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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.

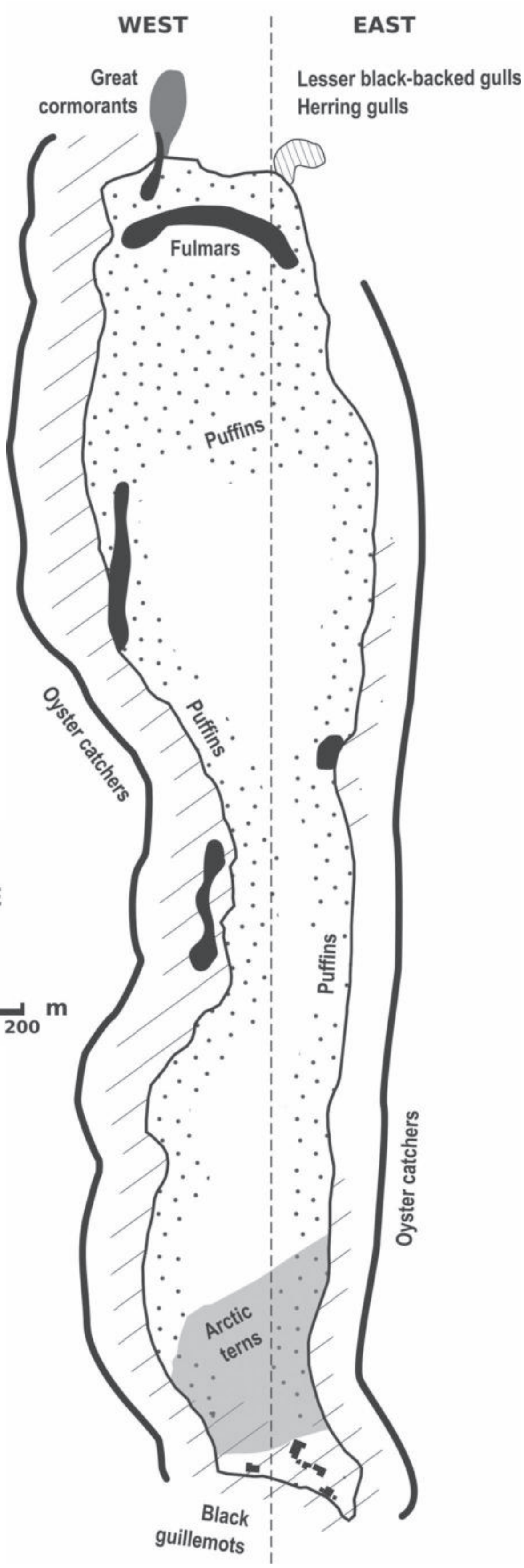
Fig. 1. Most used trio of touristic circuits in Vigur Island, Iceland.

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 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-

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



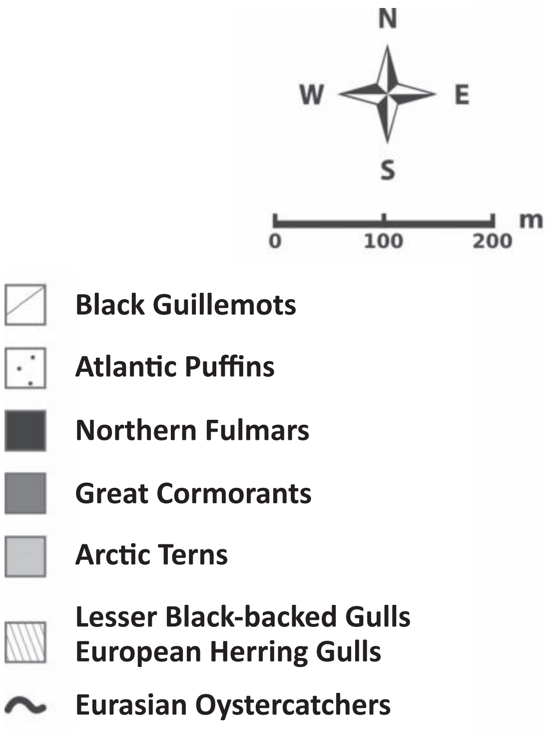


Fig. 3. Schematic distribution of the main species. Map of the seabird populations counted during the 2021 census in Vigur Island, Iceland.

makers, and conservation stakeholders, as well as a larger audience;

2) to test monitoring methods in the specific touristic context of Vigur.

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

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

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.

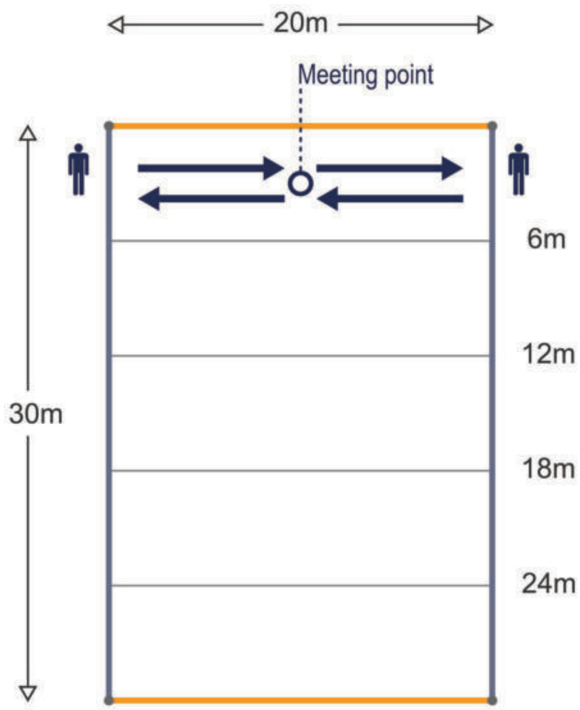


Fig. 5. Double counting by transect method used in Vigur Island, Iceland.

