Polychlorinated Biphenyls and Reproductive Hormones in Female Polar Bears at Svalbard

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High concentrations of polychlorinated biphenyls (PCBs) in polar bears from Svalbard have increased concern for that population’s reproductive health. We examined whether there were associations between the plasma concentrations of PCBs and reproductive hormones [progesterone (P₄) and 17β-estradiol (E₂)] in free-living female polar bears from Svalbard. Concentrations of P₄ depended on reproductive status, and concentrations were lowest in females with offspring—females with cubs and females with yearlings. In these females, the P₄ concentrations were positively correlated with plasma 2PCBs (sum of all analyzed polychlorinated biphenyl congeners) concentrations. The 2PCBs concentrations explained 27% of the variation in the P₄ concentrations. There were no correlations between 2PCBs and E₂ and cortisol in any of the groups of polar bears, or between 2PCBs and P₄ in single polar bears. Although the 2PCBs–P₄ relationship in female polar bears with offspring is not evident per se of a direct cause–effect association, the results indicate that PCBs may affect levels of P₄ in polar bear females. There is a clear need to further assess the hormone balance and population health of polar bears at Svalbard. Key words: Arctic, Barents Sea, endocrine disruption, endocrine disruptors, estradiol, pollution, population, progesterone, Svalbard. Environ Health Perspect 111:431–436 (2003). doi:10.1289/ehp.5553

Materials and Methods

This study is part of a project designed to study levels, tissue distribution, and possible effects of OCs in polar bears in the Norwegian Arctic. Blood samples for OC analyses were collected from 360 male and female polar bears of different ages. We used a subsample consisting of 86 adult female (≥ 4 years of age) polar bears to examine the possible effects of PCBs on reproductive hormones. These females were live-captured in the spring (27 March–8 May) from 1995 to 1998. The samples were collected at Svalbard, Hopen, Edgeøya, and in the Barents Sea region, east to the border of the Russian economic zone (74°–79°N and 16°–44°E).

The animals were captured by remote injection of a drug-filled dart (Palmer Cap-Chur Equipment, Douglasville, Georgia, USA) fired from a helicopter (Stirling et al. 1989). The drug Zoletil (Virbac Laboratories, Carros, France) was administered in a solution of 200 mg/mL at a dosage of 5–10 mg/kg of body mass. Blood samples were collected from the femoral vein into evacuated, high concentrations of PCBs reported in polar bears from the Svalbard area have thus resulted in growing concerns for the population’s reproductive health (Skaare et al. 2000; Wiig et al. 1998).

The aim of the present study was to study if PCB exposure in free-living female polar bears from Svalbard may affect their reproductive hormone concentrations. Thus, we tested to what extent PCB plasma levels in different reproductive groups of female polar bears could explain variations in plasma concentrations of the reproductive hormones progesterone (P₄) and 17β-estradiol (E₂), and cortisol.

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Long-range transport of persistent organic compounds by air and ocean currents from industrialized areas has produced high levels of these pollutants in top predators in the Svalbard area, Barents Sea, and Kara Sea (Andersen et al. 2001; Norstrom et al. 1998; Skaare et al. 2000). The cold Arctic environment acts as a sink where the semivolatile, persistent contaminants are deposited and enter the marine food web (Oehme 1991). Polychlorinated biphenyls (PCBs), chlordane (trans-nonachlor, oxy-, cis-, and trans-chlordane), 1,1-dichloro-2,2-bis(4-chlorophenyl)ethylene (DDE), hexachlorobenzene (HCB), hexachlorocyclohexanes (α- and β-HCHs), polychlorinated dibenzo-p-dioxins (PCDDs), and dibenzofurans (PCDFs) are among the OCs that have been given special attention with respect to reproductive toxicity and endocrine disruptive potential. Reijnders (1986) reported that common seals (Phoca vitulina) fed PCB-contaminated fish had lower reproductive rates than the control group fed relatively unpolluted fish. Furthermore, it has been reported that PCB exposure before or during gestation led to fetal growth retardation and fetal mortality in mink (Mustela vison) (Backlin et al. 1998; Kihlstrom et al. 1992). PCBs have also been shown to produce trophoblastic lesions in mink (Backlin et al. 1998) and are believed to be the cause of uterine occlusions in seals (Bergman and Olson 1985; Helle et al. 1976). The biochemical mechanisms by which PCBs exert their reproductive effects are poorly understood, but PCBs may affect several steps in the reproductive cycle from ovulation and fertilization to implantation and fetal development (Backlin et al. 1998; Kihlstrom et al. 1992). It is also known that PCB congeners may act both estrogenic and antiestrogenic (Colborn et al. 1993; Connor et al. 1997; Nesaretnam et al. 1996). These factors suggest that PCBs may have the potential to interfere with reproduction by disturbing the steroid-hormone balance. The
heparinized containers and stored cool and dark until centrifugation (3,000 rpm for 10 min) within 8 hr of collection. Plasma was pipetted off and stored at −20°C until analysis. A vestigial premolar tooth was extracted from all bears for age determination (Calvert and Ramsay 1998).

