

1 **High goose abundance reduces nest predation risk in a simple**
2 **rodent-free high-Arctic ecosystem**

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13 **Abstract**

14 Breeding geese are the preferred prey of the Arctic fox *Vulpes lagopus* in the high-Arctic
15 Svalbard archipelago. According to the *apparent competition hypothesis (ACH)*, less
16 abundant prey species (e.g. ptarmigan, waders and small passerines) will experience higher
17 predation rates when breeding in association with the more common prey (geese), due to
18 spill-over predation by the shared predator. As many of these less abundant species are
19 endemic and/ or red-listed, increased predation can have negative repercussions on their
20 populations. We used a one-year baited artificial nest study to assess relative nest predation
21 risk on Svalbard Rock Ptarmigan *Lagopus muta hyperborea*, small waders (Purple Sandpiper
22 *Calidris maritima*, Dunlin *Calidris alpina*, plovers *Charadrius spp.*, and phalaropes *Phalaropus*
23 *spp.*) and Snow bunting *Plectrophenax nivalis* in two study locations contrasted by nesting
24 density of Arctic breeding geese (Pink-footed Goose *Anser brachyrhynchus* and Barnacle
25 Goose *Branta leucopsis*). We predicted higher predation risk for the less abundant species in
26 the study location with higher goose abundance. However, we found that relative nest
27 predation risk was lower in the study location with higher goose abundance, thus being
28 compatible with apparent mutualism and / or prey swamping mechanisms. Our results
29 contrast with those from more structurally complex Arctic ecosystems and suggest that
30 allochthonous subsidies from temperate ecosystems structure the predation pattern in this
31 high-Arctic tundra ecosystem.

32 **Key words:** Apparent competition, Arctic fox *V. lagopus*, artificial nest, predator, Pink-footed
33 Goose, Svalbard

34 **Introduction**

35 Recent circumpolar studies have demonstrated that at high latitudes, predation can exert
36 strong top-down control on small to medium-sized vertebrates and be a major driver of their
37 population dynamics (Legagneux et al. 2012; Legagneux et al. 2014). In tundra ecosystems
38 lacking lemmings and voles, key resources for predators are typically geese, seabirds and
39 carrion from reindeer *Rangifer tarandus platyrhynchus* and seals (Jepsen et al. 2002; Fuglei
40 et al. 2003; Eide et al. 2005; Eide et al. 2012; Giroux et al. 2012; McKinnon et al. 2013, 2014).
41 The magnitude of such resources may be decisive in structuring predation patterns (Tombre
42 et al. 1998; Jepsen et al. 2002; Fuglei et al. 2003; Roth 2003; Eide et al. 2012) including the
43 level of predation on less preferred prey such as smaller ground-nesting birds (Bety et al.
44 2001; McKinnon et al. 2013, 2014).

45 Abundant prey availability may attract predators and can lead to increased predator
46 densities in proximity to prey (Giroux et al. 2012). According to the apparent competition
47 hypothesis (Holt and Kotler 1987), an increase in the abundance of a predator's main prey
48 (in time or space) can cause spill-over predation on alternative prey (Iles et al. 2013;
49 McKinnon et al. 2013). However, the relationship is complex as high availability of main prey
50 can also buffer predation on alternative prey, resulting in a positive relationship between the
51 two (i.e. apparent mutualism (Abrams and Matsuda 1996; Abrams et al. 1998)). The
52 occurrence of contrasting abundances of breeding geese in the valleys of Svalbard provide a
53 setting in which to test the apparent competition hypothesis (Jepsen et al. 2002; Eide et al.
54 2005).

55 The terrestrial ecosystem in the Svalbard archipelago is one of the world's most
56 simple vertebrate tundra food webs (Ims et al. 2014). The main terrestrial resident generalist
57 predator and scavenger is the Arctic fox *Vulpes lagopus* (Frafjord 1993; Prestrud 1992).

