Vigur Research Campaign 2022

Annual Report

2022

Introduction

It is with great pleasure that we are able to present this overview of the 2022 Vigur Research Campaign. The summer of 2022 was a significant step in the further development of valuable scientific activity on Vigur following the establishment of annual research campaigns in 2021. We are still in formative stages but we are extremely proud of everything that was achieved, particularly given the challenging circumstances of the year – from climate change making itself evident in unseasonable weather, to the arrival of Covid on the island, to Avian Influenza devastating seabird colonies across the North Atlantic, to the invasion of Ukraine playing havoc with the cost of fuel and other vital supplies. Particularly devastating was the arrival of industrial aquaculture 1 km from the southern shore of Vigur with licences agreed for further installations to the north of the island and right across the fjord.

Despite these challenges, fieldwork on Arctic terns, seals and black guillemots was completed as well as on the island's flora. The annual harvest of eiderdown enabled the first detailed records of common eider nests on Vigur to be collated. Much of this work will provide the foundation on which future work and valuable archive records can be developed.

Having remained Covid free throughout the pandemic, Covid arrived on the island in June 2022. We saw the impact of the global recovery from the pandemic and re-introduction of travel on visitor numbers, however, we did not see evidence of the inflated tourism 'bounce-back' that had been predicted. Pre-Covid there were more than 10,000 annual visitors to Vigur. In 2020 this fell to less than 300, in 2021 it was 5500 and in 2022 approximately 8000 people came to the island. While these depressed figures have a continued impact on the financial resources of Vigur, it did enable studies of the impact of tourism on wildlife to continue and various management and mitigation strategies to be trialled – most of which happily proved to be very successful.

We paid careful attention to the news of Avian Influenza which caused mass fatalities in seabird colonies across northern Europe, the Nordic region and the north of the UK in 2021 and 2022. Vigur has large numbers of migrating seabirds and waders so we remained vigilant for any unexplained bird deaths on the island. Thankfully, we did not observe anything that gave us cause for concern – but we remain cautious.

Each year brings new sights to Vigur – 2022 was notable for the number of eagles observed on the island and the frequency of the visits. They have been previously a rare sight in Ísafjarðardjúp. The number of humpback whales observed from the island was greater than expected and two families of orca also spent time around the island, both families had calves. One calf was first seen by a kayaker to the north of Vigur and we were very honoured that when the kayaker was invited to name the calf he chose the name 'Vigur'. We very much look forward to following Vigur's adventures in the future as sightings of him are reported.

Finally, a word of gratitude to all those who helped us complete the field campaign in 2022 – particularly David Pierre Milesi-Gaches who has been so instrumental in its establishment. Thank you for all your hard work to help shape Vigur into the place we all hope it will become.

Felicity Aston and Gísli Jónsson
Owners and Operational Managers of Vigur
December 2022

Contents

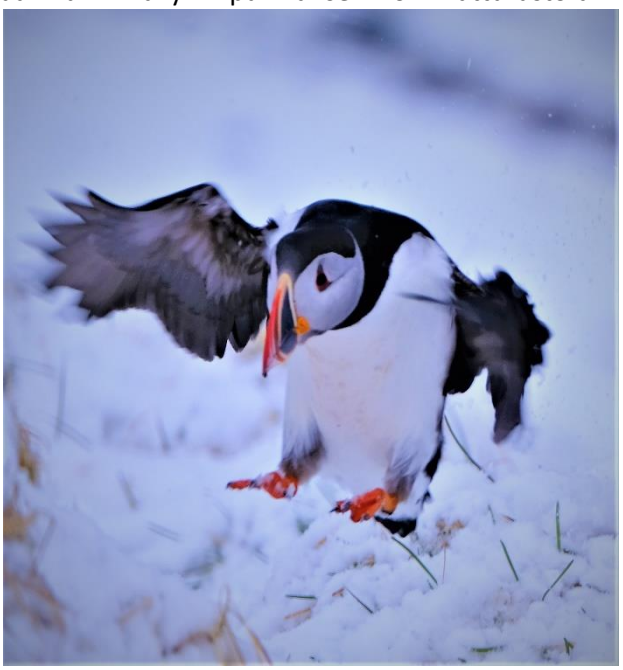
1. Bird Counts and Population Monitoring

We are delighted to congratulate David Milesi-Gaches and Alexandre Lhériau on the publication in the journal Bird Census News of the count of breeding seabirds in Vigur completed during the Vigur Island Research Campaign 2021. (See Appendix 1).

Following the methodology described in Milesi-Gaches and Lhériau (2022) a census of the black guillemot population was undertaken again in the summer of 2022. Deliberately, it was decided not to repeat the census of breeding Arctic terns for fear of the disturbance it would involve causing negative impact to the colony.

A small team from Náttúrustofa Vestfjarða (NAVE) were hosted overnight on Vigur in order to complete a count of black guillemot around the island. It was found that more time and possibly more observers were needed and a plan for a NAVE team to return in 2023 is already underway.

We were also pleased to once again host the annual 'Puffin Rally'. Erpur Hansen from Náttúrustofa Súðurlands and his team of volunteers visited us once in June and again in July. This year they not only observed the 'occupancy' percentage (the number of burrows in the colony with an egg) and successful hatching of pufflings for continued monitoring of the colony population, but also collected blood samples for additional DNA studies.



The occupancy rate observed in June was significantly lower than that observed the previous year. This was attributed to disruption caused by late snowfall in May and early June. The number of pufflings observed during the Puffin Rally's second visit was not significantly different to previous years.

A daily record of wildlife observed on and from Vigur was maintained through May, June, July, August and September in 2022. These records indicated 47 species of birds present on Vigur, 4 species of whale observed in the waters around Vigur and 2 species of seal (harbour seal and grey seal) observed throughout the summer period.

2. Beach clean ups

Removal of unwanted waste on the beaches of Vigur happened informally in a variety of ways throughout the year. It varied from one or two individuals picking up any marine litter observed on the beach while out walking, to the opportunistic collection of waste during the eiderdown harvest when the island is systematically traversed by small teams, to the collection of larger waste by boat involving a planned journey and team cooperation specifically for the purpose.

Items and / or materials collected during clean ups that produced a larger volume were photographed together to form a rudimentary record. By far the most common source of unwanted waste found and collected was historical waste from the island due to the inadequate waste management practises of the past – for example, items dumped into the sea which are then returned to the shore over time. Items found washed up on the beach included computer hard drives, domestic furnishings and vehicle parts. The number of items identified as fragments of fishing equipment, such as nets and buoys, was also high as was the number of plastic items such as sealed plastic drinking bottles, food containers, synthetic clothing and unidentifiable plastic fragments.

Items and material gathered from beach clean ups are sorted into different material types and taken to the mainland to be recycled or disposed of appropriately. Some of the more unusual items have been kept to form a visitor display for the purposes of awareness and engagement.

Waste management on Vigur has been significantly improved. No waste is deposited into the sea or burned on the island. All waste is now removed to the mainland for appropriate disposal. In addition, some of the measures introduced to reduce waste generated on the island include; composting food waste, asking cruise ship companies sending groups of visitors to the island not to bring bottled water for their guests onto the island (we offer free spring water from the island instead), napkins are no longer provided by default in the café and visiting kayakers have been asked to take away any waste they bring to Vigur.

3. Eider Ducks

The annual eiderdown harvest on Vigur was completed from 2nd June until 14th June. During the harvest the island is split into sections and the nests of the common eider in each section are visited so that the eiderdown in the nests can be collected by hand when appropriate.

This year, radios were carried by those collecting the eiderdown so that details of each nest could be recorded. Information reported included number of eggs in the nest, number of ducklings if any, if the nest was already abandoned after hatching of the clutch, whether there were signs of predation and/or any plastic found in the nest. The eiderdown collected from each section of the island was weighed so that an estimate of the average weight of down in each nest could be calculated.

In 2022, 2803 nests were visited during the harvest period and 8289 eggs were recorded. The average number of eggs per nest was 3.5 eggs. Some 15% of the nests visited either showed signs of having been predated or were empty after successful hatching of the clutch and the ducklings having already left the nest. We found that we were not able to distinguish with confidence between the two scenarios as the wind removes eiderdown from empty nests in a way that resembles a predated nest. We also noted in the record that the number of possibly predated nests increased in sections of the island that were further from inhabited buildings and places of human activity.

Plastic and/or synthetic fibres were found incorporated into 8 separate nests, all located in sections of the southern part of the island where the buildings are located as well as the majority of human activity takes place. This suggests that the plastic found in the nests originated from the island. This has prompted changes to be made to waste management routines on Vigur to ensure a reduction in any plastic waste escaping into the environment. Waste is now secured inside purpose-made containers or within a designated building in order to prevent any items being blown around the island.

