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Winter distribution of Steller's Eiders in the Varangerfjord, northern Norway

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Abstract. Arctic warming and decreasing sea-ice cover along the Siberian coast in the Arctic Ocean leads to greater accessibility for operations such as oil drilling and traffic of tankers. This implies increasing risks for Steller's Eider *Polysticta stelleri* wintering, moulting and staging along the coasts of the Varanger Peninsula, Norway. Steller's Eiders were surveyed by monthly counts during winter and early spring 2016/2017 to investigate numbers and distribution throughout the winter. The highest number of wintering Steller's Eiders was found in January, representing ~7 % of the European population. In February–April numbers were lower, but at a rather stable level. We found relatively little variation in distribution between months, although the birds were more evenly distributed along the coast later in winter. Mean flock size was significantly larger in January than in March and April. Feeding behaviour was exclusively observed in shallow water, generally at depths of up to 6 m. Areas of focus for an oil pollution emergency plan are pointed out and discussed.

Keywords: Steller's Eider, *Polysticta stelleri*, winter distribution, flock size, oil pollution

INTRODUCTION

Among several threats to present day Arctic fauna and flora, the direct and indirect threats of a warming climate may be the most critical of all. Along with shifts in temperature, ice cover, vegetation, ranges and communities of species and the prevalence of infectious diseases (Tulp & Schekkerman 2008, Lafferty 2009, Pearson et al. 2013, Descamps et al. 2016), a number of threats related to an ever-increasing human utilisation of Arctic resources and accessibility are also likely to arise (Fox et al. 2015, Meier et al. 2014, Wauchope et al. 2016).

One Arctic species at risk is the Steller's Eider *Polysticta stelleri*. This small seaduck, distributed in Arctic Russia, Alaska and Northeast-Europe, is declining in numbers, and is listed as Vulnerable (VU) on the IUCN Red List of Threatened Species (BirdLife International 2016). Although the causes of decline are largely unknown, Steller's Eiders face a number of anthropogenic and climatic threats, including bycatch in gillnet fisheries, oil spills and habitat loss (Pihl 2001, Zydelis et al. 2006a, BirdLife International 2016). In Europe, the largest winter populations are found in Russia and northern Norway (Aarvak et al. 2012, BirdLife International 2015). The Norwegian range is largely confined to the northern coastline of the Varangerfjord, although flocks are frequently found further west along the coast according to the Norwegian Species Observations System Artsobservasjoner (www.artsobservasjoner.no).

Oil drilling in Arctic waters is increasingly relevant due to the withdrawal of the ice margin and the thereby greater accessibility, as well as better technology for carrying out such operations in extreme environments. In 2013, the Norwegian Parliament decided to open the south eastern and eastern region of the Norwegian Barents Sea to petroleum activity (Ministry of Petroleum and Energy 2014). In the eastern regions of the Russian Barents Sea, the Pechora Sea and the Kara Sea, there are already several offshore installations, including oil platforms. Drilling, transport and transhipment of oil in this region increase the risk of Steller's Eider exposure to oil spills (Bambulyak & Frantzen 2009). As the northern hemisphere icecap melts, an increase in oil tanker traffic along the Siberian coast in the Arctic Ocean is to be expected (e.g. Fox et al. 2015). This may further increase the risk of oil spills in wintering, moulting and staging areas for Steller's Eider.

The strong congregatory nature of Steller's Eiders as well as their restricted habitat ranges make them vulnerable to oil spills (Zydelis et al. 2006b). Their limited distribution in northern Norway, and the occurrence of large flocks in harbours in the region (Fox et al. 2015), place them at risk from even small-scale oil spills.

Previous studies have looked into habitat use and distribution of Steller's Eiders in the Varangerfjord (Henriksen & Lund 1994, Fox et al. 1997, Bustnes & Systad 2001, Systad & Bustnes 2001), although these were carried out before 2000, when the winter population was significantly larger than it was in 2017. Moreover, none of those studies investigated monthly changes in distribution throughout an entire wintering season.

