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NWRI Contribution No. 89-28

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MANAGEMENT PERSPECTIVE

This study demonstrates a link between trophic status and contaminant bioavailability in lakes that could have a significant impact on lake management strategies. Most lake management plans are based on the formulation of objectives, either for nutrients or contaminants. In general, trophic considerations are not taken into account in the formulation of contaminant objectives and the state of an ecosystem with respect to contaminants is not considered when nutrient objectives are formulated. In lakes with significant contaminant inputs, nutrient controls to lower lake productivity could have the unintentional effect of increasing contaminant concentrations in lake biota in the absence of better controls on contaminant loading. Therefore, we recommend that in the development of lake management plans involving nutrient loading reductions, consideration should be given to the potential for increased contaminant concentrations in biota.

The NWRI Nutrient-Contaminants Interactions Project was based on the hypothesis that trophic status influenced contaminant pathways in lakes. Now that the original hypothesis has been shown to be correct, research emphasis is shifting to studies of the importance of various processes in controlling the interaction. This information is needed by water management agencies to set objectives for nutrients and persistent chemicals which include considerations of nutrient-contaminant interactions.

PERSPECTIVE ADMINISTRATIVE

La présent étude a permis de mettre en évidence une relation entre l'état trophique et la biodisponibilité des polluants dans les lacs. Il est possible que cette relation ait des conséquences sur les stratégies de gestion des lacs. La plupart des plans de gestion sont basés sur la formulation d'objectifs s'appliquant soit aux éléments nutritifs, soit aux polluants. En général, les considérations trophiques n'entrent pas en ligne de compte lorsqu'on formule les objectifs relatifs aux polluants. L'état de l'écosystème en ce qui concerne les polluants n'est pas non plus considéré lors de l'élaboration des objectifs relatifs aux éléments nutritifs. Dans les lacs où les apports de polluants sont importants et en l'absence de meilleurs moyens pour limiter des apports, on pourrait, sans le vouloir, faire augmenter les concentrations de polluants dans le biote aquatique en limitant les éléments nutritifs dans le but de faire diminuer la productivité de ces lacs. C'est pourquoi nous recommandons que le risque de l'augmentation des concentrations de polluants dans le biote soit pris en considération dans l'élaboration des plans de gestion des lacs comportant des réductions des apports d'éléments nutritifs.

Le projet relatif aux interactions entre les éléments nutritifs et les polluants de l'INRE était basé sur l'hypothèse selon laquelle l'état trophique influence le cheminement des polluants dans les lacs. Maintenant que cette hypothèse a été confirmée, on cherche à étudier l'importance des divers procédés qui régissent cette interaction. Les organismes de gestion des eaux ont besoin de cette information afin d'établir des objectifs relatifs aux éléments nutritifs et aux produits chimiques persistants qui tiennent compte des interactions entre les éléments nutritifs et les polluants.

RÉSUMÉ

On a déterminé les concentrations des polluants organochlorés transportés par voie atmosphérique dans 33 lacs du sud de l'Ontario, au Canada. Le zooplancton des lacs profonds, oligotrophes, d'eau douce était plus contaminé que celui des lacs peu profonds, plus eutrophes, d'eau dure. Cependant, les proportions relatives des polluants étaient assez constantes dans tous les lacs. Le phosphore total mesuré au printemps constitue un indicateur des concentrations des polluants atmosphériques dans le zooplancton des lacs. Il ne faut donc pas envisager de mettre en oeuvre des plans de gestion des lacs comportant des réductions de l'apport en phosphore sans prendre en considération les conséquences de la bioconcentration accrue de la contamination par les organochlorés.

The Influence of Lake Trophic Status on Concentrations of Atmospherically Transported Organochlorine Contaminants in Lake Zooplankton

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Concentrations of atmospherically transported organochlorine contaminants in zooplankton from 33 lakes in Southern Ontario, Canada, were determined. Zooplankton in deep, oligotrophic, soft water lakes were more contaminated than those from shallow, more eutrophic hard water lakes but the relative proportions of the contaminants were fairly constant in all lakes. Spring total phosphorus provides a predictor of concentrations of atmospherically transported organochlorine contaminants in lake zooplankton. Lake management plans involving phosphorus loading reductions should not be implemented without considering the consequences of increased bioconcentration of organochlorine contamination.

