Contaminants in Arctic Wildlife in Nunavut, Canada






Nunavut Wildlife Health Assessment Project

CONTAINMINANTS IN ARCTIC WILDLIFE IN NUNAVUT, CANADA:
NUNAVUT WILDLIFE HEALTH ASSESSMENT PROJECT

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EXECUTIVE SUMMARY

This report summarizes the key results of the Nunavut Wildlife Health Assessment Project (NWHP) generated through the chemical analysis and histological survey (i.e., microscopic examination of cellular structure) of selected tissues of Arctic char, ringed seal and beluga. Inuit hunters collected these tissues during their subsistence harvests. Despite being banned in Canada for more than 20 years, many legacy persistent organic pollutants (POPs), such as polychlorinated biphenyls (PCBs) and dichlorodiphenyltrichloroethane (DDT), were detected in tissues of Arctic wildlife. Organoclorine (OC) contaminant levels in char muscle were generally low (mean values of 5 nanograms per gram [ng/g] for DDT and 7 ng/g for PCBs); higher OC concentrations were found in blubber of ringed seal (mean values of 299 ng/g for DDT and 375 ng/g for PCBs). The blubber of beluga contained the highest levels (2,900 ng/g for PCBs and 6,700 for DDT) of all three species. The NWHP results revealed the presence of a newer generation of contaminants, such as polybrominated diphenyl ethers (PBDEs) and the OC insecticide endosulfan, although the levels of these emerging contaminants of concern were generally one to two orders of magnitude below the levels associated with the more notable legacy POPs.

Mercury, a potent trace element that targets the nervous system and developing brain, was detected in various tissues and organs of Arctic char, ringed seal and beluga. Mercury levels in the kidney and liver of ringed seal, along with levels in the muscle, kidney and liver of beluga, are much higher than the 0.5 micrograms per gram (μg/g) level Health Canada recommends as a safe upper limit for human consumption.

Despite the lack of gross anomalies (i.e., physical changes evident to the naked eye) in harvested animals, the histological survey did reveal conditions in some tissues that appeared unusual. Anomalies in ringed seal and beluga included reactive and/or draining lymph nodes (suggestive of infection in surrounding tissues) and evidence of bacterial infection in liver tissue and of inactive spermatogenesis in a few animals. No correlation was found between histological anomalies and contaminant body burdens. Interpreting the significance of these results was hampered by small sample sizes, a general lack of baseline knowledge of the histopathology of Arctic species, and hunter bias towards the selection of healthy looking animals. Despite these limitations, the weight of evidence generated from hunter observations (Inuit Qaujimajatuqangit, or IQ, summarized in a separate report), the elevated presence of several chemical contaminants in tissues, and histological anomalies suggest that subtle changes to the health of Arctic wildlife are occurring. More effort is needed to better document the prevalence and frequency of these conditions in order to develop benchmarks of current animal health. Such benchmarks will become invaluable in the detection and interpretation of future trends. Starting this work now is particularly important since many environmental factors affecting animal habitat are currently undergoing rapid change due to human-induced alteration of climatic conditions and human use of resources.

ABBREVIATIONS

NON-SCIENTIFIC TERMS

DEW Line	Distant Early Warning Line
DFO	Department of Fisheries and Oceans
HTOs/HTAs	Hunters' and Trappers' Organizations/Associations
IQ	Inuit Qaujimajatuqangit
NWHP	Nunavut Wildlife Health Assessment Project
WWF	World Wildlife Fund for Nature
WWF-Canada	World Wildlife Fund Canada

SCIENTIFIC TERMS

µg	microgram (one-millionth of a gram)
bw/d	body weight per day
g	gram
mm	millimetre
N	sample size
na	not available
nd	not determined
ng	nanogram (one-billionth of a gram)
ppb	parts per billion
SD	standard deviation
SE	standard error
TDI	tolerable daily intake

CHEMICALS

BFRs	brominated flame retardants
Cd	cadmium
CHL	chlordane
DDT	dichlorodiphenyltrichloroethane
HCB	hexachlorobenzene
HCH	hexachlorocyclohexane
Hg	mercury
MeHg	methylmercury
OC	organochlorine
OCS	octachlorostyrene
Pb	lead
PBDEs	polybrominated diphenyl ethers
PCBs	polychlorinated biphenyls
PCNs	polychlorinated napthalenes
PCP	pentachlorophenol
PFOA	perfluorooctanonate
PFOS	perfluorooctanesulfonate
POPs	persistent organic pollutants
SCCPs	short-chained chlorinated paraffins

FIGURES

TABLES

Table 1. Major groupings of legacy contaminants the NWHP measured and some of their potential negative effects on wildlife health

Table 2. Major groupings of emerging contaminants of concern and some of their potential negative effects on wildlife health

Table 3. Human tolerable daily intake (TDI) levels compared to the magnitude by which contaminant levels in wildlife exceed human TDIs. The animal values were generated by dividing the tissue concentration (not shown) by the corresponding TDI. Human TDIs were established by Health Canada and the World Health Organization.

Overview

Landscape © WWF-Canada/Wendy L. Douglas

part 1 // **1.0 the nunavut wildlife health assessment project: overview**

The Nunavut Wildlife Health Assessment Project (NWHP) is a joint initiative of the Hunters' and Trappers' Organizations/Associations (HTOs/HTAs) of Arviat, Coral Harbour and Pangnirtung, World Wildlife Fund Canada (WWF-Canada) and Trent University. The overall goal of the NWHP is to assess the impact of contaminants on wildlife health, using histological survey (i.e., microscopic examination of cellular structure) of sensitive tissues, analysis of contaminant levels in affected tissues and documentation of hunters' observations (Inuit Qaujimajatuqangit, or IQ) of gross anomalies in harvested wildlife. The NWHP aims to develop a research framework that allows for meaningful collaboration between Inuit hunters and environmental scientists in assessing the potential effects of persistent organic pollutants (POPs) and other stressors on the health of Arctic wildlife. It is believed that this approach will benefit northern communities by facilitating capacity building with the aim of helping local stakeholders participate more fully in the evolution of wildlife management and the identification of risk-management options tailored to meet their needs and to ensure the long-term sustainability of their wildlife resources. This approach also is consistent with the global initiative of World Wildlife Fund for Nature (WWF) on toxic chemicals, which calls for the elimination and phase-out, by 2007, of 30 toxic, bioaccumulative and persistent substances currently in use globally, and of 100 more such substances by 2014. The Stockholm Convention on POPs, which came into force on May 17, 2004, will implement a phased approach to the elimination of 12 POPs. Governments must now focus on other persistent and bioaccumulative substances, such as those being detected in Arctic wildlife and the Arctic environment.

The three primary goals of the NWHP are as follows:

1. To develop a community-based protocol for assessing and monitoring wildlife health

2. To investigate potential linkages between the status of wildlife health and animals' exposure to chemical contaminants found in the environment

3. To communicate the results of wildlife health assessment and monitoring, and to promote environmental education and capacity building in participating communities

Community involvement and the transfer of traditional and scientific knowledge are two of the most important aspects of the NWHP initiative. The project began with community consultations, which led to significant contributions to the design of the study.

The NWHP has three major phases:

PHASE 1 — to document Inuit local knowledge (IQ)

PHASE 2 — to investigate whether current levels of contaminants in wildlife species (Arctic char, ringed seal and beluga) are associated with histological anomalies

PHASE 3 — to communicate the results of phases 1 and 2

This report summarizes the highlights of the second phase of the NWHP, which focused on measuring contaminant levels in tissue samples and carrying out a histological review of those tissues to investigate whether correlations between chemical body burden and histological anomalies exist.

Introduction

Nunavut Elder © WWF-Canada/Wendy L. Douglas

introduction

There is a growing awareness of the fragility of the Arctic ecozone and the need to better control the management of POPs that can be transported long distances from elsewhere to circumpolar regions of the North. Most of the POPs now present in the Canadian Arctic have never been used or produced in this region. Some, such as polychlorinated biphenyls (PCBs) have been used in this region, but only in limited quantities in small areas associated with the Distant Early Warning (DEW) Line. Still others, such as mercury, are present as a result of both natural local and human-induced long-range sources, each of which can be influenced by changing climatic conditions. Many legacy POPs, such as PCBs and dichlorodiphenyltrichloroethane (DDT), have been banned in Canada for more than 20 years. Although the levels of some compounds are slowly declining, their resistance to breakdown in the environment means that many persist and accumulate in wildlife. Other more recently manufactured compounds, such as the brominated flame retardants (BFRs, including polybrominated diphenyl ethers [PBDEs]), are on the rise. Environmental concentrations of these emerging chemicals of concern, however, are often one to two orders of magnitude lower than concentrations of the more notable legacy POPs (e.g., PCBs).

The levels of POPs in the abiotic compartment (i.e., ice, snow, water, sediments) are relatively low but could bioaccumulate and biomagnify in the northern food web, eventually reaching levels of concern in some apex wildlife (i.e., top predators such as polar bear). Northern communities that rely on local wildlife as an important dietary and cultural resource have expressed concern about the potential impacts that these contaminants may have on the long-term health of wildlife populations.

