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BearHealth: Polar bear *(Ursus maritimus)* circumpolar health assessment in relation to toxicants and climate changing.

Responsible applicant: Professor Bjørn Munro Jenssen, Department of Biology, Norwegian University of Science and Technology, NO-7490 Trondheim, Norway.

Main aim:
Identify region specific health effects (biomarker responses) of persistent organic pollutants (POPs) and climate change in polar bears.

Subgoals:
-Identify interacting effects between exposure to POPs and climate variables on hormones and vitamins.
-Population specific effects on bone density and structure.
-Sampling of polar bears at Svalbard and in the Barents Sea.
-Compile data in a circumpolar context in co-operation with other international BearHealth partners.

National partners:
Bjørn Munro Jenssen, Department of Biology, Norwegian University of Science and Technology (NTNU), Trondheim.
Jon Aars, Geir Wing Gabrielsen, and Hans Wolkers, Norwegian Polar Institute (NP), Tromsø
Øystein Wiig, Natural History Museum, University of Oslo (UiO).
Elisabeth Lie and Janneche Utne Skaare, Norwegian School of Veterinary Sciences (NVH) and National Veterinary Institute (NVI), Oslo.

International Partners
Christian Sonne (co-ordinator of the international BearHealth IPY project) and Rune Dietz, National Environmental Research Instiute (NERI), Roskilde, Denmark.
Stanislav Belikov and Andrei Boltunov, Ministry of Environmental Protection and Natural Resources, All-Russian Research Institute for Nature Protection, 113628 Moscow, Russia.
For other international partners in BearHealth who will contribute with samples, see list of partners in the attached full proposal description of the international BearHealth project.

Summary
Anthropogenic pollution and climate change are the two most significant threats for Arctic biodiversity and ecosystem functioning. Because of food chain biomagnification of lipophilic persistent organic pollutants (POPs), the polar bear is one of the species which have the highest levels of these harmful chemicals. Since POPs may have effects on hormone regulation and physiological homeostasis, reproduction and survival, POPs may adversely affect the plasticity of responses that polar bears have to environmental changes. Thus, in combination these two major anthropogenic factors may have a significant effect on Arctic ecosystem functions. The International Polar Year (IPY) project "BearHealth" aims at studying adverse health effects of POPs in polar bears, and the interacting effects of POPs and climate change on polar bears. In the circumpolar international project, several biomarker endpoints, such as immune, hormonal, vitamin, bone, and histological variables will be examined in relation to exposure to POPs and other emerging novel environmental pollutants. Analyses of chemicals and biomarkers will be conducted on archived material from biobanks, and on samples which will be sampled during the project period. In the Norwegian part of the project we will focus on health effects of POPs related to thyroid and reproductive hormone homeostasis and on vitamin A, E and D status, and on interactions between biomarkers, environmental pollutants and climate change variables, and on including new samples from polar bears from Svalbard and Barents Sea region. Efforts will also be made to obtain samples from the Russian Arctic. In cooperation with Danish researchers (which are the coordinators of the international BearHealth project), a study on POP related effects on bone density and structure will be performed on a large collection of polar bears skulls from the Norwegian Arctic and Greenland, and Russia if possible. The results from the Norwegian study will be integrated with the studies conducted by the other participating countries, and the project will end up in an integrated health risk assessment of the interactive effects of POPs and climate change in polar bears

Background
In spite of that levels of anthropogenic pollutants are much lower in Arctic environments than in temperate and industrialised environments, very high levels of some lipophilic anthropogenic pollutants (persistent organic pollutants: POPs) are found in Arctic endothermic top predators, and in particular in polar bears (Ursus maritimus).

Global atmospheric and oceanic pathways and processes result in the deposition of semi-volatile organic contaminants in the Arctic. Because POPs are lipophilic, and because lipids constitute an important energetic factor in polar marine food chains, POPs are biomagnified in the long Arctic marine food chain. Due to this, POP levels become very high in polar bears in spite of their relatively good ability to biotransform lipophilic compounds in enzymatic processes and thus excrete these compounds

.With the ratification of the Stockholm POPs protocol (www.pops.int), which regulates the production, use and release of the POPs that are of most environmental conc ern, the Arctic has become a strategic location to monitor global contaminants. Because levels of POPs are particularly high in the polar bear, and because tissue samples of polar bears are readily available in a circumpolar context due to indigenous hunting and research live captures, polar bears are ideal biomonitors of spatial and temporal trends in distribution, dynamics, fate, biomagnification and potential effects of legacy of existing POPs. Because of food chain transfer and bioaccumulation, polar bears are in addition excellent bioindicators when identifying the presence of emerging organic contaminants of anthropogenic origin in the Arctic environment.

