The Condition of the Bay of Green Bay/Lake Michigan 1993

THE STATE OF THE BAY

A WATERSHED PERSPECTIVE

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Dedicated to:
The 1993 State of the Bay is dedicated to my mother Dorothy Harris Ryan whose love of life and the natural world brought me to what I do.

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Introduction

WHERE WE'VE BEEN

■ The first State of the Bay was published in 1990 as a capsule report on water quality and condition of water-related resources and uses of Lake Michigan's Green Bay. In that report, the status of particular chemical, physical and biological indicators of the "health" of the bay were identified and trends were examined. This report will update some previously identified indicators, introduce new indicators, and examine the impact of land-based activities on the bay.

Scientists have recognized generally that land-based human (economic) activities such as manufacturing, forestry, agriculture and urbanization compromise the water resources of a region. For the last few decades (1970s - 1990s), water quality managers have focused most of their attention at the "end of pipes." These sources of water pollution were certainly the most obvious and, in many cases, the most important. Municipal and industrial waste discharges such as organic waste, suspended solids and polychlorinated biphenyl (PCBs represent a whole class of chlorinated organic compounds) have been greatly reduced.

While the 1990 State of the Bay recorded evidence that restoration efforts and monetary expenditures were leading to a healthier bay, it was clear that many problems remained. New information and further analysis since then allow us now to be more certain about what we know and to make better recommendations on what must be done to restore the beneficial uses of Green Bay and to improve the health of the Green Bay ecosystem (refer to Green Bay/Fox River Remedial Action Plan Update for detailed recommendations).

A NEW VIEW

■ New information and data in later sections of this booklet reveal that the present ills of Green Bay are due to activities and sources far from the bay itself.

The Area of Concern (AOC) (Figure 1) is where the cumulative effect of stressors in a 6,640-square-mile drainage basin are evident. In a very real sense, the area of concern mirrors the troubles in other parts of a larger system.

Consequently, if the beneficial uses of Green Bay are to be restored the Fox/Wolf system as a whole must be addressed (Figure 2).

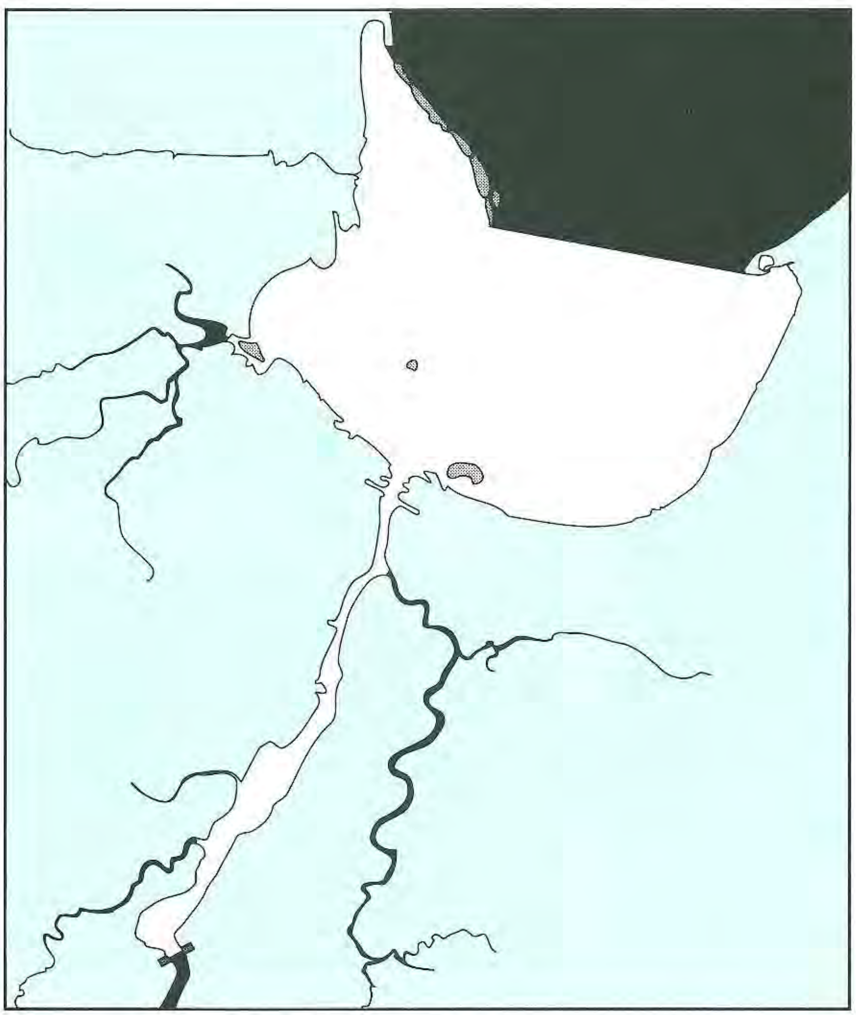

FIG. 1
(AOC) Area of Concern shown in white

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FOX AND WOLF RIVER BASINS

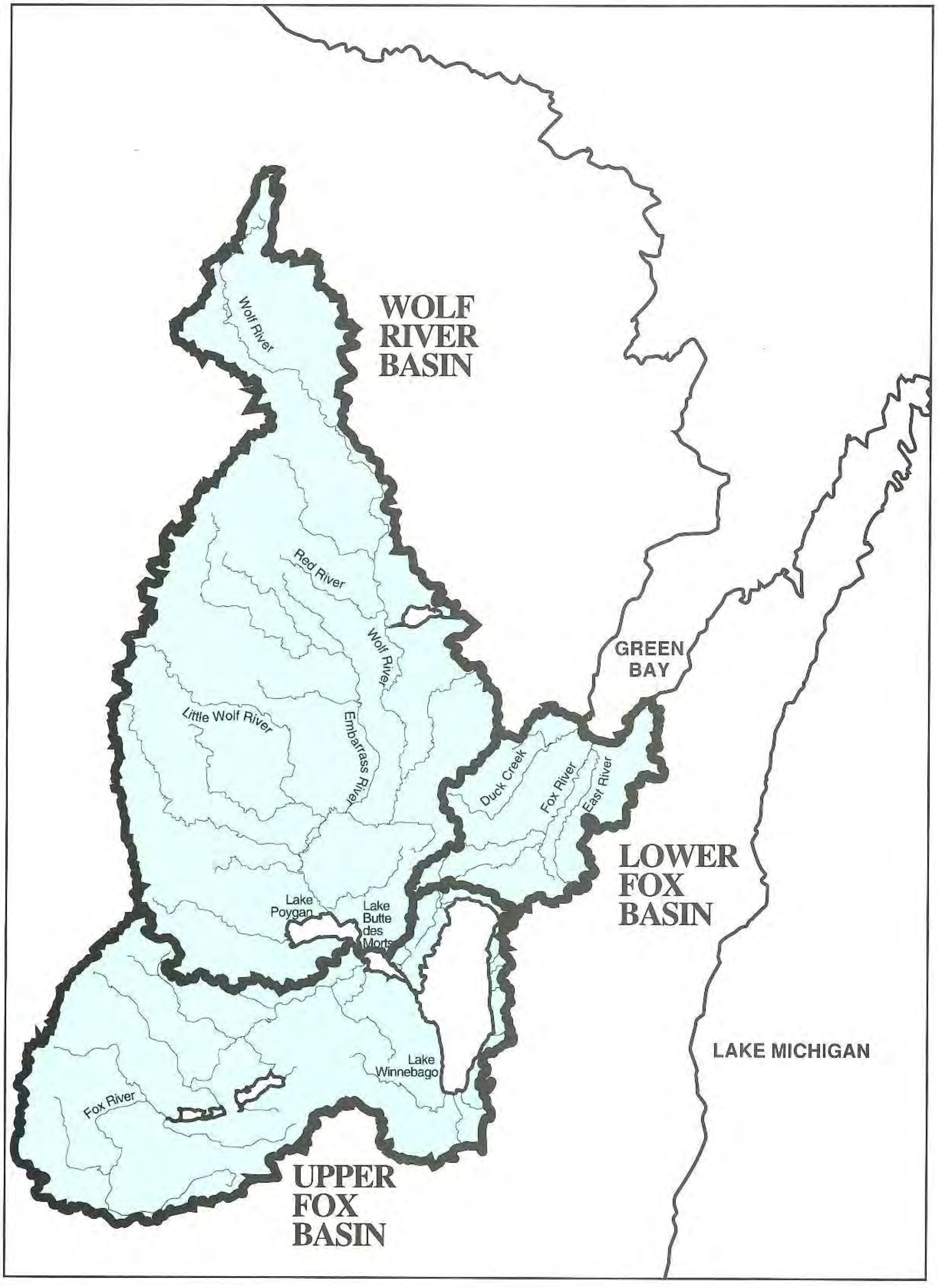

FIG. 2

3

IMPAIRED USES

- RESTRICTIONS ON FISH AND WILDLIFE CONSUMPTION (impaired use)
- TAINTING OF FISH AND WILDLIFE FLAVOR (impaired use)
- DEGRADATION OF FISH AND WILDLIFE POPULATIONS (nutrient impaired use)
- FISH TUMORS OR OTHER DEFORMITIES (impaired use)
- BIRD OR ANIMAL DEFORMITIES OR REPRODUCTION PROBLEMS (impaired use)
- DEGRADATION OF BENTHOS (nutrient impaired use)
- RESTRICTIONS ON DREDGING ACTIVITIES (impaired use)
- EUTROPHICATION OR UNDESIRABLE ALGAE (nutrient impaired use)
- DEGRADATION OF AESTHETICS (nutrient impaired use)
- LOSS OF FISH AND WILDLIFE HABITAT (nutrient impaired use)
- DEGRADATION OF PHYTOPLANKTON AND ZOOPLANKTON POPULATIONS (nutrient impaired use)
- BEACH CLOSINGS (nutrient impaired use)

impaired use — nutrient impaired use

FIG. 3

ASSESSING THE RISK

■ The problems of the Fox River and Green Bay that have ready solutions have more or less been solved. Those problems remaining have difficult and costly solutions. Two questions arise. Which problems present the greatest threat (risk) to the ecosystem? And, which combination of problems when addressed will provide the largest measure of restoration for the least cost? The first question will be addressed here, the second in a later section.

THE TASK FORCE

■ In 1991, a task force of scientists and resource managers gathered together to assess risks to the Green Bay ecosystem (ecosystem risk assessment).

The task force used previously identified impaired uses of the bay as recognizable end points or undesirable "health" anomalies that occur in the presence of particular stressors on the ecosystem (Figure 3). Group knowledge about the Green Bay ecosystem was applied through a rigorous set of rules integrated with use of well-defined mathematical technique.

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PRIMARY STRESSORS

CRITERIA	HUMAN HEALTH	AESTHETIC	ECONOMIC COSTS	ENERGY/ NUTRIENTS	BIOTA	MULTIPLIER EFFECT
STRESSORS						
Nutrient loading (NL)	0	3	2	3	3	2
Heavy metals (HM)	1	0	1	1	1	1
Wetland and shoreland filling (WSF)	0	2	1	2	3	1
Solids loading (SL)	0	3	2	3	3	2
Persistent organics (PO)	2	0	2	1	1	1
Biochemical oxygen demand (BOD)	0	1	3	1	2	2
Exotic invasions (EI)	0	1	2	2	3	1
Nonpersistent toxics (NT)	0	0	2	1	1	1

IMPACT SCALE:

0 No apparent impact 1 Minor impact 2 Moderate impact 3 Major impact

FIG. 4

The task force ranked stressors on the Green Bay ecosystem according to three criteria: 1) the degree of impact on ecosystem structure and function; 2) how long effects would persist if the stressor were removed; 3) how manageable stressors may be. It was reasoned that the stressors with greatest ecological impacts and persistence and which are least manageable, present the greatest risk.

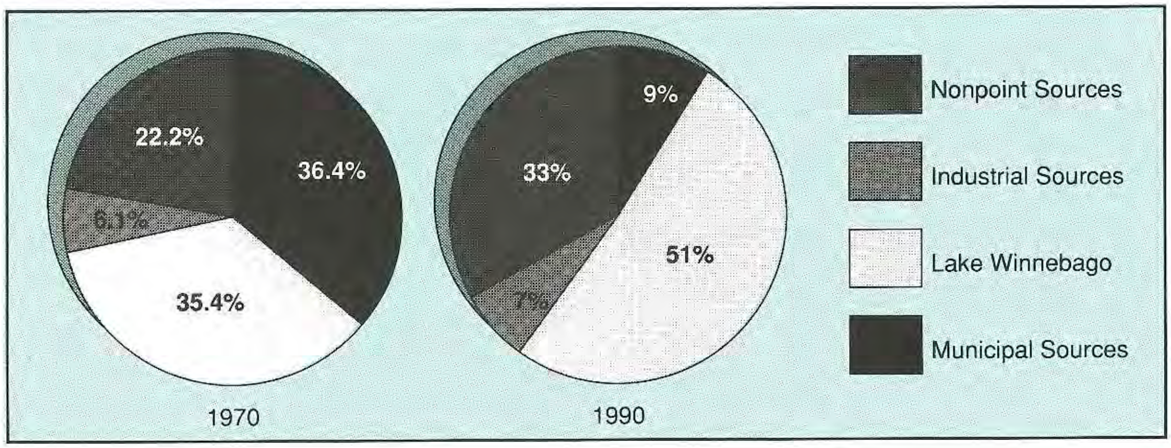
The impact of primary stressors on various aspects of the ecosystem is shown in Figure 4. The task force determined that nutrients loading (primarily phosphorus) and solids loading (e.g., soil, algae, industrial waste) have the most significant impacts on the ecosystem.

