Chapter 4 Persistent Organic Pollutants in the Great Lakes: Human Health Considerations

Introduction

Animals often act as sentinels for human health (NRC, 1991). This is especially true for humans who, through cultural tradition or free choice, live closer to nature and have lives intimately linked to the subsistence food sources in their local region. In turn, these susceptible populations can act as sentinels to the mainstream U.S. population, for whom the complexity of modern society and diverse dietary sources diffuse connections and make causal linkages to health outcomes difficult to isolate. Thus, the early findings of persistent organic pollutants (POPs) exposure and adverse effects on wildlife reproduction, development, and survival in the Great Lakes stimulated research to determine if similar effects were occurring in human populations. In particular, efforts centered on the families of sport fishers and Native Americans known to consume large amounts of Great Lakes fish. This chapter summarizes this research, providing information on human exposures, epidemiological results, and regulatory considerations for human populations in the Great Lakes region. Although the discussion is centered on the Great Lakes, its message relates to all communities in the United States exposed to POPs pollution.

The chapter is based on epidemiological information: the study of disease in human populations. Epidemiological research is a difficult endeavor, reflecting the complexity of the species under investigation. This complexity affects the multiple exposures and endpoints experienced by humans and the variations, patterns, and linkages in exposures, as well as the statistical methods necessary to tease these apart. Laboratory confirmation of low-level toxicological results in humans is not usually an option because of ethical considerations. As a result, when interpreting data consideration must be given to the inherent difficulties in analyzing potential effects from low-level exposures. For instance, an adverse human health impact may be difficult to demonstrate because the number of people affected is small relative to the statistical power of the study to isolate this effect. For POPs, the control group in a study may also be exposed, albeit to a lesser degree, leading to a situation where both exposed and control groups may be exhibiting adverse effects and there appears to be no difference between the two. Misclassification of exposure, a common difficulty, also tends to diffuse results and weaken findings of effects.

From another perspective, there may be no adverse effects from a POP exposure and yet statisti-

Paper company waste disposal basin in 1970: A source of pollutants to the Great Lakes.

Photo: Minnesota Sea Grant, March 1970

cally significant differences are found between control and exposed groups. This can be the result of such simple factors as performing multiple tests, some of which will eventually appear "abnormal" by random chance because of the common $p < 0.05$ (1 in 20) statistical significance value. More difficult to isolate are the effects of confounding and bias, where the control and exposed groups become unbalanced through study design limitations. For instance, lifestyle differences between sport fishers in the Great Lakes and the general population need to be considered before assigning health outcomes solely to dietary differences in POPs intake. For a more detailed analysis of these epidemiological data and considerations, see De Rosa et al. (1999) and Johnson et al. (1998).

Historical Background on POPs Exposure Studies in the Great Lakes

The first human exposure study of POPs in the Great Lakes was the 1974 study of polychlorinated biphenyl (PCB) intake from sport fish consumption (Michigan Sports Fishermen Cohort; Humphrey, 1976). Sport fish eaters were found to consume on average 32 pounds of fish per year, some eating as much as 262 pounds per year. During the 1970s, this average was approximately five times the national per capita fish consumption rate commonly used in risk estimates. Individuals who regularly ate 24 lbs/yr or more of Great Lakes fish had higher ($p < 0.001$) serum levels of PCBs than individuals who seldom or never ate such fish. The study was repeated in 1982, again indicating that individuals in the upper range of fish consumption had serum PCB levels approximately four times greater than unexposed individuals. These studies identified a positive correlation between human intake of toxic pollutants and the consumption of Great Lakes fish (Humphrey, 1976, 1988a,b, 1989).

Recreational fishers and the Great Lakes.
Photo: ATSDR

A similar assessment of body burden levels of PCBs and DDE was undertaken in the Wisconsin Sports Fish-Consumers Cohort Study (Fiore et al., 1989; Sonzogni et al., 1991). Using new technology for analyzing toxic chemicals in human blood, the investigators were the first to determine PCB-specific congeners in Great Lakes sport anglers. They determined that the congeners most frequently identified in human sera were also the most abundant congeners in the tissues of a variety of Wisconsin fish (Maack and Sonzogni, 1988). Body burden levels of PCB congeners and DDE were significantly correlated with the number of sport fish meals consumed.

Both of these early studies demonstrated that human populations can be exposed to POPs through consumption of fish. Multimedia analyses support this finding, showing that most human exposure to chlorinated organic compounds (80-90%) comes from the food pathway (Figure 4-1). A lesser amount (5-10%) comes from air, and very small amounts (less than 1%) come from water (Birmingham et al., 1989; Newhook, 1988). Recent data indicate that fish consumption appears to be a major pathway for exposure to POPs chemicals, especially for compounds such as PCBs and dioxins (Fitzgerald et al., 1996; Schaum et al., 1999).