Presence and age of cubs, and biologic parameters such as body length and age were recorded. Body measurements were not recorded for one bear. Body mass was estimated using a morphometric equation (Derocher and Wiig 2002).

All capture dates were transformed to Julian dates (day 1–365), and age was calculated to the nearest month assuming that all bears were born on January 1st.

For the investigation of hormone and PCB concentrations, polar bears were grouped into three reproductive classes based on the presence and age of cubs. Females with 2-year-old offspring and single females were classified as females with cubs (n = 32), because all these females enter estrus in spring and are thus available for mating (Wiig 1998). Because 2-year-old offspring receive very little milk (Polischuk et al. 1995), and the fat content in milk declines as the cubs grow older (Derocher et al. 1993), the transfer of PCBs to 2-year-olds through milk is presumed to be negligible. Females with nursing cubs less than 12 months of age were classified as females with cubs (n = 36), and those with dependent offspring 12–24 months of age were classified as females with yearlings (n = 18). When no statistical differences were found between the two groups “females with cubs” and “females with yearlings,” these groups were pooled to form “females with offspring.”

The Norwegian Experimental Animal Committee approved all capture and handling methods used.

**PCB analyses.** All polar bear plasma samples in the project were analyzed for OCs at the Environmental Toxicology Laboratory, Norwegian School of Veterinary Science/ National Veterinary Institute, Oslo, Norway, from 1998 to 2000. The laboratory is accredited by Norwegian Accreditation as a testing laboratory for OCs according to the requirements of NS-EN45001 and ISO/IEC Guide 25. Briefly, plasma samples (approximately 8 g) were extracted with cyclohexane and acetone and cleaned up with ultra-pure sulfuric acid (Andersen et al. 2001). The whole extracts were used to determine percent extractable fat gravimetrically. Aliquots of the final extract were injected on gas chromatograph–electron capture detection (GC-ECD) instruments equipped with two capillary columns (SPB-5 and SPB-1701, 60 m, 0.25 mm ID and 0.25 µm film layer; Supelco, Inc., Bellefonte, PA, USA). Quantification was performed using PCB 29, 112, and 207 as internal standards in each sample. Details on analytic procedures, equipment for chromatographic separation, detection, and calculation are given in Andersen et al. (2001). Standard procedures were used to ensure adequate quality assurance and control, and the precision, linearity, and sensitivity of the analyses were within the laboratory’s accredited requirements. A blank sample was included in each batch to test for interference. Reproducibility was continuously tested by analyzing the PCB levels in the laboratory’s own reference sample (seal blubber). The mean percent of the true value and its coefficient of variation (CV) was 103 and 11% (n = 22). Recoveries and CV of all PCB congeners in spiked blood samples varied from 72 to 116% and 6.3 to 10.0%, respectively (n = 83). Detection limits for individual PCB congeners ranged from 0.002 to 0.02 ng/g wet weight. In all samples, the following 34 PCB congeners were determined (IUPAC numbers; Safe 1994): 28, 31, 47, 52, 56, 66, 74, 87, 99, 101, 105, 110, 114, 118, 128, 136, 137, 138, 141, 149, 151, 153, 156, 157, 170, 180, 183, 187, 189, 194, 196, 199, 206, and 209. Sixteen PCB congeners that could be quantified in all samples were selected for this study. These congeners were PCB 47, 99, 118, 128, 137, 138, 153, 156, 157, 170, 180, 183, 187, 189, 194, and 206. PCB congener concentrations were expressed on a lipid weight basis (ng/g lw) calculated from PCB concentrations in nanograms per gram wet weight and percentage of fat in the analyzed plasma.

