

Andersen M, Lie E, Derocher AE, Belikov SE, Bernhoft A, Boltunov AN, Garner GW, Skaare JU, Wiig O, 2001. Geographic variation of PCB congeners in polar bears (*Ursus maritimus*) from Svalbard east to the Chukchi Sea. *Polar Biology* 24:231-238.

We present data on geographic variation in polychlorinated biphenyl (PCB) congeners in adult female polar bears (*Ursus maritimus*) from Svalbard eastward to the Chukchi Sea. Blood samples from 90 free-living polar bears were collected in 1987-1995. Six PCB congeners, penta to octa chlorinated (PCB-99, -118, -153, -156, -180, -194), were selected for this study. Differences between areas were found in PCB levels and congener patterns. Bears from Franz Josef Land (11,194 ng/g lipid weight) and the Kara Sea (9,412 ng/g 1w) had similar Sigma PCB levels and were higher than all other populations (Svalbard 5,043 ng/g 1w, East Siberian Sea 3,564 ng/g 1w, Chukchi Sea 2,465 ng/g 1w). Svalbard PCB levels were higher than those from the Chukchi Sea. Our results, combined with earlier findings, indicate that polar bears from Franz Josef Land and the Kara Sea have the highest PCB levels in the Arctic. Decreasing trends were seen eastwards and westwards from this region. Of the congeners investigated in the present study, the lower chlorinated PCBs are increasing and the high chlorinated PCBs are decreasing from Svalbard eastward to the Chukchi Sea. Different pollution sources, compound transport patterns and regional prey differences could explain the variation in PCB congener levels and patterns between regions.

Bernhoft A, Skaare JU, Wiig O, Derocher AE, Larsen HJS, 2000. Possible immunotoxic effects of organochlorines in polar bears (*Ursus maritimus*) at Svalbard. *Journal of Toxicology and Environmental Health-Part A* 59:561-574.

Associations between immunoglobulin G (IgG) levels and the organochlorine contaminants (OCs) polychlorinated biphenyls (PCBs), chlordanes, 1,1-dichloro-2,2-bis(4-chlorophenyl) ethylene (DDE), hexachlorobenzene (HCB), and hexachlorocyclohexanes (HCHs) in blood plasma from polar bears caught at Svalbard were determined. The blood samples were collected from free-living polar bears of different age and sex between 1991 and 1994. The IgG concentration increased with age and was significantly higher in males than in females. IgG was negatively correlated with Sigma PCB level and with three individual PCB congeners, IUPAC numbers 99, 194, and 206. HCB was also negatively correlated with IgG. The significant negative OC correlation with IgG levels may indicate an immunotoxic effect.

Bernhoft A, Wiig O, Skaare JU, 1997. Organochlorines in polar bears (*Ursus maritimus*) at Svalbard. *Environmental Pollution* 95:159-175.

A comprehensive survey on organochlorine (OC) contaminants in polar bears at Svalbard has been undertaken. Subcutaneous tissue, blood and milk have been sampled from anesthetized free-ranging bears of both sexes and different ages in the period from 1990 to 1994. A number of sexually mature females have been fitted with Satellite transmitters which make it possible to follow their reproductive behaviour pattern. We report on contamination levels and pattern of PCB congeners, chlordanes, DDT-compounds, HCB and HCH-isomers in the various tissues. The relation of age, sex and reproductive status to OC contamination has been described, and the capacity of polar bears in metabolising OCs has been discussed from the isomer/metabolite composition of residues. Finally, the possible association between OC contamination and reproduction success has been assessed. The PCB levels present in polar bears at Svalbard are extremely high. Especially high levels of higher chlorinated PCBs are found, and they accumulate with age, particularly in males. With females, considerable amounts of OCs are transferred to the offspring via milk. However, more efficient OC transfer between subcutaneous depot lipid and circulatory lipids than from the circulatory system to milk is found particularly for the most lipophilic compounds. The OC pattern in suckling yearlings reflects the low transfer of the highest chlorinated PCBs into maternal milk. The levels of most other OCs, however, are higher in depot lipid of yearlings than in that of their mothers. The polar bears have high capacity to metabolise several OCs. This may protect them against toxic action of the contaminants. No relation between OC levels in females and their ability to get pregnant is found in this preliminary investigation on OC effects on the polar bears at Svalbard. (C) 1997 Elsevier Science Ltd. All rights reserved.

Born EW, Wiig O, Thomassen J, 1997. Seasonal and annual movements of radio-collared polar bears (*Ursus maritimus*) in northeast Greenland. *Journal of Marine Systems* 10:67-77.

The distribution and movements of polar bears (*Ursus maritimus*) in the Northeast Water (NEW) area (NE Greenland) were studied from 28 May 1993 to 31 May 1995, using satellite telemetry. Between 28 May and 17 June 1993 satellite-linked radio transmitters were attached to eight adult females in the NEW area between approximately 79 degrees and approximately 80 degrees 30'N. By 31 May 1995 the mean duration of transmission (excluding one radio that quit on day of attachment) was 688.4 days (SD = 65.1, range: 541-718 days). These seven females generally showed a high degree of fidelity to the area between 78 degrees and 81 degrees N and 10 degrees W and the northeast Greenland coast. The average distance between capture site in 1993 and spring relocation site in 1994 and 1995 was 116.5 km (SD = 81.9, range: 3.8-210.7 km, N = 7) and 85.4 km (SD = 35.4, range: 38.7-121.8 km, N = 5), respectively. The minimum polygon home range estimates averaged 72,263 km² (SD = 71,059, range: 5,567-195,648 km², N = 7). Relocations were concentrated on the shore-fast ice and on the pack ice over the continental shelf. This local movement pattern may be facilitated by an anticyclonal gyre of the surface water between 78 degrees and 81 degrees N, and a slowing of the south-flowing East Greenland current. A male bear marked in 1993 at the NEW was taken by hunters in Scoresby Sund (approximately 70 degrees N) in February 1995, indicating that some exchange does occur with southern areas of eastern Greenland. Maternity and temporary dens were located on the coast close to the NEW. Apparently the NEW area is suitable polar bear habitat, in that the bears have access to ringed seals on the fast ice, and on pack ice adjacent to the polynya.

Braathen M, Derocher AE, Wiig O, Sormo EG, Lie E, Skaare JU, Jenssen BM, 2004. Relationships between PCBs and thyroid hormones and retinol in female and male polar bears. Environmental Health Perspectives 112:826-833.

We studied the relationships between polychlorinated biphenyls (PCBs) and thyroid hormones (THs) and retinol within two groups of female polar bears (*Ursus maritimus*), females with cubs of the year (FWCOY) and females without cubs of the year (FWOCOY), and within a group of males. Concentrations of five of the six quantified PCB congeners, i.e., PCB-99, PCB-153, PCB-156, PCB-180, PCB-194 (SigmaPCB(5)), correlated with each other, whereas the concentrations of PCB-118 did not correlate with the other congeners. SigmaPCB(5) and PCB-118 did not differ between the three different groups of polar bears, and the plasma levels ranged from 16.7 to 203.2 ng/g wet weight (ww) for SigmaPCB(5) and from 0.09 to 0.93 ng/g ww for PCB-118. PCBs did not affect the retinol status in any of the three groups. In FWCOY, we found negative correlations between SigmaPCB(5) and the three TH variables free thyroxine (FT4) ($r(2) = 0.35$), free triiodothyronine (FT3) ($r(2) = 0.30$), and the total T-4:total T-3 ratio (TT4:TT3) ($r(2) = 0.92$). In FWOCOY, SigmaPCB(5) was negatively correlated to TT4 ($r(2) = 0.14$) and positively correlated to TT3:FT3 ($r(2) = 0.31$), whereas PCB-118 was positively correlated to FT3 ($r(2) = 0.21$) and negatively correlated to TT3:FT3 ($r(2) = 0.26$). In males, SigmaPCB(5) was negatively correlated to FT3 ($r(2) = 0.56$) and positively correlated to FT4:FT3 ($r(2) = 0.78$), whereas PCB-118 was negatively correlated to FT4:FT3 ($r(2) = 0.53$). Thus, PCBs affected five TH variables in the female polar bears (TT4, FT4, FT3, TT3:FT3, TT4:TT3), but PCBs affected only two TH variables in males (FT3, FT4:FT3). Female polar bears could be more susceptible to TH-related effects of PCBs than are males. PCBs also affected T-3 to a larger degree than T-4.

Derocher AE, Andersen M, Wiig O, 2005. Sexual dimorphism of polar bears. Journal of Mammalogy 86:895-901.

Sexual dimorphism in body mass, body length, head width, head length, and foreleg guard hair length of polar bears (*Ursus maritimus*) was examined from live-captured polar bears in Svalbard, Norway. Limited evidence of sexual dimorphism was apparent in cubs shortly after den emergence but was marked after the 1st year of life. Sexual dimorphism in adults resulted from both a higher growth rate and prolonged growth period in males. In mature animals, sexual dimorphism was greatest in mass, followed by foreleg guard hair length, head width, body length, and head length. Foreleg guard hair length was age related and hypothesized to be a form of ornamentation. Geographic variation in sexual dimorphism was evident for mass and body length for seven different populations but there was no evidence of a hyperallometric relationship in sexual dimorphism.

Derocher AE, Wiig O, 2002. Postnatal growth in body length and mass of polar bears (*Ursus maritimus*) at Svalbard. Journal of Zoology 256:343-349.

The von Bertalanffy curve was used to examine growth patterns in both body length and mass of female and male polar bears *Ursus maritimus* live-captured near Svalbard, Norway. A longer growth period in

males resulted in pronounced sexual dimorphism in both body length and mass. Males were 1.16 times longer and 2.10 times heavier than females. The asymptotic body length of female and male polar bears from Svalbard was smaller than that for polar bears in four of six previously studied populations. Asymptotic body mass of females from Svalbard was lower than other previously studied populations, while males were generally lighter. The reasons for the lighter bears in Svalbard are unclear, but we believe they were not related to sampling error, ecosystem productivity, or genetic differences. The high pollution load of polar bears in Svalbard may have affected body size but this potential factor could not be assessed. The generally smaller size of polar bears in Svalbard was consistent with density-dependent growth effects but again, information on population density relative to carrying capacity was insufficient to assess this hypothesis.

Derocher AE, Wiig O, Andersen M, 2002. Diet composition of polar bears in Svalbard and the western Barents Sea. *Polar Biology* 25:448-452.

We estimated both the numerical and biomass composition of the prey of polar bears (*Ursus maritimus*) from 135 opportunistic observations of kills in Svalbard and the western Barents Sea collected from March to October 1984-2001. By number, the prey composition was dominated by ringed seals (*Phoca hispida*) (63%), followed by bearded seals (*Erignathus barbatus*) (13%), harp seals (*P. groenlandica*) (8%) and unknown species (16%). However, when known prey were converted to biomass, the composition was dominated by bearded seals (55%), followed by ringed seals (30%) and harp seals (15%). Results indicated that bearded seals are an important dietary item for polar bears in the western Barents Sea. We believe that different patterns of space use by different bears may result in geographic variation of diet within the same population.