Identification of Critical Great Lakes Pollutants

Cooperation between Canada and the United States on the Great Lakes is managed through the International Joint Commission (IJC), established under the 1909 Boundary Waters Treaty. Among the IJC's mandates is the responsibility for protecting the lakes and river systems along the border for the benefit of citizens and future generations. In 1985, the IJC identified 11 of the most persistent and widespread toxic substances as critical Great

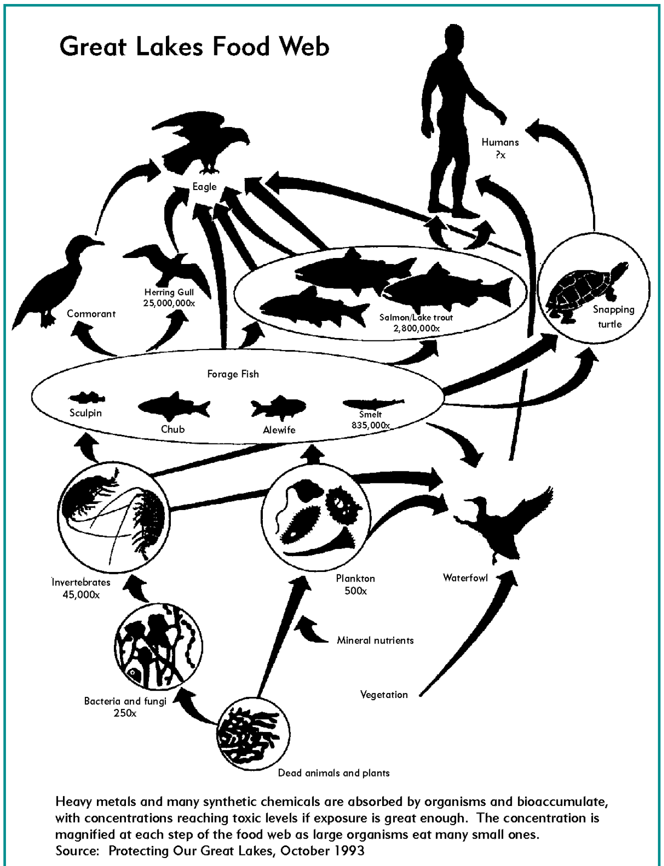

Figure 4-1. The Great Lakes food web. Heavy metals and many synthetic chemicals are absorbed by organisms and biaccumulate, with concentrations reaching toxic levels if exposure is great enough. The concentration is magnified at each step of the food web as large organisms eat many small ones (Hicks et al., 1996).

Lakes pollutants: PCBs, dichlorodiphenyl trichloroethane (DDT), dieldrin, toxaphene, mirex, methylmercury,benzo[a]pyrene (a member of a class of substances known as polycyclic aromatic hydrocarbons [PAHs]), hexachlorobenzene (HCB), polychlorinated dibenzo-*p*-dioxins and dibenzofurans, and alkylated lead (IJC, 1983). Eight of these pollutants are on the initial list for the Stockholm Convention, with the remaining four global POPs incorporated under subsequent Great Lakes binational agreements (*http://www.epa.gov/glnpo/bns*).

Forty-two geographic locations in the U.S. and Canadian Great Lakes basin have been identified by the IJC as "Areas of Concern" because of high concentrations of these toxic pollutants (National Health and Welfare Canada, 1991) (Figure 4-2).

Of these 42 locations, 31 are located within the boundaries of the United States (Hicks, 1996). Beyond the substances and locations prioritized by the IJC, many more commercial and industrial compounds (~30,000) are produced or used in the Great Lakes basin, about 1,000 of which have been identified in the Great Lakes environment.

ATSDR Great Lakes Human Health Effects Research Program

In 1990, the U.S. Congress amended the Great Lakes Critical Programs Act to investigate human health concerns and pollutants in the Great Lakes. In response, the Agency for Toxic Substances and Disease Registry's (ATSDR) Great Lakes Human Health Effects Research Program (GLHHERP) was initiated in 1992. This program is designed to characterize exposure to toxins through consumption of Great Lakes fish and to investigate the