In recent years, contamination of aquatic ecosystems by organochlorines has occurred on a global scale. Although they can be readily detected in precipitation and surface waters throughout the northern hemisphere[(1)], factors affecting their fate in receiving waters are not well understood. In general, contaminants research has focused largely on chemical properties and ignored ecological considerations. As a consequence, most current models of contaminant behaviour in the environment rely on laboratory derived rate constants and are of limited applicability to real systems. Predicting contaminant fate and effects requires knowledge not only of the transport and transformation processes but of ecosystem factors that could interact with or modify contaminant processes. One such ecosystem factor is likely to be productivity or trophic status of the receiving water.

We studied a series Ontario lakes extending from north of Kingston to the Minden-Haliburton region. Human impact in this region is mostly due to recreational and limited agricultural activities. With few exceptions, contaminant inputs to the study lakes likely occurs via the atmosphere. This region is an area of transition between igneous and sedimentary bedrock. Therefore, over a rather limited geographical area, lakes with a range of water chemistry were available for study.

A total of 33 lakes were sampled. Springtime total phosphorus (TP) values were used as an indicator of lake trophic status[2] and ranged from a low of 3.8 ug P/l to a high of 16.8 ug P/l. Lakes were grouped in ranges of: 3-7 ug P/l (N=14); 7-12 ug P/l (N=10); and 12-17 ug P/l (N=9). In general, the higher TP lakes are shallower and conductivity is higher (Table 1) and autocorrelation exists to some extent. High TP lakes are located in the region where farming activity is more common while the low TP lakes tended to be located on the Canadian Shield. If farming activities were significant contaminant sources to our lakes, we would expect that this would affect the high TP lakes more than the low TP lakes.

Contaminant bioavailability was determined by analyzing concentrations of organochlorine compounds in zooplankton.[3] Zooplankton were chosen because their rates of contaminant accumulation and depuration are fast enough for them to exist in equilibrium with their surroundings. In addition, they accumulate contaminants by both main pathways of bioaccumulation in aquatic systems, i.e. directly from the water and in their food. Therefore contaminant concentrations in these organisms are a good indicator of contaminant bioavailability in a water body.[4] In addition, they are generally uniformly distributed throughout the pelagic zone and are readily sampled. They are not subject to the patchiness and habitat selection of fish.

As expected, organochlorines were detected in all samples analyzed. The most prominent organochlorines came from the DDT, BHC, chlordane and PCB families. These results support the assumption that the atmosphere was the major contaminant source since members of the same families are commonly the most prominent organochlorines in precipitation from the Great lakes Basin.[5] In general, the most abundant contaminant in our samples was DDE, followed by DDD, DDT, a-chlordane, g-chlordane, a-BHC, lindane, and the individual PCBs (158, 138, 118, 101, and 180) in that order. To confirm that lakes had a common source, i.e. the atmosphere, they were taken in pairs and values for the individual contaminant concentrations in one lake were regressed against the corresponding values for the other lake. An example of this regression is given in Figure 1, which compares Drag, a low TP lake, and Jacks, a high TP lake. Both linear and log transformed data were highly correlated with R values generally in excess of 0.9. Poorer correlation occurred when values were low and in some cases the lower molecular weight contaminants were poorly represented. This may occur during the evaporation phase under nitrogen blowdown.

Concentrations of major families of organochlorines for the three groups of lakes are summarized in Figure 2. In general, contaminant concentrations decrease with increasing TP. This trend is most clearly seen in the chlordane (Fig. 2b), DDT (Fig. 2c) and PCB families (Fig. 2d) where levels for lakes in the highest TP group were approximately half those for lakes in the lowest. For the BHC family (Fig 2a), values were the same for the mid and high TP concentrations. When the results were averaged for each group of lakes, zooplankton from lakes in the high TP group were found to contain only 42 % of the contaminants of those in the low TP lakes ($r=0.95$) while those in the mid-range group had 67 % of the contaminant content of those in low TP lakes ($r=0.96$).

