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1 A gravel-covered iceberg provides an offshore breeding 2 site for ivory gulls *Pagophila eburnea* off Northeast 3 Greenland

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6
7 **Abstract** The ivory gull *Pagophila eburnea* is an Arctic seabird species whose distribution is
8 tightly coupled to the availability of sea ice. During the last decades strong declines have been
9 reported for breeding colonies in Canada and Greenland, which are usually located on
10 nunataks or remote coastal islands. Here, we report the observation of a colony of ivory gulls
11 breeding on a gravel-covered iceberg 70 km off Northeast Greenland in August 2014. It
12 concerned approximately 60 adults, including two ringed individuals, and many chicks. This
13 represents an unusual breeding site for the species, to be compared with a few cases of
14 colonies on gravel-covered sea ice. Breeding on an offshore iceberg may be advantageous
15 since it provides ultimate protection from predators. Furthermore, the proximity to the
16 productive North East Water polynya may have been attractive to these gulls. As a
17 consequence of this and previous observations, colony surveys should not solely focus on
18 inland and coastal breeding habitats but should be extended towards the ocean.

19
20 **Keywords** Ivory gull · Breeding colony · Iceberg · Ice-rafted gravel · East Greenland
21 Shelf

22
23 **Introduction**

24

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25 The ivory gull *Pagophila eburnea* is a small, pure white gull and inhabits the high Arctic
26 (Gilchrist et al. 2008). It is closely associated with sea ice (Brown 1984; Melhum 1989;
27 Spencer et al. 2014), where it feeds either on fish and invertebrates or scavenges on marine
28 mammal carcasses killed by polar bears *Ursus maritimus* (Gilchrist et al. 2008; Karnovsky et
29 al. 2009). Little is known about the ecology of this species but dramatic population declines
30 have already been observed in Canada and Greenland during the last decades (Mallory et al.
31 2003; Chardine et al. 2004; Gilchrist and Mallory 2005; Gilg et al. 2009). Our own data,
32 collected from the same observation platform with the same methodology, show a decrease in
33 ivory gull abundance in the Greenland Sea from a mean of 1.7 individuals per 30 minute
34 count in the 1990 – 1993 period (Joiris et al. 1997) to 0.4 and 0.3 in 2008 and 2011,
35 respectively (Joiris 2011; Joiris et al. 2014). Its relative abundance deeply changed as well: it
36 was one of the three most abundant species in the nineties – together with northern fulmar
37 *Fulmarus glacialis* and black-legged kittiwake *Rissa tridactyla* - but now does often not even
38 belong to the top ten any more. The ivory gull is therefore currently listed as ‘Endangered’
39 under the Species at Risk Act in Canada (COSEWIC 2006) and as ‘Near Threatened’ by the
40 International Union for Conservation of Nature (IUCN) Red List of Threatened Species
41 (BirdLife International 2012). The global population is estimated to be between 19,000 and
42 27,000 individuals with still high uncertainties due to its occurrence in highly remote areas
43 (BirdLife International 2012).

44 Its breeding range includes the Canadian Arctic, Greenland, Svalbard and Russian Arctic
45 islands (Gilchrist et al. 2008). North-East (NE) Greenland in particular seems to be a hotspot
46 for breeding sites (Gilg et al. 2009), possibly due to the vicinity to an attractive feeding
47 ground: the North East Water (NEW) polynya. The ivory gull usually breeds in colonies,
48 either inland on steep cliffs and nunataks or coastal on barren islands and lowlands. Colony
49 size ranges between a few pairs and several hundred individuals with an average of 69 birds
50 for the Greenland breeding population (Gilchrist and Mallory 2005; Gilchrist et al. 2008; Gilg
51 et al. 2009). In rare cases ivory gulls use gravel-covered sea ice close to the coast as breeding
52 platforms: Boertmann et al. (2010) discovered a breeding site including 125 adults and 35
53 chicks on an ice floe covered with gravel in Independence Fjord, NE Greenland. We report
54 here an even more extreme breeding habitat: a gravel-covered iceberg 70 km off NE
55 Greenland.

56

57 **Materials and Methods**

58

59 The observation was made during research expedition PS87 on board RV *Polarstern* to the
60 Arctic Ocean from 5 August to 8 October 2014. We conducted continuous surveys of seabirds
61 and marine mammals divided into 30 min transect counts from the bridge of the vessel
62 (approx. 18 m above sea level) as part of our long-term study on the at-sea distribution of
63 upper trophic levels in the polar regions (see Joiris et al. 2014 for detailed method
64 description). The main objective is to improve the knowledge on distribution and densities of
65 marine birds and mammals in relation to influencing environmental factors, such as water
66 masses, fronts and ice conditions (Joiris and Falck 2011; Joiris et al. 2014).

