LONG-TERM CHANGES IN POPULATION SIZE AND DISTRIBUTION OF *STERCORARIUS MACCORMICKI* (STERCORARIIDAE, CHARADRIIFORMES) ON THE HASWELL ISLANDS, EAST ANTARCTICA

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Long-term studies are crucial in ecology, environmental change assessment, resource management and biodiversity conservation. *Stercorarius maccormicki* (hereinafter – south polar skua) are predators that can threaten populations of bird species of the orders Sphenisciformes and Procellariiformes. At many places in Antarctica, abundance trends for the skua are not known or have not been updated. This study is an attempt to answer the question: how did a south polar skua population react to changes in environmental conditions during 1956–2013? The objectives of the study was (1) to establish the dynamics of the breeding skua population on the Haswell Islands, i.e. Haswell Island and the small islands of the Haswell Archipelago during 1956–2013, and (2) to explain the reasons of the changes in the studied population. A secondary research question was whether there were changes in the spatial distribution of the breeding skua population on the Haswell Archipelago during the study period? The studies have been carried out on the Haswell Archipelago (Davis Sea), mainly in Antarctic Specially Protected Area №127 «Haswell Island and adjacent emperor penguin rookery on fast ice». Ground count was the main method for determining the size of bird colonies. South polar skua bred on 3–8 islands of the Haswell Archipelago. In the study period, the population size of the south polar skua has changed on the Haswell Archipelago. A decrease in the number of individuals (-52%) was observed between 1956–1957 and 1966–1967 breeding seasons. Between 1966–1967 and 1999–2000 breeding seasons, the skua population declined by 30.7% and reached the lowest value of 18 pairs. Population growth (344.4%) was recorded between 1999–2000 and 2009–2010 breeding seasons, with an increase of 33.8% and reaching the maximum value (83 pairs) in 2010–2011 breeding season. By 2012–2013 breeding season, the south polar skua population has declined by 13.2%. On Haswell Island, between 1956–1957 and 2012–2013 breeding seasons, there was a change in skua abundance that was similar to the change in the total breeding population on Haswell Archipelago during the entire period. On the small islands of the Haswell Archipelago, the number of breeding south polar skuas declined (-80%) between 1956–1957 and 1962–1963 breeding seasons. The breeding seasons of 1962–1963, 1966–1967 and 1999–2000 were characterised by the lowest number of individuals. Between 1999–2000 and 2009–2010 breeding seasons, the number of south polar skuas increased by 400%. A decrease in abundance (-41.6%) occurred between 2009–2010 and 2010–2011, followed by the consequent increase (by 36.3%) by 2012–2013 breeding season. During the study period, changes in the abundance of south polar skuas on the Haswell Archipelago were independent of changes in average daily November temperatures between 1956–1957 and 2012–2013 breeding seasons (Mann-Whitney test $U = 0$, $p = 0.0017$, $n = 7$ (asymptotic (2-sided))), when they were laying eggs and heating them. The number of south polar skuas changed independently of changes in the number of individuals of their prey, represented by *Aptenodytes forsteri*, *Pygoscelis adeliae*, and *Fulmarus glacialoides* (respectively $U = 49$, $p = 0.0006$, $n = 7$; $U = 16$, $p = 0.029$, $n = 4$; $U = 16$, $p = 0.029$, $n = 4$ (asymptotic (2-sided))). The high mortality of eggs, chicks and local weather conditions could influence the breeding success of the south polar skua, which could have a delayed effect on their long-term dynamics. Human activities have influenced the skua population, but have not been studied quantitatively. On the Haswell Archipelago, the reasons for historical changes in abundance of the breeding skua population remain largely unclear.

Key words: abundance, conservation, human activity, monitoring, south polar skua, tendency, trend

Introduction

Long-term studies are crucial in ecology, environmental change assessment, natural resource management and biodiversity conservation (Lindenmayer et al., 2012). They enable the tracking of changes in natural systems before and after natural and anthropogenic disturbances (Taig-Johnston et al., 2017; Philippe-Lesaffre et al., 2023). Long-term data on changes in the abundance of bird populations are valuable for identifying possible causes of fluctuations and for conservation measures (Reif, 2013). Gaps in long-term population studies contribute to less reliable explanations of the processes occurring in populations and ecosystems, as well as the causes that induce these changes. Seabirds are found in all oceans, from coastal areas to the high seas, and, compared with most other marine animals, they provide a better understanding of threats to their populations and population trends (Dias et al., 2019).

Stercorarius maccormicki (Saunders, 1893) (hereinafter – south polar skua or skua; see Fig. 1) is an opportunistic predator that breeds around Antarctica (Ritz et al., 2008), mainly on the coasts (Higgins & Davies, 1996; Carneiro et al., 2016). It is listed under the Least Concern category in the Global IUCN Red List (BirdLife International, 2018). The state of the world population of this species (6000–15 000 adults) has been assessed as stable (BirdLife International, 2018). Approximately 50% of the global skua population is estimated to inhabit the Ross Sea region (Wilson et al., 2017).

In continental Antarctica, the south polar skua is a food generalist, which uses a wide range of prey including marine mammals, penguins, flying birds, fish and invertebrates, as well as kitchen refuse and garbage (Reinhardt et al., 2000). Skuas are sensitive to human activities (Chwedorzewska & Korczak, 2010) and by breeding near stations or sites of intense human activity, they are able to benefit from this by increasing predation on eggs and chicks of other bird species (Sander et al., 2005). In East Antarctica, the south polar skua is the only avian predator that seriously affects breeding populations of seabirds (Norman & Ward, 1990), which form the basis of its diet (Reinhardt et al., 2000). Any increase in the skua population is an additional pressure on their prey, i.e. birds that may already be influenced by human activities (Hemmings, 1990).