Our results demonstrate the utility of zooplankton as indicators of bioavailability of organochlorine contaminants in lakes. While exact predictions of organochlorine contaminant concentration in lake zooplankton from atmospheric sources are beyond the scope of this paper, we have demonstrated that approximate values can be predicted from spring TP values. Should observed values fall outside these predictions, point sources should be anticipated. In our lakes, limited farming activity occurred in the drainage basins of the high TP lakes but values for the contaminants was less suggesting this was not a problem. One outlier occurred in a lake located in a town with a railway track along one side.

Most lake management plans are based on the formulation of objectives, either for nutrients or contaminants. In general, trophic considerations are not taken into account in the formulation of contaminant objectives and the state of an ecosystem with respect to contaminants is not considered when nutrient objectives are formulated. Our results demonstrate a link between trophic status and contaminant bioavailability in lakes. This link could have a significant impact on lake management strategies because nutrient controls to lower lake productivity could have the unintentional effect of increasing contaminant concentrations in lake biota.

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(3) In November 1987, zooplankton samples were collected from near the deepest part of each lake using vertical hauls from 1 m above the sediments to the surface. The Nitex net had diameter of 0.5 m and a pore size of 150 um. Sufficient sample was collected to give a volume of approximately 60 ml. Samples were freeze dried and extracted by soxhlet extraction using DIG dichloromethane. The soxhlet extractors were prepared by pre-extracting a small quantity of Celite 545 in a glass thimble with dichloromethane. The weighed sample was then added to the thimble and extracted with fresh dichloromethane for at least 20 cycles. After extraction, the extract volumes were reduced to 10-15 mls and stored cold until cleanup. To facilitate analysis, extracts were cleaned-up by gel permeation chromatography using a mixture of hexane:dichloromethane (55:45 v:v) as eluting solvent. A chromatography column (2 cm o.d.) was plugged with teflon wool and filled to a length of 50 cm with preswelled Bio-Beads S-X3 (200-400 mesh; Bio-Rad Laboratories, Richmond CA). A 250 ml solvent reservoir was maintained full to give a flow rate of 1.5 ml/min through the column. Under conditions of gravity flow, the first 110 mls contain nearly all the lipids. This fraction was collected and evaporated under vacuum to a constant weight to give total lipid weight in the sample. The next 110 mls contain the organochlorines. This fraction was collected and evaporated to 10-15 mls under vacuum, 2 ml of 2,2,4-trimethylpentane was added as a keeper and the extract was reduced to a final volume of 1 ml using nitrogen gas blowdown at room temperature.

Extracts were analyzed by dual column capillary gas chromatography on a Varian 4600 gas chromatograph equipped with two ^{63}Ni electron capture detectors. Samples were quantitated against an external standard containing 16 common organochlorine pollutants and against a series of four standards containing a total of 50 individual PCB congeners (NRCC Halifax Nova Scotia). A DB-5 capillary column was used for quantitation while confirmations were obtained with a DB-17 column. After a 2 min. initial hold at 90 °C, the oven temperature was programmed from 90 to 270 °C at 2 °/min where it was held for 25 min. Helium was the carrier gas and nitrogen was used as a make-up gas at the detectors.

