TEMPORAL VARIATION IN CIRCULATING CONCENTRATIONS OF ORGANOCHLORINE POLLUTANTS IN A PELAGIC SEABIRD BREEDING IN THE HIGH ARCTIC

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Abstract: The present study explored short-term temporal variations in circulating concentrations of three legacy organochlorines (OCs) with different physicochemical properties (polychlorinated biphenyl 153 [PCB-153], *p,p'*-dichlorodiphenyldichloroethylene [DDE], and hexachlorobenzene [HCB]) in breeding kittiwakes (*Rissa tridactyla*) in a colony in Svalbard (78^{o}N), Norwegian Arctic. Concentrations were measured in blood of a large number (n = 412-521 blood samples, depending on the data-analyses), of pre-breeding, incubating and chick-rearing birds over a period of five years (2007-2011). PCB-153 concentrations were equal in male and female blood in the pre-breeding period, whereas females had significantly lower concentrations during incubation and chick rearing, probably due to their ability to eliminate OCs through egg laying. A similar temporal pattern was observed with DDE although the lower concentrations in incubating females were not significant. Males and females had similar concentrations of HCB over all reproductive stages. The concentrations of all three compounds varied greatly between years. PCB-153 tended to decline over the study period while HCB showed an increasing trend, especially among chick-rearing males late in the season. Concentrations of PCB-153 increased about 2.5 times from the pre-breeding to the chick-rearing period, concurrent with mobilization of body lipids (reduced body mass). A similar, but less pronounced trend was found for HCB. For DDE, however, kittiwakes had the highest concentrations in the pre-breeding period, suggesting relatively high exposure in their winter areas. The present study documented large variations in circulating concentrations of legacy OCs among and within breeding seasons in kittiwakes, but the alterations within seasons were relatively consistent from year to year.

Keywords: Kittiwake Organochlorines Marine pollution Seasonal variation

INTRODUCTION

Organochlorines (OCs) are lipid-soluble pollutants that may undergo long-range transport to the Arctic, where they bio-magnify in local food webs [1, 2]. Due to their high trophic positions, arctic seabirds accumulate relatively high loads of such compounds [3, 4]. Many OCs were, however, banned in most countries decades ago (e.g. DDT and PCB), which has resulted in declining concentrations in arctic biota, also in seabirds [5, 6].

In seabirds, as in other wildlife species, OCs are distributed among different body compartments: e.g., they may be stored in lipids within various organs, in adipose tissue, or they may be circulating in the blood stream. There are three main processes determining the concentrations of circulating OCs: 1) intake via food; 2) degree of remobilization of OCs from adipose tissue; 3) removal through different elimination routes, including egg laying [7]. In addition, the lipid content of blood and tissue is also an important determinant for these concentrations [8].

OC concentrations in blood of arctic seabirds may show high inter-annual variation due to temporal variability in: 1) long-range transport through alterations in the atmosphere and oceans [9-11] and/or; 2) diet; i.e. variation in the availability of prey with different lipid and OC loads [12, 13]; 3) Variation in temperatures; i.e. at low temperatures the daily energy expenditure and thus lipid metabolism increase, which remobilize more stored OCs, and subsequently the circulating concentrations will increase [8, 14]; 4) Arctic seabirds may also carry OCs during migration (bio-transport), and annual variation during breeding may be a reflection of the variation in OCs exposure at the wintering grounds [15, 16].

Variation in circulating OC concentrations within breeding seasons may also arise from altered transport, diet and remobilization due to temperature variability, but also because the body condition (lipid stores) of seabirds often vary consistently within breeding seasons [17, 18]. Moreover, there may be variation across the sexes, and females may eliminate some

of their OC loads through egg production. Although some seabird studies have found lower concentrations of OCs in the blood of incubating females compared to males [19-21], the importance of egg laying as a determinant for OCs in blood has been little studied in wild birds [7, 22].

The circumpolar black-legged kittiwake (*Rissa tridactyla*) (hereafter 'kittiwake') is a pelagic and surface-feeding seabird with a diet of different fish species and invertebrates [23]. Arctic breeding kittiwakes usually lay two eggs (1-3) and incubate for approximately27 days. Hatching occurs in early July, and parents rear chicks at the nest for 4-5 weeks [24]. The kittiwake leaves the Arctic in October/November and returns in April [25, 26]. In order to explore the short-term dynamics of circulating OCs, we measured three legacy OCs with different physicochemical properties; polychlorinated biphenyl 153 (PCB-153); *p,p'*-dichlorodiphenyldichloroethylene (DDE) and; hexachlorobenzene (HCB) in more than 500 kittiwake blood samples from a colony at Svalbard, over 5 years. Samples were collected during three reproductive stages (April: pre-breeding; mid-June: incubation; and late-July: chick rearing). HCB is a semi-volatile compound with high long-range transport potential that show high concentrations at remote locations such as the Arctic and the Antarctic. In comparison, PCB-153 is a much heavier and very persistent molecule with a relatively lower atmospheric transport potential. DDE is a metabolite of DDT and in seabirds, its occurrence correlates to a varying degree with other legacy OCs such as PCB [14, 27-32], even if historical industrial applications have been quite different. These three OCs were chosen as key compounds because they have been linked to changes in physiology, reproduction and survival of Svalbard kittiwakes and they represent a broad range of physiochemical properties characteristic of the OC class of compounds [3, 33, 34].

