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The Green Bay saga: Environmental change, scientific investigation, and watershed management

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ABSTRACT

The Green Bay watershed, draining a total area of approximately 40,468 km^2, comprises about a third of the Lake Michigan drainage. In the early years, fur trade was the dominant economic activity within the watershed. Later, when timber harvesting, papermaking, and agriculture came on the scene in the 19th and early 20th centuries, major environmental changes occurred in a relatively short period of time. Nutrient and sediment loadings, accompanied by organic wastes from sawmills and paper mills, resulted in a pollutant overload in the Fox River and in the eutrophication of the waters of lower Green Bay. Citizen complaints about these severely degraded conditions initiated a period of scientific investigation. Starting slowly with a few studies and surveys in the first half of the 20th century, serious investigatory work began at mid-century with support from the University of Wisconsin Sea Grant Institute. Examples of topics that have been investigated since then with support from numerous sources are: biological oxygen demand (BOD), phosphorus and total suspended solids loads, trophic status and food chain efficiencies, coastal wetland characterization, dynamics of the benthic layer, algae and abiotic solids, phosphorus cycling and mass balance, PCBs, seasonal hypoxia, and climate change impacts. These studies have provided the scientific foundation for government-led programs such as the Green Bay Remedial Action Program, the PCB clean-up program, and the TMDL program. Progress has been made—reduction in BOD is an example—but a fuller rehabilitation of this large-scale ecosystem remains an elusive goal. The saga goes on.

The Green Bay saga

The head of Green Bay receives water from the lower Fox River that drains from Lake Winnebago, the largest inland lake in Wisconsin. Lake Winnebago receives water from the Upper Fox River, the Wolf River and their respective watersheds. The total Green Bay watershed drains approximately 40,468 km^2 and, as such, it comprises about a third of the total Lake Michigan drainage. The name Green Bay is a bit of an enigma. The early French explorers referred to this water body as Baye Des Puans during their period of occupation. In 1778, in a publication by Jonathan Carver, it was given the name Green Bay (Kraft, 1984). The renaming was apparently due to the early spring greening of the extensive marshes and forested wetlands that were particularly prominent on the west shore of the bay. Clifford Mortimer, a noted limnologist/oceanographer, believed Green Bay was "somewhat misnamed as a 'bay'" and characterized it as a relatively shallow "gulf" connecting into the northwest part of Lake Michigan (Mortimer, 1978). Green Bay has also been referred to as the largest freshwater estuary in the world (Smith et al., 1988). However it may be characterized, Green Bay and its watersheds have had a long history of exploitation and a shorter but significant period of scientific exploration (Fig. 1) (Bertrand et al., 1976; Harris et al., 1987; Smith et al., 1988; Kraft and Johnson, 1999).

Early on, the economy of the region was based on the fur trade. During this period—which lasted through the early part of the 19th century until about 1834—little environmental change occurred in the watershed, river, or the bay. A federal land survey was conducted during the period from 1834 to 1836, after which land sales were opened by the United States Government. This opening marked the beginning of major changes in the watershed. The lumber industry came to the fore, and by the early 1880s one billion board feet of virgin timber had been harvested. Soon thereafter, from 1870 to 1930, economic development shifted to papermaking and manufacturing. The paper mills were essentially unrestricted in their use of the river as a source of water and power, and as a waste-disposal outlet. The agricultural economy began in the mid-1800s with the growing of wheat as the dominant farming activity, to be followed later by the start of the dairy industry. By 1900, much of the land in the lower Fox River watershed was under cultivation or utilized for grazing. In a relatively short period of time, from 1840 to 1900, these large scale changes in the watershed resulted in increased nutrient and sediment loadings into the river and bay. These

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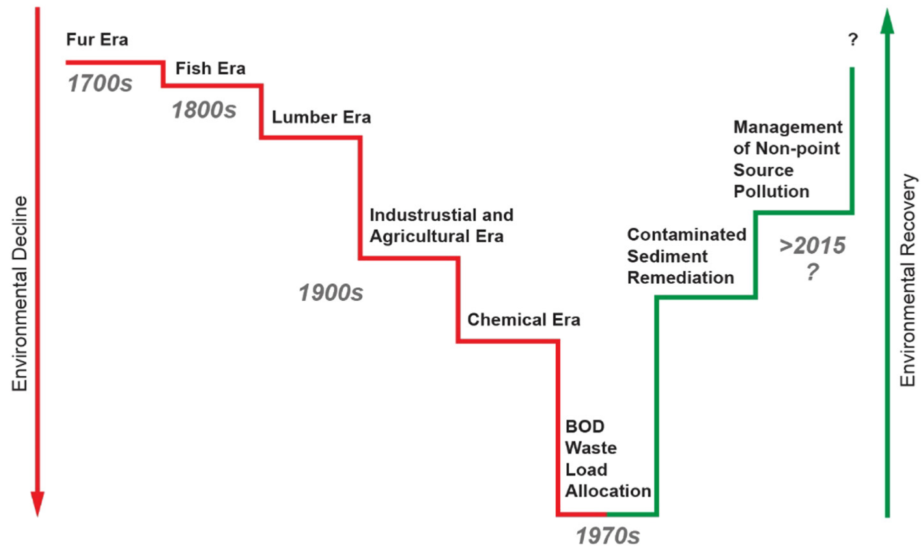

Fig. 1. An abbreviated timeline of the environmental history of the Green Bay ecosystem from the 1700s to present.

loadings were accompanied by the discharge of organic waste from sawmills and paper mills and the discharge of sewage from developing communities. In combination, these inputs led to an overloading of the river, resulting in a rapid eutrophication of the waters of Green Bay.