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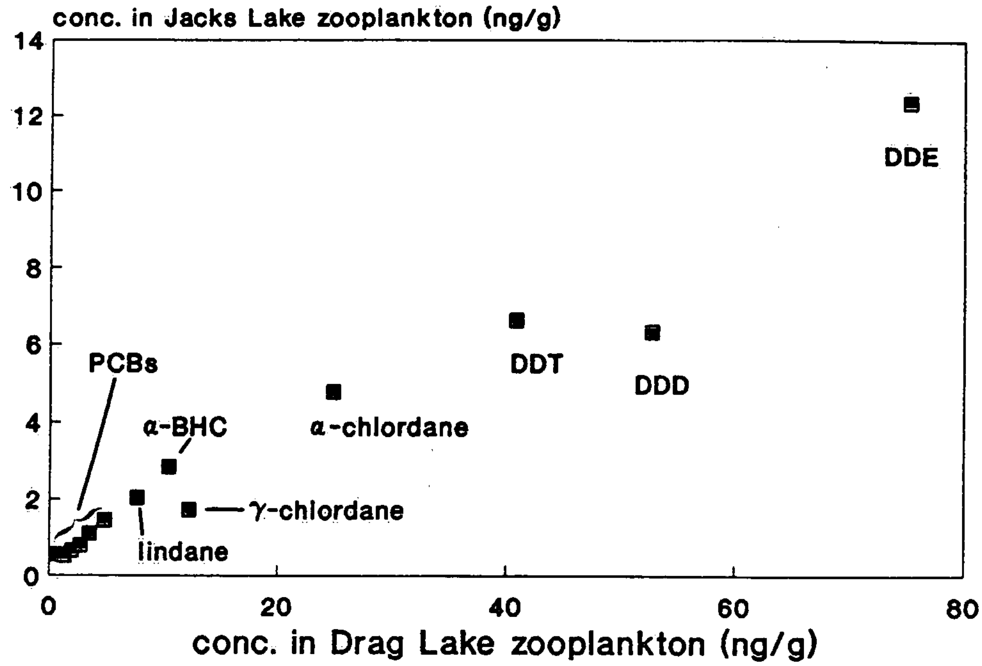
Table 1. Total spring phosphorus (ug P/l), mean depth (m) and conductivity (umho/cm) for study lakes grouped in ranges of total phosphorus, mean (SD).

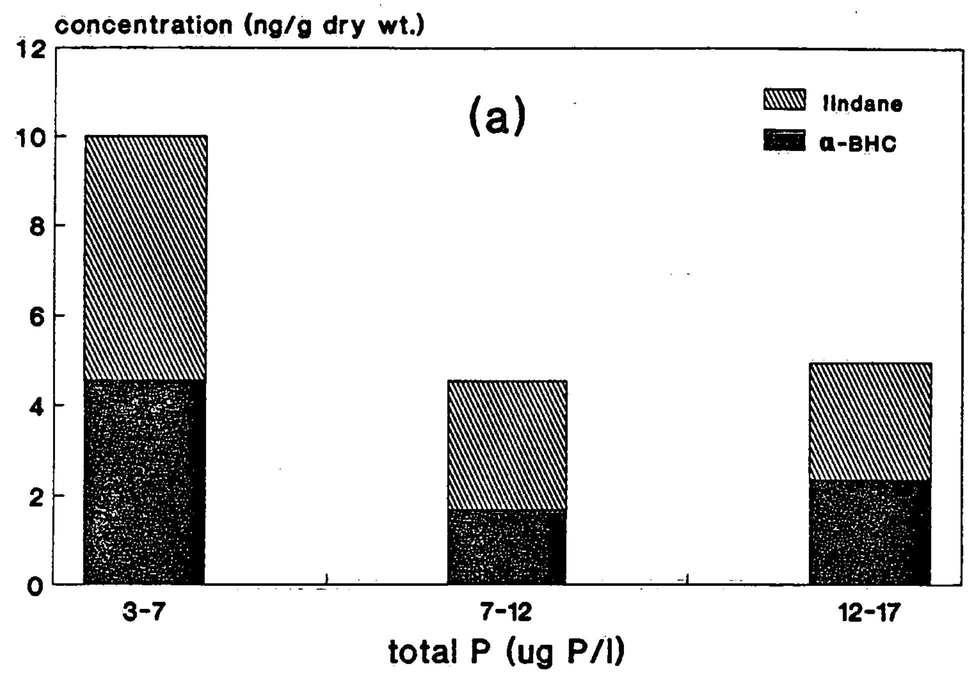
Group	3-7	7-12	12-17 ug P/l
n=	14	10	9
Spring TP	5.1 (1.0)	10.1 (1.3)	14.6(1.4)
Mean Depth	21 (11)	11 (6)	12 (3)
Conductivity	40 (16)	121 (15)	129 (43)