In the present study, we hypothesized that egg laying induces differences in OC circulating concentrations between the as females may reduce their OC loads through

106 contaminant deposition into their eggs. Consequently, we predicted that concentrations would
107 be equal for male and female kittiwakes prior to egg laying, but lower for females after egg
108 laying. Secondly, since body condition of kittiwakes tend to decline from the pre-laying to the
109 chick-rearing stages [18, 35, 36] we hypothesized increasing remobilization of OCs from
110 adipose tissue, thus increasing blood concentrations as breeding progressed. One central
111 question was whether changes in body mass (body lipids) over the breeding season could
112 explain alterations in OC concentrations, or if some other factors related to the different
113 reproductive stages would be of importance. Based on the different physiochemical properties
114 of the three OCs, we predicted different dynamics in kittiwakes, with a stronger fluctuation in
115 HCB concentrations over the breeding season, relative to PCB-153 and DDE (higher
116 volatility and lower K_{ow} and less lipophilic of HCB compared to PCB and DDE). We tested
117 the hypotheses both for wet weight and lipid normalized concentrations.

118

119 **MATERIALS AND METHODS**

120 *Study species and field procedures*

121 The kittiwake is a long-lived gull with a circumpolar distribution, breeding in
122 colonies on cliffs. In Svalbard, it feeds mainly on capelin (*Mallotus villosus*), polar cod
123 (*Boreogadus saida*) and amphipods [37, 38]. Krykkjefjellet, our study colony, is a seabird
124 cliff located 6 km southeast of Ny-Ålesund in Kongsfjorden, Svalbard (78˚54′N, 12˚13′E).
125 The kittiwakes were caught on their nest with a snare on a long fishing rod. All birds were in
126 adult breeding plumage: i.e. no dark patches on their heads or black fields on their outer
127 primaries [23].

128 Blood samples for contaminant analyses were taken from both sexes during the pre-
129 breeding, incubation and chick rearing periods between 2007 and 2011. Samples (~1.5 ml

blood) were taken from the brachial vein using a heparin treated 2 mL syringe and a 23G needle. In the field, the samples were immediately stored in darkness at ambient temperatures in June and July. In April, the samples were kept from freezing. When returning from the field all the samples were frozen at -20°C.

Body mass and skull length (head and bill) were measured with an accuracy of 5 g and 0.1 mm, respectively, and the birds were banded with a metal and a three-letter coded plastic ring [34]. Confirmation of breeding status (pre-laying, incubation and chick rearing) was done by inspecting nest content using a mirror at the end of a long rod.

Permissions for fieldwork and blood sampling of the birds were granted by the Governor of Svalbard and complied with the Norwegian Regulations on Animal Experimentation.

POPs analyses

The concentrations of POPs in the blood samples were analyzed at the Norwegian Institute for Air Research (NILU) in Tromsø, Norway. Details regarding the analyses are provided in Herzke et al. [39] and in Nordstad et al. [36]. Lipid content in the blood samples were analyzed gravimetrically. We analyzed blood lipids for all years, except in 2009 due to a laboratory problem. We analyzed the correlations of different factors both on wet weight (all years except 2009) and lipid normalized concentrations.

Molecular sexing

The sex of the birds was determined at the Centre d'Etudes Biologiques de Chizé (CEBC-CNRS, University of La Rochelle). To sex the birds, DNA was extracted from red blood cells and the CHD gene was amplified in a PCR procedure, as described by Weimerskirch et al. [40].

Statistical Analysis

Statistical analyses and plotting of results were carried out in R [41]. All tests were two-tailed, the null-hypothesis was rejected at an α-level of 0.05, and we used the treatment contrast comparing each level of a factor to its baseline level. Standard plotting diagnostics tools were used in all analyses, and as none of the residuals was normally distributed, the responses were $\log_e$-transformed.

