morph. Therefore, the Oasis and its surroundings are visited by Snow Petrels belonging to the small morph (*P. n. minor*). However, in this regard, we cannot deny the mixed breeding of Snow Petrel morphs on Lake Untersee, which was previously assumed (Rümmeler *et al.* 2024). The range of extreme values of Snow Petrel wing lengths that we measured was 79 mm, which could also be explained by the fact that SPS prey belonged to different geographical populations, different age classes, or the duration of existence of isolated wings after killing the prey. However, these hypotheses require further testing. The sizes of the skulls as body fragments of Snow Petrels (mm) were (n=133):  $60.2 \pm 13.1$  (24–92)  $\times$   $27.1 \pm 3$  (10–46). Antarctic Petrels have not been recorded breeding at the Oasis during the historical period (Ryan 2024). Therefore, only transient adults were targeted by SPS. In the second half of the 20<sup>th</sup> century, SPS rarely fed on Antarctic Petrels in summer (Richter 1995). In the early 21<sup>st</sup> century, various types of Antarctic Petrel bones were found in SPS nests along with bones of other Antarctic bird species (Survade 2006–2007). In April 2019, Antarctic Petrel skulls and wings were found at two SPS nesting sites, accounting for 10% of SPS prey remains at one nest (Chupin 2019).

The results of the 2024/2025 field season showed that inclusions of Antarctic Petrels in SPS pellets were found in six of the eight nesting territories studied. The frequency of occurrence of inclusions of Antarctic Petrels in pellets from different nests averaged 7.3%. In the nests most remote from human settlements it increased significantly. Remains of the prey of these petrels (skulls, wings and paws) were found in all studied nesting territories of SPS and in the eastern old nesting territory.

Thus, Antarctic Petrels served as food for SPS throughout the entire historical period. The importance of this prey category varies greatly between the nests studied. It increases with distance from the centre of the Oasis to the periphery and from human settlements in its western sector (*Figure 6*). The sizes of the skulls as body fragments of Antarctic Petrels (mm) were ( $n=48$ ):  $84.3 \pm 15.3$  (44–99)  $\times$   $32.9 \pm 2.2$  (28–39).

Wilson's Storm Petrels were probably rare in SPS food samples in the past, based on historical publications (Mathew 1986, Richter 1995, Chupin 2001, 2019). In April 2019, Wilson's Storm Petrel fragments were found at two SPS breeding sites, and in one of the examined nests, they occupied 7% of SPS prey remains (Chupin 2019). The prey remains and pellets analysis data from eight SPS breeding sites in the 2024/2025 season, together with the data from previous breeding seasons that we collected, did not contain Wilson's Storm Petrels. Inclusions were also absent from pellets from two old SPS breeding territories. Thus, Wilson's Storm Petrels, like other petrel species, have been found in SPS prey throughout the historical period, but very rarely and in small numbers. Depending on the abundance of SPS prey, Wilson's Storm Petrels were not a constant component of the SPS diet, varying from season to season. The lack of detail in the observations does not allow us to confidently judge the age of the birds taken and the feeding strategies used by SPS when hunting Wilson's Storm Petrels.

Among the three species of petrels, only fledged individuals fell victim to SPS, since in the local natural conditions of the Oasis SPS do not have the habit of extracting petrel eggs and chicks from nesting crevices in rocks and feeding on them for a long time. In addition, SPS breed openly, and if necessary, they use both adult birds and chicks and eggs of their own species as food (Mathew 1986, Richter 1995, our data). Moreover, we observed cases ( $n=4$ ) when adult SPS refused to consume their own recently dead downy chicks ( $n=1$ ) or downy chicks of Adélie Penguins in abandoned nests ( $n=1$ ) and from recently dead adult Adélie Penguins ( $n=2$ ). A fact has also been established when SPS ignored feeding on a dead chick and an egg in a nest abandoned by Adélie Penguins (Voevodin 2002). There is an observation when SPS abandoned a clutch of 2 eggs, which were subsequently covered with snow, but did not use the eggs for food, although they were near the nest (Voevodin 2002). Such behaviour may indicate individual food habits of some individuals or pairs that avoid cannibalism, and the degree of their physiological satiety. We found chicken eggshells in only 6 pellets out of 330 pellets examined, but no eggshells of local breeding bird species were found in the pellets. In fact, eggs and chicks were rarely used for food by the breeding SPS population.

SPS breeding on the Antarctic coast and islands are also known to occasionally consume seal excrement (authors' observations). SPS use of their own excrement as food in the Oasis (Surwade 2006–2007) is likely to be an exceptionally rare phenomenon not only for this area but also for SPS breeding populations elsewhere around Antarctica and adjacent islands.