Somateria spectabilis

King eider were spotted on the island during the eiderdown harvest as they have been in previous years. Three male king eiders were observed in the same location together, apparently in breeding pairs with female common eider which were incubating. King eider males were spotted in several other locations around the island at various times but as it was difficult to know if we were seeing the same or different individuals we didn't include these observations in the record. The king eider males were most often seen together with common eider females. No king eider females were observed.

4. Black Guillemot

Black guillemot have become an ever more dominant feature of Vigur birdlife. The population is most dense around the main buildings at the southern end of the island where many nesting sites can be found. As well as nesting in stone walls and rock piles, the black guillemot also nest and raise chicks under wooden decking, around farm equipment and among cultivated rhubarb. It has been suggested that this is happening due to a scarcity of appropriate nesting sites.

College student, Max Zeltsar, was invited to carry out an initial feasibility project to investigate the construction of various designs of artificial nesting sites for black guillemot. His report on the project is attached as Appendix 2. Three different designs of artificial nesting sites were constructed on the island with the intention of monitoring the success of each design in the 2023 breeding season.

5. Seals

During the 2021 Vigur Research Campaign, independent researchers, David Milesi-Gaches and Alexandre Lhériau completed some 20+ hours of seal observations from the island. The observations were conducted from lookout points with views over the skerries to the south of the island which are popular haul-outs for harbour seals and grey seals. They recorded the observed response of seals to human activity on the island, particularly tourism.

Several measures were implemented during the 2022 summer season to mitigate any potentially negative impacts of tourism on the seal population. An immediate and positive effect was observed in the response of the seals.

Seal Fence

It was identified that there was an issue with tourists arriving on Vigur wandering immediately onto the beaches closest to regularly used seal haul out areas. Wooden posts connected by a chain were positioned to form a barrier between the tourist arrival point (the landward end of the pier) and the beach. This achieved immediate success in preventing the problematic movement of people onto the beach and enabled an opportunity for the risk to seals to be explained to visitors.

Seal Poster

A poster introducing the two seal species regularly observed on and around Vigur was created in collaboration with David Milesi-Gaches and Alexandre Lhériau. (See Appendix 3). The poster was displayed both on the beach close to the seal fence and in the down processing house which forms part of the regular visitor tour route around the island. The poster includes the guidelines on recommended behaviour around seals issued by the Icelandic Seal Centre. We found that most tourists visiting the island, once they knew of the risk to seals and the ways in which they could reduce the impact of their visit, were happy to follow the recommendations and were pleased to be given the information.

Some 40+ hours of seal observations were undertaken from Vigur throughout the 2022 summer season in order to assess the effect of these mitigation measures and others on the impact of tourism on harbour and grey seals. It is intended that the findings will be published by the researchers.

6. Flora and Herbarium

Visiting Marine Biology and Environmental Science graduates, Sally Herzig and Julia Mast began the long process of collecting and identifying the various species of flowering plants and grasses found on Vigur.

They split the island into 8 different plots that had the approximate dimensions of 100 m x 200 m. Within each plot 4 randomly generated coordinates were selected to be sampled along with the centre point of the plot. This gave a total of 40 sample points across the island.

A 1 m by 1 m quadrat was placed over each sample point. Within each quadrat the two observers identified any species found and recorded the percentage of the area within the quadrat that each identified species covered. The survey of all 40 sample points were completed within June, July and August 2022.

A Shannon diversity index was calculated and produced a result of 3.11 which might indicate that Vigur has a lot of species diversity. While some identified species were found to have an almost universal distribution across the island, others were only found in a single location. However, the proper identification of several species, particularly grasses, was found to be more challenging than expected. As well as reference books and digital sources, the knowledge of online specialist interest groups with expertise in Icelandic flora was recruited – but often found to have mixed success.

An herbarium was established and by the end of the season 46 different samples had been collected, identified, pressed and catalogued into 19 different families and groups. It became clear that the task of compiling a complete census and herbarium of plantlife on Vigur is too great for a single season but the work completed in 2022 can be seen as a good foundation on which future work can build. The intention is to develop this project into a baseline study and continuing record of flora diversity and distribution.

Appendix 1: Census of breeding seabirds in Vigur Island, Westfjords, Iceland in 2021. Bird Census News 2022, 35/1–2: 10–20. David Milesi-Gaches and Alexandre Lhériau.

Census of breeding seabirds in Vigur Island, Westfjords, Iceland in 2021

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Abstract. The Vigur Island bird census focused on the main bird species found on the island: Black Guillemots *Cepphus grylle*, Northern Fulmars *Fulmarus glacialis*, Great Cormorants *Phalacrocorax carbo*, gulls *Larus* sp., Eurasian Oystercatchers *Haematopus ostralegus*, and Arctic Terns *Sterna paradisaea*. The Arctic Tern population was estimated by counting nests, using a transect line method. Due to the hatching of the eggs, the survey had to be stopped and only 60% of the colony area was covered. The results show that in summer 2021, Vigur hosted 1092 ± 246 SD Black Guillemot individuals, 28 ± 8 SD oystercatchers, 19 ± 8 SD Cormorants, 120 ± 34 SD Fulmars, and 58 ± 20 SD European Herring Gulls *Larus argentatus* and Lesser Black-backed Gulls *Larus fuscus*. We counted 440 occupied Arctic Tern nests, leading to an estimation of 880 breeding adults.

Introduction

Located just South of the Arctic circle, Vigur Island is a famous Icelandic touristic place in the Westfjords, known for being home to several iconic bird species, such as the Atlantic Puffin *Fratercula arctica* (hereafter Puffin), the Black Guillemot *Cepphus grylle* or the Common Eider *Somateria mollissima* (hereafter Eider). Famous for being home to 100,000 Puffins (Hansen 2019), a colony of Black Guillemots, and nesting Arctic Terns *Sterna paradisaea.* Vigur also welcomes marine mammals. Indeed, both Harbour Seals *Phoca vitulina* and Grey Seals *Halichoerus grypus*, come to rest in the southern part of the island. Vigur is also part of the maritime heritage with one of Iceland's oldest windmills, associated buildings, and a working boat (Fig. 1). Moreover, the island has a long tradition of wild Eider farming (circa 5,000 breeding pairs). Owned by a family living there year-round, this private island can be visited both for its historical heritage and for its abundant wildlife. The island attracts many tourists, photographers, and nature lovers from all around the world, mostly from June to September (BirdLife International and Directorate-General for Environment, European Commission 2015; Vigur Island 2021). With an average of 100 and up to 200 tourists visiting the island daily through several boat rotations, birds are likely to suffer from extensive disturbances.

Despite the efforts of the local guides to keep cohesive groups, visitors often find themselves scattered in several patches, progressing at different speeds, as tourists often have heterogeneous physical conditions (Fig. 2). This can be of particular concern when visitors enter the tern colony, thereby disturbing both terns and other bird species for several tens of minutes, often exceeding half an hour. This duration directly clashes with Walsh et al. (1995) recommendation that the disturbance should not exceed 20 min. Even though different tours can be proposed to visitors, the average journey consists of boats coming from the nearby city of Ísafjörður, with groups of 10 to 60 tourists (Figs 1–2). With a pier located in the southeast, visitors immediately see seals, at low tide,

before visiting the eiderdown workshop. They usually follow a guided tour during which they walk alongside the coast. There, they can observe birds breeding in Vigur. Between May and August, an Arctic Tern colony nests close to the buildings in the southern part of the island (Fig. 3). Arctic Terns are a highly territorial species, which does not hesitate to attack predators or humans coming close to the nests. Visitors are given a wooden stick they hold above their head to avoid any direct attack from terns, while they walk on the pathway (Fig. 2). Finally, they are invited to have coffee, to taste rhubarb jam, and traditional Icelandic sweets like happy marriage cake (Hjónabandssæla) made on site.

Depending on their condition and the time of the visit, some visitors (e.g., groups of photographers, scientists, etc.) are welcomed to 'free roam' on the island, where they can see Northern Fulmars *Fulmarus glacialis* (hereafter Fulmar), Great Cormorants *Phalacrocorax carbo* (hereafter Cormorants), gulls, Puffins, and Black Guillemots in wild landscapes. Two guest houses also give visitors the possibility to stay overnight. With a length of 2 km for a width of only 400m, mostly rocky shores, and an important cliff in the north of the island, Vigur is a place where different species cohabit close to each other, including the vicinity of humans, in a context of tourism. Hence, monitoring bird populations is of critical importance, to evaluate the condition of each colony and develop appropriate

Fig. 1. Most used trio of touristic circuits in Vigur Island, Iceland.

management and conservation strategies to avoid stress linked to tourism activity.