Prior to the statistical analyses, we assessed collinearity in several steps. Firstly, we assessed the extent to which kittiwake body mass varied as a function of the other predictors by forming a set of different *a priori* models. The selected model explained >60 % of the variance in body mass. As body mass was related to year, period and sex in addition to two interactions involving period we chose to separate the analyses between the sexes. Secondly, collinearity was then assessed by checking if the effect sizes or their level of statistical significance differed depending on whether each of the other predictors was excluded or not. Thirdly, Variance Inflation Factor (VIF), with a cut-off value of 5, was used to assess which predictors that are collinear and consequently should be dropped prior to the analyses [42]. As we were unable to reveal any collinearity, we concluded that our separation of the analyses of contaminants between the sexes were sufficient to avoid potential problems with serious confounding.

We performed our statistical analyses in several steps. Firstly, we performed a set of overall analyses in order to assess the extent in which the different responses varied according to period and sex (keeping body mass out due to the collinearity issues outlined above), by fitting linear mixed-effect models (LME) [43] with reproductive period, sex and their interaction as fixed effects, whereas the constant term for year was used as a random effect (i.e. random intercepts only). Secondly, we performed more detailed analyses (on each sex

separately), where we fitted linear models (LMs), using the *lm* function in *R* in order to assess the effects of body mass, period and year. In these analyses, we calculated the second-order *Akaike's Information Criterion* (AICc) values for several candidate models [42, 44]. The models used for inference were selected by: 1) forming a set of candidate models where we rescaled and ranked models relative to the model with the lowest AICc value (Δ_i denotes this difference for model *i*) and then by 2) selecting the simplest model with a $\Delta_i \leq 1.5$ even though we also provide Akaike's weights. Model selection was performed using the *AICcmodavg* library in *R* [45]. We kept body mass in all models based on our *a priori* expectations, whereas the other covariates were excluded or included in the different candidate models. It can be argued that LMEs using individual as a random effect represent a more correct statistical approach than the LM approach applied in the above analyses [42]. Nonetheless, there are several reasons why we applied LMs and not LMEs. Firstly, out of our total sample of 529 observations, 27 were data from unknown individuals. Second and more importantly, approximately 50% of our observations (from known individuals) were single samples taken from one individual and 70% consisted of individuals being samples only once or twice (both sexes), whereas only 15% (males) and 10% (females) consisted of individuals that had been sampled ≥ 4 times. Thirdly, as a precautionary action we fitted LME versions of all selected models, i.e. a model with the same fixed effects and random intercepts only, using the nlme library [46]. As neither the estimates nor the statistical significance for our estimates changed notably when comparing the reported output for the analyses using period and body mass as predictors to LMEs (results not shown), we conclude that our inference were not sensitive to our choice of statistical approach.

RESULTS AND DISCUSSION

Differences between sexes

Studies of different seabird species have shown that males may have higher circulating concentrations of OCs than females during breeding [19-21], but this does not appear to be consistent [47]. Differences in OC loads between sexes have been attributed to both egg laying and diet specialization [7, 22]. Since we had data both prior to – and after egg laying (n = 521), we were able to test the hypothesis that such differences was an effect of female kittiwakes eliminating OCs through the eggs. In the LMEs, i.e. when year was used as a random factor, the sexes had equal levels of PCB-153 in the pre-laying period, whereas males had higher concentrations during incubation and chick rearing (~10%): interactions being significant for lipid-normalized concentrations (p = 0.033; Supplemental Data, Table S4A), and marginally significant (p = 0.075; Supplemental Data, Table S3A) for wet weight concentrations (Figure 1A; Supplemental Data, Figure S1A; bar plots are used for visualizing model predictions, whereas points are used to show descriptive statistics). For DDE the differences were in the same direction as PCB-153, but the blood concentrations tended to decline over the breeding season in both sexes and the interactions between period and sex were not significant (p = 0.107, Figure 1B; Supplemental Data, Figure S1B, Table S3B, S4B). This suggests that egg laying has some impact on the circulating concentrations of DDE in the breeding season, but the effect appear to be weak, and it is important to note the variation among and within breeding seasons (Figure 2A-C; Supplemental Data, Figure S2A-C). That is, in some years females had equally high blood concentrations as males during both incubation and chick-rearing periods. This might be a result of poor feeding conditions in which females are forced to emancipate their body lipid reserves and thereby remobilize more OCs during egg laying and incubation periods [21]. For HCB, however, there appeared to be no difference (interaction: p = 0.38) between sexes in any of the periods (Figure 1C;

Supplemental Data, Figure S1C, Table S3C, S4C). This was unexpected since maternal transfer of contaminants to eggs often favors low K_{ow} and/or less persistent OCs, whereas more lipophilic compounds such as PCB-153 are more likely to be retained in the mother's adipose tissue [48-50]. The lack of difference between the sexes after egg laying could result from the relatively high continuous exposure of HCB in our study area. Hence, the observed air concentrations on Svalbard are 80 pg/m^3 for HCB and only 10 pg/m^3 for PCB, showing different background exposure [51]. Moreover, in the same location and time period as the present study, blood concentrations of HCB increased more during incubation fast in common eiders (*Somateria mollissima*), a benthic top predator, than did PCB-153, suggesting high intake of HCB during pre-breeding accumulation of body reserves [14]. Hence, female kittiwakes in Kongsfjorden may rapidly regain the loads lost through the eggs, and thus potential differences between sexes may not be detected. Alternatively, HCB has relatively low affinity for adipose tissue compared to other compounds [50, 52], and this compound may therefore be more readily redistributed from body fat to blood after egg laying.

