Cover photos: Landsat 7 satellite image of western Lake Erie Basin and Detroit River corridor provided by USGS Landsat Project; Upper left: angler with walleye (*Sander vitreus*) by Jim Barta; Middle left: lake sturgeon (*Acipenser fulvescens*) by Glenn Ogilvie; Lower left: *Hexagenia* by Lynda Corkum; Center: lake whitefish (*Coregonus clupeaformis*) by James Boase/U.S. Fish and Wildlife Service; Lower right: juvenile peregrine falcon (*Falco peregrinus*) by Craig Koppie/U.S. Fish and Wildlife Service; Bottom left: bald eagle (*Haliaeetus leucocephalus*) by Steve Maslowski/U.S. Fish and Wildlife Service.

State of the Strait

Status and Trends of Key Indicators

Edited by: John H. Hartig, Michael A. Zarull, Jan J.H. Ciborowski, John E. Gannon,
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www.StateoftheStrait.org
www.epa.gov/med/grosseile_site/indicators/index.html

3.0 Comprehensive and Integrative Assessment

The Detroit River-Western Lake Erie Indicator Project has compiled considerable useful information on long-term patterns of 50 key trend data sets and indicators (Table 1; Appendix B). Indeed, it is surprising how many long-term databases exist, but are neither accessible nor available. These databases were not integrated, nor comprehensively evaluated and assessed. However, collectively the information and knowledge from these 50 data sets have considerable value to management.

This assessment is comprehensive in that it makes use of all available information. It is integrative in that it identifies emerging trends from suites of indicators that may not be evident from analyzing single indicators. By the same token, all recommendations, as well as the research and monitoring needs, are a result of this integrative assessment.

If one were to look at a small number of these indicators, one might get an incomplete and possibly inaccurate assessment or picture. For a comprehensive assessment of ecosystem health, all indicator databases are important. However, a more limited suite of trend data or indicators may be sufficient for specific resource management needs like fisheries or wildlife. Presented below is an initial comprehensive and integrative assessment that draws on all available databases. This summary and interpretation is heavily weighted on state information – there are 38 state, seven pressure and five response indicators. Although there are important data and knowledge gaps, this initial assessment lays the foundation for continuous improvement in the future in the spirit of adaptive, ecosystem-based management.

3.1 Pollution Prevention/Control and Evidence of Improved Environmental Quality

The Detroit River and western Lake Erie have received considerable local, regional, national, and international media attention over many decades from oil spills, phosphorus pollution, the "Mercury Crisis of 1970," and more. Growing public awareness and concern over controlling pollution resulted in a number of key regulatory and nonregulatory initiatives being implemented in the early 1970s in both Canada and the United States (e.g., U.S. Clean Water Act, Canada Water Act, U.S. Endangered Species Act, Canada-U.S. Great Lakes Water Quality Agreement, etc.).

These national initiatives and U.S.-Canada agreements, and complementary state, provincial, and local programs, provided the framework and impetus for billions of dollars of pollution prevention and control over the last 35 years. All environmental and natural resource agencies and organizations are interested in results – what has been achieved by pollution prevention and control.

Table 1. A compilation and summary of indicators/trend data for the Detroit River and western Lake Erie.

Indicators/Trend Data	Period of Record	Overall Trend	Quantitative Target	Target Achieved
Human Population Growth and Distribution in Southeast Michigan	1900-2005	Steady increase in population within seven-county region; Detroit's population grew steadily until 1950, then decreased by 50% between 1950 and 2005	No	
Land Use in Southeast Michigan	1900-2006	There has been a substantial increase in the conversion of agricultural land to urban development; there has also been a decrease in housing density	No	
Transportation	1960-2000	88% increase in people driving personal vehicles since 1960; 26,000 fewer people using mass transit since 1980; average travel time to work has increased by three minutes in the last 20 years	No	
Phosphorus in the Maumee River	1975-2006	There has been a general decline in total phosphorus from the mid-1970s through the mid-2000s; dissolved reactive phosphorus declined from the mid-1970s to the mid-1990s and is now increasing through the mid-2000s	No	
Carbon Emissions	1960-2001	Michigan's carbon emissions have increased by 59.7 million metric tons between 1960 and 2001, representing a 46% increase	No	
Oil Pollution of Detroit and Rouge Rivers	1946-2005	Between 1946-1948 and 1961 there was a 97.5% reduction in oil discharges; between 1961 and the 1990s and early 2000s there was another order of magnitude reduction, with the exception of 2002 and 2004 when major oil spills occurred	No	
Shoreline Hardening	1870-1990	The Lake Erie shoreline along two counties in Ohio were almost unaltered until the 1930s; there has been a dramatic increase in shoreline hardening through the 1990s; shoreline hardening in Ottawa and Lucas counties has increased to 78% and 98%, respectively	No	
Lake Erie Water Levels	1918-2005	Water levels vary on both seasonal and long-term scales; high water levels were recorded in Lake Erie in the 1950s and 1980s-1990s, while low water periods have occurred in the 1930s and 1960s; currently, Lake Erie water levels are slightly below the long-term average; water levels are projected to decline 1-2 m over the next 70 years	No	
Water Clarity in Western Lake Erie	1980s-2000s	Water clarity has generally increased since the invasion of zebra mussels in the mid-1980s	No	
Lake Erie Ice Cover	1963-2005	General decreasing trend of ice cover as measured by Annual Maximum Ice Cover between 1963 and 2005	No	
Phosphorus Concentrations in Kingsville Water Intake in Western Lake Erie	1976-2004	High seasonal variability, but there has been a general decline from the 1970s to mid-1990s; there has been an increasing trend from the 1990s to the early 2000s	Yes	No
Chlorides in Western Lake Erie Water	1900-2005	Chloride concentrations increased from 7 to 25 mg/L between 1900 and the 1960s; slight decreasing trend between the late 1960s and mid-1980s; slight increasing trend between mid-1980s and 2005	No	
Dissolved Oxygen in the Rouge River	1973-2006	In the lower Rouge River, the percentage of dissolved oxygen measurements that exceed the 5 mg/L state standard for protection of a warm water fishery has increased from approximately 20% in 1973 to 80% in recent years (early to mid-2000s)	Yes	No (not consistently)

