IMPACT OF AT SEA DISPOSAL ON RESIDENT KILLER WHALE (ORCINUS ORCA) CRITICAL HABITAT: SCIENCE IN SUPPORT OF RISK MANAGEMENT

Photo: Graeme Ellis

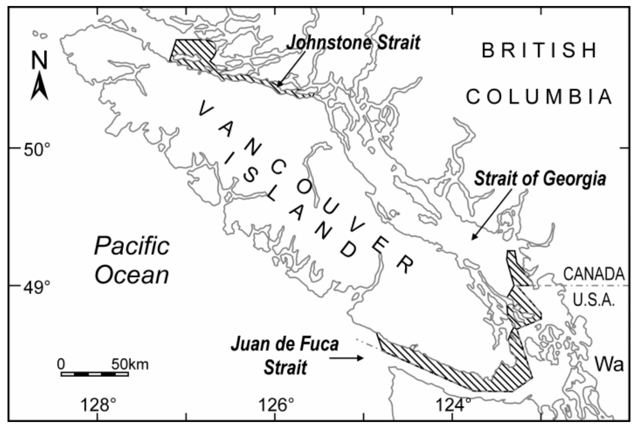

Figure 1: PCBs in ocean disposal materials is evaluated in the context of Critical Habitat for SARA-listed northern and southern resident killer whales. Map by Tango.

Context :

Resident killer whales in the coastal waters of British Columbia are heavily contaminated with persistent organic pollutants (POPs), including polychlorinated biphenyls (PCBs). The northern and southern populations of resident killer whales are listed, respectively, as threatened and endangered under the Species at Risk Act (SARA) which protects species at risk from being killed or harmed (section 32; Appendix I) and protects any part of their Critical Habitat from destruction (section 58; Appendix I). High PCB concentrations have been identified in the recovery strategy as one of three major threats to resident killer whales. While Disposal at Sea operations are governed by the Canadian Environmental Protection Act,1999 (CEPA), DFO has provided habitat-based advice on disposal permits, and is now evaluating operations with respect to SARA. This report provides science advice on the possible impact of PCBs in disposal materials on the health of killer whales, and provides guidance on risk management opportunities that would reduce disposal-related PCB risks for SARA-listed killer whales.

SUMMARY

- Resident killer whales in the coastal waters off British Columbia and Washington are heavily contaminated with persistent organic pollutants (POPs), including banned polychlorinated biphenyls (PCBs).

- The northern and southern populations of resident killer whales are listed, respectively, as *threatened* and *endangered* under the Canadian *Species at Risk Act* (SARA), which protects species at risk from being killed or harmed (section 32; Appendix I) and protects any part of their Critical Habitat from destruction (section 58; Appendix I).

- A PCB food web modeling tool was developed to explore hypothetical scenarios related to disposal at sea of dredged sediment material, evaluate the contaminant risks associated with possible disposal practices on resident killer whales and their habitat, and facilitate the development of risk management practices and protocols.

- Results of PCB food web biomagnification modeling from sampled sediments confirm that BC's killer whales are highly vulnerable to the effects of biomagnification by PCBs.

- Despite Canada's move to ban PCBs over 30 years ago, these persistent contaminants are still found in sediment and still affect biota.

- Natural sedimentation buries PCB-contaminated sediments, but mixing by benthic animals can keep older, more contaminated sediment near the surface, slowing the reduction of PCB concentrations in the surface sediments and prolonging the exposure of food webs to PCBs.

- Because killer whales are long-lived animals, and pass on a portion of their contaminant burden to their offspring, a significant reduction in PCB concentrations in killer whales will take decades.

- Disposal of materials with less than ambient PCB concentrations at a receiving site is not expected to increase PCB delivery to killer whales and may help to bury ambient PCBs.

- Disposing of dredge materials into killer whale Critical Habitat in particular, and to a lesser extent their habitat in general, containing PCBs at concentrations that are higher than the ambient PCB concentrations, are predicted to increase the delivery of PCBs to killer whale food webs.

- Disposal of materials containing greater than ambient PCB levels would benefit from an alternative strategy, including disposal at a site with high natural sedimentation rate, as long as this new site is deemed to be depositional and dredge materials are not further dispersed. This would ultimately help to bury such PCBs, and could reduce overall habitat exposure of killer whales to PCBs.

- A case-specific approach to SARA-based permitting and advice for ocean disposal would best enable an evaluation of any possible effect of a particular disposal operation on killer whales and their habitat.