Extensive research has been conducted in the Arctic since the early 1980s to identify anthropogenic chemicals (i.e., human-made chemicals) and their concentrations in Arctic ecosystems. Studies have provided a valuable database identifying contaminant sources, pathways and sinks (locations where contaminants deposit and accumulate), making assessment of future contaminant trends possible. Relatively less is known about the current health status of wildlife populations and the potential long-term impact these contaminants may have on them, particularly in the harsh environment of the Far North where animals experience prolonged periods of cold and fasting. Even fewer studies have investigated how contaminants influence wildlife health in a multi-stressor environment where Arctic animals are being affected by climate change, changing disease patterns and alterations to habitat, as well as exposure to new contaminants.

Monitoring the health status of Arctic wildlife can be prohibitively expensive given the logistic difficulty of undertaking scientific field studies in remote Arctic regions. The monitoring and assessment of wildlife health could be facilitated through the development of an approach involving local wildlife users. Northern Aboriginal peoples possess in-depth knowledge of the physical condition of the wildlife in the Arctic environment. These observers may identify subtle changes in animal health or behaviour that could be logistically challenging to identify in routine monitoring programs.

The lack of studies on wildlife health in the Arctic is particularly disturbing since a growing body of evidence indicates that the exposure of animals to highly polluted environments can negatively affect their health, causing alterations to the endocrine system, immune suppression and neurological disruption (Braathen et al., 2004; Derocher et al., 2003; Lie et al., 2004, 2005; Oskam et al., 2004; Zhou et al., 1999). Climate change is an additional factor that could modulate the sensitivity of Arctic wildlife to the impacts of chemical contaminants (Gordon, 2003). Furthermore, it is not clear what long-term impacts may occur in Arctic wildlife as animals cope with multiple stressors such as habitat loss, migration of disease and pathogens, and changes to prey items and food sources (Boonstra, 2004; Hoberg et al., 2002; Kutz et al., 2004; Thompson et al., 1997). A decrease in overall fitness may lessen an animal's resilience to contaminant-related effects and, in combination with other stressors, may reduce the long-term survival of wildlife populations.

The NWHP entailed three phases. The first phase was documentation of IQ, also known as local traditional knowledge. The Inuit Qaujimajatuqangit report (Sang, Booth and Balch, 2004) documented the local environmental knowledge of a selected group of local Elders and hunters on wildlife health based on their observation during subsistence harvesting. The second phase was to determine current levels of POPs (both legacy and emerging contaminants of concern, such as PBDEs) and trace elements (including mercury) in selected tissues of Arctic char, ringed seal and beluga. A histological survey of selected tissues from ringed seal and beluga was also conducted to evaluate potential associations between contaminant levels and tissue anomalies. The third phase was devoted to communicating study results and transferring knowledge to the participating communities.

This report provides a brief overview of the highlights of the POPs analysis and histological survey results from phase 2 of the NWHP. During this phase, tissues from 18 Arctic char, 18 ringed seal and 6 beluga were analyzed for a suite of trace metals such as mercury (i.e., methylmercury and total mercury) and legacy POPs (e.g., PCBs, DDT, toxaphene), along with several classes of emerging contaminants of concern — the BFRs (including PBDEs), octachlorostyrene (OCS) and hexachlorobenzene (HCB).

Participating Communities

Nunavut hunter and family © WWF-Canada/Wendy L. Douglas

part 3 // 3.0 communities participating in the nwhp

The Kivalliq region communities of Arviat and Coral Harbour (located in the western Hudson Bay region) and the south Baffin Island community of Pangnirtung participated in the tissue collection (Figure 1).

FIGURE 1: LOCATION OF THREE ARCTIC COMMUNITIES, PANGNIRTUNG, CORAL HARBOUR AND ARVIAT, NUNAVUT

The selection of these three communities was based on recommendations that the Qikiqtaaluk Wildlife Board and the Kivalliq Wildlife Board provided and on extensive consultation with the HTOs/HTAs of candidate communities. After being selected, HTOs/HTAs of participating communities signed memorandums of understanding with WWF-Canada.

Arviat (formerly Eskimo Point), located north of Churchill, Manitoba, on the western shore of Hudson Bay, is the most southerly community in Nunavut. With a population of 1,500 (96% Inuit), Arviat is one of the larger communities in the Kivalliq region. Inuit in Arviat traditionally hunt ringed seal, beluga, caribou, polar bear and Arctic char.

In Inuktitut, **Coral Harbour** is called Salliq (Big Island). Approximately 700 people (94% Inuit) occupy this small community located in the southern part of Southampton Island. Wildlife of the area includes caribou, which were once on the brink of extinction on the island but now are plentiful. An abundance of marine wildlife lives offshore, including polar bear, beluga, walrus and ringed seal. Many marine and land animals, as well as birds, inhabit Coates Island and Walrus Island, just off Coral Harbour.

Pangnirtung (also known as the "place of the bull caribou") is located on a narrow coastal plain on the eastern coast of the Cumberland Peninsula on southern Baffin Island. The community has a population of over 1,200 (93% Inuit). Marine wildlife — traditional food items such as beluga, ringed seal, walrus and Arctic char — are important to the subsistence of the community, as are caribou, which typically are found a considerable distance from Pangnirtung.

Methods


Nunavut hunters © WWF-Canada / Wendy L. Douglas

methods

Coordinators for the NWHP were appointed in each community on the basis of recommendations by the local HTO/HTA. The community coordinator, working in conjunction with the local HTO/HTA governing board, invited hunters to participate in training workshops and in the collection of samples. The training workshops outlined the purpose of the study and provided details regarding sample collection. The community coordinators issued sample kits to hunters who were to participate in the NWHP. They were asked to provide specific tissue samples from wildlife harvested for food and to comment briefly on the health condition of each animal sampled. The community coordinators shipped the tissues and accompanying data sheets to Trent University for contaminant analysis and histological examination.

Each community was asked to provide a total of 30 Arctic char and 20 ringed seals collected between the autumn of 2002 and the spring of 2003. During the autumn of 2003 communities were asked to provide samples from up to 15 beluga. Tissue samples collected for both chemical analysis and histological review were sent to Trent University, where samples were analyzed for contaminants and microscope slides were prepared. A veterinary pathologist then examined the microscope slides for any pathological anomalies.

Greater detail regarding the methodology of the NWHP is given in Appendix 1.

Results

part 5 // 5.0 results / 5.1 contaminant levels / 5.2 histological findings

results

5.1 CONTAMINANT LEVELS

Arctic char

Overall the mean contaminant levels of individual chemical groups were low, less than 10 nanograms per gram (ng/g). Toxaphene, PCBs, DDT and chlordane were the dominant contaminants found in the muscle tissue of char. Greater than 95 percent of the organic contaminant burden of analyzed compounds was attributed to the seven major classes of organochlorine (OC) contaminants outlined in Figure 2. Appendix 2 provides numerical summaries of all measured contaminants. The mean age of sampled fish was 10 years, plus or minus 3 years (sample size [N] = 18). Contaminant levels were generally higher in the two communities in the Kivalliq region (Arviat, Coral Harbour) in comparison with those in Pangnirtung in the southern Baffin Island region. Examples of these regional differences for are shown in Figure 3.

FIGURE 2. DOMINANT ORGANOCHLORINES (OCs) MEASURED IN ARCTIC CHAR

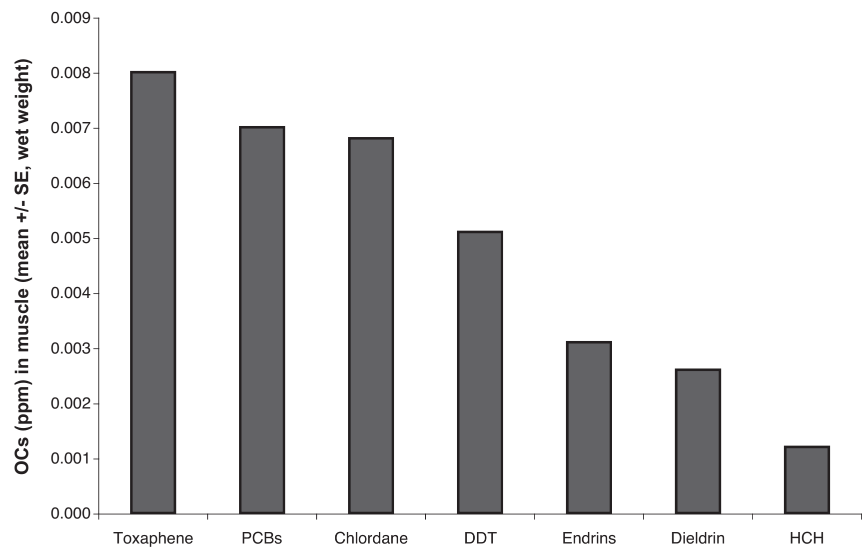
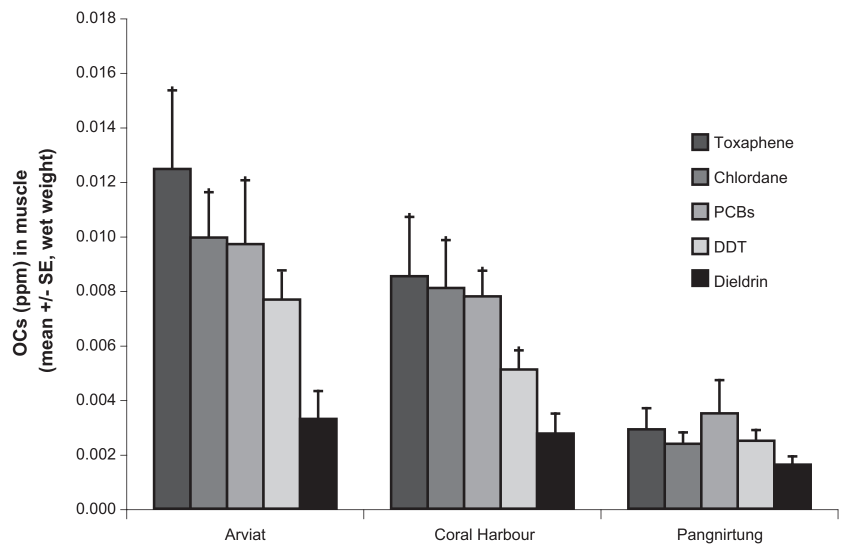


FIGURE 3. REGIONAL TRENDS IN ORGANOCHLORINE (OC) LEVELS IN ARCTIC CHAR



The concentration of trace metals (wet weight basis) in the dorsal muscle of char was 0.062 micrograms per gram (μg/g) total mercury, 26 μg/g lead and 1.4 micrograms per gram (μg/g) cadmium.