Indicators/Trend Data	Period of Record	Overall Trend	Quantitative Target	Target Achieved
Contaminants in Western Lake Erie Sediments	1971 and 1995	70% decline in mercury in sediment since the 1970s; at least a 50% decline in PCBs and other organochlorine contaminants since the 1970s	Yes	No
Air Quality in Southeast Michigan	Contaminant-specific 1960s-2005	• Carbon monoxide: 83% decline between 1979 and 2005 • Lead: 96% decline between 1981 and 2005 • Nitrogen dioxide: 60% decline between 1979 and 2005 • Ozone (8-hour average): no clear trend between 1988 and 2005 • Particulate matter ($PM_{2.5}$): no clear trend between 1999 and 2005 • Sulfur dioxide: 72% decline between 1979 and 2005	Yes Yes Yes Yes Yes Yes	Yes Yes Yes No No Yes
Contaminants in Lake Erie Fish	1977-2004	Mercury in walleye (60% decline between the late 1970s and early 1980s; levels have remained steady since); mercury in smelt (an apparent decrease between the late 1970s and the late 1990s; possibly increasing through the early 2000s); DDT in smelt (60% decline between the late 1970s and early 2000s); DDT in walleye (90% decline between the late 1970s and the early 2000s); PCBs in smelt (high year-to-year variability); PCBs in walleye (generally lower in the 1980s and 1990s compared to the 1970s)	No	
Mercury in St. Clair Walleye	1970-2004	Mercury in Lake St. Clair walleye has decreased by 80% since 1970; however, health advisories still remain for certain fish species and sizes	Yes	No (not all species)
Contaminants in Herring Gull Eggs	1974-2004	PCBs (approximately 80% decline); DDE (approximately 90% decline); dioxin (generally lower concentrations in the late 1990s and early 2000s, compared to the mid-1980s to mid-1990s)	No	
Algal Blooms	1960s-present	Algal blooms common in the 1960s and 1970s; no massive algal blooms during the 1980s; algal blooms returned in the 1990s and early and mid-2000s	No	
Plankton Communities in Western Lake Erie	1970-2004	Evidence of plankton degradation was first observed in the mid-twentieth century; during 1995 and 1997 plankton index scores were higher than 1970, reflecting more mesotrophic conditions; during 2000-2003 plankton index scores were below three and similar to the score for 1970, reflecting more eutrophic conditions	No	
Recovery of Wild Celery	1950-1997	Wild celery tuber abundance declined 72% between 1950-1951 and 1984-1985, and then increased 200% between 1984-1985 and 1996-1997	No	
Aquatic Macrophytes	1898-2006	In the Put-in-Bay area of western Lake Erie, there were 40 taxa in 1898, 32 in 1940, 26 in 1949, and 20 in both 1957 and 1967; increased water clarity since 1985 has allowed reestablishment of many long-absent species	No	
Detroit River Coastal Wetlands	1815-present	97% of the coastal wetlands on both sides of the Detroit River have been lost to development since 1815	No	
Erie Marsh Invasion by Common Reed	1984-2003	Vegetation was reported as stable from the early 1900s to the 1970s; common reed was reported at low densities during the 1950s; spatial coverage increased from 5 to 132 ha between 1984 and 2003 (over a 26-fold increase)	No	
Mayfly Abundance in Detroit River	1964-2004	Mayfly densities and distribution have been variable among years; since 1980, they have been more widespread than previously, but little change has been seen since then; sampling is too infrequent to ascribe differences among years to "trends"; mayflies are still rare or absent from much of the lower half of the Detroit River	Yes	No

Indicators/Trend Data	Period of Record	Overall Trend	Quantitative Target	Target Achieved
Mayfly Abundance in Western Lake Erie	1950s-2004	Few mayflies present in western Lake Erie between the 1950s and 1992; mayflies increased between 1997 and 2004 being "good" to "excellent" in the biological reference point since 2002, but generally has shown high variability	Yes	Yes
Chironomid Abundance in Detroit River and Western Lake Erie	1930-2004	In western Lake Erie, density increased fourfold between 1930 and 1961; similar in 1982; densities declined and richness increased by 1993; in Detroit River, densities have risen sevenfold since 1980	No	
Chironomid Deformities	1983-2004	At the mouth of the Detroit River incidence of deformities has declined from two times baseline in 1982 to baseline in 1994	No	
Oligochaete Abundance in Detroit River	1929-2004	1960s-early 1990s had up to 1 million worms/m^2; densities have since declined by 80-90%, but the numbers suggest some locations (e.g., Trenton Channel) still fall in the "heavily polluted" category	Yes	No
Dreissenids (Zebra and Quagga Mussels)	1987-2004	Zebra and quagga mussels arrived in the mid- to late 1980s; western Lake Erie maximum in early 1990s; declines since then	No	
Yellow Perch Population	1975-2006	The yellow perch population in western Lake Erie increased through the late 1970s; was variable in the 1980s, plummeted in the late 1980s; increased through the 1990s; and then was relatively stable through the 2000s	No	
Lake Whitefish Spawning	1870-2004	Substantial decline in whitefish population between the late 1800s and early 1900s; in 2006 whitefish spawning in the Detroit River was documented for the first time since 1916	No	
Lake Sturgeon Population	1879-2000	Substantial decline in sturgeon population between the late 1800s and early 1900s; no sturgeon spawning recorded from 1970s to 1999; in 2001 sturgeon reproduction was documented for the first time in the Detroit River in 30 years	Yes	No
Walleye Population of Lake Erie	1978-2005	The walleye population in Lake Erie was rated in "crisis" in 1978; it increased through the late 1980s and then declined through the late 1990s; walleye have been increasing since the late 1990s; it now is rated as "high quality"	Yes	Yes
Canvasback Population	1974-2004	High year-to-year variability; however, 12 of the last 20 years were above the long-term average	No	
Common Tern Reproduction	1960-2005	98% decline in common tern nests in the Detroit River between the 1960s-1980s and the mid-2000s; only about 300 nests remain	No	
Double-Crested Cormorants	1979-2005	Dramatic increase in cormorant population in western Lake Erie over the period of record	No	
Detroit River Christmas Bird Count	1978-2005	Bird count trends are species-specific; examples include an increase in Canada geese, mute swan, and waterfowl	No	
Rockwood Christmas Bird Count	1978-2004	Bird count trends are species-specific; examples include decreasing trends for corvids such as American crow; little change in American black duck; Canada goose and mute swan have both increased	No	
Raptor Migration over Holiday Beach, Ontario	1974-2004	Hawk trends are species-specific; decrease in immature red-shouldered hawks since 1993; substantial increase in turkey vultures; increases in peregrine falcons, osprey, and bald eagles; decline in sharp-shinned hawks since 1987	No	

Indicators/Trend Data	Period of Record	Overall Trend	Quantitative Target	Target Achieved
Raptor Migration over Lake Erie Metropark	1992-2004	Hawk trends are species-specific; decrease in immature red-shouldered hawks; increase in turkey vultures; substantial increase of peregrine falcons, osprey, and bald eagles; no change in red-tailed hawk	No	
Peregrine Falcon Reproduction	1986-2005	Falcon population in Michigan decimated in the 1950s; falcons reintroduced in Detroit in 1987; since the early 1990s falcon reproductive success has steadily increased; falcon removed from endangered species list in 1999	Yes	Yes
Bald Eagle Reproductive Success	1961-2006	Population was evenly distributed throughout the region in the early 1900s; almost complete reproductive failure by the mid-1970s; overall eagle production in the region has increased since then and has leveled-off in Ontario and Michigan with Ohio reproduction much greater and continuing to grow; in the vicinity of the Detroit River International Wildlife Refuge there are now at least seven active bald eagle nests producing young after a 25-year absence; the species is now off the federal list of threatened and endangered species in the U.S.	Yes	Yes
Asthma Trends in Wayne County, Michigan	1990-2003	In general, hospitalization rates in Wayne County have not changed since 1990 and remain significantly higher than statewide levels	Yes	No
Lead Poisoning in Detroit	1998-2004	The number and percent of Detroit children with blood lead levels of ten micrograms per deciliter or more have decreased by at least 60% from 1998 to 2004; however, children are still at risk	Yes	No
West Nile Virus	2001-2005	First detected in Michigan in 2001 with 65 West Nile virus-positive birds; first human case detected in 2002; human death due to West Nile virus in Wayne County has been reported in 2002 and 2005	No	
Phosphorus Discharges from Detroit Wastewater Treatment Plant	1966-2003	90% reduction in phosphorus concentration and loading	Yes	Yes
Combined Sewer Overflow (CSO) Controls in Southeast Michigan	1960s-2000s	In the 1970s, CSOs were identified as a major water pollution problem; CSO control programs began in the mid-1980s; approximately $2 billion was invested in CSO controls during the 1990s and 2000s; additional CSO controls will be required	No	
Contaminated Sediment Remediation	1993-2006	Dramatic increase in volume of sediment remediated and cumulative financial resources expended	Yes	No
Detroit River International Wildlife Refuge Growth	2001-2007	The Detroit River International Wildlife Refuge has grown from approximately 123 hectares (304 acres) in 2001 to over 2,042 hectares (5,047 acres) in 2007	Yes	No
Greenways in Southeast Michigan	1970s-2000s	Limited greenways development during the 1970s and 1980s; regional greenways catalyzed in the 1990s; over $100 million invested in greenways since the late 1990s	No	

