Contaminants in Polar Regions – COPOL

Dynamic range of contaminants in polar marine ecosystems

1. Overall aim and relevance for the International Polar Year

The multinational project initiative "Fate, uptake and effects of contaminants in the Arctic and Antarctic ecosystem" (short name "Contaminants in Polar Regions" COPOL, Appendix 1) was endorsed by the Joint Committee of the International Polar Year (IPY) (Appendix 2). The international COPOL initiative consists of two research pillars: 1) transport and fate of contaminants to and in Polar Regions, 2) food web transfer and contaminant status of higher organisms. The Norwegian contribution to COPOL; Dynamic range of contaminants in polar marine ecosystems, focuses on Pillar 2. The overall aim is *to understand the dynamic range of man-made contaminants in marine ecosystems of Polar Regions, in order to better predict how possible future climatic change imposed alterations of the marine food webs will be reflected in levels and effects at higher trophic levels*.

To fulfill the aim, the project addresses IPY research themes defined by the International Council for Science (ICSU)'s such as to establish i) the basis contaminant concentrations, which will be available for future reference (*status*), ii) the dynamic range of contaminant in a marine ecosystem, due to seasonal, annual and regional variability, so that future changes can be identified (*change*), iii) the circumpolar and bipolar contaminant variability and reasons for regional differences (*global linkages*). As there are few local sources of contaminants in Polar Regions, they act as tracers of *human impact* on the natural environment. The Norwegian COPOL also fulfils the Norwegian IPY goals of coordinating a large scale multidisciplinary project combining applied and basic science with bipolar aspects, Russian and international collaboration, as well as contributing to educating the next generation of polar ecotoxicologists. The project will benefit strongly from, but is not dependent on, the linkages to the Netherlands' and Canadian COPOL projects as well as other IPY and NARE (Norwegian Antarctic Research) projects (Table 1).

2. Scientific rationale[1]

Both the Intergovernmental Panel on Climate Change (IPCC) and the Arctic Climate Impact Assessment (ACIA) document climatic changes and consequences for ecosystems [1,2]. One of the motivations for the present project is the conclusion from the Arctic Monitoring and Assessment Programme (AMAP) that there is evidence that "the routes and mechanisms by which persistent organic pollutants (POPs) […] are delivered to the Arctic are strongly influenced by climate variability and global climate change" with a recommendation "to further investigate how climate change and variability may influence the ways in which contaminants accumulate in and affect biota" [3].

Our understanding of processes governing the behavior and fate of organic contaminants within the Polar Regions is based on the polar environment of today. This understanding, though limited, is important and relevant to elucidate processes related to current contamination levels, and also to ascertain the likely impact of future contamination events or changes within the polar environment. Elevated levels of man-made contaminants have been detected in both Polar Regions [4,5,6] due to the cold-condensation effect [7]. Due to climatic changes, several processes have already drifted off the baseline, and there is a need to increase the knowledge of how this is propagated through the ecosystem [8].

[1] All research will be carried out according to the ethics and regulations established in current Norwegian legislations. Permissions will be obtained through the Government on Svalbard (Sysselmannen). The project results in no negative environmental consequences. Due to the close collaboration with the ongoing project MariClim, and WP integration, sampling will be minimized, and the use of all sacrificed animals will be maximized.

Table 1. Related COPOL, IPY and Norwegian Antarctic Research Expedition (NARE) projects for bipolar or Arctic regional comparison

Project	Title	Lead contact
IPY-COPOL	New and old contaminants in Antarctica: food chain accumulation and levels in top-predators, a circumpolar approach.	Nico van den Brink, Alterra Wageningen UR, The Netherlands.
IPY-COPOL	Comparison of effects of halogenated compounds on Antactic and Arctic marine seabirds, a bi-polar approach.	Nico van den Brink, Alterra Wageningen UR, The Netherlands.
IPY-COPOL	Legacy and emerging contaminants in an Antarctic benthic food web; concentrations, model predictions and risk assessments.	Nico van den Brink, Alterra Wageningen UR, The Netherlands.
IPY-COPOL	Contaminant pathways and dynamics in polar bear - seal - seabird food	Rob Letcher, Environment Canada,
IPY-ATMOPOL (ID 76)	Atmospheric Monitoring Network for Anthropogenic Pollution in Polar Regions	Roland Kallenborn, University studies on Svalbard, Longyearbyen, Svalbard.
IPY-BIRDHEALTH (ID 172)	Health of Arctic and Antarctic Bird Populations.	M. Loonen, Arctic Centre, Univ. Groningen, The Netherlands.
NARE	Influence of environmental variability and anthropogenic stress in an Antarctic ecosystem	Torkild Tveraa, Norwegian Institute for Nature Research, Tromsø, Norway.
NARE	Flux of organic contaminants through lower trophic levels of the Antarctic marine food web.	JoLynn Carroll, Akvaplan-NIVA AS, Norway.
NARE	Flux and fate of organic matter across environmental gradients on the Antarctic continental shelf	Paul Renauld, Akvaplan-NIVA AS, Norway.