During the recent years, several reports have compiled temporal and spatial data on levels of "classic" organochlorinated compounds (OCs) in polar bears. The highest levels of POPs such as oxychlordane, transnonachlor and p,p'-DDE were found in bears from Franz Josef Land and Kara Sea in the Russian Arctic. Polar bears from the Western Russian Arctic are exposed to higher levels of chlordanes and p,p′-DDE than polar bears from locations westwards and eastwards from this region (Lie et al. 2003). Bears from the Western Russian Arctic (Franz Josef Land and Kara Sea) also had highest polychlorinated biphenyls (PCBs) levels compared to Svalbard, East Siberian and Chukchi Sea (Andersen et al. 2001; see also Verrault et al. 2005a; Braune et al. 2005). Whereas levels of PCBs seem to decrease (Henriksen et al. 2001; Verrault et al. 2005a), a number of emerging environmental pollutants, such as polybrominated diphenylethers (PBDE), perfluorooctane sulfonate acids (PFOS) have been reported in polar bears (Muir et al. 2006; Verrault et al. 2005b; Smithwick et al. 2005, Sørmo et al. 2006) and are expected to increase to high levels. There is urgent need for updated data on circumpolar spatial and temporal distribution of previously investigated and new and emerging environmental pollutants in polar bears. Because of the high capacity of polar bears to biotransform lipophilic compounds, polar bears also have high levels of metabolites of POPs (Sandala et al. 2004; Verrault et al. 2005a). Paradoxically these water soluble metabolites are often more toxic than their mother compounds, and may thus have toxic effects, particularly on the thyroid hormone system and on toxic processes induced via oxidative stress (Brouwer et al. 1998). There is a lack of information on to which extent these metabolites contribute to the adverse health effects of POPs in wildlife.

The ultimate reason for regulating production, use and release of POPs are that these compounds impose a health hazard to humans and wildlife if concentrations reach critical levels. In the Arctic there is especial concern about the high levels reported in indigenous people who consume blubber of marine mammals, and in endothermic top predators such as polar bears, glaucous gulls (Laurus glaucescence), ivory gulls (Phagophila eburnean), white whales (Delphinapterus leucas), narwhals (Monodon monoceros) (AMAP 2004). In humans, high levels of POPs, such as dioxins, (PCBs and organochlorine pesticides (OCPs) are associated with reduced birth weights, thyroid hormone imbalance and adverse effects on learning, cognitive and motor abilities (Zoeller 2005). In wildlife, many of the same effects are reported, as well as effects on reproductive hormones, reproduction per se, and probably also on survival (Jenssen 2006). Thus, the concerns that populations and ecosystem functioning may be severely affected by anthropogenic pollution is scientifically based. In polar bears, levels of POPs are reported to correlate to a number of ecologically relevant biomarker endpoints such as bone density and pathology, histology of immunological organs, renal lesions, liver morphology, immune function, thyroid hormones, reproductive hormones and vitamin A status (Sonne et al. 2004; 2005a; 2006; Kirkegaard et al. 2005; Haave et al. 2003; Braathen et al. 2004; Lie et al. 2004; 2005; Oskam et al. 2003; Skaare et al. 2001)

Polar bears are also threatened by habitat loss due to climate warming and the resultant ice melting (Wiig 2005). At the meeting of the IUCN Polar Bear Specialist Group in Seattle in June 2005, it was agreed that the polar bear should be listed as vulnerable in the IUCN Red List of Threatened animals due to a future assumed habitat loss from global warming (www.pbsg.npolar.no). Studies have documented relationships between the spatial behavior of polar bears and levels of POPs (Olsen et al. 2003). Throughout evolutionary history, present Arctic animals have survived multiple warm climatic periods, and probably have a functional plasticity to tackling large environmental variations. However, since the adaptations are based on adequate physiological and behavioral responses, it is likely that environmental pollutants with adverse physiological (endocrine) or neurological effects will interfere with the ability of Arctic animals to adapt to changing environmental changes. Because of the high levels of POPs and their metabolites, there is serious concern about the combined impact of exposure to anthropogenic pollutants and climate change on populations of polar bears (Jenssen 2006).

In the present project, which is approved as an IPY project (#134) (http://www.ipy.org/development/eoi/proposaldetails.

php?id=134), the aim is to examine region specific effect parameters (biomarker responses; histology on internal organs, bone morphology, hormones, vitamins) from necropsy samples of polar bears taken by local Inuit hunters. Furthermore, in on-going live capture studies such as telemetry studies, clitoris biopsies and rectal, vaginal and tracheal swabs and blood samples for bacteriology/virology, cytology and parasitology, vitamin and hormone profiles will be examined. Analyses of POPs have been conducted in a large number of the already sampled polar bears, and analyses will be conducted in polar bears which are sampled during the project period. These analyseswill be conducted in Canada and Norway. Fatty acid profiles and stable isotopes will be determined to assess regionspecific similarities and differences in polar bear diets linked to habitat climate factors - such as ice extent - from climate changes. This will make it possible to elucidate the combined confounding effects of two of the greatest anthropogenic threats to polar bear populations, and to focus on these effects in relation to temporal and in particular spatial trends.

The BearHealth project will be facilitated through the IUCN PBSG (Polar Bear Specialist Group) lead by Denmark as given in the resolutions from the last IUCN PBSG meeting in Seattle, June 2005 (www.pbsg.npolar.no).

Norwegian project

In the Norwegian part of BearHealth, we apply for funding for the Norwegian participation in the project. We apply for funding of one PhD student, analysis of biomarker variables and pollutants performed in Norwegian laboratories, and for collecting new samples of live captured polar bears in the Norwegian Arctic (Svalbard and the Barents Sea). Efforts will also be made to obtain samples from the Russian Arctic. By 2007 it will be almost a decade since the last semi-circumpolar assessment of the spatial and temporal distribution of legacy and emerging POPs, and their metabolic by-products, was conducted in polar bears. The last truly circumpolar assessment, including bears from the Russian Arctic, will have been at least 15 years past. Emerging contaminants such as PBDEs and other brominated flame retardant compounds (BFRs) and perfluorinated compounds (PFCs), have yet also to be determined in polar bears from the Russian Arctic.