Derocher AE, Wiig O, Bangjord G, 2000. Predation of Svalbard reindeer by polar bears. *Polar Biology* 23:675-678.

Polar bears (*Ursus maritimus*) are believed to be obligate predators on marine mammals, and particularly, on two species of seals. This paper reports on observations of polar bears preying ($n = 7$) and scavenging ($n = 6$) on Svalbard reindeer (*Rangifer tarandus platyrhincus*). Similar to their closest evolutionary ancestor, the brown bear (*U. arctos*), polar bears are opportunistic and will prey on ungulates. Reindeer are likely of minor importance to the foraging ecology of polar bears in Svalbard, but the observations suggest behavioural plasticity in response to a novel prey item.

Derocher AE, Wolkers H, Colborn T, Schlabach M, Larsen TS, Wiig O, 2003. Contaminants in Svalbard polar bear samples archived since 1967 and possible population level effects. *Science of the Total Environment* 301:163-174.

Blood plasma samples were collected in 1967 from 32 polar bears (*Ursus maritimus*) in eastern Svalbard. These samples were stored frozen until 2001 and then analyzed for 33 polychlorinated biphenyls (PCB), two toxaphene congeners, DDTs, chlordanes (CHL), hexachlorobenzene, hexachlorocyclohexanes (HCHs), and polybrominated flame retardants (biphenyls and diphenyl ethers). The 1967 pollutant levels were compared with values from 1993 to 1994 for adult females and adult males to obtain insights into the historical development of pollution in the Norwegian Arctic. Differences in the OC levels measured between 1967 and 1993-1994 ranged from a decrease (PCB 187 and P,P-DDE) to unchanged in both sexes (PCBs 105, 118, 209, and HCH) to an increase in females (PCBs 99, 128, and CHL), to increases in both sexes (PCBs 138, 153, 156, 157, 170, 180, 194, and 206). The maximum change was a nine-fold increase in PCB 157 in adult females. Changes from 1967 to 1993-1994 in contaminant pattern expressed relative to PCB 153 could be explained by a combination of selective metabolism and accumulation of organochlorines in polar bears and temporal changes in the contaminant mixture being transported to the Arctic. Harvest of polar bears in Svalbard ended in 1973 and it appears that most pollutant levels were increasing at the same time that the population was expected to recover from over-harvest. The mean age of adult females in the Svalbard population was similar to other populations where pollution levels are lower but harvest is intense. Females with cubs-of-the-year greater than or equal to 16 years old are uncommon in the population for unknown reasons. The impacts of contaminants on the Svalbard polar bear population are inconclusive but there are suggestions of contaminant-related population level effects that could have resulted from reproductive impairment of females, lower survival rates of cubs, or increased mortality of reproductive females. (C) 2002 Elsevier Science B.V. All rights reserved.

Dietz R, Riget F, Born EW, Sonne C, Grandjean P, Kirkegaard M, Olsen MT, Asmund G, Renzoni A, Baagoe H, Andreasen C, 2006. Trends in mercury in hair of greenlandic polar bears (*Ursus maritimus*) during 1892-2001. *Environmental Science & Technology* 40:1120-1125.

Mercury concentrations in hair from 397 Greenland polar bears (*Ursus maritimus*) sampled between 1892 and 2001 were analyzed for temporal trends. In East Greenland the concentrations showed a significant ($p < 0.0001$, $n = 27$) increase of 3.1%/year in the period 1892-1973. In Northwest Greenland, a similar ($p < 0.0001$, $n = 69$) increase of 2.1%/year was found, which continued until 1991, when the most recent samples were obtained. In East Greenland, a significant ($p = 0.009$, $n = 322$) decrease of 0.8%/year was observed after 1973. Two Northwest Greenland samples from 1300 A.D. had a mean value of 0.52 mg/kg of dry weight, which can be considered as a baseline level. The Hg concentration during 1985-1991 from Northwest Greenland (mean value of 7.45 mg/kg of dry weight) was more than 14-fold higher than the assumed baseline level from 1300 A.D. from the same region (i.e., about 93% anthropogenic). Although a decrease was found in East Greenland after 1973, the concentration is still ca. 11 fold higher than the baseline level (i.e., about 90% anthropogenic).

Dietz R, Riget FF, Sonne C, Letcher R, Born EW, Muir DCG, 2004. Seasonal and temporal trends in polychlorinated biphenyls and organochlorine pesticides in East Greenland polar bears (*Ursus maritimus*), 1990-2001. *Science of the Total Environment* 331:107-124.

Persistent organochlorine (OC) contaminants (PCBs, DDTs, chlordanes (CHLs), dieldrin, hexachlorocyclohexanes (HCHs), chlorobenzenes (CBzs)) were determined in adipose tissue of 92 polar bears (*Ursus maritimus*) sampled between 1999 and 2001 in central East Greenland (69degrees00'N to 74degrees00'N). OC data were presented from subadults (S: females: X 5 years and males: X 6 years), adult females (F: X 5 years) and adult males (M: X 6 years). Summed chlorobiphenyl (SigmaCBs) concentrations (41 congeners including co-eluters), SigmaCHLs and SigmaDDTs were the dominant classes of OCs. SigmaCBs concentrations were found to be 6470, 8240 and 9100 ng/g lipid weight (lw) i subadults, adult females and adult males, respectively. The corresponding figures were: 2010 (S), 2220 (F) and 1710 (M) ng/g lw for SigmaCBs and 462 (S), 462 (F) and 559 (M) ng/g lw for SigmaDDTs. The dominant CB congeners were CB153 (32.3%), CB 180 (21.4%), CB 170 (12.2%) and CB 138 (11.0%). The metabolite p,p'-DDE (88.2%) dominated the SigmaDDTs, while oxychlordanes was the dominant (57.1%) CHL-related compound. Concentrations of SigmaCBs, SigmaCBzs, SigmaDDTs, mirex and dieldrin were highest in adult males, whereas concentrations of SigmaHCHs were lower than in adult females but not than those in subadults. Adult females had the lowest concentrations of SigmaCBzs, mirex and dieldrin. Concentrations of SigmaCHLs were lowest in adult males, intermediate in subadults and highest in adult females. SigmaCB, SigmaHCH and SigmaCHL concentrations showed high seasonal variability in adult females but remained relatively constant in adult males and subadults. In general, the OC levels in females appeared to be highest in March and lowest in January or September. Concentrations of SigmaCBzs and dieldrin showed seasonal variability in all three groups, with a maximum in March in adult females. SigmaCBz concentrations in adult males and subadults of both sexes peaked in April-July, and dieldrin concentrations peaked in April-July in subadults, but not until August in adult males. SigmaDDT concentrations increased from January to a maximum in April-July for subadults and in August for adults. Temporal trends within the last decade were examined by comparing the present data to the concentrations reported in samples from 1990 from the same region. SigmaCB, p,p'-DDE and SigmaHCH concentrations in 1999-2001 were 22.1%, 66.3% and 39.3% lower than the 1990 concentrations, respectively. In contrast, SigmaCHL and dieldrin concentrations showed differences amongst sex and age groups in the temporal trends, where present concentrations are between 24.4% to 69.3% and 27.0% to 69.0% lower, respectively, relative to the 1990 levels. However, power analysis suggested that firm conclusions could not be drawn regarding the general time trend based on these two sampling periods. The range of half-lives of the various OC classes were estimated to lie between 4.5 and 20.6 years depending on the age and sex groups considered. (C) 2004 Elsevier B.V. All rights reserved.

Foreid S, Rundberget T, Severinsen T, Wiig O, Skaare JU, 2000. Determination of toxaphenes in fish and marine mammals. *Chemosphere* 41:521-528.

An analytical method for the determination of toxaphene in biological materials using gas chromatography with an electron capture detector (GC-ECD) has been established and validated for three single congeners (chlorinated bornanes (CHB) 26, 50 and 62). The analytical method was based

on a method for determination of PCB, DDT and other chlorinated pesticides. To include toxaphene congeners an extra step, adsorption chromatography on silica columns, was introduced to separate the pesticides from PCB. The recovery of CHB-26, 50 and 62 were 97 +/- 11%, 94 +/- 10% and 99 +/- 12%, respectively. Samples from cod, ringed seal and polar bear from the Norwegian arctic environment have been analysed. The levels of CHB-26 and 50 found were 13-55 ng/g fat in cod, 1.3-7.7 ng/g fat in ringed seal and 0.4-119 ng/g fat in polar bear. The levels of CHB-62 were 2.0-13, 0.8-3.4, 0.2-11 ng/g fat in cod, ringed seal and polar bear, respectively. (C) 2000 Elsevier Science Ltd. All rights reserved.

Grahl-Nielsen O, Andersen M, Derocher AE, Lydersen C, Wiig O, Kovacs KM, 2003. Fatty acid composition of the adipose tissue of polar bears and of their prey: ringed seals, bearded seals and harp seals. Marine Ecology-Progress Series 265:275-282.

Polar bears *Ursus maritimus* are predators of phocid seals, but they also forage opportunistically on a variety of other species. In the Barents Sea-Svalbard area, their diet is thought to consist almost exclusively of ringed seals *Phoca hispida*, bearded seals *Erignathus barbatus* and harp seals *P. groenlandica*. When a seal is killed, polar bears preferentially consume the blubber. The fatty acid (FA) compositions of the outer, middle and inner adipose layer of 18 polar bears were compared to each other and also with the FA composition of the blubber of their prey, represented by 10 ringed seals, 10 harp seals and 9 bearded seals. The composition of the FAs in the inner layer of the bear adipose tissue differed from the composition of the outer layer, and was also distinctly different from the composition of the blubber from the prey. Fifteen of the 28 FAs analysed were found in lower relative amounts in the polar bears than in any of the 3 seal species. Eight of the FAs were found in higher relative amounts in polar bears when compared to the 3 prey species. Only 5 of the FAs in polar bears were within the range of relative values found in the prey. This strongly suggests that polar bear adipose tissue has a unique FA composition that is not a straightforward mixture of what they consume, but rather is the result of selective processes prior to and during deposition of lipids in the tissue.

Heier A, Sonne C, Grøne A, Leifsson PS, Dietz R, Born EW, Bacciarini LN, 2005. An immunohistochemical study of retinol-binding protein (RBP) in livers of free-living polar bears (*Ursus maritimus*) from East Greenland. Journal of Zoo and Wildlife Medicine 36:440-446.

From 1999 to 2002 samples from 114 free-ranging polar bears (*Ursus maritimus*) were collected in the municipality of Scoresby Sound, East Greenland, to detect levels of organochlorines and potential histopathologic changes. Livers of 16 female polar bears from this group were evaluated histologically and analyzed for hepatic retinol-binding protein by immunohistochemistry. Retinol-binding protein is the main transport protein for retinol, an important vitamin A metabolite in the polar bear. Only mild pathologic changes were noted on histologic evaluation of the livers. Small lymphocytic or lymphohistiocytic infiltrates were present in all the livers. Small lipid granulomas, mild periportal fibrosis, and bile duct proliferation were found in several cases. Immunohistochemistry for retinol-binding protein of hepatic tissue from free-ranging polar bears showed no distinct difference in staining intensity by a number of criteria: age, season (fasting and nonfasting), or lactation status. The staining was diffuse to finely stippled in the cytoplasm and showed very little variation among the animals. Because of the lack of macroscopic changes and the absence of severe histologic liver lesions, these polar bears were assumed to be healthy. The diffuse cytoplasmic retinol-binding protein staining in hepatocytes of free-ranging polar bears varies markedly from the prominent granular, less intense staining of captive polar bears investigated previously.