Native marine fish and squid were not mentioned in historical documents. Bones of local marine fish were found in pellets (n=2) in two SPS nesting territories. They were present in 0.61% of the pellets from the total number of pellets examined. A similar picture was established for squid beaks in pellets (n=2), also from two SPS nesting territories.

Bones of native marine fish and squid beaks found in SPS pellets containing Snow Petrels and Adélie Penguins may have originated from their stomachs. The exceptional rarity of native marine fish bones and squid beaks in the pellets we examined indicates that the SPS do not feed at sea during the breeding season, relying on food resources obtained inside the Oasis. In contrast, bone fragments of fish introduced from stations and bases were much more common in SPS food samples (*Figure 3F*).

Gastroliths (stone and gravel fragments) were not mentioned in historical documents. We found gastroliths in pellets from nests of the current and previous breeding seasons, as well as in pellets from one of the two old nesting territories. Gastroliths were contained in 8.48% of pellets (n=28) of the total number of pellets examined. This ratio of gastroliths content is apparently sufficient for the utilization of victims by SPS, which abundantly use the flesh of Snow Petrels as food. The largest stones could have been captured accidentally together with food. Dimensions (mm) of the largest stones (average (min-max), n=15): 12.9 (6–25) × 8 (3–16).

Anthropogenic items included bones and feathers of introduced animals, chicken eggshells, and fruits of agricultural plants. In the 2024/2025 season, they were found in 19 pellets (frequency of occurrence 5.76%) out of 330 examined. Waste was contained in pellets from 5 active nests out of 8 examined nests and in 1 of 19 pellets (frequency of occurrence 5.26%) from the eastern old nesting territory. The frequency of occurrence of food waste in pellets from 5 nests averaged 9.6%. Bone fragments of introduced animals were common. Plant components were rarely found among anthropogenic food inclusions (e. g. nut shells, watermelon seeds). Natural vegetation was not found in food samples. Most breeding SPS used food waste.

Station garbage and food waste were present in the SPS diet, apparently, throughout the entire historical period (*Table 7*). There are records of feeding of large numbers of SPS at Novolazarevskaya, George Forster, Maitri stations (Venkataraman 1998, Chupin 2001, 2019, Voevodin 2002, Venkataraman & Hazra 2005, Surwade 2006–2007, Chandra 2007) and near them (Richter 1995, Chupin 2001). At the Novolazarevskaya Station in 2001, for example, up to 16 SPS fed (Voevodin 2002), in the 2000/2001 season at a garbage dump in the eastern part of the Oasis up to 14 individuals (Chupin 2001). In addition, SPS received food from seasonal research staff at a distance from the stations (Voevodin 2002). At least half (n=4) of the nesting territories in 2002 contained bones of introduced animals (Voevodin 2002). In 2019, they were also found near SPS nests, and in one of the nesting territories, remains of introduced animals accounted for 4.5% of the total amount of remains of SPS prey (Chupin 2019).

In fact, food scraps such as chicken, meat and fish (Venkataraman 1998, Venkataraman & Hazra 2005, Chandra 2007) from human activity sites in the Oasis are attracted only by SPS. Currently, access to food resources and feeding of SPS are not practiced at the Maitri Station. We have visited this station many times, now free of SPS. Only once did we observe

a solitary SPS that had not received food, sitting at the western entrance to the main building of the station. SPS were absent from the White Desert Antarctic Camps area visited by us on 14 December 2024. Surveys of active nests in the vicinity of these human settlements did not reveal fresh food scraps from introduced animals.

At the Novolazarevskaya Station, SPS access to food was stopped in the 2024/2025 season. In the 2024/2025 season, SPS visited the station daily, and the maximum number of individuals observed simultaneously during the day varied from 1 to 4. The station was primarily visited by birds that bred closest to it – on the shores of Glubokoe and Pomornik lakes. Sometimes SPS with unclear status were encountered.

Station litter included fragments of plastic, paper, and ceramics. The frequency of occurrence of station debris in pellets from different nests averaged 9.1%. The most common type of station litter present as inclusions in pellets was plastic. It was contained in 14 pellets (4.2% of the total number of pellets from all nests studied). The pellets included fragments of wrapping material (n=14), a piece of rubber rope (n=1), and of unknown purpose (n=1). The colour of the plastic in the pellets was green (n=8), black (n=4), white (n=2), or colourless (n=2). Paper was found in four pellets, accounting for 1.2% of the total number of pellets in all nests examined. A ceramic fragment was found in one of the pellets (0.3% of the total number of pellets in the nests examined).

Potentially, marine mammals (seals) could have been used as food by SPS in the historical past. Isolated, extremely rare cases of seal wandering have been repeatedly recorded in the Oasis. Mummies and carcasses of the crabeater seal (*Lobodon carcinophagus*) and the Weddell seal (*Leptonychotes weddelli*) have been found here (Bardin 1961, Der & Richter 1983, Richter 1995). However, direct evidence of the use of marine mammals in the diet of local SPS has not been obtained.