Ringed seal

The dominant OC contaminants in blubber of ringed seal were PCBs, DDT, HCH and chlordane (Figure 4). Regional differences in the level of contaminants between the Kivalliq and Baffin Island samples were not evident (Figure 5). The concentration of contaminants in the muscle (wet weight) of seal was generally two orders of magnitude less than that found in the blubber. Most seals sampled were less than 1 year old, with the exception of a 13-year-old female seal and a 14-year-old male seal from Coral Harbour and a 19-year-old male seal from Pangnirtung. The 13- and 14-year-old seals from Coral Harbour did not exhibit PCB levels that were elevated in comparison with those found in the four remaining seals, which were pups (less than 1 year old). Although the 14-year-old male was the oldest seal sampled from Coral Harbour, it had a PCB concentration (315 ng/g blubber, wet weight) that was in the range of values measured for the four seal pups (144–324 ng/g blubber, wet weight). However, the 19-year-old male seal from Pangnirtung exhibited a PCB concentration (1,293 ng/g blubber, wet weight) that was well above the PCB concentration in the remaining five seals, which ranged from 152 ng/g to 381 ng/g (blubber, wet weight).

FIGURE 4. DOMINANT ORGANOCHLORINES (OCs) MEASURED IN RINGED SEAL

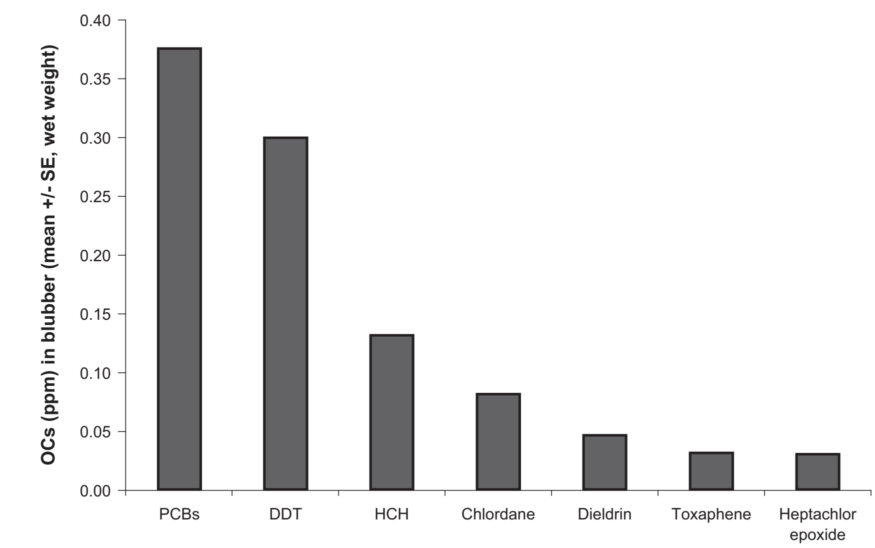
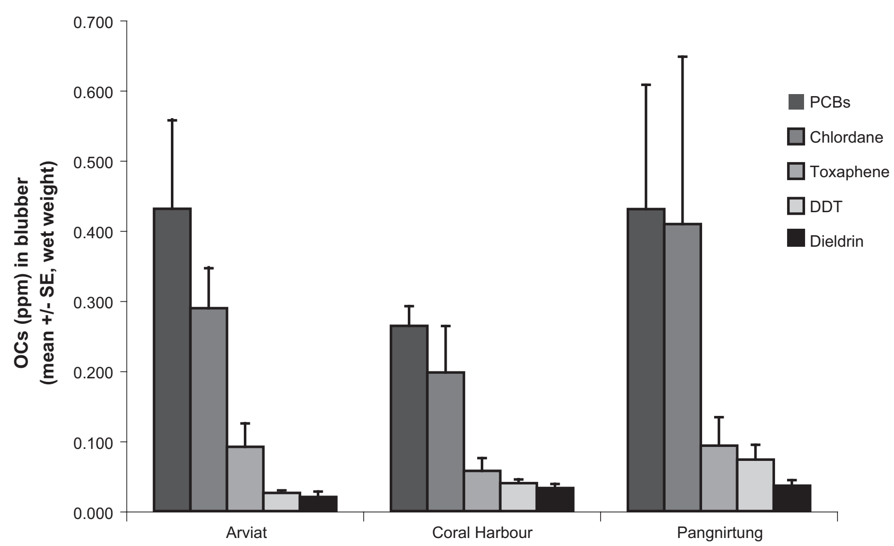


FIGURE 5. REGIONAL TRENDS IN ORGANOCHLORINE (OC) LEVELS IN RINGED SEAL



The concentrations of cadmium were the highest concentrations among the three trace elements analyzed; the highest cadmium concentrations were observed in the kidney and the lowest in muscle tissue. The average concentration of cadmium determined for all kidney tissue analyzed (i.e., for all three communities) was

24 µg/g (N = 18, wet weight), although slight regional differences were observed (Figure 6). The highest concentration of mercury was found in the liver. The lowest levels of mercury were found in the muscle; however, greater than 90 percent of the mercury in the muscle was methylmercury (Figure 7). The mean concentration of lead was similar in both liver and kidney tissue and lowest in muscle. In all tissues, mean lead concentrations were below 0.06 µg/g. Appendix 3 provides mean values of all contaminants analyzed in ringed seal tissue.

FIGURE 6. MEAN CADMIUM (Cd) CONCENTRATIONS IN RINGED SEAL MUSCLE, LIVER AND KIDNEY

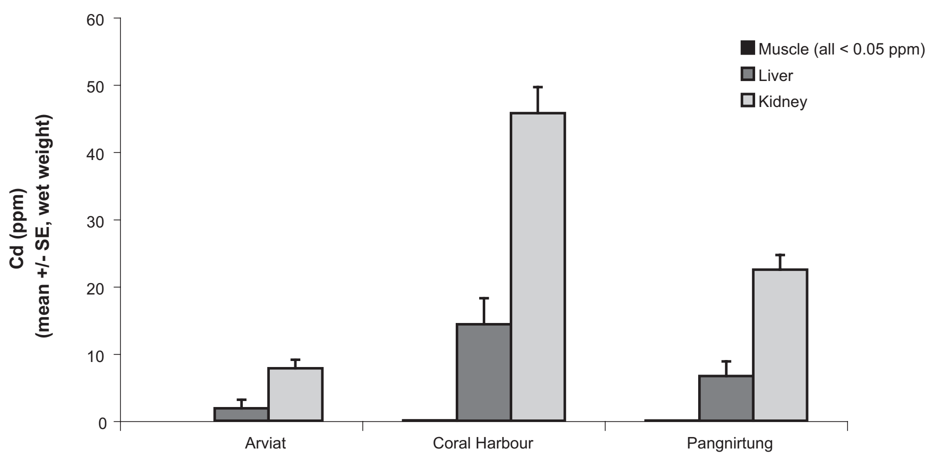
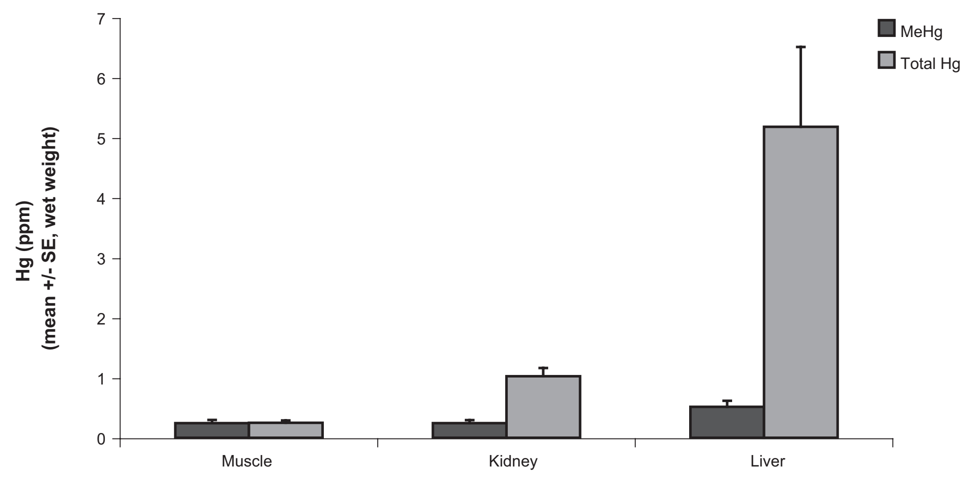


