pilings for a bridge and melting glass fixtures thirty feet above the surface of the water.

In 1964, in response to public demands for action, Canada and the U.S. asked the International Joint Commission to investigate and recommend remedial measures to stop the deterioration of the lakes. Following the IJC's report in 1970, concerted binational action was initiated. In 1972, the two governments signed the first Great Lakes Water Quality Agreement (GLWQA); it dealt specifically with eutrophication in lakes Ontario and Erie.

The agreement set the stage for co-ordinated prevention activities on both sides of the border; it set effluent targets for sewage treatment plants, and contained a schedule for reducing phosphorus loadings into the lakes. Canada's federal government took the lead by restricting phosphate concentrations in detergents and providing funds to upgrade sewage treatment plants. The Province of Ontario set tougher guidelines for effluents from treatment plants and also assisted municipalities to pay the costs of upgrading. The outcome was significant: the fishery in Lake Erie eventually recovered, and the thick green mats of algae, once so common, are now rarely seen.

This does not mean that conventional pollutants like phosphorus, suspended solids or bacteria have disappeared: site-specific problems still exist. In Toronto, for example, phosphorus levels across the waterfront are still too high, and some old combined sewers, which spew raw sewage into the nearshore of Lake Ontario in heavy rain storms, still exist. As a result, beaches have to be closed every summer because of high bacterial levels, and recreational opportunities


*Sunnyside Beach*

are reduced for swimmers, boardsailors, rowers, and others. In Toronto and 42 other places around the Great Lakes, these site-specific problems are being addressed within the framework of Remedial Action Plans to improve water quality.

However, the overall success of programs triggered by and agreed to under the 1972 GLWQA clearly demonstrates what can be achieved on the basis of co-ordinated action. Indeed, as pointed out in the report, *The Great Lakes in the 1990s*, "the rapid improvement in the condition of these lakes after 1972 encouraged Canada and the USA to sign a new agreement in 1978" (Jackson and Runnalls 1991).

The new agreement — the 1978 Great Lakes Water Quality Agreement — contains both an eloquent vision and a bold statement of purpose. While the 1972 document focused on eutrophication in two of the Great Lakes, the 1978 Agreement set out as its purpose nothing less than the restoration and maintenance of "the chemical, physical, and biological integrity of the Great Lakes Basin ecosystem" (International Joint Commission 1988). It bound both federal governments to consider the whole ecosystem in the basin, not just parts of it, and to examine the quality of the ecosystem (air, water, soil, humans, wildlife, and the connections among them).

The problems that had been addressed by the 1972 agreement were conventional pollutants — the so-called "lumps and solids" — the impact of which was visible in the form of scum, slicks, algae growth, and dead fish. The 1978 agreement tackled more complex problems — including one that was largely invisible: the myriad of synthetic toxic chemicals that could often be neither seen nor smelled. Therefore, the IJC's Water Quality Board (its principal advisory body) began compiling lists of synthetic toxic chemicals discovered in Great Lakes waters. Year by year, as detection methods improved, the list grew.

It now includes 362 compounds, of which 32 are metals, 68 are pesticides, and 262 are other organic chemicals. Of the total, at least 126 have been shown to be toxic to living beings, but there is little or no information about the toxicity of the remainder to humans or wildlife. Acceptable standards for the presence in water of many of these compounds do not exist: the IJC has set objective levels for 28 compounds in water, while the Province of Ontario has water quality objectives for 87 compounds.

By 1985, after 13 years of compiling data, the IJC was able to target a sub-set of pollutants of great concern. They include:

- three industrial chemicals (PCBs, mercury, and alkylated lead);
- five pesticides (DDT, dieldrin, toxaphene, mirex, and hexachlorobenzene); and
- three waste by-products (dioxins, furans, and benzo (a) pyrene).

These were singled out in the basin because of their persistence in the environment, and their toxicity to wildlife and possibly human health.

The Water Quality Board has recently subjected six of the 11 pollutants — PCBs, DDT, dieldrin, toxaphene, mirex, and hexachlorobenzene — to further scrutiny. The manufacture and use of these chemicals have been significantly restricted for years; for example, most uses of DDT were stopped in Canada in 1970. The use of toxaphene virtually ceased in the early 1980s. Dieldrin, once widely used, may no longer be utilized for termite control. Because of restrictions on their use and manufacture, these chemicals are found in much lower levels in the environment now than 20 years ago. In fact, the levels found in the water of the Great Lakes are lower than the objectives set under the GLWQA and (in respect of these six pollutants) is "safe". It would seem that the problem should be solved.