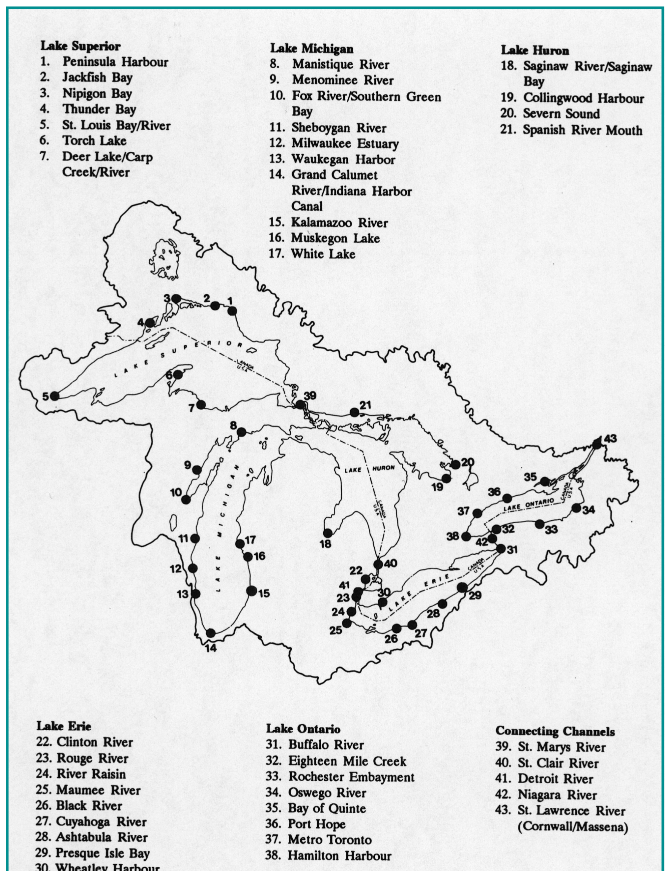

Figure 4-2. IJC areas of concern in the Great Lakes Basin (Great Lakes Fishery Commission, 1993). (#19 Collingwood Harbor has been delisted as an area of concern.)

potential for short- and long-term adverse health effects. The research program focuses on the initial 11 critical Great Lakes pollutants identified by the IJC, as well as other chemicals of concern in the Great Lakes basin. The program has identified several sensitive human health endpoints for study, including behavioral, reproductive, developmental, neurologic, endocrinologic, and immunologic measures. ATSDR's Great Lakes research further identified several human populations that may be at particular risk because of higher exposures to Great Lakes pollutants via fish consumption (Table 4-1). Predisposition to toxic injury in these populations can be due to behavior (e.g., degree of contaminated fish consumption), nutritional status, physiology (e.g., developing fetuses), or other factors. These communities of concern include subsistence fish anglers, Native Americans, pregnant women, fetuses, nursing infants of mothers who consume contaminated Great Lakes sport fish, young children, the elderly, the urban poor, and those with compromised immune function.

Contemporary data support the association between the consumption of contaminated Great Lakes fish and elevated body burdens of POPs and mercury, summarized by the following findings (Table 4-2):

- Communities of concern in the Great Lakes basin are still exposed to POPs, including PCBs, polychlorinated dibenzo-*p*-dioxins and furans, and chlorinated pesticides (e.g., DDT) (Hanrahan et al., 1999; Stewart et al., 1999; Schantz et al., 1999; Johnson et al., 1998; Anderson et al., 1998; Dellinger et al., 1996; Fitzgerald et al., 1996; Lonky et al., 1996; Schantz et al., 1996; and Humphrey et al., 2000).
- Levels of some contaminants in Great Lakes sport fish are above the advisory limits set by the State and Federal governments (Dellinger et al., 1996).
- Sport fish eaters consume on average two to three times more fish than the estimate of 6.5 g/day for the general U.S. population (Courval et al., 1996, 1999; Fitzgerald et al., 1996, 1999; Schantz et al.,1996, 1999; Anderson et al., 1998; Hanrahan et al., 1999; He et al., 2001). In one survey in Michigan, Great Lakes sport fish consumers reported eating on average 42 g/day (Michigan Department of Environmental Quality, 1996). The reported weight of fish consumed declined from the early 1970s to 1990s (He et al., 2001).
- Consumption of Great Lakes fish appears to be the major pathway of exposure for some POPs (Fitzgerald et al., 1996, 1999; Stewart et al., 1999). Men eat more fish than do women, both genders eating Great Lakes fish during most of their reproductive years (Courval et al., 1996; Fitzgerald et al., 1996, 1999; Lonky et al., 1996; Waller et al., 1996; Hanrahan et al., 1999).
- Body burden levels for some of the POPs are two to eight times higher than those of the general U.S. population (Anderson et al., 1998; Hanrahan et al., 1999; Schantz et al., 1996, 1999; He et al., 2001). A significant trend of increasing body burden is associated with increased fish consumption (Fitzgerald et al., 1996, 1999; Falk et al., 1999; Hanrahan et al., 1999).
- Although background levels of PCBs appear to have declined in Great Lakes residents by the early 1990s, serum PCB levels among consumers of sport-caught Great Lakes fish did not significantly decrease (He et al., 2001).

