IONAL
TER
RESEARCH
INSTITUTE

INSTITUT
NATIONAL
de RECHERCHE
sur les
EAUX

CONTAMINANTS IN WILDLIFE UTILIZING CONFINED DISPOSAL FACILITIES

R.Z. Dobos, D. S. Painter and
A. Mudroch

NWRI Contribution No. 90-41

CONTAMINANTS IN WILDLIFE UTILIZING CONFINED DISPOSAL FACILITIES

R.Z. Dobos, D. S. Painter and A. Mudroch

Lakes Research Branch
National Water Research Institute
867 Lakeshore Road, P.O. Box 5050
Burlington, Ontario L7R 4A6

NWRI Contribution No. 90-41

Management Perspective

Sediments dredged for navigational purposes from the Great Lakes have been evaluated using the 1976 Ontario Ministry of the Environment guidelines for open water disposal of dredged material. Sediments with concentrations of contaminants exceeding these guidelines have been considered unsuitable for open water disposal and placed in confined disposal facilities (CDFs) constructed along the Great Lakes shoreline.

Since the early 70s about 56% of sediments dredged from Great Lakes harbours and navigational channels have been placed in CDFs. Present management of CDFs in Ontario usually results in the development of aquatic (i.e. marsh) habitat, which gradually changes into terrestrial habitat as the sediment dewaters. Once the disposed sediment has dried out it should be considered soil for which the Ontario Ministry of Environment has soil guidelines for comparison. Consequently, contaminated dredged sediments which have been confined with all precautionary measures to eliminate contaminant mobility become terrestrial soils that could be acceptable for agricultural, parkland or residential land use because the concentrations of contaminants in the soil guidelines are 3 to 40 times greater than those in the sediment guidelines.

This report is the second report in a series on the long term environmental health of Canadian confined disposal facilities in the Great Lakes. The first report documented the environmental contaminant concentrations in the sediments/soils and vegetation of 12 CDFs. This report describes the concentrations of environmental contaminants in voles, shrews and hatchery-reared ducks from the Thunder Bay CDF.

Metal concentrations in shrews, voles and ducks from the Thunder Bay CDF were comparable to the control sites and to other reported studies. Bioaccumulation of mercury in waterfowl muscle was observed and the bioaccumulation factor determined when applied to other Canadian CDFs would suggest that mercury would not accumulate to hazardous concentrations elsewhere.

Bioaccumulation of priority PCB congeners was observed in waterfowl, shrews and voles. Extrapolating our data to other Canadian CDFs in the Great Lakes, waterfowl at the Hamilton Harbour CDF would accumulate PCBs to concentrations greater than the USFDA poultry consumption guideline. The USFDA poultry consumption guideline which is being applied to watefowl in several US states, would be exceeded if the sediment had a total PCB concentration of 300 μg/kg. Bioaccumulation factors for total PCBs from sediments to shrews and voles would suggest that a 1 kg predator could experience reproductive failure by consuming 1-2 shrews or voles per day from the Hamilton CDF.

Generally, the creation of confined disposal facilities for the dredged sediments and the creation of terrestrial habitat for parkland is an acceptable option for dredged sediments on the

Canadian side of the Great Lakes except in Hamilton Harbour. In the near future, the confined disposal option will be evaluated for the remediation of contaminated sediment problems in the Areas of Concern. In light of the two CDF reports, this option should be evaluated using the sediment guidelines during the first phase after the CDF is created and the soil guidelines during the next phase after the sediment is dry and partly consolidated. If the contaminant concentrations in the sediment of interest are significantly higher than the sediment guidelines but below the soil guidelines, every effort should be made to minimize the length of time of the first aquatic phase and reach the second terrestrial phase as quickly as possible. Sediments with PCB concentrations greater than 300 μg/kg would be unacceptable as waterfowl habitat.

The use of confined disposal facilities in Hamilton Harbour should be reviewed carefully in light of the high PCB concentrations. The depth of the cap isolating the contaminated sediments may need to be thicker than normal and rooting of vegetation through the cap should be prohibited. The cap will have to be designed in such a way as to discourage shrews and voles from burrowing through the cap into the dredged "soil".

Perspectives de la direction

On a évalué les sédiments dragués dans les Grands Lacs pour y faciliter la navigation au moyen des directives de 1976 concernant l'élimination des déblais de dragage dans les eaux libres du ministère de l'Environnement de l'Ontario. Les sédiments présentant des concentrations de contaminants excédant les valeurs présentées dans les directives ont été jugés impropres à ce mode d'évacuation et ont été transportés jusqu'à des décharges protégées, aménagées le long du rivage des Grands Lacs.

Depuis le début des années 1970, environ 56 % des sédiments dragués dans les ports et les chenaux des Grands Lacs ont été mis en décharge dans de tels lieux protégés. En Ontario, grâce aux techniques actuelles de gestion, des habitats aquatiques (c'est-à-dire, des marais) se forment habituellement dans ces décharges, puis les marais se transforment progressivement en habitats terrestres au fur et à mesure que les sédiments sèchent. Une fois qu'ils sont secs, les sédiments se classent parmi des sols dont les caractéristiques peuvent être comparées à celles des directives touchant les sols du ministère de l'Environnement de l'Ontario. En conséquence, les sédiments contaminés dragués, qui ont été mis en décharge avec toutes les précautions qu'il faut prendre pour empêcher la migration des substances contaminantes, pourraient être employés à des fins d'agriculture, de construction domiciliaire ou pour l'aménagement de forêts-parcs, car les concentrations de matières contaminantes précisées dans les directives au sujet des sols sont de 3 à 40 fois plus élevées que celles des matières contaminantes présentées dans les directives touchant les sédiments.

Il s'agit du deuxième d'une série de rapports touchant la salubrité à long terme des décharges protégées canadiennes en bordure des Grands Lacs. Le premier rapport donnait les concentrations de contaminants mesurées dans les sédiments-sols et la végétation dans douze décharges protégées. Le présent rapport porte sur les concentrations de contaminants relevées chez les campagnols, les musaraignes et les canards provenant d'écloseries fréquentant la décharge protégée de Thunder Bay.

Les concentrations de métaux mesurées chez les musaraignes, les campagnols et les canards de la décharge protégée de Thunder Bay étaient comparables à celles relevées dans les sites témoins et signalées dans d'autres rapports d'étude. On a observé une bioaccumulation du mercure dans les muscles des espèces de sauvagine, et le facteur de bioaccumulation appliqué aux autres décharges protégées canadiennes révèle que le mercure n'atteint pas des concentrations dangereuses dans les autres sites.

On a observé une bioaccumulation des congénères de BPC prioritaires chez les espèces de sauvagine, les musaraignes et les campagnols. En extrapolant nos données aux autres décharges protégées canadiennes situées dans la région des Grands Lacs, on présume que, chez les espèces de sauvagine fréquentant les décharges protégées du port d'Hamilton, les concentrations de BPC excéderaient les objectifs de l'USFDA pour la consommation des volailles. Cette valeur, qu'on applique à la sauvagine dans plusieurs États américains, ne serait pas respectée si les concentrations totales de BPC dans les sédiments atteignaient 300 ug/kg. D'après les facteurs de bioaccumulation des BPC totaux à partir des sédiments jusqu'aux musaraignes et aux campagnols, un prédateur de 1 kg pourrait avoir une défaillance du système reproducteur s'il consommait 1-2 musaraignes ou campagnols provenant de la décharge du port d'Hamilton par jour.