Of the endocrine systems that have been shown to be affected by POPs in humans and wildlife, there is particular concern about the effects on thyroid hormones and the associated effects on vitamin A and possibly vitamin E, effects on reproductive hormones and effects on bone metabolism. Disruption of thyroid hormone function may affect the neurodevelopment, and thus affect behaviour and cognitive abilities of humans and wildlife (Jenssen 2003). BFRs, such as PBDEs, hexabromocyclododecane (HBCD) and tetrabromobisphenol A (TBBPA) and PFCs, such as PFOS also have thyroid disruptive effects (Hamers 2004; Lau et al. 2003; Legler 2003). Because of the severe effects on neurodevelopment, behaviour, cognitive and learning abilities and motor coordination, the thyroid disruptive effects are among the most worrying effects of POPs and PFCs in both humans and wildlife.
Thyroid hormone disruptive effects of POPs are often associated with disruption of the retinoid (vitamin A) status of the animals (Brouwer et al. 1998). Retinoids are important for the normal development of neonates, and for the immune system (Brouwer et al.1998). Indeed, in polar bears from the Norwegian Arctic, plasma levels of vitamin A correlates to POP levels (Skaare et al. 2001).

Vitamin E constitutes part of an organisms protection against anti-oxidants. In several studies on mammals and seabirds, vitamin E has been applied as a biomarker to assess oxidative stress caused by POPs (Nyman et al. 2003; Murvoll et al. 2006a;b). Vitamin E can be measured alongside with vitamin A, and in the present study both vitamin A and E will be applied as biomarkers for studying possible health related effects of POPs on polar bears.
Several POPs have been demonstrated to affect bone structure and bone density, most likely via vitamin D regulated processes. In polar bears correlations between bone density and levels of POPs have been identified (Sonne et al. 2004). Adverse effects of POPs on bone density may have adverse effects on the health of polar bears, and may be a significant factor in the possible effects of POPs on population dynamics of polar bears. Thus, a study of bone structure and density and vitamin D status in polar bears from several populations will provide valuable insight into the effects of POPs relative to possible genetically inter-population confounding effects.

The combined effects of POPs and climate variables on thyroid hormones in Polar bears from the Norwegian Arctic is exemplified by the preliminary analysis of currently available data (Jenssen 2005; Fig. 1). Principal component analysis showed that there were strong intercorrelations between levels of PCBs, capture location (latitude and longitude), home range area, and thyroid hormone levels in the polar bears. Table 1 show that there were significant relationships between PCB levels and total thyroxin (tt4). However, tt4 was also affected by capture latitude. Free thyroxin (ft4) and total triiodothyronine (tt3) was also affected by capture latitude, whereas both tt3 and free triiodothyronine (ft3) was correlated to home range size. Since climate varies significantly as a function of latitude (and longitude), it can be hypothesized that hormone status is not only affected by exposure to pollutants, but that climate variables (here: geographical position) also may have significant effects on thyroid hormone levels. This implies that there may be strong confounding effects of PCBs, climate and behavioral variables (home range) on

hormone status. In the present study we aim to study these confounding effects in more detail, and also to include more biological and climatic variables into the statistical models. This part of the study will give new knowledge into the interacting effects of these two anthropogenic factors on polar bear health.

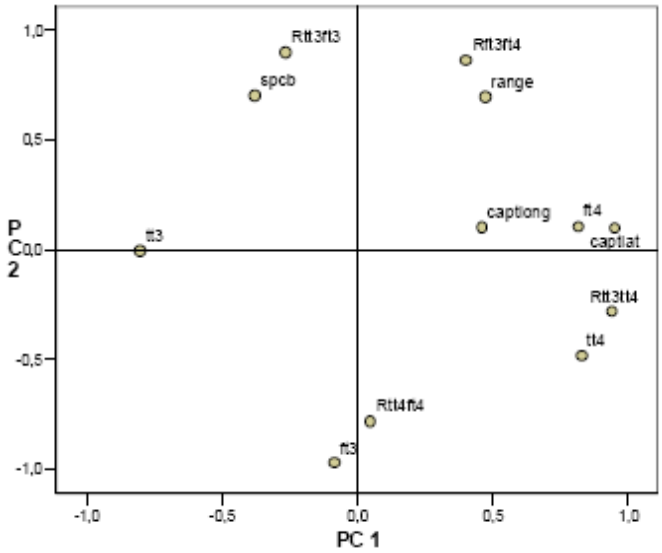

Fig 1: Principal component analyses showing relationships between levels of PCBs, thyroid hormones (tt4, tt4, ft4, ft3), home range and capture longitude and latitude in polar bears from the Norwegian Arctic. sPCB: sum PCBs, range: annual home range area, captlong: capture longitude, captlatt: capture latitude, tt4: total thyroxin, ft4: free thyroxin, tt3: total triodithyronine, ft3: free triiodothyronine, Rtt4ft4: tt4/ft4-ratio, Rtt3ft3: tt3/ft3-ratio, Rtt3tt4: tt3/tt4-ratio, Rft3ft4: ft3/ft4-ratio.