After the group integrated the time and manageability components with the impact matrix, it assessed the filling of wetlands and the introduction of exotic species to be the greatest risks to Green Bay, followed by the introduction of persistent toxic organic chemicals such as PCBs. Wetland filling and the introduction of exotic species are high risk because they constitute permanent changes. Persistent organic compounds, e.g., PCBs, are high risk because of their longevity, toxicity and the difficulty in managing them once they are introduced into the environment. The loading of nutrients and solids constitute a significant risk because of the multiple effects on the ecosystem resulting in the loss of many beneficial uses (Figure 3).

CONCLUSIONS

■ So the bottom line is this: if the beneficial uses of Green Bay are to be restored, nutrient and sediment loading must be significantly reduced, wetland habitat must be better protected and restored, and persistent organics (PCBs) must be eliminated or reduced to a level where no adverse effects (injury) to the ecosystem can be detected. In addition, the introduction of exotic species must be better controlled.

Physical and Chemical Indicators 5



1970 AND 1990 ESTIMATES OF PHOSPHORUS LOADS TO THE FOX RIVER

Source: Green Bay Remedial Action Plan Update; Paul Sager, UW-Green Bay data

FIG. 5

PHOSPHORUS AND SEDIMENTS

■ Phosphorus and sediments, as noted earlier, are implicated as "bad actors" for the bay ecosystem. Phosphorus is a primary plant nutrient that in excess creates massive algae "blooms." Algae, along with sediment particles and other particulate matter, reduces water clarity. Low water clarity limits underwater light and thus limits submerged aquatic vegetation (see section on wetlands).

New estimates have been made of the sources of phosphorus and sediments in Green Bay. Fifty-one percent (51%) of the phosphorus comes from Lake Winnebago which receives drainage from the Upper Fox and Wolf River basins (Figure 5). Seventy-seven percent (77%) of all phosphorus comes from nonpoint sources such as agricultural and urban runoff. These figures emphasize the systemic nature of the problem.

Sediment loads which flow over the last dam on the river (De Pere) reach 150,000 tons per year (Figure 6). This amounts to 411 tons a day, or the equivalent of 27 dump-truck loads — more than one dump-truck load of sediment every hour! Phosphorus and sediments negatively impact small streams, Lake Winnebago, the Fox River and Green Bay alike. Changes in land use and land management practices are required to solve the problem.

How much will the phosphorus and solids loading need to be reduced? The answer is: enough to change water clarity to the point where more underwater vegetation can grow. One simple measure of water clarity is secchi disc depth (the depth at which a black and white disc when lowered in the water disappears from sight). A secchi disc depth of 0.7 meters (2.3 feet) is the absolute minimum required for the growth of wild celery, an important species of underwater plant.

Recent studies reveal the relationship between secchi disc depth, total suspended solids (TSS) and chlorophyll concentrations. Chlorophyll concentration, resulting from excess phosphorus, is an index to algae production. Total suspended solids is a measure of all particles in the water including algae.

Average secchi disc measures over growing seasons since 1986 vary between 0.71 meters and 0.30 meters (Figure 7). The average is 0.50 meters. To attain the desirable secchi disc depth of at least 0.7 meters, the chlorophyll level must decrease to 30 micrograms per liter (μg/L) (Figure 8) and total suspended solids to approximately 15 μg/L, which are about one half the present levels.

A 30 μg/L chlorophyll level would correspond to 100 μg/L of total phosphorus (Figure 9). This would lead to about a 50 percent reduction in blue-green algae. Many species of blue-green algae produce unpleasant odors, are toxic and are too large to be consumed by small grazing organisms (zooplankton).

Total phosphorus levels in Green Bay over the past two decades are recorded in Figure 10. To reach desired water clarity, phosphorus loading needs to be reduced approximately 50 percent. Expressed in pounds, this constitutes a reduction of 770,000 pounds of phosphorus. This magnitude of reduction will be difficult to achieve and cannot be achieved without addressing phosphorus inputs from Lake Winnebago and other sources to the Fox River. Improvement in

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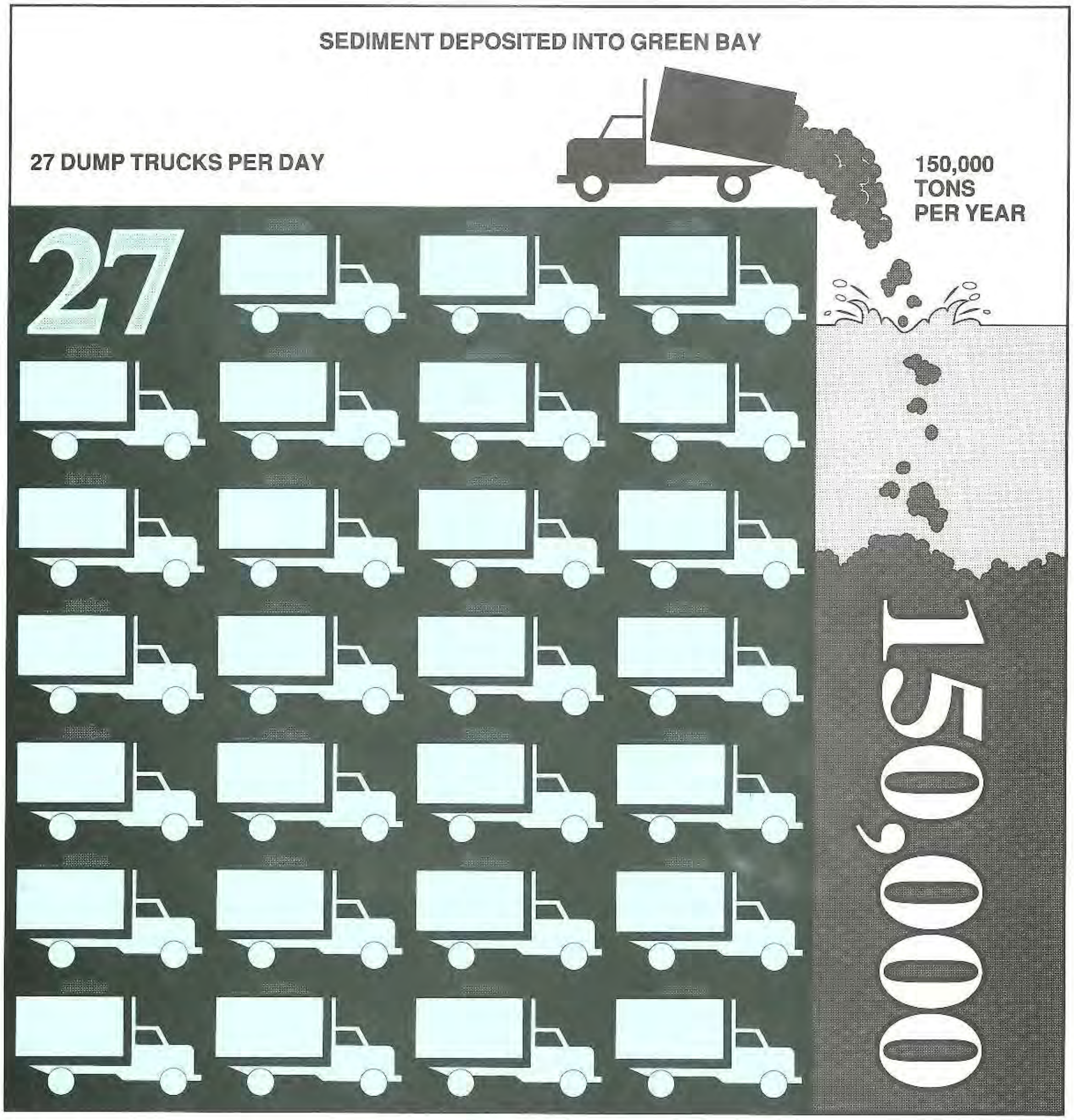
SEDIMENT DEPOSITED IN GREEN BAY

Assume one truck holds 15 cubic yards weighing roughly 15 tons.

Source: Sediment load estimates from U.S. Geological Survey.

FIG. 6

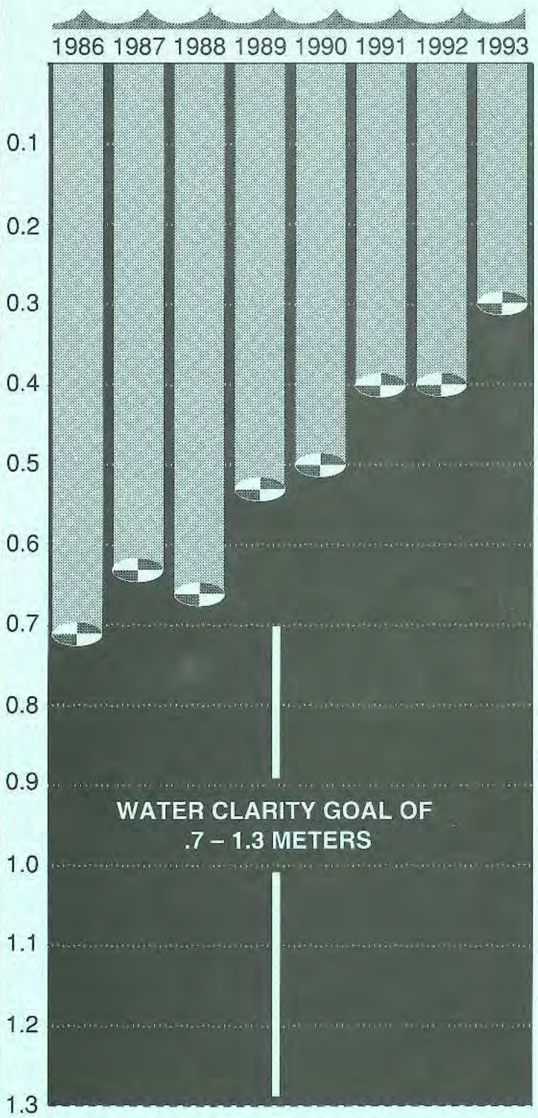


water clarity will more likely be achieved via reductions in loading of both phosphorus and abiotic solids (i.e., soil particles).

The 150,000 tons of sediment delivered to the bay each year is not only grossly detrimental to the river and bay and represents a loss of a critical resource (soil), but also necessitates a costly maintenance dredging program in Green Bay harbor and lower Fox River. Before 1985, approximately 600,000 cubic yards of sediment were dredged every year to maintain a navigation channel. In 1993, the maintenance dredging target was 400,000 cubic yards. The lower volume was necessitated by inadequate storage space for dredging spoils disposal. Assuming that 600,000 cubic yards of sediment needs to be dredged each year, the amount of sediment for disposal over 10 years is six-million cubic yards. At a cost of $14 per cubic yard (*Great Lakes Water Quality Board Dredging Register*), the total cost for dredging and disposal over 10 years would be $84 million. Clearly, investment in best-management land-use practices has dividends beyond the conservation of soil.

WATER CLARITY

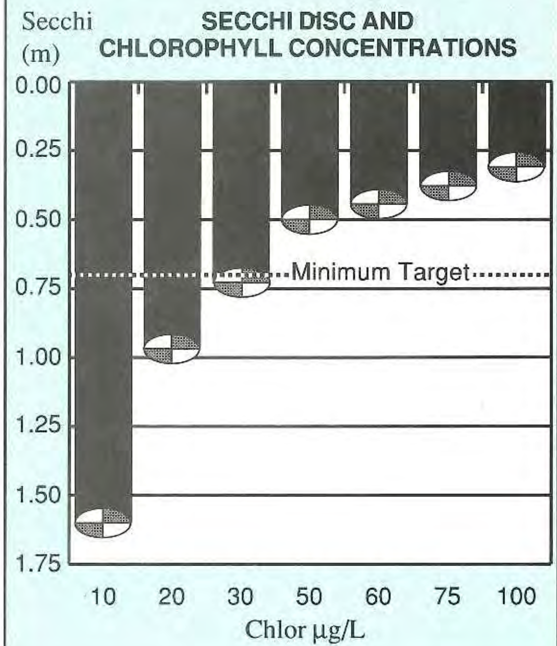
Data represents average of readings taken at eight stations in the inner bay during spring and summer months.



Source: Green Bay Metropolitan Sewerage District

FIG. 7

Predicted relationship of Secchi Disc and Total Suspended Solids and Chlorophyll a Concentrations



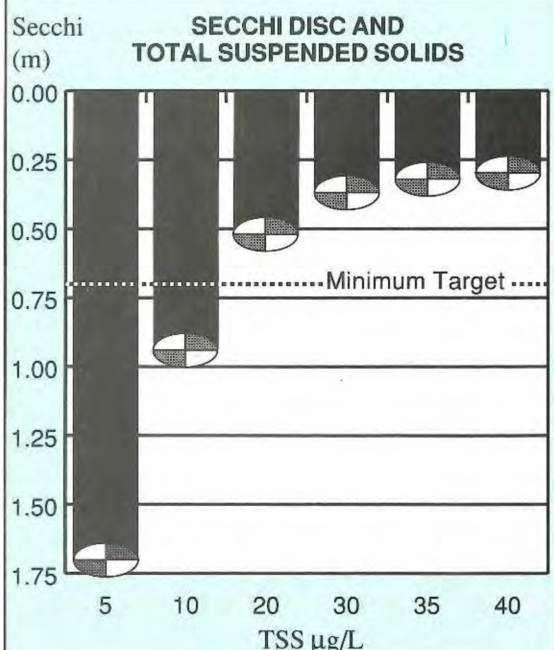


FIG. 8

WATER CLARITY

Based on regression model developed by Paul Sager, UW-Green Bay.

