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ORIGINAL PAPER

Drastic decrease in high Arctic gulls—ivory *Pagophila eburnea* and Ross's *Rhodostethia rosea*—density in the northern Greenland Sea and Fram Strait between 1988 and 2014

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Abstract Our long-term study on top predator (seabirds and marine mammals) distribution in polar marine ecosystems aims at detecting possible temporal and spatial population changes, especially in the context of global changes in temperature and ice cover. Quantitative data on the seabird distribution were collected in the northern Greenland Sea and Fram Strait onboard the icebreaker RV *Polarstern* between 1988 and 2014, applying 30-min transect counts from the bridge, without width limitation ($n = 7320$). A drastic decrease in numbers by a factor of seven was detected for the ivory gull *Pagophila eburnea* from 2007 on. These data confirm the decrease of ivory gull previously detected in North Canada and North Greenland, leading to the conclusion that the species is "endangered" or "near threatened". These changes are discussed in relation to the decreasing Arctic pack ice coverage leading to the opening of the Northwest and Northeast Passages in 2007, at the time the year with the lowest ice coverage ever recorded. On the other hand, the decrease was even stronger for Ross's gull *Rhodostethia rosea* after 1993, apparently reflecting changes in migratory habits. The third high Arctic gull, Sabine's gull *Xema sabini,* was only tallied in very low numbers, without any clear temporal evolution in numbers.

Keywords Ivory gull · Ross's gull · Sabine's gull · Greenland Sea · Fram Strait

Introduction

The distribution and status of the three Arctic gulls can be summarised as follows (Dement'ev and Gladkov 1969; Meltofte 1972; Blomqvist and Elander 1981; Cramp and Simmons 1983; Hjort et al. 1983; Brown 1984; Mehlum 1989; Decker et al. 1998; Kondratyev et al. 2000; Mallen Olsen and Larsson 2003). The ivory gull *Pagophila eburnea* is associated with pack ice in the high Arctic, feeds on fish and invertebrates, and scavenges on marine mammal carcasses killed by polar bears *Ursus maritimus,* on seals Pinnipedia and on bear faeces (Gilchrist et al. 2008; Karnovsky et al. 2009; Gilg et al. 2010; Spencer et al. 2014). Its breeding range includes the Canadian Arctic, North (N) Greenland (Gilchrist et al. 2008) and mainly the Russian Arctic from Franz Josef Land to Siberia (Gavrilo 2009), with what seems a breeding hotspot in northeast (NE) Greenland (Gilg et al. 2009), apparently bound to the vicinity of the Northeast Water (NEW) polynya. It usually breeds in colonies, either inland on cliffs and nunataks or on coastal barren islands and lowlands (MacDonald and Macpherson 1962; Gilchrist and Mallory 2005; Gilchrist et al. 2008). Rarer breeding sites are on gravel-covered ice floes (Boertmann et al. 2010) and we recently encountered a breeding colony on a gravel-covered iceberg off NE Greenland, close to the NEW polynya (Nachstheim et al. 2015). Important population declines have been detected during the last decades, mainly in N Canada around the North Water polynya (Mallory et al. 2003; Chardine et al. 2004; Gilchrist and Mallory 2005; Gilg et al. 2009; Gaston et al. 2012). This lead to a status of "endangered" species

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in Canada (COSEWIC 2006) and "near threatened" by the International Union for Conservation of Nature, its global population being estimated at between 19,000 and 27,000 individuals (BirdLife International 2015) of which 80 % are in Arctic Russia, i.e. 6300–11,500 pairs (Gilchrist et al. 2008; Gavrilo 2011; Eamer et al. 2013).

Ross's gull *Rhodostethia rosea* breed mainly in the deltas of the Kolyma and Khroma rivers, N Siberia, between 142° and 160°E. Many fewer breed in Greenland (Egevang and Boertmann 2008). Its world population was estimated to be around 50,000 individuals (between 27,000 and 100,000).

Sabine's gull *Xema sabini* breed in the same area, including Wrangel Island, as well as further East in the N Bering Sea. Its world population is estimated as a maximum of 100,000 individuals, of which 1000 pairs are in the Russian Far East and 100–200 pairs in Greenland.