58 Rodents are almost functionally absent in the ecosystem, apart from a small, local,
59 geographically isolated population of sibling voles *Microtus levis* (Henttonen et al. 2001). In
60 summer, the preferred food resource consists of eggs, chicks and adult Arctic-nesting geese
61 (Pink-footed Goose *Anser brachyrhynchus* and Barnacle Goose *Branta leucopsis*). The
62 increase in the populations of Pink-footed Goose (i.e. 15000 [1965] to 81500 [2012]; Madsen
63 et al. 2016) and Barnacle Goose (i.e. 3000 - 4000 birds [1960's] to 35000 individuals [2008];
64 Mitchell et al. 2010) has been large and rapid. Seabirds (e.g. family *Alcidae* and Fulmar
65 *Fulmarus glacialis*), remains of reindeer carcasses and occasionally newborn calves are
66 typically secondary prey (Eide et al. 2005). In addition, Arctic fox *V. lagopus* can prey upon
67 terrestrial ground nesting birds (Eide et al. 2005), many of which are of conservation concern
68 due to their small populations in Svalbard. This includes the endemic Svalbard Rock
69 Ptarmigan *Lagopus muta hyperborea*, locally red-listed waders living at the northern end of
70 their range (Common Ringed Plover *Charadrius hiaticula*, Ringed Plover *Charadrius hiaticula*,
71 Dunlin *Calidris alpina*, Sanderling *Calidris alba*, Red Phalarope *Phalaropus fulicarius*, Red-
72 necked Phalarope *Phalaropus lobatus*, Ruddy Turnstone *Arenaria interpres*; Henriksen and
73 Hilmo (2015)), and the only passerine, the Snow bunting *Plectrophenax nivalis* (Kovacs and
74 Lydersen 2006). We expect these species to be incidental prey taken during the predator's
75 search for preferred prey (see Cornell 1976), and for predation to be relatively limited due to
76 their low abundances (Eide et al. 2005).

77 In this one-year observational study, we used artificial nests to compare the relative
78 nest predation risk on small to medium sized ground-breeding birds (Svalbard Rock
79 Ptarmigan *L. muta hyperborea*, small waders [Purple Sandpiper *Calidris maritima* and the
80 seven locally red-listed waders described above] and Snow bunting *P. nivalis*) between two
81 valleys that differed in abundance of nesting geese. According to the apparent competition

82 hypothesis and McKinnon et al. (2013), we predicted higher predation rates on ground-
83 nesting birds in the study location with high abundance of nesting geese compared to the
84 study location with low abundance of nesting geese due to increased spill-over predation by
85 Arctic fox *V. lagopus*.

86 **Methods**

87 **Study area**

88 The high-Arctic archipelago of Svalbard, Norway (62 700 km²; 74-81°N, 15-30°E), has only 15
89 % of land covered with vegetation. Glaciers (60 %) and barren rocky ground (25 %) cover the
90 remaining areas (Johansen et al. 2012). We conducted the study in the middle Arctic tundra
91 zone of the largest island, Spitsbergen. The landscape is mountainous and moderately
92 glaciated and continuous vegetation cover is only present in the valley bottoms and on the
93 lower parts of the mountain slopes (Elvebakk 1999; Elvebakk 2005). The study sites are
94 located in two adjacent open, u-shaped river valleys, *Adventdalen* and *Sassendalen* (78°15'N,
95 17°20' E; Fig. 1) which are characterized by differences in prey availability (Jepsen et al.
96 2002; Eide et al. 2004, 2005; see below for a description).

97 **Prey resource landscapes and predator abundance**

98 Former studies by Jepsen et al. (2002) and Eide et al. (2004, 2005) have characterized
99 *Adventdalen* (termed 'prey-poor') as a poor prey resource landscape consisting mainly of
100 reindeer, while *Sassendalen* (termed 'prey-rich') has richer prey resources consisting of both
101 reindeer and geese (Fig. 1 and Table 1). The study locations have similar Svalbard reindeer *R.*
102 *platyrhynchus* densities that show synchronous population dynamics (Aanes et al. 2003;
103 Pedersen et al. 2014). Thus, we expect no significant differences between the study
104 locations in the availability of reindeer carcasses as food for the Arctic fox *V. lagopus* (Jepsen

105 et al. 2002; Eide et al. 2005). The abundance and density of Arctic-nesting geese (Pink-footed
106 Goose and Barnacle Goose) differ between the study locations. The prey-rich study location
107 is an important breeding area for Pink-footed Goose in Svalbard, in cliff habitat (e.g.
108 Nøisdalen cliff colony, area of 0.19 km²), there is a range of 25 - 55 nests per colony and in
109 open tundra slope (e.g. Gåseflatene slope colony, area 0.76 km²) there is a range of 170 -
110 230 nests per colony (see Anderson et al. 2015 for details and colony maps). In contrast,
111 nesting geese are almost absent in the prey-poor study location (Mehlum et al. 1998; Eide et
112 al. 2004, 2005; Wisz et al. 2008; Fig. 1). Both goose species incubate nests in June and most
113 of the goslings have hatched around the beginning of July (Madsen et al. 2007) with post-
114 hatching aggregations forming along rivers and small lakes (Fox et al. 2009). Several large
115 seabird cliff colonies are found in close proximity to the prey-rich study location (between 1 -
116 - 7 km from the transects), while they are further away in the prey-poor study location
117 (between 16 - 20 km from the transects) (for additional details see Eide et al. 2004; Fig. 1
118 and Table 1). Fulmar *F. glacialis*, Brünnich's Guillemot *Uria lomvia*, Little Auk *Alle alle* and
119 Puffins *Fratercula arctica* dominate these colonies. While all of these species are potential
120 prey for the Arctic fox *V. lagopus*, Eide et al. (2005) found that geese, eggs, goslings and
121 adult individuals were the preferred prey to seabirds and reindeer carcasses. In the absence
122 of geese, seabirds were preferred to reindeer.