Population trends of the skua are poorly understood (Wilson et al., 2015), and the number of skua individuals has been infrequently assessed in most locations (Wilson et al., 2017). Information on trends of the south polar skua is available on a very few sites, particularly in the last 10–20 years (Phillips et al., 2019). This is partly true because changes in skua colonies due to human activity make them less useful for monitoring of marine ecosystems than penguins, but may be useful, if such links are not present (Ainley et al., 1986). However, the skua population trends with various time ranges (i.e. an interval between the first and last population counts in a particular location) and detailing (i.e. the number of population counts in a known time range) remain the focus of interest of researchers. They are analysed and used in the monitoring of the Antarctic environment, in particular in the environmental policy of Antarctic stations and their neighbourhood (e.g. Chwedorzewska & Korczak, 2010). Research in the Antarctic Peninsula with adjacent islands (West Antarctica), Pointe Géologie, Terre Adélie (East Antarctica) and the Ross Sea region claim leadership in this direction (e.g. Ainley et al., 1986; Quintana et al., 2000; Micol & Jouventin, 2001; Grilli, 2014; Krietsch et al., 2016). However, there are still many places in Antarctica and adjacent islands where skua population trends are not known or have not been updated.

Fig. 1. South polar skua (*Stercorarius maccormicki*) on the Haswell Archipelago, Davis Sea.

The south polar skua is a common avian species, a seasonal resident of the Haswell Archipelago (East Antarctica). It breeds in loose colonies, small groups or single pairs on islands free of snow and ice. The breeding population of the skua is the least abundant compared to the size of breeding populations of other bird species, it is relatively well studied and has a long series of intermittent observations (Mawson, 1915; Korotkevich, 1959; Pryor, 1964, 1968; Syroechkovsky, 1966; Kamenev, 1968; Starck, 1980; Mizin, 2015; Golubev, 2018). The local skua population represents about 1–2% of the global adult population, where Haswell Island supports 70.0–91.5% of breeding skuas on the Haswell Archipelago.

On the Haswell Islands, the south polar skua usually feeds on eggs, chicks and adults of the most abundant bird species, such as *Aptenodytes forsteri* Gray, 1844, *Pygoscelis adeliae* (Hombron & Jacquinot, 1841), and *Fulmarus glacialoides* (Smith, 1840) (Pryor, 1968). They mainly feed on carrion (Korotkevich, 1958, 1959; Pryor, 1965; Kamenev, 1977, 1978) and rarely turn to predation (Pryor, 1968). *Pygoscelis adeliae* suffers the most from predation by skuas (Mawson, 1915; Pryor, 1964; Kamenev, 1971). At the Mirny Station, skuas also visited the food waste dump for several decades (Starck, 1980; Mizin, 2015; Golubev, 2018). South polar skuas have no food competitors on land, except for *Stercorarius antarctica lonnbergi* (Mathews, 1912), which has recently entered the Haswell Islands (Mizin, 2015; Golubev, 2020, 2021). As an avian predator, south polar skua can pose threats to other Haswell Archipelago seabird populations. Therefore, studying of the exploitation of prey trophic relationships of skuas is important for our understanding of the long-term survival and coexistence of local seabird populations. Skua interactions with their prey should be considered in Antarctic Specially Protected Area №127 «Haswell Island and adjacent emperor penguin rookery on fast ice» (hereinafter – ASPA №127 «Haswell Island»), as *Aptenodytes forsteri* and *Pygoscelis adeliae* are vulnerable and require conservation measures (BirdLife International, 2024). *Aptenodytes forsteri* is a Near Threatened taxon (BirdLife International, 2020).

Updated information on skua population trends on the Haswell Archipelago has not been published until recently (Carneiro et al., 2016). This study attempts to answer the question: how did the south polar skua population reacts to changes in environmental conditions during the period of 1956–2013? The objectives of the study were (1) to establish the dynamics of the breeding population of the skua on the Haswell Islands, i.e. Haswell Island and the small islands on the Haswell Archipelago during the period of 1956–2013, and (2) to explain the reasons for skua population changes. A secondary research interest was to answer the following question: have there been changes in the spatial distribution of the breeding skua population on the islands of the Haswell Archipelago during the study period, and if so, what has changed?

Material and Methods

Study area

Haswell Archipelago (66.55° S, 93.01° E) is located in the coastal part of the continental shelf of Davis Sea (Treshnikov Bay, Queen Mary Land, southern Indian Ocean). The area is rich in icebergs. For most of the year, the sea is covered with fast ice. Its width can exceed 30 km (Shesterikov, 1959; Mirny Observatory, 2020). The Haswell Archipelago includes 17 relatively large islands scattered no further than 3 km (excluding Ploskiy Island) from the coast of Antarctica, where the Russian Mirny Antarctic Research Station has operated year-round since 1956, providing the basis for research activities. Haswell Island is the largest (0.82 km^2) and highest (93.1 m a.s.l.) rock of the Haswell Archipelago (Voronov & Klimov, 1960; Kashin & Chistyakov, 2022; Fig. 2).

The altitude of smaller islands generally ranges from 10 m a.s.l. to 35 m a.s.l. (Voronov & Klimov, 1960). The study area (about 12 km^2) included islands and sea ice hosting breeding populations of nine bird species, namely *Aptenodytes forsteri*, *Pygoscelis adeliae*, *Oceanites oceanicus* (Kuhl, 1820), *Fulmarus glacialoides*, *Thalassoica antarctica* (J.F. Gmelin, 1789), *Daption capense* (Linnaeus, 1758), *Pagodroma nivea* (G. Forster, 1777), *Stercorarius maccormicki*, and *S. antarctica*. All bird species breeding in this area are concentrated on Haswell Island and near it (Golubev, 2018). In order to preserve this biodiversity, Site of Special Scientific Interest №7 «Haswell Island» (Report, 1976) was allocated in 1975 on the Haswell Archipelago. This Protected Area was later named as (hereinafter – ASPA №127 «Haswell Island»). Its boundaries coincide with those of Important Bird Area «ANT 141: Haswell Island» (Harris et al., 2015).

