Scientific Issues in Relation to Lakewide Management Plans: Linking Science and Policy

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Environmental health researchers and administrators around the world look to the successful work on the Great Lakes as an example of what can be done when national governments intervene to implement programs to control pollution, particularly by persistent toxic substances. In terms of the science, the investigations into the effects on human health from consumption of contaminated Great Lakes fish have warned of the necessity for public health interventions. The signing of the Great Lakes Water Quality Agreement by the United States and Canadian governments and the use of the International Joint Commission to aid in the implementation of the agreement have been the hallmark of progress in terms of institutional arrangements.

One of the requirements in the agreement is for the governments to prepare lakewide management plans

> that embody a systematic and comprehensive ecosystem approach to restoring and protecting beneficial uses … in open lake waters.

Further such plans are designed to reduce loadings of critical pollutants and to include *a*) a definition of the threat to human health and to aquatic life posed by critical pollutants; *b*) an evaluation of information available on concentrations, sources, and pathways of critical pollutants in the Great Lakes; *c*) a schedule of load reductions of critical pollutants; and *d*) a description of surveillance and monitoring to track effectiveness. In February 1999, the Great Lakes Science Advisory Board of the International Joint Commission held a meeting to assess scientific issues in relation to lakewide management plans. The purpose of the meeting was to assess the adequacy of scientific knowledge used as a basis for preparation and implementation of the lakewide management plans, and to provide a scientific forum for informed discussion among managers, planners, and scientists related to the linkage of science and policy.

Progress in Defining the Threat to Human Health

During the past 10 years there has been substantial progress on the definition of the threat of critical pollutants to human health. By the end of the 1980s, researchers had shown in a western Michigan cohort of infants that maternal consumption of Lake Michigan fish before and during pregnancy caused irreversible growth retardation, subtle behavioral effects on newborns, and changes in short-term memory associated with prenatal exposure to polychlorinated biphenyls (PCBs). In the 1990s, this study was replicated for a cohort of infants in upper New York State, with the added finding that the infants of the mothers who ate the most Lake Ontario fish before pregnancy were unable to adapt to frustrating events. Meanwhile, researchers continuing to investigate effects on the western Michigan cohort showed that the children who were more highly exposed *in utero* had lost more than 6 IQ (intelligence quotient) points and were more likely to be 2 years behind in writing and arithmetic.

The Agency for Toxic Substances and Disease Registry has funded 10 Great Lakes studies to investigate various aspects of the effects of persistent toxic substances on human health. Similarly, Health Canada has funded a series of surveys to investigate the exposure of critical subpopulations, including certain ethnic populations, sport anglers, the elderly, children and pregnant women, who are dependent on Great Lakes fish. The general findings from these investigations are that, in addition to the neurobehavioral and developmental deficits in children from *in utero* exposures to PCBs and other persistent toxic substances, reproductive function may be disrupted (characterized by delays in time to conception). Administrators are confronted by a dilemma: Great Lakes fish are an important source of nutrition, particularly for certain disadvantaged people. On the other hand, the health implications of consumption should be communicated to the public and particularly to those at risk. In its report to the International Joint Commission, the Great Lakes Science Advisory Board has noted the need to better address these human health findings in the lakewide management plans.

Contrasting Ecosystem Approaches

The evidence of the effects of persistent toxic substances on Great Lakes wildlife preceded the investigations of the effects on human health. There have been extensive investigations undertaken during the past 40 years into the reproductive failures and declines in Great Lakes populations of fish-eating birds, particularly bald eagles, herring gulls, terns, herons, and double crested cormorants. Similarly, ranch mink that were fed Great Lakes fish had severe kit mortality associated with exposures to PCBs. In the early 1970s there were observations of chick deformities, and subsequent forensic toxicology established the diagnosis of an outbreak resembling chick-edema disease and the presence of teratogenic compounds including polychlorinated dibenzo-*p*-dioxins (PCDDs) in the Great Lakes. Similar effects were found in exposed Great Lakes populations of snapping turtles. Lake Ontario has a unique signature of pollutants because of the presence of substantial concentrations of mirex. Critical pollutants from Lake Ontario were transported in migrating American eels down the St. Lawrence River to the remaining population of beluga whales in the Gulf of St. Lawrence; this contributed to the mortality and reproductive impairment of the whales.

Although wildlife researchers attributed population declines, reproductive failure, and deformities to exposures to specific persistent toxic substances, the general consensus within the fisheries science community is that persistent toxic substances did not enter the Great Lakes until after the changes in the fish populations occurred; therefore, these stressors could not have been involved in the changes, decline, and extinctions of Great Lakes fish populations. The cumulative impact of other ecosystem stressors such as overfishing, eutrophication, the depredations of sea lamprey and other exotic species, and changes in the physical habitat are generally regarded as more important in "flipping" the Great Lakes ecosystem into alternative equilibrium states. The advice to fisheries management from this multicausal interpretation of the threat to Great Lakes fisheries has been to interlink these issues and attempt to manage every anthropogenic stressor. This has been widely understood among the fisheries research community as the meaning of the "ecosystem approach." The term is,

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however, ambiguous because wildlife and human health researchers and environmental chemists and modelers understand it to refer to the multimedia sources, distribution, and pathways of exposures to persistent toxic substances. This ambiguity has undermined the achievement of a scientific consensus on the threat of critical pollutants to aquatic life.