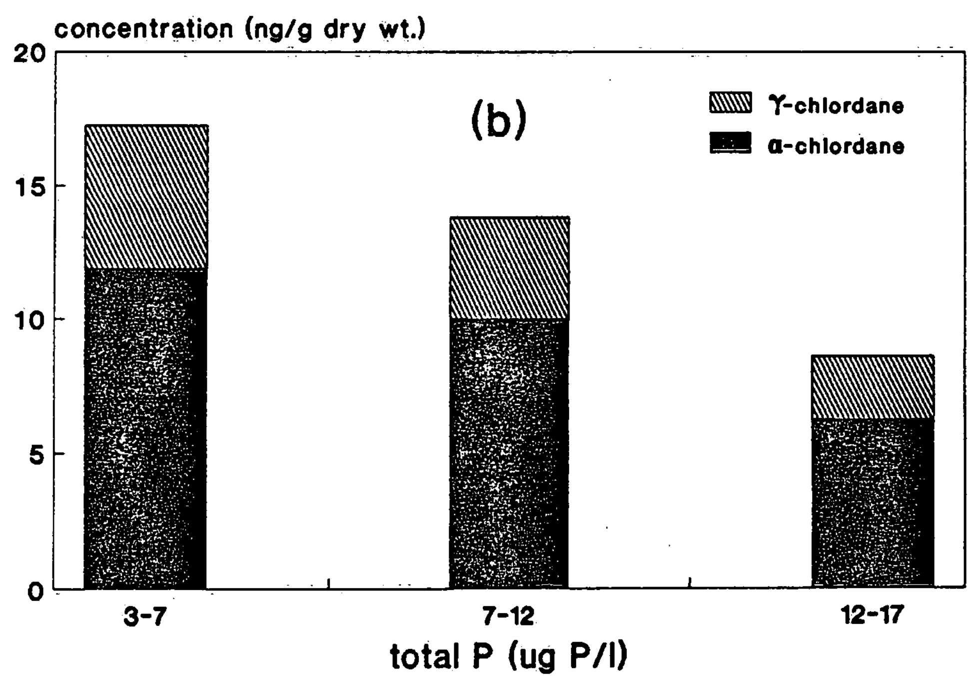
Figure Headings

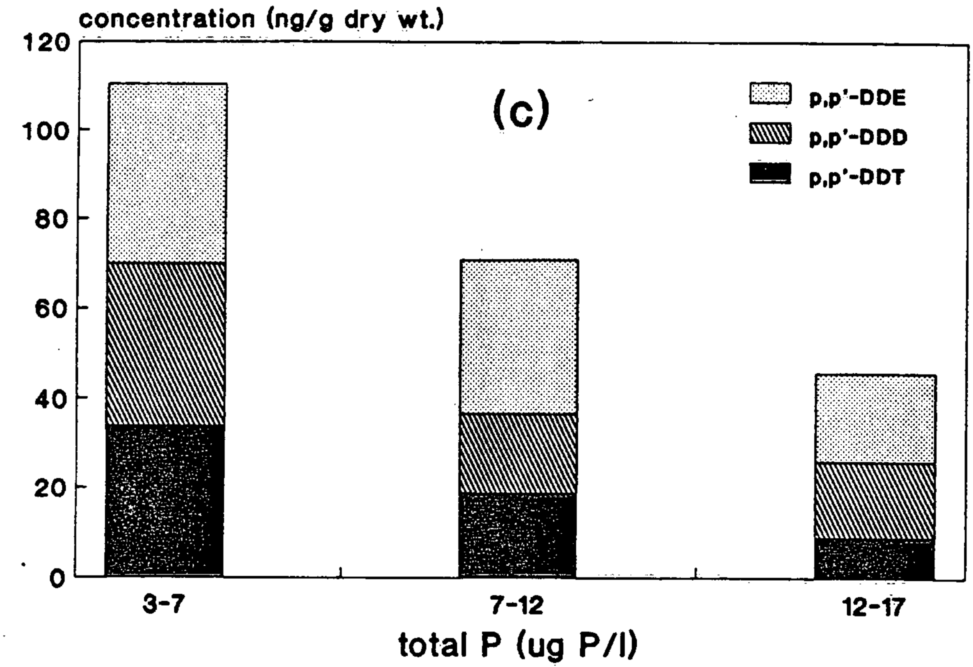
Figure 1. Concentration of organochlorine contaminants in zooplankton from Jacks Lake plotted as a function of contaminants in zooplankton from Drag Lake.