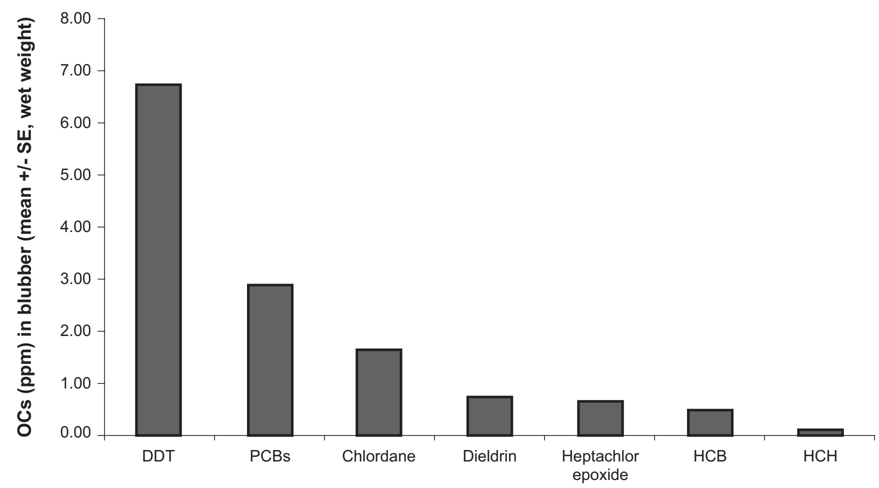
FIGURE 7. MEAN MERCURY CONCENTRATIONS IN RINGED SEAL EXPRESSED AS TOTAL MERCURY (Hg) AND METHYLMERCURY (MeHg)



Beluga

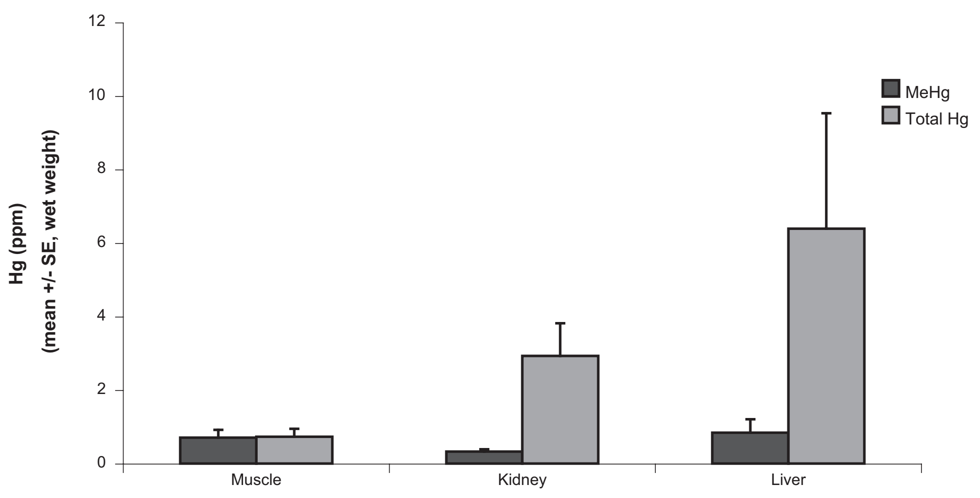
DDT, PCBs and chlordane were the dominant OC contaminants observed in the beluga samples collected in Arviat in 2003 (Figure 8). The concentration of these compounds in beluga was approximately one order of magnitude higher than the concentration found in ringed seal. Contaminant concentrations in the muscle tissue were generally two orders of magnitude lower than the concentrations measured in the blubber (Appendix 4). Mercury concentrations were the highest in the liver, followed by lower levels in the kidney and muscle tissues. The ratios between total mercury and methylmercury were similar to the trends observed in ringed seal in that approximately 13 percent of the mercury burden of the liver was methylmercury, yet in the muscle over 90 percent of the total mercury (Figure 9) was in the form of methylmercury.

FIGURE 8. DOMINANT ORGANOCHLORINES (OCs) MEASURED IN BELUGA*



***NWHP did not measure toxaphene in beluga; however, the toxaphene concentration in beluga blubber sampled in 1992 from Baffin Island Region was 9.4 ppm (Stern, 1999).**

FIGURE 9. MEAN MERCURY CONCENTRATIONS IN BELUGA EXPRESSED AS TOTAL MERCURY (Hg) AND METHYLMERCURY (MeHg)



5.2 HISTOLOGICAL FINDINGS

A histological survey was conducted on selected tissues (liver, kidney, adrenal, gonadal and lymph nodes) collected in 2003 from 38 seals harvested near all three communities and from seven beluga harvested in the Coral Harbour region of Nunavut. In the same year, tissues from approximately 50 Arctic char were also collected for histological review. However, the fish were captured with the use of gill nets, which meant that most, if not all, had died hours before their tissues were placed in fixative. Therefore these tissues where not useful for histological purposes because of the ensuing cell damage.

The hunters collected tissue samples from animals that had no apparent gross anatomical anomalies. Despite the lack of such anomalies, the histological survey did reveal unusual conditions in some tissues. Highlights from the histological survey are presented on the next page.

Ringed Seal (N = 30) — Arviat, Coral Harbour and Pangnirtung:

- Over 80 percent of seal lymph nodes (those from 31 of 38 seals) were reactive or showed draining suggestive of an inflammatory response in surrounding tissues, and over 70 percent of seals (27 of 38) exhibited what may be bacteremia in liver tissues. The cause or biological significance of these responses is unknown.

- Seven male ringed seals exhibited inactive spermatogenesis, most likely the result of sexual immaturity. One ringed seal had somewhat larger necrotic and inflamed lesions in the hepatic parenchyma, which appear to have resulted from the migration of metazoan parasites in the liver.

- Another ringed seal had prominent areas of damage in the liver, which could have been caused by exposure to a toxic substance or a viral pathogen.

- One ringed seal displayed hypertrophy (swollen or enlarged cells) of the tunica media of renal arteries (smooth muscle cells of the artery walls in the kidneys) of unknown cause.

Beluga (N = 7) — Coral Harbour:

- Twenty-nine percent of beluga (2 of 7) exhibited what may be bacteremia in liver tissues. The cause or biological significance of these responses is unknown.

- Forty-two percent of beluga lymph nodes (3 of 7 beluga) were reactive or draining, which suggests an inflammatory response in surrounding tissues.

One of the most interesting observations from the histological survey originated from the lymph nodes. In the case of ringed seal, the majority of lymph nodes were reactive, which suggests that zoonotic pathogens (those that can be transmitted from animals to humans) may be present. A similar condition was noticed in approximately one-half of the beluga examined. The significance of these findings is currently unknown since few data exist concerning the extent of the occurrence of this condition.

Discussion

discussion

In recent years, we have realized that more effort should be devoted to investigating the biological effects on Arctic wildlife due to the exposure to anthropogenic compounds and that we can no longer use experimentally derived thresholds (i.e., those derived from research on non-Arctic species) as our only predictor of impact. Much of this thinking has been influenced by recent studies examining the health of free-roaming animals. These findings suggest that some Arctic species, such as the polar bear, may be negatively affected by contaminants. Polar bears are at the apex of a long marine food web. This species generally accumulates a greater body burden of chemical contaminants than other animals do and therefore has received the most research attention. Work by Lie et al. (2004, 2005), Oskam et al. (2004), Braathen et al. (2004) and Derocher et al. (2003) indicates that contaminant-related effects are occurring in this species. The types of effects observed in polar bear are not easily identified in routine monitoring programs. Most effects are best characterized as subtle changes, such as alterations to the immune system or hormone levels. Although the significance of these subtle changes is generally unknown, they suggest that the future sustainability of the current health condition of polar bear may be jeopardized if this species continues to be exposed to anthropogenic compounds, and particularly when such exposure is combined with predicted changes in climatic conditions and an associated degradation of habitat quality. Less is known about the potential effects on other Arctic species, especially marine mammals, which also accumulate elevated levels of organic contaminants.

A recent survey of Inuit traditional knowledge, or IQ, conducted by WWF-Canada and Trent University (Sang, Booth, and Balch, 2004) as phase 1 of the NWHP, documented that hunters in Pangnirtung, Coral Harbour and Arviat, Nunavut, perceive reduced fitness among harvested wildlife. Most of the changes hunters noticed are subtle and not easily detected with standard contaminant monitoring programs. One of the observed changes is incomplete moulting in seals, which suggests that these animals spend a shorter period than normal on platform ice. Other changes noticed were in the texture (firmness) of internal organs or adhesion of organs to the lining of the peritoneal cavity, which are both suggestive of scar tissue resulting from chronic inflammation, possibly resulting from chemically or pathogen-induced tissue damage.

6.1 CONTAMINANT LEVELS AND HISTOLOGICAL SURVEY

NWHP investigations did not find any association between the concentration of analyzed compounds and histological anomalies of harvested wildlife. These results were not completely unexpected; researchers realized at the start of the project that elements of the study design would limit the sensitivity of this investigation. Following are some of the limiting factors:

1. Hunters generally avoided harvesting animals that appeared unhealthy, therefore biasing the sample collection towards healthy animals.