Henriksen EO, Wiig O, Skaare JU, Gabrielsen GW, Derocher AE, 2001. Monitoring PCBs in polar bears: lessons learned from Svalbard. Journal of Environmental Monitoring 3:493-498.

Monitoring pollutants in the biota of the Arctic is a high priority activity of the circumpolar Arctic nations. Polar bears (*Ursus maritimus*) are one species that have been selected for monitoring, owing to their high trophic position in the Arctic marine ecosystem and high contaminant levels. Considerable research has been directed at understanding the effects of pollutants, and ultimately these effects are tied to temporal trends in pollutant levels. This paper reports on the state of contaminant monitoring of polar bears in the Norwegian Arctic and provides recommendations for future monitoring programmes. PCB-153 decreased significantly in plasma collected from polar bears sampled at Svalbard during the 1990s. Future monitoring efforts should sample annually at the same location, at the same time of year and analyse 10-25 samples per year.

Haave M, Ropstad E, Derocher AE, Lie E, Dahl E, Wiig O, Skaare JU, Jensen BM, 2003. Polychlorinated biphenyls and reproductive hormones in female polar bears at Svalbard. Environmental Health Perspectives 111:431-436.

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 (P-4) and 17beta-estradiol (E-2)] in free-living female polar bears from Svalbard. Concentrations of P-4 depended on reproductive status, and concentrations were lowest in females with offspring—females with cubs and females with yearlings. In these females, the P-4 concentrations were positively correlated with plasma SigmaPCBs (sum of all analyzed polychlorinated biphenyl congeners) concentrations. The SigmaPCBs concentrations explained 27% of the variation in the P-4 concentrations. There were no correlations between SigmaPCBs and E-2 and cortisol in any of the groups of polar bears, or between SigmaPCBs and P-4 in single polar bears. Although the SigmaPCBs-P-4 relationship in female polar bears with offspring is not evidence per se of a direct cause-effect association, the results indicate that PCBs may affect levels of P-4 in polar bear females. There is a clear need to further assess the hormone balance and population health of polar bears at Svalbard.

Kirkegaard B, Sonne C, Leifsson PS, Dietz R, Born EW, Muir DCG, Letcher RJ, 2005. Histology of selected immunological organs in polar bear (*Ursus maritimus*) from East Greenland in relation to concentrations of organohalogen contaminants. Science of the Total Environment 341:119-132.

Samples of lymph nodes (axillary, n=54 and inguinal, n=45), spleen (n=60), thymus (n=11) and thyroid tissue (n=5) from a total of 82 polar bears (*Ursus maritimus*) collected in East Greenland 1999-2002 were examined histologically. The purpose was to relate histology to concentrations of organohalogen contaminants (OHCs) [i.e., sum (&USigma;)PCBs, &USigma; DDTs, &USigma; HCHs, &USigma; CHLs, HCB, Dieldrin and &USigma; PBDES] determined in adipose tissue, as studies on polar bears have indicated that some OHCs act as immunosuppressive agents. Secondary follicle counts were evaluated in spleen and lymph nodes, and semiquantitatively divided into four groups (0: few/absent to 3: high). In the spleen, a high secondary follicle count was found in 21% of the cases (12/60), and this was significantly higher in subadults (p<0.01) compared to adults of both sexes. Also in the lymph nodes a high secondary follicle count was found in 20% of the cases (20/99), and in the axillary lymph nodes changes were significantly higher in subadults (p<0.05) compared to adults of both sexes. Significantly weak correlations between concentrations of OHCs and the amount of secondary follicles in lymph nodes was found, but probably occurred as a consequence of other multiple stress factor(s) (all: p<0.05) and also one significant, but modest positive correlation was found between &USigma; PBDE concentrations and secondary follicle counts (p<0.01; r=0.41). In spleen, a significant relation between low concentrations of OHCs in adipose tissue and few/absent secondary follicles was found with respect to &USigma; CHLs, &USigma; HCHs, HCB and Dieldrin. No histopathological observations (e.g., neoplasia) were found in spleen or lymph nodes, nor in thymus or thyroid. In conclusion, the present data suggest that the exposure concentrations of OHCs to polar bears are unlikely to have resulted in adverse effects on the tissues in question, although &USigma; CHLs, &USigma; HCHs, HCB and Dieldrin were related to increased secondary follicle counts in the spleen. © 2004 Elsevier B.V. All rights reserved.

Lie E, Bernhoft A, Riget F, Belikov SE, Boltunov AN, Derocher AE, Garner GW, Wiig O, Skaare JU, 2003. Geographical distribution of organochlorine pesticides (OCPs) in polar bears (*Ursus maritimus*) in the Norwegian and Russian Arctic. Science of the Total Environment 306:159-170.

Geographical variation of organochlorine pesticides (OCPs) was studied in blood samples from 90 adult female polar bear (*Ursus maritimus*) from Svalbard, Franz Josef Land, Kara Sea, East-Siberian Sea and Chukchi Sea. In all regions, oxychlordanes were the dominant OCPs. Regional differences in mean levels of HCB, oxychlordanes, trans-nonachlor, alpha-HCH, beta-HCH and p,p'-DDE were found. The highest levels of oxychlordanes, trans-nonachlor and DDE were found in polar bears from Franz Josef Land and Kara Sea. HCB level was lowest in polar bears from Svalbard. Polar bears from Chukchi Sea had the highest level of alpha- and beta-HCH. The lowest alpha-HCH concentration was found in bears from Kara Sea. In all the bears, SigmaHCHs was dominated by beta-HCH. The geographical variation in OCP levels and pattern may suggest regional differences in pollution sources and different feeding habits in the different regions. Polar bears from the Western Russian Arctic were exposed to higher levels of chlordanes and p,p'-DDE than polar bears from locations westwards and eastwards from this

region. This may imply the presence of a significant pollution source in the Russian Arctic area. The study suggests that the western Russian Arctic is the most contaminated region of the Arctic and warrants

Lie E, Larsen HJS, Larsen S, Johansen GM, Derocher AE, Lunn NJ, Norstrom RJ, Wiig O, Skaare JU, 2005. Does high organochlorine (OC) exposure impair the resistance to infection in polar bears (*Ursus maritimus*)? Part II: Possible effect of OCs on mitogen- and antigen-induced lymphocyte proliferation. *Journal of Toxicology and Environmental Health-Part a-Current Issues* 68:457-484.

Previous studies have reported alarmingly high levels of organochlorines (OCs), particularly polychlorinated biphenyls (PCBs), in free-ranging polar bears (*Ursus maritimus*). In this study plasma concentration of PCBs ranged from 14.8 to 200 ng/g wet weight. The aim of the study was to investigate associations between OCs and lymphocyte proliferation after in vitro stimulation with different mitogens and antigens. In 1998 and 1999, 26 and 30 free-ranging polar bears from Svalbard and Churchill, Canada, respectively, were recaptured 32-40 d following immunization with inactivated tetanus toxoid and hemocyanin from keyhole limpets (KLH) to sensitize lymphocytes. At recapture, blood was sampled for determination of plasma levels of PCBs and organochlorine pesticides (OCPs) and lymphocyte proliferation after in vitro stimulation with specific mitogens-phytohemagglutinin (PHA), pokeweed mitogen (PWM), concanavalin A (Con A), lipopolysaccharide (LPS), and purified protein derivative of *Mycobacterium avium* subsp. *paratuberculosis* (PPD)-and antigens: tetanus toxoid and KLH. The combinations of SigmaPCBs (sum of 12 individual PCB congeners), SigmaOCPs (sum of 6 OCPs), and their interactions contributed up to 15% of the variations in the lymphocyte responses. By using multiple regression analyses, followed by classical mathematic function analyses, thresholds for immunomodulation were estimated. Depending on the lymphocyte proliferation response studied, the estimated thresholds for significant immunomodulation were within the concentration ranges 32-89 ng/g wet weight (ww) and 7.8-14 ng/g ww for SigmaPCBs and SigmaOCPs, respectively. Thus, this study demonstrated that OC exposure significantly influences specific lymphocyte proliferation responses and part of the cell-mediated immunity, which also is associated with impaired ability to produce antibodies (Lie et al., 2004).

Lie E, Larsen HJS, Larsen S, Johnsen GM, Derocher AE, Lunn NJ, Norstrom RJ, Wiig O, Skaare JU, 2004. Does high organochlorine (OC) exposure impair the resistance to infection in polar bears (*Ursus maritimus*)? part 1: effect of OCs on the humoral immunity. *Journal of Toxicology and Environmental Health-Part a-Current Issues* 67:555-582.

This study was undertaken to assess if high levels of organochlorines (OCs) are associated with decreased ability to produce antibodies in free-ranging polar bears (*Ursus maritimus*) and thus affect the humoral immunity. In 1998 and 1999, 26 and 30 polar bears from Svalbard, Norway, and Churchill, Canada, respectively, were recaptured 32-40 d following immunization with inactivated influenza virus, reovirus, and herpes virus and tetanus toxoid. Blood was sampled at immunization and at recapture for determination of plasma levels of polychlorinated biphenyls (PCBs) and organochlorine pesticides (OCPs), serum immunoglobulin G (IgG) concentrations, and specific antibodies against influenza virus, reovirus, and herpes virus, tetanus toxoid, and *Mannheimia haemolytica*. The OCs alone contributed with up to 7% to the variations in the immunological parameters. The combination of SigmaPCBs (sum of 12 individual PCB congeners), SigmaOCPs (sum of 6 OCPs), and biological factors accounted for 40-60% of the variation in the immunological parameters. Negative associations were found between SigmaPCBs and serum immunoglobulin G (IgG) levels and between SigmaPCBs and increased antibody titers against influenza virus and reovirus following immunization. In contrast, a positive association was registered between SigmaPCBs and increased antibodies against tetanus toxoid. SigmaOCPs also contributed significantly to the variations in the immunological responses. OCs did not have the same impact on the antibody production against *M. haemolytica*. The present study demonstrated that high OC levels may impair the polar bears ability to produce antibodies and thus may produce impaired resistance to infections.

Mauritzen M, Belikov SE, Boltunov AN, Derocher AE, Hansen E, Ims RA, Wiig O, Yoccoz N, 2003a. Functional responses in polar bear habitat selection. *Oikos* 100:112-124.

