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Survival rate and breeding outputs in a high Arctic seabird exposed to legacy persistent organic pollutants and mercury

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ABSTRACT

Chronic exposure to pollutants may represent a threat for wildlife. We tested whether adult survival rate, breeding probability and breeding success the year of sampling and the following year were affected by blood levels of mercury or persistent organic pollutants in Svalbard black-legged kittiwake *Rissa tridactyla*, by using capture–mark–recapture models over a five-year period. Survival rate was negatively linked to HCB levels in females, to chlordane mixture and oxychlordane, tended to decrease with increasing PCBs or DDE levels, but was unrelated to mercury. Breeding probability decreased with increasing mercury levels during the sampling year and with increasing CHL or HCB levels during the following year, especially in males observed as breeders. Surprisingly, the probability of raising two chicks increased with increasing HCB levels. Although levels of these legacy pollutants are expected to decline, they represent a potential threat for adult survival rate and breeding probability, possibly affecting kittiwake population dynamics.

1. Introduction

Contaminants, such as mercury (Hg) and persistent organic pollutants (hereafter POPs) may represent a threat for wildlife, because of their detrimental effects on developmental, neurological, physiological, endocrine and immune functions (Barron et al., 1995; Bustnes et al., 2003a; Tan et al., 2009; Letcher et al., 2010). Despite a growing environmental concern during the last decades, the demographic consequences of pollution remain poorly evaluated in free-living vertebrates. Only a few long-term monitoring studies have addressed the consequences of environmental pollutants on survival rate and long-term reproductive outputs. Hg or POP levels were negatively related to long-term breeding probability and success in the wandering albatross *Diomedea exulans* and in two *Catharacta skua* species (Goutte et al., 2014a,b). Apparent survival rate was lower in glaucous gulls *Larus hyperboreus*, bearing the highest levels of oxychlordane, a metabolite of the chlordane mixture, which is regarded as one of the most toxic POPs (Erikstad et al., 2013). However, adult survival rate was not related to POPs or Hg in tree swallows (*Tachycineta bicolor*), king eiders (*Somateria spectabilis*), white-winged scoters (*Melanitta fusca*), wandering albatrosses and two *Catharacta* skua species (Wayland et al., 2008; Hallinger et al., 2011; Goutte et al., 2014a,b).

Some seabird species appear as ideal models for assessing the demographic consequences of environmental pollution. Firstly, individual detection probabilities of seabirds at breeding colonies are generally high because of high overall site fidelity (e.g. Gauthier et al., 2012). Secondly, large sample sizes and accurate measures of breeding outputs are relatively easy to obtain in seabird's colonies. Thirdly, these long-lived top predators are particularly exposed to contaminants, because of bioaccumulation process and

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biomagnification along the trophic web (Rowe, 2008; Letcher et al., 2010).

The present study focusses on black-legged kittiwakes *Rissa tridactyla* breeding in Svalbard, a Norwegian archipelago in the north-western part of the Barents Sea. The Norwegian Arctic is recognized as a final sink for organic and metallic pollutants, which are transported by atmospheric and oceanic currents and by large rivers (Gabrielsen and Henriksen, 2001). Previous studies in this population of Svalbard kittiwakes have reported deleterious effects of Hg and POPs on endocrine mechanisms (Nordstad et al., 2012; Tartu et al., 2013, 2014). The estimated number of breeding pairs in the Svalbard archipelago is 270 000 in 215 colonies (Strøm, 2006). The status of black-legged kittiwakes is near threatened, with a pronounced population decline from 1995 to 2002 and a slight increase from 2002 to 2012 (Barrett et al., 2012). This study aims at detecting whether breeding probability the year of sampling and demographic traits the following year (apparent adult survival rate, breeding probability, probability of successfully raising at least one chick and probability of successfully raising two chicks) were correlated with individual blood levels of Hg or POPs. According to the few available long-term studies on polar seabird species (Erikstad et al., 2013; Goutte et al., 2014a,b), we predicted deleterious effects of Hg or POPs on breeding probability and breeding success during the year of sampling and during the following year and deleterious effects of the chlordane mixture and metabolites on survival rate in black legged kittiwakes.

2. Materials and methods

2.1. Study area and birds

Our study was conducted in a colony of black legged kittiwakes at Kongsfjorden, Svalbard (78°54′N, 12°13′E), seven kilometers southeast of Ny-Ålesund, Norway. Kittiwakes are colonial seabirds that breed on cliffs throughout the northern parts of the Pacific and Atlantic, including the Barents Sea region up to the Svalbard Archipelago (Anker-Nilssen et al., 2000). Kittiwakes were studied in one plot of around 150 pairs breeding on cliff ledges at heights of 5–10 m. Male and female kittiwakes were sampled once, between 2007 and 2010 years, during the pre-laying stage (arrival, nest building, courtship and mating period) from 23rd of April to 16th of June. Table 1 summarizes sampling information: a total of 105 kittiwakes were sampled for measurement of Hg and 138 kittiwakes for POPs. We chose to focus our study on the pre-laying period, because sampling kittiwakes during the incubating or chick-rearing period would have biased our demographic study towards good-quality birds (breeders) and would have missed possible effects in non-breeders.