Table 4-1. Human populations at increased risk
Native Americans
Sport anglers
Elderly
Pregnant women
Fetuses
Nursing infants
Women and men of reproductive age
Immunologically compromised persons

Table 4-2. Exposure studies in human populations

Population	Findings	Reference
Lake Michigan fisheaters cohort	PCB levels in breast milk and maternal serum correlate with consumption of contaminated fish.	Humphrey, 1983
Native Americans (Mohawk) in New York State	Mean serum PCB level in men of 5.4 parts ppb (max. 31.7 ppb), versus 2 ppb in the general population (Jensen, 1989). Serum PCB levels were positively related to the number of fish meals consumed per year and increasing age.	Fitzgerald et al., 1996
Elderly cohort of Lake Michigan sport anglers	PCBs, DDE, and mercury levels were significantly higher in high fisheaters. High fisheaters presented disproportionately higher body burden levels of PCBs and DDE than low fisheaters in each age group, i.e., 50-59, 60-69.	Schantz et al., 1996
Pregnant women who consumed Lake Ontario fish	Women in the high fish consumption group ate an average of 2.3 salmon or trout meals per month for an average of 16 years.	Lonky et al., 1996
Pregnant African-American women who consumed Lake Michigan fish	Women were exposed to POPs via fish consumption during most of their reproductive years. Seventy-five percent were less than 26 years of age and consumed lake fish for more than 15 years.	Waller et al., 1996
Reproductive-age (18-34) Lake Michigan sport anglers	Approximately 50% ate 1-12 sport-caught meals in the past year, and 20% consumed 13-24 meals. Fish consumption was greater in males than females, with some males consuming 49 or more fish meals per year.	Courval et al., 1996
Charter boat captains, their spouses, and Great Lakes anglers	Serum levels of dioxins, furans, and coplanar PCBs vary by gender. Fish species consumed predicted coplanar PCBs and furan body burden levels, but not dioxin.	Falk et al., 1999

Epidemiological Data

Epidemiological studies of Great Lakes populations have centered principally on reproductive effects and neurobehavioral/cognitive impacts on children. On the basis of these and similar studies, the National Research Council (1999) concluded that:

> In humans, results of cognitive and neurobehavioral studies of mother-infant cohorts accidentally exposed to high concentrations of PCBs and PCDFs, and mother-infant cohorts eating contaminated fish and other food products containing mixtures of PCBs, dioxin, and pesticides (such as DDE, dieldrin, and lindane) provide evidence that prenatal exposure to these HAAs [hormonally active agents] can affect the developing nervous system.

Many of the studies on which this conclusion is based originated from Great Lakes epidemiological research and are summarized below.

Reproductive Effects

In a cross-sectional mail survey of reproductive-age Michigan licensed anglers and their partners, Courval et al. (1999) reported a modest association in men between sport-caught fish consumption and the risk of conception failure after trying for at least 12 months. On the basis of answers to questionnaires, 15% of couples had reported conception failure. Among men, the unadjusted odds ratios (ORs) for conception failure were 1.2, 1.3, and 2.0 across the three increasing levels of sport-caught fish consumption compared to no consumption (trend test p = 0.06). Adjusting for variables, i.e., age, region of Michigan, smoking, and alcohol consumption, the ORs were 1.4, 1.8, and 2.8, respectively. For women, the unadjusted ORs for conception were 0.9, 1.0, and 1.4 with increasing fish consumption (trend test p = 0.35). When the same covariates and partner's sport-caught fish consumption were included in the model for conception failure in women, the ORs became 0.8, 0.8, and 1.0, respectively, indicating no increased risk from female exposure.

A series of studies on reproductive health has been performed on a cohort of New York State anglers and their spouses. In this cohort, questionnaires provided data on each person's species-specific fish consumption pattern, medical and reproductive histories, sociodemographic characteristics, and other lifestyle behaviors. Individual fish consumption at the time of enrollment in this study was characterized by duration and frequency, and used to calculate a PCB exposure index. Health outcomes were assessed through a combination of questionnaires and birth certificates. Multiple regression statistical analyses were carried out to control for identified variables. Findings from this cohort include the following:

- Mendola et al. (1995) found no significant relationship between estimated low-to-moderate PCB intake from Great Lakes fish (up to 7 mg/lifetime) and the risk of clinically recognized spontaneous fetal death.
- Mendola et al. (1997) identified significant menstrual cycle length reductions with consumption of more than one fish meal per month (+1.11 days). Women who consumed contaminated fish for 7 or more years also had shorter cycles (–0.63 days). The results were consistent with measures of frequency of consumption and the index of lifetime PCB exposure having a stronger relationship with menstrual cycle length than the number of years of fish consumption.
- Buck et al. (1997) found no adverse association between the duration of consumption of contaminated fish from Lake Ontario and time-to-pregnancy.
- Buck et al. (2000) found that maternal, but not paternal, consumption of fish from Lake Ontario may reduce fecundability (ability to conceive) among couples attempting pregnancy.