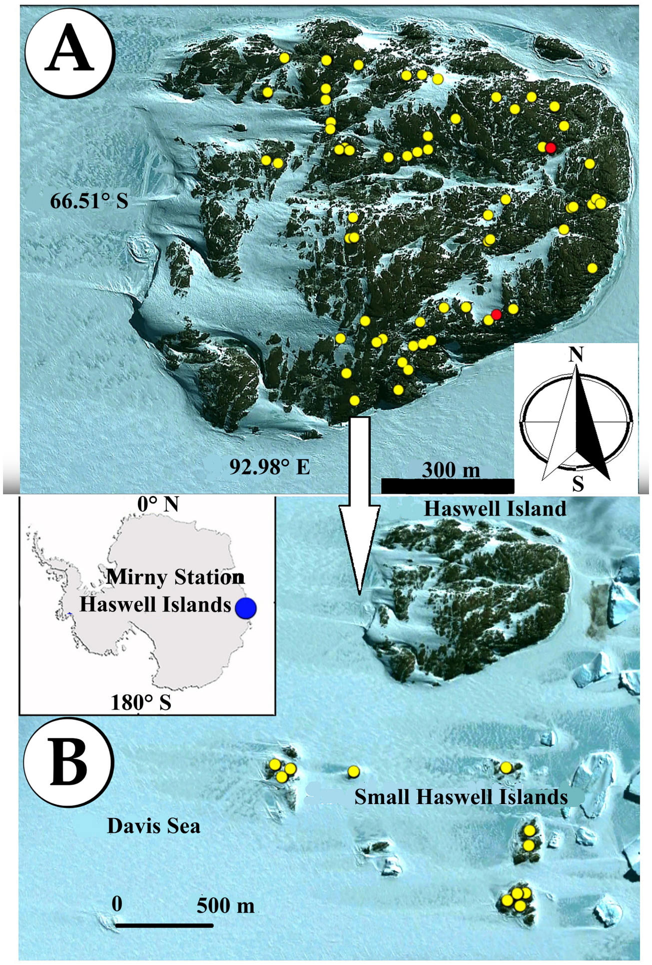

Fig. 2. Distribution of active nest sites of the skua (*Stercorarius maccormicki*) on the Haswell Islands based on 2012–2013 breeding season censuses (Fig. 2A). Yellow circles – nests of *Stercorarius maccormicki*; red circles – nests of mixed pairs (*Stercorarius maccormicki* with *S. antarctica lonnbergi* or possibly hybrid individuals between these species). The inset in the upper left corner of Fig. 2B shows the location of the study area and the Mirny Station.

Bird survey methods

The fieldwork of Sergey V. Golubev has been carried out during the 2012–2013 and 2015–2016 breeding seasons inside the Haswell Archipelago. South polar skuas were counted in November and December 2012. The counts of mixed pairs (*Stercorarius maccormicki* with *S. antarctica lonnbergi* or possibly hybrid individuals between these species) were carried out in November – January from 2012–2013 to 2015–2016. Data from 1912–1913 to 2010–2011 were taken from publications and unpublished reports of biologists (Table 1).

The research mainly covered the period of laying eggs, incubation of eggs and the beginning of chick hatching. Ground counts have been the main method for studying breeding populations of seabirds. For skuas, we counted 1) pairs with nests containing eggs or chicks, 2) adult birds sitting on nests, without clutches of eggs and chicks, 3) territorial pairs without nests. In 2012, skua surveys were carried out in November and December. During a later count (December) of the same breeding season, the status of pairs (i.e. breeding pairs or territorial pairs without nests) of adult birds sitting on nests, without clutches of eggs and chicks and territorial pairs without nests may have changed. Data analysis was based on counting breeding pairs on occupied nests. A pair with a clutch of eggs or chick(s) has been considered a breeding pair. The standard approach for counting skuas by recording territorial pairs or brooding birds in occupied territories (Carneiro et al., 2016; Krietsch et al., 2016; Phillips et al., 2019) has been used partly based on the specifics of historical information and our own data sets.

The size of skua colonies, trends of their prey (*Aptenodytes forsteri*, *Pygoscelis adeliae*, *Fulmarus glacialoides*) in the breeding skua populations on the Haswell Archipelago, and changes in the spatial distribution, abundance and population density of birds (pair/km^2) were also the focus of our attention. They were established by comparing historical (Korotkevich, 1959; Pryor, 1968; Kamenev, 1968; Starck, 1980; Mizin & Chernov, 2000; Dorofeev, 2011; Mizin, 2015) and our (from 2012–2013 to 2015–2016 breeding seasons) data. The population density of breeding skua pairs on Haswell Island was calculated together with glaciers on its surface. The geographic co-ordinates of the nest position, occupied territories, the distance from the nest to the nearest border of Haswell Island and the distance between the nearest nests with clutches of eggs without taking into account uneven terrain, as well as the height of the nests above sea level, were recorded using a GPS (Global Positioning System) navigator. Each nest with eggs or chicks was mapped using Google Earth Pro programme to eliminate double fixation (Phillips et al., 2019; Fig. 2A). Nests were photographed with one or both partners of a pair. Whenever possible, the number and combinations of coloured plastic marks, number of metal rings on legs of breeding skuas were recorded. This also contributed to the elimination of double fixation of one nest. For each nest on Haswell Island, we calculated (1) the nearest-neighbour index (NNI index) as an average distance from the nest to three other closest nests (Carneiro et al., 2010), (2) distance from the nest to the edge of the island (Carneiro et al., 2010), and (3) nest position above sea level. The number of eggs in the clutch or their absence and the standard morphometric parameters of the nest and eggs were recorded. Identification of *Stercorarius maccormicki* and *S. antarctica lonnbergi* has been carried out based on a set of features, namely size, plumage colour, voice, and posture during the demonstration of a long call. The hybrid status of transitional individuals has not been established.