This paper highlights the first census of this kind in Vigur Island. During Summer 2021, populations of the following bird species were censused: Black Guillemot, Eurasian Oystercatcher *Haematopus ostralegus* (hereafter Oystercatcher), Fulmar, Cormorant, European Herring Gull *Larus argentatus* and Lesser Black-backed Gull *Larus fuscus*. Three species of these are nationally threatened according to IUCN Red List criteria: Puffin (Critically endangered, CR), Black Guillemot (Endangered, EN) and Arctic Tern (Vulnerable, VU) (Fuglavernd 2021) and three species are also threatened in Europe: Fulmar (VU), Oystercatcher (VU) and Puffin (EN) (BirdLife International 2021). Linked to the eiderdown harvesting activity, Eider were not counted. The aims of this research were:

1) to estimate population sizes of different bird species in Vigur Island for researchers, policy-makers, and conservation stakeholders, as well
2) to test monitoring methods in the specific as a larger audience; touristic context of Vigur.

Methods

Arctic Tern census

The Arctic Tern colony population was estimated through a survey using the transect line method (Steinkamp et al. 2003; Sutherland et al. 2004). To properly assess the maximal extent of the colony on Vigur Island, two complete rounds of the perceived area were done along the shore while taking the GPS coordinates of the isolated nests. The GPS position of the farthest tern taking off during human disturbance was recorded (Fig. 4, Table 1). Transects were defined according to topography and safety (e.g., rocks, Puffin holes, and open galleries), paying special attention not to disturb terns beyond an acceptable threshold of 20 minutes (Walsh et al. 1995). Consequently, we organised the survey into several short sessions rather than a single long visit. Particular attention has been paid to birds' eventual signs of stress. Similarly, work has been avoided in poor weather conditions such as wind, since high winds make it difficult for terns to return to their nest (Walsh et al. 1995). Moreover, the hatching season began during the counting process, increasing the risk of hurting new-born chicks.

Arctic Tern nests and eggs were counted over six days from the 25th of June to the 29th of June 2021, and the 1st of July. The two-day gap between the 29th and 1st is due to exceptionally strong winds, causing the adults to sometimes take 10 minutes to get back to their nest.

The time at which eggs were counted was defined in accordance with the touristic schedule, both to protect birds and tourists (Fig. 2). As much as possible, we tried not to have transect lines crossing pathways when tourists were on the island.

The transect line method consists of dividing the research area into units where counting is performed using mobile lines to avoid re-counting areas. 30 units of 20 × 30 metres were defined, starting on the 30m borders of the transect and dividing it into 6 meter wide corridors (Fig. 5), ob- servers counted half of the sampled area. Joining at the middle, the two observers exchanged their respective counts and finished the transect by verifying the other's number. This, to double check results and decrease observers' biases (Fig. 5) (Voříšek et al. 2008).

Due to access difficulties in some parts of the colony, and after having found many hatched eggs and chicks, we were unable to survey the whole colony. Consequently, we decided to analyse our data to see if an estimation of the total population was possible.

A correlation test was done between the cumulated number of nests and the area covered. The correlation was calculated using a generalised model approach in R (version 4.1.0; R Core Team 2021), plotting the cumulative number of nests against the sampled area, and

Fig. 2. Tourists, holding flag sticks, walking through the Arctic Tern *Sterna paradisaea* colony, thus generating disturbance in Vigur Island, Iceland.

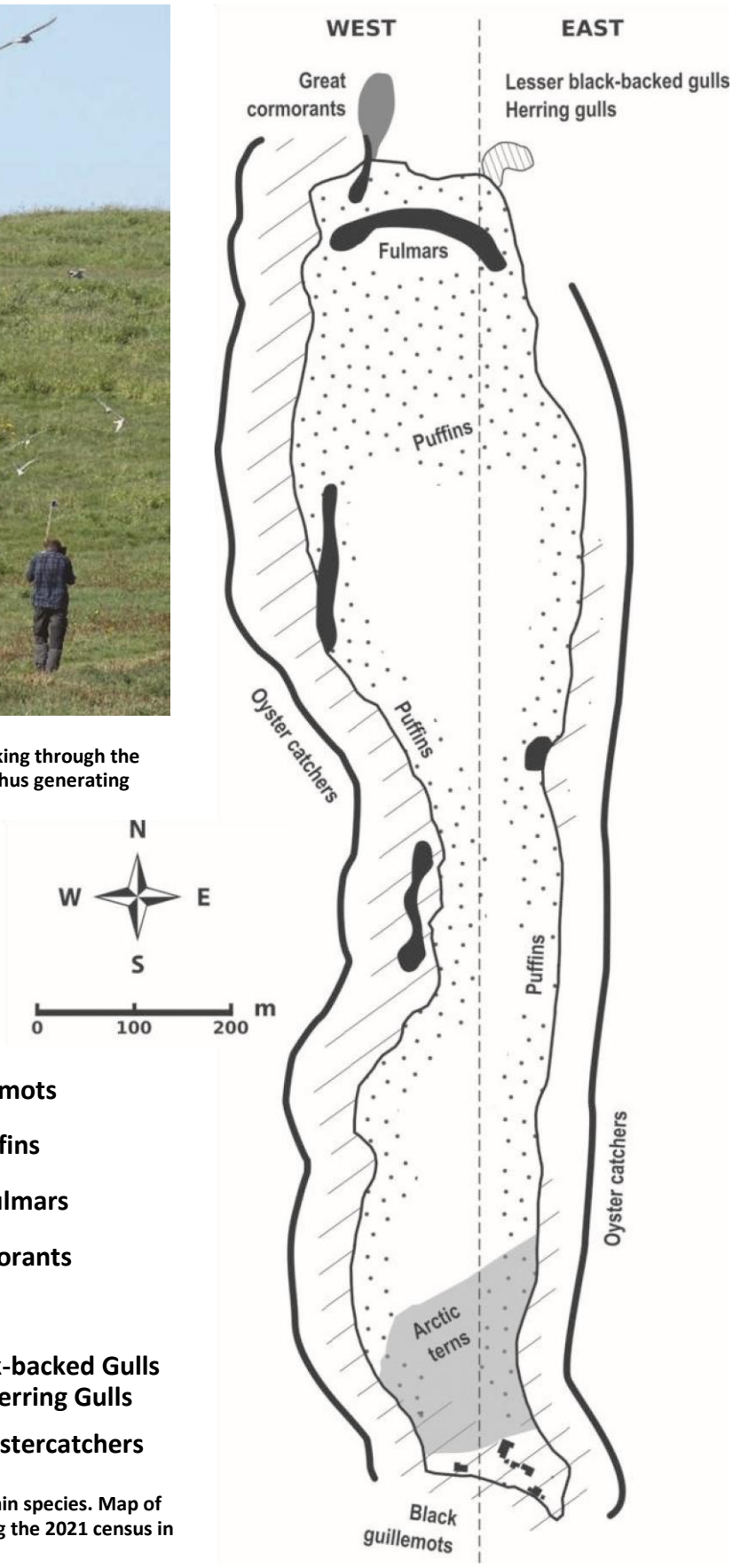

Fig. 3. Schematic distribution of the main species. Map of the seabird populations counted during the 2021 census in Vigur Island, Iceland.

Fig. 4. Arctic Tern *Sterna paradisaea* colony area and sampled units in Vigur Island, Iceland.

Table 1. GPS coordinates of Arctic Tern *Sterna paradisaea* nests* defining the colony boundaries in Vigur Island in 2021.

Outer nest	Latitude	Longitude
1	66.050163	–22.827526
2	66.049485	–22.827735
3	66.048935	–22.828074
4	66.048657	–22.827967
5	66.048389	–22.827849
6	66.047944	–22.827315
7	66.048051	–22.828070
8	66.048017	–22.828503
9	66.047797	–22.829916
10	66.047709	–22.830076
11	66.047905	–22.830660
12	66.048745	–22.831522
13	66.049508	–22.829945

* Outer nests are nests defining the limits of the Arctic tern colony. Three remote nests were also observed out of the area, with no apparent connection to the colony.

using the Kendall correlation coefficient. We used Kendall's τ as it is non-parametric, hence fitting the relatively low number of points we had, and our assumption that we did not cover the full extent of the colony. The total number of nests for the whole colony was then estimated using the equation obtained, as well as using the mean density (nests per square metre) multiplied by the maximum estimated area. This created a range estimate of the population size. Heatmaps of the census were obtained using the software QGis version 3.10.14 (Fig. 6).