En général, la création de décharges protégées pour l'élimination de sédiments dragués, où se forment ultérieurement des habitats terrestres se transformant en forêts-parcs est une méthode acceptable d'évacuation des sédiments extraits dans les zones canadiennes des Grands Lacs, sauf dans le port d'Hamilton. Dans un avenir proche, on entend évaluer la possibilité d'avoir recours aux décharges protégées pour régler la question des sédiments contaminés dans les zones à risques. À la lumière des résultats des deux rapports d'étude portant sur les décharges protégées, on devrait, dans un premier temps (après la création des décharges protégées), se servir des directives concernant les sédiments, puis, dans un deuxième temps, une fois que les sédiments sont secs et partiellement consolidés, des directives au sujet des sols. Si les concentrations de polluants dans les sédiments d'intérêt sont notablement plus élevées que celles présentées dans les directives qui leur sont propres, mais qu'elles sont inférieures aux concentrations précisées dans les directives au sujet des sols, on devrait déployer tous les efforts possibles pour minimiser la durée de la première phase "aquatique", de manière à obtenir des habitats terrestres dans les meilleurs délais. Les sédiments présentant des teneurs en BPC supérieures à 300 ug/kg ne pourraient servir à abriter la sauvagine.

Il faudra examiner de façon minutieuse la possibilité de créer des décharges protégées dans le port d'Hamilton, car ces "sols" ne pourraient servir à aucune utilisation en Ontario, en raison de leur forte teneur en BPC. La couverture isolant les sédiments contaminés devrait peut-être être plus profonde que la normale, et il faudrait interdire la pénétration des racines de la végétation dans les sédiments sous-jacents. De plus, la couverture devra être telle que les musaraignes et les campagnols ne puissent atteindre le "sol" dragué.

Résumé

On a analysé des campagnols, des musaraignes et des plantes aquatiques de la décharge protégée de Thunder Bay ainsi que des canards d'élevage, libérés et capturés 4 à 10 semaines après leur libération, afin d'y mesurer les concentrations de métaux lourds et de BPC. Les concentrations de métaux dans les foies des canards étaient comparables aux valeurs relevées dans notre site témoin et à celles signalées dans d'autres rapports. Selon les observations, il peut se produire une bioaccumulation de mercure chez la sauvagine. D'après le facteur de bioaccumulation de 0,55 depuis les sédiments jusqu'aux foies, les concentrations de mercure n'atteindraient pas des valeurs dangereuses chez les espèces de sauvagine fréquentant les décharges protégées canadiennes dans la région des Grands Lacs. Pour ce qui est des concentrations de métaux, les valeurs observées chez les campagnols et les musaraignes étaient similaires à celles mesurées dans notre site témoin et signalées dans d'autres rapports d'étude.

On a observé une bioaccumulation des congénères de BPC prioritaires dans les échantillons de muscles de sauvagines. L'extrapolation de nos données aux autres décharges protégées canadiennes des Grands Lacs révèle que les concentrations de BPC chez les espèces de sauvagine fréquentant les décharges protégées du port d'Hamilton excéderaient les directives de l'USFDA en ce qui concerne la consommation des volailles. Chez les musaraignes, la bioaccumulation de BPC était dix fois plus élevée que chez les campagnols, probablement en raison des régimes alimentaires différents des deux espèces. Les concentrations de BPC mesurées chez les campagnols de la décharge protégée de Thunder Bay étaient environ le double des concentrations mesurées dans le site témoin. D'après les facteurs de bioaccumulation des BPC totaux depuis les sédiments jusqu'aux musaraignes et aux campagnols, un prédateur de 1 kg pourrait avoir une défaillance du système reproducteur s'il consommait 1-2 musaraignes ou campagnols provenant de la décharge protégée du port d'Hamilton par jour.

Summary

Voles, shrews and aquatic plants from the Thunder Bay CDF and hatchery-reared ducks, released and obtained 4 and 10 weeks after release, were analyzed for heavy metals and PCBs. Metal concentrations in duck livers were comparable to our control site and other reported studies. Mercury bioaccumulation was observed to occur in waterfowl. The bioaccumulation factor of 0.55 from sediments to liver would imply that waterfowl would not accumulate hazardous mercury concentrations in Canadian CDFs in the Great Lakes. Metal concentrations in voles and shrews were similar to our control site or other reported studies.

Bioaccumulation of priority PCB congeners was observed in waterfowl muscle samples. Extrapolating our data to other Canadian CDFs in the Great Lakes, waterfowl at the Hamilton Harbour CDF would accumulate PCBs to concentrations greater than the USFDA poultry consumption guideline. Shrews bioaccumulated PCBs to concentrations 10 times higher than voles presumably due the dietary differences between the two species. PCBs concentrations in voles from the Thunder Bay CDF were approximately twice the control site concentrations. Bioaccumulation factors for total PCBs from sediments to shrews and voles would suggest that a 1 kg predator could experience reproductive failure by consuming 1-2 shrews or voles per day from the Hamilton CDF.

Introduction

Confined disposal facilities (CDFs) are used on the Great Lakes for the disposal of contaminated sediments dredged for navigational purposes. These CDFs may develop aquatic and upland habitats during the filling phase if no management is undertaken, and thus provide suitable habitat for many species of wildlife. Therefore, the potential exists for contaminants to re-enter the ecosystem through uptake by vegetation or invertebrates, and accumulate in higher organisms which feed on them.

In 1987, a study was undertaken by the Lakes Research Branch, National Water Research Institute, Environment Canada, into the environmental health of CDFs on the Canadian Great Lakes (Dobos et al. 1989). Sediment, vegetation and earthworm samples were analysed from the CDFs for a range of metals and organic contaminants. In 1988, the study was expanded to include the sampling of wildlife utilizing CDFs to determine the potential movement of contaminants into higher organisms. This report summarizes the methods and results of the 1988 study.

The CDF at Thunder Bay, Ontario (Fig. 1), was selected as the site for a detailed study of contaminant concentrations in wildlife at CDFs for several reasons. It is the largest CDF on the Canadian Great Lakes, and has several largely unmanaged cells at different stages of completion. This has resulted in the development of a range of different natural habitats of substantial size, including meadow, successional shrub-thicket, marsh and pond habitats. At present, the area supports a diversity of wildlife. The sediments contain increased concentrations of contaminants, particularly mercury and PCBs. Also, the area is accessible and logistically suitable for the studies undertaken.

The potential contamination of wildlife using both terrestrial and aquatic habitats was studied. Pond areas of uncapped cells and open water cells of CDFs are used extensively by waterfowl as staging areas and to a lesser degree as nesting areas. Transport of contaminants from sediments into waterfowl may occur via benthic invertebrates or aquatic vegetation. The sampling of wild ducks using these areas presents a problem, in that it is not known how long they actually feed at the site and therefore how much of their contaminant load is due to uptake from the CDF sediments. For this reason, domestically-raised ducks with a known contaminant body burden were released into the open water cell (cell 4) at Thunder Bay (Fig. 2) for a set exposure period, and then sampled to determine the contaminant uptake from the sediments.