The aim of this article is to report on the status of the three High Arctic gulls in the N Greenland Sea and Fram Strait with special attention to changes in abundance and/or distribution during the last decades.

Materials and methods

Data were collected during (strip) transect counts from the *Polarstern* bridge in the N Greenland Sea and Fram Strait during summer (June–September). Each count lasted 30 min, without width limitation. Description and comments about the counting method have already been published (Joiris 2007, 2012; Joiris and Falck 2011; Joiris et al. 2014). In order to allow comparison, the results presented in this article were collected by the same team using the same counting method and same platform. Basic data are shown as numbers per count without any correction. The main *Polarstern* route consisted of longitudinal transects between NE Greenland and W Spitsbergen, at 79°N and 75°N (see tracks in Online Resource 1). Photos of ivory and Sabine's gulls are included in Online Resource 2 as an illustration.

Results

A synopsis of the data collected in the N Greenland Sea and Fram Strait, *partim* in and close to the pack ice, is presented in Table 1. They can be grouped in two periods, from 1988 to 2005 and from 2007 to 2014, on the basis of obvious changes in density for the most numerous species: ivory gull.

The ivory gull was present in high numbers during the first period with a mean of almost 1.5 individuals per 30-min count ($n = 2700$ counts), all mean values being above 0.6 per count. Peak value per count was tallied on 7 September 2005: 52 individuals, of which 12 were juveniles, at 78.50°N, 7.30°W. Moreover the gull's relative density was high as well, the ivory gull being often among the three to five most abundant species together with fulmar *Fulmarus glacialis,* kittiwake *Rissa tridactyla* and little auk *Alle alle* in the eastern part of the area (e.g. Joiris 1992, 1996; Joiris and Tahon 1992; Joiris et al. 1997). Their numbers obviously decreased during the next period with a mean of 0.2 per count and a maximum mean value of 0.5 per count ($n = 4600$) (Table 1; Fig. 1), i.e. without overlap of mean values between both periods. Its relative density also strongly decreased, being now no longer represented among the ten most abundant species (Joiris 2011; Joiris et al. 2014; Joiris et al. submitted).

The Ross's gull used to be recorded every year until 1993, especially in the NEW polynya area. Its presence reflected a clear seasonal pattern: they were recorded from 15 July on (Table 2). A total of 249 individuals were tallied in the first period, i.e. a mean value of 0.1 per count—more than 0.6 after 15 July. The contrast is striking in comparison to the second period, with only one individual being recorded, while the counting effort was much more significant (Table 1; Fig. 1).

The Sabine's gull was only encountered in very low numbers. Moreover, no clear evolution could be detected, with a mean of 0.01 per count in both periods (Table 1; Fig. 1).

Discussion

The decline in ivory gull numbers in the NEW polynya was striking, a confirmation of the previously recorded decline in the North Water polynya, Canada (see Introduction). The decline might partially have been an old one, since the Spitsbergen breeding population showed a strong decrease by more than one order of magnitude between 1930 and 1966 (Birkenmajer 1969). This is usually interpreted as a decline of the whole species, leading to the status of "endangered" or "near to threatened" species (see Introduction). The recent major decline was not progressive but a drastic one taking place in 2007, at the time the year with the lowest ice coverage ever recorded and thus corresponding to the first opening of the Northeast and Northwest Passages (Online Resource 3), potentially allowing contacts between populations previously separated by heavy pack ice. In contrast, densities were very high in the Russian Arctic, as confirmed by our own observations. During a circumpolar navigation in 2008 I tallied mean ivory gull concentrations off the East Siberian Islands of 4.4 per count, ($n = 27$) around 77°30 N, 175°E, and of eight per count ($n = 13$) around 78°N, 100°E (Joiris, unpublished), and in 2011 a local mean of one individual per count was recorded in the same area ($n = 160$) (Joiris

Table 1 Temporal evolution of high Arctic gull numbers recorded on board RV *Polarstern* in the northern Greenland Sea and Fram Strait: ivory gull *Pagophila eburnea*, Ross's gull *Rhodostethia rosea* and Sabine's gull *Xema sabini*; n = number of 30 min counts; N = total number recorded; mean per count