Habitat selection may occur in situations in which animals experience a trade-off, e.g. between the use of habitats with abundant forage and the use of safer retreat habitats with little forage. Such trade-offs may yield relative habitat use conditional on the relative availability of the different habitat types, as

proportional use of foraging habitat may exceed proportional availability when foraging habitat is scarce, but be less than availability when foraging habitat is abundant. Hence, trade-offs in habitat use may result in functional responses in habitat use (i.e. change in relative use with changing availability). We used logistic and log-linear models to model functional responses in female polar bear habitat use based on satellite telemetry data from two contiguous populations; one near shore inhabiting sea ice within fjords, and one inhabiting pelagic drift ice. Open ice, near the ice edge, is a highly dynamic habitat hypothesised to be important polar bear habitat due to high prey availability. In open ice-polar bears may experience a high energetic cost of movements and risk drifting away from the main ice field (i.e. trade off between feeding and energy saving or safety). If polar bears were constrained by ice dynamics we therefore predicted use of retreat habitats with greater ice coverage relative to habitats used for hunting. The polar bears demonstrated season and population specific functional responses in habitat use, likely reflecting seasonal and regional variation in use of retreat and foraging habitats. We suggest that in seasons with functional responses in habitat use, polar bear space use and population distribution may not be a mere reflection of prey availability but rather reflect the alternate allocation of time in hunting and retreat habitats.

Mauritzen M, Derocher AE, Pavlova O, Wiig O, 2003b. Female polar bears, *Ursus maritimus*, on the Barents Sea drift ice: walking the treadmill. *Animal Behaviour* 66:107-113.

For animals in dynamic habitats, the contribution of passive (i.e. by wind or current) and active (movements by the animals themselves) displacement determines whether their space use reflects physical or adaptive behavioural processes. Polar bears in the Barents Sea undertake extensive annual migrations in a habitat that is highly dynamic because of continuous sea ice drift. Using combined information from satellite telemetry, satellite images and atmospheric pressure recordings, we estimated the contribution of sea ice drift and movements in the monthly net displacement of female polar bears. We found that movements, and thus behavioural processes, were dominant. Net displacement was directed northwards during summer ice retreat and southwards during winter ice advance. Conversely, movements were directed northwards counteracting a continuous southward drift. Acting as a treadmill, ice drift probably increased the energetic cost of migrations relative to that expected from observed net displacement distances; this suggests that pelagic and adjacent near-shore bears, on stable land-fast ice, have different energy costs. Little concordance between ice drift rates and net displacement and movement rates suggest that polar bears do not adjust their displacement relative to attractive areas with fixed locations, but rather adjust their movements to local habitat suitability. Furthermore, selective use of less dynamic drift ice when with cubs-of-the-year, and use of terrestrial denning areas, appear to be behavioural adaptations to the dynamics of the Barents Sea drift ice. Hence, understanding the behaviour and ecology of animals inhabiting dynamic habitats necessitates incorporation of both dynamic and static habitat variables. (C) 2003 Published by Elsevier Ltd on behalf of The Association for the Study of Animal Behaviour.

Mauritzen M, Derocher AE, Wiig O, 2001. Space-use strategies of female polar bears in a dynamic sea ice habitat. *Canadian Journal of Zoology-Revue Canadienne De Zoologie* 79:1704-1713.

In environments with high spatiotemporal variability in resources, animals may exhibit nomadic movements for resource tracking as opposed to long-term area fidelity. Polar bears (*Ursus maritimus*) inhabit the dynamic sea ice, preying on seals, and demonstrate considerable intraspecific variation in space use. We studied patterns of fidelity and annual range size for 74 adult female polar bears captured in the Norwegian Arctic that were tracked for up to 5 years using satellite telemetry data. We used the autocorrelation structure of movements and distance between observations at a 1-year interval as measures of fidelity. The female polar bears had a circannual migration pattern. Annual range size varied with reproductive state and geographic location of the range. Females entering maternity dens had smaller annual ranges than females not entering dens. Nearshore females had smaller annual ranges than pelagic females, demonstrating different space-use strategies. Repeatability of movement patterns indicated strategy specialization. We suggest that the different space-use strategies result from variation in habitat and prey selection and in sea-ice dynamics. Factors affecting population and predator-prey dynamics may interact differently with the different space-use strategies and yield strategy-dependent outcomes, therefore a knowledge of movement strategies may be important for understanding polar bear population dynamics.

Mauritzen M, Derocher AE, Wiig O, Belikov SE, Boltunov AN, Hansen E, Garner GW, 2002. Using satellite telemetry to define spatial population structure in polar bears in the Norwegian and western Russian Arctic. Journal of Applied Ecology 39:79-90.

1. Animal populations, defined by geographical areas within a species' distribution where population dynamics are largely regulated by births and deaths rather than by migration from surrounding areas, may be the correct unit for wildlife management. However, in heterogeneous landscapes varying habitat quality may yield subpopulations with distinct patterns in resource use and demography significant to the dynamics of populations. 2. To define the spatial population structure of polar bears *Ursus maritimus* in the Norwegian and western Russian Arctic, and to assess the existence of a shared population between the two countries, we analysed satellite telemetry data obtained from 105 female polar bears over 12 years. 3. Using both cluster analyses and home-range estimation methods, we identified five population units inhabiting areas with different sea-ice characteristics and prey availability. 4. The continuous distribution of polar bear positions indicated that the different subpopulations formed one continuous polar bear population in the Norwegian and western Russian Arctic. Hence, Norway and Russia have a shared management responsibility. 5. The spatial population structure identified will provide a guide for evaluating geographical patterns in polar bear ecology, the dynamics of polar bear-seal relationships and the effects of habitat alteration due to climate change. The work illustrates the importance of defining population borders and subpopulation structure in understanding the dynamics and management of larger animals.

Muir DCG, Backus S, Derocher AE, Dietz R, Evans TJ, Gabrielsen GW, Nagy J, Norstrom RJ, Sonne C, Stirling I, Taylor MK, Letcher RJ, 2006. Brominated flame retardants in polar bears (*Ursus maritimus*) from Alaska, the Canadian Arctic, East Greenland, and Svalbard. Environmental Science & Technology 40:449-455.

Polybrominated diphenyl ethers (PBDEs) were determined in adipose tissue of adult and subadult female polar bears sampled between 1999 and 2002 from sub-populations in Arctic Canada, eastern Greenland, and Svalbard, and in males and females collected from 1994 to 2002 in northwestern Alaska. Only 4 congeners (BDE47, 99, 100, and 153) were consistently identified in all samples. BDE47 was the major PBDE congener representing from 65% to 82% of the sum (Σ) PBDEs. Age was not a significant covariate for individual PBDEs or Σ PBDE. Higher proportions of BDE 99, 100, and 153 were generally found in samples from the Canadian Arctic than from Svalbard or the Bering-Chukchi Sea area of Alaska. Geometric mean Σ PBDE concentrations were highest for female polar bear fat samples collected from Svalbard (50 ng/g lipid weight (lw)) and East Greenland (70 ng/g lw). Significantly lower Σ PBDE concentrations were found in fat of bears from Canada and Alaska (means ranging from 7.6 to 22 ng/g lw). For the entire dataset, Σ PBDE concentrations were correlated with Σ PCBs. Higher total hexabromocyclododecane (HBCD) concentrations were found in fat of bears from Greenland and Svalbard than in those from Alaska. The geographical trends for PBDEs and HBCD parallel those for PCBs implying similar source regions for long range transport to the Arctic and bioaccumulation pathways in the arctic marine food web. All four major PBDE congeners were found to biomagnify from ringed seals to polar bears. BDE153 showed the greatest (71 x) biomagnification factors (BMFs) and, on average, had a BMF that was 5.5-fold higher than for PCB congener 153 (13x) but similar to PCB congener 194 (73x), indicating that it is a highly bioaccumulative compound.

Norheim G, Skaare JU, Wiig O, 1992. Some Heavy-Metals, Essential Elements, and Chlorinated Hydrocarbons in Polar Bear (*Ursus-Maritimus*) at Svalbard. Environmental Pollution 77:51-57.

During the period 1978-1989, samples of liver, kidney and subcutaneous fat from 24 polar bears, *Ursus maritimus*, from Svalbard were analysed for mercury, cadmium, lead, copper, zinc, selenium, arsenic, HCB, DDE, and PCBs (as Aroclor 1260R or Phenoclor DP6R). In a selected number of liver (seven) and fat (three) samples, the composition of individual PCB congeners was studied by comparison with 23 individual PCB congeners (IUPAC nos. 28, 52, 74, 101, 99, 110, 149, 118, 114, 105, 153, 141, 138, 187, 128, 183, 156, 157, 180, 170, 194, 206 and 209). In the seven liver samples, the concentrations of o,p'- and p,p'-isomers of DDT, TDE, DDE, alpha-, beta- and gamma-HCH, oxychlorane, heptachlor, heptachlorepoxyde, aldrin and dieldrin were also determined. The hepatic concentrations of mercury, cadmium and lead in animals of all ages were 0.4-6.0, < 0.1-1.2, and < 0.5-1.6-mu-g g-1, respectively. This indicates a moderate exposure. Concentrations of mercury and selenium were correlated (r = 0.80). The levels of copper and zinc represented normal physiological concentrations. The concentrations of

HCB, DDE and PCBs in fat were < 0.05-1.5, < 0.1-3.4 and 2.9-90- μ -g g⁻¹, respectively. The corresponding results for liver were < 0.01-0.11, < 0.1-0.5 and 0.1-78- μ -g g⁻¹, respectively. Six PCB congeners, PCB-99, -153, -138, -180, -170 and -194 accounted for about 99 and 87% of the total PCB content (sum of the 12 congeners, nos. 28, 99, 153, 138, 128 + 187, 156, 157, 180, 170, 194, 206 and 209) in liver and fat, respectively. PCB-153 represented 37 +/- 3 and 30 +/- 16% of the sum PCB (sum of 12 congeners) in liver and fat, respectively. The range of the hepatic concentration of oxychlordane was 5-19- μ -g g⁻¹. Quantifiable concentrations of heptachlor, heptachlorepoxide, beta-HCH and dieldrin were also found in all the liver samples analysed. Low concentrations of p,p'- and o,p'-DDT were found in two of seven liver and two of two fat samples. Comparisons are made with investigations from Canada and Greenland. Possible effects of PCBs, especially on reproduction, cannot be excluded. Ringed seal, *Foca hispida*, and to some extent bearded seal, *Erignathus barbatus*, are the main food of the polar bear. It is therefore likely that the exposure to environmental pollutants occurs via the consumption of these two species.

Norstrom RJ, Belikov SE, Born EW, Garner GW, Malone B, Olpinski S, Ramsay MA, Schliebe S, Stirling I, Stishov MS, Taylor MK, Wiig O, 1998. Chlorinated hydrocarbon contaminants in polar bears from eastern Russia, North America, Greenland, and Svalbard: Biomonitoring of Arctic pollution. Archives of Environmental Contamination and Toxicology 35:354-367.