FIG. 8a

FIG. 8b

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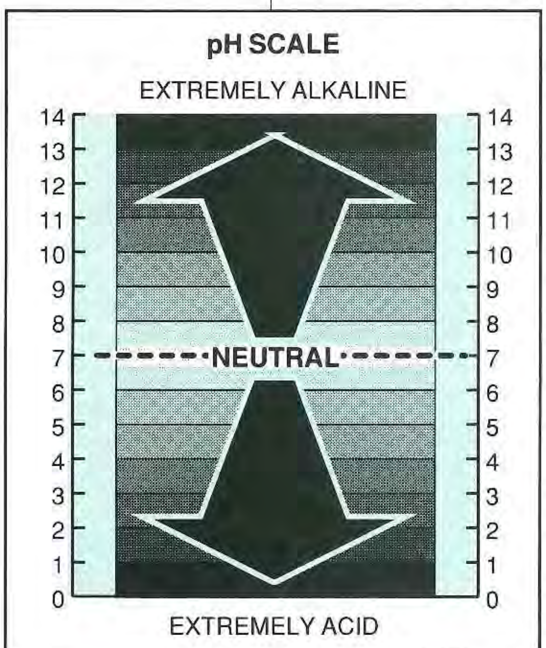
AMMONIA

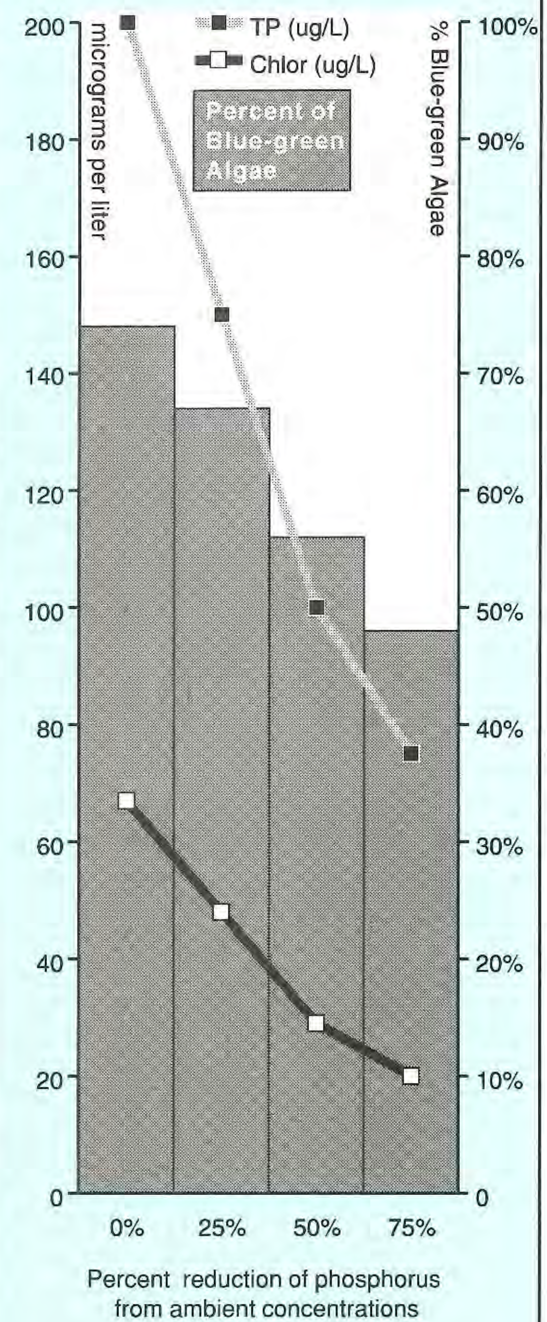
■ Ammonia, a nonpersistent toxic substance, has been found to exert significant toxic effects on bottom dwelling organisms in the Fox River and Green Bay. Ammonia is naturally generated from decomposing organic material (e.g., sewage, paper fibers, manure, algae) and can be abated by reducing the amount of these materials.

Ammonia concentrations in the river and bay have not decreased over the past several years (Figure 11). Concentrations in the river below the De Pere dam, in the inner bay and in the outer bay follow changes in ammonia concentration (over years) similar to those in the Fox River above the De Pere dam. This suggests that a significant amount of ammonia is coming from above the De Pere dam. High total ammonia concentrations in the river and bay in combination with alkaline pH (pH is a measure of acidity/alkalinity) and warm summer temperatures can create conditions chronically toxic to aquatic organisms (i.e., unionized ammonia concentration is greater than 0.04 mg/L).



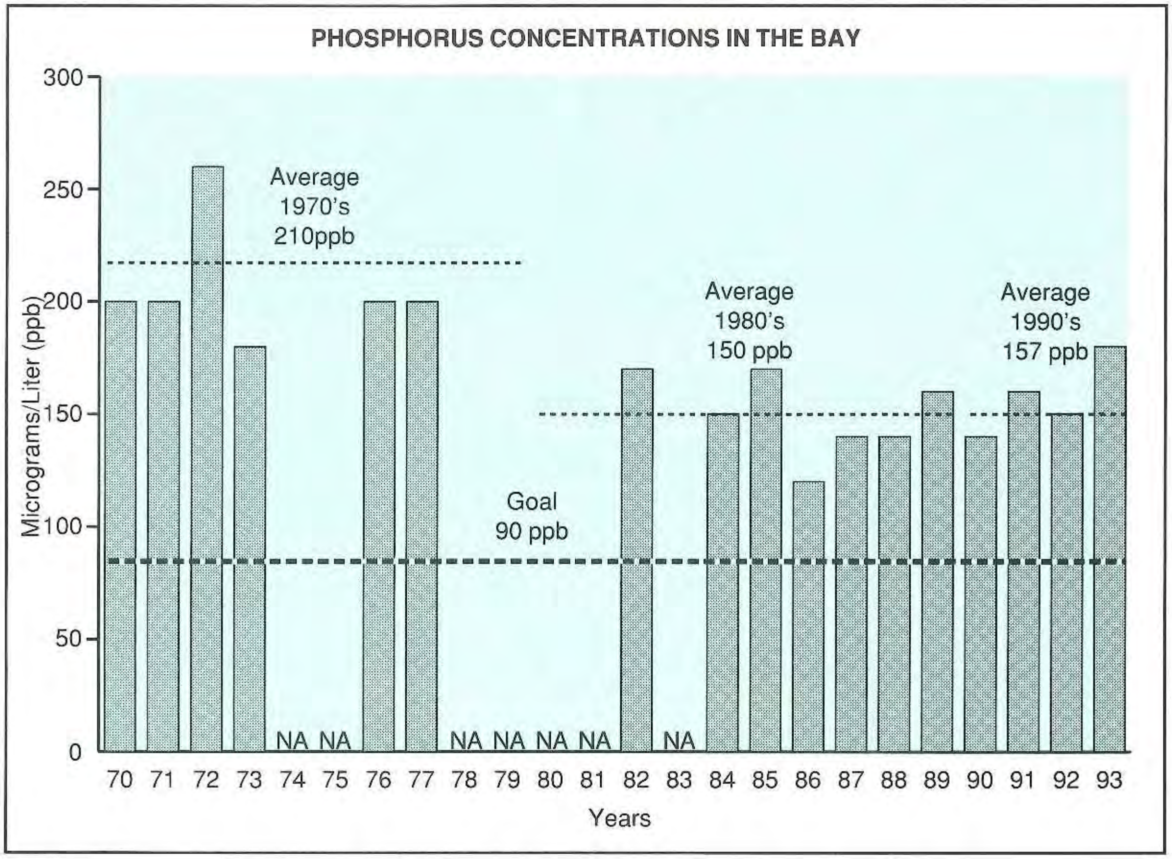
Controlling point sources of ammonia is an appealing solution because it has a direct connection, but this may not be sufficient to avoid periods of chronic toxicity. Quantities of ammonia may be generated by accumulation of organic material (soft sediments) above the De Pere dam. Each year much organic matter is generated in the form of algae and become part of the organic sediment accumulation. In other words, the ammonia problem likely has a direct link to the excess phosphorus loading problem and cannot be effectively addressed separately.

PREDICTED CHANGE IN CHLOROPHYLL a, AND PERCENT BLUE-GREEN ALGAE FOR INCREMENTAL REDUCTION IN PHOSPHORUS



TP = total phosphorus
Chlor = chlorophyll a
µg/L = micrograms per liter

FIG. 9
Source: UW-Green Bay, Paul Sager; RAP Update.

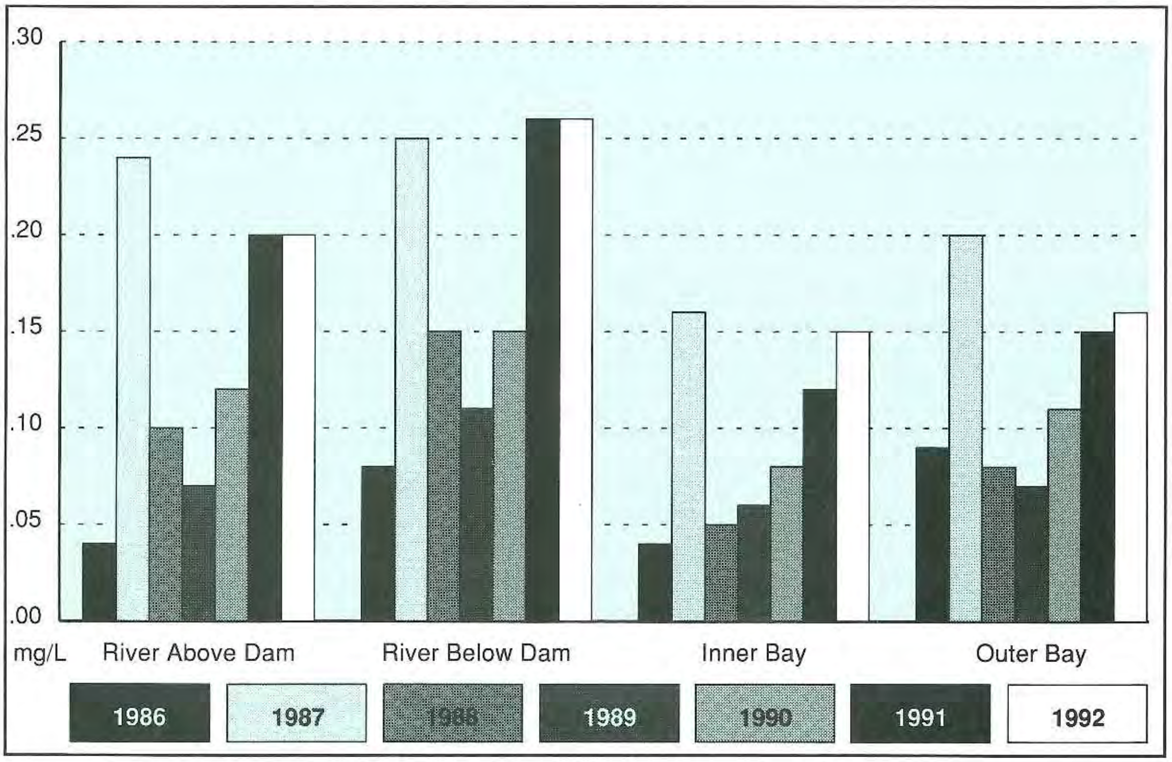


TOTAL PHOSPHORUS

The data represent the average concentration of all measurable forms of phosphorus, known as total phosphorus, collected from eight stations in the inner bay during spring and summer months.