123 Diet studies of Arctic fox *V. lagopus* scats have documented that foxes also prey on
124 Svalbard Rock Ptarmigan and smaller migratory birds such as waders and Snow buntings
125 (Prestrud 1992; Eide et al. 2005). The ptarmigan is non-cyclic on Svalbard and has low
126 breeding densities (1.5 – 4.7 males / km²) across the study locations (Soininen et al. 2016).
127 Among the eight wader species commonly breeding in Svalbard, seven are locally red-listed
128 (listed in the introduction; see also Henriksen and Hilmo 2015 for a complete species list).

129 There is no information on abundances of Snow bunting or small waders within the two
130 study locations; however, we expect them to occur in low densities due to the high-Arctic
131 location of our study sites (Ims et al. 2014).

132 In terms of predator abundance in the two study locations, the Arctic fox *V. lagopus*
133 den occupancy rate is slightly, but not statistically, higher in the prey-rich compared to the
134 prey-poor study location (see Figure 4b in Eide et al. 2012; Table 1 for occupancy rates in
135 2012 study year). Currently, there is no knowledge about abundances of the avian predators,
136 the glaucous gull (*Larus hyperboreas*) and skuas (*Stercorarius spp.*), which scavenge and prey
137 upon the same resources as the Arctic fox *V. lagopus*.

138 **Study design**

139 We used an observational study design with artificial nests (cf. McKinnon et al. 2013) to
140 assess nest predation rates along transects spanning from the valley bottom to the upper
141 vegetation limit (altitude range; Adventdalen 110 – 384 masl., Sassendalen 3 – 182 masl.,
142 Fig. 2). Thus, the transects represented both a gradient in terms of vegetation productivity and
143 type of nesting habitat (e.g. wetlands in the valley bottom, snow-bed/moss tundra in the
144 foothills, heath and ridge vegetation on the slopes and rocks with sparse vegetation at the upper
145 vegetation limit) for ground-nesting birds. We used 120 artificial nests deployed between 1st
146 and 20th July 2012 to obtain spatial replication and controlled stratification that would not
147 be possible using natural nests (McKinnon et al. 2010, 2013, 2014). This time-period covers
148 the main breeding season for the most common ground-nesting birds in Svalbard (e.g.
149 Svalbard Rock Ptarmigan *L. muta hyperborea*, Steen and Unander 1985; Snow bunting *P.*
150 *nivalis*, Hoset et al. 2004; Purple Sandpiper *C. maritima*, Summers and Nicoll 2004). This type
151 of study design provides information about spatial and temporal prevalence of egg-
152 consuming predators, thus indicating relative predation-risk patterns for ground-nesting

153 birds from both mammalian and avian predators (e.g. Angelstam 1986; Storch 1991; Villard
154 and Part 2004; Manzer and Hannon 2005; McKinnon et al. 2010).

155 Based on a random start position, we placed 12 transects in each study location with
156 five artificial nests in each transect (N = 60 artificial nests per study location; total N = 120;
157 Fig. 1). In the prey-poor study location, we placed the 12 transects adjacent to each other on
158 one side of a large glacial river due to difficulties involved in crossing the river. In the prey-
159 rich study location, we placed six transects on each side of a large glacial river which could
160 act as a barrier for Arctic fox *V. lagopus* movement in summer. The overall mean distance
161 between transects was 1190 m (range [932 – 2852 m]) and differed slightly between study
162 locations (prey-poor, mean = 1099 m, range [932 – 1701 m]; prey-rich, mean = 1281 m,
163 range [1004-2852 m]). The overall mean transect length was 911 m (range [99 - 1652 m])
164 and differed also slightly between study locations (prey-poor, mean = 994 m, range [99 –
165 1652 m], the lowest number is due to that only two nests were placed in this short transect
166 due to topographical constraints; prey-rich, mean = 828 m, range [381 - 1401 m]). The
167 artificial nests (n = 5) were deployed at equal distance intervals along a low to high elevation
168 gradient of individual transects. Due to varying transect length the mean distance between
169 two artificial nests was 239 m (range [99 - 558 m]).