Adipose tissue samples from polar bears (*Ursus maritimus*) were obtained by necropsy or biopsy between the spring of 1989 to the spring of 1993 from Wrangel Island in Russia, most of the range of the bear in North America, eastern Greenland, and Svalbard. Samples were divided into 16 regions corresponding as much as possible to known stocks or management zones. Concentrations of dieldrin (DIEL), 4,4'-DDE (DDE), sum of 16 polychlorinated biphenyl congeners (Sigma PCB), and sum of 11 chlordane-related compounds and metabolites (Sigma CHL) were determined. In order to minimize the effect of age, only data for adults (320 bears age 5 years and older) was used to compare concentrations among regions. Concentrations of Sigma PCB were 46% higher in adult males than females, and there was no significant trend with age. Concentrations of Sigma CHL were 30% lower in adult males than females. Concentrations of Sigma PCB, Sigma CHL, and DDE in individual adult female bears were standardized to adult males using factors derived from the least-square means of each sex category, and geometric means of the standardized concentrations on a lipid weight basis were compared among regions. Median geometric mean standardized concentrations (lipid weight basis) and ranges among regions were as follows: Sigma PCB, 5,942 (2,763-24,316) μ g/kg; Sigma CHL, 1,952 (727-4,632) μ g/kg; DDE, 219 (52-560) μ g/kg; DIEL, 157 (31-335) μ g/kg. Geometric mean Sigma PCB concentrations in bears from Svalbard, East Greenland, and the Arctic Ocean near Prince Patrick Island in Canada were similar (20,256-24,316 μ g/kg) and significantly higher than most other areas. Atmospheric, oceanic, and ice transport, as well as ecological factors may contribute to these high concentrations of Sigma PCB. Sigma CHL was more uniformly distributed among regions than the other CHCs. Highest Sigma CHL concentrations were found in southeastern Hudson Bay, which also had the highest DDE and DIEL concentrations. In general, concentrations of Sigma CHL, DDE, and DIEL were higher in eastern than western regions, suggesting an influence of North American sources. Average Sigma PCB concentrations in bears from the Canadian Arctic were similar to those in 1982-84, while average Sigma CHL and DDE concentrations were 35-44% lower and DIEL was 90% lower. However, the significance of these temporal trends during the 1980s is not conclusive because of the problems of comparability of data.

Olsen GH, Mauritzen M, Derocher AE, Sormo EG, Skaare JU, Wiig O, Jenssen BM, 2003. Space-use strategy is an important determinant of PCB concentrations in female polar bears in the barents sea. Environmental Science & Technology 37:4919-4924.

Space-use was examined in 54 female polar bears (*Ursus maritimus*) from Svalbard and the Barents Sea that were collared with satellite transmitters to provide information on their spatial positions and annual home range sizes. Plasma samples from the same animals were analyzed for concentrations of six relevant PCB congeners (PCB-99, -153, -156, -180, -194, and -118). Factors related to space-use strategy (such as home range size; annual, spring, and winter longitudinal position; and spring and summer latitudinal position) were important determinants of PCB concentrations in plasma. In addition, reproductive status of the polar bears and plasma lipid content affected PCB concentrations. Among the tested variables, annual home range size was the variable that affected SigmaPCB(5) (SUM of PCB-99, -153, -156, -180, and -194) to the largest degree ($r^2 = 0.22$). We propose that the positive effect of home range size on SigmaPCB(5) in female polar bears is related to the higher energetic costs required

to occupy large home range sizes as compared to small home range sizes. Polar bears with large home range sizes would need to consume more prey than bears with small home range sizes, and increased feeding without a change in elimination of persistent compounds can explain their higher SigmaPCB(5) concentrations. Polar bears with large home range sizes were also more pelagic, inhabiting areas further east, closer to the ice-edge zone than animals with small home range sizes. Thus, prey choice associated with a pelagic space-use strategy may also explain the higher SigmaPCB(5) in polar bears with large home range sizes.

Oskam IC, Ropstad E, Dahl E, Lie E, Derocher AE, Wiig O, Larsen S, Wiger R, Skaare JU, 2003. Organochlorines affect the major androgenic hormone, testosterone, in male polar bears (*Ursus maritimus*) at Svalbard. *Journal of Toxicology and Environmental Health-Part A* 66:2119-2139.

Normal sexual development and subsequent reproductive function are dependent on appropriate testosterone production and action. The regulation of steroid hormones, including androgens, can be influenced by both biological and environmental factors, including environmental chemicals. Concentrations of organochlorines are considerably greater in Svalbard polar bears than in polar bears from other regions. Between 1995 and 1998, samples were collected from 121 male polar bears (*Ursus maritimus*) from the Svalbard area. In this study, testosterone concentration variations were described for male polar bears during different seasons and for all age groups. To study possible relationships between plasma testosterone concentrations and biological factors, such as age, axial girth, and extractable plasma fat, and organochlorine contaminants including hexachlorocyclohexanes, hexachlorobenzene, chlordanes, p,p'-DDE, and 16 individual polychlorinated biphenyl (PCB) congeners, identical statistical analyses were performed on the total population and a subsample of reproductively active adults. Of the biological factors, axial girth showed a significant positive relationship and percentage extractable fat and a significant negative relationship with the testosterone concentrations. Both the Sigmapesticides and SigmaPCBs made significant negative contributions to the variation of the plasma testosterone concentration. The continuous presence of high concentrations of organochlorines in male polar bears throughout their life could possibly aggravate any reproductive toxicity that may have occurred during fetal and early postnatal development.

Oskam IC, Ropstad E, Lie E, Derocher AE, Wiig O, Dahl E, Larsen S, Skaare JU, 2004. Organochlorines affect the steroid hormone cortisol in free-ranging polar bears (*Ursus maritimus*) at Svalbard, Norway. *Journal of Toxicology and Environmental Health-Part a-Current Issues* 67:959-977.

Since the polar bear (*Ursus maritimus*) is among the most highly organochlorine-contaminated species of the Arctic mammals, there is growing concern that in addition to the natural stressors in the polar bear's environment, several organochlorines (OCs) may be able to change basic endocrine pathways. Alterations in the hypothalamic-pituitary-adrenal (HPA) axis may affect plasma cortisol concentrations and inhibit physiological processes involved in the maintenance of homeostasis in a way that may endanger the animal's health. Between 1995 and 1998, samples were collected from 121 male and 130 female free-ranging polar bears from the Svalbard area. The aim of the study was to investigate relationships between plasma cortisol concentrations, biological factors, and OCs. The variation in plasma cortisol concentrations was determined for the total sample. Axillary girth and body mass together with their interactions explained more than 50% of the variation in the plasma cortisol concentration. The sum of pesticides (Sigmapesticides) combined with the sum of polychlorinated biphenyls (SigmaPCBs) and their interactions explained over 25% of the variation in the cortisol concentration. Although Sigmapesticides contributed negatively and SigmaPCBs contributed positively to the variation in the plasma cortisol, the overall contribution of the OCs to the plasma cortisol variation was negative. Despite the complexity on stress responses and the interactions with environmental factors, this study demonstrated that high concentrations of OCs in polar bears might alter plasma cortisol concentrations.

Skaare JU, Bernhoft A, Derocher A, Gabrielsen GW, Goksoyr A, Henriksen E, Larsen HJ, Lie E, Wiig O, 2000. Organochlorines in top predators at Svalbard - occurrence, levels and effects. *Toxicology Letters* 112:103-109.

Alarming high polychlorinated biphenyl (PCB) levels have been found in the top predators such as glaucous gull (*Larus hyperboreus*) and polar bear (*Ursus maritimus*) at Svalbard [Gabrielsen, G.W., Skaare, J.U., Polder, A., Bakken, V., 1995. Chlorinated hydrocarbons in glaucous gull (*Larus hyperboreus*). *Sci. Total Environ.* 160/161, 337-346; Bernhoft, A., Skaare, J.U., Wiig, O., 1997.

Organochlorines in polar bears (*Ursus maritimus*) at Svalbard. *Environ. Pollut.* 95, 159-175; Henriksen, E.O., Gabrielsen, G.W., Trudeau, S., Wolkers, H., Sagerup, K., Skaare, J.U., 1999. Organochlorines and possible biochemical effects in glaucous gull (*Larus hyperboreus*) from Bear Island, the Barents Sea. *Arch. Environ. Contam. Toxicol.* (in press).] Studies of the possible toxic effects, particularly on the immune system and reproduction, of the very high PCB levels in these species are currently being investigated. Data obtained in the field (f.i. reproductive success in polar bears and intestinal nematodes in glaucous gulls), as well as levels of various biochemical and physiological parameters (f.i. thyroid hormones, retinol, EROD activity, CYP1A, IgG), have been coupled with the PCB levels [Skaare? J.U., Wiig, O., Bernhoft, A., 1994. Klorerte organiske miljøgifter; Nivaer og effekter i isbjorn. Norwegian Polar Institute Reportseries no. 86, 1-23 (in Norwegian); Bernhoft, A., Skaare, J.U., Wiig, O., 1997. Organochlorines in polar bears (*Ursus maritimus*) at Svalbard. *Environ. Pollut.* 95, 159-175; Bernhoft, A., Skaare, J.U., Wiig, O., Derocher, A.E., Larsen, H.J., 2000. Possible immunotoxic effects of organochlorines in polar bears (*Ursus maritimus*) at Svalbard (in press), Henriksen, E.O., Gabrielsen, G.W., Skaare, J.U., Skjeggstad, N., Jensen, B.M., 1998a. Relationship between PCB levels, hepatic EROD activity and plasma retinol in glaucous gull, *Larus hyperboreus*. *Marine Environ. Res.* 46, 45-49; Henriksen, E.O., Gabrielsen, G.W., Trudeau, S., Wolkers, H., Sagerup, K., Skaare, J.U., 1999. Organochlorines and possible biochemical effects in glaucous gull (*Larus hyperboreus*) from Bear Island, the Barents Sea. *Arch. Environ. Contam. Toxicol.* (in press); Sagerup, K., Gabrielsen, G.W., Skorping, A., Skaare, J.U., 1998. Association between PCB concentrations and intestinal nematodes in glaucous gulls, *Larus hyperboreus*, from Bear Island. *Organohalogen compounds* 39, 449-451; Skaare, J.U., Wiig, O., Bernhoft, A., 1994. Klorerte organiske miljøgifter; Nivaer og effekter i isbjorn. Norwegian Polar Institute Reportseries no. 86, 1-23. (in Norwegian). (C) 2000 Published by Elsevier Science Ireland Ltd. All rights reserved.

Skaare JU, Bernhoft A, Wiig O, Norum KR, Haug E, Eide DM, Derocher AE, 2001. Relationships between plasma levels of organochlorines, retinol and thyroid hormones from polar bears (*Ursus maritimus*) at Svalbard. *Journal of Toxicology and Environmental Health-Part A* 62:227-241.

Associations were determined between retinol and the thyroid hormones thyroxine (T4) and triiodothyronine (T3), respectively, and the organochlorine contaminants (OCs) polychlorinated biphenyls (PCBs), 1,1-dichloro-2,2-bis-(4-chlorophenyl)ethylene (DDE), hexachlorobenzene (HCB), and hexachlorocyclohexanes (HCHs) in blood plasma from polar bears (*Ursus maritimus*) caught at Svalbard. The blood samples were collected from free-ranging polar bears of different age and sex in 1991-1994. The retinol concentration and the ratio of total T4 (TT4) to free T4 (FT4) (TT4/FT4 ratio) decreased linearly with increasing concentrations of PCBs and HCB. Retinol was also negatively associated with HCHs, while the TT4/FT4 ratio was positively associated with DDE. The concentrations of retinol and thyroid hormones were significantly higher in females than in males. However, the TT4/FT4 and TT3/FT3 ratios were significantly higher in males than in females. The concentrations of thyroid hormones were negatively correlated with age in male bears, while in females, thyroid hormones did not change with age. The OCs were found to explain 12, 30, and 7% of the variation of retinol concentrations and the TT4/FT4 and TT3/FT3 ratios, respectively, after correcting for age and sex. The potential consequence of these associations for the individual and the population is unknown.