In order to identify areas of focus for a future oil

Table 1. Monthly numbers (# ind.) and distribution of Steller's Eiders *Polysticta stelleri* along the northern coastline of the Varangerfjord, northern Norway, during winter 2016/2017. Diving depth is given as weighted means. Directional distribution is expressed as monthly standard deviational ellipse sizes. The consistency in distribution of individuals between months is expressed as overlap between monthly ellipses and source layer ellipses. The degree of clustering of individuals is expressed as the average nearest neighbour ratio, which is the ratio between observed and expected (random distribution) mean distance between neighbouring flocks. Z-scores and p-values tests the null hypothesis of random distribution.

					Directional distribution Source layer overlap						Average nearest neighbour		
Month	# ind.	Flock size ($\bar{x}$)	Diving depth ($\bar{x}$)	Ellipse size	Dec	Jan	Feb	Mar	Apr	$\bar{x}$	Ratio	z	p
Dec	477	43.4	0.4–4.1 m	87 km^2	–	97 %	100 %	98 %	100 %	99 %	1.71	4.50	< 0.001
Jan	1 749	53.0	2.3–6.8 m	187 km^2	45 %	–	81 %	96 %	96 %	80 %	0.66	-3.70	< 0.001
Feb	1 181	26.2	–	194 km^2	45 %	78 %	–	81 %	95 %	75 %	0.35	-8.29	< 0.001
Mar	1 144	22.0	0.9–4.6 m	187 km^2	45 %	96 %	84 %	–	99 %	81 %	0.44	-7.73	< 0.001
Apr	1 241	20.6	–	313 km^2	28 %	57 %	59 %	59 %	–	51 %	0.28	-10.4	< 0.001
Mean		28.6	1.7–5.9 m	194 km^2	41 %	82 %	81 %	84 %	98 %	77 %			

pollution emergency plan in this region, the aim of the present study was to investigate the occurrence of wintering Steller's Eiders along the northern coastline of the Varangerfjord, and to detect possible changes in distribution, flock size and habitat use throughout the wintering season.

METHODS

We performed monthly censuses of Steller's Eiders along the entire coastline between Vadsø/Andersby and Vardø/Svartnes on the Varanger Peninsula, northern Norway in six periods between November 2016 and April 2017 (2–4 November, 5–6 December, 23–24 January, 14–15 February, 15–16 March, 25–27 April). Each census was performed over two or three consecutive days. The counts were performed from along a main road (European route E75) that follows the coastline at a distance of approx. 50–500 metres from the shoreline and by making stops about every 500 m, during which the nearest coastline and coastal waters were scanned with 8–10x binoculars and 20–70x spotting scopes. In areas where the shore was not visible from the main road, detours were made in order to come closer to the shoreline. We counted, sexed and aged Steller's Eiders and noted approximate positions of individuals and flocks found. A Samsung Galaxy Tab S2 with the map application "Norgeskart" and a GPS function where the exact position of the observer could be seen made it easier to judge the position of the flock and to fix it on the map. The exact position of the fix could be read directly from the map application. Steller's Eiders form very dense flocks, which are easily separated in the field. Individuals not belonging to such dense flocks were noted separately. Where conditions allowed, the count was accurate (down to individual level). We only performed censuses during good counting conditions, i.e. not during heavy precipitation, wind or unsettled seas.

Data analyses

All data were imported into ArcMap version 10.5.1 (ESRI 2017). Monthly and summed distribution models were prepared using Kernel density, with cell size and search radius specified at 0.0001 and 5,000 m, respectively. Plugins "directional distribution (standard deviational ellipses)" and "average nearest neighbour" were used to investigate monthly differences in distribution (with "flock size" as a weighting parameter) and clustering of individuals, respectively. The clustering of individuals was expressed as the average nearest neighbour ratio, which is the ratio between observed and expected (random distribution) mean distance between neighbouring flocks (i.e. larger distance between flocks gives a higher ratio, which corresponds to a higher degree of clustering). Degree of overlapping between standard deviational ellipses was calculated from overlay analyses (plugin "intersect").