Temporal variation in OCs and the effect of body condition

Descriptive data on concentrations for both sexes (n = 270 males and 224 females) can be found in SI Table 5. The sexes were analyzed separately, and for each contaminant, the same models were selected and used for inferences (Supplemental Data, Table S1, S2). For wet weight, the best models explained 37% and 34% of the variance in blood concentrations for PCB-153 for male and female kittiwakes, respectively (Table S6A), whereas the corresponding values were 16% and 21% for DDE (Table S6B), and 19% and 18% for HCB (Table S6C). The corresponding values for lipid-normalized concentrations were within the same order of magnitude, although lipid data for 2009 was lacking (Supplemental Data, Table S7A-C).

The variation in wet weight blood concentrations among years was generally the most important variance component explaining 23% and 30% (partial R^2) of the variation in PCB-153 in males and females, respectively. The corresponding values were 8% and 12% for DDE, and 10% and 8% for HCB, respectively. For PCB-153, the mean wet weight concentrations over the whole seasons varied from ~4000-8000 pg/g (wet weight) between years in males, and between ~2200-7500 pg/g in females (Supplemental Data, Table S5). The individuals sampled from 2009 to 2011 had lower levels (negative estimates for these years after controlling for body mass) when compared to the first year of the study (2007), whereas the levels in 2008 were slightly higher, although not significantly different from 2007 (SI Table 6a). Interestingly, 2008 was a very cold summer [14] and kittiwakes may have been forced to increase daily energy expenditure by metabolizing more lipids and thus remobilizing more PCB to the blood [14]. The lipid-normalized concentrations for PCB-153 (Supplemental Data, Figure S2A) showed a similar pattern as for wet weight, especially in females (Supplemental Data, Table S7A, Figure S2A), suggesting that PCBs are declining in the study area consistent with declining background exposure [53].

For DDE, mean concentrations in males varied from ~2000-3500 pg/g (wet weight) between years, over all seasons, and between ~1700-3300 pg/g in females (Supplemental Data, Table S5). Males sampled in 2009 had lower wet weight concentrations compared to 2007, whereas the concentrations in other years (2008 and 2010-2011) were not significantly different from 2007. For the females, however, all years except 2008 showed lowered levels compared to 2007, similar to PCB-153 (Supplemental Data, Table S6B, Figure S2B). For lipid-normalized concentrations, however, year did not improve the statistical models and was not included in the best model after controlling for reproductive period and body mass (Supplemental Data, Table S7B, Figure S2B). Consistent temporal trends of legacy OCs may be impossible to document with certainty over just five years, and for DDE it seems more

likely that the trends observed are results of differences in lipid content in blood between years.

The mean concentrations of HCB in male kittiwakes varied from ~1500-2900 pg/g (wet weight) between years over the whole seasons, and between ~1600-3200 pg/g in females (Supplemental Data ,Table S5). For HCB, however, the wet weight concentrations tended to increase over the years when controlling for body mass (Supplemental Data, Table S6C, Figure S2C). The temporal patterns were, however, different between the sexes: males showed increasing levels of HCB from 2009 to 2011 (relative to 2007), whereas females showed lower levels in 2008 and higher levels in 2009 compared to 2007 (Supplemental Data, Table S5C, Figure S2C). For lipid-normalized concentrations, there was still an increase of HCB in 2008 and 2010 compared to 2007 after controlling for body mass and reproductive period (Supplemental Data, Table S7C, Figure S2C). Hence, despite the short period, wet weight concentrations showed a directional increase for HCB, especially in males (Figure 2C; Supplemental Data, Figure S2C). The changes in HCB concentrations may be expected since the background exposure of HCB in Kongsfjorden is increasing [53]. This explanation is strengthened by the fact that the most pronounced increase seemed to occur late in the breeding season, when the birds had spent about four months in the Kongsfjorden area.