This evaluation of Detroit River and western Lake Erie indicator trends, based on available data, provides concrete evidence of substantial environmental improvement and remarkable ecological recovery. However, the available indicator trends also show that much remains to be done.

This evaluation of Detroit River and western Lake Erie indicator trends...provides concrete evidence of substantial environmental improvement and remarkable ecological recovery.

Presented below are the most compelling trends of pollution prevention/control and evidence of environmental improvement. In most cases, the findings are based on an integrative assessment of several trend data sets.

3.1.1 Oil Pollution

As a result of massive duck kills due to oil pollution (e.g., 11,000 ducks died in 1948), considerable regulatory effort was placed on controlling oil discharges. Michigan's industrial pollution control program brought about a 98% reduction in oil discharges to the Detroit River between 1946 and 1961. Between 1961 and the early 2000s, there was another order of magnitude reduction in oil discharges, with the exception of major oil spills in 2002 of 378,500 liters (100,000 gallons) and in 2004 of 83,441 liters (22,043 gallons). As a result of these reductions in oil discharges, winter duck kills due to oil pollution have been eliminated.

Figure 2. Combined sewer overflow outfall along the Detroit River (Photo credit: Robert Burns, Detroit Riverkeeper).

3.1.2 Municipal Waste

Since the late 1960s, billions of dollars have been invested in the construction, operation, and continuous improvement of municipal wastewater treatment plants. Consequently, water quality has improved. In addition, nearly $2.2 billion has been spent in southeast Michigan to eliminate, capture, and treat waste from combined sewer overflows (CSOs; Figure 2). In 1960 none of the 119.2 billion liters per year (31.5 billion gallons per year) of CSO volume was treated. There has been a 65% reduction in untreated CSO volume discharged between 1960 and 2005. It is projected that by 2012, when all currently designed CSO control projects come online, there will be an 85% reduction in the annual untreated CSO volume discharged from 1960 levels. The treated CSO volume has increased from 9.1 billion liters per year (2.4 billion gallons per year) in 1993 to 22.7 billion liters per year (6 billion gallons per year) in 2005 (150% increase). It is projected that by 2012, when all currently designed CSO control projects come online, there will be a 200% increase in treated CSO volume from 1993 levels.

There has been a 65% reduction in untreated CSO volume discharged between 1960 and 2005.

3.1.3 Phosphorus and Eutrophication

The Detroit Wastewater Treatment Plant (WWTP) is the largest wastewater treatment plant in North America. Since 1966 there has been a 90% reduction in phosphorus concentration and loading from the Detroit WWTP to the Detroit River. Lower ambient phosphorus concentrations were evident in Lake Erie, reversing many of the impacts of cultural eutrophication. However, in recent years, phosphorus concentrations in western Lake Erie have been increasing, algal blooms have returned, and Planktonic Index of Biotic Integrity values have decreased, reflecting a return to more eutrophic conditions. This may be related to some combination of increased nonpoint source loading of phosphorus, unmonitored point discharges (possibly from CSOs), and internal recycling of nutrients.

3.1.4 Chloride

Chloride concentrations in Lake Erie increased from approximately 7 mg/L in the early 1900s to approximately 25 mg/L in the 1960s. Chloride loadings from five chemical industrial facilities decreased from a high of 4,247 tonnes/day (4,681 tons/day) in 1964-1966 to zero in 1986, due to process changes. Chloride concentrations in western Lake Erie dropped from about 25 mg/L in the late 1960s to about 17 mg/L in the mid-1980s. Since then, chloride concentrations have been rising gradually as a result of increasing nonpoint source inputs.

3.1.5 Persistent Toxic Substances

Regulatory controls on persistent toxic substances have increased since the 1960s. The manufacture and use of some chemicals have even been banned as a result of their effects on human health and wildlife. The pesticide DDT was banned in Michigan in 1969, the remainder of the U.S. in 1972, and in Canada in 1985. Since the late 1970s, total DDT concentrations in rainbow smelt and walleye in western Lake Erie have declined by 70% and 90%, respectively. In herring gull eggs from Fighting Island, DDE (a breakdown product of DDT) has declined by 90% since the late 1970s.

In the U.S., cradle-to-grave management of PCBs was enacted through the Toxic Substances Control Act of 1976. Since 1977, Canada has prohibited import, manufacture, sale for reuse, and use of PCBs for purposes other than those stated in Canadian regulations. These strict PCB regulations have resulted in an 85% decline in concentrations of PCBs in herring gull eggs from Fighting Island since the late 1970s. PCB levels in rainbow smelt and walleye from Lake Erie have shown high year-to-year variability since the late 1970s.

As a result of the "Mercury Crisis of 1970," both the U.S. and Canada imposed regulatory controls on mercury discharges. Mercury cell plants operated by chemical companies in Sarnia, Ontario and Wyandotte, Michigan were shut down to eliminate mercury discharges. Such control measures have contributed to an 85% reduction of mercury in Lake St. Clair walleye since 1970. Mercury levels in western Lake Erie walleye have declined by approximately 50% since the late 1970s.

Figure 3. Ellias Cove (formerly Black Lagoon) remediation project along the Detroit River (Photo credit: Robert Burns, Detroit Riverkeeper).

3.1.6 Contaminated Sediment

Control of contaminants at their source, as well as industrial process changes, have resulted in significant reduction in sediment contaminant levels. For example, PCB levels have declined by approximately 50% and mercury levels have declined by about 70% in Lake Erie sediment since the 1970s.

Despite some signs of improvement, contaminated sediment remains a universal obstacle in restoring beneficial uses in the Detroit River and western Lake Erie (Figure 3). For example, despite a 50-70% reduction in contaminant concentrations in fish, consumption advisories still exist, and contaminated sediment as well as atmospheric inputs continue to impair this beneficial use. Since 1993 over $154 million has been spent to remediate over 989,000 cubic meters of contaminated sediment in the watershed of the Detroit River and western Lake Erie. However, it is estimated that an additional two million cubic meters of contaminated sediment require remediation to fully restore beneficial uses.