		spcb	tt4	ft4	tt3	ft3	Rtt4ft4	Rtt3ft3	Rtt3tt4	Rft3ft4	range	captlat
tt4	r	-,749										
	P	**,026**										
ft4	r	-,344	,703									
	P	,225	**,039**									
tt3	r	,178	-,616	-,345								
	P	,351	,070	,225								
ft3	r	-,588	,384	-,113	,153							
	P	,083	,198	,405	,371							
Rtt4ft4	r	-,499	,376	-,383	-,371	,677						
	P	,127	,203	,198	,206	**,047**						
Rtt3ft3	r	,585	-,587	-,124	,207	-,894	-,660					
	P	,084	,083	,396	,328	**,003**	**,053**					
Rtt3tt4	r	-,551	,944	,712	-,821	,163	,390	-,477				
	P	,100	**,001**	**,036**	**,012**	,364	,250	,140				
Rft3ft4	r	,305	-,012	,498	,259	-,900	-,700	,762	,154			
	P	,253	,490	,128	,287	**,003**	**,040**	**,023**	,371			
range	r	,441	**,025**	,188	-,658	-,757	-,204	,537	,297	,744		
	P	,161	,479	,343	**,054**	**,024**	,330	,107	,259	**,028**		
captlat	r	-,212	,668	,772	-,732	-,142	-,059	-,222	,817	,412	,510	
	P	,324	**,050**	**,021**	**,031**	,380	,450	,316	**,012**	,179	,121	
captlong	r	,108	,137	,476	-,162	**,016**	-,297	-,244	,251	,118	,119	,690
	P	,409	,385	,140	,365	,486	,259	,299	,294	,400	,400	**,043**

Table 2. Correlation matrix on relationships between levels of PCBs, thyroid hormones, home range and capture longitude and latitude in polar bears from the Norwegian Arctic. sPCB: sum PCBs, range: annual home range area, captlong: capture longitude, captlatt: capture latitude, tt4: total thyroxin, ft4: free thyroxin, tt3: total triodithyronine, ft3: free triiodothyronine, Rtt4ft4: tt4/ft4-ratio, Rtt3ft3: tt3/ft3-ratio, Rtt3tt4: tt3/tt4-ratio, Rft3ft4: ft3/ft4-ratio.

The Norwegian part of BearHealth consists of five work packages (WP1-5).

WP1 will focus on relationships between levels of POPs and their metabolites on hormones (thyroid and reproductive hormones) and vitamins (vitamin A, E and D), and also on the interacting effects of climatic and behavioural parameters on these biomarkers. This part of the study is based on a unique archived material from East-Greenland (ca. 150 polar bears), on which a large number of POPs, metabolites and other biomarker variables have been studied. We are presently developing and validating methodology for analysing hormone and vitamin levels in

this material (four MSc projects in Environmental Toxicology at NTNU). If possible, archived material from Canadian and Alaskan partners will also be analysed. Samples taken during the project period from polar bears at Svalbard, that belongs to the Barents Sea population and sheared between Norwegian and Russian Arctic will also be analysed. By use of satellite telemetry data, we will be able to group some of these bears into local Norwegian bears and bears that use a significant part of the time in the Russian Arctic. By including all biomarker and chemical, and capture sites and dates, as well as climatic data, in a statistical meta-analysis using multiple statistical computing we will be able to study interacting effects of the anthropogenic factors of environmental pollution and climate change on the health of polar bears.

The present project will generate a large dataset with concentrations of a very wide range of POPs and measurements of several biomarker variables. An ongoing project financed by the Norwegian Research Council (project no.: 166470/V10), post doctoral research fellow Elisabeth Lie and project leader Janneche Utne Skaare, NVH/VI) are currently using an exixting dataset to validate, improve and integrate various already developed methodologies and approaches with the aim to establish models as valuable tools for exposure monitoring and risk assessment of POPs. These variables will be utilized in the present study to investigate possible significant explanatory variables for exposure, bioaccumulation, biotransformation, and effects of POPs.

In **WP 2** we will obtain new samples from polar bears from the Norwegian Arctic in the western Barents Sea, and if possible from the western Russian Arctic. This activity will be co-ordinated by the Norwegian Polar Institute and conducted as part of their ecological research projects on polar bears in the Norwegian Arctic. The available funding does not allow a research expedition into Russian waters due to the large costs of equipping and conducting such an expedition. However, funding is set aside for co-operation with the Russian partners so that possible sampling can be made. Efforts to obtain additional funding for the conducting a research expedition into the Russian Arctic will be continued. Blood and fat biopsy samples will be collected from live-captured animals, and levels of contaminants and biomarkers will be analysed. In addition, samples related to immune function will be taken, and the animals will be subjected to veterinary examinations by the Danish partners. In this material, a range of ecological data will also be available, and for some of the animals data on spatial movements (migration and home range) will be available through the use of satellite transmitters. Thus, this material will allow statistical meta-analysis of relationships between POPs, climate variables, ecological variables, disease related variables, and biomarkers, and will thus give novel knowledge about the interacting effects of anthropogenic factors on polar bear health.

In **WP 3** chemical analyses will be conducted on the material from the Norwegian Arctic, Barents Sea and Russia sampled during the project period. These analyses will be performed at the Laboratory of Environmental Toxicology at the Norwegian School of Veterinary Sciences and the Norwegian Veterinary Institute. A number of POPs and their metabolites will be analysed, and will constitute the basis of the exposure identification part of the Norwegian field study.

WP 4 will focus on effects of POPs on reproductive organs (histology) and bone density and pathology of polar bear skulls. The University of Oslo will provide a large collection of polar bears skulls for examination of bone density and structure for the Danish National Environmental Research Institute (NERI). This material will comprise the basis of a study on temporal trends in osteological variables related to temporal variations in POP exposure and spatio-climatic variables. The Danish participants also plan to incorporate material from Greenland, Russia, Canada and Alaska to conduct a circumpolar assessment of bone density in polar bears. Since vitamin D is an important factor in determining bone density and structure, examination of relationships between vitamin D and bone structure will be examined in archived parallel samples of bone material, blood and tissue from East-Greenland polar bears.