2. Limited financial resources for sample analysis and the logistical challenges of sample collection limited sample sizes to levels that were too small and insensitive for the identification of infrequent tissue anomalies.

3. The use of histology is often an insensitive indicator of chemical exposure. Chemically induced histological alterations are most often associated with relatively high levels of exposure to contaminants and therefore may not provide a sensitive indicator of effects arising from chronic exposure to relatively low contaminant levels.

Despite these limitations, the histological results did reveal what appears to be an elevated incidence of inflammation in lymph nodes and liver tissue of both ringed seal and beluga. The causative agent(s) and biological significance of these findings are unknown. These conditions may, however, support the IQ observations, which suggest that the textural condition of some organs, such as the liver, is firmer than hunters observed historically. One explanation may be a greater incidence of scar tissue as a result of chronic inflammation. This explanation, however, is only speculative. The interpretation of this data will require more investigation to identify (i) the baseline frequency, prevalence and intensity of inflammatory responses and other histological alterations in Arctic wildlife; (ii) agents and mechanisms responsible for the alterations and anomalies; and (iii) the biological significance of these responses. Also, an animal's sex, stage of life, reproductive maturity, degree of fasting and many other natural parameters are generally known to greatly influence organ morphology observed at the cellular level. At present, the specific influence that these parameters have on Arctic wildlife is not fully understood; their influence must be investigated in order to increase the interpretive abilities of histological investigations.

6.2 NWHP CONTRIBUTIONS TO CONTAMINANT DATABASES

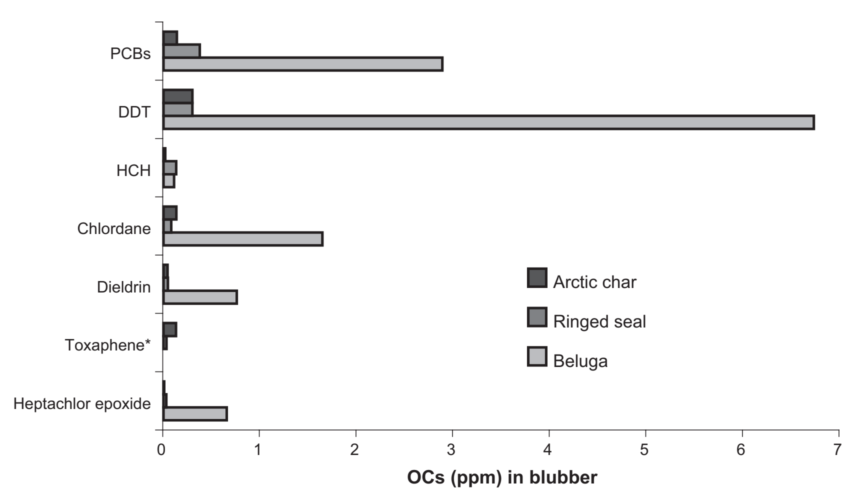
Information regarding the concentration levels of contaminants in Arctic char is limited, and the NWHP has contributed to scientific knowledge by providing additional information, particularly for PBDEs and toxaphene. In addition, the NWHP has provided information for emerging contaminants of concern in char, seal and beluga, about which relatively little is known. The contaminants of concern are endrin, endosulfans, dieldrin, methoxychlor, mirex, HCB, OCS, pentachloroanisole and heptachlor epoxide.

6.3 COMPARISON OF NWHP CHEMICAL RESULTS WITH PUBLISHED DATA

Contaminant levels determined in the NWHP are generally in agreement with the range of concentrations summarized in CACAR II (2003). Both the NWHP and CACAR II (2003) summaries identify PCBs, DDT, toxaphene and chlordane as being the dominant OC compounds and mercury and cadmium as the major trace elements found in Arctic char, ringed seal and beluga. The concentration levels the NWHP found were slightly different from other published results, but most of the differences can probably be explained by differences in sample years, sample locations, organism age and sex, and sample size. In the NWHP data, slight regional differences were apparent between the Kivalliq and Baffin Island locations with respect to char but not with respect to ringed seal. The mean age of char was near 10 years (N = 18), while most seals sampled were pups less than 1 year old. The significantly younger age of seals may be a factor contributing to a lack of regional difference for this species. The higher contaminant concentration in char from the Kivalliq region may be partially explained by the relatively greater levels of precipitation and longer retention of water (i.e., flushing rate of Hudson Bay), which could reflect slight differences in contaminant exposures.

Figure 10 illustrates the relative OC concentrations among char, seal and beluga (based on lipid content). As expected, the concentrations in beluga are many times greater than those found in char and seal, and therefore beluga are at greater risk of sustaining negative effects from exposure to contaminants.

FIGURE 10. COMPARISON OF ORGANOCHLORINE (OC) CONCENTRATIONS IN ARCTIC CHAR, RINGED SEAL AND BELUGA

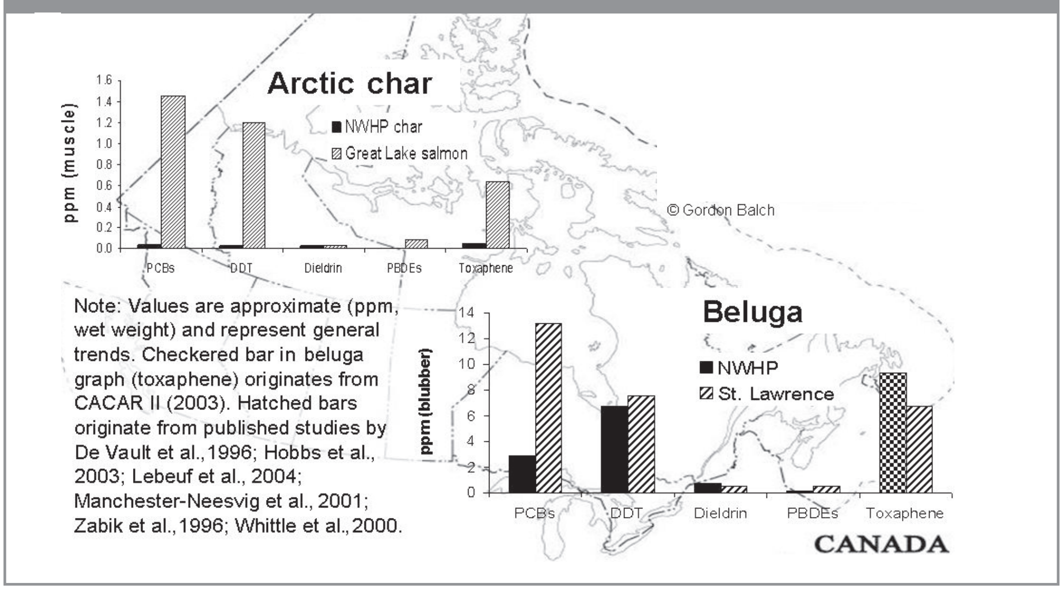


***NWHP did not measure toxaphene in beluga; however, the toxaphene concentration in beluga blubber sampled in 1992 from Baffin Island Region was 9.4 ppm (Stern, 1999).**

6.4 COMPARISON OF ARCTIC CONTAMINANT LEVELS WITH LEVELS IN OTHER REGIONS OF CANADA

Contaminant levels that the NWHP measured in Arctic char are generally 15 to 40 times lower than the concentrations of PCBs, DDT and toxaphene measured in salmonids (salmon and trout) from the Great Lakes (Figure 11). The magnitude of difference between contaminant concentrations found in Arctic beluga and those of the St. Lawrence are not as great as seen with fish. Concentrations of PCBs and DDT are only one to four times lower in Arctic populations. Toxaphene levels in Arctic beluga are similar to, and possibly slightly higher than, levels measured in St. Lawrence beluga. Toxaphene was never used in the Great Lakes region and exposure to this chemical in both groups is assumed to have resulted from the long-range transport of this compound, a factor that has probably contributed to toxaphene levels in these two regions being similar. PCBs and DDT were used in the Great Lakes area and therefore are expected to be found in greater concentrations in the St. Lawrence animals. Environmental concentrations of PCBs and DDT still continue to be present in animals of the Baltic region of Europe (Nyman et al. 2002), where concentrations in ringed seal are approximately three fold higher than those observed in the NWHP ringed seal samples collected in the Kivalliq and Baffin Island regions.

FIGURE 11. COMPARISON OF ARCTIC CONTAMINANT LEVELS WITH THOSE IN OTHER REGIONS OF CANADA



6.5 POTENTIAL EFFECTS OF ARCTIC CONTAMINANTS ON WILDLIFE HEALTH

The major contaminants the NWHP identified in the tissues of char, ringed seal and beluga are reflective of the dominant contaminants reported elsewhere, such as those summarized in CACAR I and II (CACAR, 1997, 2003). Table 1 lists the primary contaminants the NWHP identified and some of their potential effects on wildlife health. Many of these compounds, along with emerging contaminants of concern (discussed below), are known to negatively affect animals' neurological development and function, immune systems, endocrine systems, homeostasis of various hormone complexes, and reproduction. Most mechanisms of action have been determined in experimental models or in wildlife from heavily industrialized or polluted temperate regions. Only recently have investigations begun to document molecular mechanisms of action demonstrating the potential effects specific to the health of Canadian Arctic wildlife.