Despite some signs of improvement, contaminated sediment remains a universal obstacle in restoring beneficial uses in the Detroit River and western Lake Erie.

3.2 Ecological Recovery

*Figure 4. Bald eagle (*Haliaeetus leucocephalus*) (Photo credit: Dave Menke, USFWS).*

Over 35 years of U.S. and Canadian pollution prevention and control programs have led to significant ecological recovery in this region. Trend data document the return of reproducing populations and improving condition of bald eagles, peregrine falcons, walleye, lake sturgeon, lake whitefish, and burrowing mayflies to large areas from which they had been extirpated or negatively impacted. Examples of this ecological recovery are presented below.

3.2.1 Bald Eagles

In the early 1900s, bald eagles were distributed throughout Michigan, but by the 1950s, the bald eagle population had significantly declined due to organochlorine pesticide contamination, loss of habitat, and other species changes (Figure 4). Reproductive impairments in bald eagles reached a crisis point in the mid-1970s when only 38% of Michigan's bald eagles could successfully fledge young. Bald eagle recovery efforts were catalyzed by the banning of DDT in Michigan in 1969 and the remainder of the U.S. in 1972, and by the passage of the Endangered Species Act in 1973. From 1961 to 1987, there were no bald eagles fledged in Michigan, likely due to contaminants and the low number of breeding pairs. Since 1991, bald eagle fledging success has steadily increased, particularly in Ohio where over 60 young were fledged in 2006. Fledging success in Michigan and Ontario has also increased since 1990, but to a lesser extent than in Ohio. In the vicinity of the Detroit River International Wildlife Refuge, there are now at least seven active bald eagle nests producing young after an absence of more than 25 years. In 2007, the U.S. Fish and Wildlife Service removed the bald eagle from the federal list of endangered species.

3.2.2 Peregrine Falcons

Peregrine falcons experienced a dramatic decline in the 1950s, mostly due to organochlorine pesticide contamination. DDT caused reproductive problems in peregrine falcons and other species. Again, DDT was banned in Michigan in 1969 and in the remainder of the U.S. in 1972. A peregrine falcon reintroduction program was initiated in Detroit in 1987 when one nesting pair was reintroduced, but no young were produced for the next five years. Then the number of young produced in southeast Michigan gradually increased from zero in 1992 to a peak of ten in 2005. This represents a major success story. In 1999, the U.S. Fish and Wildlife Service removed peregrine falcons from the federal list of endangered species.

3.2.3 Walleye and the Walleye Fishery

In 1978 the walleye population of Lake Erie was considered to be in crisis by fishery managers. The cause was overfishing and pollution. The walleye population is much improved following a complete ban on fishing as a result of the "Mercury Crisis of 1970," and the subsequent implementation of harvest quotas once the ban was lifted. The walleye population of Lake Erie has shown year-to-year variability since the early 1990s, but in 2005 it was four times larger than in 1978. Fishery managers categorize the 2005 population of over 40 million walleye as achieving a high quality population rating. As a result of this exceptional recovery of the walleye fishery, Lake Erie and the Detroit River are now considered the "Walleye Capital of the World" (Figure 5).

Figure 5. Angler with 13.5-pound walleye caught in the Detroit River in April 2006 (Photo credit: Downriver Walleye Federation).

3.2.4 Lake Sturgeon

In the 1800s, lake sturgeon were considered a delicacy because of their sought-after smoked flavor and their eggs as caviar. In 1880, Lakes Huron and St. Clair produced over 1.8 x 10^6 kg (4 million pounds) of lake sturgeon. During the spawning period in June 1890, over 4,000 adult lake sturgeon were caught in Lake St. Clair and the Detroit River on setlines and in pond-nets. Populations plummeted during the early 1900s due to overharvesting, limited reproduction, destruction of spawning habitats, and water pollution. Today, there is no active commercial fishery for lake sturgeon in the Huron-Erie corridor. Sport fishing harvest of lake sturgeon is now restricted in the St. Clair River and Lake St. Clair, and no sturgeon may be possessed by anglers from Michigan or Ontario waters of the Detroit River.

From the 1970s to 1999, no lake sturgeon spawning was reported in the Detroit River, which at one time was one of the most productive sturgeon spawning grounds in the United States. However, in 2001, lake sturgeon spawning was documented in the Detroit River near Zug Island for the first time in over 20 years. Improvements in water quality as a result of pollution prevention and control programs laid the foundation for lake sturgeon to once again spawn in the Detroit River.

> *...in 2001, lake sturgeon spawning was documented in the Detroit River near Zug Island for the first time in over 20 years.*

3.2.5 Lake Whitefish

During the late nineteenth and early twentieth centuries, large numbers of lake whitefish entered the Detroit River each fall to spawn. Natural bedrock spawning grounds were destroyed and removed during the construction of the Livingstone Channel in 1907-1916. By the 1960s and 1970s, lake whitefish numbers in Lake Erie were at an all-time low because of overexploitation, predation by and competition with invasive species, degradation of water quality and habitat, and the loss of *Diporeia*, a major nutrient-rich food source. Improvements in water quality due to pollution prevention and control programs during the 1970s-1990s resulted in more favorable conditions for whitefish. In 2005, U.S. Geological Survey and U.S. Fish and Wildlife Service scientists documented natural reproduction of lake whitefish in the lower Detroit River for the first time since 1916.

3.2.6 Mayflies

Burrowing mayfly populations (*Hexagenia* spp.) were extirpated from western Lake Erie in the 1940s and 1950s as a result of water pollution. Burrowing mayfly nymphs first reappeared in sediments of western Lake Erie in 1992-1993 after an absence of 40 years. They returned in response to improved water quality resulting from pollution prevention and control programs, along with changes in trophic status ascribed to zebra mussels. Mayfly nymph densities have increased in recent years to a level considered good for healthy aquatic ecosystems. It is interesting to note that fishery managers have documented an increase in yellow perch abundance in western Lake Erie between the early 1990s and early 2000s, likely due to increased mayfly abundance.

3.3 Key Environmental and Natural Resource Challenges and Priority Management Actions

The return of bald eagles, peregrine falcons, walleye, lake sturgeon, lake whitefish, and mayflies represents a remarkable story of ecological recovery, but many environmental and natural resource challenges remain. Below is a discussion of six key environmental and natural resource challenges. The time trends in these data point to threats to ecosystem integrity. We discuss these challenges and recommend corresponding priority management actions, based on this assessment of all available indicator trends.

3.3.1 Population Growth, Transportation Expansion, and Land Use Changes

3.3.1.1 Challenge

Southeast Michigan's population growth rate and pattern of development are similar to that experienced in many major metropolitan areas in North America. Between 1900 and

1950, Detroit's population steadily increased to nearly two million people. Between 1950 and 2004, Detroit's population decreased by 50% as people moved to the suburbs. The seven-county region of southeast Michigan grew from about 600,000 residents in 1900 to nearly five million in 2005. While Detroit experienced a 50% decline in population between 1950 and 2004, the seven-county region experienced an increase in population of over 50%.

Movement out of the city of Detroit in the 1950s was helped by the ease of owning an automobile and the creation of an expanding, heavily subsidized transportation network. This movement to surrounding areas has, in general, increased distance and travel time to work, and nearly doubled the use of personal vehicles between 1960 and 2000. This phenomenon, often referred to as urban sprawl, causes nonpoint source pollution and creates loss, degradation, and fragmentation of habitats, among other impacts.