Although the inter-year variation in blood concentrations was large, there was also considerable variation between the different reproductive stages. For PCB-153 the lowest wet weight concentrations were generally found in the pre-breeding periods, increasing on average approximately 2.5 times until the chick-rearing periods (Figure 2A; Supplemental Data, Table S5). HCB increased on average about 1.2 times over the same period (Figure 2C; Supplemental Data, Table S5). For both compounds, the increase occurred concurrently with reductions in body mass (Figure 3), and the changes in body mass (lipid stores) eliminated reproductive stage as a significant predictor in the statistical models (Supplemental Data,

Table S6A, S6C). For PCB-153, body mass explained 26.5% of the variation in males, but only 9% in females, possibly an effect of egg laying. The values for HCB were lower: 6% and 3% for males and females, respectively. For PCB-153, the lipid-normalized concentrations showed similar patterns as wet weight (Supplemental Data, Table S6A, Figure S2A), whereas for lipid-normalized HCB concentrations, the best model also included reproductive stage. The effect of body mass was, however, not included in the best model for females (Supplemental Data, Table S6C, Figure S2C). The relatively low explanatory power of the statistical models for HCB compared to PCB-153 may again originate from the higher local exposure of HCB and more rapid remobilization of this compound.

DDE showed a different pattern compared to the other compounds, as the highest concentrations were found in the pre-breeding periods, mean concentrations being approximately 1.25 times higher than during incubation, with a slight increase during chick rearing (Figure 2B; Supplemental Data, Table S5). Changes in body mass explained 5% and 3% of the wet weight concentrations of DDE in male and female kittiwakes respectively, whereas the corresponding values for the reproductive stage predictor were 9% and 8% (Supplemental Data, Table S6B). The lipid-normalized DDE concentrations (Supplemental Data, Figure S2B) showed the same pattern as for wet weight concentrations with regard to reproductive stage and body mass (Supplemental Data, Table S7B). Hence, despite decreasing body mass from April to June (Figure 3), DDE in blood decreased, suggesting that the breeding area in Kongsfjord has lower background exposure of DDE, or the mother compound DDT, than the winter areas. Kittiwakes thus seem to eliminate DDE from their bodies relatively fast until concentrations reach an equilibrium with their breeding environment [7]. This indicates that kittiwakes are net-transporters of DDE/ DDT to the High Arctic. The kittiwakes breeding in Kongsfjorden winter at 40-60°N in the North Atlantic, roaming across the western- (Grand Banks and Labrador Sea), central (Mid Atlantic) and

eastern parts (Mid-Atlantic Ridge to Portugal/Ireland) [25, 26]. Exposure of organic pollutants in this offshore region is not well studied: i.e. whether the high levels of DDE compared to other legacy OCs in pre-breeding kittiwakes can be attributed to this region is not known. However, Espin et al. [54] reported that razorbills (*Alca torda*) were exposed to high amounts of DDT along the coast of Spain, which was almost completely metabolized when they reached their breeding grounds in Northern Europe. In Norwegian lesser black-backed gulls (*Larus fuscus*), high levels of DDE were found in eggs and blood of birds wintering in African lakes where DDE is a dominating contaminant, compared to gulls wintering in areas dominated by PCB [15]. This may indicate that DDE and/or DDT are compounds prone to bio-transport.

Diet variability may cause variation in circulating concentrations of OCs [13]. In 2007, when the study started, 75% of the kittiwake diet during chick rearing consisted of capelin, a relatively lipid-rich fish, whereas in the other years capelin made up <15% of the diet. In 2010, low trophic krill (Euphausiids) made up nearly 50% of the diet. In 2009 and 2011 nearly 50% of the diet was made up by polar cod (G.W. Gabrielsen, Norwegian Polar Institute, unpublished data). Although high concentrations of OCs in 2007 could potentially result from high intake of lipid-rich capelin, this cannot explain the high levels in 2008. Hence, there seems to be no consistent pattern in the diet data, e.g. trophic position of prey, coherent with the variation in OC concentrations in the present study. There may be several reasons for this, notably that the diet data has been collected in a limited period of the breeding stage (during chick rearing), whereas blood has been sampled over the whole breeding season. It might also be that diet samples were intended for the chicks, whereas the adults are feeding on different prey as found in some other seabirds [55].