Table 1
Levels (mean ± SD) of Σ PCBs (CB, −99, −118, −138, −153, −180, −183 and −187), p,p′-DDE, HCB, CHL (transchlordane, trans-, cis-nonachlor, oxychlordane) and Hg (mercury) in blood of male and female kittiwakes sampled during the pre-laying period.

	Year	Males	Females
Σ PCBs (pg.g^{-1} ww)	2007	14,700 ± 9630	12,640 ± 6421
	2008	14,896 ± 11,029	13,399 ± 9197
	2009	9282 ± 7915	10,375 ± 4705
	2010	12,786 ± 10,966	21,168 ± 14,390
DDE (pg.g^{-1} ww)	2007	3622 ± 1730	3152 ± 1422
	2008	4025 ± 2642	4189 ± 3490
	2009	2618 ± 1660	2184 ± 890
	2010	3249 ± 2739	4725 ± 3584
HCB (pg.g^{-1} ww)	2007	1616 ± 966	1600 ± 407
	2008	1616 ± 444	1691 ± 697
	2009	2416 ± 1493	2699 ± 451
	2010	2670 ± 877	3487 ± 1288
CHL (pg.g^{-1} ww)	2007	1352 ± 782	1329 ± 508
	2008	1237 ± 510	1275 ± 765
	2009	1344 ± 1155	1353 ± 403
	2010	1766 ± 650	2482 ± 1602
Hg (μg.g^{-1} dw)	2008	2.06 ± 0.44	1.97 ± 0.44
	2009	2.33 ± 0.55	2.01 ± 0.41

2.2. Capture and blood sampling

Male and female kittiwakes were caught on the nests with a noose at the end of a 5 m fishing rod. Blood samples were collected from the alar vein with a 2 ml heparinized syringe and a 23-gauge needle. Kittiwakes were individually marked with metal rings and PVC plastic bands engraved with a three-digit code and fixed to the bird's tarsus for identification from a distance without perturbation.

2.3. Laboratory analyses

Blood samples were centrifuged. Plasma and red blood cells were separated and stored at − 20 °C. Molecular sexing was performed on red blood cells as detailed in Weimerskirch et al. (2005). Total Hg was measured at the laboratory Littoral Environnement et Sociétés (LIENSs) from lyophilized red blood cells with an Advanced Mercury Analyzer spectrophotometer (Altec AMA 254). At least two aliquots ranging from 5 to 10 mg dry weight were analyzed for each individual until having a relative standard deviation < 5%. As described by Bustamante et al. (2006), accuracy was checked using a certified reference material (CRM, Tort-2 Lobster Hepatopancreas, NRC, Canada; certified Hg concentration: 0.27 ± 0.06 μg g−1 dry mass; with recoveries of 98–102%). Mass of CRM was adjusted to represent the same amount of Hg introduced in the AMA compared to that in blood samples. Blanks were analyzed at the beginning of each set of samples and the detection limit of the method was 0.005 μg g−1 dry mass. Mean values of replicates were used in statistical analyses.

POPs were analyzed from whole blood samples at the Norwegian Institute for Air Research (NILU) in Tromsø. The following compounds were analyzed: polychlorinated biphenyl (CB, −99, −118, −138, −153, −180, −183 and −187) hereafter referred as $\sum$ PCBs, p,p′-DDE (p,p′-dichlorodiphenyldichloroethylene), HCB (hexachlorobenzene), and the chlordane mixture (trans-chlordane, trans-, cis-nonachlor) and metabolites (oxychlordane), hereafter referred as CHL. To a blood sample of 0.5–1.5 ml, an internal standard solution was added (13C-labeled compounds from Cambridge Isotope Laboratories: Woburn, MA, USA). The sample was extracted twice with 6 ml of *n*-hexane, after denaturation with ethanol and a saturated solution of ammonium sulfate in water. Matrix removal on florisil columns, separation on an Agilent Technology 7890 GC and detection on an Agilent Technology 5975C MSD were performed as described by Herzke et al. (2009). The limit for detection was threefold the signal-to-noise ratio, and for the compounds investigated the limit ranged from 0.4 to 122 pg.g^{-1} wet weights (ww). For quality assurance, blanks (clean and empty glass tubes treated like a sample) were run for every 10 samples similar to standard reference material (1589 a human serum from NIST). The accuracy of the method was within the 70 and 108% range.

2.4. Life history traits

From 2007 to 2012, individuals were individually identified, through PVC plastic bands reading. Using a mirror at the end of an 8 m fishing rod, we checked the whole plot (about 120 nests) every