TABLE 1. MAJOR GROUPINGS OF LEGACY CONTAMINANTS THE NWHP MEASURED AND SOME OF THEIR POTENTIAL NEGATIVE EFFECTS ON WILDLIFE HEALTH

CONTAMINANT	POTENTIAL NEGATIVE EFFECTS ON WILDLIFE HEALTH
PCBs	Neurobehavioural effects, disruption of sex hormones, increased risk of cancer, impairment of fine motor skills, effects on thyroid and immune systems
DDT	Reproductive effects, possible increased risk of cancer
Chordane	Damage to internal organs (liver, kidney, adrenals); developmental, neurological and immunological effects on the fetus
Toxaphene	Neurological and immunological effects, increased risk of cancer
HCH (hexachlorocyclohexane)	Effects on endocrine, immunological and neurological systems
HCB (hexachlorobenzene)	Damage to internal organs (liver, kidney, adrenals); effects on endocrine, neurological and immunological systems
Dieldrin	Liver damage, possible risk of cancer, suppression of the immunological system
Endrins	Effects on nervous system; potential birth defects, particularly those relating to bone abnormalities
Endosulfans	Effects on the central nervous system, reproductive impairment
Heptachlor epoxide	With high exposure levels, effects on liver, kidney and adrenal glands
Mirex	Effects on liver and kidney, impairment of neurological and endocrine (thyroid, sex hormones) systems
Hg (total)	Neurobehavioural effects

Emerging contaminants of concern for which much less is known include polychlorinated napthalenes (PCNs), BFRs, perfluorooctanesulfonate (PFOS), perfluorooctanonate (PFOA), HCB, short-chained chlorinated paraffins (SCCPs), OCS and pentachlorophenol (PCP). In most cases body burdens of these compounds are still low in comparison with body burdens of the legacy contaminants; however, much less is known about the implications of long-term exposure to emerging contaminants of concern. Table 2 shows some potential negative effects of these contaminants on wildlife health.

TABLE 2. MAJOR GROUPINGS OF EMERGING CONTAMINANTS OF CONCERN AND SOME OF THEIR POTENTIAL NEGATIVE EFFECTS ON WILDLIFE HEALTH

CONTAMINANT	POTENTIAL NEGATIVE EFFECTS ON WILDLIFE HEALTH
PCNs (polychlorinated napthalenes)	General disruption of the hormone systems
PFOS (perfluorooctanesulfonate)	Detected in Arctic wildlife but effects on health largely unknown
PFOA (perfluorooctanonate)	Detected in Arctic wildlife but effects on health largely unknown
SCCPs (short-chained chlorinated paraffins)	Effects largely unknown; suspected disruption of thyroid and possibly other hormonal systems
HCB (hexachlorobenzene)*	Damage to internal organs (liver, kidney, adrenals); effects on endocrine, neurological and immunological systems
OCS (octachlorostyrene)*	Effects largely unknown; suspected disruption of endocrine systems
PCP (pentachlorophenol)	Effects largely unknown; suspected disruption of endocrine systems
PBDEs (polybrominated diphenyl ethers)*	Disruption of thyroid hormone homeostasis

*Analyzed by NWHP

One of the major factors hindering predictive interpretation of the effects of contaminants on wildlife is the general lack of knowledge of how physiological parameters specific to Arctic species influence the effects these compounds have. The following section (6.6) provides a brief overview of how toxicity thresholds have been generated and used historically as an assessment tool to predict contaminant concentrations believed to cause harm to wildlife. This section also summarizes how some of the qualities specific to Arctic species may limit the applicability of laboratory-derived thresholds.

6.6 TOXICITY THRESHOLDS

Assessing the potential effects of contaminants on the health of Arctic wildlife is difficult in the absence of the necessary relevant toxicological data. Researchers have therefore had to make comparisons with other studies often conducted with non-Arctic species (model laboratory animals) investigated under environmental conditions very different from those that occur in the Arctic. Most studies involve the investigation of single compounds at relatively high exposure levels administered over short periods. Although these investigations are extremely helpful in providing insight into determining the relative toxicological potency of one substance versus other substances, often such investigations fail to adequately address questions that arise when trying to extrapolate from high experimental doses to lower doses that are more relevant to the environment. The short exposure periods often necessitated by experimental design, cost and testing resources may not take into account many of the sensitive developmental stages that could be affected over the course of an animal's lifetime, beginning in utero and continuing during critical periods of physical and neurobehavioural development.

Physiological, behavioural and environmental differences also exist between Arctic wildlife and laboratory animals that could significantly influence the sensitivity of Arctic wildlife to contaminants. For example, many Arctic species have adapted strategies to deal with the harsh environmental realities of the North. One survival strategy is for animals to seek foods rich in energy in preparation for prolonged periods of fasting. Polar bears, for example, feed heavily on the blubber of seals, which often contains elevated levels of POPs. Many contaminants are relatively inert (inactive) when sequestered in the fat reserves of the animal, but, in periods of fasting or lactation, the fat reserves are metabolized and circulate in the plasma of the adult or are passed on to nursing young during critical periods of development. Because of these differences, researchers are recognizing the need for toxicological assessments specific to Arctic wildlife and that laboratory-derived data using non-Arctic species may not be sufficient as the only assessment tool for identifying toxicity thresholds.

Given that little is known about threshold levels relevant to Arctic wildlife, the NWHP compared tissue residues analyzed in Arctic char, ringed seal and beluga with the tolerable daily intake (TDI) levels for human consumption (Table 3) established by either Health Canada or the World Health Organization. Note that applying human consumption rates to contaminant residues in the tissues of wildlife must be done cautiously since some animals, such as the polar bear, are known to be more efficient than humans in metabolizing and eliminating some chemical compounds. Such comparison, however, has some value in that it illustrates the relatively high levels of contaminants in the prey items of some apex animals like the polar bear. For example, polar bears feed heavily on the blubber of ringed seals, which the NWHP found to contain over 300 parts per billion (ppb) of PCBs, a value well above the 1 ppb lifetime consumption level recommended to be safe for humans.

TABLE 3: HUMAN TOLERABLE DAILY INTAKES (TDIs) LEVELS COMPARED TO THE MAGNITUDE BY WHICH CONTAMINANT LEVELS IN WILDLIFE EXCEED HUMAN. THE ANIMAL VALUES GENERATED BY DIVIDING THE TISSUE CONCENTRATION (NOT SHOWN) BY THE CORRESPONDING TDIs. HUMAN WERE ESTABLISHED BY HEALTH CANADA AND THE WORLD HEALTH ORGANIZATION.

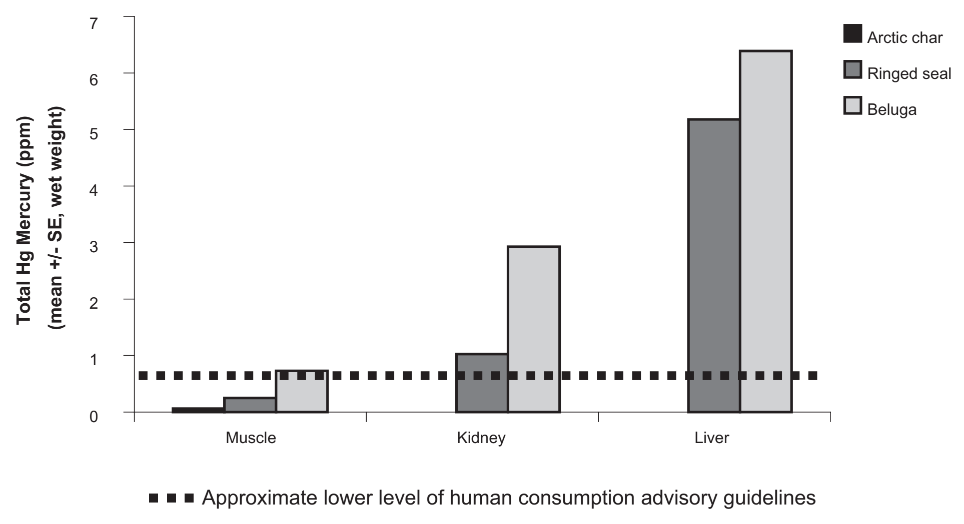
CONTAMINANT	HUMAN TDI µg/kg per bw/d*	CHAR MUSCLE INCREASE	SEAL MUSCLE INCREASE	SEAL BLUBBER INCREASE	BELUGA MUSCLE INCREASE	BELUGA BLUBBER INCREASE	BELUGA KIDNEY INCREASE	BELUGA LIVER INCREASE
PCBs	1.000	7	2	375	19	2,886	13	48
DDT	20.000	0	0	15	1	337	22	64
Toxaphene	0.200	40	2	155	nd***	38,800	nd	nd
Chordane	0.050	136	8	1,620	260	32,900	4	155
HCH	0.600	2	2	218	3	182	3	5
HCB	0.050	5	0	118	120	9,740	113	2,462
Dieldrin	0.100	26	6	460	30	7,380	11	87
Endrins	na**	nd	nd	nd	nd	nd	nd	nd
Endosulfans	na	nd	nd	nd	nd	nd	nd	nd
PBDEs	na	nd	nd	nd	nd	nd	nd	nd
Heptachlor epoxide	0.100	4	2	300	50	6,550	40	145
Mirex	0.070	0	0	71	2	214	155	66
Hg (total)	0.071	87	351	nd	1,030	nd	47	26

*bw/d = body weight per day **na = not available ***nd = not determined

Table 3 summarizes the magnitude (determined by dividing the animal contaminant level by the TDI) by which contaminant concentrations in wildlife tissue exceed the TDI level for humans. When compared with human TDI levels, the high contaminant levels in prey animals (i.e., those used for food, e.g., ringed seal eaten by polar bear) suggest that top predators could be at risk. Also, high contaminant concentrations in animals may become harmful particularly during periods of fasting when they metabolize blubber reserves and release POPs to circulate within their blood and tissues. Risks to nursing young may also increase as mothers mobilize significant portions of their contaminant burdens when producing milk and thus transfer these compounds to their young, which potentially are more susceptible to the negative effects of contaminants.