170 We placed four of the artificial nests in vegetated habitats, while the fifth nest was
171 placed in sparsely vegetated habitats with less than 25 % vegetation cover. Post fieldwork
172 we assigned each artificial nest site a habitat type using the digital habitat map of Johansen
173 et al. (2012) that defines 18 habitat classes (see Johansen et al. 2012, Table 2 for habitat
174 classes). Prior to analysis, we reclassified the habitat types into four coarse habitat
175 productivity categories assumed to be relevant for the breeding ecology of ground-nesting
176 birds in the study areas. These were barren (original classes 4 - 6, 8, 17 and 18; n = 40), moist

177 (original classes 9, 12 and 15; n = 74), wet (original classes 10 and 11; n = 29) and dry
178 (original classes 13, 14 and 16; n = 26) (Fig. 2). Since many of the plots were located in an
179 unclassified habitat type (original class 7; n = 57), we added a fifth vegetation category 'not
180 classified' to our habitat variable (Fig. 2).

181 **Artificial nests**

182 Each nest consisted of two commercially produced common quail eggs *Coturnix coturnix* that
183 were placed on the ground in a small, shallow hand-made nest cup to imitate nest
184 characteristics of the most common bird species. We followed McKinnon et al. (2013) in
185 assuming that exposure of eggs in artificial nests provided a measure of relative predation
186 risk on small to medium-sized ground-nesting birds. To reduce human scent we wore latex
187 gloves and rubber boots or plastic covered hiking-boots when handling the eggs, and we left
188 only plastic covered equipment on the ground (Bowen 1976). We noted the GPS position of
189 each nest and placed a small orange coloured wooden stick (7 mm in diameter, 2 - 5 cm
190 above ground) 5 m above or below the nest in the direction of the transect line to aid nest
191 relocation. We exposed the nests to predators for two consecutive trial periods of 10 days to
192 account for potential temporal differences in predation rates. The nests were set out for the
193 first time on 1st July, which coincided with the incubation period of the most common
194 ground-nesting bird species (Svalbard Rock Ptarmigan, Steen and Unander 1985; Snow
195 bunting, Hoset et al. 2004; purple sandpiper, Summers and Nicoll 2004). The nests were
196 visited every 10 days (two visits) and we recorded a nest as predated when at least one of
197 the eggs was missing, destroyed or distributed in the immediate surroundings of the nest
198 site.

199 **Statistical analysis**

200 We analysed relative nest predation risks using generalized linear mixed-effects models
201 using a logit-link function and a binomial distribution for the response variable, probability of
202 nest predation (Lewis 2004). Models were fitted in R (R Development Core Team 2010) using
203 the lme4 package (Bates et al. 2015). We included *location* (prey-rich and prey-poor, *period*
204 (two consecutive trial periods of 10 days from 1st – 20th July) and nesting *habitat type*
205 (barren, moist, wet, dry and not classified) as fixed factorial predictor variables. Elevation
206 (m.a.s.l.) of the artificial nest and habitat type were highly correlated and therefore we
207 chose to only include habitat type in the statistical analyses (Fig. 2). *Transect* and *plot* were
208 included as random variables with plot nested within transect to account for spatial variation
209 that could not be attributed to habitat type. The full model contained the interaction
210 between the fixed effects *location* × *period*, *location* × *habitat type* and the random effects
211 *transect* and *plot*. We selected the best model using the Akaike's information criterion
212 corrected for small sample size (AICc), ΔAIC_c and AICc-weights (Anderson and Burnham
213 2002). Where difference in ΔAIC_c was < 2, we chose the simpler model for inference. We
214 present estimates of effect sizes as odds ratios (OR) with 95 % confidence intervals (CI) for
215 the predictor variables.

216 **Results**

217 Nest predation was consistently high in both study locations with more than half of all the
218 artificial nests being predated (Table 2). A simple model including only the predictor variable
219 *location* explained best the nest predation risks (Fig. 3, Table 3 - 4). There was no support for
220 any effects of *period* or *habitat type* on predation rates. The probability of nest predation

221 was significantly higher in the prey-poor location (88 %), compared to the prey-rich location
222 (62 %) (odds ratio [OR] prey-poor/ prey-rich = 4.6, 95 % CI = 1.5 – 14.2; Fig. 3).