Persistent hydrophobic organic contaminants accumulate in lipids, and are transferred from prey to predators, where they are retained, leading to elevated contaminant levels moving up the food web [9]. Although several detailed studies of the Arctic marine food web have been carried out in the past decade (summarized in [10]), these are all momentary glimpses of the processes, and little is known about the dynamic range of the systems. In addition, recent studies reveal a discrepancy between theoretical bioaccumulation studies (on which management tools are based), and empirical data [11]. Climate changes are expected to influence the contaminant flux in food webs due to altered exposure and intrinsic food web processes as well as due to changes in uptake dynamics [12].

In several Arctic species, the contaminant levels are high, and since the mid 1990s marine top predators, such as polar bears (*Ursus maritimus*), seals and glaucous gulls (*Larus hyperboreus*), have been subject to numerous studies documenting effects of pollutants from the cellular to the ecological level [13,14,15,16,17,18,19]. Moreover, in polar environments organisms are exposed to elevated levels of natural stress, and the combination of natural and anthropogenic stress factors, such as elevated energy demands and POPs levels, may have a profound effect on Arctic organisms [20,21]. Thus, deteriorating environmental conditions, due to climate change, may alter both the effect patterns, as well as accumulation of POPs in Arctic organisms.

The above is the main motivation for participation in the international multi-disciplinary COPOL initiative. The overall aim will be addressed by 4 integrated work packages (WPs) covering the scopes of 1) food web contaminant exposure and flux, 2) transfer to higher trophic levels and potential effects, 3) chemical analyses and screening, 4) spatial variability, synthesis and integration. In WP4, obtained results will be linked to relevant national research projects, international COPOL projects and other IPY and international initiatives (Table 1), thereby strengthening the national and international exchange of knowledge, and enabling a bipolar and a circumpolar understanding of bioaccumulation issues.

The Norwegian COPOL initiative will achieve the following significant scientific advancements:

- Establish a baseline for future reference with regards to contaminant level and behavior in Arctic marine food webs
    - Establish seasonal and inter-annual range of contaminant level variability in marine food webs.
    - Establish the influence of seasonal and inter-annual variability in contaminant exposure on effects in top predators, focusing on arctic seabirds and ringed seals (*Phoca hispida*).
    - Quantify and document legacy and emerging contaminants in marine wildlife.
- Integrate bipolar and circumpolar contaminant research toward an understanding of future climate-related changes
    - Compare contaminant accumulation in benthic food webs between a clean site (Svalbard) and a site close to industrial activity (White Sea, Russia).
    - Compare contaminant accumulation in pelagic food webs between two clean sites influenced only by long-range transport of contaminants (Svalbard and Canadian Arctic).
    - Compare contaminant accumulation in Arctic and Antarctic marine food webs.
    - Compare the avian toxicological responses in similar Arctic and Antarctic species.
    - Compare the range of bioaccumulation factors in marine invertebrates among polar areas.
- Determine the contaminant flux in marine food webs under various climate scenarios, by examining ecosystem-contaminant relationships in Atlantic and Arctic water masses.
    - Identify changes in food web flux of contaminants due to altered exposure and food web structure.
    - Identify changes in food web flux of contaminants due to altered uptake kinetics of contaminants.
- Contribute to initialization of the biobank, Marbank, as central, national storage and service-function towards institutions focusing on legacy and new contaminants in marine samples.