The sediments present in cell 4 at Thunder Bay were not highly contaminated since dredged material has not yet been placed into this cell. The substrate is likely overflow from the capping material placed on cell 2 during 1986 (pers. comm., A. Khan, Public Works Canada). Despite this low contamination, a bioaccumulation factor (BF) could still be determined for contaminants taken up by waterfowl from the sediments in this cell, and then be applied to other CDFs with a higher degree of contamination, which also support waterfowl populations.

The terrestrial habitat was studied by sampling resident populations of small mammal herbivores (voles) and insectivores (shrews), which spend their whole lifecycle in a relatively small area (Haschek et al. 1979), for example, entirely on the CDF.

Analysis of the degree of contamination in these two groups of wildlife was used to assess the potential of contaminants at CDFs to re-enter the ecosystem.

Methods

Waterfowl

A total of 125 hatchery-raised ducks were obtained from Kortright Waterfowl Park in Guelph, Ontario, including 77 Mallards (Anas platyrhynchos) and 48 Call Ducks, a hybrid form which is superficially similar to a Mallard but much smaller (approximately 65 % the size). In order to prevent the birds from being able to fly, the Mallards had their primary feathers clipped on one wing after they were fully developed, while the Call Ducks had one wing pinioned as day old chicks.

The ducks were marked for ease of identification by attaching a patagial wing tag. Commercial livestock eartags (yellow plastic, approximately 5 cm long) were used for the patagial tags. They proved to be easy to attach, highly visible from a distance so as to distinguish the experimental birds from wild ducks, and did not appear to cause infection in the birds.

Sixty of the Mallards were released at the flooded cell 4 at Thunder Bay CDF (Fig. 2) on July 27, 1988. The birds were about 10 weeks old at release, and were fully fledged. A total of 55 ducks (17 Mallards and 38 Call Ducks) were released at the control site, a natural pond in the Hendrie Valley of the Royal Botanical Gardens, in Burlington, Ontario (Fig. 3), on July 30, 1989. An additional 10 Call Ducks were sacrificed on the release day to serve as day 0 control birds.

Four Mallards were collected at Thunder Bay, by trapping, on August 27, after 31 days exposure. Sixteen more were collected on October 9, after 74 days from release, using a shotgun. Four Call Ducks were collected from RBG on October 20, 82 days after release, by trapping. Ducks collected by trapping were put under by asphixiation with carbon dioxide. Samples of the sediments and submergent vegetation (Potamogeton filiformis) were also collected from cell 4 at Thunder Bay.

Small Mammals

Small mammals were trapped at the upland area of cell 3 of Thunder Bay CDF (uncapped) using a grid of 60 live traps baited with peanut butter, between August 24 and 27, 1988. A total of seven shrews (Sorex sp.) and three voles (Clethrionomys gapperi - 2; Microtus pennsylvanicus -1) were trapped in cell 3. Small mammals were also trapped at a control site, an upland meadow on Royal Botanical Gardens property near Burlington, Ontario (Fig. 3), using a similar grid of 60 live traps, between August 9 and 19, 1988. A total of seven meadow voles were trapped there. Small mammals collected were also put under by asphixiation with carbon dioxide.

Tissue Samples

Liver and breast muscle tissues were removed from ducks collected for chemical analyses. Whole bodies of small mammals were analysed. All tissues were freeze-dried and homogenized prior to analysis. The duck and shrew tissues were analysed for cadmium, chromium, copper, lead, mercury, nickel and zinc, using atomic adsorption spectrometry. The vole tissues were analysed for cadmium, lead and mercury. All tissues were quantitatively analysed for a range of PCB congeners using gas chromatography. The lipid content of the tissues was also determined.

Analytical Methods

The analytical procedure for the determination of PCBs consisted of 12 hours of Soxhlet extraction by dichloromethane. The extracts were subjected to a fractionation by column chromatography prior to to analysis using the method described by Carey and Hart (1986). Each of the resulting fractions was subjected to analyses using a dual-column capillary gas chromatography method with 30 m long BD5 and DB17 columns and electron capture detectors. Reproducibility of the analysis on replicate samples was +10 %. National Research Council, Canada, standard material CLB-1 (A,B,C and D), a mixture of 51 PCB congeners, was used as the standard in the analyses. The accuracy of the determination of PCBs was confirmed by analysis of Sediment Reference Material for Total Polychlorinated Biphenyls obtained from the Quality Assurance and Methods Section, National Water Research Institute, Burlington, Ontario (Lee and Chau 1987).

Cadmium and mercury concentrations were determined using flameless atomic adsorption. Lead concentrations were determined using graphite furnace atomic adsorption. Chromium, copper, nickel and zinc concentrations were determined using ICP methodology.

Metal concentrations are expressed as µg/g dry weight, while PCB concentrations are expressed as µg/kg lipid weight. Comparisons of our data with literature values represented on a wet weight basis were made using a percent dry weight for Mallard liver tissue and skeletal muscle of 32.7 % and 23.5 %, respectively (Scanlon 1982). Mean contaminant concentrations were calculated for each sample period and type (i.e. Mallard tissues at day-0, -31, -74 and control, and voles at RBG and voles and shrews at TB3).

The PCB congeners were summarized into priority groups based on their biological significance (Clarke et al. 1989). These five groups are comprised of 36 of the 209 possible PCB congeners. The total of these five groups are used to describe total priority PCBs in this report.

Results

Metal Concentrations

The mean concentrations and standard deviations of the metals in all of the samples are summarized in Table 1.

Very low concentrations of cadmium, chromium, lead and nickel were found in duck livers. Mercury concentrations increased from 0.042 µg/g in day-0 duck livers to 0.081 µg/g in day-31 and to 0.106 µg/g in day-74 duck livers, while the control birds had a concentration of 0.024 µg/g in livers. Copper concentrations were high in day-0 duck livers (435 µg/g) and decreased over exposure time (257 µg/g at day-31, 225 µg/g at day-74, and 133 µg/g at day-82 [control]). Zinc concentrations were also high in day-0 duck livers (208 µg/g). After an initial decrease after release, zinc increased from 108 µg/g in day-31 livers to 167 µg/g in day-74 livers. The control duck livers had a similar zinc concentration as the day 74-ducks (168 µg/g).

Sediments from Thunder Bay cell 4 had levels of cadmium below the detection limit (0.25 µg/g), and relatively low concentrations of chromium (19 µg/g), copper (8 µg/g), lead (1 µg/g), mercury

(0.193 µg/g), nickel (19 µg/g) and zinc (62 µg/g). All of these sediment concentrations were below the open water disposal guidelines for dredged material (Ontario Ministry of the Environment 1987).

Metal concentrations in pondweed from Thunder Bay cell 4 were lower than in the sediments for all metals except lead (2 µg/g), while mercury was only slightly lower in pondweed (0.193 µg/g) than in sediments.

Shrews from Thunder Bay cell 3 had concentrations of cadmium and nickel below the detection limits (0.25 µg/g and 0.10 µg/g, respectively). Chromium (0.5 µg/g), copper (2 µg/g), lead (8 µg/g) and mercury (0.119 µg/g) concentrations were all lower in shrews than in cell 3 sediments. However, the zinc concentration in shrews was many times greater (649 µg/g) than that in the sediments.