Years	Period	Expedition	Remark	Gulls:	Ross's Ivory			Sabine's		Mean	References
				n	*N*	Mean	*N*	Mean	*N*		
1988	June	ARK-V/2	*Partim* pack ice	274	360	1.31	1	0.0036	2	0.007	Joiris (1992)
1988	July	ARK-V/3	*Partim* pack ice	218	128	0.59	0		3	0.014	Joiris and Tahon (1992)
1991	June–July	EPOS II	Around Svalbard	377	253	0.67	29	0.077	0		Joiris et al. (1996)
1991	June	NEW polynya[a]		239	330	1.38	0		0		Joiris et al. (1997)
1992	July–August	NEW polynya[a]	RV *Polar Sea*	25	258	10.3	20	0.80	0		Joiris et al. (1997)
1993/1	June	NEW polynya[a]		451	758	1.68	0		3	0.007	Joiris et al. (1997)
1993/2	June–July	NEW polynya[a]		529	727	1.37	92	0.17	5	0.009	Joiris et al. (1997)
1993/3	July–August	NEW polynya[a]	RV *Polar Sea*	113	193	1.71	107	0.95	4	0.035	Joiris et al. (1997)
2005	July–September	ARK-XXI/1b	NE Greenland; *partim* N of 76°N	492	959	1.95	20	0.04	0		Unpublished
Sub-total	1988–2005			2718	3966	1.46	269	0.099	17	0.006	
2007	July	ARK-XXII/1	*Partim* N of 77°N	137	5	0.004	0		0		Unpublihed
2008	June	ARK-XXIII/1		403	32	0.079	0		4	0.010	Joiris (2011)
2008	July–August.	ARK-XXIII/2	NEW polynya[a] included	771	290	0.38	1	0.0013	21	0.027	Joiris (2011)
2009	August–September	ARK-XXIV/3		1076	297	0.28	0		11	0.010	Unpublished
2010	June	ARK-XXV/1		440	18	0.041	0		3	0.0068	Unpublished
2011	June–July	ARK-XXVI/1&2		720	93	0.13	0		3	0.004	Joiris et al. (2014)
2012	June	ARK-XXVII/1		432	233	0.54	0		2	0.005	Unpublished
2012	July	ARK-XXVII/2		201	4	0.020	0		0		Unpublished
2014	July–August	ARK-XXVIII/1&2	*Partim* 70°–82°N	419	78[b]	0.19	0		0		Joiris et al. (in press)
Sub-total	2007–2014			4599	1050	0.23	1	0.0002	44	0.010	
Total	1988–2014			7317	5016	0.69	270	0.04	61	0.008	

[a] Northeast Water polynya, off northeast Greenland

[b] Plus 60 individuals, adults and juveniles, including 2 ringed adults, at and around a breeding colony on an iceberg off Northeast Greenland (Nachtsheim et al. 2015)