3. Project description

The Norwegian COPOL focuses on the Arctic region, more specifically Kongsfjorden (79ºN, 12ºE) on the west coast of Spitsbergen, Svalbard. Kongsfjorden has been identified as particularly suitable as a study site of contaminants processes, due to the remoteness of sources, and for influences of climatic changes, due to the relationship between Atlantic water influx and the climatic index North Atlantic Oscillation (NAO) [22]. Variable Atlantic water influx will not only influence abiotic contaminant exposure, but also food web structure, food quality and energy pathways, as different water masses carry different phyto- and zooplankton assemblages [12]. Kongsfjorden thereby offers a field based experimental “microcosm” for climate change studies, where different climate regimes which are hypothesized to influence the food web dynamics of contaminants can be contrasted with respect to levels, fluxes and effects of contaminants.

The project will use the logistics of the international research station Ny-Ålesund, which aims to be an international reference station for climate- and environmental related research. Baseline knowledge of both the physical [23] and biological [24] environment of Kongsfjorden is available from past research activities. Not only will the project document the current state of environmental contamination in Kongsfjorden, but the value of using Ny-Ålesund and Kongsfjorden as a “clean” reference site will be evaluated. In addition, sampling 1) of benthic and pelagic food webs will take place in the Arctic water dominated fjord Hornsund to ensure an Arctic signal, 2) of great skua (*Catharacta skua*) on Bjørnøya, Svalbard to ensure a large enough sample size, as the population in Kongsfjorden is small, 3) of the benthic food web, from sediments through invertebrates to eider duck (*Somateria mollissima*) and seals

in the White Sea, Russia, to ensure comparison between food webs with different POP and mercury (Hg) exposure.

A summary of the different WPs are given below, whereas details on background and methodology can be found in Appendix 8. The main field campaign will be carried out in 2007, for the baseline reference and full ecosystem approach. Repeated sampling of selected compartments for characterisation of the seasonal and inter-annual variability in April–August in 2008-2009. The planning and establishment of infrastructure and logistics for polar fieldwork is expensive and demanding. The Polar Year of 2007-2008 coincides with the main fieldwork for the ongoing climatic project MariClim, financed by the Norwegian Research Council and organized by the Norwegian Polar Institute (NPI) (Appendix 6). Joining forces with MariClim and NPI in this rare opportunity provides a brief window where the necessary fieldwork can be conducted efficiently and economically which will reduce logistical requirements and ensure exchange of data and knowledge. MariClim will also provide information necessary to assess the variation in climatic conditions, both within and between the seasons. The project's study design, methodology, sample protocols, species included, and chemical analyses are planned and harmonized with the other international COPOL projects to ensure comparability with the Antarctic and other Arctic studies.

WP1. Uptake and dynamics of POPs and Hg in benthic and pelagic food webs

Responsible researchers: Katrine Borgå (Norwegian Institute for Water Research -NIVA) and Anita Evenset (Akvaplan-NIVA AS -APN)

Participants: Paul Renault (APN), Jolynn Carroll (APN), Tatiana Savinova (APN), Nico van den Brink (Alterra), Birgit Braune (Environment Canada), Derek Muir (Environment Canada), Technician (field work), PhD candidate #1 (*NN,* NIVA/APN), 2 Master students (NIVA/APN).

Scope: To identify the range of contaminant accumulation in pelagic and benthic food webs in Arctic marine ecosystems.

Sub-goal 1: To assess how present-day climatic regimes, here indicated by exposure to different water masses (Atlantic and Arctic), influence contaminant dynamics through the mechanisms 1) altered exposure and food web structure and 2) uptake kinetics associated with pelagic and benthic food webs.

Sub-goal 2: To assess how uptake and transfer of selected contaminants through food webs vary seasonally and inter-annually.

Rationale: Future changes in climate are predicted to result in major modifications in the community structure of both pelagic and benthic organisms, due to changes in temperature, salinity, nutrient content etc. that may occur as a result of changes in dominating water masses [1,2]. Understanding how climatic changes may affect contaminant transport in pelagic and benthic food chains is necessary in order to evaluate the future vulnerability and consequences of longer term directed climate changes for organisms at higher trophic levels, including humans [12]. Arctic food web studies during the 1990s (reviewed by Borgå et al. [10]) built the platform for continued research as several questions have arisen such as what is the "natural" range of contaminants in polar marine ecosystems. Apart from studies by Hargrave et al. [25] and Fisk et al. [26] in the Canadian Arctic, studies of POPs and Hg in Arctic zooplankton and the base of the arctic marine food web suffer from being momentary, with lack of variance due to season, year, and changes in water masses.