Neurodevelopmental Effects

Of the epidemiological studies of POPs exposures, none is more central than the Lake Michigan Maternal/Infant Cohort Study (Fein et al. 1984; Jacobson et al. 1985, 1990a,b). This study reported both developmental disorders and cognitive deficits in the offspring of mothers who were exposed to PCBs via fish consumption for at least 6 years before and during pregnancy. Developmental effects included a statistically significant decrease in gestational age (by 4.9 days), birth weight (by 160 to 190 g), and head circumference (by 0.6 cm). These effects were still evident compared with the control population at 5 and 7 months postterm. Neurobehavioral deficits observed in babies included greater inclination to startle; poorer motor reflex and neuromuscular function; depressed responsiveness, as evidenced by a greater number of hypoactive reflexes; impaired visual recognition; and poor short-term memory at 7 months of age. At 4 years following birth, these deficits were still evident in weight gain, depressed responsiveness, and reduced performance on the visual recognition-memory test, one of the best validated tests for the assessment of human cognitive function.

Although these data provide substantial evidence of in utero effects from PCBs, some significant questions were raised regarding causality because of recognized limitations in the studies. These included loss of study participants over time, a nonrandom sampling technique for the selection of the study population, limited statistical power because of the size of the control group, and analysis only of total PCBs. Also, the standards used (Aroclor 1016 and 1260) as references to quantify total PCBs accounted for only a small portion of the PCB congeners detected (Swain, 1991). Therefore, the analytical methods used to measure PCB levels may not have been appropriate. Moreover, many potential confounding variables have been identified, including exposure to other chemical contaminants and the mothers' health status at the time of the study. Nevertheless, a subsequent retrospective analysis by Swain (1991) found that the relationship between PCB exposure and transplacental passage was strongly affirmed, and the relationship between PCB exposure and developmental effects and cognitive deficits was affirmed with reasonable certainty.

Neurobehavioral testing of a child.
Photo: ATSDR

In a followup examination of 212 children from the Lake Michigan Maternal/Infant Cohort Study, the neurodevelopmental deficits assessed in infancy and early childhood were found to persist at age 11 (Jacobson and Jacobson, 1996). The study results indicated that the most highly exposed children, those with prenatal exposures equivalent to at least 1.25 µg/g in maternal milk, 4.7 ng/mL in cord blood, or 9.7 ng/mL in maternal serum

- Were three times as likely to have low average IQ scores ($p < 0.001$)
- Were twice as likely to be at least 2 years behind in reading comprehension
- Had poorer short- and long-term memory
- Had difficulty paying attention.

The authors concluded that these intellectual impairments were attributable to in utero exposure to PCBs, and that concentrations of PCBs in maternal serum and milk at delivery were slightly higher than in the general U.S. population.

The initial findings of the Lake Michigan Maternal/Infant Cohort Study have now been replicated in independent cohort analyses. Similar results were seen in the Oswego Newborn and Infant study, a prospective longitudinal cohort study examining behavioral effects in newborns, infants, and children exposed pre- and postnatally to environmental toxicants. Lonky et al. (1996) found that maternal exposure to Lake Ontario fish contaminants (e.g., PCBs) was associated with neurobehavioral deficits when assessed shortly after birth. A total of 559 newborns of women who had high exposure, low exposure, or no exposure to Lake Ontario fish were examined using the Neonatal Behavioral Assessment Scale (NBAS) 12-24 hours after birth and again at 25-48 hours after birth. Newborns of high-fish-consuming mothers exhibited the following deficits:

- A greater number of abnormal reflexes ($p < 0.001$)
- Less mature autonomic responses ($p < 0.001$)
- Less attention to visual and auditory stimuli in comparison to newborns of low- or no-fish-consuming mothers ($p < 0.01$)

These results indicate that newborns of mothers who consumed 2.3 salmon or trout meals per month scored more poorly on the NBAS than newborns from the low-exposure or control groups. These results represented the first replication and extension of the neonatal results of the Lake Michigan Maternal/Infant Cohort study by Jacobson et al. (1984).

Further analysis of the Oswego data on newborns revealed significant relationships between cord blood concentrations of the most highly chlorinated PCBs and performance impairment on the NBAS habituation and autonomic tests. No significant relationship was found between PCBs of lesser chlorination, DDE, hexachlorobenzene, mirex, lead, or mercury on any NBAS performance test (Stewart et al., 2000). The relationship between prenatal exposure to PCBs and performance on the Fagan Test of Infant Intelligence (FTII) was also assessed in the Oswego infants at 6 months and again at 12 months of age. The results indicated a significant relationship between exposure to PCBs and poor performance on the FTII. No significant relationship was found between exposure to DDE or methylmercury on any tests of the FTII (Darvill et al., 2000).