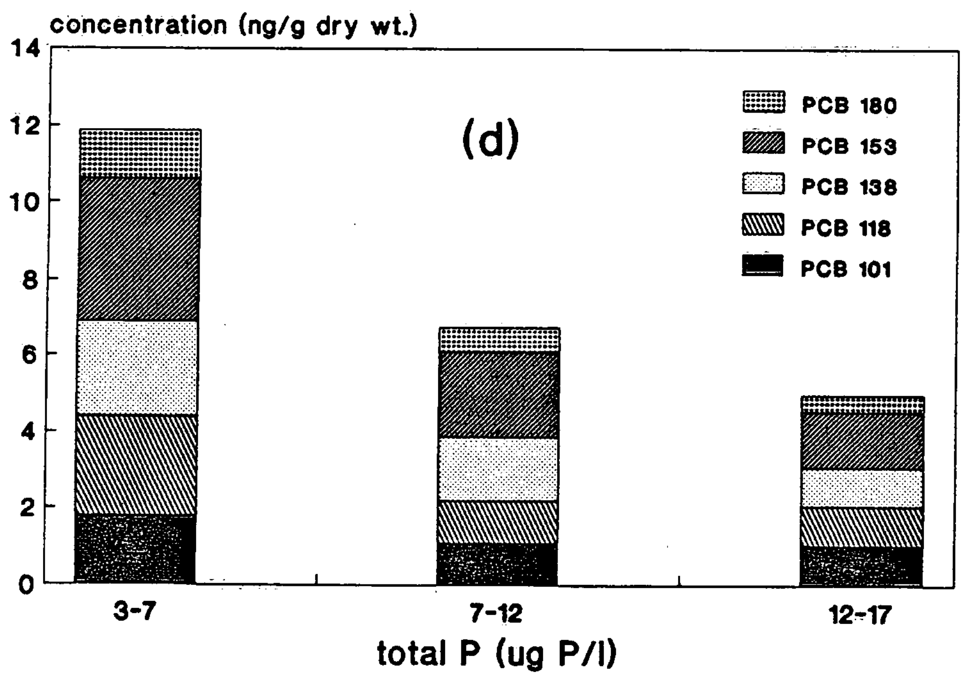
Figure 2. Average concentrations of (a) lindane and a-BHC, (b) g- and a-chlordane, (c) DDE, DDD, and DDT, and (d) PCB 180, 153, 138, 118 and 101 in zooplankton for lakes grouped by spring total phosphorus values.


conc. in Jacks Lake zooplankton (ng/g)
14
12
10
8
6
4
2
0
DDE
DDT
DDD
PCBs
α-BHC
α-chlordane
γ-chlordane
lindane
0
20
40
60
80
conc. in Drag Lake zooplankton (ng/g)


concentration (ng/g dry wt.)
12
10
8
6
4
2
0
(a)
lindane
α-BHC
3-7
7-12
12-17
total P (ug P/l)


concentration (ng/g dry wt.)
20
15
10
5
0
(b)
γ-chlordane
α-chlordane
3-7
7-12
12-17
total P (ug P/l)


concentration (ng/g dry wt.)
120
100
80
60
40
20
0
(c)
p,p'-DDE
p,p'-DDD
p,p'-DDT
3-7
7-12
12-17
total P (ug P/l)


concentration (ng/g dry wt.)
14
12
10
8
6
4
2
0
(d)
PCB 180
PCB 153
PCB 138
PCB 118
PCB 101
3-7
7-12
12-17
total P (ug P/l)

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