Data from : Paul Sager, UW-Green Bay, 1970-1985; John Kennedy and Dick Sachs, Green Bay Metropolitan Sewerage District, 1986-1993

FIG. 10



TOTAL AMMONIA

Source: Green Bay Metropolitan Sewerage District, Dick Sachs

FIG. 11

10

DISSOLVED OXYGEN

Data from: Green Bay Metropolitan Sewerage District Monitoring Program

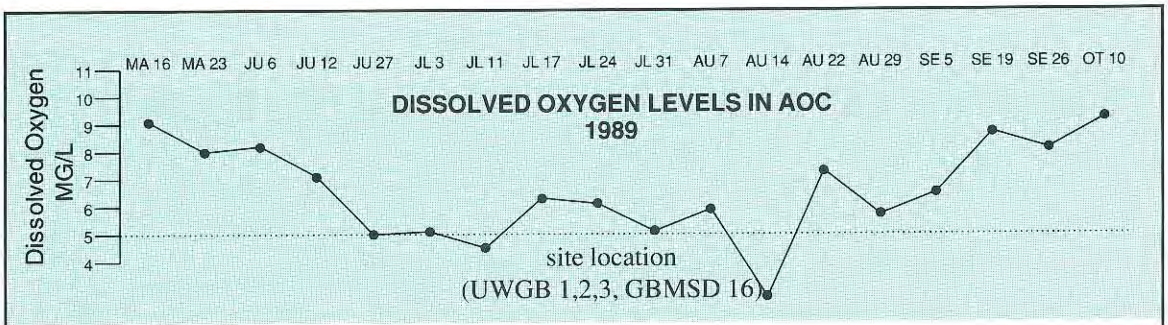


FIG. 12

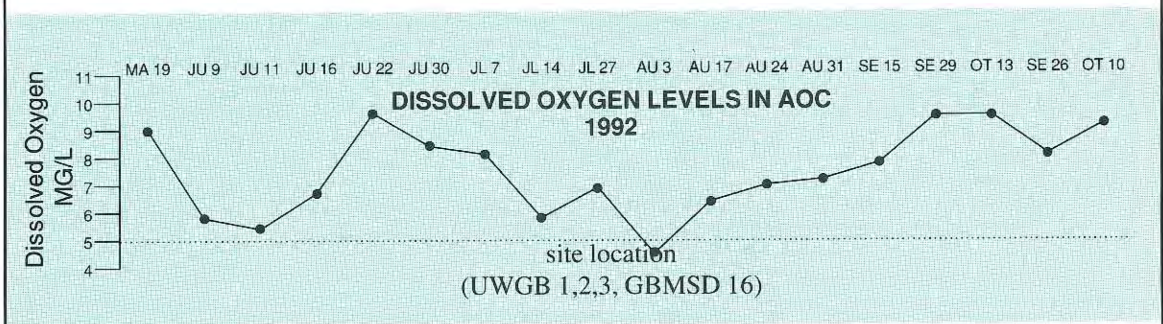


FIG. 13a

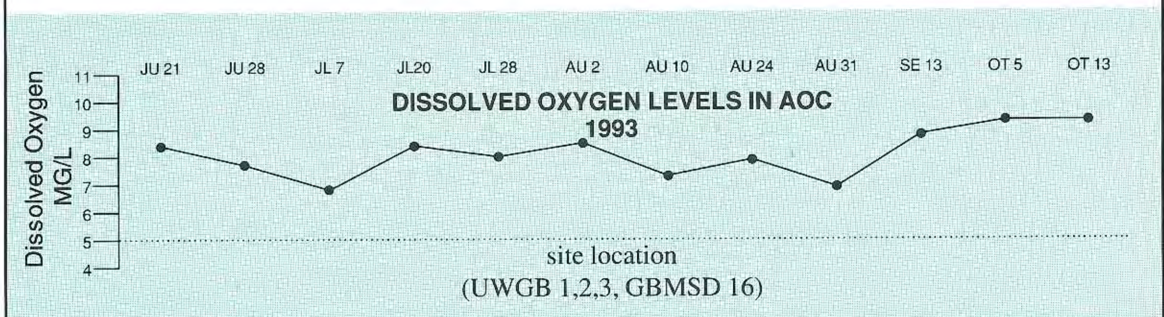


FIG. 13b

NOTE: Results reflect station averages of vertical profiles collected at one meter intervals.

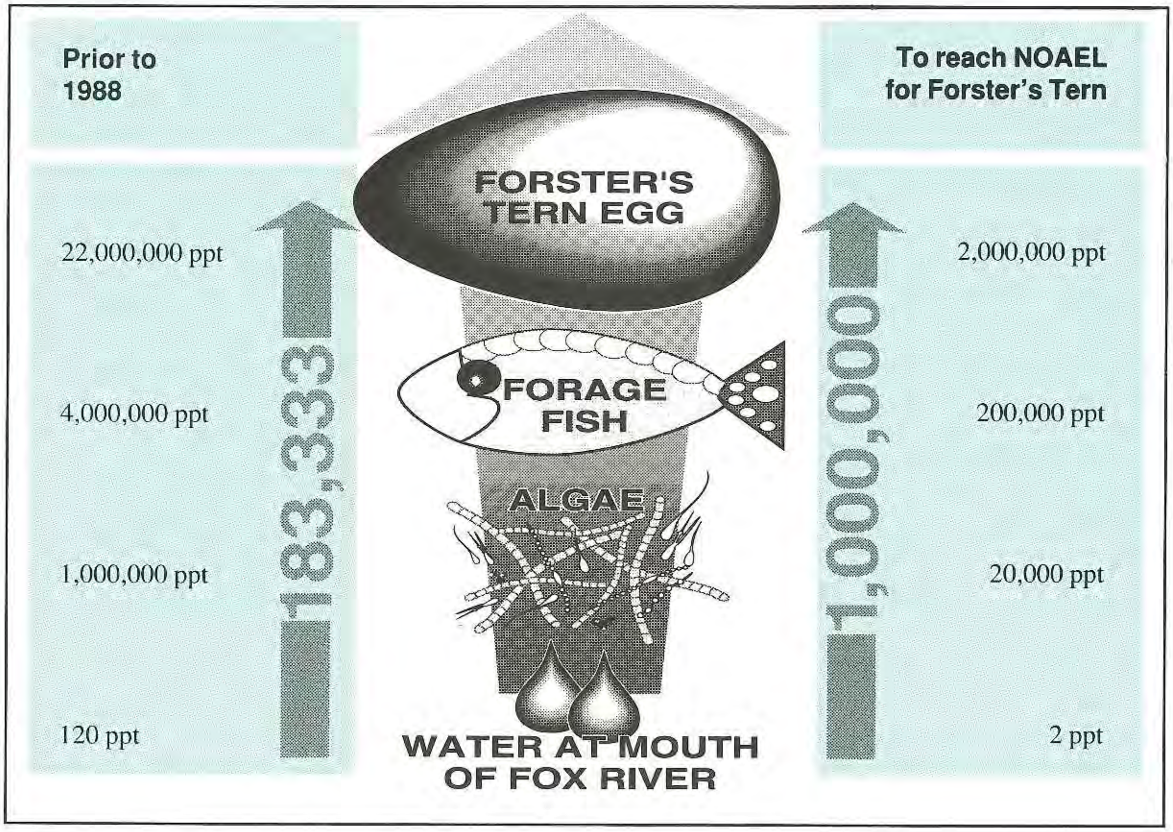
DISSOLVED OXYGEN

■ Levels of dissolved oxygen remain a specific measure of water quality and an indicator of ecosystem health. The level needed to maintain a quality sport fishery is a minimum of five milligrams per liter or parts per million (ppm).

Since the cleanup of conventional pollutants (organic wastes) in the late 1970s, average dissolved oxygen levels in the Area of Concern have generally met the desired standard of five ppm. There are times, however, when the oxygen concentration drops below this level.

Averages tell something, but as far as the organisms are concerned, it is the extreme conditions that make life difficult. For example, 1989 data collected for the Green Bay Metropolitan Sewerage District monitoring program show that on July 11 and August 14 oxygen levels were below standard at the mouth of the river and bay (Figure 12). A similar depression occurred in August 1992 but not in 1993 (Figure 13).

This likely reflects cumulative effects of upstream organic waste and algal production, sediment oxygen uptake, and bay water interactions. So while the general oxygen picture looks good, the available data reveal that it can be marginal. Once again, high phosphorus loads and excess algae production contribute to this problem.



BIO-MAGNIFICATION OF PCBS IN GREEN BAY
Prior to 1988 and future projected requirements.

Data from: Harris and others, 1993

Think of 1 part per trillion (ppt) as 1 grain of sugar in an olympic sized swimming pool. NOAEL stands for No Observable Adverse Effects Level.

FIG. 14

PCBS

■ Polychlorinated biphenyl (PCBs) remains the toxic substance of greatest concern in the Fox River and Green Bay although mercury has received additional attention over the past several years. Both are persistent toxic substances — they remain in the environment for extended periods — but PCBs have been shown to bioaccumulate and biomagnify (Figure 14) in the food chain and exert toxic effects on fish-eating birds. Biomagnification and toxicity of mercury has yet to be demonstrated for the river and bay.

Available evidence suggests that PCBs in walleye taken from the lower Fox River over the past 20 years have at first shown some decline but have now leveled off. Average concentrations remain above the two parts per million (ppm) fish advisory level. The "leveling off" phenomenon is a reflection of a dynamic equilibrium between the mass of PCBs in the river sediments and the water column. The PCBs in the sediments serve as a "source" to the water column.

The Wisconsin Department of Natural Resources (DNR) estimated in 1989 that sediment deposits in the Fox River upstream of the De Pere dam to the outlet of Lake Winnebago contain 4,000 kilograms (8,800 pounds) of PCBs. Sediment from the De Pere dam downstream to the mouth of the Fox contain approximately 25,000 -40,000 kg (or a maximum of 88,000 pounds). Less than one percent of the total annual PCBs loaded to the Fox River (between 222 and 594 pounds, depending on river flow) now comes from point source discharges.

The most recent results of the Toxic Mass Balance Study sponsored by the U.S. Environmental Protection Agency and the Wisconsin Department of Natural Resources reveal that if no action is taken to remove contaminated sediments from the effects of river flows, concentration of PCBs in the water in the Area of Concern will still average 15 μg/L (ppt) after 25 years. Even after 75 years, concentration in the water could be 5 to 10 ppt. Under these conditions, significant biomagnification of PCBs would occur and some toxic effects in fish-eating birds might be expected. The Mass Balance Study further reveals that significant quantitites of PCBs entering Green Bay from the Fox River vaporize into the atmosphere and are thus transported elsewhere.

12 Biological Indicators

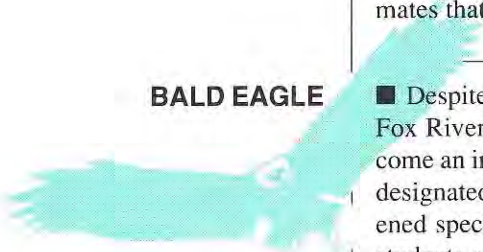
Some organisms or groups of organisms serve as a telltale for the larger system. These organisms may not be of direct public use, but their presence, absence or abundance is of major significance regarding the health of the ecosystem. For Green Bay, organisms were selected based on two factors: 1) whether sufficient data exist from which to examine trends, and, 2) whether there is adequate knowledge to know what those trends mean.

FORSTER'S TERN

■ The Forster's tern serves as a telltale of the ecosystem in two ways. First, its diet consists almost entirely of fish and thus it serves as a monitor for persistent toxic substances in the system. Second, as a marsh-nesting species it has reflected the conditions of marshes in Green Bay.

New published research on the Forster's tern estimates that the level of PCBs in forage fish needs to decrease to 0.2 ppm (200,000 ppt) to protect the tern from any measurable adverse effects such as abnormal development of young. This means that the level of PCBs in the water must be 2 ppt (see Figure 14). The level of PCBs in water from the main body of Lake Michigan is 1 ppt. In 1989, the level of PCBs in the water halfway up the bay (Chambers Island) was 5 ppt. It was 120 ppt at the mouth of the Fox River as it enters the bay.

BALD EAGLE



■ Despite high levels of human activity, the Lower Fox River between Neenah and Green Bay has become an important wintering area for the bald eagle, designated by the federal government as a threatened species. Research by Prof. Robert Howe and students at the University of Wisconsin-Green Bay documented 29 eagles along the Fox River during the winter of 1992-93. Birds begin arriving on the Fox River in early November and reach peak numbers in late December and early January. Activity is centered near the Thousand Islands Nature Center in Kaukauna, where a pair of adults has raised young since 1991. Roosts and feeding areas were observed at numerous other points along the river, especially near locks and dams where open water persists even during sub-zero temperatures. A survey during late 1993 yielded more than 30 eagles, again concentrated near Kaukauna.

Successful bald eagle nesting along the Fox River has been documented annually since 1988 with only one exception (1990). A second eagle nest was discovered near Little Lake Butte Des Morts during 1994, further adding to the resident population of bald eagles along the river. These trends are encouraging. The long-term reproductive success of eagles will serve as a sensitive monitor to the health of the Fox River.

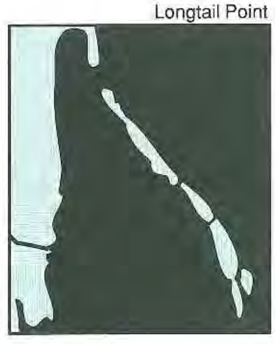
FISH COMMUNITY CHANGES

■ The composition of the southern Green Bay fish community varies greatly from year to year. Two long-term series of data collections from the Area of Concern provide a good picture of changes in the fish community over the past 15 years.

First, a late summer series of trawl surveys conducted by Wisconsin Department of Natural Resources biologists since the late 1970s provides information on changes within the bay. This series of trawl surveys has been conducted annually at two locations within the Area of Concern: south of Longtail Point and south of Point Sable (Figure 1).