Studies of the impact of POPs, particularly PCBs, on human neurobehavioral development are not limited to the Great Lakes region of the United States and have been performed in other regions of the United States and abroad. In the early 1980s, the North Carolina Breast Milk and Formula Project was conducted with more than 800 mother-infant pairs who were exposed to backgound levels of PCBs (Rogan and Gladen, 1985; Rogan et al., 1986; Rogan and Gladen, 1991). When the North Carolina children were tested after birth, they exhibited the same behavioral deficits that were characteristic of the children studied by Jacobson et al. and the newborns of the Oswego Newborn and Infant Study. However, at 3 years of age the behavioral deficits were no longer detectable in the children from the North Carolina study. In an occupational study of women exposed to PCBs during the manufacture of capacitors in New York State, decreased gestational age and depression of weight at birth were associated with PCB exposure (Taylor et al., 1989).

Internationally, a series of studies in Europe are investigating the effects of exposure to PCBs and polychlorinated dioxins and furans on neurological development in the developing fetus and newborn (Huisman et al., 1995). These studies have linked high maternal levels of PCBs, PCDDs, and PCDFs with reduced neonatal neurological performance. The data also indicate that high in utero exposure to PCBs (measured in maternal serum) is associated with lower psychomotor scores at 3 months of age (Koopman-Esseboom et al., 1996) and with poorer cognitive functioning in preschool children at 42 months of age (Patandin et al., 1999).

Neurobehavioral changes have also been demonstrated in monkey and rat offspring following low perinatal doses of dioxin (Schantz and Bowman, 1989; Markowski et al., 2001) and PCBs (Rice, 1999; Schantz et al., 1989; Levin et al., 1988).

Other Cognitive and Systemic Health Effects

Beyond the developmental neurobehavioral findings reported above, additional studies have been conducted on Great Lakes fish consumers across different age groups and different health endpoints. These include the following:

- The effects of POPs on the immune system have been investigated in breast-fed infants whose mothers consumed contaminated Great Lakes fish. Maternal serum PCB levels during pregnancy were positively associated with the number and type of infectious illnesses occurring in infants during the first 4 months of life (Smith, 1984; Humphrey, 1988b). The incidence of infections has also been found to correlate strongly with the highest rate of fish consumption (at least three times per month for 3 years) and with cumulative lifetime fish consumption (Swain, 1991).
- In an older population of sport anglers, 50-90 years of age, fine motor function skills were assessed to determine the effects of exposure

to PCBs and DDE. This population consisted of two groups: (a) high fisheaters who had consumed 24 pounds or more of Great Lakes sport-caught fish annually for more than 15 years, and (b) low (or non-fisheaters) who consumed less than 6 pounds annually. The study demonstrated that serum levels of PCBs and DDE were highly correlated, and both were significantly higher in high fisheaters than in low fisheaters. The mean serum PCB concentrations for low versus high fisheaters were 6 ppb and 16 ppb, and the maximum values were 26 ppb and 75 ppb, respectively. The mean serum DDE concentrations for low versus high fisheaters were 7.3 and 15.9 ppb, with maximum values of 33 and 145 ppb, respectively. In the cross-sectional data analysis, the authors concluded that PCB and DDE exposure from consumption of Great Lakes fish did not impair fine motor function (Schantz et al., 1996). The study also included a longitudinal component, where changes in individual scores for motor function over time were postulated to be a more sensitive indicator of exposure-related effects (Schantz et al., 1999). Recently published results of this longitudinal component reported that exposure to PCBs, but not DDE, was associated with lower scores on several measures of memory and learning in this older population of fish-eaters (Schantz et al., 2001).

Commercial fishing on the Great Lakes, Duluth, Minnesota.

Photo: Minnesota Sea Grant

Fish and Wildlife Advisories

States, U.S. territories, and Native American Tribes issue food consumption advisories in order to protect residents from the health risks associated with contaminated noncommercially caught fish and wildlife. These advisories, primarily for fish consumption, inform the public on which species to avoid or limit eating because of elevated levels of pollutants. The advisories apply primarily to noncommercial fish and shellfish obtained through sport, recreation, and subsistence activities. Each advisory is different: it may recommend no or limited consumption; be targeted to everyone or limited to women and/or children; or may apply to certain species or sizes of fish. The fish advisories are submitted annually to EPA and compiled into a national listing (*www.epa.gov/ost/fish*).