Mapping of historical records of occupied south polar skua nests on Haswell Island collected by a unified way from censuses conducted from 1956–1957 to 2009–2010 breeding seasons (n = 5, Fig. 3) was based on relevantly published maps (Korotkevich, 1959; Pryor, 1968; Starck, 1980; Mizin & Chernov, 2000; Mizin, 2015). However, the distribution of nests was still approximately due to the lack of accurate co-ordinates in publications and reports or detailed maps with the location of nests in the study area.

All the islands, except for Haswell Island, were considered small islands. Statistical analysis and data visualisation were carried out in Microsoft Excel 2013 (USA), in Google Earth Pro 2022 (USA), and Adobe Photoshop CC 2015.0.0 Portable Version (USA). Calculation of statistical indicators (Mann-Whitney U-test) was carried out using the SciPy library ver. 1.11.4. (https://scipy.org/) in Python ver. 3.11 (https://www.python.org/). Calculation of the Mann-Whitney U-test for data presented with spaces, continuity correction (1/2) was applied.

Results

Changes in the abundance of the breeding population of the south polar skua on the Haswell Archipelago (from 1956–1957 to 2012–2013)

During the study period, the breeding skua population on the Haswell Archipelago has experienced changes in breeding conditions. A decline in abundance was observed between 1956–1957 and 1966–1967 breeding seasons (-52%). Following the gap between 1966–1967 and 1999–2000 breeding seasons, the skua population size experienced a 30.7% decline and reached a historically minimal value of 18 breeding pairs. Population growth (344.4%) was recorded between 1999–2000 and 2009–2010 breeding seasons, with an increase by 33.8% and by reaching a historical maximum (83 pairs) in 2010–2011 breeding season. By the 2012–2013 breeding season, the number of breeding south polar skuas had decreased by 13.2% (Fig. 4A). The number of south polar skuas changed during the study period regardless of changes in the number of their food resources, namely *Aptenodytes forsteri*, *Pygoscelis adeliae*, and *Fulmarus glacialoides* (respectively, U = 49, p = 0.0006, n = 7; U = 16, p = 0.029, n = 4, and U = 16, p = 0.029, n = 4 (asymptotic (2-sided))).

On Haswell Island, there was a change in skua abundance from 1956–1957 to 2012–2013 breeding seasons (Fig. 4B). These changes were similar to changes in the total size of the breeding skua population on all Haswell Islands during the above mentioned period (Fig. 4A). On the small islands of the Haswell Archipelago, the number of breeding skuas declined sharply (-80%) from 1956–1957 to 1962–1963 breeding seasons. The breeding seasons of 1962–1963, 1966–1967, and 1999–2000 were characterised by the lowest or near the lowest historical minimum abundance. On the small islands of the Haswell Archipelago, the number of skuas increased by 400% between 1999–2000 and 2009–2010 breeding seasons. There was a decrease in population size (-41.6%) from 2009–2010 to 2010–2011 breeding seasons, followed by an increase (36.3%) by 2012–2013 breeding season (Fig. 4C). On the small islands of the Haswell Archipelago, the skua abundance changed independently of changes in the skua abundance on Haswell Island (U = 48.5, p = 0.002 (asymptotic (2-sided))). Moreover, during the study period, changes in the skua abundance on the Haswell Islands were independent of changes in average daily November temperature from 1956–1957 to 2012–2013 breeding seasons (Mann-Whitney test: U = 0, p = 0.0017, n = 7 (asymptotic (2-sided))), when they were laying eggs and heating them.

Dynamics of the spatial distribution of the breeding skua population on the islands of the Haswell Archipelago

In the 2012–2013 breeding season, south polar skuas occupied six islands of the Haswell Archipelago, namely Haswell Island, Tokarev Island, Gorev Island, Buromsky Island, Zykov Island, and Fulmar Island. Seventy-two breeding skua pairs were identified with nests with clutches, and three territorial pairs without nests. On Haswell Island, 61 breeding pairs (84.7% of the total number of breeding skuas on the Haswell Archipelago) were found.

Table 1. Distribution and abundance of breeding pairs of the south polar skua (*Stercorarius maccormicki*) on the Haswell Islands, 1912–2013

Breeding season	Breeding pairs on islands								∑ (breeding pairs)	References
	1	2	3	4	5	6	7	8		
1912–1913	+	–	–	–	–	–	–	–	–	Mawson, 1915
1956–1957	35	3	4	3	2	1	1	1	50	Korotkevich, 1959
1962–1963	23	1	1	0	1	0	0	0	26	Pryor, 1968
1966–1967	20	4	0	0	0	0	0	0	24	Kamenev, 1968
1978–1979	20	–	–	–	–	–	–	–	–	Starck, 1980
1999–2000	15	2	1	0	0	0	0	0	18	Mizin & Chernov, 2000
2009–2010	50	3	2	3	1	1	1	1	62	Mizin, 2015
2010–2011	76	3	1	1	1	1	0	0	83	Dorofeev, 2011
2012–2013	61	4	3	2	0	1	0	1	72	S.V. Golubev, unpublished data

Note: Designations of the islands: 1 – Haswell Island; 2 – Fulmar Island; 3 – Tokarev Island; 4 – Zykov Island; 5 – Stroiteley Island; 6 – Buromsky Island; 7 – Poryadin Island; 8 – Gorev Island; «+» – skuas bred, but counts were not carried out; «–» – counts were not carried out.