223 **Discussion**

224 Our results indicate that nest predation risk of ground-nesting birds (Svalbard Rock
225 Ptarmigan *L. muta hyperborea*, small waders (listed in introduction) and Snow bunting *P.*
226 *nivalis*) was lower in tundra landscapes with high abundances of geese, the preferred prey of
227 Arctic fox *V. lagopus*. These results contrast with those from several structurally more
228 complex Arctic ecosystems where presence of goose colonies led to elevated predation rates
229 on other ground-nesting birds (Iles et al. 2013; McKinnon et al. 2013, 2014). Our results thus
230 demonstrate the first indications that an allochthonous resource, in the form of abundant
231 migratory geese from temperate ecosystems, influences nest predation risk in a tundra
232 ecosystem lacking small rodents.

233 Based on the apparent competition hypothesis and results from the study by McKinnon
234 et al. (2013), we expected nest predation risk on ground-nesting birds to be higher in the
235 prey-rich compared to the prey-poor study location. Our results indicated the opposite, with
236 an almost five-fold decrease in relative nest predation rates in the prey-rich location and are
237 therefore compatible with an apparent mutualism mechanism (Abrahams and Matsuda
238 1996), where less abundant alternative prey benefit from high abundances of main prey.
239 Whether alternative prey benefit from being interspersed amongst the main prey of a
240 shared predator is dependent on the functional and numerical response of the predator, as
241 well as the relative abundance of the different prey species and their spatial and temporal
242 distributions (Barraquand et al. 2015). The contrasting findings to McKinnon et al. (2013)
243 may relate to differences in both abundance of main goose prey and spatial study scale, i.e.
244 local (McKinnon et al. 2013) versus landscape scale (this study). McKinnon et al.'s (2013)

245 study placed the artificial nests in the centre of a large snow-goose colony (i.e. approx. 50
246 000 individuals, four nests were set out in each of 10 quadrats of 500 × 500 m with varying
247 goose nest density). In our study, we dispersed the artificial nests along elevation gradients
248 representing different types of ground-nesting bird habitats, in tundra landscapes that
249 contained either no goose nests or colonies spread across the hill-slopes or on smaller cliffs
250 (Anderson et al. 2015; see their Table 1). McKinnon et al.'s (2013) study suggested an
251 aggregative search response of Arctic fox *V. lagopus* and indeed such behaviour might
252 happen in our study area and be directly comparable. However, as the density of the goose
253 nests is much lower in our study, the search response (and hence overspill predation) may
254 be confined to sections of the landscape where geese are present (Jepsen et al. 2002). Thus,
255 for ground-nesting birds that nest in low densities, a heterogenic aggregative search
256 response of the Arctic fox *V. lagopus* may result in a reduction in the overall predation
257 pressure on these species.

258 At the time of the study (1st - 20th July) many geese have already hatched their eggs,
259 while many of the other ground-nesting birds are still incubating. Former studies have
260 demonstrated that goose prey distribution can concentrate the aggregation of Arctic foxes
261 *V. lagopus* to certain parts of the landscape where geese congregate such as flooded areas,
262 small lakes and along river banks (Jepsen et al. 2002; Fox et al. 2009). Thus, the presence of
263 goose family groups in these areas is likely to influence the spatial pattern of fox distribution.
264 This may result in reduced time spent by the fox in the nesting habitats of other less
265 common ground-nesting birds. Seabird colonies may also act in a similar way and reduce
266 local predation pressure on other ground-nesting birds. As such, the short distance to bird
267 cliffs in the prey-rich location may also have contributed to reduced nest predation rates on
268 the ground-nesting birds in this location. In the prey-poor location, the high nest predation

269 may simply result from virtually no other prey present than ground-nesting birds in summer,
270 which leads to high search effort by Arctic foxes *V. lagopus* for ground-nesting bird nests.
271 Additionally, potential differences in abundance of the bird predator communities (e.g.
272 Glaucous gull *Larus hyperboreus* and skuas *Stercorarius spp.*) may contribute to this pattern
273 as demonstrated by Iles et al. (2013) in a more complex ecosystem. While no information
274 currently exists to evaluate this effect, the lack of both habitat and time period effects in our
275 study indicate a continuous predation pressure from both Arctic fox *V. lagopus* and avian
276 predators during the 2012 season.