The present study demonstrated large variations in circulating concentrations of different legacy OCs during breeding in high arctic kittiwakes. Firstly, egg laying seemed to

reduce circulating levels of PCB-153 in females relative to males. This effect, however, was surprisingly not significant for DDE, and not found for HCB. The OCs behaved differently in the birds and relatively simple statistical models may explain much of the variation in circulating concentrations of PCB-153, the most persistent compound. For HCB, however, the present study suggests that local exposure during the breeding season may be more important relative to the other compounds. The fact that HCB tended to increase over the years, supports this explanation since background HCB is increasing in the Kongsfjorden area [53]. This is worrying since HCB has been associated with lower adult survival probabilities in this kittiwake population [34]. For DDE, the situation seems more complex since the birds appear carry of this compound from the wintering grounds. For all three compounds, however, the present study demonstrates great variance between different reproductive stages, with mean PCB-153 concentrations increasing approximately 2.5 times over the breeding season. Moreover, these differences seem to be consistent among years, and much of the differences can be explained by reductions of the birds' lipid stores. This could be a result of energetic stress during the breeding period [18].The importance of different environmental factors (e.g. climate variables) in causing variability is poorly understood, and more data over several years is necessary to elucidate such links. Moreover, variation in diet probably has a great impact on OC intake of kittiwakes, and should be addressed in future studies, e.g. by measuring isotopes. The present study, however, emphasizes that sampling time is an important factor if seabird tissue, such as blood, should be used for monitoring purposes. In the future this might become an even more important issue since many seabirds are threatened, notably pelagic species such as kittiwakes [56], and the need for non-invasive sampling methods increases. Blood sampling is a viable alternative to various forms of invasive sampling.

SUPPLEMENTAL DATA

Supplemental Data (Table S1-S7, Figure S1, S2) is available on the Wiley Online library at DIO:

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Data availability- Data, associated metadata, and calculation tools are available from the corresponding author (jan.o.bustnes@nina.no).

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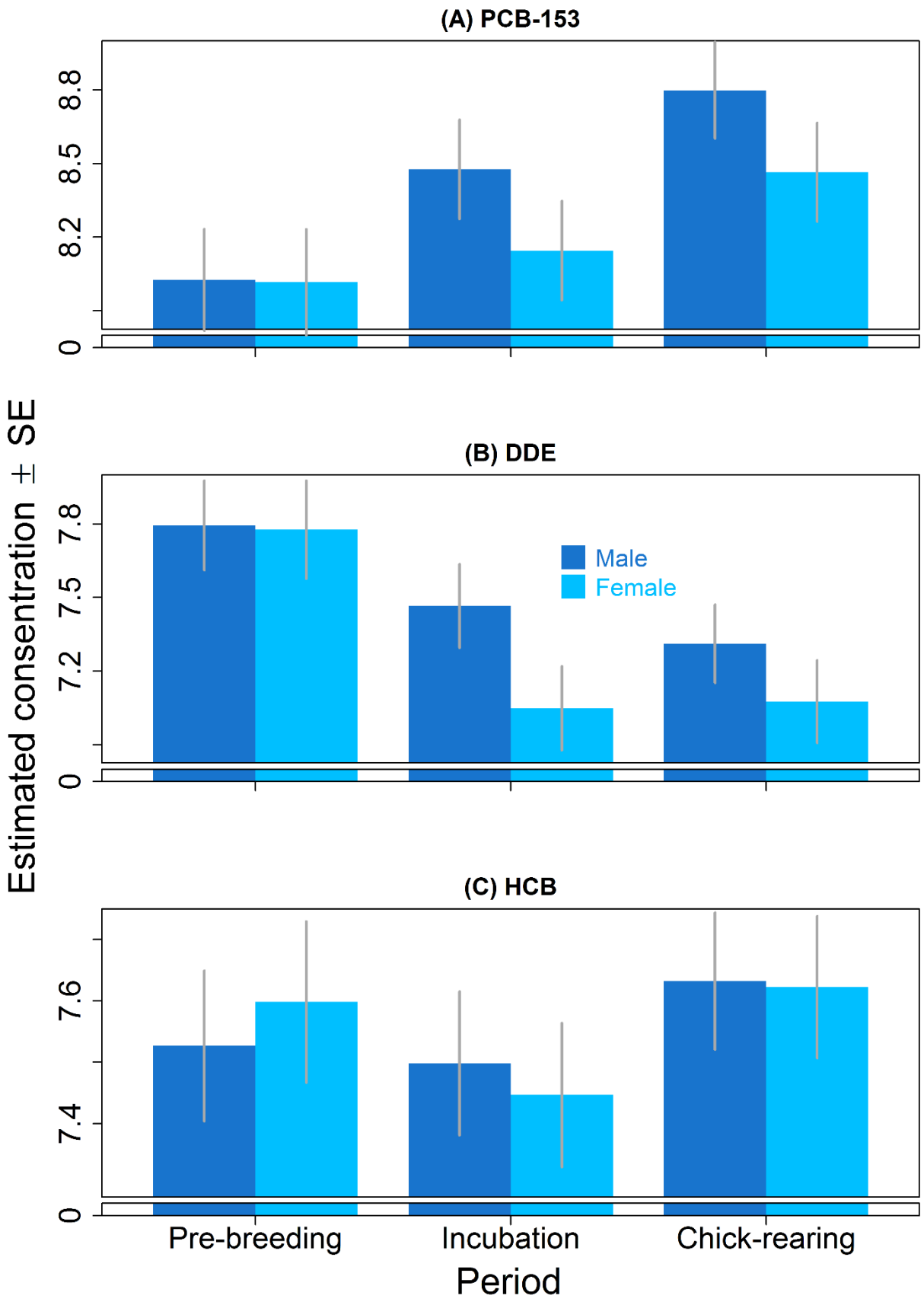
Figure legends:

Figure 1. Estimated, i.e. model predictions with precision [± 1 standard error (SE)] as bars, wet weight concentrations (Log pg/g, from LMEs where we controlled for year as a random factor) of (A) polychlorinated biphenyl 153 [PCB-153], (B) *p,p'*-dichlorodiphenyldichloroethylene [DDE], and (C) hexachlorobenzene [HCB]) in male and female kittiwakes in different reproductive stages; pre-breeding, incubation and chick-rearing. Data from Kongsfjorden, Svalbard, 2007-2011.

Figure 2. Plot showing descriptive statistics, i.e. the average (points), median (-) as well as the 25^{th} and 75^{th} percentiles (bars), for wet weight concentrations (pg/g wet weight) of of (A) polychlorinated biphenyl 153 [PCB-153], (B) *p,p'*-dichlorodiphenyldichloroethylene [DDE], and (C) hexachlorobenzene [HCB]) in male (blue bars) and female (red bars) kittiwakes in different reproductive stages; pre-breeding, incubation and chick-rearing. Data from Kongsfjorden, Svalbard, 2007-2011.

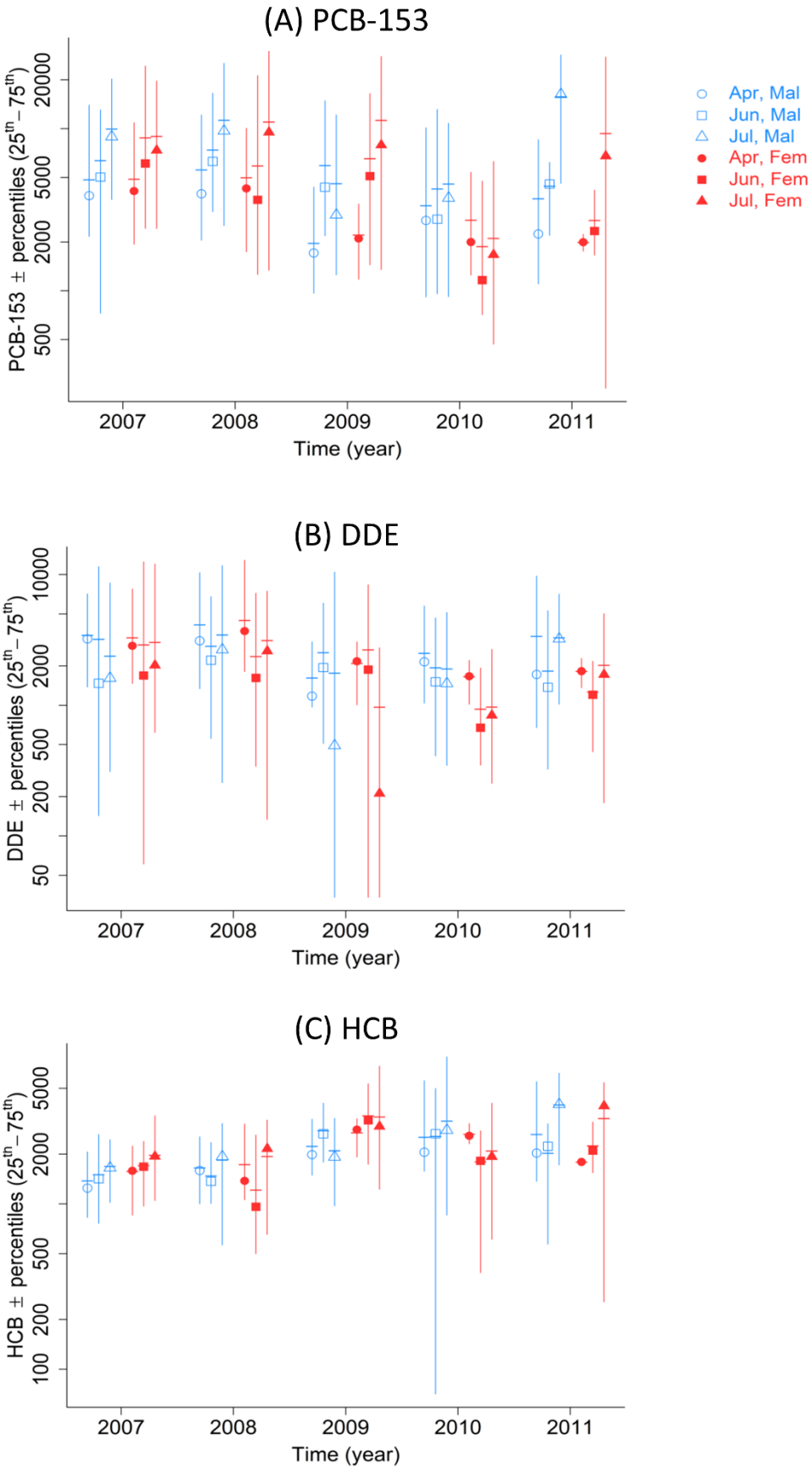
Figure 3. Plot showing descriptive statistics, i.e. the average (points), median (-) as well as the 25^{th} and 75^{th} percentiles (bars), for body mass in male (blue) and female (red) kittiwakes in different reproductive stages; pre-breeding, incubation and chick-rearing. Data from Kongsfjorden, Svalbard, 2007-2011.