Since enrichment of POPs in the food web (biomagnification) is exponential [27], even slight changes in POP levels at the base of the food web will result in pronounced effects at higher trophic levels [10,28]. Changes at the base of the food web may occur as a result of exposure to different water masses (Atlantic vs. Arctic), structural changes in the food web, and changes in parameters that influence the physicochemical properties of contaminants, and thereby the uptake kinetics. The quality

of Arctic and Atlantic prey species for higher trophic levels differs [29]. Arctic marine zooplankton are attractive prey for fish, seabirds and marine mammals, as energy assimilation is more efficient in a fat-rich diet [30]. Thus, relative food quality of potential prey species directly affects foraging behavior of pelagic-feeding seabirds and benthic feeders. These foraging decisions may have important consequences for contaminant levels in higher predators, as POPs are expected to be more concentrated in lipid-rich species.

Methods: *Sampling* - Whereas the composition of the pelagic food web in Kongsfjorden, which is composed of both boreal and Arctic species, has a marked shift in zooplankton composition between years with cold and warm water, less mobile benthic communities show less year-to-year variability as a function of water temperature [24]. During the first project year, extensive sampling of both pelagic and benthic species will be carried out in Kongsfjorden to determine which species act as important vectors for energy and contaminants to pelagic and benthic feeding predators. These species will be sampled from the different water masses 3 times a year over the following 2 years to understand the seasonal and inter-annual variability in contaminant accumulation and flux. The coupling to the abiotic environment will be investigated through contaminant analyses of water and sediment, and the transfer to upper trophic levels by analyses of ringed seals seabirds representative of the benthic or pelagic food webs. As the water mass variability in Kongsfjorden reflects a gradual continuum, an Arctic water dominated fjord, Hornsund, is included in 1997 to assure a truly Arctic signal on the marine food webs. *Chemical analyses* - All samples will be analyzed for dietary indicators such as stable isotopes of carbon and nitrogen, fatty acids, lipid classes, and contaminants such as selected POPs (see WP3) and total and methyl mercury (CH_3-Hg and Total-Hg).

Deliverables: By combining measurements of POPs and Hg from the marine food web with dietary and environmental parameters, predictors for alteration in food web fluxes of POPs and Hg will be identified. As part of WP4, results from WP1 will be implemented in the comparison with Antarctic marine food webs, as well as the other Arctic food web comparison (benthic-Russian, pelagic-Canadian). Parallel samples will be collected for the sample bank MarBank. The results from WP1 will form the basis of a PhD thesis which will be finished in 2010, as well as 2 Master Theses.

WP2. Dynamics and effects of POPs and Hg at upper trophic levels

Responsible researchers: Jan Ove Bustnes (Norwegian Institute for Nature Reseach -NINA), Geir Wing Gabrielsen (Norwegian Polar Institute -NPI), Hans Wolkers (NPI).

Participants: Bjørn Munro Jenssen (Norwegian University of Science and Technology -NTNU), Ketil Sagerup (University of Tromsø -UiTø), Sveinn-Are Hanssen (NINA), Nico van den Brink (Alterra), Birgit Braune (Environment Canada), Tatiana Savinova (APN), PhD candidate #2 (*NN,* NPI/NINA), 2 Master students (NPI/NINA).

Scope: Assess how future environmental changes will affect the levels and effects of POPs and Hg in ringed seals and different seabird species dependent upon pelagic or benthic prey items.

Sub-goal 1. Assess how levels of POPs and Hg vary in different seabird species and ringed seals during different seasons.

Sub-goal 2. Assess how different effect endpoints vary in seabird species and ringed seals under varying environmental conditions.

Rationale: At present, POPs are known to have considerable effects on organisms at upper trophic levels in the Arctic [5,14,16,31]. In addition, recent studies suggest that the effects of POPs are enhanced in deteriorating environments [15,20]. To understand how regional responses to global changes may influence the accumulation and effects of POPs and Hg at higher trophic levels, it is necessary to know how these parameters are influenced by environmental heterogeneity. Moreover, to

test specific hypotheses within a time limited framework such as the IPY, it is necessary to do a cross sectional study involving several species. Such a large scale data collection will provide baseline information for future studies about the impact of climate change on the potential effects of POP and Hg. In WP2 we will focus on upper trophic levels of the food web, specifically ringed seals and seabirds that are feeding on the pelagic or the benthic food web.