Skaare JU, Larsen HJ, Lie E, Bernhoft A, Derocher AE, Norstrom R, Ropstad E, Lunn NF, Wiig O, 2002. Ecological risk assessment of persistent organic pollutants in the arctic. *Toxicology* 181:193-197.

Ecological risk assessment of persistent organic chemicals in marine mammals in the Arctic would comprise assessments of both exposure and effect and risk characterization. Results from a comprehensive collaborative study between Norwegian and Canadian researchers, comprising epizootological (ecological) studies (reproductive rate, offspring survival), experimental studies on the immune system function, monitoring studies (e.g. physiological assays of thyroid hormones, retinol, IgG and testosterone) and registration of biological data (e.g. sex, age, reproductive status, nutritional status) were coupled with PCB exposure data. Assessment of the results indicates that population status and health of polar bears with very high PCB levels may be at risk. (C) 2002 Published by Elsevier Science Ireland Ltd.

Smithwick M, Mabury SA, Solomon KR, Sonne C, Martin JW, Born EW, Dietz R, Derocher AE, Letcher RJ, Evans TJ, Gabrielsen GW, Nagy J, Stirling I, Taylor MK, Muir DCG, 2005a. *Circumpolar*

study of perfluoroalkyl contaminants in polar bears (*Ursus maritimus*). *Environmental Science & Technology* 39:5517-5523.

Perfluoroalkyl substances were determined in liver tissues and blood of polar bears (*Ursus maritimus*) from five locations in the North American Arctic and two locations in the European Arctic. Concentrations of perfluorooctane sulfonate (PFOS), perfluorohexane sulfonate, heptadecafluorooctane sulfonamide, and perfluoroalkyl carboxylates with C-8-C-15 perfluorinated carbon chains were determined using liquid chromatography tandem mass spectrometry. PFOS concentrations were significantly correlated with age at four of seven sampling locations, while gender was not correlated to concentration for any compound measured. Populations in South Hudson Bay (2000-2730 ng/g wet wt), East Greenland (911-2140 ng/g wet wt), and Svalbard (756-1290 ng/g wet wt) had significantly ($P < 0.05$) higher PFOS concentrations than western populations such as the Chukchi Sea (435-729 ng/g wet wt). Concentrations of perfluorocarboxylic acids (PFCAs) with adjacent chain lengths i.e., C-9:C-10 and C-10:C-11) were significantly correlated ($P < 0.05$), suggesting PFCAs have a common source within a location, but there were differences in proportions of PFCAs between eastern and western location sources. Concentrations of PFOS in liver tissue at five locations were correlated with concentrations of four polychlorinated biphenyl congeners (180, 153, 138, and 99) in adipose tissue of bears in the same populations, suggesting similar transport pathways and source regions of PFOS or precursors.

Smithwick M, Muir DCG, Mabury SA, Solomon KR, Martin JW, Sonne C, Born EW, Letcher RJ, Dietz R, 2005b. Perfluoroalkyl contaminants in liver tissue from East Greenland polar bears (*Ursus maritimus*). *Environmental Toxicology and Chemistry* 24:981-986.

Perfluoroalkyl substances were determined in polar bears (*Ursus maritimus*) collected in East Greenland (69 degrees 00'N to 74 degrees 00' N) to compare with other populations and to examine effects of age and gender on concentrations of these contaminants. Hepatic tissue ($n = 29$) was analyzed for perfluorooctane sulfonate (PFOS), perfluorooctanoate (PFOA), perfluorohexane sulfonate, heptadecafluorooctane sulfonamide (PFOSA), and perfluoroalkyl carboxylates (PFCAs) with C-9-C-15 perfluorinated carbon chains by liquid chromatography tandem mass spectrometry. Concentrations of PFOS found in samples from East Greenland (mean = 2,470 +/- 1,320 ng/g wet weight) were similar to Hudson Bay, Canada, and both populations had significantly greater concentrations than those reported for Alaska, suggesting a spatial trend. Male bears showed a significant increase in concentration up to age six for PFCAs with C-10-C-14 carbon chains ($r(2) \geq 0.50$, $p \leq 0.05$). Significant correlations were found between adjacent chain length PFCAs, (e.g., PFNA to PFDA: $p < 0.05$; $r(2) = 0.90$). This may indicate a common source for these chemicals, although the specifics of source and mode of transport are unknown. No significant correlations were found between concentrations of PFCAs in liver tissue and previously reported polychlorinated biphenyl (PCB) congeners analyzed in fat samples from the same bears.

Sonne C, Dietz R, Born EW, Riget FF, Kirkegaard M, Hyldstrup L, Letcher RJ, Muir DCG, 2004. Is bone mineral composition disrupted by organochlorines in East Greenland polar bears (*Ursus maritimus*)? *Environmental Health Perspectives* 112:1711-1716.

We analyzed bone mineral density (BMD) in skulls of polar bears (*Ursus maritimus*) ($n = 139$) from East Greenland sampled during 1892-2002. Our primary goal was to detect possible changes in bone mineral content (osteopenia) due to elevated exposure to organochlorine [polychlorinated biphenyls (PCBs), dichlorodiphenyl trichloroethane (DDT) and its metabolites, chlordanes (CHLs), dieldrin, hexacyclohexanes, hexachlorobenzene] and polybrominated diphenyl ether (PBDE) compounds. To ensure that the BMD value in skull represented the mineral status of the skeletal system in general, we compared BMD values in femur and three lumbar vertebrae with skull in a subsample. We detected highly significant correlations between BMD in skull and femur ($r = 0.99$; $p < 0.001$; $n = 13$) and skull and vertebrae ($r = 0.97$; $p < 0.001$; $n = 8$). BMD in skulls sampled in the supposed pre-organochlorine/PBDE period (1892-1932) was significantly higher than that in skulls sampled in the supposed pollution period (1966-2002) for subadult females, subadult males, and adult males (all, $p < 0.05$) but not adult females ($p = 0.94$). We found a negative correlation between organochlorines and skull BMD for the sum of PCBs (SigmaPCB; $p < 0.04$) and SigmaCHL ($p < 0.03$) in subadults and for dieldrin ($p < 0.002$) and SigmaDDT ($p < 0.02$) in adult males; indications for 2:PBDE in subadults were also found ($p = 0.06$). In conclusion, the strong correlative relationships suggest that disruption of the

bone mineral composition in East Greenland polar bears may have been caused by organochlorine exposure.

Sonne C, Dietz R, Leifsson PS, Born EW, Kirkegaard M, Letcher RJ, Muir DCG, Riget FF, Hyldstrup L, 2006a. Are organohalogen contaminants a cofactor in the development of renal lesions in East Greenland polar bears (*Ursus maritimus*)? *Environmental Toxicology and Chemistry* 25:1551-1557.

Tissues of polar bears (*Ursus maritimus*) from East Greenland contain the highest concentrations of organohalogen contaminants (OHCs) among subpopulations of any mammalian species in the Arctic. Negative associations also have been found between OHC concentrations and bone mineral density and liver histology parameters for this subpopulation of polar bears. The present study examined the OHC concentrations and adverse effects on renal tissue for 75 polar bears collected during 1999 to 2002. Specific lesions were diffuse glomerular capillary wall thickening, mesangial glomerular deposits, tubular epithelial cell hyperplasia, hyalinization of the tubular basement membrane, tubular dilatation, atrophy and necrosis, tubular medullary hyalin casts, interstitial fibrosis, and mononuclear cell infiltration. With the exception of mononuclear cell infiltrations, all these parameters were correlated with age, whereas none was associated with the sex of the animals. In an age-controlled statistical analysis of covariance, increases in glomerular mesangial deposits and interstitial fibrosis were significantly ($p < 0.05$) correlated with polybrominated diphenyl ether (Sigma PBDE) concentrations in subadults. In adult males, statistically significant ($p < 0.05$) positive correlations were found for tubular epithelial cell hyperplasia and dieldrin concentration; diffuse glomerular capillary wall thickening and chlordane (Sigma CHL) concentrations, and tubular medullary hyalin casts and Sigma CHL, Sigma PBDE, polychlorinated biphenyl, and hexachlorocyclohexane concentrations. The lesions were consistent with those reported previously in highly OHC-contaminated Baltic seal populations and exposed laboratory animals. The renal lesions were a result of aging. However, based on the above statistical findings as well as the nature of the findings, we suggest that long-term exposure to OHCs may be a cofactor in renal lesion occurrence, although other cofactors, such as exposure to heavy metals and recurrent infections from microorganisms, cannot be ruled out. This is new and important knowledge in the assessment of health status among wildlife populations and humans relying on food resources that are contaminated with OHCs.

Sonne C, Dietz R, Leifsson PS, Born EW, Letcher RJ, Kirkegaard M, Muir DCG, Riget FF, Hyldstrup L, 2005a. Do organohalogen contaminants contribute to histopathology in liver from east Greenland polar bears (*Ursus maritimus*)? *Environmental Health Perspectives* 113:1569-1574.

In East Greenland polar bears (*Ursus maritimus*), anthropogenic organohalogen compounds (OHCs) (e.g., polychlorinated biphenyls, dichlorodiphenyltrichloroethane, and polybrominated diphenyl ethers) contributed to renal lesions and are believed to reduce bone mineral density. Because OHCs are also hepatotoxic, we investigated liver histology of 32 subadult, 24 adult female, and 23 adult male East Greenland polar bears sampled during 1999-2002. Light microscopic changes consisted of nuclear displacement from the normal central cytoplasmic location in parenchymal cells, mononuclear cell infiltrations (mainly portally and as lipid granulomas), mad bile duct proliferation accompanied by fibrosis, and fat accumulation in hepatocytes and pluripotent Ito cells. Lipid accumulation in Ito cells and bile duct hyperplasia accompanied by portal fibrosis were correlated to age, whereas no changes were associated with either sex or season (summer vs. winter). For adult females, hepatocytic intracellular fat increased significantly with concentrations of the sum of hexachlorocyclohexanes, as was the case for lipid granulomas and hexachlorobenzene in adult males. Based on these relationships and the nature of the chronic inflammation, we suggest that these findings were caused by aging and long-term exposure to OHCs. Therefore, these changes may be used as biomarkers for OHC exposure in wildlife and humans. To our knowledge, this is the first time liver histology has been evaluated in relation to OHC concentrations in a mammalian wildlife species, and the information is important to future polar bear conservation strategies and health assessments of humans relying on OHC-contaminated food resources.

Sonne C, Leifsson PS, Dietz R, Born EW, Letcher RJ, Hyldstrup L, Riget FF, Kirkegaard M, Muir DCG, 2006b. Xenoendocrine pollutants may reduce size of sexual organs in East Greenland polar bears (*Ursus maritimus*). *Environmental Science & Technology* 40:5668-5674.