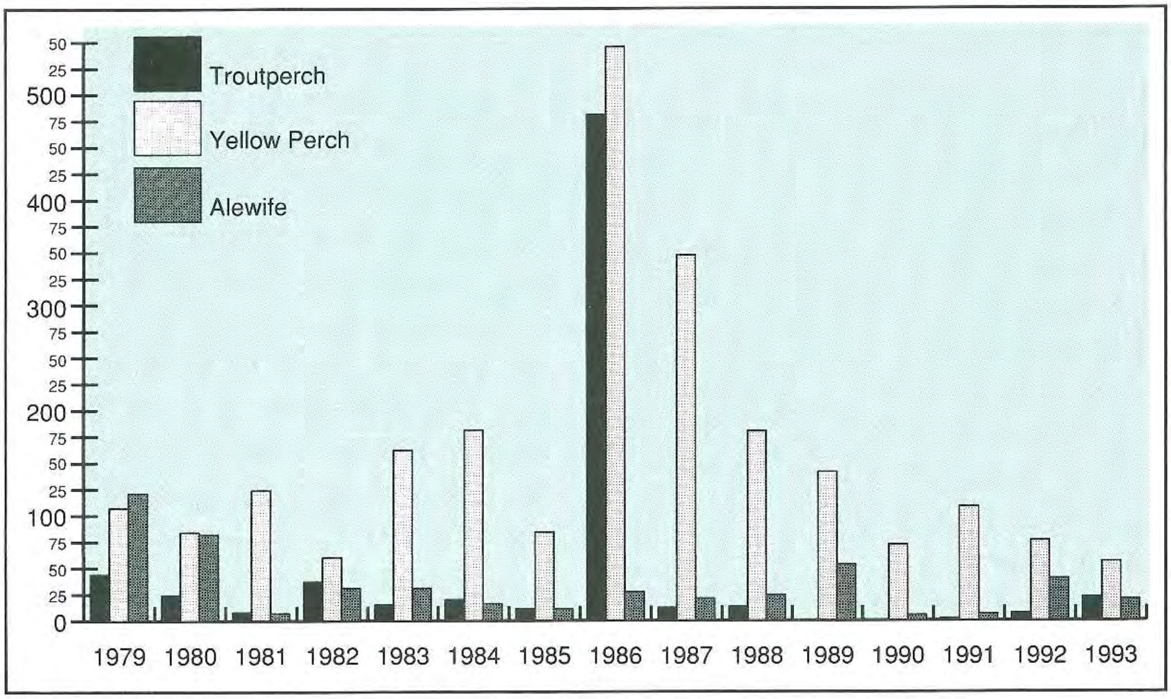
De Pere Dam

Longtail Point



Point Sable

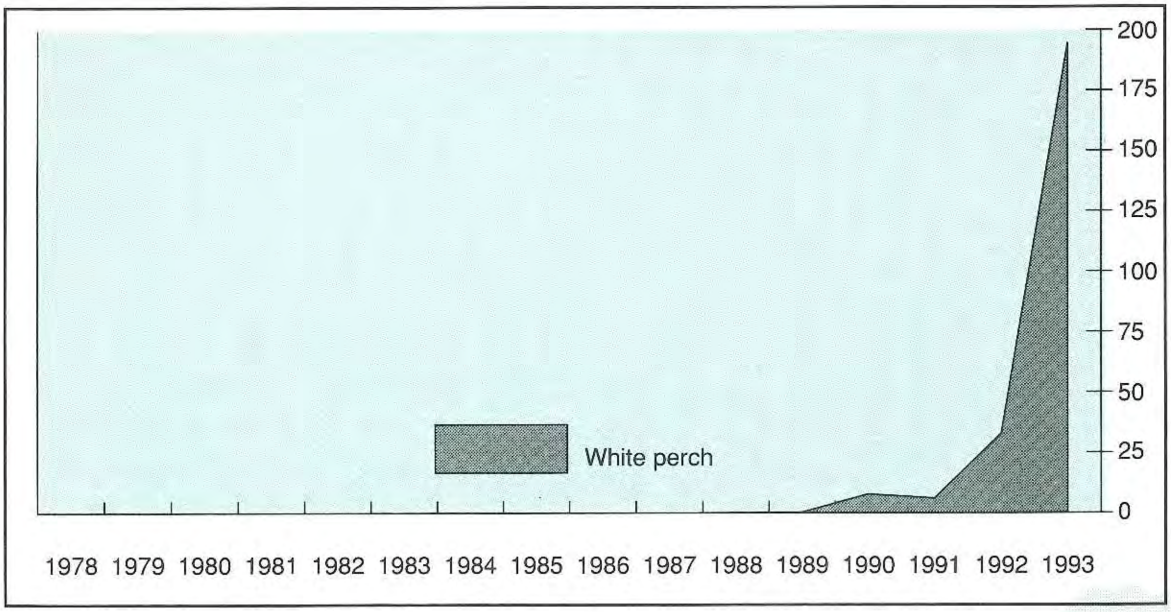
The second data set comes from collections made annually at the De Pere dam (also Figure 1) on the Fox River from mid-April through mid-June. Fish are captured using a lamprey trap operated by local personnel under contract from the U.S. Fish and Wildlife Service. For the past eight years personnel from St. Norbert College have operated the trap.



MEAN NUMBER OF FISH CAUGHT PER TRAWL
from 1979 to 1993 during August of each year at locations south of Point Sable and Longtail Point

Source: WDNR

FIG. 15



MEAN NUMBER OF WHITE PERCH CAUGHT PER TRAWL
from 1978 to 1993 during August of each year at locations south of Point Sable and Longtail Point

Source: WDNR

FIG. 16

TRAWL SURVEYS

■ Yellow perch have been the most abundant species caught during the 15 years of trawl surveys. About half of the more than 100,000 fish captured and released during these surveys have been yellow perch. Alewives, gizzard shad, spottail shiners and troutperch are other species that have dominated in numbers through the years.

However, major changes in fish species abundance have occurred in trawl surveys from year to year. In the late 1970s and early 1980s trawl catches contained greater proportions of large alewives, bullheads, burbot and carp than have been seen in more recent years. During the mid-1980s, a series of good years for yellow perch reproduction, com-

NUMBER OF SPECIES CAUGHT ANNUALLY
from early April through mid-June in the lamprey trap at the De Pere Dam

Source: P. Cochran, St. Norbert College

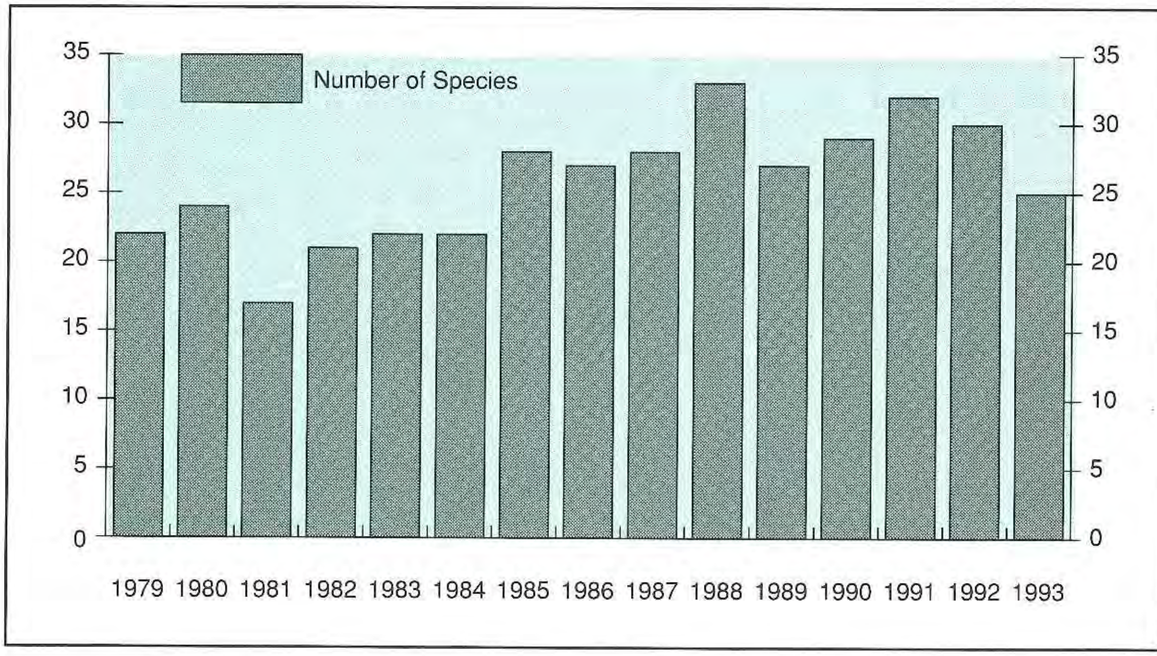


FIG. 17

NUMBER OF SPECIES CAUGHT ANNUALLY
from 10 trawl locations south of Point Sable

Source: WDNR

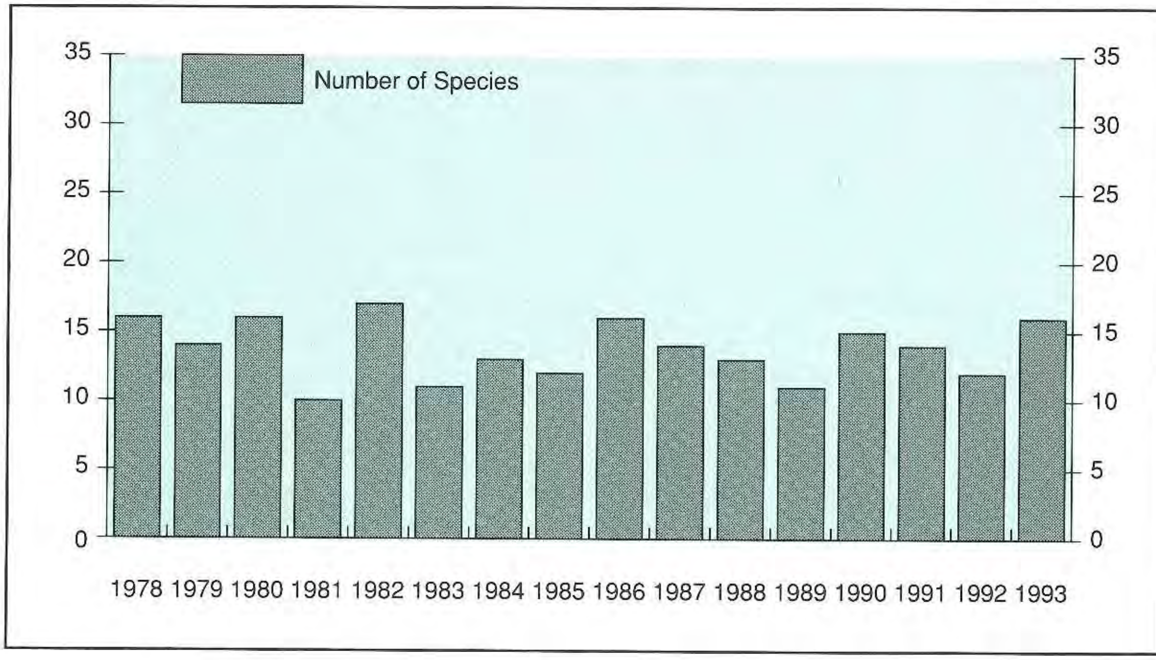
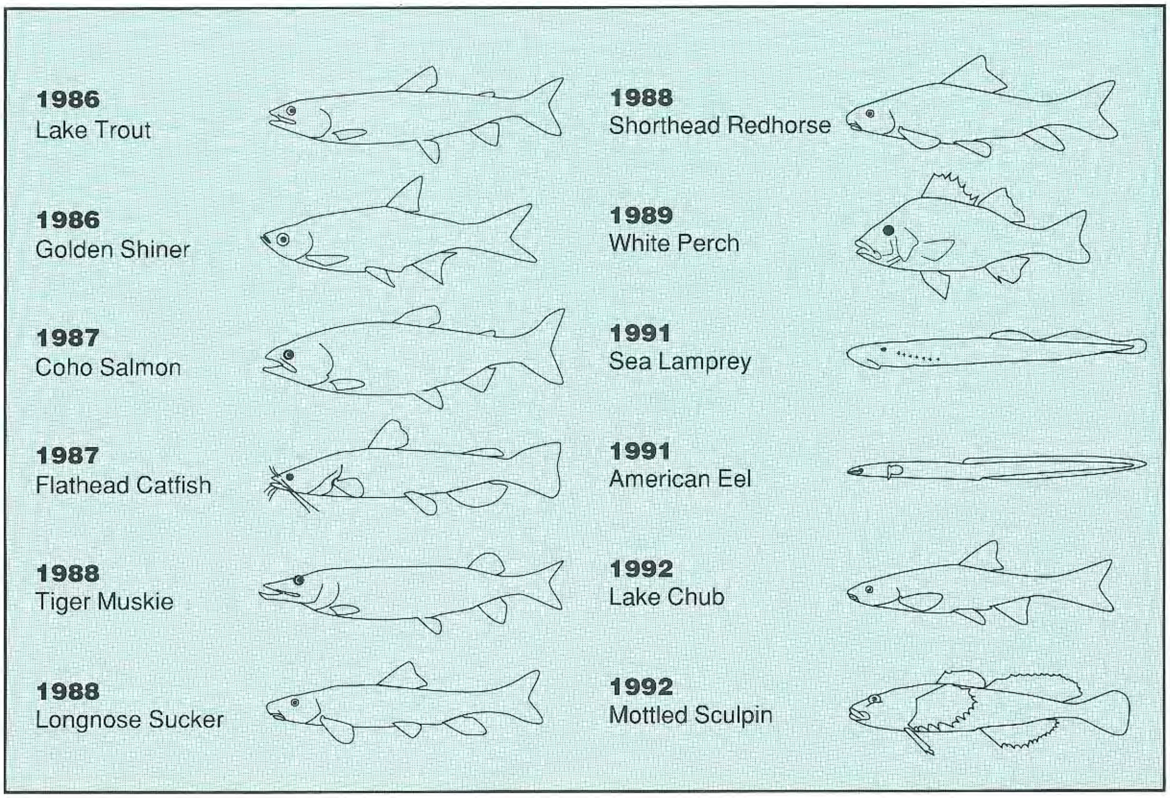


FIG. 18

bined with declining alewife catches and increases in troutperch abundance, marked a change in the fish community (Figure 15).

In the late 1980s, two relative newcomers began to dominate trawl catches. White perch invaded the Great Lakes from their native waters along the Atlantic coast, first appearing in southern Green Bay in 1988. White perch numbers have increased since their arrival: in 1993 they comprised 36 percent of the catch from trawls taken south of Point Sable (Figure 16). Gizzard shad are a southern relative of the alewife that were scarce until they briefly dominated trawl catches from 1986 through 1990. Since that time they have practically disappeared.



YEAR SPECIES FIRST CAUGHT
in the lamprey trap at the De Pere Dam.