**Hormone analysis.** Plasma concentrations of the steroid hormones P₄ and E₂ and the glucocorticoid cortisol were analyzed at the Hormone Laboratory at the Norwegian School of Veterinary Science using radioimmunoassay (RIA).

For the analysis of P₄, no modifications for polar bear plasma were necessary. The concentrations were analyzed using a commercially available kit (Spectria Progesterone 121® Coated Tube Radioimmunoassay; Orion Diagnostica, Espoo, Finland). The kit detection limit was 0.3 nmol/L, corresponding to three standard deviations from the zero sample. The interassay coefficient of variation (CV) for control samples with low (1.39 nmol/L), medium (14.8 nmol/L), and high (44.1 nmol/L) concentrations of P₄ were 4.0, 5.6, and 5.3%, respectively.

E₂ concentrations were analyzed using a commercial kit (Coat-a-Count, Estradiol, Diagnostic Products Corporation, Los Angeles, CA, USA). The detection limit was 8.0 pg/mL, corresponding to 95% binding of the labeled hormone, assuming that basic procedures were followed. The E₂ concentration was low in the samples, so both the standard curve and the samples were modified to bring the concentrations within the detection limit. The standards were diluted with 0.02 M borate buffer, pH 8.5, to concentrations ranging from 10 to 600 pg/mL. Polar bear plasma samples were up-concentrated to bring E₂ concentrations within the linear range of the modified standard curve. We extracted 300 µL plasma from each sample with newly distilled diethyl ether, evaporated it to dryness, and added it to 150 µL borate buffer (0.02 M, pH 8.5), thus doubling the concentrations of E₂ in the plasma samples. Extraction recovery was 79.5 ± 4.1%, determined from a single recovery test per run, spiked with known amounts of the hormone. All concentrations were adjusted according to the recovery sample. The interassay CV for control samples with low (49.9 pg/mL), medium (83.1 pg/mL), and high (204.1 pg/mL) concentrations of E₂ were 6.4, 10.1, and 6.2%, respectively. Because of limited plasma volume, interassay CV control samples could not be made from polar bear plasma, and analyses were not run in parallel. The E₂ concentrations were therefore rounded to the nearest picogram per millilitre. E₂ analyses were not performed on five bears because of lack of plasma. Quantification of radiation when using RIA was performed using a 1470 Wizard Automatic Gamma counter (Wallac Oy, Turku, Finland).

Plasma cortisol was measured based on the methods described by Simensen et al. (1978) and was modified for polar bear plasma. Ten-microliter plasma samples were heated in 500 µL phosphate-buffered saline (PBS) with 0.1% gelatin for 20 min to remove effects from plasma proteins. Validation showed that serial dilution of heated polar bear plasma with high cortisol concentration produced a dose–response curve parallel to the standard curve. The range of the standard curve was 3.1–50 ng/mL, and the detection limit was 2 ng/mL, corresponding to 95% binding of the labeled hormone. Samples were diluted when concentrations were outside the range of the standard curve. After cooling, samples were extracted with 1 x 3 mL dimethylchloride, followed by evaporation to dryness under a gentle stream of nitrogen. Recovery was 79.9 ± 2.3%, determined from a single recovery test sample per run, spiked with known amounts of the hormone. All concentrations were adjusted according to the recovery sample. The dry extract was resolved in 1,200 µL PBS with 0.1% gelatin overnight. Two 500-µL samples were then pipetted off and run in parallel. After adding antiserum (No. F3-314; Endocrine Science Products, Tarzana, CA, USA) and 3H-labeled cortisol mixture, the parallels were incubated for 1 hr at room temperature, then overnight at 4°C before centrifugation at 4°C with ice-cold charcoal–dextran suspension (15 min at 4,000 rpm). Scintillation liquid was added to the supernatant before counting in a Tri-carb 2100 TR.
Table 1. Concentrations (nanomoles per liter) of P₄, E₂, and cortisol in plasma samples of three reproductive groups of female polar bears (U. maritimus) from Svalbard.