Other bird species census

Prior to any counting, we performed two visits around the island to locate important nesting and resting spots, identify field specificities, potential difficulties and finalise the design of our counting plan. Therefore, we decided to split counting sessions into two types: sessions dedicated solely to guillemots and sessions dedicated to the five other species of birds. Considering an Arctic Tern colony nesting close to the buildings, and the need to lower potential disturbance, we started both sessions from the southeast, towards the northeast; consequently, we walked at the edge, and in places inside of the tern colony, at the beginning and at the end of the session (Fig. 3).

Observations were made using Observer Focus TM 10 × 34 binoculars and by sound if validated by the sighting. The 'double-observer' approach was used to account for detectability (Sutherland 2006; Voříšek et al. 2008). A total of five counting sessions were conducted around Vigur for Black Guillemots, Oystercatchers, Gulls, Cormorants, and Fulmars by two observers together at the same time.

Due to difficulties in species recognition all gull species were combined.

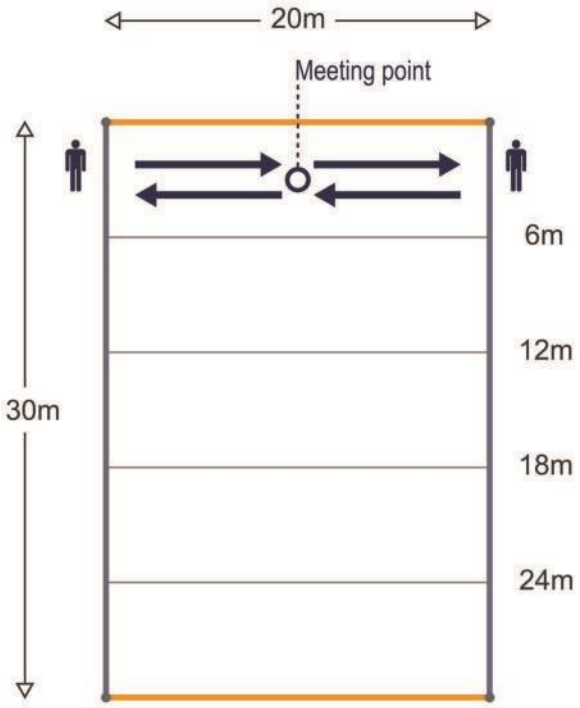

Fig. 5. Double counting by transect method used in Vigur Island, Iceland.

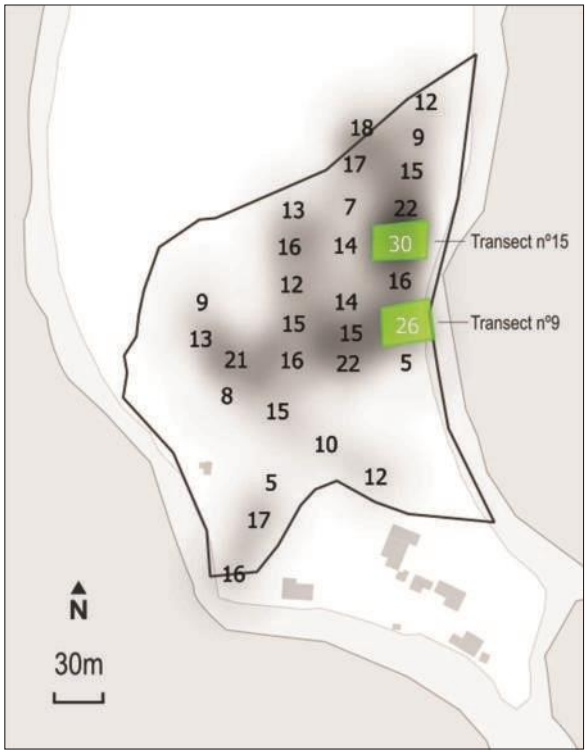

Fig. 6. Heatmap figure presenting the number of nests in the colony of Arctic Terns *Sterna paradisaea* in Vigur Island.

Black Guillemot census

Black Guillemots were counted around the island (Fig. 7). We also decided to adapt our methods and the time of counting according to the sun to help species identification. Indeed, in the morning, the sea appeared very bright due to reflectance, preventing us from distinguishing, for example, Black Guillemots from Puffins. Counts were done on the western side of the island in the mornings and on the eastern side in the afternoons. Likewise, fieldwork was adapted according to the weather or tourist groups visiting the island, considering that Black Guillemots can be found close to or on buildings that are visited. Results from counting points were recorded for later analysis and comparison between observers (Nichols et al. 2000; Sutherland 2004). Prior to mixing the data, the collected data were analysed using R to detect any bias from the observers. To do so, datasets from both observers were compared using a Wilcoxon-Mann-Whitney test. Assuming that the results of the previous test were non-significant, data were combined (2 × 5 sessions, accounting for 10 sessions) to estimate the mean and standard deviation of each species population. The results were then displayed using QGis.

Results

The Puffin and the Black Guillemot are distributed around the island in great numbers, with Puffins getting as far inland as Borg, while Black Guillemots stay along the shore. The census of Arctic Terns on the island of Vigur showed a clear concentration of the population around human structures, especially the so-called 'pump house' (transect n. 9, Fig. 4). However, the colony covers most of the southern area of the island, and up to its middle, both inland and along the shore. Oystercatchers were found to use the whole island; they were distributed in pairs around the island, stationed mainly along the coast. About 28 Oystercatcher individuals were counted and are believed to nest in Vigur. However, the GPS positions of nests were not recorded. At least 58 gulls were found resting (no nesting observed) on the far northeastern point of the island, in apparently clearly defined spots. Up to 19 Cormorants were recorded at the far northwestern spot of the island. The population of Fulmars (around 120 individuals) was divided into three areas: the north face of Borg, some specific cliffs along the western shore, and one unique spot of 12 individuals on the eastern side (Fig. 3).

Arctic terns

Figure 4 presents the Arctic Tern colony. Three remote nests were also observed outside of the area, with no apparent connection to the colony (Fig. 4, Table 1). We counted 440 nests from the 30 sampling units, which represent 18,000m² . These nests included 722 eggs and 90 chicks. This represents a density of 0.0244 nests per square metre (Table 2) and a mean number of eggs per nest of 1.8. With 440 occupied nests, it is reasonable to estimate that this corresponds to a total of 880 breeding adults (Perrins 2003).

Total	440	NA	722	90

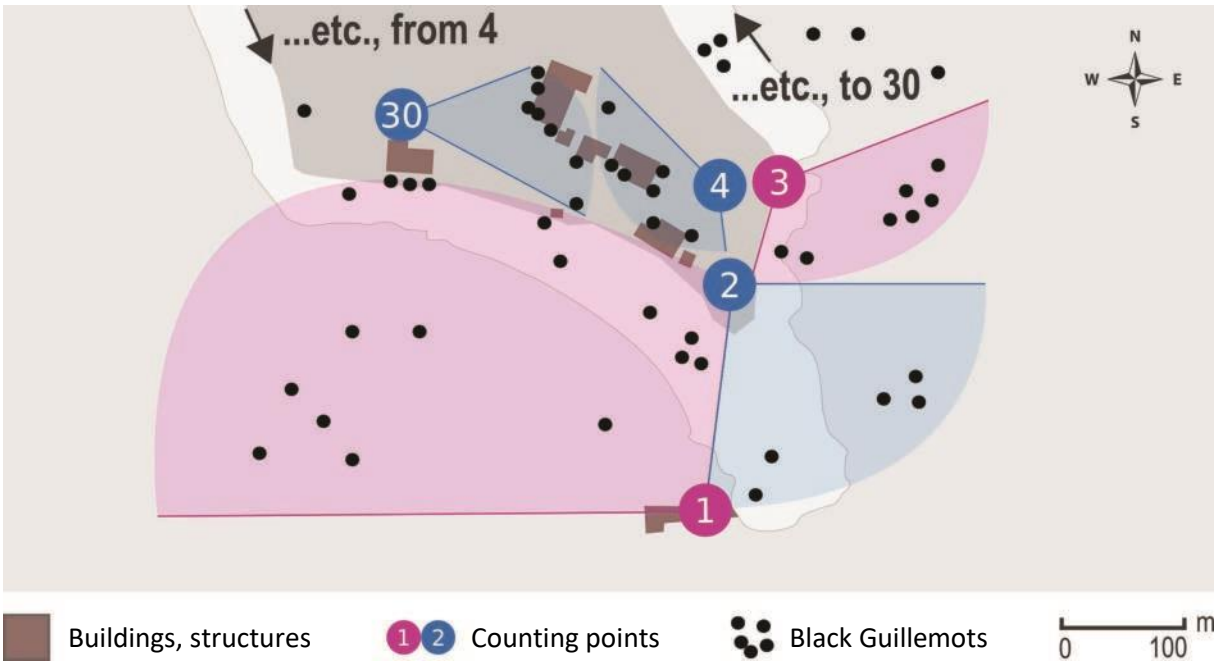

Fig. 7. Schematic illustration showing examples of the counting point principle used for the Black Guillemot *Cepphus grylle* census in Vigur Island.