But it has not been solved. Despite the significantly lower levels in the environment that resulted from actions taken, the IJC Water Quality Board concluded in their

## Table 3. Critical pollutants in the Great Lakes Basin ecosystem

**Total polychlorinated biphenyls* (PCBs)**
Insulating fluid in electrical transformers and in production of hydraulic fluids, lubricants and inks. Includes 209 related chemicals of varying toxicity. Enters from air or in sediments.

**DDT** and its components (including DDE)**
Insecticide. Still used heavily for mosquito control in tropical areas on other continents. Enters from air or in sediments.

**Dieldrin****
Insecticide used on fruits. Enters from air or in sediments.

**Toxaphene****
Insecticide developed as a substitute for DDT. Used on cotton. Enters from air or in sediments.

**2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD)**
Chemicals in herbicides used in agriculture and for prairie and forest management (contaminant in Agent Orange herbicide used in Vietnam). Also a by-product of burning fossil fuels and wastes, and of pulp and paper production processes. This chemical is the most toxic of 75 forms of dioxin.

**2,3,7,8-tetrachlorodibenzofuran (TCDF)**
Chemicals in herbicides used in agriculture and for prairie and forest management. Also a by-product of burning fossil fuels and wastes, and pulp and paper production processes. This chemical is the most toxic of 135 types of furan.

**Mirex*****
Fire retardant and pesticide to control fire ants. Breaks down to more potent chemical, photomirex, in presence of sunlight. Enters from air or in sediments.

**Mercury**
Used in metallurgy, and a by-product of paint, chlor-alkali and electrical equipment production. Also occurs naturally in soils and sediments.

**Alkylated-lead**
Fuel additive and used in solder, pipes and paint. Also released when burning fuel, wastes, cigarettes and from pipes, cans and paint chips.

**Benzo(a)pyrene**
Produced when fossil fuels, wood, wastes and charcoal are burned and from automobile exhaust. One of many forms of polyaromatic hydrocarbons, or PAHs.

**Hexachlorobenzene (HCB)**
By-product of burning fossil fuels and wastes, and in manufacturing chlorine. A contaminant in chlorinated pesticides.

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Manufacture and new uses prohibited in the United States and Canada
* Use restricted in the United States and Canada
** Banned for use in United States and Canada

Source: International Joint Commission. Great Lakes Water Quality Board. 1991. *Cleaning up our Great Lakes: a report from the Water Quality Board to the International Joint Commission on toxic substances in the Great Lakes Basin ecosystem.* Windsor: International Joint Commission.

1991 report to the IJC, *Cleaning up Our Great Lakes*, that reductions of the 11 critical pollutants:

> . . . are not as comprehensive as we now think necessary. Studies suggest that these substances actually have or threaten to have continuing important, if very subtle effects on human health and wildlife, even in very low concentrations. (IJC Great Lakes Water Quality Board 1991).

### Persistent Toxic Substances and the Health of Wildlife and Humans

How can "safe levels" of toxic chemicals in water cause problems in humans and in wildlife? The answer lies in the characteristics of the chemicals and how they move through the food chain. The 11 on the IJC's list (and many others found in the Great Lakes Basin) are persistent: they take a very long time to break down into less toxic forms. In the case of toxic metals such as mercury and lead, breakdown never occurs.

At least eight of the 11 share one other important characteristic: they have the potential to "biomagnify". In other words, the levels of dieldrin or mirex or PCBs found in animal tissues get progressively higher as one moves up the food chain. In order to understand the problems of toxics in the Great Lakes, it is important to know why this happens.

When a kilogram of a persistent toxic chemical is discharged into water, some will remain dissolved in the water, and some will become attached to particles and sink to the bottom sediment. In either case, the chemical is "available" to aquatic organisms. Bottom-dwelling invertebrates (such as clams or worms) will accumulate the toxin in tissues as they ingest sediment or water. If levels are high enough, toxic effects will be seen in the organisms. If levels are lower, the invertebrates themselves will be fine, but a problem can still appear farther up the food chain.