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), observers 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 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).

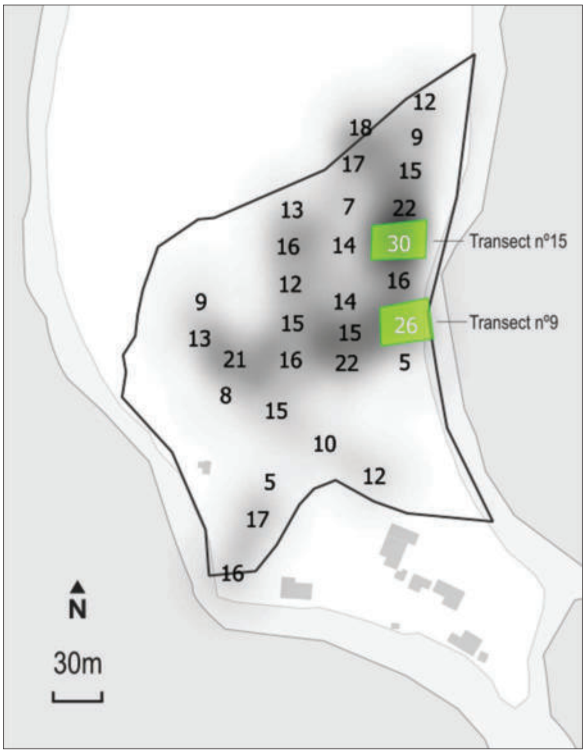


Fig. 6. Heatmap figure presenting the number of nests in the colony of Arctic Terns *Sterna paradisaea* in Vigur Island.

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.

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

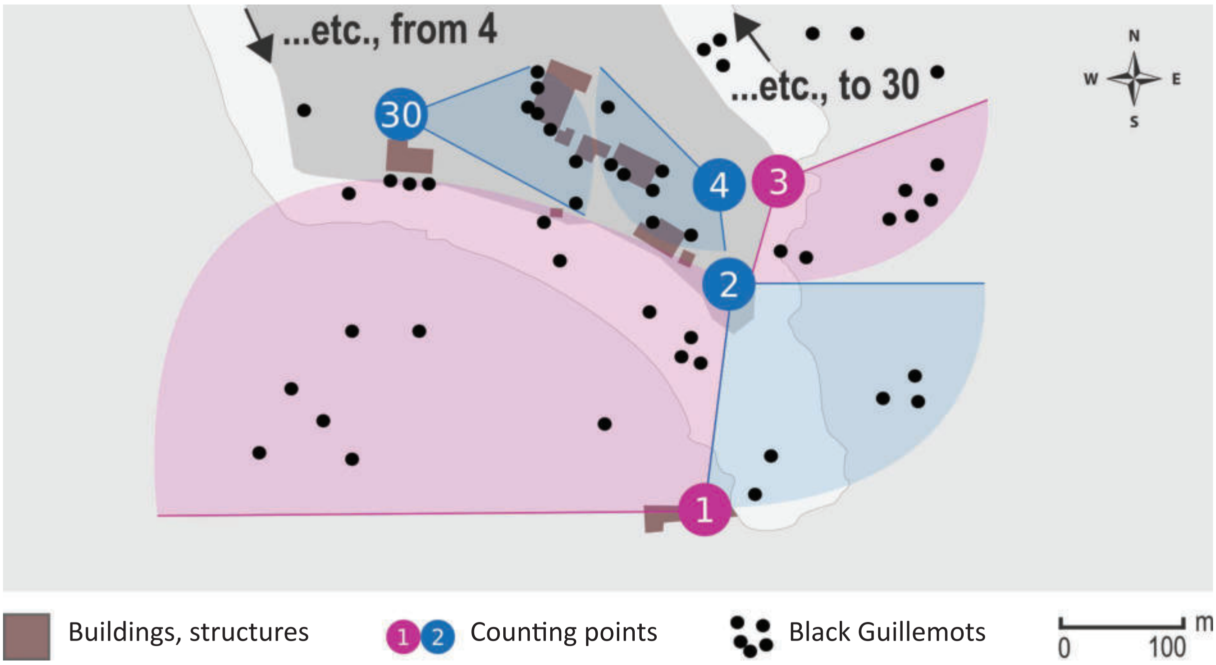


Fig. 7. Schematic illustration showing examples of the counting point principle used for the Black Guillemot *Cepphus grylle* census in Vigur Island.

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).

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

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
Total	440	NA	722	90

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

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									

were proved similar by a Wilcoxon-Mann-Whitney test (P = 0.7916), allowing us to use all 5 counting sessions in the calculation.

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 impos-

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

sible 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

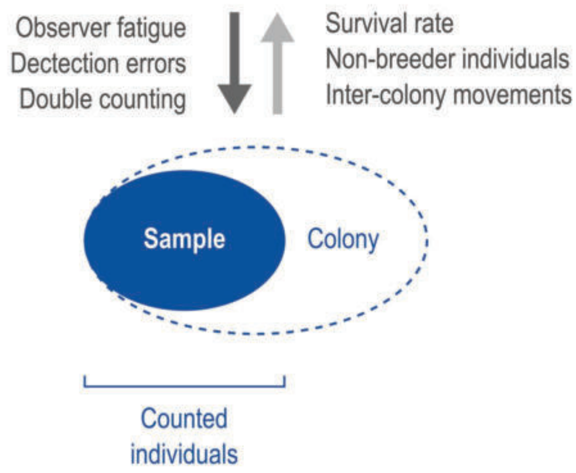


Fig. 8. Uncertainties impacting the Arctic Tern *Sterna paradisaea* census.

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). 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 Black-backed 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.

Acknowledgements

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