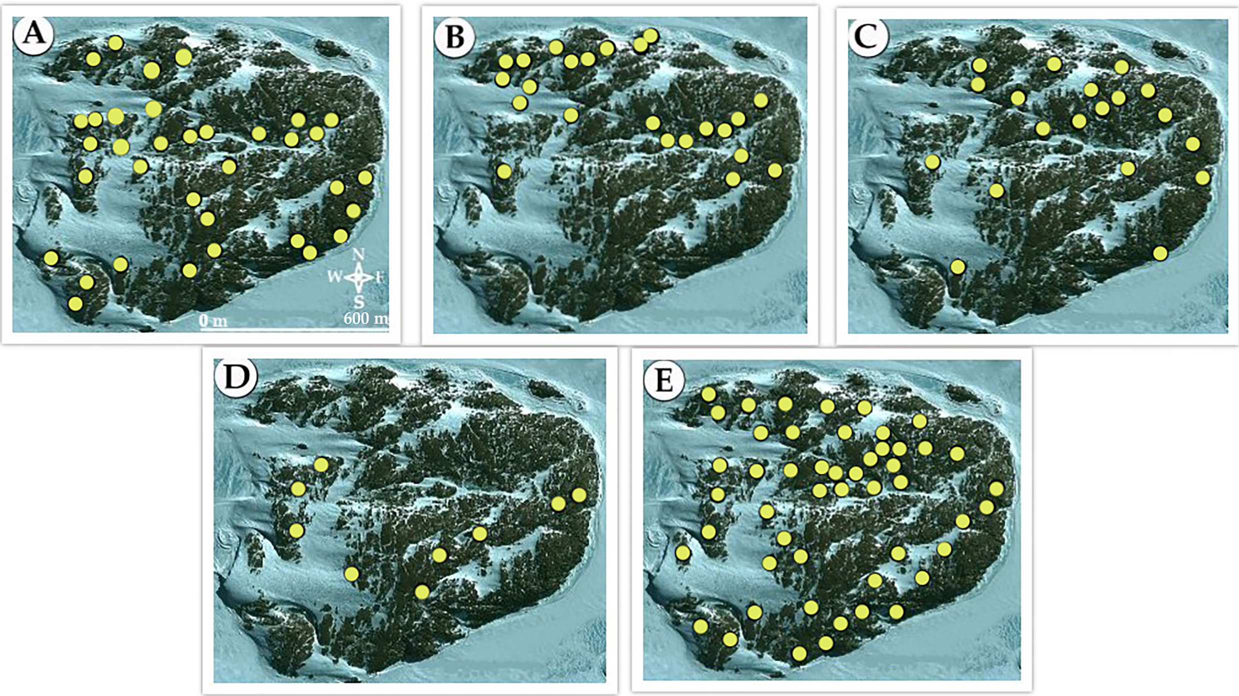

Fig. 3. Distribution of occupied nests of the south polar skua (*Stercorarius maccormicki*) on Haswell Island (yellow circles) according to surveys in a specific breeding season. Designations: A – season of 1956–1957 (redrawn from Korotkevich, 1959); B – season of 1962–1963 (redrawn from Pryor, 1968); C – season of 1978–1979 (redrawn from Starck, 1980); D – season of 1999–2000 (redrawn from Mizin & Chernov, 2000); E – season of 2009–2010 (redrawn from Mizin, 2015). Fig. 3D shows nine out of 15 nests of the south polar skua identified originally by Mizin & Chernov (2000).

Nests of mixed pairs of the skua also were identified on Haswell Island. In 2012–2013 breeding season, two nests with eggs and chicks and one territorial pair without nest were found on Haswell Island. In 2014–2015, one breeding pair was recorded on Haswell Island. In 2015–2016 breeding season, two breeding pairs and one territorial pair without nest were found on Haswell Island.

During the studied period (1912–2016), changes in the spatial distribution of south polar skua nests on the Haswell Islands have been identified. Skuas bred on 3–8 islands of the Haswell Archipelago, usually near colonies of *Pygoscelis adeliae* and species of Procellariiformes (Mawson, 1915; Korotkevich, 1959; Kamenev, 1968; Pryor, 1968; Starck, 1980; Mizin & Chernov, 2000; Dorofeev, 2011; Mizin, 2015; S.V. Golubev, unpublished data). Annual (Haswell Island and Fulmar Island) or near-annual (Tokarev Island) breeding occurred on three islands. Non-annual breeding was recorded on five islands (Zykov Island, Stroiteley Island, Buromsky Island, Poryadin Island, and Gorev Island). The rarest breeding of single pairs was observed on Poryadin Island and Gorev Island, where there were no breeding colonies of other seabird species. At breeding seasons with a relatively low bird abundance (18–26 breeding pairs), skuas occupied up to three small islands. However, they occupied up to seven small islands, if the total breeding population size was ≥ 50 pairs (Table 1).