Descriptive statistics: Arctic Terns

The correlation between the cumulated number of nests and the area covered was verified using Kendall's τ ($P < 0.001$), and was found to be a linear correlation like so:

Cumulated number of nests =
–6.467 + 0.026 * Covered area

Based on this equation, on the mean density of nests per square metre, and considering a total colony area estimation of 29850 m², the total number of nests on Vigur Island could be estimated between 730 and 769.

Table 2. Summary table of Arctic tern *Sterna paradisaea* census in Vigur Island in 2021.

Per unit	Nests	Nest density by m²	Eggs	Chicks
Minimum	5	0.0083	7	0
Mean	14.67	0.0244	24.07	3
Maximum	30	0.0500	48	9
Standard deviation	5.71	0.0095	9.81	2.51

This represents between 1460 and 1538 breeding adults during the breeding season on Vigur.

Owing to the fragmented habitat of the tern colony, leading to not evenly distributed nests, we were expecting a Standard Poisson distribution, characteristic of herd behaviour (Heinänen et al. 2008). The heat map (Fig. 6) illustrates this behaviour as the highest concentration of nests is in transects 9 and 15, associated with a more barren near coast environment (n° 15) and the pumphouse proximity (n° 9). Thus, showing gregarious nesting.

Black Guillemots

The census, made of five counting sessions, showed that 1092 ± 246 (SD) Black Guillemot individuals were present around Vigur. Table 3 presents the results of the five sessions for the two observers (A and B). The two sets of observations were proved similar by a Wilcoxon-Mann-Whitney test ($P = 0.7916$), allowing us to use all 5 counting sessions in the calculation.

Table 3. Results of the breeding Black Guillemot *Cepphus grylle* individual counts in Vigur Island in 2021.

Counting point	Session 1		Session 2		Session 3		Session 4		Session 5	
	4/07		9/07		10/07		13/07		15/07	
	A	B	A	B	A	B	A	B	A	B
1	30	30	17	19	54	44	160	151	179	194
2	16	29	11	12	19	15	60	70	45	46
3	39	40	2	2	19	19	28	21	22	24
4	67	88	5	5	16	16	12	17	32	28
5	40	40	51	47	86	90	16	18	25	25
6	52	44	2	0	38	40	32	31	24	28
7	30	43	17	23	23	20	42	46	29	60
8	57	65	6	5	17	14	28	27	29	33
9	54	41	2	0	30	33	23	22	14	13
10	15	17	2	3	60	53	26	27	22	19
11	47	47	6	6	16	17	11	13	17	14
12	15	15	0	0	39	35	67	74	57	57
13	10	10	4	4	33	35	33	31	64	62
14	21	20	12	13	35	37	14	14	20	22
15	15	28	23	28	53	46	38	38	56	59
16	2	2	28	31	47	45	27	27	81	79
17	53	100	12	13	23	22	32	30	24	24
18	20	30	0	0	30	33	53	59	33	26
19	52	52	1	1	21	26	21	21	32	33
20	14	17	1	1	33	30	22	24	11	13
21	6	9	1	0	44	35	18	19	24	23
22	0	0	0	0	17	19	28	27	19	20
23	0	0	1	0	19	17	19	18	65	62
24	4	4	77	68	33	37	19	17	28	31
25	11	11	53	43	46	45	38	35	65	63
26	5	5	85	96	157	171	35	34	25	28
27	15	15	86	87	133	126	34	32	13	13
28	24	24	187	222	44	48	62	65	10	12
29	38	40	115	121	26	26	33	33	73	77
30	14	5	45	47	195	205	85	82	82	80
Total	766	871	852	897	1406	1399	1116	1123	1220	1268
Mean/session	819		875		1403		1120		1244	
Mean	1092 ± 246									

Other bird species

The remaining four species were also counted in five sessions. The census showed that 120 ± 34 (SD) Fulmar individuals, 28 ± 8 (SD) Oystercatchers, 58 ± 20 (SD) gulls, and 19 ± 8 (SD) Cormorants were present on and around the island (see Table 4).

Discussion

Arctic Terns

The Arctic Tern density of 0.0244 nests per square metre with a mean number of 1.8 eggs per nest was found to be slightly higher than in study of Mallory et al. (2017) in the Canadian Arctic. Vigur's topography, leading to inaccessible parts of the tern colony, windy weather, and the daily presence of tourists made the complete survey of the colony by the transect line method impossible in the time allotted to us. Sampling 100% of the area would require more time, waiting for good weather conditions, or disturbing birds beyond 20 minutes. Despite having two complete weeks allocated to this study, we were only able to work six days in the field on terns. Allocating more time would inevitably have led beyond the nesting and hatching period. Consequently, the transect line method is not an ideal methodology to quickly survey the population of Arctic Terns in Vigur. However, this method is totally suitable for comparative monitoring of the tern population. We recommend collecting the GPS coordinates of the colony area on a yearly basis to monitor the size of the colony area and to regularly sample the number of nests and eggs (e.g., three to five transects a year). Although such a monitoring scheme cannot provide an absolute comparison, it can define a trend of the tern population in Vigur, particularly if the same rectangles are sampled (Fig. 6).

The results of the model show a linear correlation between the number of nests and the sampled area. Hence, we suspect that our results are still in the linear part of the logarithmic curve of the model defined by the above-mentioned linear correlation, and do not reflect the gregarious behaviour of the Arctic Tern (Heinänen et al. 2008), especially around human constructions. A more extended count of the Vigur colony would correct this model and make it more accurate, allowing us to estimate the total population of the colony from a sample, or at least to correct the number of nests counted in transects (Fig. 8). The estimate of the number of breeders could be improved by using the geographical extent of the colony and adding habitat parameters to the model. One of the major flaws in this model is that it considers the nests, hence counting only the breeders (Pomeroy et al. 2018) and excluding the non-breeder from the estimation of the population. We should stress that the model considers only nests and thus does not cover the non-breeding part of the population. Furthermore, we also lack information on hatching success and daily survival rates of the nests (Vigfusdottir 2012; Vigfusdottir et al. 2013). To reach an accurate and comprehensive population estimation, weather conditions, competition for food, predation, and behavioural responses to human disturbance should also be included in the modelling work (Syrová et al. 2020).

Table 4. Vigur seabird population census results.

Common name	Counted population (mean)	Standard deviation	Coefficient of variation
Eurasian Oystercatcher *Haematopus ostralegus*	28	8	28.5
Great Cormorant *Phalacrocorax carbo*	19	8	42.1
Northern Fulmar *Fulmarus glacialis*	120	34	28.3
Gulls *Larus* sp.	58	20	34.4

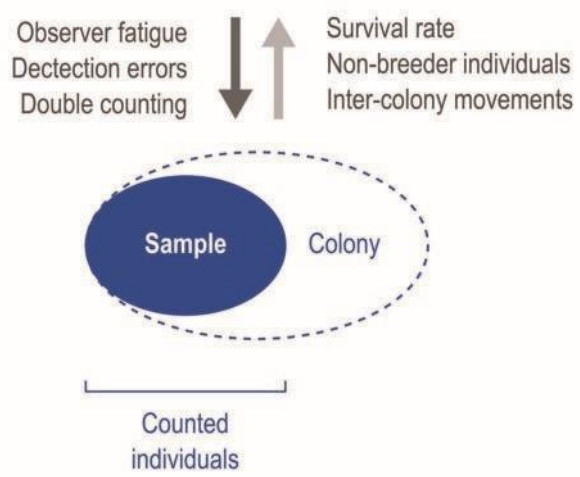

Fig. 8. Uncertainties impacting the Arctic Tern Sterna paradisaea census.

Excluding these parameters, as well as non-breeders, can lead to severe underestimation. Moreover, population studies in Greenland show that breeding dispersal between colonies is common (Egevang & Frederiksen 2011), highlighting the presence of birds changing colonies between years. Even though terns tend to return to their birth colony (Devlin et al. 2008; Perrins 2003), breeding dispersal will also influence the output of the population estimates. Hence, long-term monitoring of Vigur's bird populations is highly important, especially when evaluating the potential influence of daily tourism and eiderdown collection.