Levels of mercury in char, seal and beluga tend to be high in comparison with human TDI levels (Figure 12). Although mercury is generally believed to disrupt neurological function, there are indications that the inorganic fraction of mercury (i.e., non-methylated form) may bind in a protective manner to selenium and thus be relatively inactive in the body. More information is still required, however, to confirm this assumption and to understand the potential for selenium to interact with the methylmercury faction, which is known to have a greater neurotoxicity potential. Lastly, more research is required to understand the sum effect arising from synergistic and antagonistic actions in chemical mixtures. This is particularly important since most wildlife contain a mixture of chemical compounds. Only recently have researchers begun to investigate the toxicity of some simple mixtures such as PCBs in combination with mercury. Preliminary results suggest that the combined effect is greater than would be predicted from adding the effects of these two compounds when tested individually (Roegge et al., 2004; Stewart et al., 2003; Newland, 2002).

FIGURE 12. TOTAL MERCURY CONCENTRATIONS IN ARCTIC CHAR (MUSCLE ONLY), RINGED SEAL AND BELUGA Hg COMPARED WITH HUMAN CONSUMPTION ADVISORY GUIDELINES FOR MERCURY



The vast expanse and remoteness of the Arctic environment complicates assessment of population-level effects beyond the gross monitoring of population numbers and visible epizootics (animal diseases) such as brucellosis in caribou. Financial and analytical resources necessary for establishing baseline health indices are generally limited or lacking. Because of this, little is known about contaminant-related effects at the level of the individual animal, tissue or molecular physiology. Effects could be occurring in a small number of individuals and not be readily evident because of either unseen death or other compounding factors related to climate that may mask the effects of chemical substances. Understanding effects at levels other than the population level will provide researchers greater predictive ability.

6.7 POTENTIAL EFFECTS OF CLIMATE ON WILDLIFE HEALTH

The Arctic Climate Impact Assessment report (ACIA, 2004) indicates that climate has the potential to significantly disrupt various Arctic species at a variety of levels, ranging from alteration of the primary producers, such as the algae community structure under the polar ice, to the polar bear, which is the top Arctic predator. Shorter periods of sea ice can greatly affect species such as polar bear, ringed seal and walrus that depend heavily on the ice as a platform for birthing, hunting and transportation. For example, polar bears are now being forced onto land for longer periods and therefore must undergo longer periods of fasting as the on-ice hunting time they need to develop healthy fat reserves decreases; this has the potential to disrupt polar bear reproduction (Derocher et al., 2004). Changing climate has the potential to significantly alter the community structure of primary producers and fish stocks, which are vital to higher level organisms such as seals and whales, forcing some animals to seek alternative prey that may be scarcer or less nutritious than their usual prey. Fluctuations in temperature can also increase the freeze–thaw cycles and alter precipitation levels, resulting in crust formation on the ice or deeper snow on top of plant food supplies that animals such as caribou need. Changing climatic conditions are also expected to alter the demarcation of vegetation zones as more southerly plant species move northward, displacing traditional tundra with more shrubs or treelike species.

6.8 POTENTIAL EFFECTS OF MULTIPLE STRESSORS ON WILDLIFE HEALTH

Boonstra (2004) considers global climate change and exposure to POPs to be the two long-term, persistent and pervasive changes confronting wildlife in the 21st century. It is now imperative that we study and understand the cumulative effects arising from multiple stressors associated with climate change and exposure to contaminants. No longer can we adequately assess effects on wildlife health without understanding the interaction of these two major classes of stressors.

Contaminant-related effects on animal health appear to be occurring in polar bear. The biological significance of these effects is not fully understood. Although contaminant levels in other Arctic species appear to be relatively low and possibly below threshold effect levels, we still do not have a good understanding of what those levels are in individual species, nor do we understand how climate-related changes may alter an animal's susceptibility to other health-related effects.

The fact that climate-related changes have the potential to influence the overall health and fitness of animals is well understood. For example, Thompson et al. (1997) have documented climate-related changes to food webs and how harbour seals in northern Scotland have had to switch from their preferred prey of clupeid herring to other species of less nutritional value. This switch has resulted in widespread macrocytic anemia, which these researchers hypothesize could significantly affect seal health. Laidre and Heide-Jørgensen (2005) have also recorded that cooling conditions in the Baffin Island region have significantly reduced the size of leads (cracks in ice cover) and open water, thereby making narwhal more vulnerable to entrapment, reducing available habitat and potentially increasing stress on these animals.

Climate change may also influence the toxicological sensitivity of an animal. Higher temperatures generally exacerbate the toxic effects of many environmental toxicants (Gordon, 2003) and have been known to be a significant risk factor in disease (Schisler and Bergersen, 2000). Global climate change has the potential to alter the dynamics of various wildlife diseases and pathogens (Harvell et al., 2002) and to disrupt contemporary ecological isolation barriers (i.e., temperature barriers to pathogen distribution) (Hoberg et al., 2002). Kutz et al. (2004) document the spread of a nematode lungworm in muskoxen and suggest that a warmer climate has been one of the driving factors in the recent spread of this pathogen. Prolonged periods of fasting or starvation, which may result from climate changes, are known to significantly lower the disease resistance of some fish species (Lim and Klesium, 2003).

Conclusion

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part 7 // 7.0 conclusion

conclusion

Recent studies on polar bear indicate that contaminants do influence biochemical processes; however, the long-term significance of these alterations to population dynamics remains unknown. Relatively less is known for other marine species such as the beluga, another species that the NWHP found to exhibit elevated levels of POPs. However, in the NWHP, no associations could be drawn between contaminant burdens in wildlife and histological anomalies. Small sample sizes, hunter bias towards the harvest of healthy animals and a general lack of background data regarding histological parameters specific to Arctic species limited the ability of this study to detect contaminant-related impacts on wildlife health using a histological approach.

The Arctic environment is changing and much remains to be learned about how climatic changes will influence habitat quality, contaminant cycling and the dynamics of pathogens and diseases. More resources are urgently needed to develop baseline data regarding current wildlife health indices, which will be needed to interpret and assess future changes. Wildlife populations are, or have the potential to be, stressed by multiple factors. Future research should be devoted to assessing interactions between climate, contaminant cycling and pathogens and how these interactions influence the health of Arctic species. We can no longer view contaminant issues, climate change or development in isolation but must realize the interconnectedness of all stressors and therefore investigate the cumulative impact that multiple stressors have on wildlife health.

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Appendices

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part 9 // appendix 1: methodology of the nwhp
appendix 2: contaminant concentrations in arctic char
appendix 3: contaminant concentrations in ringed seal
appendix 4: contaminant concentrations in beluga

APPENDIX 1. METHODOLOGY OF THE NWHP

Tissue collection

Each community was asked to provide a total of 30 Arctic char and 20 ringed seals collected between the autumn of 2002 and the spring of 2003. During the autumn of 2003 communities were asked to provide samples from up to 15 beluga. To avoid duplication of sampling effort, attempts were made to coordinate with other researchers the collection and distribution of beluga samples. Tissue samples from 6 beluga originating from Arviat were collected for chemical analysis with the help of the University of Windsor. Analysis was shared between the University of Windsor and Trent University. Unfortunately, no histological tissues were collected from the Arviat beluga. Tissues from 7 beluga originating from Coral Harbour were collected for both chemical and histological examination. Histological samples were sent to Trent University for the preparation of microscope slides, while the remaining tissues were sent to the Department of Fisheries and Oceans (DFO), Winnipeg, for chemical analysis. No chemical analytical data for the Coral Harbour beluga were available at the time this report was prepared.

Samples collected for chemical analysis were wrapped in solvent-washed aluminum foil and placed in prelabelled plastic sealable bags. Thin sections (thinner than 5 millimetres [mm]) of tissues collected for histological review were placed in prelabelled tissue cassettes and fixed in a 10 percent solution of buffered formalin. When they arrived at Trent University, the tissues were rinsed with tap water and stored in 70 percent ethanol until they were embedded in paraffin in preparation for the production of microscope slides.

Fish age was determined from otiliths (ear bones) reviewed by the Ontario Federation of Anglers & Hunters (Peterborough, Ontario, website: http://www.ofah.org). For ringed seal and beluga, chemical analysis was performed on blubber, muscle, kidney and liver tissues. All analyses were performed on fresh tissue and therefore concentrations were determined on a wet weight basis, not on a dried weight basis. Staff from the Ontario Ministry of Natural Resources rabies laboratory in Peterborough, Ontario, aged ringed seal by tooth sectioning. Dr. André Dillaire (veterinary pathologist, University of Montreal) performed the histological survey on liver, kidney, gonadal (testicular, ovarian), thyroid, adrenal and lymph node tissues collected from ringed seal and beluga. Hunters had collected histological samples of liver and kidney tissues from Arctic char; however, most of these tissues had autolyzed (decomposed) prior to fixation and therefore no histological samples were reviewed for char.