Advisories in the United States exist for a total of 38 chemical contaminants, but most advisories involve 5 primary pollutants: mercury, PCBs, dioxin, DDT, and chlordane. Four of these five pollutants are under the Stockholm Convention. The fifth, mercury, is generally emitted to the environment as a nonorganic metal, and is currently slated for a global risk assessment review by the United Nations Environment Programme. The number of advisories in the United States reported in 2000 (2,838) represents a 7% increase from the number reported in 1999 (2,651) and a 124% increase from the number issued since 1993 (1,266) (U.S. EPA, 2001). The national survey indicates that 100% of the Great Lakes and their connecting waters, and 71% of the coastal waterways, were under advisory in 2000 (Table 4-3). The total number of advisories increased for mercury, PCBs, dioxins, and DDT, although often the increased number of advisories is considered to represent better monitoring of fish contamination

Table 4-3. Fish advisories issued for the Great Lakes

Great Lakes	PCBs	Dioxins	Mercury	Chlordane
Lake Superior	●	●	●	●
Lake Michigan	●	●	●	●
Lake Huron	●	●		●
Lake Erie	●	●		
Lake Ontario	●	●		

Source: U.S. EPA (2001).

rather than increased pollution. Advisories for PCBs (see Figure 4-3) increased 3% from 1999 to 2000, from 703 to 726, and increased 128% from 1993 to 2000 (319 to 726). To date, 75% of the 726 PCB advisories in effect have been issued by 9 States, 8 of which are Great Lakes States (U.S. EPA, 2001).

The issuance of fish advisories is not a solution to POPs pollution, but rather a protective measure until pollutant reductions to safe levels can be achieved. Indeed, sociobehavioral and demographic data from the Great Lakes region reveal substantial nonadherence to fish advisories for a variety of reasons, further emphasizing the need for POPs pollution prevention at the source rather than relying on dietary pathway advisories.

- A recent survey of adult residents of the eight Great Lakes states estimated that 4.7 million people, 43.9% of whom were women, consumed Great Lakes sport fish in a given year (Tilden et al., 1997).
- Knowledge of, and adherence to, health advisories for Great Lakes sport-caught fish vary across different genders and populations, e.g., men compared with women, whites compared with Native Americans (Fitzgerald et al., 1996, 1999; Waller et al., 1996; Tilden et al., 1997).
- 50% of survey respondents who had eaten Great Lakes sport fish were aware of the health advisory for fish; awareness differed significantly by race, sex, educational level, fish consumption, and state of residence (Tilden et al., 1997).
- 80% of minorities who had eaten Great Lakes sport fish were unaware of the fish advisory, and awareness was particularly low among women (Tilden et al., 1997).
- 97% of Native American men were aware of local advisories against consuming Great Lakes sport fish. However, 80% of the men ate those fish (Fitzgerald et al., 1999).
- Fish is an essential component in the diets of many minority populations and Native Americans. These populations consume fish that tend to have higher levels of contaminants (Fitzgerald et al., 1996; Waller et al., 1996).

In response to these sociobehavioral and health effects findings, advisories now target their message and actions to vulnerable subpopulations, such as pregnant women, nursing mothers, and children. There are now 5 categories of consumption advisory: (1) no consumption for the general population, (2) no consumption for sensitive subpopula-

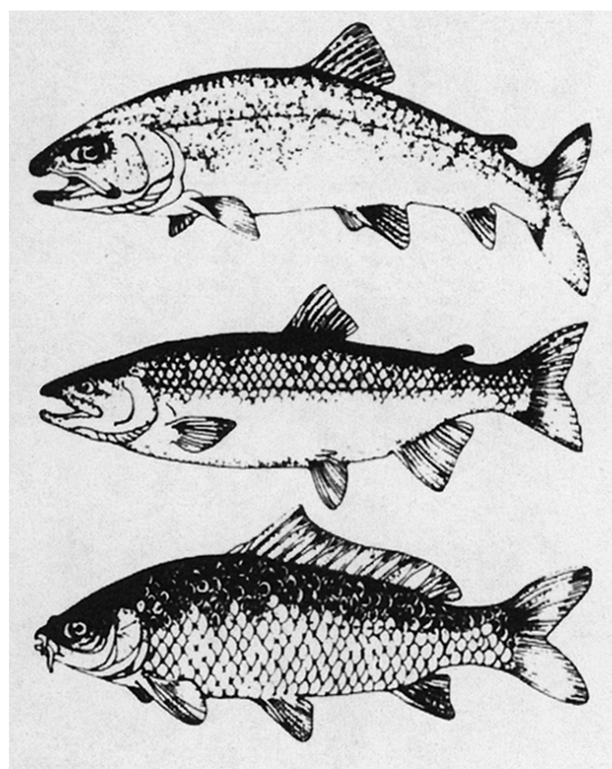

Figure 4-3. Fish most affected by PCB advisories: lake trout, coho salmon, and carp.