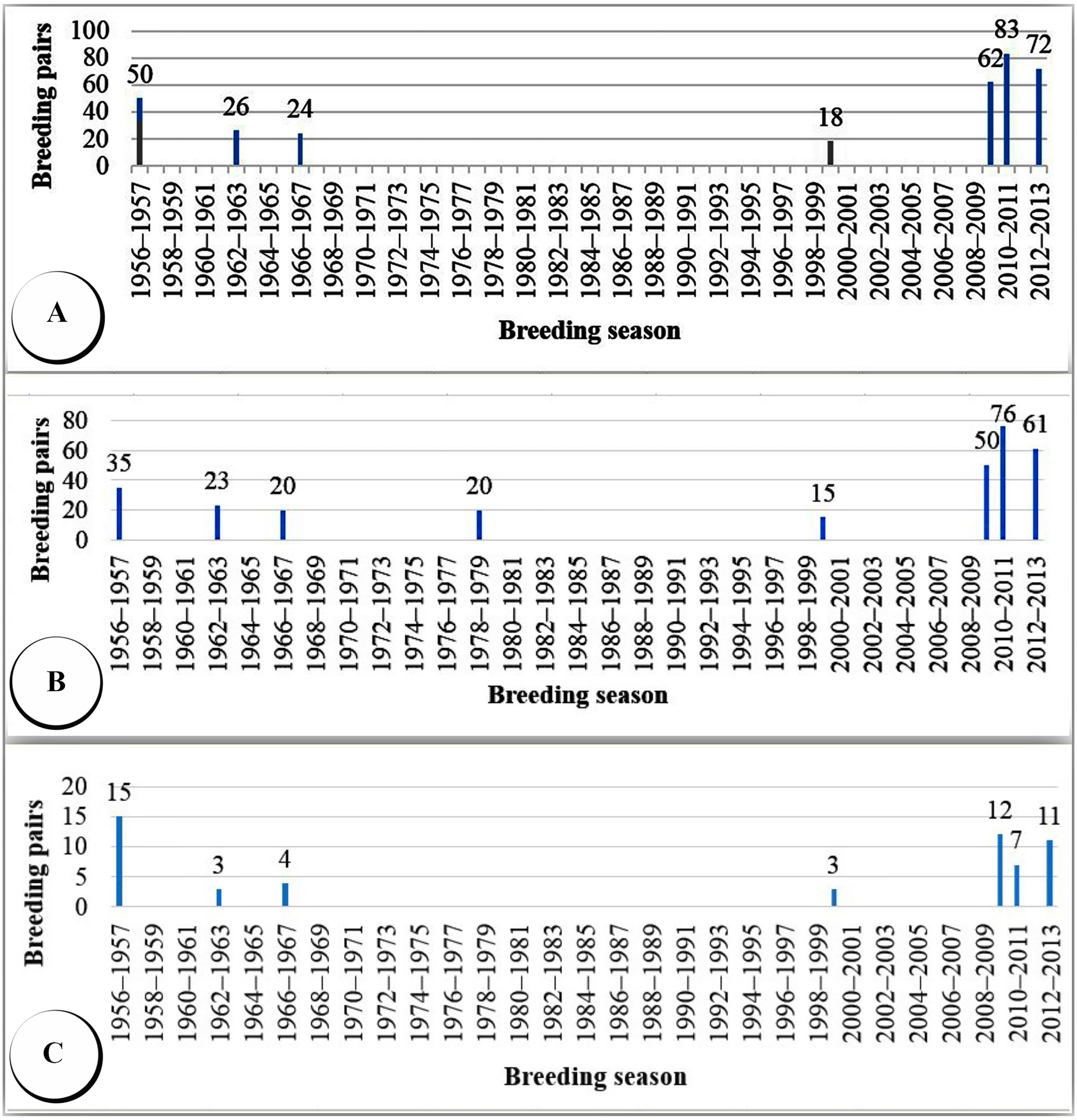

Fig. 4. Long-term changes in breeding population size of the south polar skua (*Stercorarius maccormicki*) on all islands of the Haswell Archipelago (A), on Haswell Island (B), and on the small islands of the Haswell Archipelago (C) from 1956–1957 to 2012–2013. References: Korotkevich (1959), Pryor (1968), Kamenev (1968), Starck (1980), Mizin & Chernov (2000), Dorofeev (2011), Mizin (2015), S.V. Golubev (unpublished data).

The spatial distribution of breeding skua pairs and nest density on Haswell Island varied over the study period (Fig. 2, Fig. 3). Due to the small number of breeding pairs (≤ 26 pairs), skuas tended to breed in the northern part of Haswell Island (Fig. 3B,C) or in its centre (Fig. 3D). Against this background, nest density could be either low (Fig. 3C,D) or relatively high (Fig. 2A, Fig. 3A,E). At the relatively high number (≥ 50 pairs), skuas nested from 2/3 (Fig. 2A) to the entire area of Haswell island (Fig. 3A,E). Nest placement could be relatively uniform (Fig. 3E) and locally dense (Fig. 2A, Fig. 3A). Nest density varied over the study period from 18.2 nests/km^2 to 92.6 nests/km^2, with an average of 28 nests/km^2 (n = 8). In general, the spatial distribution of active skua nests appears to be driven by environmental conditions at the beginning of a particular breeding season.

In the 2012–2013 breeding season, the distance between the nearest skua nests on Haswell Island (mean ± SE (min–max)) was 105.9 ± 9.9 m (7.0–352.2 m), with a median at 84.2 m (n = 60). The distance between mixed pairs was 413 m (n = 1). On Haswell Island, the nesting density of the south polar skua (excluding active nests of two mixed pairs) was 87.8 nests/km^2. Nests were placed on the inner surface of rocks. In the 2012–2013 breeding season, the distance from the skua nests to the nearest border of Haswell Island (mean ± SE (min–max)) was 118.0 ± 10.6 m (18–359 m) (n = 61). The distance for two nests of mixed pairs was 180 m and 78 m.

Skuas used the entire range of altitudes of Haswell Island surface to accommodate their nests. On small islands of the Haswell Archipelago, altitudes of the skua nest position (Table 2) were more than three times lower than on Haswell Island.

Compared to Haswell Island, the low location of skua nests on small islands was observed only as a result of their low altitude values. On Haswell Island, the vertical distribution of south polar skua nests follows a normal distribution (Fig. 5).

In December 2012, full clutches of the south polar skua contained one (n = 8) or two (n = 64) eggs. In nests of mixed pairs, two chicks (n = 1) and two eggs (n = 1) were found. The egg size (length × width) of the skua was 73.2 ± 2.7 mm (65.0–81.2 mm) × 51.3 ± 1.2 mm (48.0–55.1 mm) (n = 128). In the two nests of mixed pairs, the egg size was 74.1 × 52.6 mm, and 74.1 × 51.8 mm. The nest size of the south polar skua (n = 68) was 243.6 ± 19.5 mm (190–290 mm) × 261.4 ± 112.7 mm (230–340 mm). The nest size of one mixed pair (n = 1) was 280 × 290 mm.