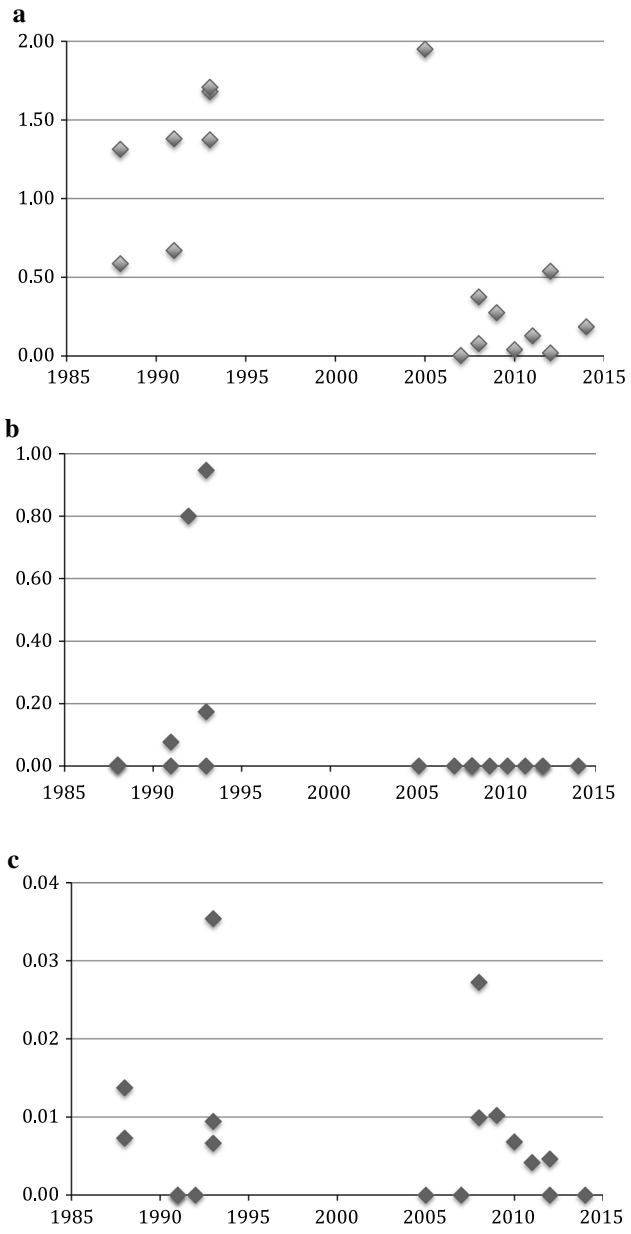

Fig. 1 Temporal evolution in numbers of high Arctic gulls in the Greenland Sea and Fram Strait; mean number per 30-min transect count: ivory gull *Pagophila eburnean* (**a***); Ross's gull *Rhodostethia rosea* (**b**); Sabine's gull *Xema sabini* (**c**); please note differences in scale. *The very high value of 1992 excluded

et al. in press). High local density of Ross's gulls was noted as well, 0.5 per count and 0.1 per count respectively (Joiris, unpublished), and a mean of 1.2 individual per count in 2011 (Joiris et al. in press). Relative concentrations were high as well, ivory and Ross's gulls being the most abundant bird species off N Siberia. A possible hypothesis could be that the drastic decline of 2007 corresponds to a movement towards the E Russian/Siberian populations in 2007 and 2008.

The decline of Ross's gull numbers was even more obvious. The birds observed from 15 July onward during the first period in 1990-1993 were mainly adults, suggesting a post-breeding migration. Apparently they changed habits after 1993 and possibly joined the main route of post-breeding migration off Point Barrow, Alaska (Maftei et al. 2014). Both routes have been known for a long time: Nansen and Johansen saw the first Ross's gulls arriving in Franz Josef Land on 15 July 1895, while the main migrating route was already localised at Point Barrow (Murdoch 1899). Another possible interpretation is that the post-breeding migration presented a kind of "loop" till NE Greenland: this loop possibly became shorter after 1993, as reflected by the movements of satellite-tagged individuals (Gilg et al. 2016).

Conclusion

A drastic decrease in ivory gull numbers was detected the N Greenland Sea and Fram Strait area from 2007 on. These observations confirm previous ones, leading to the conclusion that the species was decreasing and becoming "endangered" or "near threatened". Another mechanism might however be taken into account, namely a possible shift in geographical distribution, since ivory gull numbers were clearly decreasing in Arctic Canada and N Greenland, but high and apparently increasing in Russian/Siberian Arctic. Such a shift might be bound to changes (decrease) in pack ice coverage both in the Northeast Passage and off the Siberian Islands. On the other hand, a change in post-breeding migration might explain the rarity of Ross's gull in the N Greenland Sea and Fram Strait after 1993.

Table 2 Temporal evolution of Ross's gull *Rhodostethia rosea* in the Northeast Water polynya "box"; n = number of 30-min counts; N = total number recorded; mean per count From Joiris et al. (1997)

From	To	Years	n	N	Mean	RV	Observers
25 May	2 June	1993/1	239	0	–	*Polarstern*	C.R. Joiris
9 June	19 June	1991	451	0	–	*Polarstern*	C.R. Joiris, J. Tahon, M. Ellander
28 June	31 July	1993/2	529	92	0.18	*Polarstern*	J. Tahon
21 July	5 August	1993/3	113	107	0.95	*Polar Sea*	K. Kammp
22 July	10 August	1992	25	20	0.80	*Polar Sea*	R. Møbjerg Kristensen

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Compliance with ethical standards

Conflict of interest None.

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