277 Another plausible explanation for the lower predation risk in the prey-rich location is a
278 prey swamping effect whereby high abundances of geese buffer predation of less abundant
279 prey (Robertson 1995, Gauthier et al. 2004, Iles et al. 2013). This is documented in other
280 Arctic ecosystems where goose-nesting colonies buffered predation on vulnerable tundra
281 birds from e.g. Snowy Owls *Bubo scandiacus* (Gauthier et al. 2004). Indeed, such an effect
282 from a temporally pulsed resource, such as goose nests and goose family groups, are most
283 likely if they are dispersed across the landscape, as occurs in the Svalbard breeding Pink-
284 footed Goose *A. brachyrhynchus* populations rather than being highly concentrated spatially
285 (Ims 1990).

286 There are many shortcomings of artificial nest studies, which may lead to a discrepancy
287 between absolute predation rates of real and artificial nests. These include the lack of an
288 incubating bird and associated nest defence, as well as the limited ability to identify predator
289 species (reviewed in Moore and Robinson 2004). We argue, however, that as we use a
290 standardised study design applied in other studies of relative predation risk in similar open
291 habitats (see McKinnon et al. 2010, 2013, 2014), we capture the relative nest predation risk
292 from the predator community on the less common prey species. We thus suggest that

293 experiments with artificial nests should be part of long-term monitoring efforts. Such an
294 approach allows estimation of the inter-annual variability and climate-change related trends
295 in nest predation rates in areas of different prey abundances. The monitoring should also
296 include methods that enable identification of the nest predator species (mammalian versus
297 avian egg predators; McKinnon et al. (2009)), as well as improved data on the abundance
298 and distribution of the nests of geese and other ground-nesting birds. Implementation of the
299 “Climate-Ecological Observatory for Arctic Tundra”, which is an adaptive ecosystem-based
300 long-term monitoring program covering our study regions (Ims et al. 2013), along with
301 circumpolar initiatives such as “The Arctic Migratory Birds Initiative” (Johnston et al. 2015),
302 are important steps to enhance the knowledgebase. This will advance our understanding of
303 the interactive effects between the Arctic fox *V. lagopus*, avian predators / scavengers and
304 goose abundance on terrestrial high-Arctic birds of conservation concern, thus, allowing for
305 the effective appraisal of management actions that can reduce their vulnerability to
306 extinction.

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444 **Tables**

445 **Table 1** Summary of prey and predator characteristics of the two study locations, the prey-poor inland resource landscape with low goose
 446 abundance and the prey-rich inland resource landscape with high goose abundance (Jepsen et al. 2002, Eide et al. 2004; see also Fig. 1.). We
 447 give also Arctic fox *Vulpes lagopus* den occupancy rates for the 2012 study year

STUDY LOCATION CHARACTERISTICS	PREY-POOR	PREY-RICH
Goose abundance (Eide et al. 2004; 2005, Wisz et al. 2008; GOOSEMAP ¹⁾)	Lower	Higher
Seabird colonies (Eide et al. 2004; NPI Seabird database ²⁾)	Longer distance from Arctic fox natal den Mean = 13.5 km (± 4.32)	Shorter distance from Arctic fox natal den Mean = 8.69 km (± 3.79)
Access to other marine resources (Seal carcasses and pups on sea ice or at glacier fronts; Eide et al. 2012)	Longer distance from Arctic fox natal den	Shorter distance from Arctic fox natal den
Reindeer density and carcass availability (Jepsen et al. 2002; Eide et al. 2005, Pedersen et al. 2014)	Similar	Similar
Arctic fox den occupancy 1984-89 and 1997-2001- (Based on estimates from Eide et al. 2012; see Fig. 4b)	Lower	Higher
Arctic fox den occupancy 2012 (Fuglei unpublished)	N monitored dens = 10 N occupied dens = 4 (40 %)	N monitored dens = 10 N occupied dens = 4 (40 %)

448 1) www.goosemap.nina.no

449 2) <http://svalbardkartet.npolar.no/Viewer.html?Viewer=Svalbardkartet>.