Discussion

Skua population dynamics have been monitored on the Haswell Archipelago, a part of East Antarctica. Here warming or cooling conditions were relatively stable between 1956 and 2018, and no widespread cooling was observed at East Antarctic stations in recent decades (Turner et al., 2019). The results of the research established that the number of the south polar skuas changed regardless of changes in the number of their most abundant prey. However, early cleaning of the coastal water area from fast ice (for example, in December), where south polar skuas feed on sea ice with frozen eggs and chicks of *Aptenodytes forsteri* at the beginning of the breeding season, could negatively affect the state of the skua population. At the same time, during the seasons of decrease in number of skua individuals (namely 1962–1963, 1966–1967, 1978–1979), phenological data on the destruction of fast ice were not recorded by researchers, but were suitable in the 1999–2000 breeding season (Antipov & Molchanov, 2022). Then the size of the breeding population reached a historical minimum of 18 breeding pairs.

During long-term monitoring, the mass mortality of adult skuas on the Haswell Archipelago has not been established (Korotkevich, 1959; Pryor, 1968; Kamenev, 1968; Starck, 1980; Mizin, 2015; Golubev, 2018), as well as the mortality of young and adult birds during the marine stage of the annual cycle (migration and wintering). Mortality of adults during the breeding season is very low (usually one or two adults were recorded).

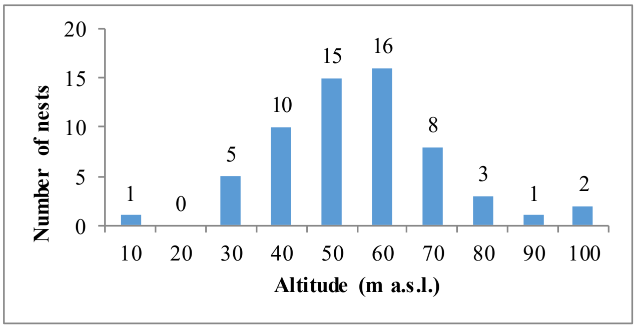

Fig. 5. Altitude distribution of south polar skua (*Stercorarius maccormicki*) nests on the Haswell Island in the 2012–2013 breeding season.

Table 2. Nesting altitude (m a.s.l.) of the south polar skua (*Stercorarius maccormicki*) and mixed pairs (*Stercorarius maccormicki* with *S. antarctica lonnbergi* or possibly hybrid individuals between these species) on the Haswell Islands at 2012–2013 breeding season

Islands	m	SE	min	max	n
Stercorarius maccormicki					
Haswell	49.9	2	6	93	61
Small islands	13.3	2.8	4	30	11
Total	44.3	2.3	4	93	72
Mixed pairs					
Haswell	48.5	0	43	54	2

Note: m – average value, SE – standard error, min – minimum value, max – maximum value, n – number of nests.

At the same time, brood (eggs and chicks) mortality was relatively high. For example, by 05.01.1963, it was 55%, of which egg losses accounted for about 68% (Pryor, 1968), and by 07.01.1967, the survival of chicks was 45% of the total number of laid eggs (Kamenev, 1968). During the study period, the reproductive success (the ratio of the number of fledged young birds capable of flying to the total number of eggs laid) of the skua has not been studied. However, sibling aggression of chicks and local weather conditions (increased winds, heavy precipitation and sharp changes in the surface temperature) of a particular breeding season could influence the breeding success of the skua, which could have a delayed effect on the long-term dynamics of their breeding population.

Partial loss and habitat modification (Pryor, 1965; Propp, 1968; Golubev, 2021), direct persecution of the skua in the Mirny Station (Propp, 1968), bird hunting, collection of eggs and chicks for scientific purposes (Yudin, 1958; Korotkevich, 1959; Makushok, 1959; Kirpichnikov, 1965; Syroechkovsky, 1966) negatively affected the skua population. Long-term use of food waste from the Mirny Station for decades (Starck, 1980; Mizin, 2015; Golubev, 2018) could positively influence the maintenance of the skua population. However, food waste is used primarily by non-breeding individuals. Thus, the human activity has influenced the breeding skua population over the study period. Nevertheless, this influence has not been quantified.

Conclusions

Our study completes the general picture of the knowledge state on long-term trends in the skua abundance in Antarctica and the reasons that may affect the annual changes in the skua abundance. Considerable gaps in the measurement of abundance, breeding success and the impact of human activities on the skua population over the study period have induced difficulties in interpreting the existing data set. In general, reasons for changes in the skua abundance on the Haswell Islands remain highly unclear. Greater clarity in understanding of the interactions between avian predators and their prey against the backdrop of a changing climate could facilitate the adoption of adequate measures to conserve the overall abundance of life on the Haswell Islands, if necessary.

Dynamic interactions of ecological variables limit the possibility of reliable identification of the causes determining trends in the number of individuals in skua populations and do not allow us making a clear distinction between the influences of certain factors. The difficulty in interpreting the results is related to the close interweaving of environmental factors, their synergistic effect, the influence of human activities, and the poor knowledge on the skua existence during the marine period of their annual cycle. Sometimes it is easier to explain the causes of changes by anthropogenic factors than by natural factors, and even more so by their combined interaction.

Progress in trend studies can be made if the results of long-term monitoring of south polar skua populations in Antarctica are considered and interpreted along with detailed studies and involving as many aspects as possible related to the life of the skua and their interactions with the environment they inhabit. It is likely that in the near future, the results of analysis of long-term monitoring of those (ideal) skua populations, which breeding sites are remote and free from human activity, but well documented for decades, will be of increasing value. Of particular scientific interest should be the breeding skua populations in the inland hard-to-reach parts of Antarctica. At such places their interactions with the environment are perhaps simpler and more straightforward than on the coast of the mainland and islands, where predator-prey interactions remain virgin, as in the prehistoric era. An undoubted continuation of monitoring and an increase in the number of publications of updated trends of local skua populations can be expected from sites with a long history where the human population density in Antarctica is relatively high.