| Reproductive class | Sample size | Mean | 95% CI | Range | Mean | 95% CI | Range |
|--------------------|-------------|------|--------|-------|------|--------|-------|
| Single             | 32          | 2.8±  | 2.1–3.8 | 0.9–10.1 | 0.03±  | 0.03–0.04 | 0.01–0.07 |
| With cubs          | 36          | 1.3±  | 1.2–1.5 | 0.7–2.2  | 0.03±  | 0.03–0.03 | 0.02–0.06 |
| With yearlings      | 18          | 1.1±  | 0.9–1.4 | 0.5–1.9  | 0.03±  | 0.02–0.03 | 0.01–0.06 |

Values are presented as means, range of 95% confidence interval (CI), and range of the measurements. *Different superscripts indicate significant differences between groups.*

Table 2. Concentrations (nanograms per gram lipid) of ΣPCB, the congener PCB-118 in plasma samples of three reproductive groups of female polar bears (U. maritimus) from Svalbard.

| Reproductive class | Sample size | ΣPCB (ng/g lipid) | PCB-118 (ng/g lipid) |
|--------------------|-------------|-------------------|----------------------|
|                    |             | Mean | 95% CI | Range | Mean | 95% CI | Range |
| Single             | 32          | 9,740± | 7,620–11,859 | 2,014–26,348 | 25±  | 21–30 | 8–62  |
| With cubs          | 36          | 8,919± | 7,748–10,091 | 2,082–18,210 | 21±  | 18–23 | 8–44  |
| With yearlings      | 18          | 5,895± | 4,128–7,653 | 1,392–15,172 | 25±  | 19–30 | 7–52  |

Values are presented as means, range of 95% CI, and range of the measurements. *Different superscripts indicate significant differences between groups.*

Liquid Scintillation Analyzer (Packard, Downers Grove, IL, USA).

The interassay CV for control samples with low (4.85 ng/mL), medium (16.9 ng/mL), and high (41.5 ng/mL) concentrations of cortisol was 7.2, 6.5, and 7.0%, respectively.

Statistical analyses. All analyses and calculations were conducted using a statistical package (SPSS 10.0, SPSS Inc., Chicago, IL, USA). The level of statistical significance was defined at p ≤ 0.05. To obtain normal distribution of investigated parameters, age (years, months), ΣPCBs (sum of all analyzed polychlorinated biphenyl congeners) (ng/g lw), PCB-118 (ng/g lw), E₂ (pg/mL), P₄ (nmol/L), and cortisol (ng/mL), were log₁₀-transformed before analysis, and converted to nanomoles per liter after analysis (E₂ and cortisol). ΣPCBs refer to the sum of all congeners except PCB-118, i.e., 15 congeners. PCB-118 was not correlated with ΣPCBs for females with cubs (n = 36, r = −0.24, p = 0.15), females with yearlings (n = 18, r = 0.46, p = 0.06), or single females (n = 32, r = −0.22, p = 0.225) and was therefore investigated separately in the statistical analyses. The reason for this may be because PCB-118 has a rather low biomagnification factor in seal to polar bear (Letcher et al. 1996), indicating that it is metabolized relatively quickly by the polar bear. Geometric means were calculated from log-transformed values. Means were compared using one-way analysis of variance (ANOVA). For post hoc multiple comparison of groups, Dunnett’s T3 test for groups with unequal variance was used. In addition, data were subjected to correlation analysis using the parametric Pearson correlation. Multiple regression analysis (backward selection method) was used to study extrinsic and intrinsic independent variables associated with variation in hormone concentrations. The independent variables were capture date (Julian date), age (years, months), body mass (kilograms), ΣPCBs (nanograms per gram lipid weight), and PCB-118 (nanograms per gram lipid weight). Effects on plasma P₄ concentrations due to stress of handling were also examined, because stress-related cortisol production may lead to higher blood levels of adrenal P₄ (Harlow et al. 1990; Plotka et al. 1983).