Initially, developed land was centered in the city of Detroit. Outlying areas, once forested, were first converted into farmland and more recently have been transformed for residential and related uses. As more area in southeastern Michigan was converted into urban and suburban development as a result of sprawl, the amount of impervious surface grew significantly, and urban nonpoint source pollution increased correspondingly.

There is also concern for loss of biodiversity and potentially more infectious diseases as a result of urbanization. The Michigan Department of Community Health reported that 70% of newly emerging infectious diseases, like West Nile virus, are due to landscape changes. One hypothesis is that landscape fragmentation caused by urbanization reduces biodiversity, which increases susceptibility to biological invasions and removes natural ecosystem population controls.

3.3.1.2 Recommended Priority Management Actions

Transportation, land use, environmental, and natural resource planning have traditionally been treated as separate initiatives and not effectively integrated. Furthermore, plans, regulations and enforcement are limited by hierarchical political boundaries, whereas stresses to the ecosystem follow watersheds and other natural boundaries. The ability of different agencies and organizations to collaborate on integrated planning and management strategies has been limited due to narrowly-focused and uncoordinated legislation and regulations, governmental fragmentation, and relatively short planning and budgeting horizons.

> *Transportation and land use planning must become better integrated to accommodate sustainable environmental and natural resource conditions on a watershed scale.*

Transportation and land use planning must become better integrated to accommodate sustainable environmental and natural resource conditions on a watershed scale. The goal should be to streamline and better coordinate the process of making land use and transportation planning decisions. All phases – from plan development to plan approval – should consider issues on a watershed basis.

Historically, transportation planning has been skewed by the promises of short-term economic gain espoused by land developers and highway department personnel who have a narrow perspective, as well as federal and state policies and funding that encourage the construction of infrastructure as a means of economic stimulus. In a major way, land conversion and urban sprawl are currently driving, and being driven by, transportation development.

There are no simple solutions to the problem of urban sprawl and its concomitant transportation needs. Alternatives to existing transportation modes and practices are needed, as well as better planning to design improved transportation systems. For example, alternatives to automobiles include a balanced intermodal mix of walking/biking (over $200 million has been invested in building greenways in southeast Michigan in the last five years), public transit, aviation, and trucks/freight. Other important solutions will use technological advances, transportation demand management, transportation supply management, good land use planning, legislation, and education.

In southeast Michigan, the Southeast Michigan Council of Governments has developed a regional analysis of the impact of planned transportation projects on the environment and a series of guidelines for mitigating impacts (www.semcog.org/TranPlan/Environment/) and the Metropolitan Affairs Coalition has championed SpeedLink as a network of rapid transit that can serve the greatest number of people in the least amount of time for the lowest cost (http://www.mac-web.org/Accomplishments/Speedlink.htm).

Ultimately, progress in developing a more balanced and environmentally-friendly transportation system – particularly one that offers better public transit options – will require political will driven by public demand. Escalating gasoline prices, an aging population that is increasingly in need of such options, and the public's growing concern about climate change provide some cause for optimism that this transformation can happen in metropolitan Detroit.

3.3.2 Nonpoint Source Pollution

3.3.2.1 Challenge

The relative contribution of nonpoint source pollutants has increased as point source pollution has been regulated through effective control programs. There is recent evidence that nonpoint source pollution problems (particularly for water) may be increasing because of increasing trends in population growth, transportation expansion, and continued land use development for suburbanization. As impervious surface increases through urban sprawl, more wetlands are lost and more nonpoint source pollution occurs. This further increases runoff, compounding nonpoint source pollution.

Bottom-dwelling invertebrate indicators for the Detroit River continue to show impacts from urban pollution. Several other key indicators suggest increasing nonpoint source problems. For example, chloride levels in water samples from the Monroe Water Intake in Michigan have been monitored since the late 1960s. Between 1968 and 1985, there was a slight decreasing chloride trend due to reduced industrial discharges. However, between the late 1980s and early 2000s, there has been a steady increase in chloride concentration due to nonpoint source inputs.

Dissolved reactive phosphorus is the form that is most available for algal and other plant growth. In the last ten years, there has been a sharp increase in dissolved reactive phosphorus concentrations in the Maumee River. Although the precise cause of this increasing trend is not clear at this time, changes in agricultural practices have been implicated.

The Union Water Intake draws water from western Lake Erie in Kingsville, Ontario. Total phosphorus levels in water samples from the Kingsville Water Intake decreased from the early 1980s to the mid-1990s as a result of the phosphorus control program. However, total phosphorus levels have nearly doubled between 1994 and 2004. The underlying cause is unknown, but food web changes resulting from introductions of exotic species like zebra mussels have been implicated in altering the phosphorus cycle and possibly increasing total phosphorus concentrations. Increasing nonpoint source inputs may be another contributing factor.

It is noteworthy that there is concurrence among recent increases in chloride concentration at the Monroe Water Intake in Michigan with increases in dissolved reactive phosphorus concentrations in the Maumee River in Ohio and increases in total phosphorus concentrations at the Kingsville Water Intake in Ontario. These recent increases have occurred in three geographically removed regions within the western basin of Lake Erie. Although the causes are not fully understood, increases from nonpoint sources could help explain these three increasing trends.

In comparison, the Rouge River watershed (48 communities and 1.5 million people), which in the past had major nonpoint source pollution problems, has achieved a significant improvement in lower river dissolved oxygen levels over the past 25 years. This has been accomplished through the development and implementation of a comprehensive watershed-wide nonpoint source control plan at a cost exceeding $600 million. This serves as a model for others and demonstrates that watershed-based efforts can be effective.

Two other important observations should be made relative to nonpoint source pollution. Urban and suburban development in southeast Michigan has been accompanied by more and more wetland loss. To date, 97% of the original coastal wetlands along the Detroit River have been lost to development. Loss of wetlands translates into a loss of natural filtering capacity and more urban runoff. Air pollution is another form of nonpoint source pollution. Asthma continues to be a major public health problem, particularly in Wayne County. Outdoor air quality factors known to affect asthma include ozone and particulate matter (PM). Detroit ranks sixth among the 25 U.S. cities most polluted with particulate matter. Since 1999, the Detroit area has met the new PM standard only once, in 2004. Currently, the Detroit area is not considered in compliance with the National Ambient Air Quality Standards (NAAQS) for ozone and particulate matter. On average, rates of hospitalization due to asthma in Wayne County are over 75% higher than in the state of Michigan as a whole. In addition, rates of asthma hospitalization in Wayne County show no appreciable change since 1990, while the asthma rates of hospitalization statewide show a significant overall decline since 1990.

3.3.2.2 Recommended Priority Management Actions

Some nonpoint source pollution problems can be addressed through management strategies and/or technological practices. However, the problem is also rooted in basic aspects of North American society, including dominant patterns of low-density suburban development. Therefore, political, as well as technical, solutions are required. Science can help propose solutions to both kinds of problems.