Diving depths for actively feeding flocks were found by matching their geographic positions with bathymetric vector data from the Norwegian Mapping Authority (https://creativecommons.org/licenses/by/4.0/) using the plugin "spatial join". Averages in diving depth for each month was calculated using flock size as a weighting parameter. Difference in diving depth between months was investigated using ANCOVA with flock size and month as covariates. Difference in flock size was investigated using one-way ANOVA. Means and parameter estimates are given with standard error (± SE). Statistical tests were performed in R version 3.4.3 (R Core Team 2017).

RESULTS

Kernel density plots of Steller's Eider distribution in the study area between December 2016 and April 2017 are presented in Figure 1. The distribution of individuals was highly consistent between months, with a 77 ± 5% mean overlap between monthly standard deviational ellipses (Table 1). Flocks were most dispersed in April, coinciding with a high degree of clustering of individuals (Table 1).

No Steller's Eiders were recorded in the study area during the November census, but by early December, several hundred had arrived. The highest number of individuals was recorded during the January census, followed by lower, but fairly consistent, numbers in February–April (Table 1). Mean flock size peaked in January and was lowest in April, and a statistically significant monthly difference in flock size was found ($F_{3, 201}$ = 3.53, p = 0.008, mean = 28.6 ± 3.2, Table 1). Tukey's method revealed significant differences in flock size between January and March (p = 0.019) and between January and April (p = 0.008).

Diving depth of Steller's Eiders was recorded in December, January and March, showing that birds preferred feeding on shallow water between 1.7 and 5.9 m depth. There was no difference in diving depth between months after controlling for flock size ($F_{2, 40}$ = 1.17, p = 0.32).

DISCUSSION

Distribution of Steller's Eiders in the present study is comparable to that found in previous studies in the same area two decades earlier (Fox et al. 1997, Bustnes & Systad 2001). Preferred feeding areas and diving depth during winter 2016/2017 were characterized by shallow nearshore waters. Similar findings have been reported from other studies carried out in wintering Steller's Eiders (Petersen 1980, Metzner 1993, Fox & Mitchell 1997). Bustnes & Systad (2001) found that flocks preferred feeding in vegetated areas dominated by hard bottom substrates along the Varanger Peninsula. The consistency between that study and the present may indicate a high degree of stability of these most important (feeding) habitats. Bustnes & Systad (2001) further concluded that these preferred feeding habitats were dominated by kelp, mostly *Laminaria hyperborea*, and that Steller's Eiders avoided areas dominated by soft bottom substrates such as sand and mud. Kelp beds dominated by *Laminaria hyperborea* typically support high densities of preferred prey such as gastropods and crustaceans (Guillemette et al. 1992, Norderhaug 1998, Bustnes et al. 2000). Such hard bottom near shore habitats are also highly vulnerable to oil spills, where it may affect not only Steller's Eiders, but also the prey they feed on.