Identification of such relationships will allow indirect assessment of bone metabolism by analysis of vitamin D levels in plasma of the live captured polar bears in the Norwegian study. Analysis of vitamin D will be performed at the Norwegian University of Science and Technology.

In **WP 5**, the results from all the studies performed by the partners in the international BearHealth project will be compiled. This part of the project is planned to take place as annual workshops. The Norwegian part of BearHealth will take responsibility of arranging one of the workshops. This workshop will take place at Ny-Ålesund, Svalbard (or at the University Centre at Svalbard, UNIS if the number of participants exceed 25), and will focus on interacting effects of POPs and climate change on polar bear health and populations. In addition to the involved scientists, PhD and MSc students, this meeting will also be open for other scientists in related fields, non-governmental organisations and for governmental institutions. The Workshop will provide a unique opportunity for students to meet experienced scientists and establish a network for their future research activities.

This workshop will provide a basis for understanding the interacting effects of multiple anthropogenic factors on polar bear health and populations, and will be an important part of the final compilation of the BearHealth project.

Methods

WP1 – Hormones and vitamins.
Work package leader: Professor Bjørn Munro Jenssen, Department of Biology, Norwegian University of Science and Technology.

Analysis of plasma levels of thyroid hormone (total and free T4 and T3), reproductive hormones (estradiol and testosterone) and vitamin D will be analysed using radioimmunoassay. Plasma and tissue (liver and blubber) levels of vitamins (vitamin A [retinol, retinol esters], vitamin E [tocopherol] will be performed using high precision liquid chromatography (HPLC). Professor Jenssen has extensive experience from research of organochlorines and BFRs on plasma levels hormone and vitamins in blood and tissues in a range of wildlife species, including polar bears (see Jenssen's CV). Methods (radioimmunoassay and ELISA techniques) are established at the Environmental toxicology lab at NTNU for such analyses (see publications in Jenssen's CV).

Associations between exposure variables, hormones and vitamins and spatio-climatic variables will be studied using appropriate statistical methods (multiple statistical models). The researchers involved have experience in applying such statistical techniques (see Skaare's, Lie's, and Jenssen's attached CVs).

WP 2 – Sampling of polar bears in the Norwegian Arctic
Work package leader: Dr. Jon Aars, Norwegian Polar Institute.

As part of their obligations, the Norwegian Polar Institute are responsible for the research and management of polar bears in the Norwegian Arctic. These bears belong to the Barents Sea subpopulation that is sheared with Russia. In their research NP regularly conduct field studies involving live capture of polar bears, and sampling of data from bears fitted with satellite transmitters. When capturing bears, blood and biopsy samples will be taken routinely for analyses of POPs and biomarkers. Furthermore, other available data on the individual polar bears will be made available, as will data linked to spatial distribution and movement data obtained from satellite tracking of animals. In co-operation with the Danish Institute of Environmental Research and the University of Oslo, live-captured animals will undergo veterinarian examination. Dr. Aars and professor Wiig has long experience in live capture of polar bears through a range of previous projects headed by the Norwegian Polar Institute. The field sampling will involve annual research expeditions using R/V Lance and a helicopter, and the present study will provide financial support for obtaining samples and examination of the animals.

WP 3 – Analysis of POPs in polar bears in the Norwegian Arctic, Barents Sea and Riussia
Work package leaders: dr. Elisabeth Lie and professor Janneche Utne Skaare, Norwegian School of Veterinary Sciences (NVH) and National Veterinary Institute (NVI)

The following organohalogenated compounds will be quantified in blood samples of polar bears from the Norwegian Arctic, Barents Sea and Russia; PCBs, PBDEs, TBBPA, HBCDs (α-, β-, and γ- isomers), pentachlorophenol (PCP) and OCPs (DDTs, HCHs, HCB, toxaphenes, chlordanes). In addition, metabolites of these compounds, such as hydroxylated-PCBs (OH-PCBs) and PBDEs (OH-PBDEs) will be analysed. All analyses will be conducted using appropriate chromatographic methods established for the particular compounds, and an interlaboratory comparison with BearHealth participating laboratories in Canada will be carried out.

The Laboratory of Environmental Toxicology at NVH/NVI has a long record in analyses of PCBs, OCPs, BFRs, and is accredited according to Norwegian and international requirements (NS-EN ISO/IEC, 17025:2000, www.iso.org) for analyses of these compounds. In addition, in the FIRE project the lab at NVI/NVH has established high quality analytical procedures for TBBPA, and HBCD isomers, which have been tested in interlaboratory ring tests. The lab has during several decades been involved in research within toxicology and environmental toxicology in Norway, the Arctic and in some developing countries. Focus has particularly been on occurrence, levels and effects of low level exposure to environmental contaminants (see Lie's and Skaare's attached CV).

WP 4 – Bone density and structure in polar bear skulls
Work package leader: Professor Øystein Wiig, Natural History Museum, University of Oslo.

A collection of ca 300 polar bear skulls from the Norwegian Arctic will be made available for partners at the Danish Environmental Research Institute. Bone density in the skulls as well as pathology will be investigated using established methods (Sonne et al. 2004; Sonne et al. 2005b). Dr. Sonne has experience in the methodology used, and relevant biological data on the animals will be provided by professor Wiig. In cooperation with dr. Belikov, samples of polar bears from Russia are also planned to be included in the study. About 500 skulls are available from museums in Moscow and St. Petersburg. Samples of reproductive organs from the Norwegian Arctic will be made available from the University of Oslo (Wiig) for analyses in Denmark.