Reproductive organs from 55 male and 44 female East Greenland polar bears were examined to investigate the potential negative impact from organohalogen pollutants (OHCs). Multiple regressions normalizing for age showed a significant inverse relationship between OHCs and testis length and baculum length and weight, respectively, and was found in both subadults (dichlorodiphenyl trichloroethanes, dieldrin, chlordanes, hexacyclohexanes, polychlorinated biphenyls (PCBs), and polybrominated diphenyl ethers (PBDEs)) and adults (hexachlorobenzene [HCB]) (all $p < 0.05$). Baculum bone mineral densities decreased with increasing chlordanes, DDTs, and HCB in subadults and adults, respectively (all $p < 0.05$). In females, a significant inverse relationship was found between ovary length and Sigma PCB ($p = 0.03$) and Sigma CHL ($p < 0.01$), respectively, and between ovary weight and T PBDE ($p < 0.01$) and uterine horn length and HCB ($p = 0.02$). The study suggests that there is an impact from xenoendocrine pollutants on the size of East Greenland polar bear genitalia. This may pose a risk to this polar bear subpopulation in the future because of reduced sperm and egg quality/quantity and uterus and penis size/robustness.

Sonne C, Leifsson PS, Dietz R, Born EW, Letcher RJ, Kirkegaard M, Muir DCG, Andersen LW, Riget FF, Hyldstrup L, 2005b. Enlarged clitoris in wild polar bears (*Ursus maritimus*) can be misdiagnosed as pseudohermaphroditism. *Science of the Total Environment* 337:45-58.

A 23-year-old female polar bear (*Ursus maritimus*) killed in an Inuit hunt in East Greenland on July 9, 1999 had a significantly enlarged clitoris resembling, in size, form and colour, those of previously reported 'pseudohennaphroditic' polar bears from Svalbard. It has been suggested that an enzyme defect (21-hydroxylase deficiency), androgen producing tumour or high exposure to organochlorines during the foetal stage or early development could be the reason for the supposed pseudohermaphroditism observed for Svalbard bears. Except for the enlarged clitoris, all dimensions of the external and internal reproductive organs of the present were similar to a reference group of 23 normal adult female polar bears from East Greenland collected in 1999-2002. The aberrant bear was a female genotype, and macroscopic examination of her internal reproductive organs indicated that she was reproductively functional. A histological examination of the clitoral enlargement in the present East Greenland specimen allows a first-time histological evaluation of the earlier macroscopic field diagnosis from Svalbard. This examination revealed intense chronic ulcerative and perivascular clitoriditis similar to "acral lick dermatitis" frequently seen in domestic dogs (i.e., we did not find any signs of pseudohermaphroditic hyperplasia of clitoral tissue due to androgenic or antiestrogenic endocrine disruption). The levels of organohalogenes and TEQ values were lower than concentration thresholds of toxicological risk. It is hence possible that the previously reported adult female polar bear pseudohermaphrodites from Svalbard are in fact misdiagnoses. Therefore, future studies examining pseudohermaphroditism in wildlife should consider that certain occurrences are natural events, e.g., enlarged clitoris in the present East Greenland polar bear. Furthermore, caution should be exercised in suggesting linkages of such inflammatory abnormalities with correlations to anthropogenic pollutant exposures. (C) 2004 Elsevier B.V. All rights reserved.

Sonne C, Riget FF, Dietz R, Kirkegaard M, Born EW, Letcher R, Muir DCG, 2005c. Trends in fluctuating asymmetry in East Greenland polar bears (*Ursus maritimus*) from 1892 to 2002 in relation to organohalogen pollution. *Science of the Total Environment* 341:81-96.

Fluctuating asymmetry (FA) was studied in skulls of 283 polar bears (*Ursus maritimus*) sampled in East Greenland from 1892 to 2002. Fourteen metric bilateral traits in skull and lower jaw were measured and compared between polar bears born until 1960 ($n=94$) and from 1961 ($n=189$). The period 1892-1960 was chosen to represent a period prior to appearance of organohalogenes (polychlorinatedbiphenyls [PCBs], dichlorodiphenyltrichloroethanes [DDTs], hexacyclohexanes [HCHs], chlordanes [CHLs], hexachlorobenzene [HCB], polybrominateddiphenylethers [PBDEs] and dieldrin) originating from long-range transport to East Greenland from southern latitudes. The period 1961-2002 represents the period when polar bears have been exposed to organohalogenes. During this latter period, the level of organochlorines is believed to have increased from 1960 to the late 1980s followed by a likely decrease from 1990 to 2002. Within this later period, other compounds such as, e.g., polybrominated flame retardants are believed to have increased throughout the period. Two different analysis showed, that the degree of fluctuating asymmetry did not differ statistically between the two periods in ten of thirteen traits (one trait excluded due to high measurement error). In fact, when significant differences were found in four of the traits, the fluctuating asymmetry was lower in skulls sampled after 1960. The degree of fluctuating asymmetry was higher in adults than in subadults for 6 of the 14 traits, whereas a higher degree of fluctuating asymmetry was found for only one trait in one of the analyses for subadults

relative to adults. Females had a higher degree of fluctuating asymmetry than males in one trait. A time trend analysis did find fluctuations over time for five traits but the relationship was weak as the trend appeared to occur by chance due to the high number of regressions analysed (n=42). A correlation analysis of FA versus the sum concentrations of various classes of organohalogens in adipose tissue from a subsample of 94 recently collected polar bears (1999-2002) did not show a trend either. Hence, the present study could not document a relationship between skull asymmetry in polar bears and periods with different exposure to organohalogens. These findings are possibly influenced by nutritional status, genetic factors, a subeffect exposure of organohalogens or confounded by other environmental factors (e.g. temperature) within the two investigated periods. © 2004 Elsevier B.V. All rights reserved.

Sormo EG, Salmer MP, Jenssen BM, Hop H, Baek K, Kovacs KM, Lydersen C, Falk-Petersen S, Gabrielsen GW, Lie E, Skaare JU, 2006. Biomagnification of polybrominated diphenyl ether and hexabromocyclododecane flame retardants in the polar bear food chain in Svalbard, Norway. *Environmental Toxicology and Chemistry* 25:2502-2511.

Concentrations of brominated flame retardants (BFRs), including polybrominated diphenylethers (PBDEs) and hexabromocyclododecane (HBCD), were investigated in an arctic marine food chain consisting of four invertebrate species: polar cod (*Boreogadus saida*), ringed seals (*Pusa hispida*), and polar bears (*Ursus maritimus*). The most abundant BFR, brominated diphenyl ether (BDE)-47, was found in detectable concentrations even in zooplankton, the lowest trophic level examined in this study. Most of the investigated BFRs biomagnified as function of trophic level in the food chain. A noticeable exception occurred at the highest trophic level, the polar bear, in which only BDE-153 was found to increase from its main prey, the ringed seal, indicating that polar bears appear to be able to metabolize and biodegrade most BFRs. In contrast, lower-brominated PBDEs, particularly BDE-47, showed clear signs of bioaccumulation in zooplankton, polar cod, and ringed seals. We suggest that this discrepancy in the fate of BFRs among the different species may be related to greater induction of oxidative detoxification activities in the polar bear. Absorption and debromination rates may be more important for bioaccumulation rates of BFRs in zooplankton, polar cod, and ringed seals. Lipid weight-based concentrations (LWCs) and whole body-based concentrations (WBCs) of BFRs were used to assess biomagnification factors (BMFs). Whole-body concentrations gave the most realistic BMFs, as BMFs derived from LWCs seem to be confounded by the large variability in lipid content of tissues from the investigated species. This study demonstrates that PBDEs and HBCD have reached measurable concentrations even in the lower trophic levels (invertebrates and fish) in the Arctic and biomagnifies in the polar bear food chain.

Tryland M, Brun E, Derocher AE, Arnemo JM, Kierulf P, Olberg RA, Wiig O, 2002. Plasma biochemical values from apparently healthy free-ranging polar bears from Svalbard. *Journal of Wildlife Diseases* 38:566-575.

To establish reference values for free-ranging polar bears (*Ursus maritimus*) at Svalbard, Norway, plasma samples from 15 females and 20 males were analyzed for 28 blood biochemistry parameters. Animals were chemically immobilized (Zoletil(R): tiletamine and zolazepam) on land at Barentsoya, Edgeoya, and the eastern coast of Spitsbergen in August 1998. All bears were apparently healthy, with ages ranging from 1-22 yr. Females had almost two times higher levels of lipase than males. Several parameters varied with age. Levels of alkaline phosphatase (ALP) and calcium (Ca) decreased with age, being significantly higher in young individuals (<6 yr) compared to middle-aged (6-13 yr) and older bears (>13 yr). Globulin was lower in animals <6 yr of age than in animals >13 yr of age, while the opposite was the case for albumin. Levels of ALP, Ca, and potassium decreased with age. We found no significant changes in total protein correlated to age, but total protein levels were higher in obese compared to lean individuals. Further, total protein levels were slightly lower and had greater variation compared to data from polar bears in captivity which may reflect food availability for the latter group. The mean ratio between urea and creatinine was 10.9 and indicated these bears were fasting. These data provide a baseline from which to compare biochemical parameters in captive and free-ranging polar bears and will be especially valuable for future studies of polar bears at Svalbard.

Tryland M, Derocher AE, Wiig O, Godfroid J, 2001. Brucella sp antibodies in polar bears from Svalbard and the Barents Sea. *Journal of Wildlife Diseases* 37:523-531.

A prevalence of 5.4% of anti-Brucella sp. antibodies was found in plasma samples from 297 polar bears (*Ursus maritimus*) from Svalbard and the Barents Sea. Plasma was tested by the classical brucellosis

tests Slow Agglutination of Wright (SAW), EDTA modified SAW and Rose Bengal test, as well as by an indirect Protein A ELISA. Only samples classified as positive in all tests were regarded as containing anti-Brucella sp. antibodies. A significant west to east increase in the proportion of bears with anti-Brucella sp. antibodies was found, with 3.6% (n = 253) at Svalbard (Spitsbergen, Nordaustlandet, Edgeoya, Barentsoya and Hopen), and 15.9% (n = 44) in the central Barents Sea. Anti-Brucella sp. antibodies were previously found in ringed seals (*Phoca hispida*) and harp seals (*Phoca groenlandica*) from the same geographical areas. The ringed seal is an important prey species for the Svalbard polar bear population, and may thus be a source of brucellosis for the bears. There are no indications of reproductive disorders caused by Brucella sp. or other infectious agents in our study polar bear population. Potential impacts of Brucella, sp. exposure on individuals or the population are unknown.

Urashima T, Nagata H, Nakamura T, Arai I, Saito T, Imazu K, Hayashi T, Derocher AE, Wiig O, 2003. Differences in oligosaccharide pattern of a sample of polar bear colostrum and mid-lactation milk. Comparative Biochemistry and Physiology B-Biochemistry & Molecular Biology 136:887-896.