- To improve the risk-based characterization of ocean disposal at sea activities, congener-specific (high resolution) techniques to measure of PCBs are recommended. In addition, measured contaminants for disposal at sea files should be expanded to additional priority contaminants (e.g. the flame retardant PBDEs or other replacements for flame retardants), particularly as they pertain to SARA concerns and SARA-listed species.

- This modeling suggests that a target sediment PCB range of 0.012 to 0.200 $\mu g \cdot kg^{-1}$ dry weight would optimally protect killer whales. However, these protective sediment PCB values are currently exceeded in many parts of coastal BC.

- An additional understanding of PCB pathways in coastal waters, including sources, sinks, sedimentation rates, and substrate types in both dredge and disposal sites will better inform risk-based decisions regarding the likely fate and consequences of disposal activities within killer whale Critical Habitat.

INTRODUCTION

The northern and southern populations of resident killer whales are listed as threatened and endangered, respectively, under the *Species at Risk Act* (SARA), which aims to protect species at risk from being killed or harmed (section 32) and protects any part of their Critical Habitat from destruction (section 58). The SARA Recovery Strategy for these populations lists prey limitation, contamination and noise/disturbance as primary threats and proposes recovery objectives and strategies aimed at understanding and mitigating these threats. Critical habitat is defined by SARA as the habitat necessary for survival or recovery of a species. Resident killer whales spend a considerable proportion of their time feeding within the Critical Habitat areas which formed the basis for their identification (Ford 2006).

Resident killer whales in British Columbia are significantly contaminated with several classes of environmental contaminants. This contamination may be attributed in part to their long lifespan and their feeding preferences, notably their consumption of large quantities of Chinook salmon. The contamination of killer whale food webs is due to a combination of their proximity to pollution sources and the amplification of chemicals with persistent, bioaccumulative and toxic properties (PBT chemicals) through the food web. PBT chemicals are hydrophobic and therefore readily attach to particles (suspended solids, organics, detritus, sediments) and/or to lipids in biota at the bottom of the food web (membranes of phytoplankton, bacteria). Sediments containing PCBs may sequester them from the water and sedimentation can bury them or, where sediment concentrations are high, (e.g. industrial harbours), sediments can provide a source to contaminate adjacent biota. PCBs have been associated with subtle yet important and permanent health effects in humans and wildlife, including reduced reproduction, altered behaviour, and increased vulnerability to disease.

Environment Canada regulates disposal at sea operations under the *Canadian Environmental Protection Act,* 1999 (CEPA 1999; Disposal at Sea Regulations, Regulations Respecting Applications for Permits for Disposal at Sea). Most disposal permits issued under CEPA are issued for dredge material being moved for capital or navigational purposes. DFO is responsible for the issuance of *SARA* permits for activities that may harm a listed species or destroy their Critical Habitat. The effort here evaluated possible risks associated with disposal at sites found both within and outside of Critical Habitat. The analysis undertaken here comprises a multi-faceted scientific effort to provide advice as to whether PCBs in dredge materials, deposited in any area of killer whale habitat, increase the risk of harm or mortality of northern and southern resident killer whales. However, it should be noted that insufficient data on actual disposal operations constrained an ability to conduct a realistic risk evaluation of specific past or current operations. Current disposal at sea rejection and screening limits for PCBs under CEPA 1999 (CEPA also screens for cadmium, mercury, and PAHs but only PCBs were evaluated in this effort as they represent the priority contaminant concern in killer whales) were evaluated against the bioaccumulation and biomagnification outcomes from the modelling conducted.

ASSESSMENT

Methodology

A food-web based bioaccumulation and biomagnification model was developed that characterizes the distribution of PCBs among sediments, the water column and biota, and estimates concentrations that will accumulate in killer whales. To develop and test this model for killer whales and their prey, previously published sediment-biota PCB bioaccumulation models were adapted using the documented physiological and ecological features of these species.

Seven geographic areas that relate to management priorities (e.g. Critical Habitat and the Strait of Georgia) and/or international boundaries (USA waters and offshore areas) were designated as a basis for this study. A biologically-based assignment of time spent in each of these areas by southern and northern resident killer whales and their prey (Chinook salmon and non-salmonid species) was compiled, based on best available information and expert consultation. The result is a compartmentalized approach to modeling sediment-food web uptake of PCBs within each of the seven areas, which guide an evaluation of site-specific impacts of hypothetical disposal operations. These results were then evaluated against three established health effects thresholds for PCBs in marine mammals as a basis for a characterization of health risks to killer whales. These thresholds included immunotoxicity, hormone disruption, and risk of mortality in marine mammals.