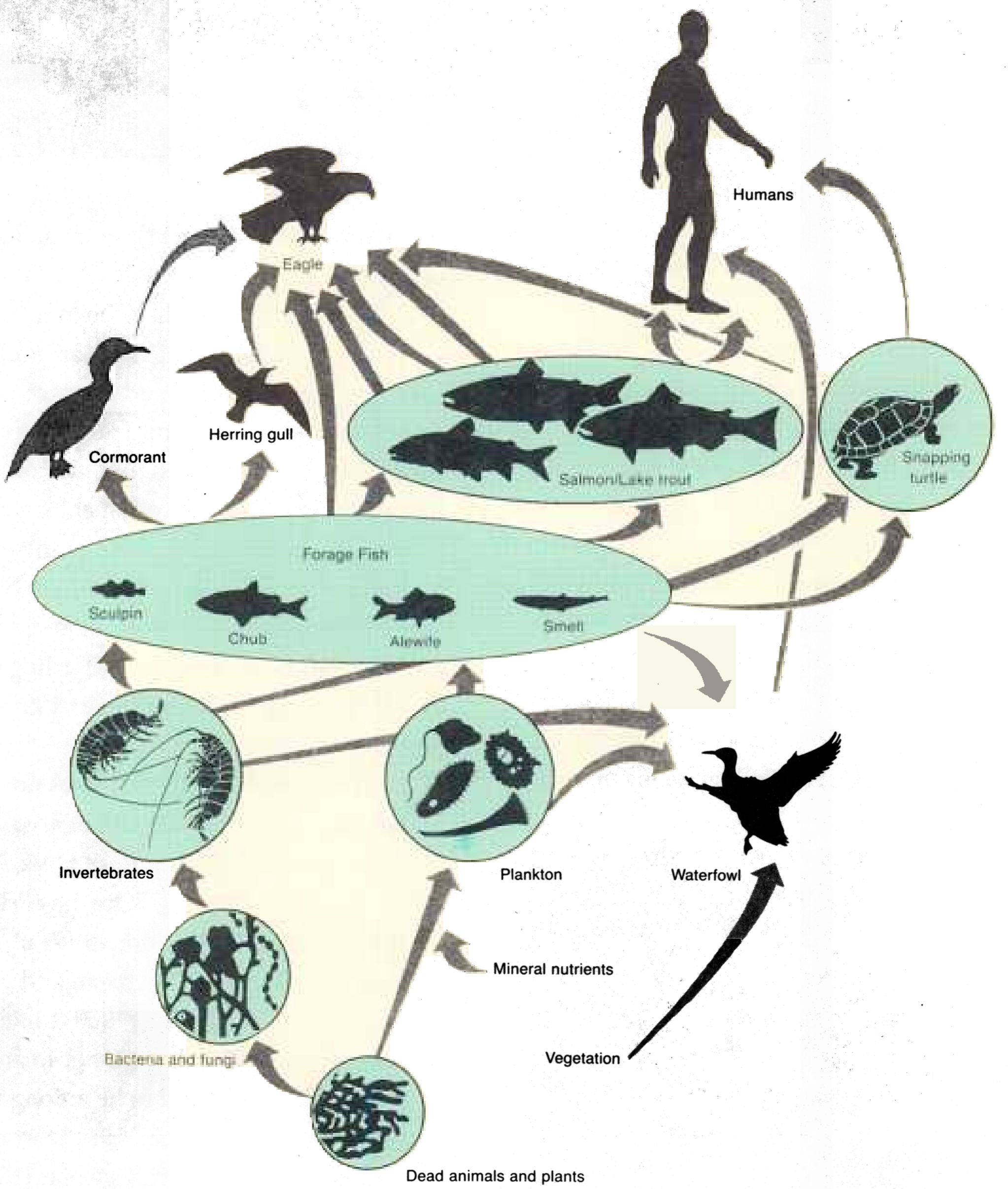
In the animal world, almost everything is a potential dinner for something else. The food web is illustrated in Figure 3.1. It shows that invertebrates are near the bottom of the food chain and get eaten by forage fish such as smelts or alewives which, in turn, are eaten by larger fish — pike or lake trout, for example — which are eaten by aquatic birds such as gulls or cormorants, or by humans.

Although levels of persistent chemicals in water may be "safe" (because they meet the standards that have been set), as a consequence of biomagnification, levels are often too high in the fish to make them safe food for humans or wildlife. In the Metro Toronto area, because of chemical biomagnification, there are restrictions on eating some sizes of eight species of fish. Similar restrictions are found elsewhere around the lakes. Because of the biomagnification process, herring gull eggs may contain levels of PCBs 10 million times greater than those found in Great Lakes waters.