WP 5 – Compilation of results and Workshop on interacting effects of POPs and climate change on polar bears
Work package leader: Professor Bjørn Munro Jenssen, Department of Biology, Norwegian University of Science and Technology.

Workshops will be held during the project period, and the Norwegian project will be responsible for a workshop on interacting effects of POPs and climate change on polar bears. This workshop will be held at Ny-Ålesund, or at the University Centre at Svalbard (UNIS) if the number of participants exceeds 25. To encourage the participation of young PhD and MSc students we wish to cover a large proportion of their costs via the project.

The work will be organised by all Norwegian partners.

Educational aspect: PhD fellow, Marie Curie PhD fellows and MSc students

The PhD fellow will do her/his PhD study at the Department of Biology at NTNU, and professor Bjørn Munro Jenssen will serve as the formal supervisor. The position will announced to obtain the best qualified applicant. Other participating scientists will also be assisting as supervisors. The main task of the PhD student will be to perform and analyse hormone (at NTNU) and POP analyses (at NVH), and to analyse the results statistically to study interacting effects of POPs and climate change on health variables of polar bears. The policy of the Department of Biology is to finance a fourth year for the PhD student.

Master students will be linked to this project through the Master program in "Environmental Toxicology and Chemistry" at NTNU, and we will encourage cooperation and visits to the other participating partners. Currently 14 students are enrolled in this program, and annually 10 students are enrolled into the program. As part of the program

a 7.5 ECTS course in multiple statistical analyses for studying effects of complex chemical mixtures is given by professor Ingvar Eide, NTNU/STATOIL (BI 3074, Complex mixtures), and this will give the PhD student and the MSc students the statistical background for studying interactions of POPs and climate variables on hormones and vitamins in polar bears.

One PhD position (up to 6 months) at the Marie Curie Training Site ENDOCLIMA (Interacting Effects of Climate Change and Endocrine Disruption) at NTNU (Project co-ordinator professor Bjørn Munro Jenssen) will be linked to the project. This position has been filled by a PhD student (Maja Kirkegaard) from our Danish partners, who is focusimg on relationships between POPs and vitamins/hormones in a closely related project on sledgedogs..
The project will provide a unique opportunity for exchange of students between the participating institutions.
The planned workshop will also provide a valuable opportunity for PhD and MSc students from the participating partners and nations to get an updated view on emerging anthropogenic threats to the Arctic environment and to establish a network for their future research activities.

Ethical aspects
The study involves of tissues sampled from polar bears hunted legally by local Inuit hunters in East Greenland. The sampling has been approved by Greenland and Danish authorities. With respect to sampling of live-captured animals, procedures are submitted to approval by national committees on animal research. Based on the competence of the involved research institutions, such permissions have been given previously. With respect to samples from Russia, archived material and/or samples from indigenous hunting or governmental confiscations is planned to be included utilized.

Data policy
The project will follow the general IPY data policy.

Research group

The research group integrates unique competence and experience within ecotoxicology, environmental toxicology and chemistry, risk assessment, as well as within field and lab based research. The design of the research group also secure national and international collaboration with exchange of competence and personnel (see attached CVs). The activities by the different participating nations will be co-ordinated by the project coordinator, Dr. Christian Sonne at NERI, Denmark. Most of the participants have joined in earlier international coordinated Arctic programmes focusing on pollution in Arctic animals.

The project will use a common protocol for sample collection (timing, tissue type, preservation) and analysis. Chemical analysis would be done in 4-5 Canadian, Danish, Alaskan, Norwegian labs (few specialised analyses might be done by a single specialized lab) while the pathological/micro pathogen analyses will be done at different national labs (not in Norway). Vitamin and hormone analyses will be performed in Norway (NTNU), and studies of bone density and structure will be conducted by the Danish partners (NERI) in close co-operation with Norway (University of Oslo). Tissues would be archived for future chemical analyses.

Competence of the main applicant with respect to project management and student supervision:
Professor Jenssen was the Head of the Department of Zoology at NTNU during the period 1996-2002. In a national
evaluation of biosciences in Norway conducted by the Norwegian Research Council in 2000, the international scientific committee stated that "The ability of the leaders and staff (at the Department of Zoology) is excellent". Jenssen has a high competence experience in co-ordinating research projects, both from own projects and as his former role as Department head. He is now co-ordinating the ENDOCLIMA Marie Curie Training Site at NTNU,
and has an extensive national and international co-operation, as a partner in 2 EU projects (BEEP and FIRE), and participant in an EU cluster network on endocrine disrupters (CREDO), and in projects funded by the Norwegian Research Council.
Jenssen has published ca. 60 scientific papers, has/is supervising three post.doc. fellows, has supervised 4 graduated
PhDs and 35 graduated MScs, and is currently supervising 1 PhD student at NTNU and 3 Endoclima MCTS PhD students and 8 MSc students. Since 1996 Jenssen has coordinated research fundings of 581,000 Euro in research support from the EU commission and more than 8 mill. NOK from the Norwegian Research Council.