In general, it should be noted that in the Dronning Maud Land mountains, Snow Petrels are the main food resource in the prey of SPS (Løvenskiold 1960, Ryan & Watkins 1988, Steele & Cooper 2012). A distinctive feature of the diet of the Oasis SPS is the dominance of Snow Petrels in the diet, which over the course of the historical period ceased to be identified as breeding residents, becoming its visitors.

### **Identification of foraging strategies of the breeding SPS population**

Kleptoparasitism is not supported by research or historical records. The identification of the other three feeding strategies (predation, scavenging and cannibalism) was possible based on our observations.

SPS are capable of covering large distances to hunt Snow Petrels and Wilson's Storm Petrels (Chandra 2007). During the 2024/2025 breeding season, we did not observe foraging trips of SPS from the Oasis north to the sea and back. Our observations also did not confirm foraging flights of SPS in the southern direction. During the search flight, SPS were repeatedly observed (the number of registrations was not considered) flying along the Oasis. In one case, a SPS crossed the Oasis with a Snow Petrel in its bill from the southeast to the northwest in the direction of the nest. All the above convinces us that SPS searches for and obtains prey exclusively within the Oasis. The absence of relatively large

colonies of Adélie Penguins, Snow and Antarctic Petrels in the Oasis is a determining factor in the choice of food obtaining strategies by SPS and their combination, which ensures autonomous seasonal survival of adults and a certain number of chicks until the stage of full plumage and the beginning of autumn migrations.

The results of the pellet and prey remains of SPS studies, historical data and thematic video evidence of a SPS catching a Snow Petrel by pinning it to the ground (video fragment shown to us by a staff member of White Desert Antarctic Camps, 2023) convince us that the main foraging strategy of SPS in the Oasis was and remains predation. It is believed that high levels of SPS predation hinder successful nesting of Adélie Penguins in the Oasis (Pande *et al.* 2020). However, historical evidence and our studies did not find confirmation of this. Only weakened, dying penguins fall prey to SPS (Chaturvedi & Tripathi 1999), but this requires further verification.

Scavenging is a less common but effective supplementary food-obtaining strategy. It is useful to distinguish between scavenging on native and anthropogenic resources. The main source of available native carrion for SPS are Adélie Penguins visiting the Oasis and attempting to breed there (Chaturvedi & Tripathi 1999). However, as mentioned above, weakened Adélie Penguins can be utilized by SPS (Chaturvedi & Tripathi 1999), and sometimes in such cases it is difficult to draw a line between predation and scavenging. The annual volumes of native carrion utilization by SPS have not been determined. Undoubtedly, the role of scavenging increases if SPS depend more on imported food than on local, native food. According to the results of our study, breeding pairs of SPS demonstrated different dependence on food waste – from complete disregard for anthropogenic resources to a deep dependence on them. In the past, SPS, which feed largely on food waste, reduce the pressure of predation on native prey items and vice versa (*Figure 6*).

We did not record cannibalism by direct observations. However, given the low overall size of the breeding population of SPS and the level of their reproductive potential in the Oasis, we note that this strategy is undoubtedly used to a minimum extent by adult SPS for short-term replenishment of energy expenditure during a deficit of food resources. Thus, on several (the number was not considered) bodies of dead fledglings or partially fledged chicks that we examined, as well as on the carcasses of fully fledged young or adult SPS, ruptures of soft tissue on the abdomen and the absence of internal organs in the abdominal cavity were identified. We also repeatedly found carcasses of adult SPS completely cleared of flesh. In such cases, the wings with fragments of the SPS carcass were identical to those of Snow and Antarctic petrels (*Figure 3*), which indicated obvious cannibalism of SPS, since other avian predators were not recorded in the Oasis. No evidence was obtained during the 2024/2025 season of other avian predators, potential food competitors of SPS – Southern Giant Petrels (*Macronectes giganteus*) and Brown Skuas (*Stercorarius antarctica lonnbergi*). Historical evidence from Oasis supports SPS cannibalism (Mathew 1986). However, SPS remains at nests both historically (Surwade 2006–2007) and in the 2024/2025 season do not always prove cannibalism in individual breeding pairs. It is also unclear whether SPS kill their chicks or consume dead ones.