The concentrations of cadmium were below the detection limit (0.20 µg/g) in voles collected at both the Thunder Bay cell 3 and control sites. Lead concentrations were similar in voles from cell 3 (6.9 µg/g) and the control site (6.6 µg/g), while mercury concentrations were higher at the control site (0.044 µg/g) than at cell 3 (0.033 µg/g).

Polychlorinated Biphenyls Concentrations

The concentrations of total PCBs and PCB priority groups in duck breast muscle tissues, small mammals, and Thunder Bay cell 4 sediment and pondweed samples are summarized in Table 2. The concentrations in the duck and mammal samples are expressed on a lipid weight basis.

The percent lipid in duck muscle tissues was 11.4 % in day-0 birds, which decreased to 7.7 % in day-31 birds and to 7.1 % in day-74 birds. The control birds had a lipid content of 7.1 % in the breast muscles. The mean total PCB concentration in day-0 duck muscles was 67 µg/kg of which approximately 51 µg/kg or 76% were priority PCBs. The day-31 ducks had a mean total PCB concentration of 34 µg/kg. The day-74 ducks had a mean total PCB concentration of 173 µg/kg of which approximately 160.2 µg/kg or 93% were priority PCBs. The mean total PCB concentration in the control birds was 123 µg/kg. Group 1A congeners were undetected in all duck muscle samples. The group 2 congeners were the most abundant in all of the duck muscles.

The mean lipid content in shrews and voles from Thunder Bay cell 3 was 12.8 and 9.6 %, respectively, and in voles from the RBG control site, 9.4 %. The shrews had a mean concentration of total PCBs of 4550 µg/kg of which 89% were priority PCBs. The mean concentration in Thunder Bay voles was 587 µg/kg, while it was 214 µg/kg in RBG voles. Group 1A congeners were undetected in all of the small mammals. The group 1B and 2 congeners were the most abundant in all of the mammals.

The concentration of total PCBs in Thunder Bay cell 4 sediments was 18.1 μg/kg on a dry weight basis. Pondweed from cell 4 had a concentration of total PCBs of 34.4 μg/kg dry wt. The group 3 congeners were the most abundant in both samples. The total priority PCBs comprised 79 and 93 percent of the total PCBs in sediment and pondweed samples, respectively.

Discussion

Metals Concentrations in Biological Tissues

The low concentrations of cadmium, chromium, lead and nickel in duck livers from Thunder Bay reflected the low concentrations in the sediments from cell 4. Very little uptake occurred for these metals.

The results indicated uptake of mercury by waterfowl, since the concentration in the livers increased substantially over the exposure period. However, mercury concentrations were not extremely high in the sediments at this cell. The mercury concentrations in duck liver samples (0.024-0.106 μg/g) were lower than those reported in the literature, which ranged from 1.2 μg/g dry wt in Mallard livers in England (Parslow et al. 1982), to 16.7 μg/g dry wt in Mallard livers from northern Ontario (Fimreite 1974). A concentration of 20 μg/g of mercury in liver tissues in raptors has been shown to cause behavioural defects (Fimreite 1974). A bioaccumulation factor (BF) of 0.55 was observed for mercury from the sediments in cell 4 into the day-74 Mallards. Applying this BF to sediments at other CDFs with open water cells which are utilized by waterfowl, an expected mercury concentration in duck livers at these sites can be determined from the sediment concentrations. These mercury liver concentrations would be 0.54 μg/g at Thunder Bay cell 3, 0.38 μg/g at Hamilton Harbour and 0.02 μg/g at Oshawa-Upland (see Dobos et al. 1989 for sediment mercury concentrations at these sites). All of these concentrations would be well below the toxic level to wildlife (20 μg/g).

Uptake of copper from the sediments at Thunder Bay cell 4 was not likely occurring since the copper concentrations in duck liver tissues decreased over time. The copper concentrations in duck livers at release were up to 50 times higher than in the sediments, suggesting that the starter feed fed to the ducks at the hatchery before release may have been the source of copper.

Copper is an essential dietary metal (Bowen 1979) and the concentrations in our study (133-435 μg/g) were similar to those reported in the literature for other studies. Parslow et al. (1982) found a mean copper concentration of 115 μg/g dry wt in Mallard livers from England, and a range of 77 to 603 μg/g in livers from 8 duck species. Di Giulio and Scanlon (1984a) found a mean copper concentration of 35 μg/g dry wt in Mallard livers, and a range of 19-263 μg/g in 15 waterfowl species from Chesapeake Bay. Vermeer and Peakall (1979) reported 35-66 μg/g dry wt of copper in livers of Greater Scaups (Aythya marila) and Surf Scoters (Melanitta perspicillata) from the Fraser River Delta, British Columbia. White et al. (1979) reported a mean liver copper concentration of 252 µg/g dry wt in Chesapeake Bay Canvasbacks (Aythya valisineria).

The highest zinc concentration occurred in day-0 duck livers, suggesting that the zinc originated from the feed at the hatchery before release. The concentration decrease by day-31 may have been due to metabolism of zinc. The concentration increase by day-74 may be due to limited uptake of zinc through the diet at the CDF.

Zinc, an essential dietary metal (Bowen 1979), was found in our duck livers (108-208 µg/g) at concentrations within the ranges reported in the literature. Parslow et al. (1982) reported a mean of 157 µg/g dry wt in Mallard livers from England, and a range of 111-172 µg/g in 8 duck species. Di Giulio and Scanlon (1984a) found a mean zinc concentration of 161 µg/g dry wt in Mallard livers and a range of 103-197 µg/g in 15 duck species in Chesapeake Bay. Vermeer and Peakall (1979) reported mean zinc concentrations in livers of Greater Scaup and Surf Scoters from British Columbia of 123 µg/g and 100 µg/g dry wt, respectively. White et al. (1979) observed a mean zinc concentration of 123 µg/g dry wt in Canvasback livers from Chesapeake Bay.

The zinc concentrations found in duck livers would not be considered hazardous to waterfowl. A concentration of about 400 µg/g dry wt in Mallard liver is indicitive of zinc toxicosis (Gasaway and Buss 1972). Zinc concentrations in Mallard kidneys have been shown to increase as a result of high cadmium levels. However, this was not shown in liver tissues (Di Giulio and Scanlon 1984b).

The levels of most metals in the pondweed sample were below the normal upper levels in urban foliage, except for chromium (8 µg/g) and nickel (7 µg/g) (Ontario Ministry of the Environment 1986), which were slightly exceeded (Cr -8.3 µg/g, Ni -10.1 µg/g in pondweed). Background concentrations of copper (27 µg/g) and zinc (52 µg/g) in Potamogeton filiformis from natural areas in Pennsylvania (Adams et al. 1973) were higher than in our samples. Very little uptake was observed from the sediments into the plants for all the studied metals.

Our finding that metals were higher in shrews than in voles is consistent with the results of other studies (Beyer et al. 1985, Scanlon 1979, Williamson and Evans 1972), and would be expected since insectivorous shrews are at a higher trophic level than herbivorous voles.