Chemical analysis

Selected tissues from 6 Arctic char and 6 ringed seal from each of the three participating communities (a total of 18 char and 18 seal) were analyzed. Dorsal muscle (wet weight, skin removed) was the only tissue chemically analyzed for Arctic char, while muscle, blubber, kidney and liver (wet weight) were analyzed for ringed seal. Trace element analysis for cadmium (Cd), lead (Pb), total mercury (Hg) and methylmercury (MeHg) was also performed on a wet weight basis, not a dry weight basis. This was to ensure that analytical anomalies did not arise with the methylmercury analysis during the drying process.

The contaminants analyzed included those typically considered legacy organic contaminants — PCBs, DDT, hexachlorocyclohexane (HCH) and chlordane (CHL) — as well as toxaphenes and PBDEs. Mercury (total mercury and methylmercury), cadmium and lead were measured in the muscle of char and the muscle, kidney and liver of seal. A similar suite of contaminants (except toxaphene) was analyzed in six beluga captured from Arviat. Appendices 2, 3 and 4 provide a list of individual chemicals and congeners analyzed in each of the major chemical groupings.

Histological survey

Hunters provided a total of 164 tissue samples collected from 38 ringed seal, as well as 35 tissue samples collected from 7 beluga in the Coral Harbour area. Tissues were embedded in paraffin, sectioned to a thickness of 5 micrograms (μg) and stained (with haematoxylin and eosin) at Trent University using standard procedures. No tissue samples were collected from the Arviat beluga provided to the NWHP. Prepared microscope slides where sent to a pathologist for a histological review.

APPENDIX 2: CONTAMINANT CONCENTRATIONS IN ARCTIC CHAR

MEAN CONCENTRATION OF CONTAMINANTS THE NWHP MEASURED IN ARCTIC CHAR (ARVIAT, CORAL HARBOUR AND PANGNIRTUNG, 2002/03)

CONTAMINANT	ARCTIC CHAR MUSCLE N = 18 ng/g wet weight	
	Mean	SD
Cd	1.40	0.27
Pb	26.00	8.00
Total Hg	62.00	21.00
MeHg	—	—
Toxaphene[1]	8.00	6.40
PBDEs[2]	0.48	0.38
PCBs[3]	7.00	4.60
DDT[4]	5.10	2.70
HCH[5]	1.20	0.95
Chlordane[6]	6.80	4.70
Endrins	3.10	2.90
Endosulfans	0.43	0.42
Dieldrin	2.60	1.70
Methoxychlor	0.03	0.09
Mirex	0.01	0.02
HCB	0.23	0.46
OCS	0.13	0.19
Hexa-diene	—	—
Pentachloroanisole	0.01	—
Heptachlor epoxide	0.40	0.27

[1]Toxaphene = total toxaphene
[2]PBDEs = sum of 14 congeners (17, 28/33, 71, 47, 66, 10, 99, 85, 154, 153, 138, 183, 190) and HBCD
[3]PCBs = sum of 33 congeners (18, 17 ,31+28, 33, 52, 49, 44, 74, 70, 95, 101, 99, 87, 110, 151+82, 149, 118, 153, 132, 105, 138, 187, 128, 156, 180, 170, 201, 194, 205, 206, 209)
[4]DDT = sum of o,p' DDT, p,p' DDT, o,p' DDE, p,p' DDE, o,p' DDD, p,p' DDD
[5]HCH = sum of α, β, δ, γ
[6]Chlordane = sum of α–chlordane, γ-chlordane, tans-nonochlor, cis-nonochlor

APPENDIX 3: CONTAMINANT CONCENTRATIONS IN RINGED SEAL

MEAN CONCENTRATION OF CONTAMINANTS THE NWHP MEASURED IN RINGED SEAL (ARVIAT, CORAL HARBOUR AND PANGNIRTUNG, 2002/03)

CONTAMINANT	BLUBBER N = 18 ng/g wet weight		MUSCLE N = 18 ng/g wet weight		KIDNEY N = 18 ng/g wet weight		LIVER N = 18 ng/g wet weight	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Cd	—	—	27.00	27.00	29,036.00	7,968.00	7,968.00	8,634.00
Pb	—	—	13.00	6.10	30.00	54.00	54.00	32.00
Total Hg	—	—	249.00	169.00	577.00	5,179.00	5,179.00	5,647.00
MeHg	—	—	244.00	221.00	427.00	514.00	514.00	427.00
Toxaphene[1]	30.90	14.70	0.36	0.41	—	—	—	—
PBDEs[2]	7.40	9.10	0.18	0.14	—	—	—	—
PCBs[3]	375.00	303.00	2.40	1.50	—	—	—	—
DDT[4]	299.00	350.00	1.90	1.60	—	—	—	—
HCH[5]	131.00	44.00	1.40	1.20	—	—	—	—
Chlordane[6]	81.00	75.00	0.40	0.29	—	—	—	—
Endrins	17.00	47.00	0.01	0.02	—	—	—	—
Endosulfans	6.20	6.70	0.02	0.04	—	—	—	—
Dieldrin	46.00	36.00	0.62	0.92	—	—	—	—
Methoxychlor	0.06	0.30	—	—	—	—	—	—
Mirex	5.00	8.20	0.04	0.04	—	—	—	—
HCB	5.90	2.20	0.01	0.03	—	—	—	—
OCS	1.40	1.30	0.02	0.02	—	—	—	—
Hexa-diene	—	—	—	—	—	—	—	—
Pentachloroanisole	0.44	0.19	—	—	—	—	—	—
Heptachlor epoxide	30.00	21.00	0.22	0.30	—	—	—	—

[1]Toxaphene = total toxaphene
[2]PBDEs = sum of 14 congeners (17, 28/33, 71, 47, 66, 10, 99, 85, 154, 153, 138, 183, 190) and HBCD
[3]PCBs = sum of 33 congeners (18, 17 ,31+28, 33, 52, 49, 44, 74, 70, 95, 101, 99, 87, 110, 151+82, 149, 118, 153, 132, 105, 138, 187, 128, 156, 180, 170, 201, 194, 205, 206, 209)
[4]DDT= sum of o,p’ DDT, p,p’ DDT, o,p’ DDE, p,p’ DDE, o,p’ DDD, p,p’ DDD
[5]HCH = sum of α, β, δ, γ
[6]Chlordane = sum of α–chlordane, γ-chlordane, tans-nonochlor, cis-nonochlor

APPENDIX 4: CONTAMINANT CONCENTRATIONS IN BELUGA

MEAN CONCENTRATION OF CONTAMINANTS THE NWHP MEASURED IN BELUGA (ARVIAT, 2003)

CONTAMINANT	BLUBBER N = 6 ng/g wet weight		MUSCLE N = 6 ng/g wet weight		KIDNEY N = 6 ng/g wet weight		LIVER N = 6 ng/g wet weight	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Cd	—	—	33.00	40.00	33,311.00	21,147.00	8,310.00	4,473.00
Pb	—	—	14.00	18.00	13.00	17.00	13.00	5.00
Total Hg	—	—	731.00	432.00	2,927.00	2,176.00	6,389.00	5,439.00
MeHg	—	—	707.00	418.00	325.00	151.00	839.00	633.00
Toxaphene[1]	—	—	—	—	—	—	—	—
PBDEs[2]	30.00	9.00	—	—	—	—	—	—
PCBs[3]	2,886.00	1,680.00	19.00	6.00	80.00	47.00	115.00	83.00
DDT[4]	6,732.00	5,256.00	29.00	16.00	111.00	103.00	121.00	110.00
HCH[5]	109.00	36.00	2.00	4.00	4.00	3.00	7.00	10.00
Chlordane[6]	1,645.00	997.00	13.00	8.00	26.00	21.00	62.00	51.00
Endrins	22.00	23.00	—	—	0.16	0.26	0.32	0.78
Endosulfans	60.00	44.00	—	—	1.00	1.00	2.00	2.00
Dieldrin	738.00	605.00	3.00	5.00	29.00	23.00	54.00	30.00
Methoxychlor	—	—	—	—	—	—	—	—
Mirex	15.00	13.00	0.16	0.10	1.55	1.98	0.66	0.48
HCB	487.00	134.00	6.00	2.00	26.00	10.00	32.00	20.00
OCS	6.20	2.00	0.03	0.03	0.22	0.16	0.17	0.12
Hexa-diene	—	—	—	—	—	—	—	—
Pentachloroanisole	—	—	—	—	—	—	—	—
Heptachlor epoxide	655.00	452.00	5.00	5.00	16.00	13.00	32.00	17.00

[1]Toxaphene = total toxaphene
[2]PBDEs = sum of 14 congeners (17, 28/33, 71, 47, 66, 10, 99, 85, 154, 153, 138, 183, 190) and HBCD
[3]PCBs = sum of 33 congeners (18, 17 ,31+28, 33, 52, 49, 44, 74, 70, 95, 101, 99, 87, 110, 151+82, 149, 118, 153, 132, 105, 138, 187, 128, 156, 180, 170, 201, 194, 205, 206, 209)
[4]DDT = sum of o,p' DDT, p,p' DDT, o,p' DDE, p,p' DDE, o,p' DDD, p,p' DDD
[5]HCH = sum of *, ß, *, * – HCH
[6]Chlordane = sum of *-chlordane, *-chlordane, tans-nonochlor, cis-nonochlor

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