A new retrospective risk assessment is challenging this consensus within the fisheries science community that all Great Lakes fisheries problems are multicausal and that persistent toxic substances were not involved. From new toxicologic studies, it seems that lake trout embryos are the most sensitive vertebrates to substances with dioxin-like activity. Further analysis of a radiodated sediment core from Lake Ontario has established that the amount of 2,3,7,8-tetrachloro dibenzo-*p*-dioxin (TCDD) was high enough by around 1940 to have caused complete reproductive failure in lake trout. This date precedes the collapse of the Lake Ontario lake trout stocks; thus, on these grounds, dioxins cannot be rejected as potential contributory causes. Binational cooperation is important for successful management of fisheries resources including the assessment and control of ecosystem stressors, such as overfishing, the invasions of exotic species, and changes in the physical habitat. These management issues, however, are the responsibility of other binational institutions such as the Great Lakes Fishery Commission and the Coast Guards. It remains a moot point whether there is a need to interlink these various issues believed to affect Great Lakes fisheries and whether this interlinking should be undertaken through the Great Lakes Water Quality Agreement as advocated by fisheries scientists.

Reductions of Loads of Critical Pollutants

In the past 20 years there has been significant progress in the control of point sources of persistent toxic substances to the Great Lakes. The continuing challenge is in documenting and controlling non-point sources and sinks, including chemical landfill sites, contaminated sediment, atmospheric releases, and long-range transport and deposition of critical pollutants into the Great Lakes. Advances in the application of modeling have improved understanding of the relative importance of the multimedia sources of critical pollutants into the Great Lakes and of the multimedia pathways and routes of exposures of fish, wildlife, and human populations. For example, Lake Superior is the largest lake and is relatively unindustrialized. Atmospheric deposition of critical pollutants, such as PCBs, dioxins, and hexachlorobenzene, from remote sources outside the basin predominate. In contrast, Lake Ontario is the recipient of critical pollutants from past and present chemical manufacturing operations beside the heavily industrialized Niagara River and from industrial activities at large cities on the lakeshore. PCBs and other critical pollutants are deposited into southern Lake Michigan from the atmospheric releases in the Chicago area. In contrast, northern Lake Michigan receives PCBs predominantly from contaminated sediment from Green Bay, Wisconsin, and the Fox River, which is associated with past recycling of carbonless copying paper.

Monitoring and Surveillance

There are several challenges in deciding appropriate programs for monitoring and surveillance in relation to lakewide management plans, particularly with present constraints on government funding. Sampling and analysis of water for most persistent toxic substances is time consuming and expensive, and there are uncertainties about the interpretation of concentrations below the analytical detection limit. Selection of suitable sampling materials is further complicated by the multicausal assumptions of the fisheries ecologists. Several indicator species have been selected and used over more than two decades to track the trends in the concentrations of persistent toxic substances in the Great Lakes. For example, in 1974 the Canadian Wildlife Service initiated an annual program of sampling and analysis of herring gull eggs, and the Canadian Department of Fisheries and Oceans and the U.S. Environmental Protection Agency have sampled lake trout and other salmonids. These long-term monitoring studies have shown that the concentrations of organochlorine compounds have declined exponentially over the past 25 years.

In addition, there have been long-term studies of the trends in the prevalence of effects caused by persistent toxic substances. For example, there have been surveys of the distribution, reproductive success, and incidence of deformities in various species of fish-eating birds that were affected. Similarly, there are a few surveys that have been undertaken to investigate the specific biochemical changes induced by persistent toxic substances. For example, adult herring gulls have been sampled to determine thyroid mass and functioning, and the levels of porphyrins and retinols in the livers. Because the objective in implementing the lakewide management plans for critical pollutants is to restore populations of indigenous species that were eliminated by exposures to persistent toxic substances and to protect human health, these species are being used as sentinels.

Recommendations to the International Joint Commission

In the final plenary discussion, participants became aware of how easily these planning processes could become disjointed. Clearly, with this level of diversity of scientific disciplines, there is a challenge in integrating evidence from the various sources of information to prepare coherent statements of the threats to human health and aquatic life and to document the loadings, sources, and pathways of critical pollutants. The situation, however, seems to have been made unnecessarily complicated by the introduction of the multicausal interpretation of the Great Lakes Water Quality Agreement. One central question that emerged is whether further remedial work on leaking chemical landfill sites, contaminated sediment, and atmospheric emissions to improve water quality would be an effective use of scarce resources. Are the threats to human health and aquatic life from exposures to persistent toxic substances sufficiently serious and have they been well-enough defined in the lakewide management plans to motivate the public and their political representatives to make these decisions?

Based on this meeting, the Great Lakes Science Advisory Board has made several recommendations to the International Joint Commission.

- It is necessary that the governments prepare a statement of the human health effects of critical pollutants and refer to it in preparing the lakewide management plans
- There is a need to clarify whether the goals for the lakewide management plans relate to improving water quality or to achieving ecosystem integrity
- Because the central question in preparing the lakewide management plans concerns the cause of the threat to human health and resources, there is a priority need for those involved in the integration of the scientific evidence to state the criteria that are being used to infer the causal relations so that scientifically defensible statements can be communicated to regulatory officials
- To continue the successful work on water quality in the Great Lakes, there is a need to improve communication between researchers and officials of the various governments and agencies generally responsible for protection of human health and for restoration of resources.

These recommendations could form the basis for further binational cooperation in implementing the Great Lakes Water Quality Agreement to attain the specific purpose for which it was designed.