The lead concentrations in voles were similar at both the CDF and control sites, while mercury concentrations were higher in voles from the control site. Therefore, the metal contamination for lead and mercury is no worse at the Thunder Bay CDF than at a typical natural area in southern Ontario. Voles spend a large amount of time above ground feeding on the upper parts of plants, rather than below the surface feeding on roots and stems (Haschek et al. 1979). Thus they would be exposed largely to contaminants on the surface of vegetation resulting from atmospheric deposition, assuming that the palatability of vegetation is not affected by surface contamination, an aspect which is not well known (Scanlon 1979).

The lead concentrations in voles from the CDF and control sites were within the range reported from studies of voles near roadsides of varying traffic volumes (6.9-12.1 µg/g, Scanlon 1979; 5-10.5 µg/g, Williamson and Evans 1972). Mercury concentrations ranging from 0.04-0.09 µg/g were reported in voles from the Seaway Island CDF at the mouth of the St. Clair River (MacLaren 1984). These were slightly higher than concentrations found in our study. The lead and mercury concentrations in samples from our study do not appear to be at levels which are toxic to wildlife. The concentration of lead, 25 µg/g dry wt in kidneys, is considered diagnostic of lead poisoning in domestic animals (National Research Council 1980). Although the concentrations of cadmium in vole samples in our study were below the detection limit (0.20 µg/g), voles have been reported to accumulate cadmium to relatively high levels (200 µg/g wet wt) when fed contaminated vegetation grown on sewage sludge (Williams et al. 1978). This concentration would be considered toxic in humans.

The lead concentrations in shrews were generally lower than those reported in the literature, which ranged from 11-109 µg/g (Beyer et al. 1985, Scanlon 1979, Williamson and Evans 1972). Copper concentrations of 11 µg/g were reported in Short-tailed Shrews (Blarina brevicauda) near a zinc smelter, while cadmium ranged from 4.8-7.3 µg/g (Beyer et al. 1985), which were higher than in samples from our study. The zinc concentration in shrews from our study was at least twice as high as the level reported in shrews near a zinc smelter (201-377 µg/g), although the soil levels near the smelter (up to 24000 µg/g) were 100 times higher than sediments in our study (Beyer et al. 1985). Although the zinc concentration in shrews appears to be high in our study, zinc concentrations in carcasses are poor indicators of zinc exposure, therefore zinc poisoning is difficult to determine (Beyer et al. 1985).

Polychlorinated Biphenyls in Biological Tissues

The decrease in the lipid content of breast muscle tissue in ducks after release would be due to the fact that young Mallards undergo a switch in the predominant food source from animal matter to plant matter after fledging age is reached, and that plant matter has a lower fat content than animal matter (Sheehan et al. 1987). A lesser factor may be the birds being placed in a foreign environment and having to adapt to a new food source, and subsequently not being as successful in finding food.

The higher lipid content in shrews than in voles would be expected in an organism with a high rate of metabolism as a source of energy to drive the high metabolic rate (Vaughan 1972).

The summarization of PCB congeners into priority groups is a useful determination of the biological signifance of PCBs. Many of the lower chlorinated PCBs are metabolized easily or are not abundant in the ecosystem. Also, some of the higher chlorinated PCBs are not readily bioavailable to organisms (Clarke et al. 1989). Thus it is more useful to consider PCB congeners which are the most important in terms of toxicity and bioavailibility to organisms.

The total priority PCB concentrations (comprising all five of Clarke's groups) in duck muscle tissues indicated that uptake of PCBs was occurring at both the CDF and control sites. The highest proportion of priority PCB congeners belonged to the group 2 congeners for all of the mean duck muscle tissue samples. Group 1B congeners were abundant in the day-0 and day-74 samples. The group 1B congeners are mixed-type inducers of vertebrate enzyme systems, and are considered to be highly toxic to vertebrates, while the group 2 congeners, which are PB-type mixed function oxidase inducers, are considered to be very toxic to vertebrates (Clarke et al. 1989). In all of the duck muscle samples, the proportion of priority PCB congeners to total PCBs was very high (>74 %).

A bioaccumulation factor (BF) of approximately 10 was calculated for total PCBs from the sediments at Thunder Bay cell 4 to duck muscle tissues after 74 days. Since the sediments at cell 4 were not highly contaminated with PCBs, it would be useful to apply this BF to sediments from other CDFs which have open water cells used by waterfowl to determine the potential uptake of PCBs at those sites. Using this method of extrapolation, waterfowl using the following CDFs for a similar time period would accumulate calculated levels of total PCBs (μg/kg lipid weight) as follows: 2026 at Thunder Bay cell 3; 1106 at Oshawa-CDF; and 46247 at Hamilton Harbour (see Dobos et al. 1989 for sediment PCB concentrations). Compared to the US Food and Drug Administration's upper tolerance limit of 3000 μg/kg total PCBs (fat basis) in poultry (FDA 1977), the potential PCB uptake in waterfowl using the Hamilton Harbour CDF for a similar time period would exclude those waterfowl from consumption in the US.

The mean total PCB concentration was almost ten times higher in shrews than in voles from Thunder Bay. An approximate bioconcentration factor for total PCBs was 23 for shrews and 3 for voles at Thunder Bay cell 3. Higher PCB levels in insectivorous shrews than in herbivorous voles would be expected since insects are known to accumulate organic contaminants to a higher degree than vegetation. The higher PCB concentrations in voles from Thunder Bay than from the control site reflect the more contaminated nature of the Thunder Bay site. The priority PCB congener groups with the highest concentrations in all of the small mammal samples were 1B and 2, which are considered to be highly toxic. A very high proportion of the total PCBs in these samples were comprised of priority PCBs. Thus, the PCB mixtures in the small mammal samples are potentially of a highly toxic nature. Due to the high levels of priority PCBs in shrews from Thunder Bay, consumption of a large quantity of them by a predator could result in potentially toxic accumulations in the predator. Doses as low as 0.07 µg/g total PCBs per day have resulted in reproductive failures in mink (Hornshaw et al. 1983). The BFs, % lipid and the weight of shrews (5 g) and voles (40 g) can be used to examine the environmental significance of the total PCB concentrations in the two animals to a 1 kg predator feeding at Canadian CDFs in the Great Lakes. Only the Hamilton Harbour CDF has sediment PCB concentrations high enough to produce shrews and voles with PCB levels that could affect reproduction in a 1 kg mink. A 1 kg predator such as mink would only have to consume 1 shrew or 2 voles per day to experience reproductive effects.

Conclusion

1. A study was carried out to determine the uptake of metal and organic contaminants into wildlife using confined disposal facilities (CDF) for contaminated sediments. Mallards were released into an open water cell at the Thunder Bay CDF and collected for tissue analysis after several weeks exposure. Small mammals were trapped at a filled cell at Thunder Bay CDF and analysed for contaminants.

2. Metal concentrations in duck livers were generally low or similar to values reported in the literature. The concentration of mercury increased in duck livers over the 74 day exposure period at the Thunder Bay CDF but to relatively low concentrations. No increase in the concentrations of nickel, cadmium, chromium and lead was observed in the duck livers.

3. PCBs bioaccumulated in duck muscle tissues at both the CDF and control sites, but to higher concentrations at the CDF site. The majority of the PCB congeners in muscles were priority groups 1B and 2, which are considered to be highly toxic. When applying the PCB bioaccumulation factor observed at Thunder Bay cell 4 to other CDFs, high PCB concentrations would likely occur in ducks feeding for a similar length of time at the Hamilton Harbour CDF. The concentrations would likely exceed the USFDA guideline for consumption of poultry.