References:

AMAP, 2004. AMAP Assessment 2002: Persistent Organic Pollutants in the Arctic., Arctic Monitoring and Assessment Programme (AMAP), Oslo, Norway. (www.amap.no)

Andersen, M., Lie, E., Derocher, A.E., Belikov, S.E., Bernhoft, A., Boltunov, A.N., Garner, G.W., Skaare, J.U., Wiig, O., 2001. Geographic variation of PCB congeners in polar bears (*Ursus maritimus*) from Svalbard east to the Chukchi Sea, Polar Biol, 24, 231-238.

Braathen, M., Derocher, A.E., Wiig, O., Sormo, E.G., Lie, E., Skaare, J.U., Jenssen, B.M., 2004. PCB induced effects on retinol and thyroid hormone status in polar bears (*Ursus maritimus*), Environ Health Perspect, 112, 826-833. doi:10.1289/ehp.6809.

Braune, B.M., Outridge, P.M., Fisk, A.T., Muir, D.C.G., Helm, P.A., Hobbs, K., Hoekstra, P.F., Kuzyk, Z.A., Kwan,
M., Letcher, R.J., Lockhart, W.L., Norstrom, R.J., Stern, G.A., Stirling, I., 2005. Persistent organic pollutants and mercury in marine biota of the Canadian Arctic: An overview of spatial and temporal trends, Sci Tot Environ, 351, 4-56.

Brouwer, A., Morse, D.C., Lans, M.C., Schuur, A.G., Murk, A.J., Klasson-Wehler, E., Bergman, A., Visser, T.J., 1998. Interactions of persistent environmental organohalogens with the thyroid hormone system: Mechanisms and possible consequences for animal and human health, Toxicol Ind Health, 14, 59-84.

Haave, M., Ropstad, E., Derocher, A.E., Lie, E., Dahl, E., Wiig, O., Skaare, J.U., Jenssen, B.M., 2003. Polychlorinated biphenyls and reproductive hormones in female polar bears at Svalbard, Environ Health Perspect, 111, 431-436, doi:10.1289/ehp.5553.

Hamers, T., Kamstra, J.H., Sonneveld, E., A.J., M., Zegers, B.N., Boon, J.P., Andersson, P.L., Brouwer, A., 2004. In
vitro screening of the endocrine disrupting potency of brominated flame retardants and their metabolites, BFR2004, Proceedings of the Third International Workshop on Brominated Flame Retardants, 407-410.

Henriksen, E.O., Wiig, O., Skaare, J.U., Gabrielsen, G.W., Derocher, A.E., 2001. Monitoring PCBs in polar bears:
lessons learned from Svalbard, Journal of Environmental Monitoring, 3, 493-498.

Jenssen, B.M., 2003. Marine pollution: The future challenge is to link human and wildlife studies, Environ Health

Perspect, 111, A198-A199.

Jenssen BM. 2005 Interacting effects of pollutants and climate on thyroid hormones in marine mammals. [Poster presentation] PRIMO 13, Alessandria, Italy. 19-22. June 2005.
Jenssen, B.M., 2006. Endocrine disrupting chemicals and climate change: A worst case combination for Arctic marine mammals and seabirds?, Environ Health Perspect, in press, doi:10.1289/ehp.8057. [Online 21 October 2005].
Kirkegaard, B., Sonne, C., Leifsson, P.S., Dietz, R., Born, E.W., Muir, D.C.G., Letcher, R.J., 2005. Histology of selected immunological organs in polar bear (*Ursus maritimus*) from East Greenland in relation to concentrations of organohalogen contaminants, Sci Tot Environ, 341, 119-132.
Lau, C., Thibodeaux, J.R., Hanson, R.G., Grey, B.E., Rogers, J.M., 2003. Perfluorooctane sulfonate (PFOS) disrupts
the thyroid status in laboratory rodents, Toxicol Sci, 72, 136-136.
Legler, J., Brouwer, A., 2003. Are brominated flame retardants endocrine disruptors?, Environ Int, 29, 879-885.
Lie, E., Bernhoft, A., Riget, F., Belikov, S.E., Boltunov, A.N., Derocher, A.E., Garner, G.W., Wiig, Ø., Skaare, J.U.,
2003. Geographical distribution of organochlorine pesticides (OCPs) in polar bears (Ursus maritimus) in the Norwegian and Russian Arctic, Sci Tot. Env., 306, 159-170.
Lie, E., Larsen, H.J.S., Larsen, S., Johnsen, G.M., Derocher, A.E., Lunn, N.J., Norstrom, R.J., Wiig, O., Skaare, J.U.,
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, J Toxicol Environ Health, 67A, 555-582.
Lie, E., Larsen, H.J.S., Larsen, S., Johansen, G.M., Derocher, A.E., Lunn, N.J., Norstrom, R.J., Wiig, O., Skaare, J.U., 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, J Toxicol Environ Health, 68A, 457-484.
Muir, D.C.G., Backus, S., Derocher, A.E., Dietz, R., Evans, T.J., Gabrielsen, G.W., Nagy, J., Norstrom, R.J., Sonne,
C., Stirling, I., Taylor, M.K., Letcher, R.J., 2006. Brominated flame retardants in polar bears (*Ursus maritimus*) from Alaska, the Canadian Arctic, East Greenland, and Svalbard, Environ Sci Technol, 40, 449-455.
Murvoll, K.M., Skaare, J.U., Anderssen, E., Jenssen, B.M., 2006. Exposure and effects of polyhalogenated compounds in European shag (*Phalacrocorax aristotelis*) hatchlings from the coast of Norway, Environ Toxicol Chem, 25, 190-198.
Murvoll KM, Skaare JU, Moe B, Anderssen E, Jenssen BM. 2006. Spatial trends and effects of PCBs, pesticides and
BFRs in North-Atlantic kittiwake (*Rissa tridactyla*) hatchlings. Environ Toxicol Chem. *In press*.
Nyman, M., Bergknut, M., Fant, M.L., Raunio, H., Jestoi, M., Bengs, C., Murk, A., Koistinen, J., Backman, C., Pelkonen, O., Tysklind, M., Hirvi, T., Helle, E., 2003. Contaminant exposure and effects in Baltic ringed and grey seals as assessed by biomarkers, Mar Environ Res, 55, 73-99.
Olsen, G.H., Mauritzen, M., Derocher, A.E., Sørmo, E.G., Skaare, J.U., Wiig, O., Jenssen, B.M., 2003. Space-use
strategy is an important determinant of PCB concentrations in female polar bears in the Barents Sea, Environ Sci Technol, doi: 10.1021/es034380a, 4919-4924.
Oskam, I.C., Ropstad, E., Dahl, E., Lie, E., Derocher, A.E., Wiig, Ø., Larsen, S., Wiger, R., Skaare, J.U., 2003. Organochlorines affect the major androgenic hormone, testosterone, in male polar bears (*Ursus maritimus*) at Svalbard, J Toxicol Environ Health, 66A, 2119-2139.
Sandala, G.M., Sonne-Hansen, C., Dietz, R., Muir, D.C.G., Valters, K., Bennett, E.R., Born, E.W., Letcher, R.J., 2004. Hydroxylated and methyl sulfone PCB metabolites in adipose and whole blood of polar bear (*Ursus maritimus*) from East Greenland, Sci Tot Environ, 331, 125-141.
Skaare, J.U., Bernhoft, A., Wiig, O., Norum, K.R., Haug, E., Eide, D.M., Derocher, A.E., 2001. Relationships between plasma levels of organochlorines, retinol and thyroid hormones from polar bears (*Ursus maritimus*) at Svalbard, J Toxicol Environ Health, 62A, 227-241.
Smithwick, M., Muir, D.C.G., Mabury, S.A., Solomon, K.R., Martin, J.W., Sonne, C., Born, E.W., Letcher, R.J., Dietz, R., 2005. Perflouroalkyl contaminants in liver tissue from East Greenland polar bears (*Ursus maritimus*), Environ Toxicol Chem, 24, 981-986.
Sonne, C., Dietz, R., Born, E.W., Riget, F.F., Kirkegaard, M., Hyldstrup, L., Letcher, R.J., Muir, D.C.G., 2004. Is
bone mineral composition disrupted by organochlorines in East Greenland polar bears (*Ursus maritimus*)?, Environ Health Perspect, 112, 1711-1716.