Observed flock size in the present study was at its highest in January (and December), and significantly lower in late winter. This coincided with a higher degree of dispersion later in winter, and may be related to variations in climate, day length, predation pressure and prey abundance throughout the winter months (Lazarus 1979, Pulliam & Caraco 1984, Guillemette et al. 1993). Systad & Bustnes (2001) found that the incidence of feeding in wintering Steller's Eiders was highest at low tide, and especially during the darkest winter months. This was also the time of year with the highest estimated feeding time and the lowest mean diving depth. Similar results were found by Laubhan & Metzner (1999) investigating wintering Steller's Eiders in Alaska. Both studies emphasize the higher energy requirements of Steller's Eiders at low temperatures, which they cope for by spending more time feeding and reducing the costs of diving. The pronounced flocking behaviour of the species may be another adaptation to conserve energy, by reducing heat loss to the environments. Gathering in flocks could perhaps also make feeding more efficient through social interactions (Pulliam & Caraco 1984). Smaller flock size and greater dispersion in late winter documented in the present study may also be a consequence of prey depletion caused by high feeding pressure throughout the winter (Pulliam & Caraco 1984, Guillemette et al. 1993, Bustnes et al. 2013). The possibility that tidal cycles affected the distribution of Steller's Eiders found in the present study cannot be ruled out. However, this effect would be difficult to eliminate as it would be impossible to census the whole study area at a given tidal level within a single tidal cycle, but also due to local differences in tidal cycles within the fjord system. Nevertheless, we consider it unlikely that tidal cycle significantly influenced the distribution of Steller's Eiders found in the present study, due to the degree of consistency between monthly censuses, in addition to our general impression from sites visited more than once during the two or three consecutive days of each census.

During weekly counts of Steller's Eiders in Vadsø harbour in autumn 1993, the first wintering individuals arrived in the first week of October, with 358 individuals in the harbour on 9 October 1993 (Henriksen & Lund 1994). The median arrival date of wintering Steller's Eiders equipped with satellite transmitters in April 2001 was 13 November (range: 24 September–24 November; Petersen et al. 2006). Thus, it was somewhat surprising that no Steller's Eiders were recorded during the November census in the present study. However, the study design does not allow for exact determination of arrival date and annual variation of this parameter. Nevertheless, later arrival at the wintering grounds may not be very surprising, given that the Norwegian wintering population has decreased markedly since the mid-1980s. It has previously been