4. Metal concentrations were higher in shrews than in voles. Metals were similar in voles at the CDF and control sites. Concentrations in voles at both sites were not considered toxic. Zinc concentrations in shrews were higher than levels reported in the literature, but zinc toxicity is hard to determine.

5. Higher concentrations of PCBs were found in shrews than in voles. The majority of priority PCB congeners were groups 1B and 2, which are highly toxic. The bioaccumulation factor for PCBs for shrews and voles would suggest that daily consumption of small quantities of shrews and voles at the Hamilton Harbour CDF would affect reproduction in a 1 kg predator.

6. Literature Cited

Adams, F.S., H.C. Cole, Jr., and L.B. Massie. 1973. Element constitution of selected aquatic vascular plants from Pennsylvania: submersed and floating leaved species and rooted emergent species. Environ. Pollut. 5: 117-147.

Ballschmiter, K. and M. Zell. 1980. Analysis of polychlorinated biphenyls (PCBs) by glass capillary gas chromatography. Fresinius J. Anal. Chem. 302: 20-31.

Beyer, W.N., O.H. Pattee, L. Sileo, D.J. Hoffman and B.M. Mulhern. 1985. Metal contamination in wildlife living near two zinc smelters. Environ. Pollut. (Series A) 38: 63-86.

Bowen, H.J.M. 1979. Environmental chemistry of the elements. Academic Press, London.

Carey, J.H. and J.H. Hart. 1986. Gas chromatographic/mass spectrometric (GC/MS) identification of the major components of non-aqueous material from the St. Clair River. Water Poll. Res. J. Canada 21 (3): 309-322.

Clarke, J.U., V.A. McFarland and B.D. Pierce. 1989. Preliminary recommendations for a congener-specific PCB analysis in regulatory evaluation of dredged material. Misc. Pap. D-89-2, US Army Engineer Waterways Experiment Station, Vicksburg, Miss. 32 pp.

Di Giulio, R.T. and P.F. Scanlon. 1984a. Heavy metals in tissues of waterfowl from the Chesapeake Bay, USA. Environmental Pollution (Series A) 35: 29-48.

Di Giulio, R.T. and P.F. Scanlon. 1984b. Effects of cadmium and lead ingestion on tissue concentrations of cadmium, lead, copper and zinc in Mallard ducks. Sci. Tot. Environ. 39: 103-110.

Dobos, R.Z., D.S. Painter, A. Mudroch. 1989. Environmental health of confined disposal sites on the Canadian Great Lakes. Unpubl. rep., Lakes Research Branch, National Water Research Institute, Burlington, Ont. 147 pp.

Fimreite, N. 1974. Mercury contamination of aquatic birds in northwestern Ontario. J. Wildl. Manage. 38 (1): 120-131.

Food and Drug Administration. 1977. Polychlorinated biphenyls (PCBs). Federal Register 42 (63): 17487-17494.

Gasaway, W.C. and I.O. Buss. 1972. Zinc toxicity in the Mallard duck. J. Wildl. Manag. 36 (4): 1107-1117.

Haschek, W.M., D.J. Lisk and R.A. Stehn. 1979. Accumulations of lead in rodents from two old orchard sites in New York: pp.

192-199. In Animals as monitors of environmental pollutants. Natural Academy of Sciences, Washington. 421 pp.

Hornshaw, T.C., R.J. Auerlich and H.E. Johnson. 1983. Feeding Great Lakes fish to mink: Effects on mink and accumulation and elimination of PCBs by mink. J. Toxic. Envir. Health 11: 933-946.

Lee, H.B. and A.S.Y. Chau. 1987. Analytical reference materials. Part 7. Development and certification of a sediment reference material for total chlorinated biphenyls. Analyst 112: 37-40.

MacLaren, J.L., Ltd. 1984. Environmental monitoring of dredging and containment, South-East Bend Cut-Off Channel, Seaway Island, St. Clair River; 1983 activities and final report. For Public Works Canada, Ontario Region, Toronto. 91 pp.

National Research Council. 1980. Mineral tolerance of domestic animals. Washington, D.C., National Academy of Sciences.

Ontario Ministry of the Environment. 1986. Derivation and significance of MOE upper limits of normal contaminant guidelines. Unpubl. rep., Air Resources Branch, Phytotoxicology Section. 3 pp.

Ontario Ministry of the Environment. 1987. Handbook for dredging and dredged material disposal in Ontario, part A: Legislation, policies, sediment classification and disposal. June 1987 draft. 41 pp.

Parslow, J.L.F., G.J. Thomas and T.D. Williams. 1982. Heavy metals in the livers of waterfowl from the Ouse Washes, England. Environ. Poll. (Series A) 29: 317-327.

Scanlon, P.F. 1979. Lead contamination of mammals and invertebrates near highways with different traffic volumes: pp. 200-206. In Animals as monitors of environmental pollutants. National Academy of Sciences, Washington. 421 pp.

Scanlon, P.F. 1982. Wet and dry weight relationships of Mallard (*Anas platyrhynchos*) tissues. Bull. Environm. Contam. Toxicol. 29: 615-617.

Sheehan, P.J., A.Baril, P. Mineau, D.K. Smith, A. Harfenist and W.K. Marshall. 1987. The impact of pesticides on the ecology of prairie nesting ducks. Tech. Rep. Ser. No. 19, Can. Wildl. Serv.

Vaughan, T.A. 1972. Mammalogy. W.B. Saunders Co., Toronto: 463 pp.

Vermeer, K. and D.B. Peakall. 1979. Trace metals in seaducks of the Fraser River Delta intertidal area, British Columbia. Marine Pollution Bulletin 10: 189-193.

White, D.H., R.C. Stendell and B.M. Mulhern. 1979. Relations of wintering Canvasbacks to environmental pollutants -Chesapeake Bay, Maryland. Wilson Bull. 91 (2): 279-287.

Williams, P.H., J.S. Shenk and D.E. Baker. 1978. Cadmium accumulation by Meadow Voles (Microtus pennsylvanicus) from crops grown on sludge-treated soil. J. Environ. Qual. 7 (3): 450-454.

Williamson, P. and P.R. Evans. 1972. Lead: levels in roadside invertebrates and small mammals. Bull. Environ. Contam. Toxicol. 8 (5): 280-288.

Table 1. Metal concentrations (μg/g dry wt) in Mallard livers, small mammals, pondweed and sediment from Thunder Bay and RBG-control sites.