67

68 **Results and Discussion**

69

70 On 9 August 2014, at 6:30 (UTC) a large old tabular iceberg (~180 x 180 m) was spotted on
71 the East Greenland Shelf (80°50'59"N, 8°56'57"W), partly covered with ice-rafted debris
72 (Figs. 1 and 2; ice conditions are shown in Online Resource 1). The gravel was sampled and
73 taken on board for geological analyses. First observations showed that the debris was
74 composed of metamorphic rocks, such as quartzites and sandstones, and also igneous rocks,
75 mafic (probably gabbro) and acidic (granites), suggesting an origin from moraine on a glacier
76 in Greenland (E. Bazhenova, pers. comm.). Since the freeboard was estimated to be 10-15 m
77 and the water depth was 70 m, we assumed that the iceberg was grounded, based on
78 calculated keel depth for East Greenland icebergs (Dowdeswell et al. 1992).

79 From a distance an aggregation of ivory gulls could be observed on and around the
80 iceberg. While the ship approached the iceberg, we noticed that the pile of gravel indeed
81 supported a breeding ground for approximately 60 adult ivory gulls (Fig. 3). Juveniles of
82 different age (from chicks in downy plumage to fledglings) were observed but not quantified
83 because parts of the breeding site could not be sighted properly at close range and due to their
84 excellent camouflage on the gravel (Fig. 3). Two colour-ringed adults were encountered,
85 marked with a yellow plastic ring: one on the right leg, the other on the left leg, and a metallic
86 ring on the other leg (Online Resource 2). They seem to correspond to birds from Greenland
87 colonies where juveniles have been ringed since 2003 and adults since 2007 with yellow
88 colour rings, used in Greenland only (O. Gilg pers comm.). The exact inscription could
89 unfortunately not be read on the photographs.

90 So far, there have been some anecdotal reports of ivory gulls breeding on ice. It has long
91 been suggested that these birds nest on offshore ice islands, which could never be confirmed
92 (Uspenski in Johansen 1958). There are reports of ivory gulls breeding on gravel-covered ice

93 floes but they were located close to the coast (MacDonald and Macpherson 1962; Boertmann
94 et al. 2010). An iceberg 70 km off the Greenland coast therefore provides ultimate protection
95 against terrestrial predators, such as Arctic fox *Vulpes lagopus*, wolf *Canis lupus* and polar
96 bears due to the iceberg's freeboard, whereas coastal colonies, even if located on sea ice, are
97 still vulnerable to predation by these animals. Only avian predators (e.g. glaucous gull *Larus*
98 *hyperboreus* and skuas *Stercorarius sp*) would be able to prey on the eggs and chicks in an
99 iceberg colony.

100 Furthermore, the iceberg was located in the proximity of the NEW polynya (Online
101 Resource 1), which is known for its productivity and corresponding abundances of marine top
102 predators (Hirche et al. 1991; Joiris et al. 1997), making this is the most favourable breeding
103 site within a 70 km radius in a food-rich region. The colony was in direct proximity of the
104 polynya, not only during this period, but during the whole breeding season, from May to
105 August (Online Resource 3). This makes it especially attractive to ivory gulls since these birds
106 shuttle between breeding sites and feeding grounds in order to rear their chicks (Gilchrist et
107 al. 2008; Spencer et al. 2014). They regularly cover large distances during their foraging trips,
108 in some cases more than 100 km one-way, e.g. from inland nunataks (Gilg et al. 2009). Thus,
109 it is energetically favourable for ivory gulls to breed close to rich feeding grounds. Therefore,
110 breeding colonies tend to concentrate near polynyas, e.g. on Ellesmere Island near North
111 Water polynya and in NE Greenland near NEW polynya (Gilchrist and Mallory 2005; Gilg et
112 al. 2009). Since it has now been reported several times that ivory gulls breed on gravel-
113 covered sea ice and icebergs (MacDonald and Macpherson 1962; Boertmann et al. 2010;
114 present study), this should have implications for future colony surveys.