Controlling nonpoint source pollution must be approached in a holistic and comprehensive manner. In addition, the priority management actions to reduce nonpoint source pollution must be made visible and understandable to a broad range of stakeholders and partners. An essential step in the process is to adopt the watershed as the primary unit for planning and management. Watershed management attempts to take a comprehensive view of the physical, chemical, and biological components necessary to achieve locally-based water use goals. Site-specific goals and uses are established based on watershed characteristics and public, scientific, and regulatory input.

Controlling nonpoint source pollution must be approached in a holistic and comprehensive manner.

Watershed management brings federal, state and local partners together to address water quality issues and to identify mechanisms to solve them. Watershed management plans lay the groundwork for implementation of actions, including but not limited to:

- developing ordinances that protect current beneficial land uses, including wetland preservation, storm water controls, soil erosion controls, and waterfront setbacks;
- implementing structural and vegetative practices that control erosion and reduce pollutants;
- implementing diagnostic management practices, such as collecting and analyzing soil samples to determine how much phosphorus needs to be applied to a lawn, farm field, or golf course;
- implementing conservation easements that permanently protect river corridors, floodplains, shorelines and wetlands; and
- implementing information and education strategies to make people aware of nonpoint source pollution and what they can do to protect and improve our water.

The Rouge River Remedial Action Plan (RAP) and the Rouge River National Wet Weather Demonstration Project are excellent examples of federal, state, and local governments, and environmental and natural resource management agencies, aligning programs to address nonpoint source pollution on a watershed basis. Experience has shown that best management practices must be comprehensively implemented to achieve desired results. Also, strong partnerships are necessary to ensure the communication, coordination, and cooperation to achieve these desired results. Much greater use of economic and technical assistance incentives is required.

The importance of atmospheric nonpoint source pollution must not be overlooked. The specific atmospheric sources of persistent toxic substances must be identified, loadings must be quantified, reduction targets established, and control measures implemented to achieve the long-term goal of their virtual elimination. One example of a practical, initial management action for conventional air pollutants might be to adopt “the bubble concept” for air quality regulations as a cost-effective means for achieving target load reductions (Ryding 1992). In this system, transferable pollution rights encourage those having the best knowledge and practical means of reducing pollution sources to do so, trading this savings in mass emissions for profit to those with lesser technology or means.

3.3.3 Toxic Substances Contamination

3.3.3.1 Challenge

Although contaminant levels in fish, herring gull eggs, and sediment have declined, health advisories remain in effect on the consumption of many species of fish. Both humans and wildlife continue to be exposed to low-level toxic substance contamination and continue to be at risk. Concern has also been raised over the potential effects of environmental endocrine disruptors on avian populations and humans. Contaminated sediment in polluted areas like the Trenton Channel of the Detroit River, the lower Rouge River, the lower River Raisin and the lower Maumee River continues to contribute to beneficial use impairments.

Both humans and wildlife continue to be exposed to low-level toxic substance contamination and continue to be at risk.

3.3.3.2 Recommended Priority Management Actions

Control of contaminants at their source remains the primary imperative for action. Experience has shown that pollution prevention is much more ecologically sound and cost-effective than environmental remediation. Clearly, the old adage that an ounce of prevention is worth a pound of cure holds true. Examples of important programs to prevent toxic substance problems include:

- Design for Environment;
- ISO 14000;
- Life Cycle Assessment and Management; and
- Full Cost Accounting.

These initiatives proactively identify and prevent toxic substance problems before they become manifest in the environment. Management experience has shown that quantifying annual toxic substance loading estimates by source, making these loading data publicly accessible, and reaching agreement on toxic substance loading reduction targets are essential for measuring and sustaining progress and achieving the long-term goal of virtual elimination of persistent toxic substances.

Remediation of contaminated sediment hot spots will be essential to fully restore impaired beneficial uses like fish consumption advisories. Although nearly one million cubic meters of contaminated sediment have been remediated at a cost of $154 million in the last 13 years, approximately two million cubic meters of contaminated sediment require remediation to fully restore beneficial uses. Priority hot spots include the lower Rouge River, the Trenton Channel of the Detroit River, the lower River Raisin, and the lower Maumee River.

3.3.4 Habitat Loss and Degradation

3.3.4.1 Challenge

There is considerable concern over the continuous and incremental loss and degradation of habitat in southeast Michigan, northwest Ohio, and southwest Ontario. Increasingly, conversion of natural and agricultural land for residential uses and transportation expansion has resulted in considerable loss and degradation of natural habitat. Coastal wetland loss is the most dramatic. Since the early 1800s, most of the Detroit River's coastal wetlands have been lost to shoreline developments and channel modifications, especially encroachment into the river and hardening of the shoreline by installing steel sheet piling, building concrete breakwalls, and adding fill material to address erosion and flood control. By 1982 only 26 hectares (64 acres) of coastal wetlands on the U.S. side remained of the 2,768 hectares (6,840 acres) that were present in 1815 – a loss of 99%. Shoreline armoring increased from < 5% in the 1930s to 78% in Ottawa County and 98% in Lucas County, Ohio in the 1990s. Shore protection structures like this provide limited or no shoreline habitat value and alter coastal ecological processes and biological life cycles in the lake itself.

There is considerable concern over the continuous and incremental loss and degradation of habitat in southeast Michigan, northwest Ohio, and southwest Ontario.

3.3.4.2 Recommended Priority Management Actions

The protection and restoration of habitat, like land use planning and nonpoint source pollution with which it is so closely interlinked, should be addressed on a watershed scale. It is often said that habitat has no home (i.e., physical habitat is often overlooked and does not receive adequate attention in traditionally separate water quality management and fish and wildlife management programs). This is particularly true in urban areas. Consequently, there must be a concerted effort to ensure that habitat is an integral part of community master plans. Effective communication and strong partnerships are essential to achieve this. Critical components of a process to ensure that habitat is incorporated into community master plans include (U.S. Environmental Protection Agency and Environment Canada 1995):

- compiling habitat inventory;
- developing public participation;
- forming an intergovernmental coordinating committee; and
- developing a public/governmental partnership in plan development.

From a strategic perspective, greater emphasis needs to be placed on incorporating habitat protection and rehabilitation with other local and regional planning and development initiatives (i.e., communities should ensure that habitat gets incorporated into master plans). Although a systematic and comprehensive process of habitat conservation, rehabilitation, and restoration will be a long-term endeavor, considerable opportunities exist to move forward with short-term actions that will benefit habitat and other issues (e.g., land use, economy, agriculture, recreation). Some examples of practical actions include (U.S. Environmental Protection Agency and Environment Canada 1995):

- incorporating habitat protection into master, land use, and watershed plans, zoning ordinances, etc.;
- seeking permanent protection for ecologically significant habitats by purchasing land, establishing easements, etc.;

- ensuring that individuals with fish and wildlife expertise get involved early in project planning for waterfront redevelopment, shoreline modification, sediment remediation, navigational structures, etc., to adequately address fish and wildlife enhancement opportunities and ensure adequate assessment and monitoring;
- ensuring that agencies like state and local transportation departments, departments of public works, parks and recreation departments, and others incorporate ecologically sound techniques that enhance fish and wildlife (e.g., bioengineering, incidental habitat enhancement of physical structures, willow posts, setbacks) into operating manuals and day-to-day operations; and
- establishing citizen stewardship programs to help inventory habitat and work with landowners and agency personnel to enhance habitat.