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МНОГОЛЕТНИЕ ИЗМЕНЕНИЯ ЧИСЛЕННОСТИ И ПРОСТРАНСТВЕННОГО РАСПРЕДЕЛЕНИЯ *STERCORARIUS MACCORMICKI* (STERCORARIIDAE, CHARADRIIFORMES) ОСТРОВОВ ХАСУЭЛЛ, ВОСТОЧНАЯ АНТАРКТИДА

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Долгосрочные исследования имеют решающее значение в экологии, оценке изменений окружающей среды, управлении природными ресурсами и сохранении биоразнообразия. *Stercorarius maccormicki* (далее южно-полярный поморник или поморник) – хищник, который может угрожать популяциям птиц из отрядов Sphenisciformes и Procellariiformes. Во многих регионах Антарктики тренды численности южно-полярного поморника неизвестны или не обновлялись. Это исследование представляет попытку ответа на вопрос, как реагировала локальная популяция южно-полярных поморников на изменения условий окружающей среды в течение исторического периода? Задачами исследования было (1) установить динамику численности размножающейся популяции южно-полярных поморников Хасуэлльских островов, острова Хасуэлл и мелких островов архипелага Хасуэлл в течение исторического периода (1956–2013 гг.) и (2) попытаться объяснить причины популяционных изменений. Второстепенный исследовательский вопрос был, имелись ли изменения пространственного распределения размножающейся популяции южно-полярного поморника на островах архипелага Хасуэлл в течение исторического периода? Исследования проводились на островах архипелага Хасуэлл (море Дейвиса, залив Трешникова, Южный океан) у побережья Антарктиды (Земля Королевы Мэри), в основном на территории особо охраняемого района Антарктики №127 «Остров Хасуэлл с прилегающей к нему колонией императорских пингвинов на припае». Наземный учет был основным методом определения размера птичьих колоний. Южно-полярные поморники размножались на 3–8 островах архипелага Хасуэлл. Они использовали весь диапазон высот суши для размещения гнезд. В исторический период популяция южно-полярных поморников архипелага Хасуэлл претерпевала изменения в условиях размножения. Снижение численности особей (-52%) наблюдалось между сезонами размножения 1956–1957 гг. и 1966–1967 гг. Между сезонами размножения 1966–1967 гг. и 1999–2000 гг. численность особей в популяции сократилась на 30.7% и достигла исторического минимума (18 размножающихся пар). Рост популяции на 344.4% был зафиксирован между сезонами размножения 1999–2000 гг. и 2009–2010 гг., увеличившись на 33.8% и достигнув исторического максимума (83 пары) в сезон размножения 2010–2011 гг. К сезону размножения 2012–2013 гг. популяция сократилась на 13.2%. На острове Хасуэлл между сезонами размножения 1956–1957 гг. и 2012–2013 гг. наблюдалось изменение численности особей южно-полярного поморника, аналогичное изменению общей численности размножающихся особей их популяции на архипелаге Хасуэлл в указанный выше период. Размножающаяся популяция южно-полярного поморника острова Хасуэлл вносит основной вклад в долговременную динамику численности особей вида. На малых островах архипелага Хасуэлл численность размножающихся южно-полярных поморников резко сократилась (-80%) между сезонами размножения 1956–1957 гг. и 1962–1963 гг. Сезоны размножения 1962–1963 гг., 1966–1967 гг. и 1999–2000 гг. характеризовались наиболее низкими показателями численности особей. В сезоны размножения с 1999–2000 гг. по 2009–2010 гг. численность особей поморника увеличилась на 400%. Уменьшение численности особей в популяции (-41.6%) произошло в период с 2009–2010 гг. по 2010–2011 гг. Затем последовало увеличение численности особей (на 36.3%) к сезону размножения 2012–2013 гг. На малых островах архипелага Хасуэлл численность особей поморника менялась независимо от изменения численности особей поморника на острове Хасуэлл (тест Манна-Уитни $U = 48.5$, $p = 0.002$ (асимптотическая (2-сторонняя))). В течение исторического периода изменение численности особей поморника архипелага Хасуэлл не зависело от изменений среднесуточной температуры ноября между сезонами размножения 1956–1957 гг. и 2012–2013 гг. ($U = 0$, $p = 0.0017$, $n = 7$ (асимптотическая (2-сторонняя))), когда у них происходила кладка яиц и их обогрев. Численность особей южно-полярного поморника в течение изучаемого периода изменялась независимо от изменений численности особей их кормовых ресурсов, *Aptenodytes forsteri*, *Pygoscelis adeliae* и *Fulmarus glacialoides* (соответственно, $U = 49$, $p = 0.0006$, $n = 7$; $U = 16$, $p = 0.029$, $n = 4$; $U = 16$, $p = 0.029$, $n = 4$ (асимптотическая (2-сторонняя))). Относительно высокая гибель яиц и птенцов в конкретный сезон размножения могли влиять на изменения численности особей в популяции поморника. Сиблинговая агрессия птенцов и локальные метеоусловия (усиление ветра, обильные осадки и резкие перепады поверхностных температур) конкретного сезона размножения также могли влиять на успех размножения поморников, что отложенным эффектом могло отражаться на долговременной динамике их размножающейся популяции. Деятельность человека влияла на популяцию поморника, но не исследовалась количественно. Причины исторических изменений обилия размножающихся особей в популяции южно-полярного поморника архипелага Хасуэлл остаются во многом не ясными.

Ключевые слова: деятельность человека, мониторинг, охрана, тенденция, тренд, численность, южно-полярный поморник