FIG. 19

LAMPREY TRAP COLLECTIONS

■ The yearly number of species captured in lamprey trap collections increased consistently throughout this period (Figure 17). By contrast, no significant trend was seen in trawl surveys (Figure 18). During the late 1970s and early 1980s, spring lamprey trap catches were dominated by alewife, rainbow smelt, burbot and common suckers. By the middle of the decade increased numbers of yellow perch began to appear. At the same time sunfishes such as rock bass and pumpkinseed sunfish began to turn up, as did other species that should be present in a healthy, large-river system (Figure 19).

By the late 1980s and early 1990s predators such as gar and smallmouth bass showed up in greater numbers, as did emerald shiners, a formerly abundant forage fish. Despite these positive signs, a great increase in white perch numbers served as a reminder that this exotic has established a stronghold throughout the bay and lower Fox River.

Perhaps the most consistent pattern in both of these data sets is the lack of a constant pattern in the bay's fish community composition. Yellow perch have been the mainstay of lower Green Bay, yet also vary in abundance from year to year. The bay's mixture of forage fish—small minnows and herrings that provide a link in the food web between game fish and zooplankton—changes greatly from year to year. In some years this mix of species may be more favorable for angler catch rates, as well as the growth and abundance of game fish. But it is clear that conditions change frequently.

As we enter the mid-1990s, fish surveys conducted by the Wisconsin DNR indicate some positive trends for large predators such as walleyes and northern pike, due to some strong years for reproduction early in this decade. The absence of good yellow perch recruitment for several years is cause for concern, but whether this results from unfavorable weather conditions or changes in the fish community is not clear.

The effect of exotic species on the fish community will be the key new question in upcoming years. White perch numbers have risen in recent years, and their impact upon yellow perch is uncertain. Zebra mussels will change many aspects of the food web.

LOWER GREEN BAY: DESIRED FUTURE STATE

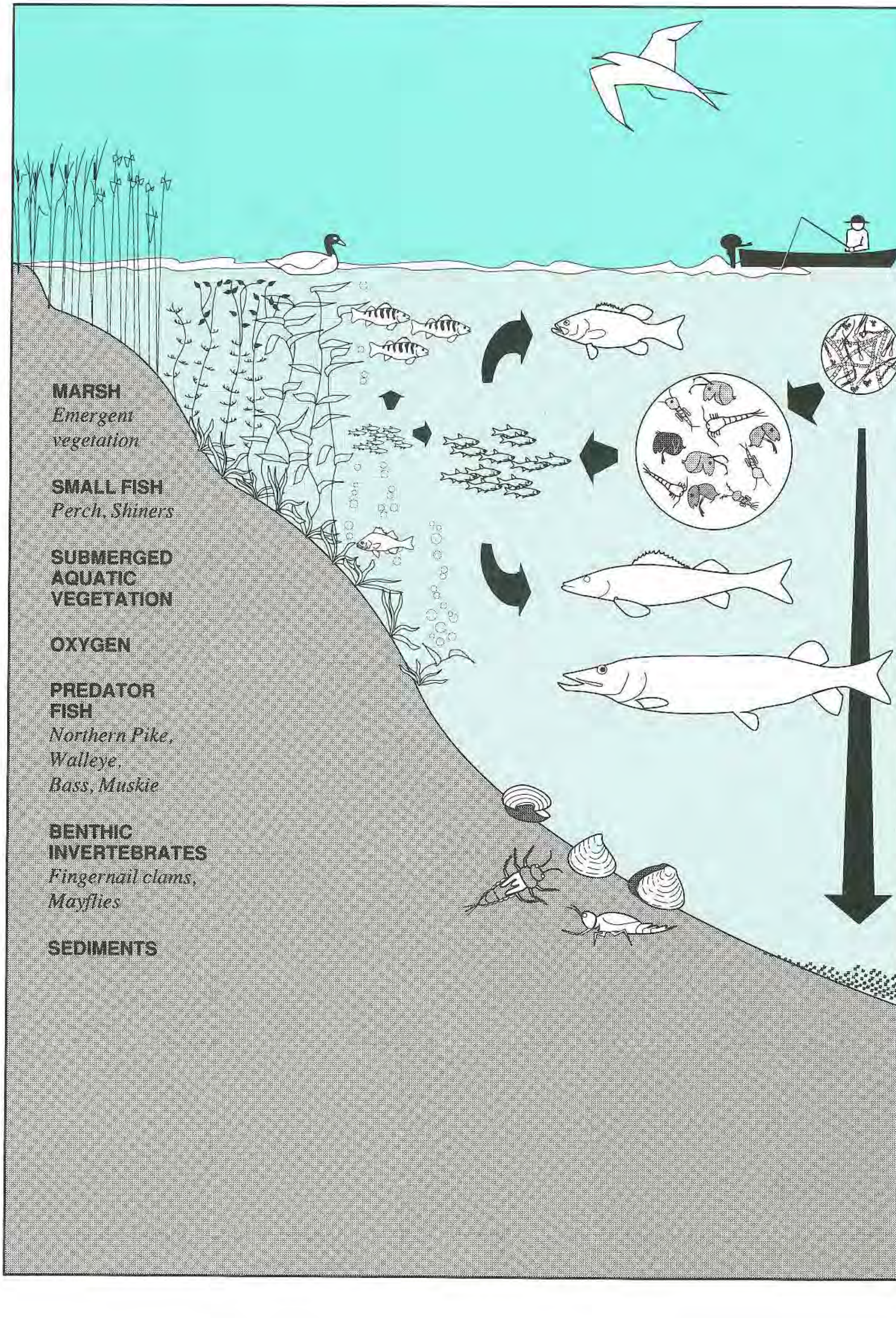


FIG. 20

17

Illustration by Dorothy Harris Ryan

COASTAL WETLANDS

■ For 140 years, wetlands in Northeast Wisconsin were viewed as wastelands or impediments to "economic and socially productive progress." Consequently, wetlands of all types have been drained, filled, channeled or otherwise altered from their natural state. The coastal wetlands of Green Bay are no exception. For all of Green Bay, approximately 60 percent of the wetlands have been permanently altered. For the Area of Concern, 90 percent of the wetlands have been filled or otherwise drastically altered. Natural scientists have valued wetlands, but only in the last decade has a positive view of wetlands emerged among a more general population.

Coastal marshes are dominated by herbaceous (non-woody) flowering plants called macrophytes. Two distinct macrophyte communities recognized are described as emergent and submergent. As the name implies, emergents are rooted plants that emerge from the water; submergents are mostly rooted but are submersed under water (Figure 20). Macrophytes are not only highly productive but provide habitat for microflora, zooplankton, larger invertebrates, fish, amphibians, reptiles, birds and mammals. Many factors interact to control the growth and distribution of submergent macrophytes. The amount of available light, however, is often considered to be the primary controlling factor.

Since submerged aquatic vegetation is so important to the health of the Green Bay ecosystem (Figure 20), an improved light climate is essential (see section on suspended solids and phosphorus).

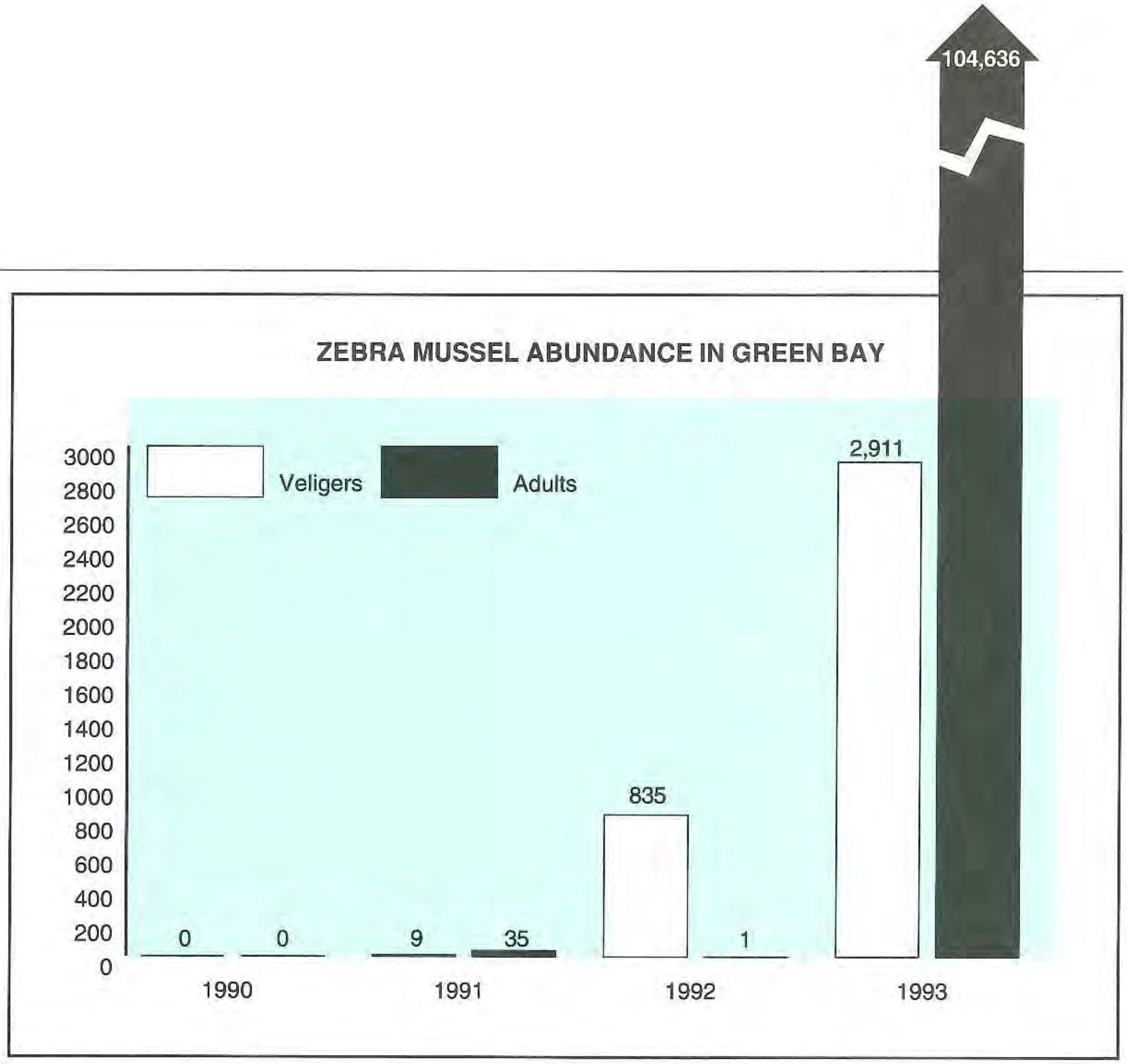
Ironically, any factor—the zebra mussle for example—that improves water clarity could change the very nature of the Green Bay ecosystem. It could be possible to get too much of a good thing: plants. Zebra mussel invasions in western Lake Erie resulted in explosive growth of underwater plants (see photo back cover). This could enhance waterfowl and some fish populations but impair people-related activities such as boating.

Records of the distribution and abundance of submersed aquatic plants are very sparse. Only two studies provide quantitative information on the composition, distribution and abundance of these plants in Green Bay. Surveys and assessment of submergent aquatic plants are important because they provide the benchmark to measure change brought about by increased water clarity.

18

MEAN NUMBER OF ZEBRA MUSSEL veligers (larvae) and adults collected in waters south of Dyckesville during the growing season.

Source: University of Wisconsin Sea Grant Institute



ZEBRA MUSSELS

■ The most notorious recent immigrant to Green Bay has been the zebra mussel, a small striped mollusk. The arrival of zebra mussels was anticipated with much fanfare. They had already created havoc with their great abundance in other parts of the Great Lakes since arriving from Europe in the 1980s.

What makes zebra mussels notorious is their habit of attaching to hard surfaces in great numbers—often resulting in layers of mussels several inches thick. Water intakes operated by Great Lakes water and power utilities and industries provide ideal conditions for zebra mussel attachment and growth. These same intakes provide a gateway for zebra mussels to enter miles of internal water pipes that are vital to power plant operations. Frequent and expensive measures are required to control mussel infestations in these facilities.

From an ecological standpoint zebra mussels are a "keystone species," which means that they are capable of changing the ecosystems in which they live. The great filtering capacity of zebra mussels was responsible for improvements in water clarity in other fertile areas of the Great Lakes with a resulting increase in submerged aquatic plants, but by the end of 1993 it was unclear whether zebra mussels would have a similar impact on Green Bay.

Isolated zebra mussels were first observed in Green Bay during the summer of 1991, but they did not become a dominant animal in the bay until the summer of 1993. The explosive potential of these animals to grow and reproduce in the fertile waters of southern Green Bay became clear in July 1993, when 400,000 recently-settled zebra mussels were found on one square meter of a plexiglass sampling device near the entrance lighthouse.

Within six weeks, zebra mussels were found completely covering rocks and other hard surfaces in the southern bay, and had grown to around one-half inch in length. In a matter of a few months, zebra mussels had become one of the most abundant animals in southern Green Bay.