Results

The plasma P₄ concentration was significantly higher in single females than in females with cubs and in females with yearlings (F₂,₅₈ = 21.7, p < 0.001; Table 1). There was no difference in P₄ concentrations between females with cubs and females with yearlings (Dunnett’s T3, p = 0.3; Table 2). The plasma E₂ concentrations did not differ between the reproductive groups (F₂,₇₈ = 2.5, p = 0.09; Table 1), and ranges were similar for all reproductive groups.

E₂ and P₄ concentrations of females with cubs and females with yearlings did not differ, presumably because all females with nursing offspring (cubs and yearlings) are in lactational anestrus. The two groups were thus pooled into one group (n = 54) to study relationships between the independent factors and P₄. In females with offspring, the P₄ concentrations were related only to log(ΣPCBs) (estimate = 0.326, E = 0.073, F₁,₅₁ = 20.15, p < 0.001, r²adj = 0.269; Figure 1) and not to age, body mass, capture date, PCB-118, or cortisol (F < 2.71, p > 0.21).

Multiple regression analysis showed that P₄ concentrations in the single females were related only to the independent factor capture date (estimate = 0.01202, SE = 0.003, F₁,₅₁ = 12.61, p = 0.001, r²adj = 0.273) and not to the factors age, body mass, ΣPCB, PCB-118, or cortisol (F < 2.71, p > 0.16). Thus, P₄ concentrations for single females increased throughout the capture period (Figure 2).

The E₂ concentrations were not significantly related to any of the predictors reproductive group, age, body mass, capture date, cortisol, ΣPCBs, or PCB-118 (F < 2.71, p > 0.21). However, there was a borderline negative relationship between E₂ and PCB-118 in females with offspring (n = 54, coefficient = −0.227, p = 0.062, r²adj = 0.05). Plasma concentrations of cortisol did not differ significantly between the reproductive groups (F₂,₅₈ = 0.95, p = 0.4; Table 1).

ΣPCBs concentrations differed between the three reproductive groups (Table 2). Females with yearlings had lower ΣPCBs concentrations than single females and females with cubs (ANOVA, F₂,₅₈ = 6.5, p = 0.002). ΣPCBs concentrations did not differ between females with cubs and single females (Dunnett’s T₃, p = 1.0). PCB-118 did not differ between the reproductive classes (ANOVA, F₂,₅₈ = 1.2, p = 0.3). Plasma fat did not differ between the reproductive classes (ANOVA, F₂,₅₈ = 0.7, p = 0.5).

Females with cubs were significantly younger than females with yearlings (ANOVA, F₂,₅₈ = 5.4, p = 0.006), but not younger than single females (Dunnett’s T₃, p = 0.1; Table 3). The body mass of females with cubs was significantly lower than that of single females (ANOVA, F₂,₅₈ = 4.9, p = 0.01), whereas the body mass of females with yearlings did not differ from that of either females with cubs or single females (Dunnett’s T₃, p = 0.4 and 0.6, respectively).

Discussion

In female polar bears with offspring, the plasma concentration of ΣPCBs explained 27% of the variation in the P₄ levels. To our knowledge, a positive relationship between ΣPCBs and P₄ in lactating female mammals has not previously been documented. Previously, a study on pregnant mink documented that serum P₄ concentrations were significantly increased by experimental exposure to PCB-153 (Patnode and Curtis 1994). Furthermore, an in vitro study has documented significantly increased...
secretion of P₄ in granulosa cells from porcine ovaries after exposure to PCB-153 (Wojtowicz et al. 2000). Thus, although the relationship between ΣPCBs and P₄ reported herein in female polar bears does not prove a causal exposure–effect relationship per se, the result represents an indication that PCBs may affect levels of P₄ in polar bear females.