Samples	Cadmium		Chromium		Copper		Lead		Mercury		Nickel		Zinc	
	X	SD	X	SD	X	SD	X	SD	X	SD	X	SD	X	SD
Mallard Livers:														
Day 0	0.50	0.50	0.6	0.3	435.0	301.8	0.6	0.6	0.042	0.029	<0.1	--	208.2	28.8
Day 31-TB4	<0.25	--	0.4	0.4	257.0	45.7	0.2	0.0	0.081	0.031	<0.1	--	108.1	11.5
Day 74-TB4	<0.25	--	0.6	0.8	225.3	119.8	0.4	0.5	0.106	0.047	0.3	1.2	166.7	18.3
Control-RBG	<0.25	--	0.4	0.1	133.1	53.8	0.5	0.1	0.024	0.012	<0.1	--	168.3	13.1
Small Mammals:														
Shrews-TB3	<0.20	--	0.5	0.5	2.1	1.1	8.4	5.8	0.119	0.025	<0.1	--	648.7	289.8
Voles-TB3	<0.25	--	--	--	--	--	6.9	4.5	0.033	0.031	--	--	--	--
Voles-RBG	<0.25	--	--	--	--	--	6.6	3.9	0.044	0.028	--	--	--	--
Pondweed-TB4:	<0.25	--	8.3	--	3.5	--	2.0	--	0.189	--	10.1	--	20.9	--
Sediment-TB4:	<0.25	--	19.3	--	8.2	--	1.2	--	0.193	--	18.5	--	62.4	--

Table 2. Summary of mean total and priority PCB congener group concentrations (μg/kg lipid wt) in samples from Thunder Bay and RBG.

Sample	n	% Fat	Priority Groups 1A	1B	2	3	4	Average Priority Total	Average Total	% Priority of Total PCBs
Duck Muscle:										
Day 0	10	11.4	ND	13.7	27.9	9.4	ND	51.0	67 +/- 111	76
Day 31-TB4	4	7.7	ND	ND	18.8	6.3	ND	25.1	34 +/- 34	74
Day 74-TB4	16	7.1	ND	65.1	78.6	16.2	0.3	160.2	173 +/- 310	93
Control-RBG	4	7.1	ND	10.5	65.9	23.9	0.6	100.9	123 +/- 68	82
Sediment (dry wt)	1	--	ND	3.4	4.2	5.4	1.3	14.3	18.1	79
Pondweed (dry wt)	1	--	ND	0.6	10.0	21.4	ND	32.0	34.4	93
Small Mammals:										
Shrews-TB3	7	12.8	ND	1628.9	2025.8	350.0	43.8	4048.5	4550 +/- 810	89
Voles-TB3	3	9.6	ND	182.3	149.0	90.6	22.9	444.8	587 +/- 48	76
Voles-RBG	7	9.4	ND	54.3	78.7	38.3	10.6	181.9	214 +/- 128	85

ND -Below detection limit <0.01

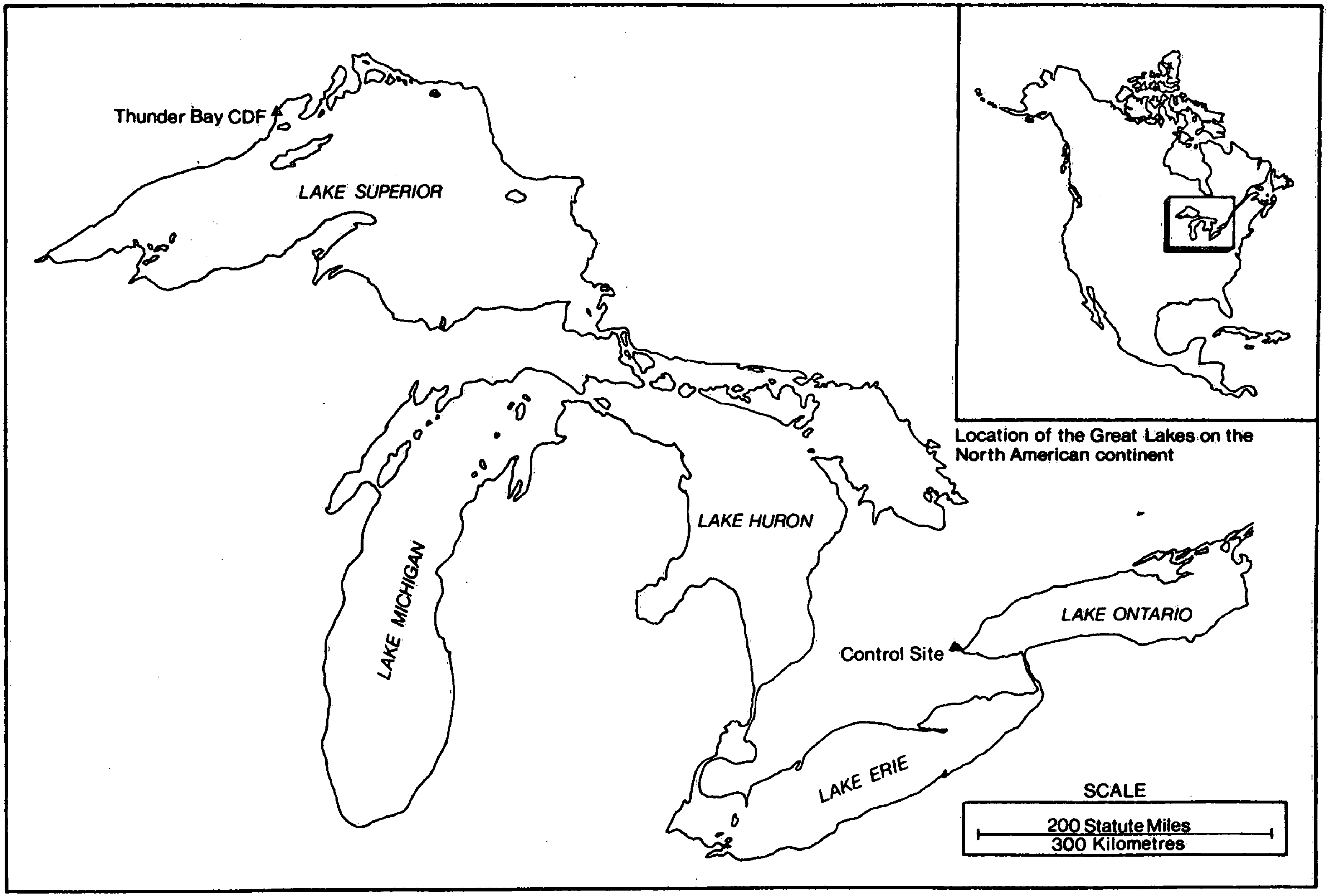

Fig. 1. Location of Thunder Bay CDF and the control site near Burlington, Ontario.