People-Related Activities 19

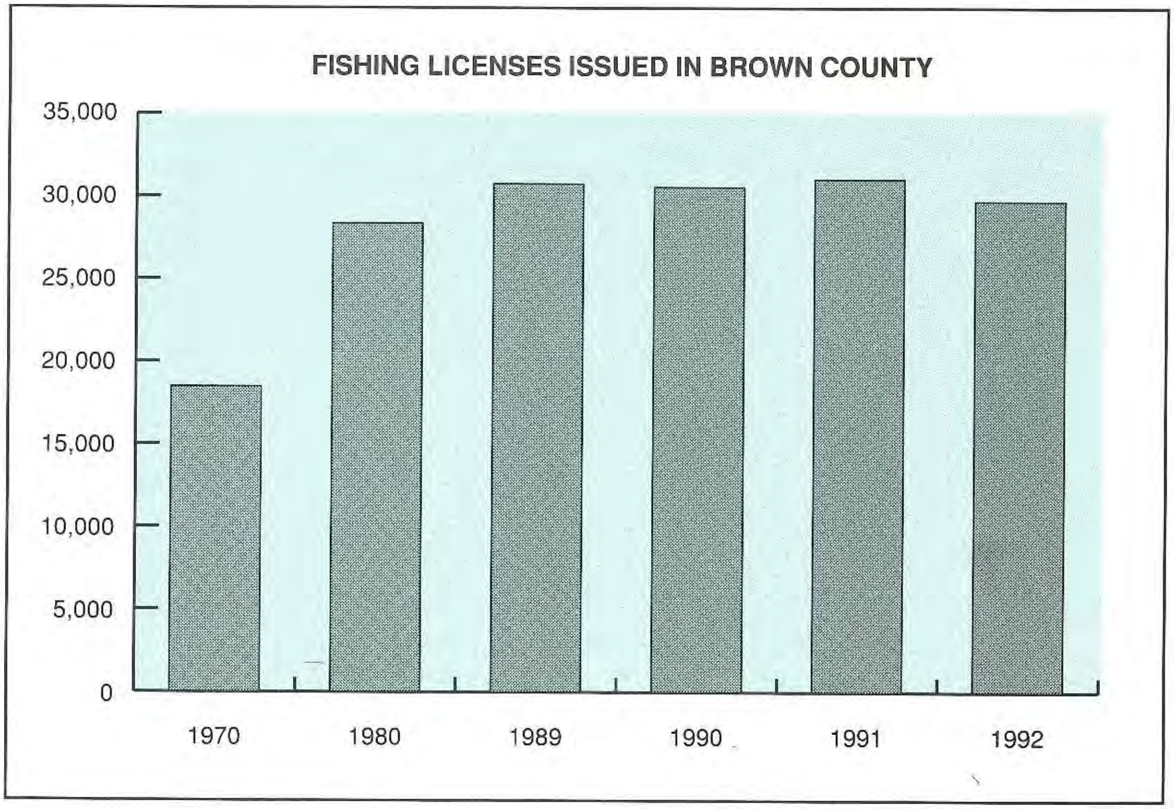
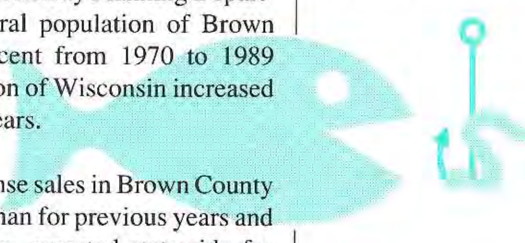


FIG. 21

SPORT FISHING



■ Fishing has been a popular sport on the bay for a long time. In recent years that popularity has spread to portions of the Fox River as well. Increases in dissolved oxygen in the water and a walleye stocking program by the Wisconsin DNR helped establish a fishery that now attracts large numbers of anglers.

Determining the actual numbers of people who fish in the Area of Concern is difficult. A general indication of sport fishing trends was obtained from fishing license information compiled annually for the state and county by the Wisconsin DNR. License information tells how many licenses were purchased in the county, not necessarily used. Nor does it represent the total fishing population since certain segments — children under 16, adults over 65 and the disabled — are not required to purchase fishing licenses. The information can be used, however, to compare license sales trends over time. Data from 1970, 1980 and 1989 show a significant upward trend from 18,000 purchased in Brown County in 1970 to 31,000 in 1989 (Figure 21). That's a 73 percent increase in the Brown County fishing population compared to a 48 percent increase in the Wisconsin fishing population for the same years. Figures provided by the Green Bay Planning Department show that the general population of Brown County increased 23 percent from 1970 to 1989 while the general population of Wisconsin increased ten percent for the same years.

In recent years fishing license sales in Brown County increased at a slower rate than for previous years and declines in sales have been reported statewide for certain years. This downward trend is reflected nationwide and may be due to increased urbanization, a change in leisure time activities and changing family structure. It may also be due to declining perch catches (Figure 22).

Despite recent data, however, the popularity of fishing in Brown County appears to remain strong. The number of walleye caught per hour (CPU) in 1993 increased almost six times over that in 1991 and 1992 (Figure 22a). The opposite was true for perch, where the CPU (fish caught per hour) was only half that of 1991 (Figure 22b). These creel surveys provide a means of monitoring fishing pressure on these very popular species.

20

WALLEYE AND PERCH CREEL SURVEYS

Source: Wisconsin Department of Natural Resources – Terry Lychwick and Brian Belonger

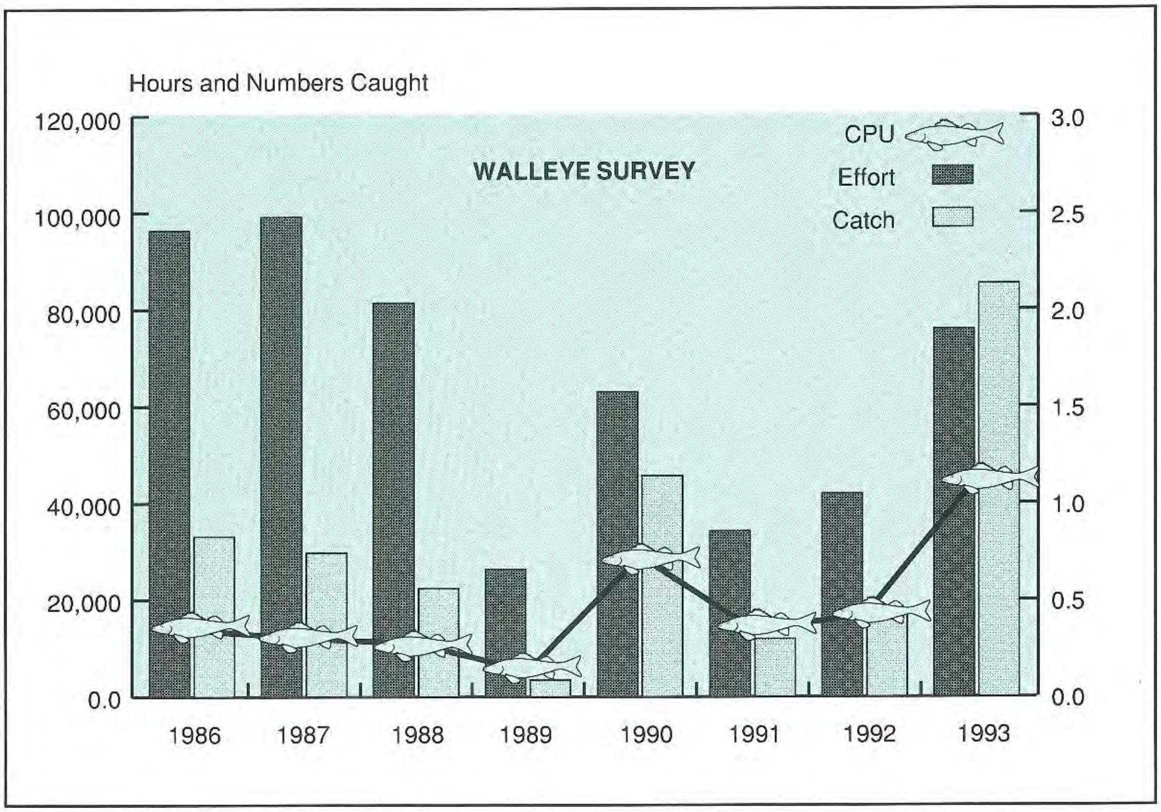


FIG. 22a

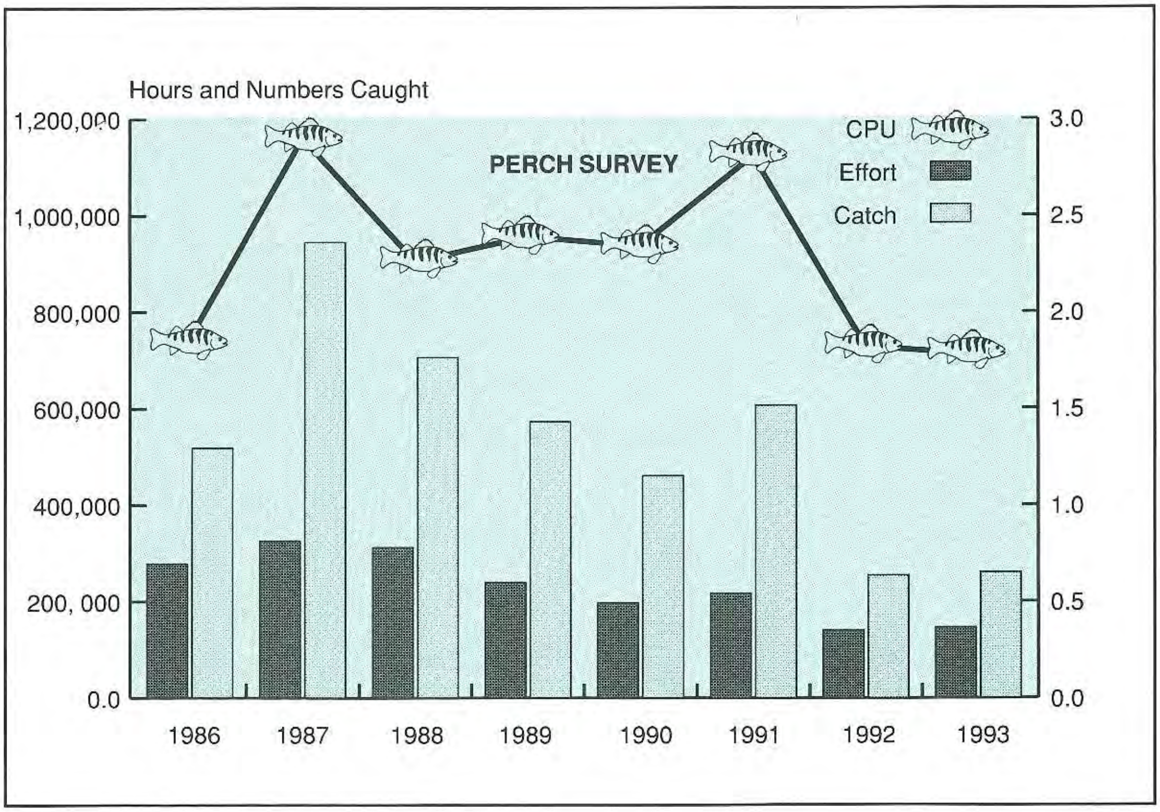


FIG. 22b

RECREATIONAL BOATING

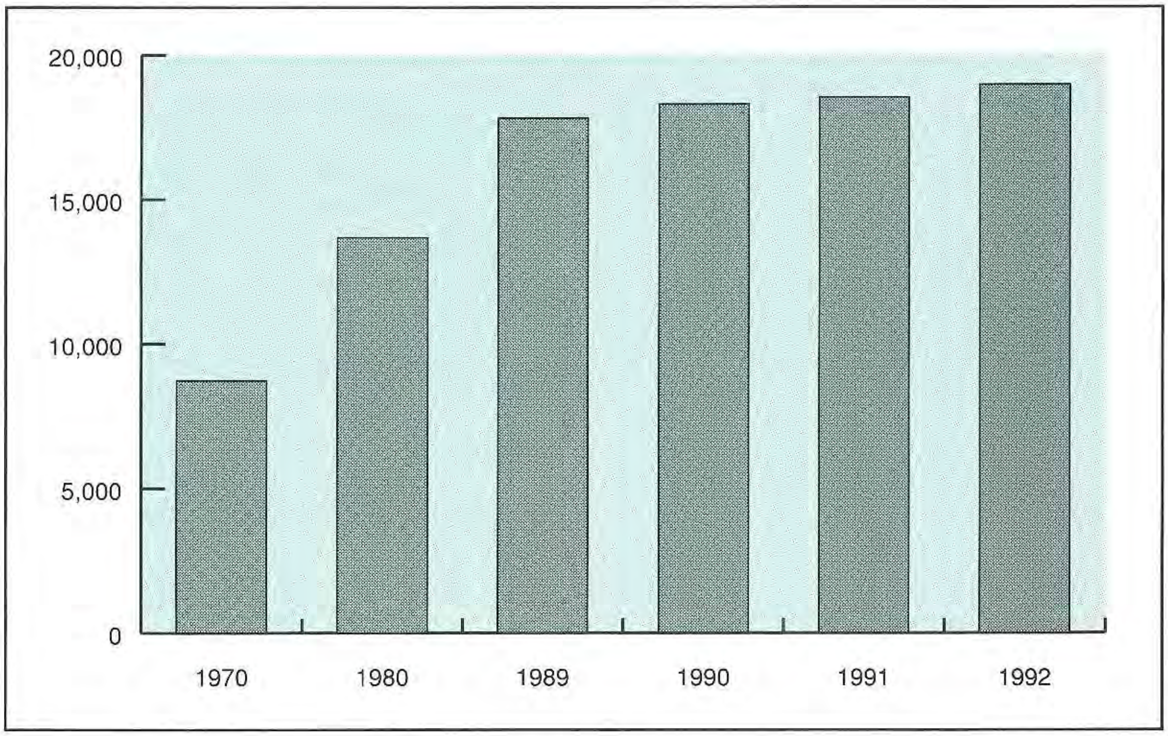


FIG. 23

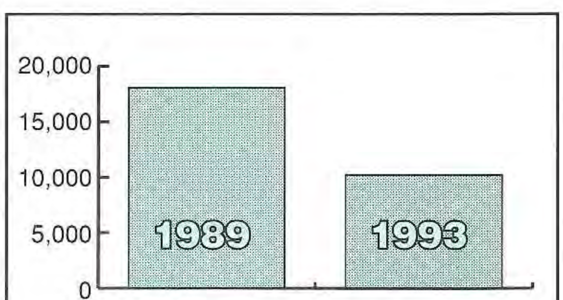
BOAT REGISTRATIONS ISSUED IN BROWN COUNTY

■ Boating on the Lower Fox River and bay is a popular form of recreation. As soon as the weather warms, long lines of fishing boats and pleasure craft can be seen almost any weekend at area launch sites. Just how popular is boating in the Area of Concern?