Other bird species

Black Guillemots' count was the only one being statistically analysed prior to mixing each observer's counts due to the sheer number of birds found notably at sea. Such a high number of Black Guillemots at several counting points didn't allow proper communication between the observers, thus increasing the risk of missing individuals. Our survey found more than twice as many Black

Guillemots than reported in the earlier survey conducted in 2000 (200 pairs or 400 individuals in 2000, this study 1092 ± 246 individuals) by the local research institute (Náttúrufræðistofnun Íslands, 2021a). This difference could be explained by different factors, among which the method used or the age of the last count (2000). Another explanation would be the population of Black Guillemots fleeing the observers while they moved forward, thus resulting in double counts during this survey. However, since Black Guillemots were counted when on the shore most of the time (i.e., near their nest), this is highly unlikely. Despite being found at sea on different belts, with Puffins usually the farthest, followed by Common Eiders, Black Guillemots were sometimes hard to identify where the belts overlapped. Cormorants and Fulmars were counted at their resting spots, making the communication quick and accurate, leading to equal counts between the observers. Gulls and Oystercatchers, being vocal in the presence of humans, were easy to spot using both hearing and visual perception, allowing equal counts as well.

For Puffins, binocular counting led to unusable results. Puffins were too numerous all around the island to perform an accurate, reliable, and relevant population estimation, regardless of the method used. Attempts to count birds from photographs led to similar results, with poorly identifiable and distinguishable puffins among other birds, especially Black Guillemots when at sea. Furthermore, they are estimated to be around 30,000 pairs according to Náttúrufræðistofnun Íslands (Icelandic Institute of Natural History IINH) giving about 100,000 birds, including non-breeders (Hansen 2019). Other methods based on the number of burrows present in Vigur will be used to estimate the breeding population. To properly count Puffins, a photographic approach seems to be the most sensible, as it allows minimal disturbance and an ideal counting environment. The approach developed by Pérez-García (2012) was done precisely with this mindset and would be ideal to test in Vigur. Precaution should however be taken regarding this method, as it was developed to count birds while flying rather than resting at sea (e.g., Black Guillemots and Puffins). In addition to alcids, Arctic Terns and Eider (i.e. the most abundant species on the

island) could be counted by using this methodology. Using the IUCN global Red List classification, none of the species fall above the 'Near threatened NT' category, except puffin, deemed EN (IUCN, 2019, 2018a, 2018b, 2018c, 2018d, 2018e, 2018f). Things change drastically when the classification is done according to the European Red List, where most of the species are either EN or VU. Except the Lesser Blackbacked Gull and Black Guillemots, categorised as LC (BirdLife International 2021). Finally, at the Icelandic level, the image gets grimmer as only the Cormorant stays at the LC level. All the others are VU at best, with the Puffin being the highest at 'Critically Endangered CE'. The lack of data on the state of the gull populations in Iceland puts them de facto in the 'Data Deficient DD' category (Náttúrufræðistofnun Íslands, 2021b, 2021a). The Red list classifications of the breeding species in Vigur highlights that surveys like this one are needed to understand and assess status of seabird populations around Iceland. It then remains important to monitor wildlife in the case of a place like Vigur Island, which is a keystone for both conservation and local tourism.

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Appendix 2: Use of Artificial Nesting Sites to Aid and Study the Nesting of Black Guillemots (Cepphus grylle) on Vigur Island in Iceland. A report by Max Zeltsar. February 2023.

Use of Artificial Nesting Sites to Aid and Study the Nesting of Black Guillemots (*Cepphus grylle)* on Vigur Island in Iceland

Max Zeltsar

February 25th, 2023

Introduction:

Black Guillemots (Cepphus grylle) are small seabirds who belong to the auk family which consists of species such as puffins, murrelets, guillemots, and razorbills. Black Guillemots are the smallest type of guillemot and unlike other guillemots and many other seabirds, they do not usually form nesting colonies (Petersen 1981). With that said, in Arctic regions, Black Guillemots have sometimes been observed to form colonies with hundreds to thousands of breeding pairs (Cornell Lab of Ornithology 2019). Vigur Island in Iceland is the home to one of these colonies with an estimated 1,092 +/- 246 individuals and roughly 500 breeding pairs. The Black Guillemots on Vigur nest all around the island but have a high concentration of breeding pairs at the southern end of the island in close proximity to the houses and other buildings that make up the small settlement area. Black Guillemots are normally observed to take up nesting sites in rocky sheltered areas close to the ground; however, the Black Guillemots on Vigur have been observed as deviating from this behavior for some of the breeding pairs (Hof 2018). Some of the breeding pairs have been found to lay eggs under buildings, vehicles, human created piles of wood, under rhubarb plants, and other artificial and abnormal locations. While some of these locations seem to suit the adults and chicks well, there is a concern about the exposure to disturbance and destruction for some of the nests as well. Some of the locations that the Black Guillemots choose to nest is under unstable and nonstationary structures as well as in locations that experience frequent human disturbance and traffic. This has posed a concern for the health of the population for the survival rate of eggs and chicks, and overall pressure for the colony to find nesting spaces on Vigur and especially around the southern end of the island.

Aims:

The aims of this project are to create new artificial nesting sites for the Black Guillemots to try and give them a more natural option than some of the abnormal nesting sites they have previously chosen as well as to try and study their nesting behavior to see if they take preference to any particular type of artificial nesting sites.

Methodology:

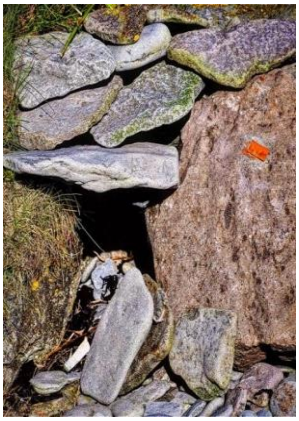
For this project, 70 new nesting sites were created around the southern end of the island. These 70 nesting sites can be classified into three types of designs as seen in Table 1. These nesting sites were placed around the southern end of the island with the wooden pallets and some of the conjoined stone piles being isolated in separate locations. The wooden pallets were placed on the western beach and 16 of the conjoined stone pile sites were placed on the eastern beach. The rest of the conjoined stone piles and the 10 isolated stone piles were placed on the southern point of Vigur. Each of these locations has been observed as having Black Guillemots nesting in proximity or being frequently spotted in those locations. The purpose in isolating these designs was to try to spread some of the population out and to see what kind of success rate they have separate from the other designs. All of the nesting sites are placed in close proximity to the sub population of the colony that nests near the settlement on the southern end of Vigur.

Table 1.

Design Name	**Number of Nesting Sites**	**Description**	**Intention**
Wooden Pallet (Figure 1 **A**)	24	Two wooden pallets stacked on top of each other. Each wooden pallet has dividers that separate the space into 4 nesting sites. Each nesting site within the pallet is closed on three sides with rocks on the bottom of the nesting sites. Palettes were constructed by nailing wood along the bottom side in order to seal the palettes on 3 sides while leaving one entrance for the guillemot. Palettes were then covered on top to be stacked to prevent leaking and water damage to nests. The palettes were standard shipping palettes as seen in Figure 1.	This design is meant to simulate the artificial spaces they take up under porches and houses but increase structural soundness and decrease disturbances.
Isolated Stone Pile (Figure 1 **B**)	14	Constructed by stacking stones between larger rocks in order to create a cavity of about 40 inches tall by 20 inches wide by 40 inches deep. Most piles have a narrower entrance in order to protect eggs from predation. All rocks for these sites were from stones washed along the beach and were all sourced on Vigur.	To simulate natural breeding locations and to see whether the Black Guillemots take preference to solitary breeding sites within their colony.
Conjoined Stone Pile (Figure 1 **C**)	32	Same method as the isolated stone piles except that each stone pile is stacked into a wall with other piles in order to create a stone wall. Nesting cavities are approximately the same size as those in the isolated stone piles. All rocks for these sites were from stones washed along the beach and were all sourced on Vigur.	To simulate natural breeding locations and to see whether the Black Guillemots take preference to more communal nesting sites within their colony.