Sonne, C., Dietz, R., Leifsson, P.S., Born, E.W., Letcher, R.J., Kirkegaard, M., Muir, D.C.G., Riget, F.F., Hyldstrup,
L., 2005a. Do organohalogen contaminants contribute to histopathology in liver from east Greenland polar bears (*Ursus maritimus*)?, Environ Health Perspect, 113, 1569-1574.
Sonne, C., Riget, F.F., Dietz, R., Kirkegaard, M., Born, E.W., Letcher, R., Muir, D.C.G., 2005b. Trends in fluctuating asymmetry in East Greenland polar bears (*Ursus maritimus*) from 1892 to 2002 in relation to organohalogen pollution, Sci Tot Environ, 341, 81-96.
Sonne, C., Dietz, R., Leifsson, P.S., Born, E.W., Kirkegaard, M., Letcher, R.J., Muir, D.C.G., Riget, F.F., Hyldstrup,
L., 2006. Are organohalogen contaminants a co-factor in the development of renal lesions in East Greenland polar bears (*Ursus maritimus*)?, Environ Toxicol Chem, 25, in press.
Sørmo, E.G., Salmer, M.P., Jenssen, B.M., Hop, H., Kovacs, K.M., Lydersen, C., Falk-Petersen, S., Gabrielsen, G.W., Lie, E., Skaare, J.U., 2006. Biomagnification of polybrominated diphenyl ether and

hexabromocyclododecane flame retardants in herring gulls in the polar bear food chain in Svalbard, Norway., Environ Toxicol Chem, *in press*.
Verreault, J., Gabrielsen, G.V., Chu, S.G., Muir, D.C.G., Andersen, M., Hamaed, A., Letcher, R.J., 2005b. Flame
retardants and methoxylated and hydroxylated polybrominated diphenyl ethers in two Norwegian Arctic top predators: Glaucous gulls and polar bears, Environ Sci Technol, 39, 6021-6028.
Verreault, J., Muir, D.C.G., Norstrom, R.J., Stirling, I., Fisk, A.T., Gabrielsen, G.W., Derocher, A.E., Evans, T.J.,
Dietz, R., Sonne, C., Sandala, G.M., Gebbink, W., Riget, F.F., Born, E.W., Taylor, M.K., Nagy, J., Letcher, R.J., 2005a. Chlorinated hydrocarbon contaminants and metabolites in polar bears (*Ursus maritimus*) from Alaska, Canada, East Greenland, and Svalbard: 1996-2002, Sci Tot Environ, 351, 369-390.
Wiig, Ø. 2005. Are polar bears threatened. Science 309: 1814-1815.
Zoeller, R.T., 2005. Environmental chemicals as thyroid hormone analogues: New studies indicate that thyroid hormone receptors are targets of industrial chemicals?, Mol Cell Endocrinol, 242, 10-15.