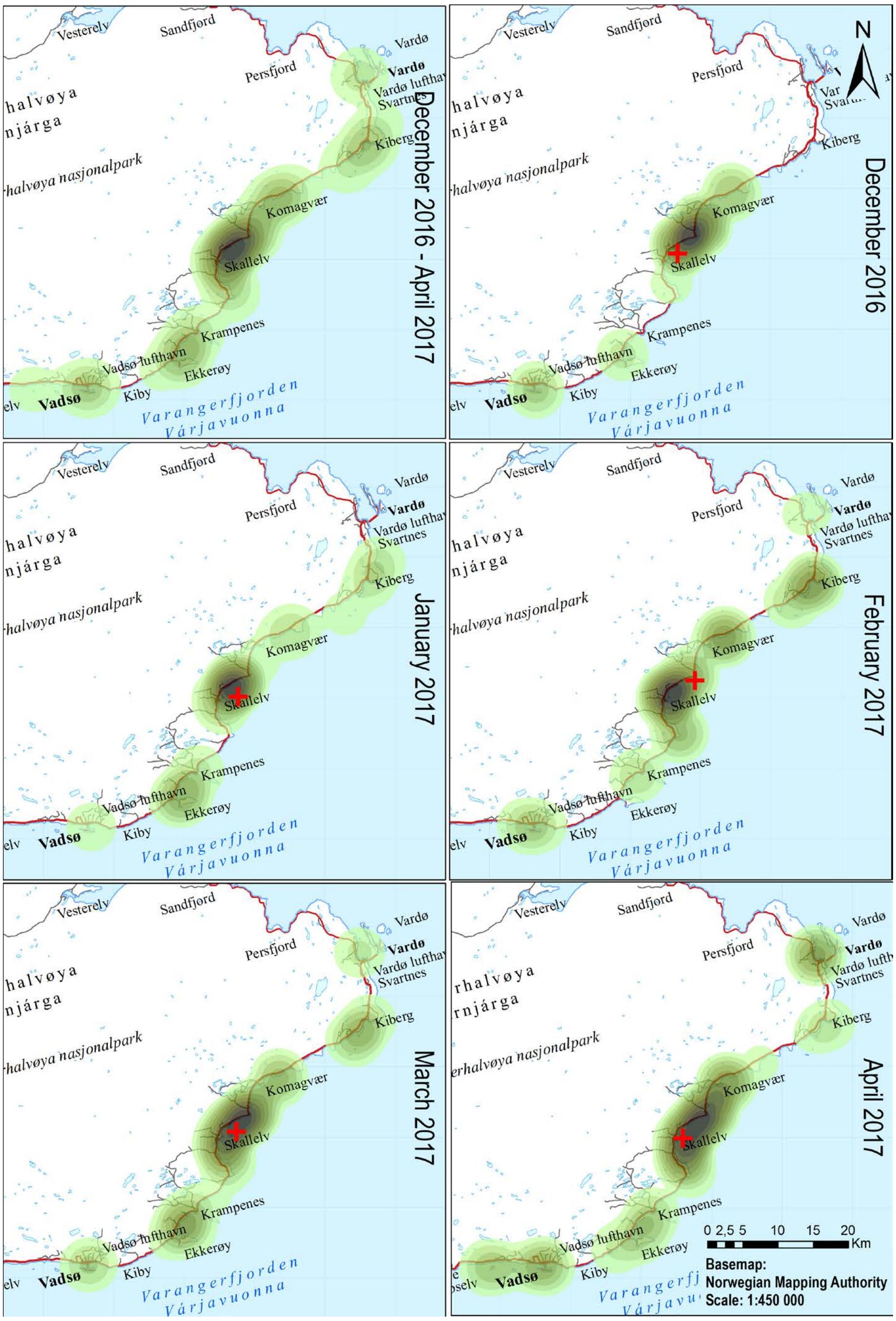

Figure 1. Kernel density plots of Steller's Eider *Polysticta stelleri* distribution along the northern coastline of the Varangerfjord, northern Norway, December 2016–April 2017. Darker green colour indicates higher density of individuals. Monthly geographical centres are expressed as red pluses.

shown that population trend may be an important factor in determining arrival time in migrating species (e.g. Miller-Rushing et al. 2008, Tryjanowski et al. 2005). The decline in the Norwegian Steller's Eider wintering population is most likely caused by an eastward shift in distribution, with a larger share of the population now wintering in Russia (Aarvak et al. 2012). The present January count was 15 % lower than the count in 2009 for Norway for the similar count section (holding approx. 75 % of the Norwegian wintering population), and representing 6.7 % of the total European count from that year (Aarvak et al. 2012).

The results from the present study clearly demonstrate the areas of greatest importance to wintering Steller's Eiders between Vadsø and Vardø during winter 2016/2017, and at what time of year the numbers peaked. Visual investigation of distribution patterns reveals that several of the areas of importance in the present study were also the most important two decades earlier (Fox et al. 1997, Bustnes & Systad

2001). This fact has significant implications for the conservation of the species in the area, and is of particular relevance to the planning of a potential future oil pollution emergency plan in this region. To provide the best possible emergency plan, data on distribution of Steller's Eiders must be combined with models of the most likely oil pollution scenarios. For instance, local oil spills may be more frequent in harbours than elsewhere (e.g. Nygård et al. 1995).

Observations reported in Artsobservasjoner (www.artsobservasjoner.no) and previous studies indicate that the Steller's Eiders depart from their Norwegian wintering grounds during the three first weeks of May (Henriksen & Lund 1994). Thus, there may be a need for complemental surveys at this time of year. Similarly, further surveys may be needed in October/November to investigate arrival time of Steller's Eiders to Finnmark. There is also a need for investigating the importance of the northern coastline of Finnmark to wintering Steller's Eiders, in particular the Nordkinn Peninsula area. Satellite telemetry may be a valuable tool to provide better knowledge of individual movements throughout the winter, and how this is influenced by variables such as day length, weather and food availability.

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