According to Wisconsin Department of Natural Resources figures, 17,817 boats were registered to Brown County residents in 1989, 104 percent more than in 1970. That compares to a 54 percent increase in the state boating population for the same years. The general population increased at a more modest rate in both Brown County and Wisconsin during that same time. Boat registration for Brown County in 1992 was 18,958. The increase from 1989 to 1992 was 6.5 percent, or approximately two percent per year. There was roughly a six percent increase in population for Brown County over the same time period.

A boat license is valid for two years and entitles the owner to use the boat anywhere in the state. Boat registration figures do not indicate how many boats are actually used in the Area of Concern. Other measures can be used to get a better idea of boat usage.

For instance, 1989 was the first complete year that launch fees were collected for the five sites managed by the City of Green Bay and Brown County. Daily and seasonal passes combined totaled 18,052 (Figure 23). In 1993, this total was down to 10,195. The new boat launch facility in De Pere (Fox Point) accounts for an additional 2,000 receipts in 1993. Still these numbers produced by surveys conducted in standard fashion represent a 30 percent drop in usage from 1989 to 1993. Use of the Bayshore Park ramp declined precipitously from nearly 6,000 receipts in 1989 to 2,900 in 1993. There appears no clear, single explanation for the decline. Weather conditions and decline in perch catch may be partial explanations.



Sites include: Green Bay Metro, fairgrounds, Suamico, Bayshore, Wrightstown and De Pere (Bomier Street)

DAILY AND SEASONAL BOAT LAUNCH RECEIPTS
for City of Green Bay and Brown County

Source: 1989 and 1993 Boat Launch Inventory, Brown County Planning Commission

FIG. 24

22 Targeting the Watershed

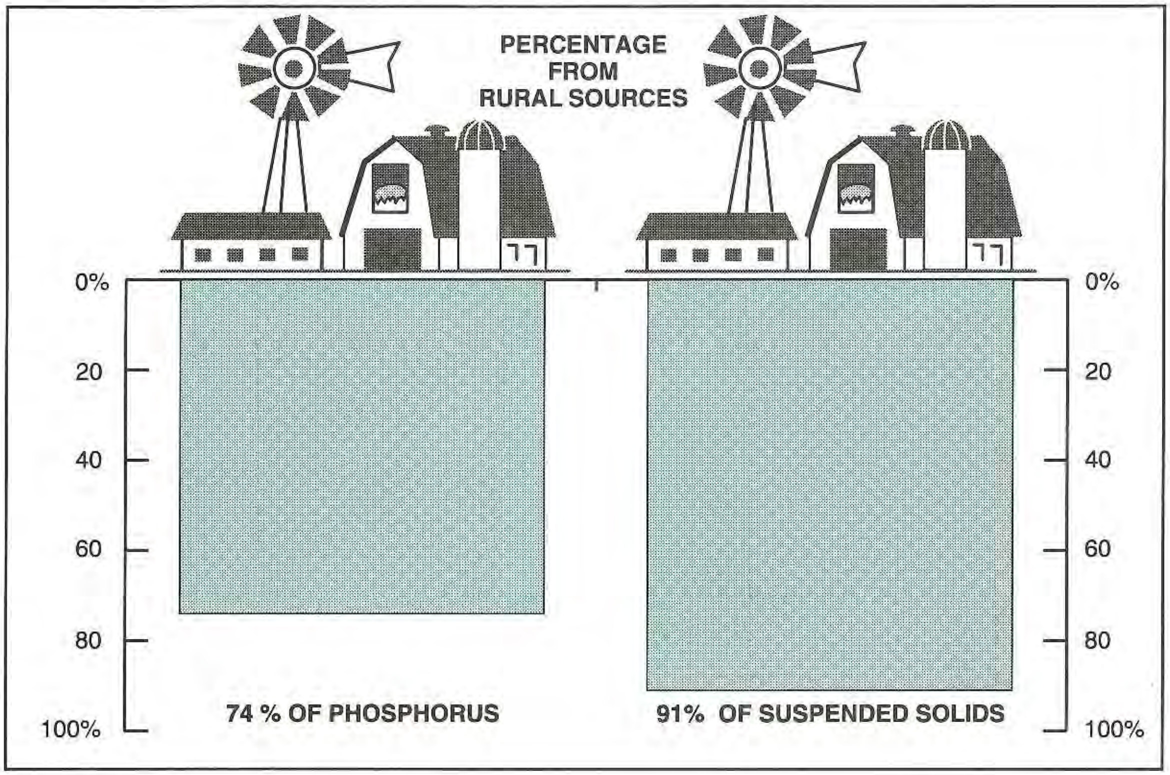


FIG. 25

DEVELOPING A DIFFERENT APPROACH

■ In early 1992 a small group of citizens formed a non-profit organization called Northeastern Wisconsin Waters of Tomorrow (NEWWT). The group raised funds from local sources and recruited scientists, engineers and policy analysts to form an interdisciplinary analysis team. Building on a 20-year research base on Green Bay and its watersheds, the analysis team was charged with answering one question: Where should the citizens of the watershed and state invest money and energy to have the greatest impact on cleaning up the waters in the watershed and Green Bay? The challenge was to analyze alternative management strategies for both land and water in the entire watershed and to estimate strategies' costs and their contributions to improving water quality by the year 2010.

To put it another way, the goal was to develop and perform an initial cost-effective analysis methodology for water quality in the Green Bay watershed.

The analysis team had only one year to arrive at a first-cut analysis. To accomplish this, the scope of the effort was reduced primarily to questions regarding cost-effective reductions of phosphorus and sediment. While the results are preliminary and need further refinement, they are still telling with regard to the source reductions on a watershed basis.

The team used data from existing studies and existing nonpoint source computer models to model the entire 6,640-square-mile watershed. The team used 1990 as the base year for analysis. Four sets of demographic, economic and land-use conditions were projected for the year 2010 for each of the 41 subwatersheds that comprise the Fox-Wolf basin. The resulting effects on the quality of water resources in the watershed was estimated assuming no new management initiatives and using 1990 weather patterns. These baseline projections indicate how much reduction in phosphorus and suspended solids would be needed to meet water quality objectives in 2010.

About 74 percent of the phosphorus and 91 percent of the total suspended solids that reach the lower Green Bay come from rural sources (Figure 25), based on analysis team estimates.

COSTS PER POUND
for reducing phosphorus and suspended solids

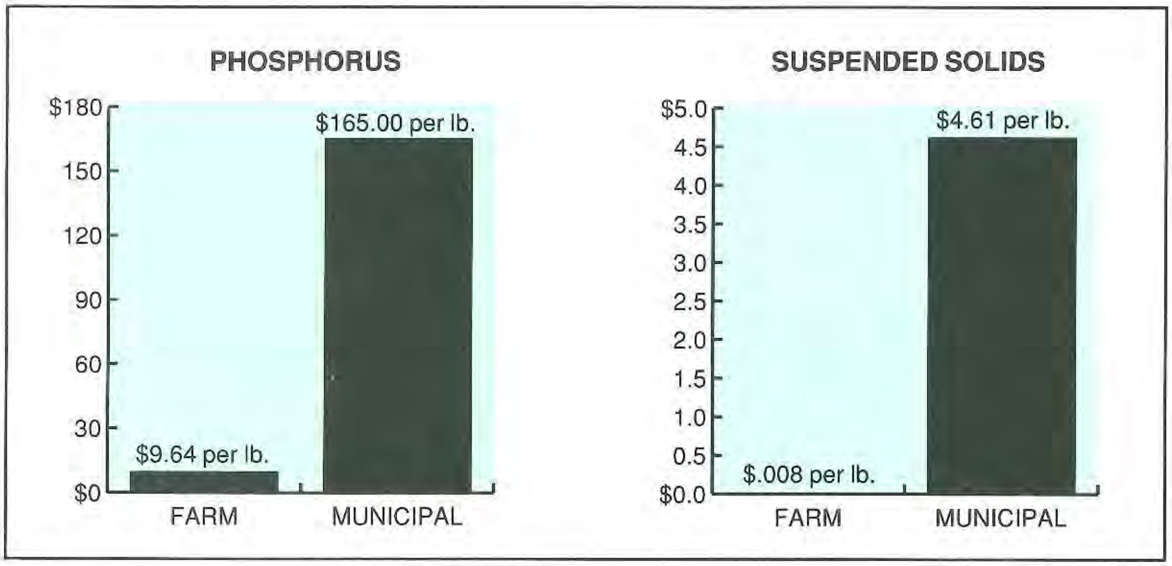


FIG. 26

COSTS

■ The cost of reducing phosphorus and suspended solid loadings to the watershed is estimated to be significantly less for agricultural sources than for other sources (Figure 26). For the 41 subwatersheds draining into Green Bay, the average annual cost of reducing phosphorus from agricultural sources is estimated at about $9.64 per pound. That compares with an average cost of $165 per pound to reduce phosphorus in municipal treatment facilities.

The story is the same for suspended solids. The annualized cost of reducing total suspended solids at the outlet of the sample watershed is $0.008 per pound or less than a penny a pound from agricultural land, contrasted with almost $4.61 per pound at municipal treatment facilities.

Four of the subwatersheds that contribute the most phosphorus and suspended solids at their outlets have been selected as priority watersheds. However, even success in four of 41 subwatersheds in the Fox-Wolf basin will not be sufficient to reduce phosphorus loads to meet objectives stated in either the Remedial Action Plan or the Lake Winnebago Comprehensive Management Plan.

The unit costs of reducing phosphorus and total suspended solids are lowest for agricultural sources, but they are not insignificant. The annualized cost for a farm with 200 acres of cropland converting from conventional to best-management practices is estimated at between $2,400 and $4,200 ($12 to $21 per acre depending on discount rate chosen and type of farm). These figures do not include management, education, incentive or regulatory costs, which depend on implementation and institutional arrangements. Nor do they include such factors as risk, cultural resistance to changing management practice, or enforcement costs at the state or local level.

ACHIEVING THE GOAL

■ Policy implications of NEWWT's first-cut analysis are clear.

First, we cannot achieve our collective goals for clean water in the Fox and Wolf rivers, lakes Butte des Morts and Winnebago, or in the bay of Green Bay by focusing primarily on either point or nonpoint sources of phosphorus and suspended solids. We must reduce loadings from both. We have to change our way of doing business. We already have made substantial headway on point source discharges, but, right now, the biggest payoff for the least cost will come from reducing phosphorus and suspended solids entering the waters from agricultural land.

Nor can we achieve our goals without looking at the whole watershed. We cannot clean up lower Green Bay unless we clean up Lake Winnebago. We cannot clean up Lake Winnebago unless we clean up the Fox and Wolf rivers. We have to attack pollution at its source and we have to do it through the entire watershed.

WHERE ARE WE NOW?

■ If we were to answer this question using only our simplified scoreboard (Figure 27) the answer would be, "about the same place we were in 1990." Yet there is evidence to show that there has been general improvement of fish populations since the 1970s, although this is countered by new threats from exotic species.

Disappointingly, water clarity appears to continue to decline. This water clarity decline could be related to high river flows in 1993 and increased loads of suspended solids. Yet it still reflects conditions in the watershed and can hardly be interpreted as improved conditions. It could be argued that expecting improvement in a mere three years is unrealistic. Quite so, but at the same time the facts tell us that we cannot expect improvements in the bay until we address problems in the watershed as a whole. This is true for toxic substances and conventional pollutants alike.

The hopeful side is this: there does appear to be increased awareness of the need for natural resource and regulatory agencies to manage ecological systems (ecosystems) on the scale of watersheds and river basins rather than chemical-by-chemical and stream-by-stream. Remedial programs are being formulated and new resources are appearing for continued research.

Some have become understandably impatient with the "glacial" speed of the restoration process. People have every right to urge expediency and demand action. But there are no "fix-it" manuals for large-scale ecosystems, and the economic and social matrix of our society resists change. It is not a matter of applying the right technological fix, but rather a matter of changing the whole way we count environmental costs and measure the effectiveness of expenditures. We are in that process and the learning curve is steep. It will take time to mobilize resources appropriate to the scale that is needed. The results, however, should be sustainable because we will come to see ourselves as part of a larger system, the "health" of which is necessary for our own health and economic well being.

SCOREBOARD (since 1990)	I	S	W
Water Clarity			☹
Dissolved Oxygen	☺		
Phosphorus Levels		😐	
Ammonia		😐	
PCB		😐	
Fish Populations	☺		
Habitat		😐	
Exotic Species			☹
Recreational Activities		😐	
	2	5	2

STATE OF THE BAY SCOREBOARD

☺ *I = Improvement*

😐 *S = Same*

☹ *W = Worse*

FIG. 27

August 1994