Methods: *Data collection* – Individuals of different seabird species will be captured early and late in the breeding season in Kongsfjord in all 2007-2009. Blood samples will be collected for analyses of POPs (see WP3) and effect endpoints. In addition, seabirds and ringed seals killed within WP1 will be subject to further study within WP2 to evaluate non-evasive methodology for POP quantification. *Sampling parameters* - Based on a small screening sample analysed for a wide range of POPs a limited number of the most important POPs will be selected. As endpoints to evaluate the effects of POPs under different environmental conditions we will use effect parameters that can be readily measured non-destructively. These will involve hormones and immune parameters known to be affected by POPs (thyroid hormones, testosterone, estradiol) and immune parameters such as IgG and IgM and white blood cells on blood smears. In killed birds and seals this will also involve endpoints such as ethoxyresorufin (EROD) activity. Supplementary to the Kongsfjorden area, for comparison of levels and effects in avian predators between the Polar Regions in WP4, great skuas will be sampled at Bjørnøya, Svalbard in collaboration with an ongoing project at the Norwegian Polar Institute, as the Kongsfjorden colony is too small to allow a sound effect study.

Deliverables: By combining measurements of POPs and Hg in upper trophic levels from different seasons (within and between) with measurements of a range effect endpoints and measurement of environmental conditions (abiotic and biotic), we will record and estimate potential future effects of POPs and Hg in marine top predators. Toxicity and contaminant data from fulmar (*Fulmarus glacialis*) and skua will be implemented in the comparison with harmonized Antarctic studies, whereas other species will be included in the circumpolar study, as part of WP4. Parallel samples will be collected for the sample bank MarBank. The results from WP2 will form the basis of a PhD thesis which will be finished in 2010, as well as 2 Master theses.

WP3. Chemical analyses

Responsible researchers: Henrik Kylin (Norwegian Institute for Water Research -NILU) and Torunn Berg (NILU).

Participants: Postdoctoral fellow (*NN*, NILU), Derek Muir (Environment Canada), Nico van den Brink (Alterra), Alexei Konoplev (Center of Environmental Chemistry SPA "Typhoon" -CEC) other WP1 and WP2 participants, 1 Master student.

Scope: Screening of the samples to select target analytes, and to provide analytical methodology for the selected analytes.

Subgoal 1: To screen the first set of samples for a wide set of contaminants to select appropriate target analytes, and to identify emerging compounds of concern.

Subgoal 2: Intercalibration of target analytes with other laboratories, primarily with other laboratories within the international COPOL framework and the Russian collaborants.

Rationale: High quality contaminant data in the respective abiotic and biotic compartments are crucial. The focus of the present project is primarily on the legacy POPs that are included in the United Nations' Environmental Programme (UNEP) Stockholm convention (www.pops.int) and mercury (Hg) (www.unece.org/env/lrtap/hm_h1.htm). As far as feasible, additional hazardous organic compounds (e.g., brominated flame retardants and perfluorinated compounds) will be included. Even though legacy POPs are declining in the environment [5], they are of interest as they are still the dominating organic

contaminants in Arctic wildlife. Despite substantial mercury emission reductions in North America and Western Europe during the 1980s, global mercury emissions may in fact be increasing, and there is a trend of increasing mercury levels in marine birds and some mammals in some part of the Arctic [5]. There is a firm knowledge base on legacy POPs and mercury that provide confirmation of data and behaviour, which are important for understanding behaviour of emerging compounds, as well as validation of the food web model that will be developed for scenario-predictions (WP4). In depth analyses are presently planned chiefly of polychlorinated biphenyls (PCB), chlorinated pesticides, total mercury, and methyl mercury as model compounds.