Newly-designated killer whale Critical Habitat in coastal British Columbia includes five existing disposal sites: two in northern resident killer whale Critical Habitat (Hickey Point and Hanson Island) and three in southern resident killer whale Critical Habitat (Sand Heads, Victoria, and Roberts Bank). There are eight additional disposal sites in the Strait of Georgia that do not fall inside Critical Habitat, but are in general, killer whale habitat.

Key assumptions in the model were tested through a sensitivity analysis of key parameters, a comparison of two different models, and comparisons between model predictions and empirical data available for Chinook and killer whales. Model estimates for PCB levels in killer whales compared favourably with those observed in samples from killer whale blubber. In addition, the results of the biomagnification model were compared with an independent killer whale life history model, to provide additional information related to the very slow PCB metabolism in killer whales. Specific recommendations for improved data collection and monitoring, including additional information on killer whale and Chinook salmon feeding ecology and distribution, are described in the Research Document developed in support of this advice.

Results

Based on both predicted values and measured tissue samples, PCB levels in some Chinook salmon exceed the tissue residue guidelines for fish-eating wildlife outlined by the Canadian Council of Ministers of the Environment (CCME). Modeled results indicate that current PCB levels in Chinook lead to PCB levels of concern in killer whales. These results underscore the legacy attributable to a class of chemicals that were banned over 30 years ago in Canada, and emphasize the value of source control and regulations that prevent widespread contamination of the marine environment.

Irrespective of disposal operations, the geographically-based modelling effort described here generated apportioned estimates for each of seven described areas. Results suggest that southern resident killer whales acquire via their prey 49% of their PCBs in US inland waters

(Puget Sound and Juan de Fuca Strait), 18% in Canadian inland waters (Critical Habitat and the rest of the Strait of Georgia), and 33% in outer coast waters (Canada, USA and international waters). Results suggest that northern resident killer whales acquire 14% of their PCBs in Canadian inland waters (Critical Habitat and Queen Charlotte Strait) and 86% in outer coast waters (Canadian, international and USA). PCBs attributable to Critical Habitat were approximately 3% for northern residents and 15% for southern residents.

PCB concentrations in marine sediments deemed to be protective of killer whale health were calculated at 0.012 to 0.200 $\mu g \cdot kg^{-1}$ PCBs dry weight. This range of sediment PCB values represents the range above which adverse specific health effects in killer whales are expected (i.e. based on observed endocrine disruption, immunotoxicity and increased risk of mortality in harbour seals and bottlenose dolphins), and below which reduced health risks are expected. Based on sediment PCB measurements predominantly carried out in the Strait of Georgia and Puget Sound, and to a lesser extent in remote parts of coastal BC and Washington, only 4/61 (6.6%) sites fell below the most liberal end of this protective range (0.200 $\mu g \cdot kg^{-1}$).

Sources of Uncertainty

Best available information and expert knowledge generated killer whale and prey distributions and guided the design of food web models on a geographical basis. It was assumed that no significant variation in metabolic elimination existed for the 209 different PCBs in killer whales; this was evaluated and deemed to be a reasonable assumption.

Many questions would benefit from clarification, and research over the coming years would better enable an understanding of transport and fate of persistent contaminants in the marine environment, and would help to solidify the findings of this report. While sensitivity analyses, a comparison of two different models, and comparisons between model predictions and empirical data for Chinook and killer whales suggested that model performance was internally consistent, the model could be improved with:

- additional sediment chemistry data from remote areas and disposal sites; additional seawater PCB measurements, particularly in offshore/remote areas; information on air-seawater PCB partitioning to better characterize the relative importance of sediments as a source of PCBs to food webs;
- a better understanding of how PCBs enter the marine environment;
- additional information on feeding ecology of Chinook salmon and killer whales;
- additional information on killer whale and Chinook distribution over time and space;
- a better understanding of the relative contribution of sediments to killer whale food webs in nearshore (~shallow) vs. offshore (~deeper) waters.

CONCLUSIONS AND ADVICE

DFO Science has previously reported that BC's killer whales are among the world's most PCB-contaminated marine mammals. Killer whales are long-lived and occupy a high trophic level of the food web. For these reasons, killer whales are at particular risk to accumulating high concentrations of POPs and currently lag environmental trends of declining PCBs. Consequently, PCB-related health risks in killer whales will not be substantially reduced for decades to come.

While many persistent contaminants have been detected in BC's killer whales, PCBs appear to be the principal health concern. PCBs have been associated with subtle yet important and permanent health effects in humans and wildlife, including reduced reproduction, altered behaviour, and increased vulnerability to disease.