450 **Table 2** Summary of artificial nest predation by study location (prey-rich = high goose
 451 abundance; prey-poor = low goose abundance; Fig. 1) and time period (period 1 = 1st - 10th
 452 July; period 2 = 10th – 20th July) the nests were available for predation. Total predation = the
 453 number of eggs depredated. Nest = the total number of artificial nests available for
 454 predation

	Prey-rich		Prey-poor	
	Period 1	Period 2	Period 1	Period 2
Total predation	30 (57 %)	35 (59 %)	43 (75 %)	51 (89)
Nest (n)	53	59	57	57

455

456 **Table 3** Ranking of the five best generalized linear mixed-effect models for assessment of relative nest predation risk on small to medium-sized
457 ground-nesting birds (e.g. Svalbard Rock Ptarmigan *Lagopus muta hyperborea*, small waders [Common Ringed Plover *Charadrius hiaticula*,
458 Ringed Plover *Charadrius hiaticula*, Dunlin *Calidris alpina*, Purple Sandpiper *Calidris maritima*, Sanderling *Calidris alba*, Red Phalarope
459 *Phalaropus fulicarius*, Red-necked Phalarope *Phalaropus lobatus*, Ruddy Turnstone *Arenaria interpres*; Henriksen and Hilmo (2015)] and the
460 Snow bunting *Plectrophenax nivalis*) in the prey-rich (high goose abundance) and the prey-poor (low goose abundance) study locations.; Fig.
461 1). *Transect* and *plot* were always included as random effect variables in the models. Models were ranked according to Akaike’s information
462 criterion corrected for small sample size (AIC_c), differences in ΔAIC_c and ΔAIC_c . K = number of parameters estimated. The model in bold was
463 used for inference

Model rank	Location	Period	Habitat	Location × Period	Location × Habitat	K	AIC_c	ΔAIC_c	AIC_c weights
1	X	X			-	5	256.12	0.00	0.50
2	X				-	4	256.38	0.26	0.44
3			X	X	-	10	262.58	6.46	0.02
4	X	X	X		-	9	262.89	6.77	0.02
5	X		X		-	8	263.06	6.94	0.02

464

465 **Table 4** Estimated effect sizes (on the logit scale) from the selected model describing
 466 artificial nest predation risks in the two study locations contrasted by prey resources (prey-
 467 rich = high goose abundance; prey-poor = low goose abundance; Fig. 1). Coefficients for the
 468 random effect variables and residual variability are standard deviations. Residual degrees of
 469 freedom = 222

Explanatory variable		Estimate	SE	p
<i>Fixed</i>	Intercept (prey-rich location)	0.49	0.37	0.18
	Location (prey-poor location)	1.53	0.57	<0.01
<i>Random</i>	Transect × Plot	0.92		
	Transect	0.87		