Methods: Details on methodology is given in Appendix 8. In brief, mercury (Hg) and methyl mercury (CH_3-Hg) will be analysed using atomic spectroscopy techniques, e.g., atomic fluorescence. Speciation of mercury compounds will be done with high performance liquid chromatography coupled to inductively coupled plasma – high resolution mass spectrometry. For the majority of the organic compounds, e.g., legacy POPs, brominated flame-retardants, and some current use pesticides, gas chromatography with low or high resolution mass spectrometry are appropriate. However, for some compounds, especially perfluorinated compounds and some current use pesticides, high performance liquid chromatography with high resolution mass spectrometry will have to be used. To ensure high analytical quality and comparability with other laboratories, intercalibration studies will be organized by Dr. Muir (National Water Research Institute, Burlington, Canada).

Deliverables: High quality concentrations of mercury and the legacy POPs and newer hazardous compounds (e.g. brominated flame retardants, perfluorinated compounds), as well as identification of emerging compounds of concern for Arctic wildlife. The data will be made available to AMAP and should be applicable in a regulatory framework and within international negotiations on POPs (the Stockholm Convention) and mercury (the heavy metal convention).

WP4. Spatial variability, synthesis and integration

Responsible researchers: Katrine Borgå (NIVA), Geir Wing Gabrielsen (NPI), Victor Berger (Zoological Institute –ZIN, White Sea Biological Station -WSBS), Tatiana Savinova (APN)

Participants: WP1-3 participants, Tuomo Saloranta (NIVA),Vlad Svetochev (Knipovich Polar Research Institute of Marine Fisheries and Oceanography -SevPRINO) Alexei Konoplev (CEC), Alexander Koryakin (KR), Dr. Nina Nemova (Institute of Biology -IB), Vladimir Savinov (APN), Paul Renaud (APN), Russian Ph.D. students (APN/WSBS/ZIN/IB), 1 Master student.

Scope: To integrate the results for the Arctic achieved through WP1-3 in an Arctic regional, bipolar and climate change perspective through integration with international COPOL results and other related programs.

Sub-goal 1: Compare accumulation of POPs and Hg in similar benthic food webs from Arctic and sub-Arctic areas in the Barents Sea under different contaminant loads.

Sub-goal 2: Compare bioaccumulation, levels and effects of contaminants in Arctic pelagic marine food webs between two pristine sites under different influence of long range transport (Svalbard and the Canadian Arctic).

Sub-goal 3: Compare bioaccumulation, levels and effects of contaminants between Arctic and Antarctic benthic and pelagic marine food webs.

Sub-goal 4: Predict contaminant flux in the Arctic marine food web under different climate scenarios and assess the potential effects in avian and mammalian predators.

Rationale: Different Polar Regions have different exposure to POPs and Hg. As part of the international COPOL consortium, collaboration with Russian, Dutch, and Canadian colleagues, and

strong linkages to Norwegian Antarctic Research Expedition (NARE) (Table 1), the IPY platform allows a circum- and bi-polar comparison of processes, levels and effects. These comparisons are of importance, as they address the sources of contaminants to the various regions, and also the various ecosystems responses to the contaminants in both accumulation at the base of the food web and in effects at upper trophic levels. The White Sea (Russia) is a valuable comparative site due to the influence of both long-range transport contaminants and regional sources of contamination, and due to a similar species composition to Kongsfjorden, but with different climate conditions [32]. The Canadian Arctic (Lancaster Sound/Resolute Bay) also has a species composition that is comparable to the Arctic regime in Kongsfjorden, but the POP and Hg accumulation pattern may differ among polar pristine sites due to regional specific process and transport pathways of POPs and Hg [5]. Both Polar Regions have strong seasonal amplitude in irradiation, leading to strong seasonal primary production and food availability, and thereby adaptation in animals to these variations. Although the Arctic and Antarctic ecosystem differ in species and ecosystem structure, the processes governing the transfer of carbon and contaminants are likely similar, although at different scales. This, in combination with a difference in POP and Hg exposure most likely result in a different bioaccumulation pattern in food web, and thus exposure to higher trophic levels, but few studies are available.

The proposed COPOL project provides a unique opportunity to identify contaminant accumulation within a polar marine ecosystem, including benthic and pelagic components, as well as animals feeding low and high in the food web (WP1). Further, dynamics and effects of contaminants at upper trophic levels are quantified (WP2), and the integration of these results will optimize the knowledge and understanding gained from these WPs. Because climatic changes occur over a long time frame, mechanistic mass balance models are useful tools to create predictive scenarios for contaminant behavior. The present project is unique as it will also provide the needed data for validation of such predicted scenarios.