Although the concentrations of carbohydrate in the colostrum and in the mid-lactation milk of polar bear (*Ursus maritimus*) were similar, the oligosaccharide patterns differed. The colostrum sample contained Neu5Ac(alpha2-3)Gal(beta1-4)Glc (3'-N-acetylneuraminylactose), GalNAc(alpha1-3)[Fuc(alpha1-2)]Gal(beta1-4)Glc (A-tetrasaccharide), Fuc(alpha1-2)Gal(beta1-4)Glc (2'-fucosyllactose) and Gal(beta1-4)Glc (lactose). The mid-lactation milk contained Gal(alpha1-3)[Fuc(alpha1-2)]Gal(beta1-4)[Fuc(alpha1-3)]Glc (B-pentasaccharide), GalNAc(alpha1-3)[Fuc(alpha1-2)]Gal(beta1-4)[Fuc(alpha1-3)]Glc (A-pentasaccharide), Gal(alpha1-3)[Fuc(alpha1-2)]Gal(beta1-4)Glc (B-tetrasaccharide), A-tetrasaccharide, Gal(alpha1-3)Gal(beta1-4)[Fuc(alpha1-3)]Glc (3-fucosylisoglobotriose), Gal(alpha1-3)Gal(beta1-4)Glc (isoglobotriose) and lactose. The dominant saccharides in the colostrum were 3'-N-Acetylneuraminylactose and lactose, whereas isoglobotriose was the dominant saccharide in the mid-lactation milk in which lactose was only a minor component. Isoglobotriose, which had previously been found to be a dominant saccharide in mature milk from the Ezo brown bear, the Japanese black bear and the polar bear, was not found in the polar bear colostrum. (C) 2003 Elsevier Science Inc. All rights reserved.

Verreault J, Muir DCG, Norstrom RJ, Stirling I, Fisk AT, Gabrielsen GW, Derocher AE, Evans TJ, Dietz R, Sonne C, Sandala GM, Gebbink W, Riget FF, Born EW, Taylor MK, Nagy J, Letcher RJ, 2005. Chlorinated hydrocarbon contaminants and metabolites in polar bears (*Ursus maritimus*) from Alaska, Canada, East Greenland, and Svalbard: 1996-2002. Science of the Total Environment 351:369-390.

A suite of chlorinated hydrocarbon contaminants (CHCs) including organochlorine pesticides (OCPs) and by-products, polychlorinated biphenyls (PCBs), and methyl sulfone (MeSO₂) PCB and p,p'-dichlorodiphenyldichloroethylene (p,p'-DDE) metabolites were determined in adipose tissue of 107 adult and sub-adult polar bears, almost exclusively females, sampled between 1996 and 2002 from populations spanning Arctic and Subarctic regions of Alaska, Canada, East Greenland, and Svalbard. The East Greenland and Svalbard populations of polar bears were distinguished by higher proportions of dichlorodiphenyldichloroethane (DDT)-related compounds, nonachlors, oxychlordane, and higher-chlorinated and persistent PCB congeners (hepta- to nona-chlorinated). Conversely, Alaska, the westernmost population of the North American Arctic, was characterized by higher proportions of relatively volatile compounds such as hexachlorocyclohexanes (HCHs) and pentachlorobenzene (PnCBz), lower-chlorinated PCB congeners (tri- to penta-chlorinated), and lower proportions of oxychlordane. Geometric mean (GM) with 95% confidence limits (CL) Sigma HCH concentrations were highest in Alaska male polar bear fat samples (GM 593; CL 363-909 ng g⁻¹ lipid weight), Sigma DDT concentration were highest in East Greenland female samples (GM 309; CL 249-490 ng g⁻¹ l.w.), and Sigma(42)PCB (GM 5972; CL 4637-9129 ng g⁻¹ l.w.) and IMeSO₂-PCB (GM 198; CL 162-279 ng g⁻¹ l.w.) concentrations were highest in female samples collected from Svalbard. The distribution of Sigma-chlordane-related compounds (Sigma CHL), Sigma CBz, mirex, and dieldrin was relatively uniform among the populations of polar bears investigated. The present 1996-2002 data of female polar bear fat samples was compared to spatial assessments of female polar bear fat samples collected between 1989 and 1993 from comparable populations. The two-point temporal comparisons showed a general decrease for age-adjusted mean concentrations of Sigma CHL, p,p'-DDE, 142PCB, Sigma MeSO₂-PCB and 3-MeSO₂-p,p'-DDE over a period of approximately 10 years. However, concentrations of dieldrin were comparatively unchanged. Comparisons of present 2001-2002 concentrations in fat of female polar bears from Western Hudson Bay showed great consistency with

temporal trends (1991-1999) previously reported for the same region, i.e. the apparent non-decreasing trend of Sigma CHL, beta-HCH, Sigma HCH and dieldrin, and the apparent declining trend for Sigma PCB. However, present concentrations of alpha-HCH and Sigma CBz were elevated, and Sigma DDT was notably lower in Western Hudson Bay samples compared to the last measurements in fat samples collected in 1999, which was not in accord with reported temporal trends for this region. As a result of their relatively high degree of contamination, East Greenland and Svalbard polar bears are at higher health risk of contaminant exposure among Arctic and Subarctic populations. In addition to continued biomonitoring, further research on health and population status is needed to evaluate the impact from chronic exposure of polar bear populations to CHCs and their metabolites. Crown Copyright (c) 2005 Published by Elsevier B.V. All rights reserved.

Wiig O, 1995. Distribution of polar bears (*Ursus maritimus*) in the Svalbard area. *Journal of Zoology* 237:515-529.

The distribution and movements of polar bears (*Ursus maritimus*) in the Svalbard area were studied, using mark and recapture and satellite radio-telemetry in the period 1988 to 1994. A total of 172 bears has been captured, mostly in the southern and south-eastern parts of Svalbard, and 36 females have been tracked by satellite for more than 330 days. Two bears out of 389 tagged in the period 1966 to 1993 have been reported from the Greenland catches, which have been about 100 per year in the same period. About 95% of tracking days and 89% distance covered were from the Norwegian part of the area, the rest were from Russian territory. Minimum polygon home-range estimates for 36 females, each tracked for more than 330 days, were 69468 +/- 79136 km². Twenty-five percent (9/36) of the females have moved eastwards into Russian territory. Only two of them (6%), one of them in two different years, have landed at Franz Josef Land and one at Novaja Zemlja. Information on seasonal fidelity based on the distance from first spring capture location to spring locations in consecutive years exists for 38 female and four male bears. For 30 females, the average distance after one year was 149.3 +/- 143.2 km from the first tagging site. After two years the average distance was 78.9 +/- 82.5 km for 15 females. After three years the distance was 51.1 +/- 29.5 km for nine females and after four years 32.0 +/- 31.9 km for four. The regression slope between distances and time is negative. The denning locations of 25 of the females were recorded based on satellite data. Twenty-four of these were at Svalbard and one (4%) at Franz Josef Land. Satellite data combined with mark recapture data show that the polar bears have a very high degree of seasonal fidelity to Svalbard. This suggests that the migration of polar bears between Svalbard and Greenland and between Svalbard and Russia is relatively low and that the Svalbard population of polar bears can be managed as a local population.

Wiig O, Born EW, Pedersen LT, 2003. Movements of female polar bears (*Ursus maritimus*) in the East Greenland pack ice. *Polar Biology* 26:509-516.

The movements of two adult female polar bears (*Ursus maritimus*) in East Greenland and the Greenland Sea area were studied by use of satellite telemetry between the fall of 1994 and the summer of 1998. One female was tracked for 621 days, the other for 1,415 days. During this time the females used maternity dens on land. If denning periods on land were excluded, the two females used between 73% and 100% of the tracking time offshore where they were able to navigate in the dynamic pack ice and counteract the fast southward movement of the ice (up to 30 km/h) in the East Greenland Current. Mean monthly movement rates varied between 0.32 and 0.76 km/h. Both bears had very large home ranges (242,000 and 468,000 km²) within the dynamic pack ice of the Greenland Sea. The facts that the bears made extensive use of the offshore sea ice and that there is a marked reduction of the Greenland Sea ice call for a closer monitoring of the effects of this change on the East Greenland polar bear population.

Wiig O, Derocher AE, 2001. Body composition of three polar bear (*Ursus maritimus*) cubs found dead at Svalbard. *Polar Biology* 24:383-385.

We determined the body composition from the carcasses of three 3- to 4-months-old polar bear cubs found dead at Svalbard, Norway. Two of the cubs were killed by a male bear at the den and one cub died from starvation. These three carcasses weighed 70-77% of total body mass of cubs. The ash and protein content of the three carcasses were similar but the starving cub had higher water content and lower fat content than the two killed cubs. The fat content varied from 1.3% (starving cub) to 12.9% while the content of water and fat was similar (about 76%) in the three cubs. More data on the body

composition of polar bear cubs at time of emergence from the den are needed to understand the breeding ecology and reproductive energetics of female polar bears.

Wiig O, Derocher AE, Cronin NM, Skaare JU, 1998. Female pseudohermaphrodite polar bears at Svalbard. *Journal of Wildlife Diseases* 34:792-796.

During research on polar bears (*Ursus maritimus*) at Svalbard in April 1996, we captured two yearlings with a normal vaginal opening and a 20 mm penis containing a baculum. The penis was located caudal to the location in a normal male and was concealed within the vaginal opening by a single pair of labia. The urethral opening was situated laterally about 5 mm from the distal end of the penis. Neither of the yearlings showed signs of a Y chromosome, so both bears were regarded as female pseudohermaphrodites. On separate occasions in two bears, we recorded aberrant genitalia morphology with a high degree of clitoral hypertrophy in Svalbard, which we also classified as female pseudohermaphroditism. The observed rate of female pseudohermaphroditism in this area was 1.5% (4/269). Pseudohermaphroditism in this polar bear population could result from excessive androgen excretion by the mother caused by a tumor, or it could be a result of endocrine disruption from environmental pollutants.

Wiig O, Renzoni A, Gjertz I, 1999. Levels of cadmium and mercury in the hair of Atlantic walruses (*Odobenus rosmarus rosmarus*) from Svalbard, Norway. *Polar Biology* 21:343-346.

Hair samples of 15 adult male Atlantic walruses (*Odobenus rosmarus rosmarus*) collected from anaesthetized individuals at Svalbard, Norway, were analysed for cadmium and total mercury. The mean level of cadmium was 0.860 +/- 0.321 mu g/g dry weight (median = 0.811, range = 0.349-1.51 mu g/g dry weight) and the mean level of mercury was 0.235 +/- 0.100 mu g/g dry weight (median = 0.251, range = 0.121-0.424 mu g/g dry weight). Levels of cadmium and mercury in hair of walruses from other areas are not known. Both cadmium and mercury levels in hair of walruses from Svalbard are relatively low compared to the levels found in the hair of other marine mammal species. It has been documented from a number of marine species, including marine mammals such as ringed seals and polar bears, that both cadmium and mercury levels at Svalbard are lower than in other areas. It is uncertain as to what degree levels in hair reflect levels in internal organs in walruses. In rare and highly endangered species or populations tissue samples can be difficult to collect. In walruses, it is possible to collect hair from anaesthetized individuals or at the haul-out sites during moult, to monitor heavy metal levels of the population.