P₄ is synthesized in the maturing follicles as a step in the E₂ synthesis. Stimulation of the enzymes preceding P₄ or inhibition of enzymes following P₄ in the synthesis may lead to an increase in P₄ concentrations. In common seals, P₄ metabolism was significantly decreased with increasing liver PCB concentration (Troisi and Mason 2000). An inhibition of the enzymes transforming P₄ to E₂ has been suggested as one explanation for the increased P₄ secretion and decreased testosterone and E₂ secretion by granulosa cells after exposure to PCB-153 (Wojtowicz et al. 2000). PCB-153 is one of the most commonly detected PCB congeners in biologic tissues and is the dominant PCB congener in polar bears (Bernhoft et al. 1997; Norheim et al. 1992; Norstrom et al. 1998).

The exact mechanisms for the many observed reproductive effects of PCBs are poorly understood. One effect of PCB is to exert negative feedback on secretion of gonadotropin-releasing hormone from the hypothalamus, thus inhibiting secretion of follicle-stimulating hormone (FSH) and luteinizing hormone (LH) from the anterior pituitary (Richards 1986). PCB-induced elevation of P₄ may thus affect FSH/LH-stimulated maturation of follicles in single females and prevent normal ovulation from taking place. Previously, disruption of hormonal feedback mechanisms caused by increased P₄ concentrations during estrus has been demonstrated in rabbits (Chang 1967). Furthermore, slightly elevated P₄ concentrations in heifers at the time of artificial insemination led to significantly lower fertility (Waldman et al. 2001). Functionally, it is therefore possible that PCB-induced elevation of P₄ concentrations in polar bears may affect reproductive success.

The higher P₄ concentrations in single females than in females with cubs and females with yearlings can be explained by physiologic differences due to reproductive status. Females with nursing offspring are anestrous and will not ovulate and form a P₄-secreting corpus luteum. P₄ concentrations for these two reproductive groups are therefore low. On the contrary, the higher P₄ concentrations in single females are due to the formation of a P₄-producing corpus luteum after ovulation (Tsubota et al. 1994; Wimsatt 1963). This also explains the increasing concentrations of P₄ with capture date.

The P₄ concentrations reported in the single female polar bears herein are consistent with those previously reported in solitary females from the Canadian Arctic during February and March (Derocher et al. 1992; Ramsay and Stirling 1988). Because levels of PCBs are lower in Canadian compared with Svalbard polar bears (Norstrom et al. 1998), the assumption of a positive relationship between PCB burden and P₄ should result in higher P₄ concentrations in solitary polar bear from Svalbard compared with those from the Canadian Arctic. The apparent lack of such a finding may be because P₄ levels in single female bears vary considerably over a short time during the spring (Figure 2), depending on when samples are taken relative to their ovulation. The resulting large variation may override possible effects caused by PCB exposure, rendering it impossible to evaluate the effect of PCB on P₄ in single female polar bears. To study possible effects of PCB on P₄ in single polar bear females, the timing of the sampling should be standardized in relation to their ovulation.

Reijnders (1986) has reported a lower E₂ concentration in plasma of common seals fed PCB-contaminated fish than in the control group, and several studies have shown that different PCB congeners and their metabolites may exert both estrogenic and antiestrogenic effects through a wide range of mechanisms (Battershill 1994; Connor et al. 1997; Danzo 1998; Dechaud et al. 1999; Kester et al. 2000; Moore et al. 1997; Neserentam et al. 1996; Wojtowicz et al. 2000). In this study, no relationships between E₂ and the investigated factors (age, body mass, capture date, cortisol, ΣPCBs, and PCB-118) were found. However, a borderline negative relationship between E₂ and PCB-118 (n = 54, p = 0.062) was found in females with offspring. This indicates that further studies are required to assess the possible relationship between PCBs and estrogen in polar bears.