470

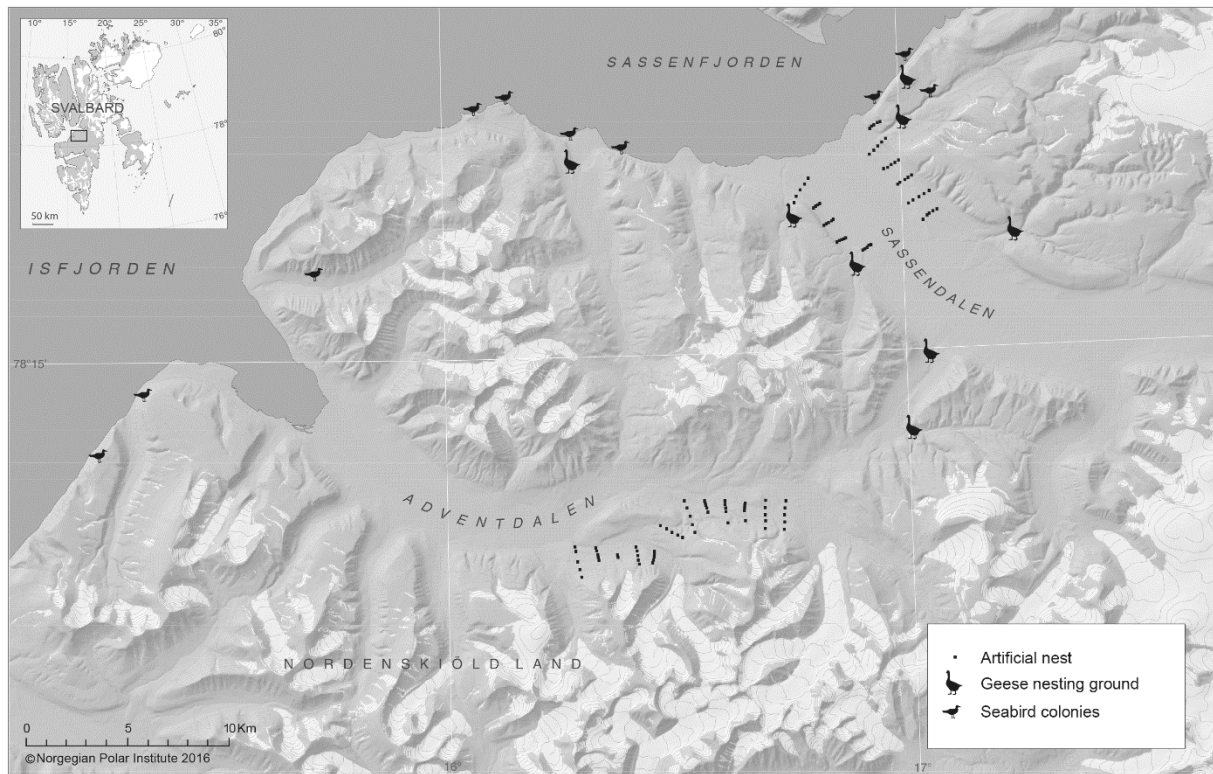
471 **Figures legends**

472 **Fig. 1** Location of the study area with the spatial design of the 24 transects for assessing
473 relative nest predation risks in two study locations contrasted by prey resources
474 (*Adventdalen* = prey-poor [low goose abundance]; *Sassendalen* = prey-rich [high goose
475 abundance]; see Jepsen et al. 2002, Eide et al. 2004). The transects span along a vegetation
476 productivity gradient from the valley bottom to the upper vegetation limit at higher
477 elevations. Symbols indicate the distribution of goose breeding grounds and seabird
478 colonies. The inset shows the study area on the Svalbard archipelago. The figure is modified
479 after Eide et al. (2004; Fig. 1)

480 **Fig. 2** Habitat and altitude characteristics for assessing relative nest predation risk in the
481 prey-poor and prey-rich study locations between 1st and 20th July in 2012. . The bar-plots (a -
482 c) show the proportion of the habitat types across: a) the prey-poor and prey-rich study
483 locations; b) plots in the prey-poor study location; and c) plots in the prey-rich study
484 location. The box-plots (d - f) show the altitude (m) across: d) the prey-poor and prey-rich
485 study locations; e) plots in the prey-poor study location; and f) plots in the prey-rich study
486 location.

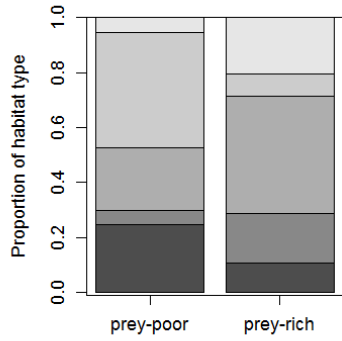
487 **Figures**

488 **Fig. 1**

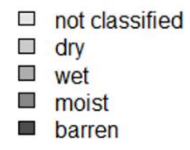
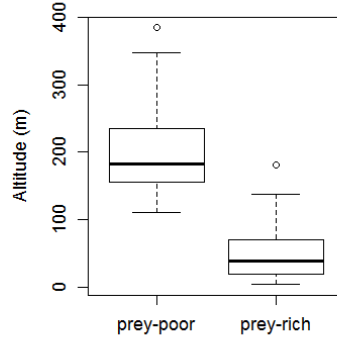


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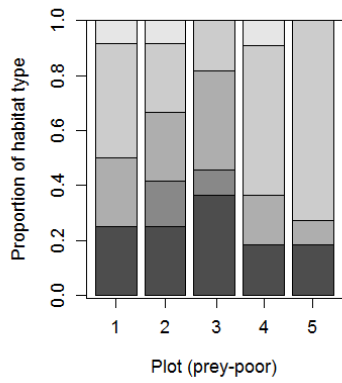
a)



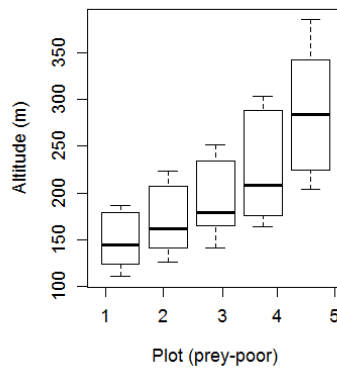
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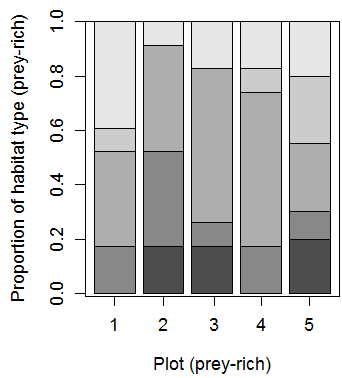
b)



e)



c)



f)