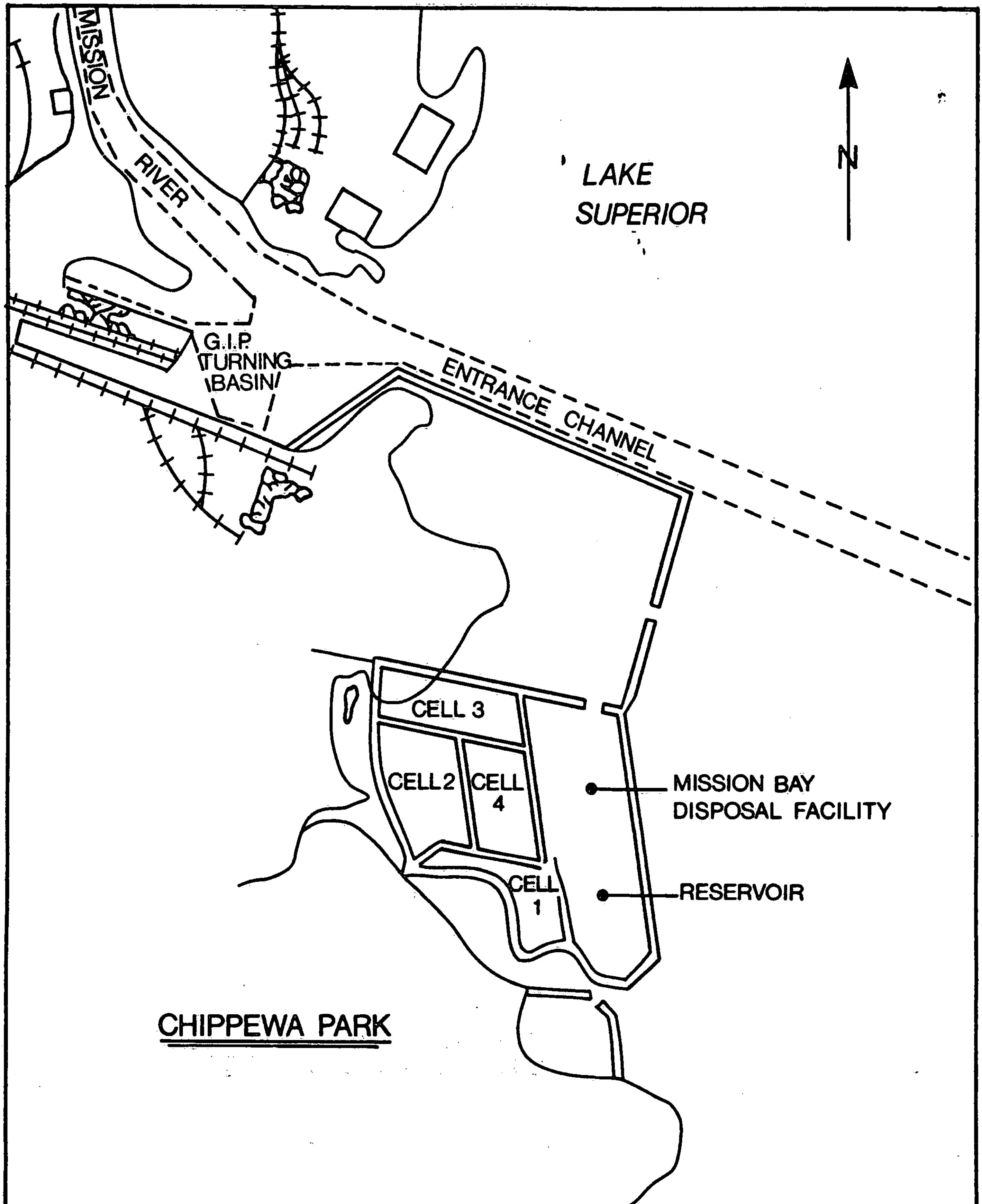

Fig. 2. The Mission Bay Disposal Facility at Thunder Bay, Lake Superior.

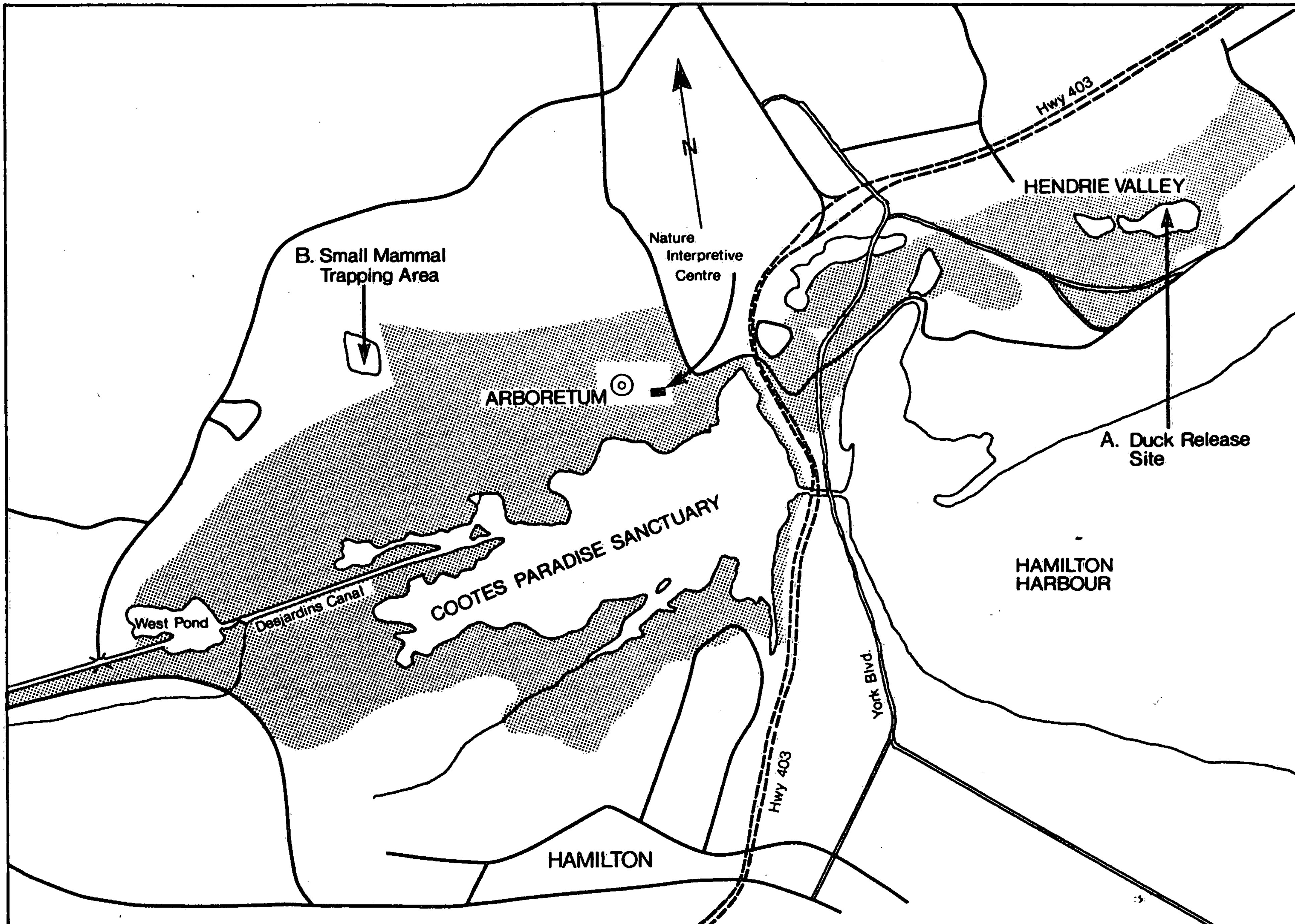

Fig. 3. Locations of control sites for the duck release (A) and small mammal trapping (B) at the Royal Botanical Gardens

NATIONAL WATER RESEARCH INSTITUTE
P.O. BOX 5050, BURLINGTON, ONTARIO L7R 4A6

Environment Canada Environnement Canada

Canada

INSTITUT NATIONAL DE RECHERCHE SUR LES EAUX
C.P. 5050, BURLINGTON (ONTARIO) L7R 4A6

Think Recycling!

Pensez à recycler !