Credit: The ABC's of PCBs, University of Wisconsin Sea Grant Institute tions, (3) restricted consumption advisory for the general population, (4) restricted consumption advisory for sensitive subpopulations, and (5) a commercial fishing ban. The value of strategically targeted fish advisories has been demonstrated through health education outreach efforts in two populations of Native Americans. In these vulnerable communities, body burden levels had been elevated two- to eightfold for some POPs. These levels were reduced through working with community "gatekeepers" and organizing health fairs and public meetings to provide information on cooking practices to reduce exposures. The targeted intervention strategies helped to reduce body burden levels to U.S. population averages within a 6-year period, without sacrificing fish as a nutritionally important dietary component (Hicks et al., 2000).

The continuing need for fish advisories over the entire Great Lakes region emphasizes that POPs remain a major concern. However, the reductions seen for POPs in many places are encouraging. In particular, PCB concentrations in fish from the Great Lakes region have declined over the years (ATSDR, 2000). In 1985, coho salmon from Lake Michigan contained 0.99 ± 0.6 ppm of PCBs, whereas by 1992 the level was 0.78 ± 0.29 µg/g (Eggold et al., 1996). Between 1976 and 1994, mean levels of PCBs declined in Lake Ontario rainbow trout from 3.9 to 0.97 ppm wet weight (Scheider et al., 1998). Similar trends in PCB levels were found for other fish species (ATSDR, 2000). These initial reductions in POPs levels following pollution control by industry and through government regulation have now, in a number of instances, slowed or plateaued, unmasking the importance of long-range atmospheric transport as a continuing source to the Great Lakes (Figure 4-4). As stated by the IJC (1996):

> We are increasingly recognizing that a variety of pollutants emitted to and transported by the air have become the major pathway of pollution to the Great Lakes. These pollutants may come from direct sources, ... distant sources in North America and beyond...

Additional detail on the deposition and contribution of atmospheric transport loadings to the Great Lakes can be found in Deposition of Air Pollutants to the Great Waters, Third Report to Congress (U.S. EPA, 2000).

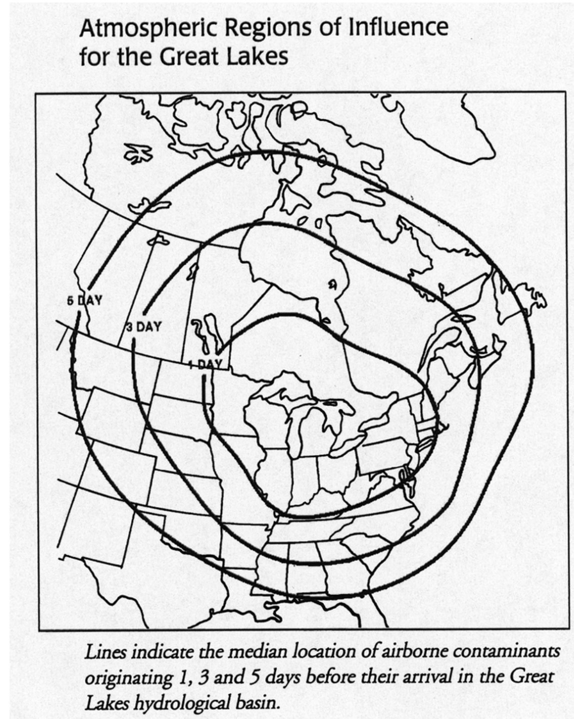

Figure 4-4. Atmospheric deposition: a major pathway of pollution for the Great Lakes (IJC, 1996).

Conclusion

Adverse effects from POPs have been demonstrated on Great Lakes wildlife and in laboratory studies at environmentally relevant levels. Similar effects are reported in epidemiological studies of human populations with high consumption of Great Lakes fish. Many of these vulnerable populations are still being exposed to higher levels of POPs than the general U.S. population. These findings have national as well as international public health implications because of the known toxicity of these chemicals and their persistence and ubiquity in the environment (Hicks et al., 2000). The good news is that levels of POPs pollutants in the Great Lakes environment have declined dramatically, particularly in the 1970s and 1980s. This is a success story of primary prevention, in this case pollution prevention through a partnership among Federal, State, and local regulatory and health agencies, with industry and communities to

A successful day's fishing.
Photo: ATSDR

reduce emissions to the environment. More recent trends in environmental levels are less clear, indicating a possible plateau and unmasking the importance of inputs from outside the Great Lakes basin via atmospheric transport. Further progress in reducing exposure levels will require increased attention to pollution prevention, particularly toward addressing long-range atmospheric sources. Great Lakes sport fish still contain POPs levels that are potentially harmful to human health, even though two decades of environmental regulation have significantly reduced chemical residues in waters, sediments, fish, and shellfish (U.S. EPA, 2001). Considering the societal, cultural, and health benefits (Albert et al., 1998) from fishing and fish consumption, pollution prevention efforts must be maintained consistent with the goal of virtual elimination of POPs from the Great Lakes.

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