A severalfold variation in the E₂ concentration was observed within each of the three reproductive groups, but there were no differences in mean E₂ concentrations between the groups. Because the rate of E₂ secretion from the maturing follicle increases before ovulation (Senger 1997), single females were expected to have higher E₂ concentrations than anestrous (lactating) females in spring. It may therefore be speculated that the E₂ concentrations in the single females may be suppressed because of PCB exposure. However, no evidence can be given to support such a speculation. On the contrary, large variation in E₂ concentrations has been reported in female black bears (Ursus americanus) during the perimplantation period (Hellgren et al. 1991; Tsubota et al. 1998). It is possible that similar natural large variations were present in the single polar bears around the time of ovulation, and that this was the reason why their mean E₂ concentration did not differ from that of the other reproductive groups.

The E₂ concentrations reported herein (0.0–0.07 nmol/L) are low compared with the concentrations reported for polar bears near Churchill, Manitoba, Canada, and on the Beaufort Sea (approximately 0.07–0.09 nmol/L) (Palmer et al. 1988). Similar methods (RIA) were used for determination of hormone concentrations in the two studies. Because levels of PCBs are higher in polar bears from Svalbard compared with Canadian polar bears (Norstrom et al. 1998), the lower E₂ concentrations in Svalbard bears is in accordance with the expectation that PCB lowers the levels of circulating estrogen. However, it is also possible that the interpopulation difference in E₂ is caused by a wide range of confounding factors, such as the age structure of the animals in the two studies, their reproductive status relative to ovulation, and their nutritional status. Thus, further investigations are needed to explain the apparent interpopulation

![Figure 2](image-url)  
**Figure 2.** In single female polar bears, P₄ concentrations increased throughout the capture period (March–May 1995–1998), whereas no such relationship was observed in females with offspring.

**Table 3.** Age, body mass, and plasma fat content in the three reproductive groups of female polar bears (U. maritimus) from Svalbard.

| Reproductive class | Sample size | Mean (95% CI) | Range | Mean (95% CI) | Range | Mean (95% CI) | Range |
|--------------------|-------------|---------------|-------|---------------|-------|---------------|-------|
| Single             | 32          | 11.7±4.0      | 9.6–13.8 | 5.2–26.4 | 190±8 | 182–199 | 133–234 | 1.2±0.4 | 1.1–1.3 | 0.6–1.8 |
| With cubs          | 36          | 8.10±2.4      | 7.8–10.1 | 4.4–21.4 | 174±10 | 168–180 | 136–214 | 1.2±0.4 | 1.1–1.3 | 0.8–1.8 |
| With yearlings      | 18          | 12.7±2.3      | 10.6–14.10 | 5.4–20.4 | 183±12 | 172–194 | 152–234 | 1.3±0.5 | 1.1–1.4 | 0.5–1.7 |

Values are presented as means, range of 95% CI, and range of the measurements

*Different superscripts indicate significant differences between groups.*
The relative scarcity of female polar bears ≥ 16 years of age with cubs of the year in the Svalbard population compared with the other polar bear populations has been interpreted as a sign that reproduction in the Svalbard polar bear population may be impaired (Derocher et al. 2003). Even though it is functionally possible that a PCB-induced elevation of P4 concentrations in polar bears may reduce their fertility, it is not possible to make a causal link between the low reproduction rate in the Svalbard population of polar bears (Derocher et al. 2003) and PCBs.

**Conclusions**

In female polar bears with offspring, concentrations of ΣPCBs explained 27% of the variation in the P4 concentrations. PCBs causing either increased synthesis or decreased transformation of P4 may explain the observed positive correlation between P4 and ΣPCBs. Although this relationship is not evidence per se of a direct cause–effect association, the results may represent an indication that PCBs may affect levels of P4 in polar bear females. There is a clear need to further assess the hormone economy and population health of polar bears at Svalbard.

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