Management of the Detroit River International Wildlife Refuge is guided by a Comprehensive Conservation Plan (CCP). In total, the Detroit River International Wildlife Refuge has grown from approximately 123 hectares (304 acres) in 2001 to 2,042 hectares (5,047 acres) in 2007. The CCP for the Detroit River International Wildlife Refuge has set a U.S. land conservation target of 4,856 hectares (12,000 acres; i.e., the U.S. Fish and Wildlife Service has identified 4,856 hectares of marshes, wetlands, islands, shoals, and uplands that could potentially be conserved through acquisitions, easements, and cooperative agreements). Canadian targets have not been established. Land conservation must continue to be a priority while opportunities exist.

3.3.5 Introduction of Exotic Species

3.3.5.1 Challenge

Invasive exotic species are organisms that are not native to the regional ecosystem and often cause substantial ecological harm and economic impact. Exotic species are a major problem in the Huron-Erie corridor. The zebra mussel was first introduced into Lake St. Clair in 1988 and the quagga mussel in 1989. The goby was introduced into the St. Clair River in 1990. The spiny amphipod was first found in the Detroit River in 1994. The emerald ash borer was first discovered in southeast Michigan in 2002. Viral hemorrhagic septicemia (VHS) was introduced into Lake St. Clair in 2002 or 2003.

Key indicator trends for the Detroit River and western Lake Erie have shown that zebra and quagga mussels are well established and have had major negative economic impacts on municipal water intakes and power plant intakes. They may have affected the ecosystem itself by altering food web dynamics and biodiversity. Fishery managers have found that the zebra/quagga mussel invasion has generally increased water clarity in nearshore parts of western Lake Erie, which in turn has led to resurgence of submerged aquatic plants and plant-loving sunfishes (centrarchid fishes like pumpkinseeds and bluegills). West Nile virus was first discovered in birds in southeast Michigan in 2001, and has impacted both birds and humans. The first human case of West Nile virus was found in Wayne County in 2002 and has since resulted in 15 human deaths. The Rockwood Christmas Bird Count has documented a decline in the American crow population as a result of West Nile virus. In the 897-hectare (2,217-acre) Erie Marsh, common reed (*Phragmites australis*) has dramatically increased in coverage from 5 hectares (12 acres) in 1984 to 132 hectares (326 acres) in 2003.

Nearly $100 billion in U.S. economic losses have occurred over an 85-year period from just 79 exotic species (U.S. Congress-Office of Technology Assessment 1993). Pimentel et al. (2000) estimated losses to the United States economy of at least $137 billion per year associated with the effects of exotic species on native ecosystems, agriculture, and natural resources, including the costs for control efforts. In addition to economic and human health costs, exotic species are believed to be the leading cause of biodiversity change in the Great Lakes and extinctions in North American freshwater ecosystems (International Association for Great Lakes Research 2002).

The governments…must stop the introduction of exotic species into the Great Lakes.

3.3.5.2 Recommended Priority Management Actions

The governments of the United States and Canada, the eight Great Lakes states and the provinces of Ontario and Quebec, must stop the introduction of exotic species into the Great Lakes. Every year of delay results in substantial ecological harm and economic impacts.

3.3.6 Greenhouse Gases and Global Warming

3.3.6.1 Challenge

There is new and strong evidence that most of the warming over the last 50 years is attributable to human activities. Human activities have altered the chemical composition of the atmosphere through the buildup of greenhouse gases – primarily carbon dioxide, methane, and nitrous oxide. The heat-trapping property of these gases is undisputed, although uncertainties exist about exactly how Earth's climate responds to them.

According to the U.S. Environmental Protection Agency (2006), atmospheric concentrations of carbon dioxide have increased nearly 30%, methane concentrations have more than doubled, and nitrous oxide concentrations have risen by about 15% since the beginning of the Industrial Revolution. These increases have enhanced the heat-trapping capability of the Earth's atmosphere.

Between 1960 and 2001, Michigan's carbon emissions from fossil fuel combustion increased from 129.4 million metric tons per year (142.6 million tons per year) to 189.1 million metric tons per year (208.4 million tons per year) – an increase of 59.7 million metric tons (65.8 million tons). This represents a 46% increase over four decades.

Evidence of potential effects of global warming on Lake Erie is being compiled. Maximum winter ice cover on Lake Erie has shown a general decline since the late 1970s. Extremely mild winters have been recorded in 1983, 1991, 1998, 2002, and 2006, resulting in low winter ice cover.

Lake Erie water levels fluctuate on short-term and long-term scales. Currently, Lake Erie water levels are slightly below the long-term average and are coming down from historic highs seen in the 1980s. Even though there is considerable uncertainty as to the effects of global warming on Lake Erie water levels over the next several decades, projections are that there will be a decline. For example, it has been predicted that global warming will result in a 1-2 meter decline in water levels over the next 70 years (Lofgren et al. 2002; Mortsch and Quinn 1996). A 1.5 meter drop in Lake Erie water levels is expected to result in a 4% reduction in surface area of the western basin and a 20% reduction in volume of the western basin. The shoreline would move lakeward by distances of less than 1 km to as much as 6 km (Lee et al. 1996). It should also be noted that less ice cover on Lake Erie increases evapotranspiration that can result in further reductions in water levels.

There is growing concern over potential effects of global warming on birds and other wildlife. To date, no concrete evidence exists about global warming impacts on birds in the watersheds of the Detroit River and western Lake Erie. However, it is interesting to note that hawk monitoring programs at both Holiday Beach and Lake Erie Metropark have shown increasing trends of turkey vultures. Kiff (2000) suggests that the northern range expansion of turkey vultures may be due to global warming.

Price (2006) has reviewed the scientific literature on songbirds in Michigan and has identified many possible bird changes that might occur as a result of global warming. Some examples include:

- some species might disappear as summer residents in the Lower Peninsula (e.g., alder flycatcher, least flycatcher, tree swallow, yellow-throated vireo, bobolink);
- some species might have their climatic ranges contract (e.g., black-capped chickadee, house wren, yellow warbler, Baltimore oriole, house finch); and
- some species might include Michigan in their future climatic summer ranges (e.g., Carolina chickadee, Kentucky warbler, Bell's vireo).

Monitoring is essential to document changes.

It should also be noted that there are potential effects of global warming on illness and death related to West Nile virus. Environmental Entrepreneurs (2005) have reported that higher temperatures in Michigan could increase heat-related deaths and illnesses from insect-borne diseases like West Nile virus. Over 200 human cases of West Nile virus were reported in Wayne County in 2002, resulting in 15 deaths.

3.3.6.2 Recommended Priority Management Actions

There is growing public concern about global warming and growing public demand for actions to address it consistent with the Precautionary Principle.

There is growing public concern about global warming and growing public demand for actions to address it consistent with the Precautionary Principle (i.e., if an activity raises threats of harm to human health or the environment, precautionary measures should be taken even if some cause-and-effect relationships are not fully established scientifically). Indeed, the 2007 report of the United Nations Intergovernmental Panel on Climate Change calls for speedy and decisive international action on climate change (http://unfccc.int/2860.php).