PCBs are fat-soluble and, therefore, attach to water-borne particles which can then be deposited into marine sediments. In this way, contaminated sediments can then serve as a source to adjacent food webs. On the other hand, where sedimentation rates are high and/or the PCB concentrations are low, sediments can serve as a sink for PCBs through deposition and burial processes. It is this duality of roles for the sediments that provide a range of case-specific options for disposal decisions. Contaminated sediments, if disposed of in marine waters, may therefore deliver PCBs to aquatic food webs, underscoring concerns outlined in this report.

Since PCBs were banned several decades ago, and they are highly persistent, sediments in BC will improve only slowly, and significant improvements in killer whale PCB burdens are expected to take several decades. Prudent management of disposal materials could accelerate these improvements.

Key conclusions and recommendations resulting from this assessment include:

- Killer whales are extraordinarily vulnerable to the accumulation of PCBs. This vulnerability can be attributed to their long lifespan and feeding preferences, notably their consumption of large quantities of high trophic level salmonids (i.e. up to 150 kg of primarily Chinook salmon/day).
- The disposal of dredged sediments has the potential either to reduce or to increase PCB-related health risks in resident killer whales. This is due to variation in disposal-site specific features including depth, tidal and other currents, substrate type, organic content, benthic fauna, habitat use by Chinook and killer whales, and sedimentation rates. A case-specific approach to SARA-based permitting and advice for ocean disposal would best enable an evaluation of any possible effect of a particular disposal operation on killer whales and their habitat.
- Based on both predicted values and measured tissue samples, PCB levels in some Chinook salmon exceed the tissue residue guidelines designed to protect fish-eating wildlife outlined by the Canadian Council of Ministers of the Environment (CCME; 50 µg/kg). Modeled results indicate that current PCB levels in Chinook lead to PCB levels of concern in killer whales.
- Disposing of dredge materials into killer whale Critical Habitat in particular, and to a lesser extent their habitat in general, containing PCBs at concentrations that are higher than the ambient PCB concentrations, are predicted to increase the delivery of PCBs to killer whale food webs.
- Disposal of materials containing greater than ambient PCB levels would benefit from an alternative strategy, including disposal at a site with high natural sedimentation rate, as long as this new site is deemed to be depositional and dredge materials are not further dispersed. This would ultimately help to bury such PCBs, and could reduce overall habitat exposure of killer whales to PCBs.
- Where the dredged sediments have lower than ambient PCB concentrations, disposal in killer whale Critical Habitat may ultimately provide a net environmental benefit by increasing the burial of more highly contaminated local sediment.
- This modeling suggests that a target sediment PCB range of 0.012 to 0.200 $\mu g \cdot kg^{-1}$ dry weight would optimally protect killer whales. However, these protective sediment PCB values are currently exceeded in many parts of coastal BC, and are below the screening levels currently used for Ocean Disposal permitting under CEPA 1999.
- The bioaccumulation model developed provides an acceptable approach to evaluating the risk to resident killer whales from contaminated sediments, and provides a means to guide

risk management of ocean disposal activities. New sediment quality guidelines could be developed to incorporate biomagnification concerns and the vulnerability of long-lived, high trophic level species such as killer whales.

- Enhanced analytical measurements of PCBs are recommended to improve advice and support decision-making regarding disposal at sea permits. In addition, the list of measured contaminants for disposal at sea files could be expanded to additional priority contaminants (e.g. PBDEs), particularly as they pertain to SARA concerns. Given the very low concentrations of PCBs that can affect killer whale health, High Resolution analytical techniques (which capture all 209 PCB congeners) with lower Detection Limits than currently in practice are recommended for PCB determinations of dredge materials. Such methods are readily available and add value to the interpretation of resulting data (Ikonomou *et al.* 2001).
- Sediments and dredged materials may contain many other contaminants. Of these, PBDEs (flame retardants) were also identified as a concern for resident killer whales, given that they have similar immune, reproductive and other endocrine health effects as PCBs, and that they are not currently screened. Furthermore, despite recent regulatory prohibitions in Canada, PBDEs continue to increase in the environment as a result of widespread domestic use in Canada and a lack of international controls.

OTHER CONSIDERATIONS

Environment Canada (EC) administers permits to disposal operators and controls the disposal of waste (dredge materials, fisheries waste, ships, inert matter, uncontaminated organic matter and bulky substances) in the ocean. Under the Canadian Environmental Protection Act, 1999 (CEPA 1999), two to three million tonnes of material are disposed of at dedicated sites in the marine environment. DFO is responsible for the issuance of *SARA* permits for activities that may harm a listed species or destroy their Critical Habitat, including the disposal of contaminated sediments into the Critical Habitat of resident killer whales.

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