115

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122

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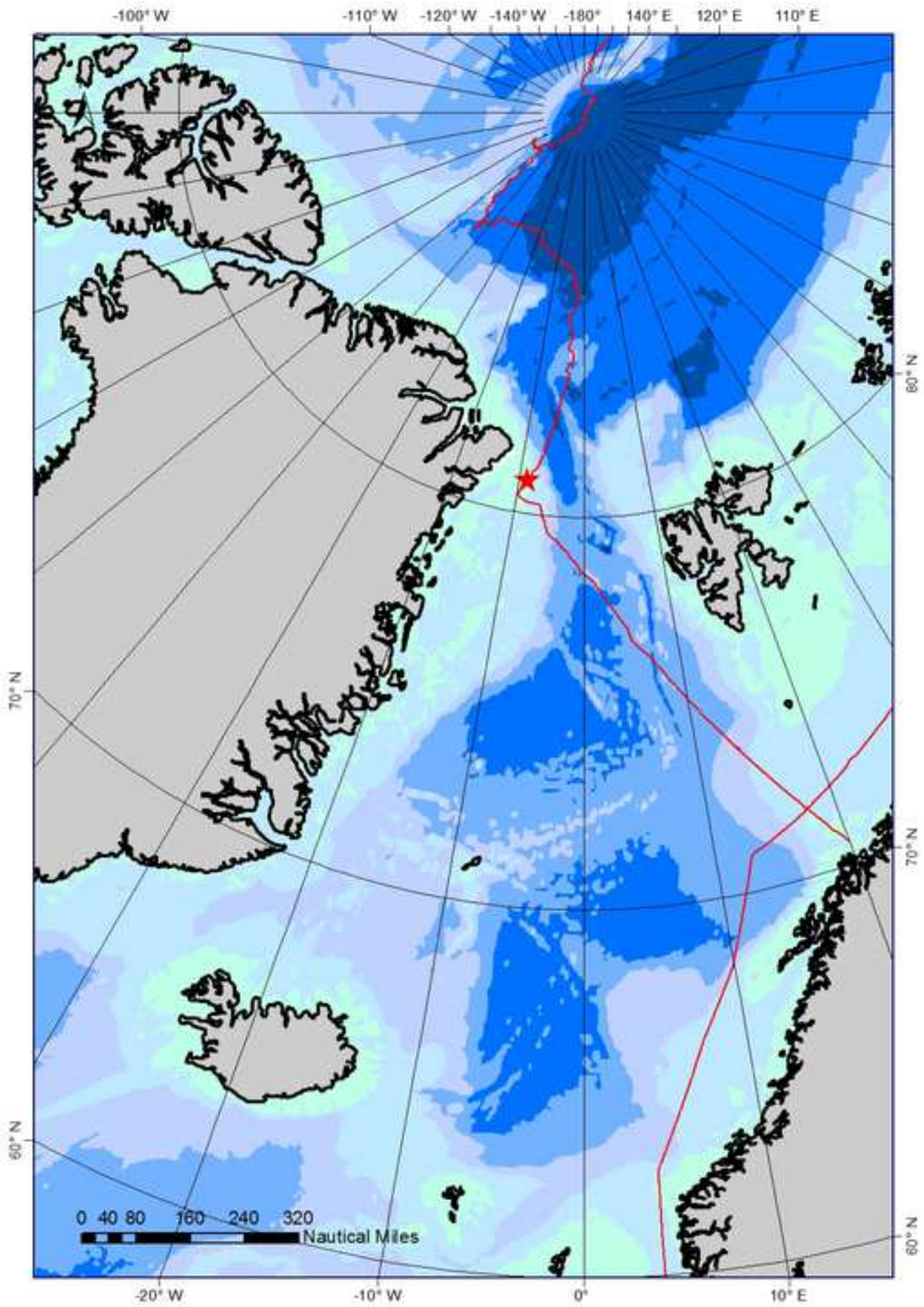
163 **Fig. 1** Location of the gravel-covered iceberg, indicated by a red star. Red line illustrates
164 cruise track of RV *Polarstern* during expedition PS87 (*partim*)

165 **Fig. 2** View of the gravel-covered iceberg, 9 August 2014, 80°50'59"N, 8°56'57"W.
166 Photograph W. Geissler (AWI)

167 **Fig. 3** Ivory gulls *Pagophila eburnea* breeding on a gravel-covered iceberg: adults and
168 juveniles of different age. Photograph D. A. Nachtsheim

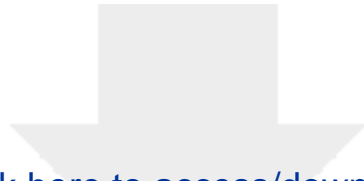
Figure 1

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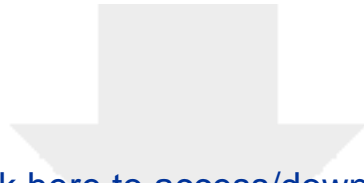




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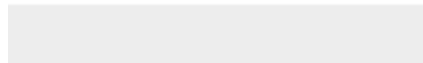
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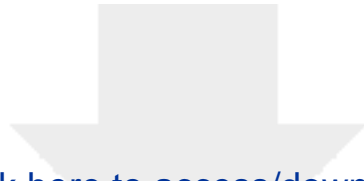




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