Clearly, international cooperation will be needed to stop global warming. However, action can and should be taken at the national, state/provincial, local, and individual levels. Examples of recommended priority actions include:

- ensuring public disclosure of annual inventories of greenhouse gas emissions;
- establishing short- and long-term greenhouse gas reduction targets;

- accelerating research on global warming and environmentally sustainable technologies;
- supporting international cooperation on solutions to global warming;
- supporting business leadership on global warming (e.g., Business Environmental Leadership Council - www.pewclimate.org);
- supporting market-based solutions to reduce greenhouse gas emissions;
- scheduling a global warming speaker at a community event;
- using environmentally sound products (e.g., replacing incandescent light bulbs with compact fluorescent bulbs);
- signing up for electricity from renewable energy sources;
- planting native trees (that take in carbon) in communities;
- when replacing appliances, choosing ones with the Energy Star label;
- carpooling to work, using mass transportation, driving a hybrid, or riding a bicycle; and
- calculating and offsetting one's carbon dioxide footprint at www.carboncounter.org.

3.4 Priority Research/Monitoring Needs

Specific research and monitoring needs are identified in each indicator write-up. Presented below are six priority research/monitoring needs based on this comprehensive and integrative assessment.

3.4.1 Demonstrate and Quantify Cause-Effect Relationships

Research is needed to achieve a better understanding of cause-and-effect relationships. For example, we must better quantify biological effects of contaminated sediment in order to properly target sediment remediation. Such cause-and-effect relationships must be quantified and incorporated into models to predict outcomes and guide management actions. Such quantitative understanding will, in the long run, not only better focus management actions, but will potentially save money.

3.4.2 Establish Quantitative Endpoints and Desired Future States

Of the 50 indicators presented in this report, only 34% have quantitative targets...only five are achieving them.

There is a need to identify scientifically defensible quantitative endpoints and desired future states for management agencies. Of the 50 indicators presented in this report, only 34% have quantitative targets (17 out of 50 indicators; Table 1). Of the 17 indicators with quantitative targets, only five are achieving them. Quantitative endpoints and desired states should be tied to beneficial use impairment criteria for the Detroit River, Rouge River, River Raisin, and Maumee River RAPs, Lake Erie Lakewide Management Plan objectives and those of the Comprehensive Conservation Plan for the Detroit River International Wildlife Refuge.

3.4.3 Determine Cumulative Impacts and How Indicators Relate

Research is needed to better understand the cumulative impacts of multiple pressure indicators or stressors. In addition, research is needed to determine how indicators relate to one another. It is necessary to know which pressures affect what state indicators, to what degree, and what is the appropriate type and level of response necessary to provide the desired result/state.

3.4.4 Further Modeling and Prediction

Modeling is needed to better understand and quantify the controlling factors and the relationships among indicators. Contaminant-food web modeling is needed to identify and prioritize remaining source reduction strategies and contaminated sediment remediation projects. Both scientists and managers need to recognize the changing nature of the system and anticipate and predict future scenarios. For example, water level changes in Lake Erie are projected to result in substantial changes to the shoreline. Modeling is needed to better predict these changes, especially in wetlands, in order to make better waterfront planning and conservation decisions.

3.4.5 Prioritize Areas for Protection and Restoration

Research is needed to help establish protection and restoration priorities in order to most effectively reach the quantitative targets of state indicators. Greater emphasis must be placed on establishing and maintaining the link between scientific information and management actions (science-policy linkage).

3.4.6 Foster Long-Term Monitoring for Adaptive Management

Without a commitment to long-term monitoring, management is flying blind.

Long-term monitoring is essential to practice adaptive management, in which assessment is undertaken, management priorities are established, and management actions are taken in an iterative fashion for continuous improvement. Without a commitment to long-term monitoring, management is flying blind.

3.5 Concluding Thoughts and Recommendations

Clearly, there is a need for comprehensive and integrative assessments of ecosystem health based on the evaluation of long-term trend data from a variety of indicators. As part of these comprehensive and integrative assessments, there is a need to identify priority management actions and research/monitoring needs. Trend data must be compiled, interpreted, translated, and made accessible to all stakeholders. Experience throughout the Great Lakes has shown that public reporting on scientific trends and simultaneous public discussion of necessary remedial and preventive actions, as well as research and monitoring needs, strengthens the science-policy linkage and accelerates prevention, remediation, and restoration actions.

There is much to be gained by the integration of monitoring/assessment and management activities of the RAPs, the Lake Erie Lakewide Management Plan, the Comprehensive Conservation Plan for the Detroit River International Wildlife Refuge, the Lake Erie Committee of the Great Lakes Fishery Commission, watershed and conservation organizations, and land use/transportation planning organizations like the Southeast Michigan Council of Governments. Indeed, the Detroit River and Lake Erie cannot be managed without such integration.

Comprehensive and integrative assessments are a way to bring key organizations and initiatives together to practice adaptive management.

Current policies associated with human population growth, land use planning and transportation are uncoupled from the science and management of the ecosystem. That must change. Comprehensive and integrative assessments are a way to bring key organizations and initiatives together to practice adaptive management.

Currently, there is no mechanism to continue comprehensive and integrative assessment work. Collectively, millions of dollars are spent annually on research, monitoring, and environmental management in the Detroit River and western Lake Erie. Comparatively, very little is spent on periodically performing comprehensive and integrative assessments of ecosystem health. Therefore, it is recommended that

> resources be pooled through the Canada-U.S. collaborative monitoring effort under the Binational Executive Committee (BEC) on a regular basis (e.g., at least every five years) to undertake comprehensive and integrative assessments of the health of the Detroit River and western Lake Erie ecosystem. Key coordinating organizations that should be responsible for these assessments should include the RAPs, Lake Erie Lakewide Management Plan, the Detroit River International Wildlife Refuge, the Lake Erie Committee of the Great Lakes Fishery Commission, watershed and conservation organizations, and land use/transportation planning organizations like the Southeast Michigan Council of Governments.

The assessment presented in this report will serve as a baseline that can be improved upon in the next iteration in the spirit of adaptive management.

Quantitative targets or endpoints do not exist for most indicators. Of the 50 time trend data sets assessed, only 17 have quantitative targets (Table 1). Only five of the 17 indicators with targets are meeting them. Therefore, it is recommended that

> a high priority should be placed on quantifying targets and endpoints for indicators in order to clearly focus management efforts and track progress consistent with adaptive management. The responsibility for quantifying targets and endpoints should rest with the key coordinating organizations such as those identified above.

All time trend databases are important to the organizations and agencies collecting the data. However, future iterations of comprehensive and integrative assessments may want to focus on a smaller set of key indicators that best meet the needs of management. In addition, this assessment was heavily weighted on state information – there are 38 state, seven pressure and five response indicators. It is further recommended that

> future comprehensive and integrative assessments of the Detroit River and western Lake Erie should include more pressure and response indicators as they become developed, and more economic and social indicators, including indicators of sustainability and human health. Examples of available pressure and response trend data include: air emissions, watershed-specific urban and agricultural nonpoint

source loadings, watershed-specific impervious land use, other watershed-specific land-based stressors as summarized by the Great Lakes Environmental Indicator Project (http://glei.nrri.umn.edu), industrial point source loadings, etc.

Finally, some trend data were only available from one side of the international border. Therefore, it is recommended that

binational harmonization be achieved to truly undertake comprehensive and integrative assessment.