Biomagnification illustrates one of the weaknesses of the traditional approach to managing chemicals: water quality standards are set for the "most sensitive receptor", often to ensure the survival of sensitive species such as trout. But our water quality standards are *not* set to protect the gull that eats the smelt, or the human who eats the trout that ate the smelt.

The levels of persistent toxic chemicals found in the waters or tissues of animals in the Great Lakes are generally not high enough to cause acute toxic effects, including immediate death. Rather, scientists worry about chronic effects, the more subtle effects that can occur in humans or wildlife after years of carrying a chemical burden of PCBs or dioxins or toxaphene in body tissues. These effects can manifest themselves as cancer or reproductive failures; recently, scientists have begun to examine

**Figure 3.1** Simplified Great Lakes food web



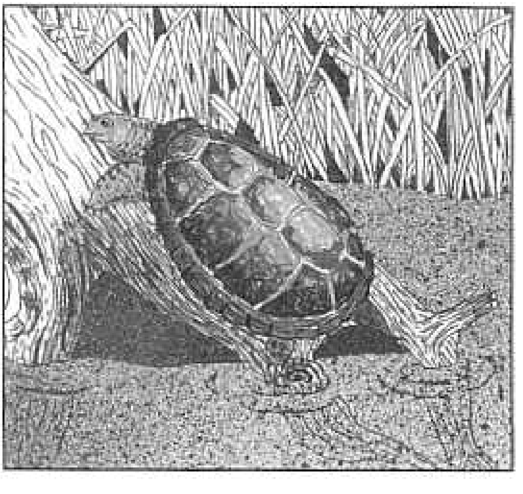

Note: This is a simplified representation of the Great Lakes food web showing the main pathways. Levels of toxic chemicals found in animal tissues get progressively higher as one moves up the food chain.

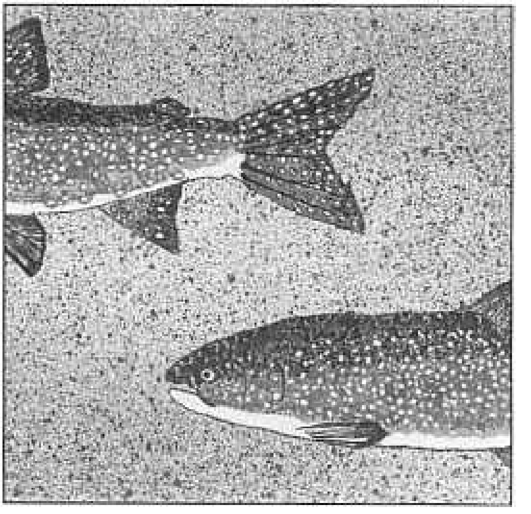
We've gone too far...we're going to wipe ourselves out. It will be like a frog in a pot of water. If you bring the temperature up slowly, it will stay there and paddle around until it dies in the hot water. But if you heat the water and throw the frog in, it will jump out. Well, the trouble is that the water around us is warming slowly and it's so comfortable and it feels so good and life is so great in Canada. . . . But what we have to do is look around and we'll realize that the water's getting hot.

Potter, P. August/September 1991. "Classrooms without walls". In *Canadian geographic.*

the possibility that there are other, more subtle effects, such as hormonal or behavioural changes.

Since the 1950s, persistent toxic chemicals have been implicated in problems suffered by some 14 species of wildlife near the top of the food chain in the Great Lakes Basin. (See Table 3.2). They include reproductive problems, deformities, and sometimes dramatic population declines. They have been noted in two species of mammals (otter and mink), reptiles (snapping turtles),





and in three species of fish (lake trout, brown bullhead, and white sucker).

Similar difficulties have been noted in eight species of fish-eating birds around the basin: caspian, common, and Forster's terns, ring-billed and herring gulls, double-crested cormorant, black-crowned night heron, and bald eagle. Because of levels of chlorinated organic chemicals such as DDT in the environment, the populations of all these birds declined sharply in the 1960s. In fact, some decreases were so great that, according to the IJC Water Quality Board in its 1991 report:

> . . . records show that there was no known successful breeding of double-crested cormorants on Lake Ontario between 1954 and 1977. By the early 1960s and 1970s, this breeding failure had spread to lakes Michigan and Superior. . . . By the late 1960s some fish-eating birds in lakes Ontario and Michigan were found to be among the most contaminated birds in the world.

After uses of chemicals such as DDT were restricted and environmental levels dropped, populations of most of these birds recovered. In Toronto, we have night