Methods: *Sub-goal 1*- As part of the Norwegian COPOL, the benthic food web leading to eider ducks, bearded seals (*Erignathus barbatus*) and ringed seals will be collected in the White Sea in collaboration with Russian colleagues, and analyzed for contaminants using methodology harmonized with WP1 and 2 and international COPOL projects (see Appendix 8 for detailed description). Contaminant concentrations, bioaccumulation factors and trophic magnification factors will be compared using suitable statistical tools such as analyses of variance and ordination techniques. *Sub-goal 2* – will be reached by collaboration with Canadian colleagues specific inter-comparison as in sub-goal 2. of *Sub-goal 3* – Same as Sub-goal-2, but with comparison with Antarctic studies. *Sub-goal 4* – will be reached by adapting and parameterizing a mechanistic mass-balance model for polar ecosystems that describes contaminant flux in the food web. The model will be based on SEDFLEX [33], which builds on the framework of Mackay [34]. The model results (accumulation in biota) will be compared to the effect studies of WP2. Contaminant data from WP1–3 will be used for model validation. The model could be parameterized for the other Arctic and Antarctic regions in WP4 to test its validity and increase its roboustness.

Deliverables: By comparing POP and Hg accumulation across Arctic regions, exposed and pristine sites, Antarctic and Arctic marine food webs, a through understanding of bioaccumulation processes will be achieved for benthic and pelagic ecosystems. Further, a predictive mechanistic model on POP and Hg flux in polar marine ecosystems will be parameterized and validated based on the synthesis of data from WP1 and WP2. This model will be a usefull tool for future predictions of changes in POP and Hg accumulation and exposure to higher trophic levels due to changes within the ecosystem (such as food web structure and primary production) and due to changes in exposure (due to changes in temperature and transported POPs and Hg into the ecosystem). The results from WP4 will form the basis of a Russian PhD thesis which will be finished in 2010, as well as 1 Master Theses.

WP5. Project management

Organization: This research initiative is from the Polar Environmental Centre (POMI, www.pomi.no). The project will be lead and administered by Dr. Geir Wing Gabrielsen (Norwegian Polar Institute), and coordinated and managed by Dr. Katrine Borgå (Norwegian Institute for Water Research). An internal project steering committee, co-led by Gabrielsen and Borgå, will include all WP leaders (see partner description in Appendix 7). All researchers have extensive experience with polar research, and many are designated experts for the Arctic Monitoring and Assessment Programme (AMAP). The project is well balanced in terms of gender and experience, as both sexes are represented in the project at all levels of organization and career stages from Master and doctorate students, recently finished doctorates, post-doctorates, to young (<35 years) and senior scientists.

The proposed project is a highly prioritized research area within POMI, and is supported and prioritized by the POMI research committee (Appendix 5). The project is clearly anchored in the strategic plans of all project partners.

Dissemination and outreach: Public outreach activities will be organized and coordinated through project connections to the international COPOL initiative, the Polar Environmental Centre, the ARCTOS network, individual participating institutes, as well as potential activities arranged by planning and implementation organizations of the Norwegian national IPY. At a minimum, the Tromsø University Museum journal OTTAR will have one special COPOL issue at the end of the project period, and we will contribute to articles to Norwegian newspapers such as the knowledge-directed A-Magasinet of Aftenposten, as well as contribute with information on the IPY and COPOL research to the Norwegian broadcasting. A web portal (web log) will be active and accessible, in which the project can be followed, and information on cruises etc will be updated with pictures and text continuously, at least weekly during field season.

Scientific results will be disseminated in international, peer reviewed journals of high scientific quality such as *Environmental Science and Technology*, *Environmental Toxicology and Chemistry*, and *Environmental Pollution*. Results obtained under the Norwegian COPOL will also be edited for contributions to the monograph in the planned "From Pole to Pole" IPY book series (Springer Publishers), editor Roland Kallenborn (University Studies on Svalbard).

During the course of the project, results will be presented at relevant international conferences such as the annual Society of Environmental Toxicology and Chemistry (SETAC), the Conference on halogenated contaminants (DIOXIN). As a part of the COPOL process, due to its interdisciplinarity and scale, one workshop will be arranged each year to calibrate the progress of the project. Participation will be open to other relevant IPY projects, as well as the international COPOL participants.