The increase in the SPS population at Oasis may have been due to the use of abundant food waste from the stations (Bhatnagar 1999). Past and current impacts of SPS affect petrels

and Adélie Penguins, but the magnitude of the impact overall requires further verification. The change in breeding status was primarily documented for Snow Petrels, the main prey of SPS. Increased predation pressure by SPS may explain the loss of a small number of potential preys, nesting Snow Petrels, at Oasis (Ryan 2024). The disappearance of the Snow Petrel as a breeding species at Oasis may be a result of increased SPS and subsequent nest predation (Chattopadhyay 1995, Bhatnagar 1999, Pande *et al.* 2020), where direct human intervention may have played a role (Ryan 2024). We believe that the balance between the top predator and its main prey was upset by the influx of food subsidies from humans. This could have led to the disappearance of Snow Petrels breeding in the Oasis and, as a consequence, to compensatory hunting of background prey by SPS already in the status of non-breeding transients. It should be noted that by the beginning of the 1959/1960 field season and the onset of human activity, Snow Petrels could breed in the Oasis in small numbers (Konovalov 1962a, Ryan 2024) and, apparently, gradually reduced breeding there.

The continued coexistence of humans and SPS in the Oasis should aim to achieve a prehistoric balance of interactions between avian predators and their prey by eliminating access to imported food resources from areas of human activity and strictly adhering to the requirements of the Madrid Protocol on the Protection of the Antarctic Environment.

Limitations of our study include that prey remains and pellets collected prior to the 2024/2025 season cannot be accurately dated to a specific past breeding season. At the same time, fresh samples from the 2024/2025 season were rare and not representative in the samples for each SPS nest studied. Therefore, we were forced not to separate all collected material into food samples from the 2024/2025 season and historical food samples, which could be several, ten or more years old since the 2023/2024 season. This research approach allowed us to confirm the presence of some already established prey categories and supplement the historical data with new prey categories not listed in known sources, thereby expanding the already established dietary spectrum of SPS in the Oasis.

The small size of the Oasis allows for monitoring to be carried out throughout its entire territory during one field season. However, in reality this does not always happen. In this paper we demonstrate and propose to researchers to use the differentiation of the Oasis into western, central and eastern sectors with specific boundaries. In the long term, such differentiation will allow us to increase the potential of comparable scientific data and have consistent time series of observations for some of them, if an ornithological survey of all land sectors in a specific breeding season is impossible.

In the future, it will be important to study in detail the diet of SPS during the pre-breeding, breeding and post-breeding periods and to identify seasonal changes in diet composition, or lack thereof. Periodic inspection of active SPS nests under monitoring may also shed light on the dynamics of Antarctic and Snow Petrel records at specific geographical locations in the Oasis. To date, this aspect remains poorly understood. Although prey remains and pellets around SPS nests, together with field observations, provide very valuable and relatively abundant information on the composition of SPS food, it would be important to deploy video cameras and camera traps to better understand the daily rhythms of adult SPS and their prey throughout the breeding season. This information may shed new light on the scarce data on SPS foraging strategies.

The question remains, what would the diet of the SPS be without human food subsidies? What would be the size of the breeding population of SPS without full access to imported food resources? Would the size of the breeding population of SPS be stable if SPS access to food scraps were completely cut off? What changes would occur in the bird population of the Oasis if human-predator interactions tended to the natural background of prehistoric levels?

## Conclusion

1. In the Oasis conditions, the diet of SPS was limited in the spectrum of diversity of prey categories compared to the potential diversity on the coast of Antarctica. It included five species of birds, fish, squid, as well as food waste and garbage from Antarctic stations and bases. Native marine fish and invertebrates (squid) were likely incidental dietary components that were included in the pellets along with the SPS prey – Snow Petrels and Adelie Penguins. Anthropogenic inclusions were found in 32 pellets out of 330 examined. Plastic fragments were found in 14 SPS pellets, a ceramic fragment was found in one pellet, and paper in four pellets. Gastroliths were found in 28 pellets.
2. Antarctic bird species are the main component of the diet of Oasis SPS, where the diet is completely dominated by visiting non-breeding Snow Petrels, which distinguishes the Oasis SPS population from populations that hunt breeding Snow Petrels elsewhere in Queen Maud Land.
3. Predation is the dominant foraging strategy of SPS. Scavenging plays a secondary role. Cannibalism is rare.
4. During the historical period, human activities have affected the diet of the Oasis-wide breeding SPS by introducing imported food and garbage into their diet. Food garbage from stations and bases was found in seven of the eight surveyed breeding territories and in one of the two old SPS breeding territories. Food garbage was not recorded at the active SPS nest in the west of the Oasis, which is the furthest from the stations and bases.
5. Analysis of pellets and prey remains of SPS and direct observations indicate that breeding SPS do not fly to feed at sea, relying on food resources within the Oasis and possibly in its surroundings.
6. Diet composition and behaviour of SPS at sites of human activity in Antarctica can be used as an indicator of the quality of local human waste management and as an indicator of overall ecosystem health.

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