How did the river and the bay come to such a degraded state? On the surface, the answers to this question are fairly clear. When it comes to the question of why the resource was allowed to degrade, the answers are more difficult. Perhaps it is another case of "the tragedy of the commons", a situation in which users of a common resource keep claiming larger shares until the carrying capacity is exceeded and the system shifts to another state, one that is less beneficial (Hardin, 1968). It could also have been a matter of indifference resulting from society's movement along a "progressive path" in which fewer and fewer people involved in this collective endeavor were directly dependent on the bay and its resources. What mattered was that progress was, defined primarily as economic growth and development, largely through natural resource exploitation. The case of Green Bay, as was no doubt true of other systems in the Great Lakes, appears to "reflect historic allocation of resources toward those uses and beneficiaries who were not dependent on maintaining high environmental quality or sensitive species" (Harris et al., 1990).

The degradation does not end in this period, however. By the 1920s, the river and the lower bay as far as Red Banks (about 15 miles north of the mouth of the Fox River) were in such a degraded state that people took note and began to complain. In the decades that followed, reports of dying fish and offensive stenches arising from the East River and the lower Fox River were common. A newspaper account in 1961, for example, tells the story of workmen using a powered scow to remove tons of dead fish from the waters of the Fox River. Homes along the west bank of the river were said to be seriously affected by strong odors. Mysteriously, an accompanying photograph purports to show health department officials spraying DDT on the waters of the river (Green Bay Press Gazette, 14 June 1961).

This nadir of the period of degradation stimulated the first actions to determine the causes, calling into use the relevant science that was available at the time. A pollution survey conducted by the Bureau of Sanitary Engineering in 1925 revealed that depressed oxygen levels existed in the water over the last 15 miles of the river to its mouth at the bay. The survey also demonstrated that the dissolved oxygen concentration in the river was dependent on flow and temperature, two variables that were to be used in the waste load allocation model a half century later (WSBOH, 1927). A 1938 comprehensive study, jointly conducted by the State Committee on Water Pollution (SCOWP) and the newly formed Green Bay Metropolitan Sewerage District (now named NEW Water), reported the occurrence of blue-green algae blooms (*Aphanizomenon*) and linked the blooms to organic waste and nutrient loads (WSCOWP, 1939). Additional surveys that were conducted in 1955–56 and 1966–67 on the lower Fox River and Green Bay again implicated oxygen depletion. Benthic surveys conducted by SCOWP in 1938 (Surber and Cooley, 1952; Balch et al., 1956; Howmiller and Beaton, 1967; Harris, 1998), revealed the impact of hypoxia on the lower bay *Hexagenia* populations, an impact that resulted in the extirpation of these populations by 1967.

The evidence between cause and effect had been clear for several decades, but it was not until 1972 with the passage of the Federal Clean Water Act that action was taken to address the problem (Harris et al., 1987). Focused research by the Wisconsin Department of Natural Resources (WDNR) led to the development of a waste load allocation model that was used to partition waste loads from individual dischargers based on the river's flow and temperature and its assimilative capacity (Patterson, 1973; Patterson, 1980; Patterson, 1984).

Some $338 million ($1.9 billion in 2017 dollars) was invested in wastewater treatment facilities by both municipalities and industries, with the largest single expenditure of $80 million incurred by the Green Bay Metropolitan Sewerage District (GBMSD). The decrease in the average total discharge of biochemical oxygen demand from 1971 to 1978 was just over 90%. This action resulted in a marked increase in dissolved oxygen in the waters of the lower bay (Sager, unpublished data; Harris et al., 1987). The reduction in BOD was achieved through the Wisconsin Pollution Discharge Elimination System (WPDES), a program that was established in response to the Clean Water Act. While this was a remarkable success, the waters of lower Green Bay remained highly eutrophic. As a result, it had become clear to some in the science community that a more comprehensive understanding of Green Bay was needed.

An effort toward an improved understanding began in 1969 when the University of Wisconsin Sea Grant Institute initiated a more comprehensive research effort on Green Bay. The program was funded at a level of $579,107 ($3.86 million in 2017 dollars) over a four-year period (1970–1974); both federal and state dollars provided the source for these funds. This initiative occurred at the same time as the establishment of a new University of Wisconsin campus—the University of Wisconsin-Green Bay—on the eastern shore of Green Bay and in the city of Green Bay. These significant undertakings and events took place early in the so-called environmental movement in the United States. The first Earth Day occurred on 22 April 1970. The Clean Air

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