646 **Fig.1.**

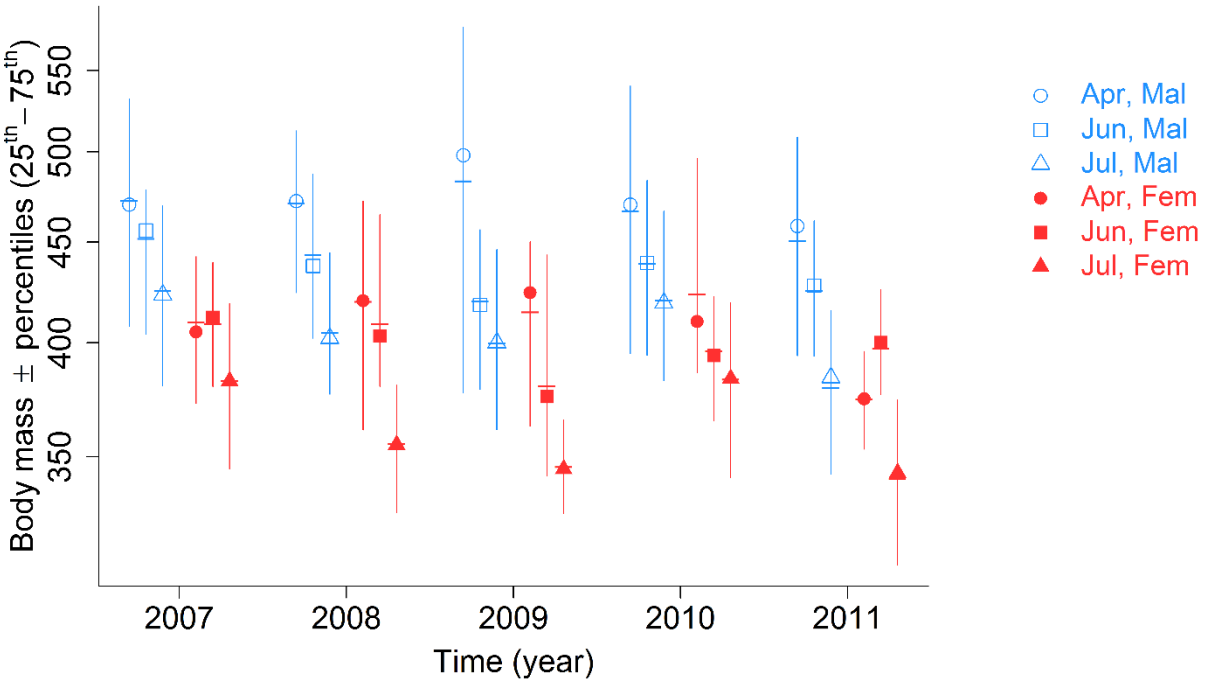

(A) PCB-153
0
8.2
8.5
8.8
(B) DDE
0
7.2
7.5
7.8
Male
Female
(C) HCB
0
7.4
7.6
Estimated consentration ± SE
Pre-breeding
Incubation
Chick-rearing
Period

647

Fig. 2


(A) PCB-153
PCB-153 ± percentiles (25th – 75th)
500
2000
5000
20000
2007
2008
2009
2010
2011
Time (year)
Apr, Mal
Jun, Mal
Jul, Mal
Apr, Fem
Jun, Fem
Jul, Fem
(B) DDE
DDE ± percentiles (25th – 75th)
50
200
500
2000
10000
2007
2008
2009
2010
2011
Time (year)
(C) HCB
HCB ± percentiles (25th – 75th)
100
200
500
2000
5000
2007
2008
2009
2010
2011
Time (year)

650 **Fig. 3.**



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