Within the framework of AMAP, a COPOL conference will be arranged in Tromsø 2008, hosted by the Norwegian Polar Institute (Geir Wing Gabrielsen). Finances for this conference will be sought elsewhere, and are not included in the COPOL budget.

4. Policy rationale

Legacy: Whereas the last 50 years represented impact on the environment from the industrial revolution, the next 50 will be all about climate change. Therefore the IPY time frame represents a critical transition point between these two reference frames. A project linking contaminants to climate change at the cusp of this important transition will serve as an invaluable assessment interval for future generations of polar scientists. Further, studies on marine food web bioaccumulation only provide momentary glimpses. This IPY initiative is the first attempt to provide baseline knowledge and documentation on both seasonal and inter-annual variability within the marine pelagic and benthic ecosystem, from water to avian top predators. Similarly, the understanding of the impact of

environmental variation on the effects of POPs and Hg is very limited, and this project, with its bipolar, international activities will provide new insight into risks that POPs and Hg represent in interactions with environmental heterogeneity.

AMAP/UNEP (Appendix 4): COPOL is central for the AMAP process of management of the Arctic environment, and covers gaps identified in the latest AMAP report on POPs [5]. AMAP's responsibilities are defined by the Arctic Council, which is composed by the 8 Arctic countries, which being hosted by the Norwegian Ministry of Environment during the IPY period (2007-2008). Due to direct input and advice from AMAP, Arctic research results have short distance from the scientists to UNEP and Stockholm convention on POPs

Ny-Ålesund: There is a national legacy associated with Ny-Ålesund in Kongsfjorden, and its development as a major research platform for Norwegian Arctic research. Although extensive basic research has been carried out in Kongsfjorden, surprisingly few studies are directed towards contaminant accumulation and effects in the marine environment. The aspect of contaminant accumulation is especially valuable within this fjord system, as there is profound basic knowledge of the system.

ARCTOS network: Two partners in this project, Akvaplan-niva and the Norwegian Polar Institute, are founding members of the ARCTic marine ecOSystem research network (ARCTOS http://www.nfh.uit.no/arctos/index.html). ARCTOS has several NRC- and privately- funded projects that relate directly to the proposed studies in COPOL. The projects include MariClim (described above), microbial cycling in Kongsfjorden, ecotoxicological studies of ice amphipods and polar cod, and benthic system modeling in the Barents Sea. Insights gained from these studies will be valuable for interpretation of contaminant data from pelagic and benthic food webs.

Education: Additional to the research and increased knowledge resulting from the project, the project will contribute a legacy of new scientists and teaching tools. In addition to the six Master, two PhD students and one post doctoral fellow working on the project on the Norwegian side, Russian doctorate and Master students are involved in WP4 Sub-goal 1. We also aim to organize a research-based course at Master and doctorate level at the University Centre on Svalbard (UNIS www.unis.no). The course will consist of two parts: one in Longyearbyen (UNIS) for theory and lectures, and the second in Ny-Ålesund by participation in fieldwork and student projects. Funding for the course will be sought through the education and outreach part of IPY as well as from NordForsk (www.NordForsk.org). Dr. Gabrielsen is responsible for organizing the course, which will be conducted in collaboration with international COPOL partners. The COPOL researchers have extensive Arctic experience, good publication records, and experience with university teaching and supervision of graduate students.

Sample bank: A national marine repository, Marbank, is recently established in Tromsø, Norway, with present focus of archiving biological material for marine bioprospecting/biodiscovery. Marbank has a national responsibility for collection and preservation of marine resources for research, commercial and exploitation purposes, and has facilities for secure long-time sample storage in bio-freezers and liquid nitrogen refrigerators. Small adjustments of the infrastructure of the biobank have been proposed to arrange for additional storage of samples for chemical analysis of environmental compounds. This way, Marbank will obtain a central, national storage and service- function towards institutions focusing on legacy and new contaminants in both recently collected and historical marine samples. Such an adjustment of Marbank will be of great importance for future environmental monitoring, and the Norwegian COPOL project intends to contribute to its initialization by collecting parallel samples from the respective WPs for inclusion into the biobank.

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