A

B



C

*Figure 1. Images of all 3 types of nesting sites. Photo **A** features the palette design showing the 3 stacks of 2 palettes which are covered in rocks to both protect the palettes from weather and make the nesting sites appear more natural. **B** shows the isolated stone pile design with a protected entrance and an orange tag marking the location towards the right of the photo. The last photo (**C**) shows the stone wall of conjoined nesting sites where some of the cavities are visible especially towards the right of the frame. All photos were taken by Felicity Aston.*

Maps:

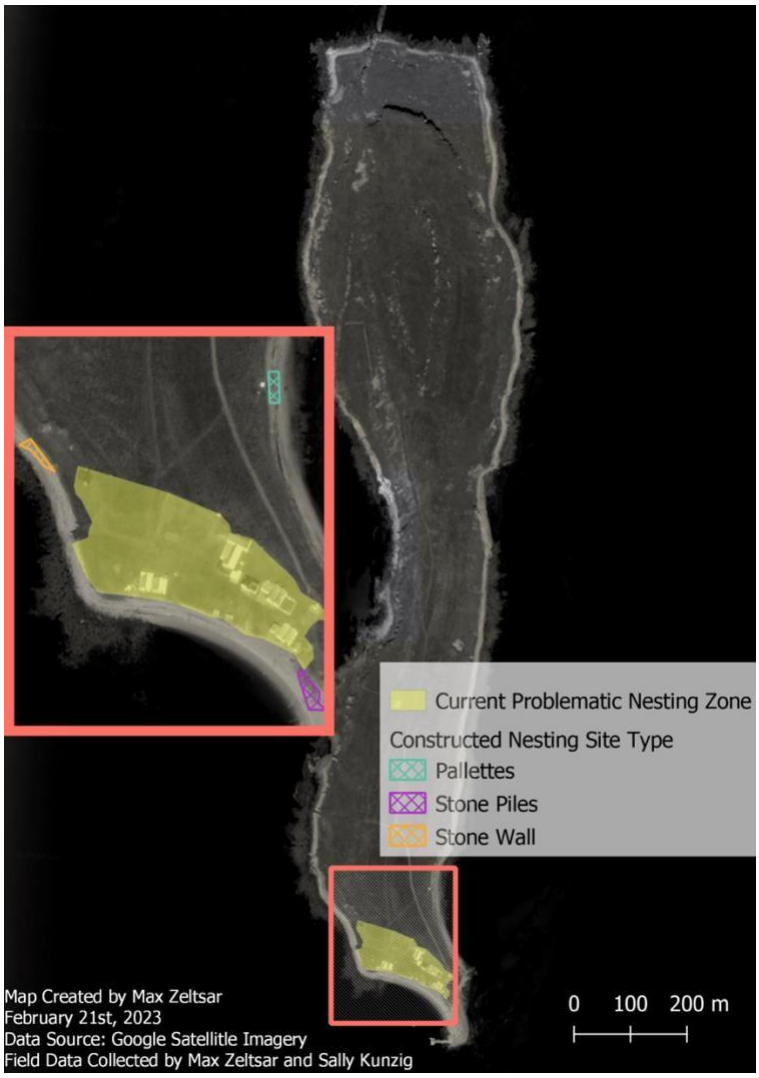


Figure 2. A map of the current "Problematic Nesting Zone" for Black Guillemots. This area is subjected to heavy human traffic and is also the location where Black Guillemots can be found nesting under houses, rhubarb plants, and other abnormal locations referenced in the ***Introduction****. This zone is what was considered in deciding the location of the constructed nesting sites referenced in Figures 3 and 4. On the left central side of the map is a zoomed in image of the problematic nesting zones as well the zones where artificial sites were constructed for comparison. This map was created in QGIS 3.22 by Max Zeltsar with GPS data from Max Zeltsar and Sally Kunzig and Google Satellite Imagery.*

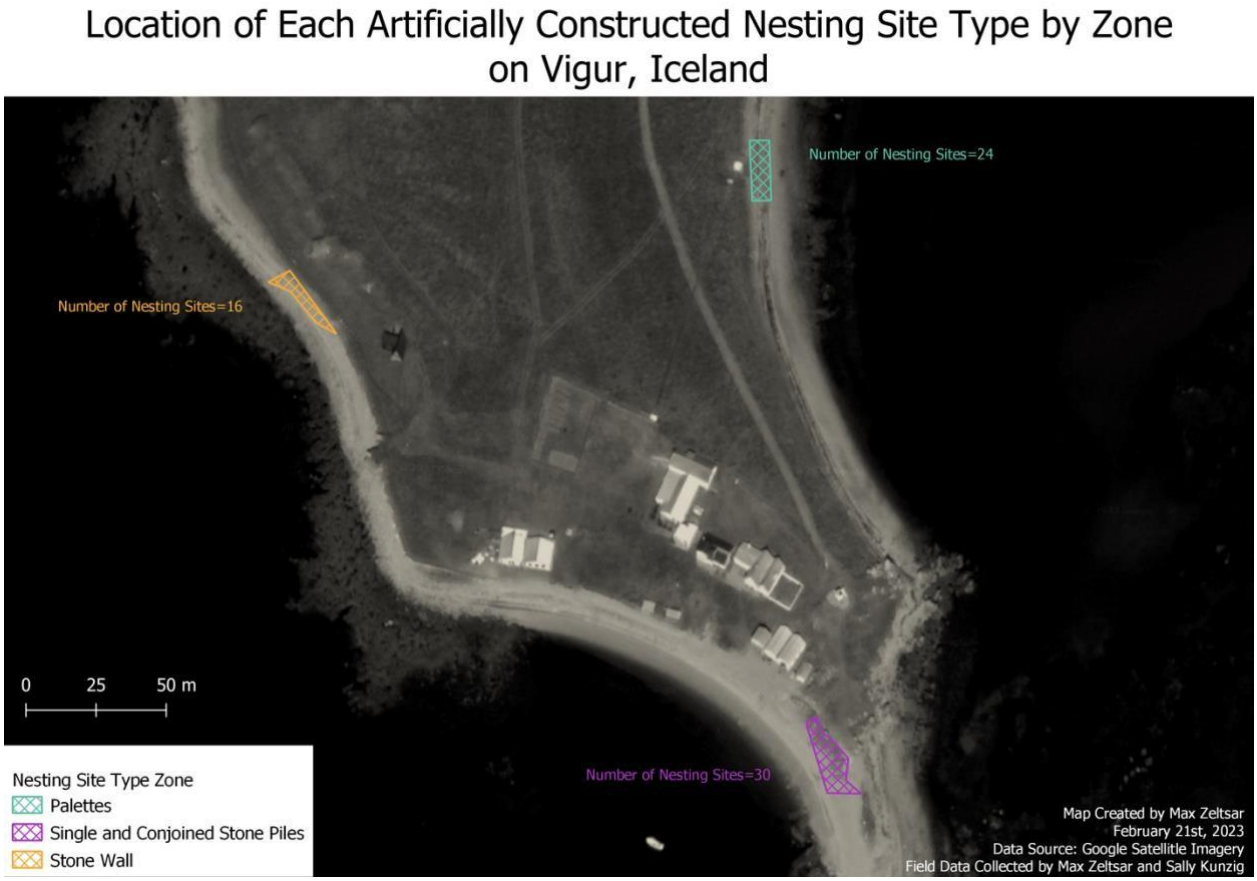


Figure 3. This is a look into the specific location of constructed nesting sites based on the type of nesting site that was constructed. The pink "Stone Wall" zone located in the upper right-hand side of the map represents the stone wall described as ***C*** *in Figure 1. The constructed palettes (Figure 1,* ***A)*** *were placed on the western coast of the island as seen in the turquoise "Palettes" zone in the upper central area of the map. Lastly the individual stone piles and conjoined stone piles (Figure 1,* ***B)*** *are located on the southern coast of the island represented in the purple "Stone Piles" zone. The buildings on the island are also visible on the map as a reference for the location of each site. Map was created in QGIS 3.22 by Max Zeltsar using GPS data collected by Sally Kunzig and Max Zeltsar and Google Satellite Imagery.*

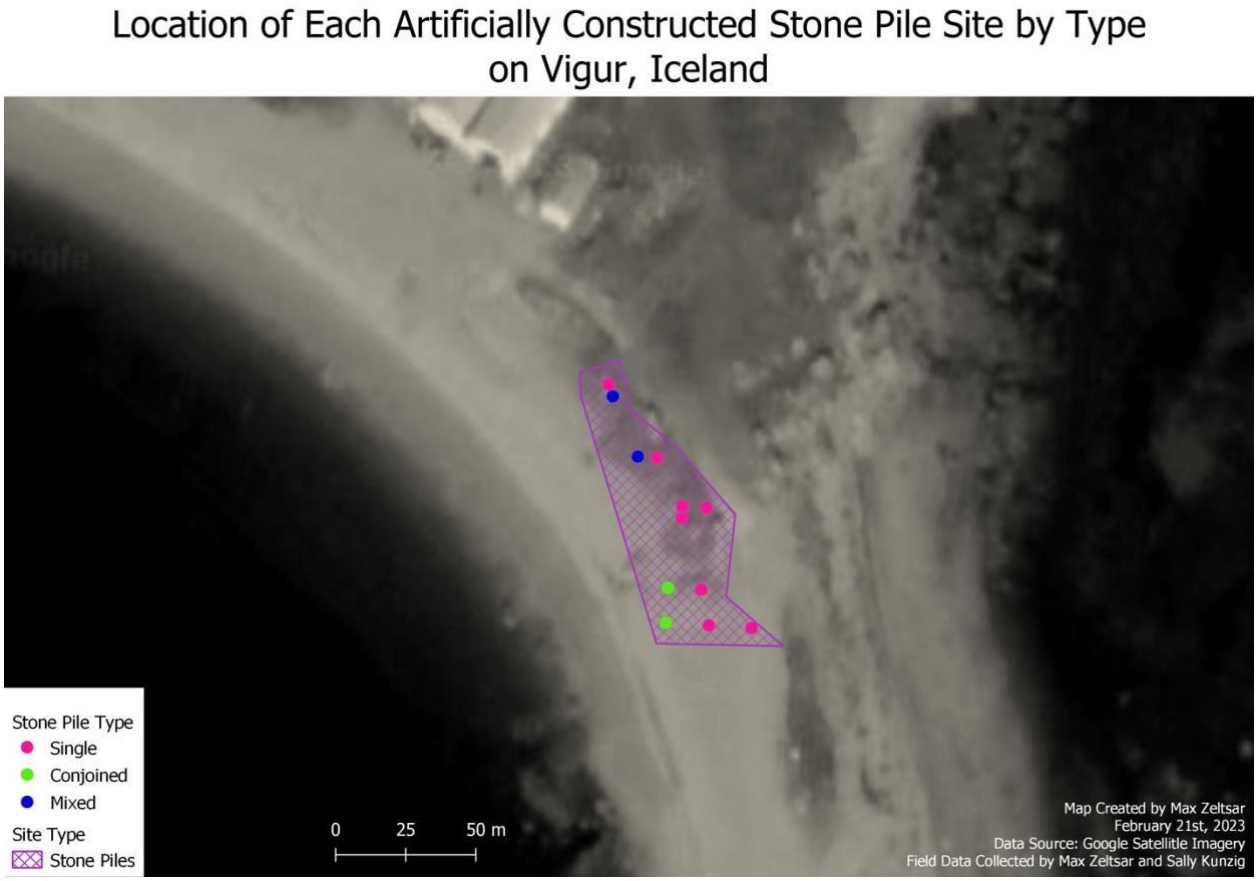


Figure 4. A closer image of the location of each of the individual and conjoined stone piles (shown in Figure 1,

***B**). All sites fall within the purple "Stone Pile Zone" in Figure 3. Visible in the upper central and right side of the map are some of the barns on the island for geographical reference. Each type of stone pile site is also represented on this map which coordinate with the color of the dot shown in the map legend. A "single" site consists of only one totally isolated stone pile, while a site listed as "multiple" consists of multiple conjoined stone piles next to each other, and a "mixed" site being one with a combination of "multiple" and "single" stone pile sites. This map was created in QGIS 3.22 by Max Zeltsar using GPS data collected by Sally Kunzig and Max Zeltsar and Google Satellite Imagery.*

Results:

Since these nesting sites were created after the Black Guillemots had taken up their nesting locations in 2022, no results could be determined for the success of the nesting sites this year. In the following years, the sites will be monitored to determine the success of the project both cumulatively and amongst the individual designs. Monitoring for the project will consist of checking the nesting sites twice each summer, once at the beginning of June, and once at the beginning of July. Sites will be checked for eggs or chicks and a tally of how many nesting sites have eggs or chicks will be taken. It will also be noted which of the three types designs the site falls under. This data can then be used to determine the occupancy rate of all of the nesting sites as well as the occupancy rates of the individual designs.

Based on the success of this project and the individual designs, this can dictate the design that new sites should be created in. It should be observed whether the Black Guillemots continue to nest under the abnormal locations listed in the **Introduction** and shown in *Figure 2*. A careful count of the population should also continue each year similar to the method outlined in a paper by Milesi-Gaches and Lhériau (2022) about bird counting on Vigur. The population count in conjunction with the success or lack of success of the new artificial nesting sites can help determine whether the new nesting sites are allowing the population to grow. It is also possible in coming years to build more nesting sites of different styles around a location with only one style to give stronger evidence of if the Black Guillemots take preference to a certain artificial nesting site design. Based on the occupancy rates of each design it can then be determined of whether the preference was a design preference or a location preference for the Black

Guillemots. In the coming years, the occupancy rates of the new nesting sites should help to give more understanding of Black Guillemot breeding behavior on Vigur, and the creation of the new nesting sites should hopefully ease some of the competition for nesting locations and disturbances experienced by the breeding pairs who are forced to nest in abnormal locations.

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Appendix 3: Seal Poster

Seals on Vigur

Be a friend, not a foe...

While seals are famously curious when meeting humans underwater - often approaching divers and swimmers confidently - they are, in contrast, very cautious while out of the water. They come to 'haul out' on the rocks around Vigur up to two hours before low tide and most will stay until two hours after low tide - although some stay longer. You may also observe the seals sleeping in the water with their noses pointed to the sky - this is called 'bottling'. Time spent hauled out on the rocks is also an important resting time for the seals. Normally they will lie flat with frequent 'scanning' - lifting the head to look around for any signs of danger. While on the rocks they can be easily frightened by loud and sudden noises, exaggerated movement or being approached either over land or by water (for example in kayaks). If they are disturbed enough to flee into the water it will be a number of days before the seals return and will have significant impact on the stress of the animal. For this reason, we ask all visitors to take care not to disturb or approach the seals when they are hauled out on the rocks or bottling close to shore.

Grey and harbour seals were hunted in Iceland and on Vigur for both meat and skins right up until the last century. Seal products are now banned by the European Union, but to date, seals receive no formal protection.

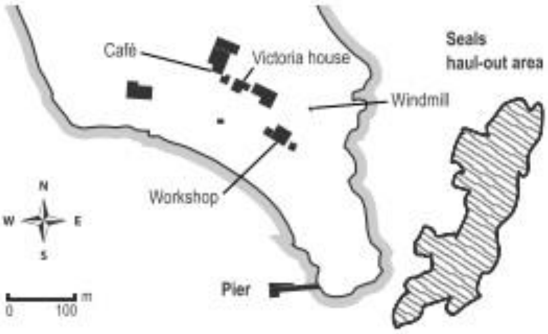
Harbour seal Landselur

Phoca vitulina (Linnaeus, 1758)

The harbour seal is the most common species of seal in Iceland and one of the only two species of seal to pup in Iceland (the other being the grey seal). The adults can grow to a maximum of 1.85m in length and can weigh between 50 and 170kg. Females tend to be smaller than males, but have a decade longer life expectancy. The fur can vary from dark brown to light tan but usually features lighter-coloured patterns on the back while the belly is plain. In August adults shed their fur and the mating season begins. Pups are born in June and the female will look after her pup for just 3-4 weeks, after which the pup must be fully independent. Harbour seals will prey on cod, herring, salmon, flatfishes and shrimps. In Iceland, their only predators are orca and humans. The number of harbour seals in Icelandic waters was estimated at more than 30,000 in the 1980s, but by 2016 that number had fallen to less than 8,000. The species is now considered critically endangered in Icelandic waters by the Icelandic Institute of Natural History.

Male

Female



Grey seal Útselur

Halichoerus grypus (Fabricius, 1791)

Grey seals are instantly distinguishable from harbour seals as they are significantly larger. Males can be up to 2.5m long and weigh over 300kg while females are smaller at up to 190kg and between 1.6 to 1.9m in length. As indicated by their name, their fur is a dark to silver grey and they are patterned all over with large spots. They are sometimes called 'horsehead seals' - a reference to the long, blunt nose of the males. The females pup from September to November. The pups are born with long white fur which moults after 3-4 weeks during which time they stay on shore nursing from their mother. The adults moult from March to May. Grey seals are only present in the North Atlantic Ocean and there are estimated to be some 316,000 individuals worldwide, but since 1990 the numbers in Icelandic waters have decreased from 13,000 to 6,000. They prey on eel, cod, flatfishes and skate, while their only predators in Iceland are humans, orca and very rarely Greenland Shark.

Male

Female

Code of conduct for seal watching

as recommended by the Icelandic Seal Centre

- Move gently, keep your voice down, **never** throw stones or other objects.
- Keep a distance of at least **80m** (whether on land or in a boat/kayak).
- **Never** approach a sole pup as the female will be nearby.
- **Move away** if the seals show any sign of awareness of your presence.
- Drones scare the seals. **No drones please.**

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